NUREG/CR-4554, Vol. 1, Rev. 2
UCID-20674

SCANS (Shipping Cask ANalysis System) A Microcomputer-Based Analysis System for Shipping Cask Design Review

User's Manual to Version 3a

Manuscript Completed: January 1998
Date Published: March 1998

Prepared by
G.C. Mok, G.R. Thomas, M.A. Gerhard, D.J. Trummer, G.L. Johnson

Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, CA 94550

Prepared for
Spent Fuel Project Office
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001
NRC Job Code A0291

Abstract

SCANS (Shipping **C**ask **AN**alysis **S**ystem) is a microcomputer-based system of computer programs and databases developed at the Lawrence Livermore National Laboratory (LLNL) for evaluating safety analysis reports on spent fuel shipping casks. **SCANS** is an easy-to-use system that calculates the global response to impact loads, pressure loads and thermal conditions, providing reviewers with an independent check on analyses submitted by licensees.

SCANS is based on microcomputers compatible with the IBM-PC family of computers. The system is composed of a series of menus, input programs, cask analysis programs, and output display programs. All data is entered through fill-in-the-blank input screens that contain descriptive data requests. Analysis options are based on regulatory cases described in the Code of Federal Regulations 10 CFR 71 and Regulatory Guides published by the U.S. Nuclear Regulatory Commission in 1977 and 1978.

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Acknowledgments

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

H. W. Lee, C. R. Chappell, H. L. Graves, and W. E. Campbell of the U.S. Nuclear Regulatory Commission for their support and technical direction.

C. J. Mauck, J. F. Leonard, and M. Wangler of the U.S. Department of Energy for their support and comments.

T. A. Nelson, A. B. Shapiro, and R. Serbin of Lawrence Livermore National Laboratory for their significant technical contributions.

Executive Summary

Lawrence Livermore National Laboratory has developed a microcomputer-based analysis system to assist the Nuclear Regulatory Commission in performing confirmatory analyses for licensing review of radioactive-material shipping cask designs. **SCANS** documentation includes multiple volumes. This volume (Volume 1) is the user's manual and program reference. In this volume we describe the system requirements, installation and operation of **SCANS**, the contents of the **SCANS** distribution diskettes, how **SCANS** is implemented in a DOS environment, and the structure of **SCANS** databases. Volumes 2 and following are the theory documents for each analysis module. The titles and contents for each **SCANS** theory document are given in Appendix F.

Revisions

Date: June 1, 1989 Version: 1b

Page 1-4,5 Added that DOS file COMMAND.COM must be in the root directory of the hard disk drive which will contain **SCANS**.

Page 3-9,10 Modified Figure 3-4 and the description of the end cap shield radius to indicate that the value for the shield radius must be larger than the cavity radius.

Date: May 21, 1991 Version: 2a

All Pages All pages were revised or reissued in order to accommodate the extensive changes associated with the additional capabilities of the program. The major new capabilities are: options to modify material data set and thermal-analysis conditions; puncture analysis; elastic-plastic lead slump analysis; and buckling analysis.

Date: March 31, 1997 Version: 3a

All Pages All pages were revised or reissued in order to accommodate the extensive changes associated with the additional capabilities of the program. The major added capabilities are the load combination and the options for distributing contents heat on the cavity surface. In addition, both the SCANS thermal modeling and thermal/mechanical properties were improved.

Introduction

SCANS — Shipping Cask ANalysis System*

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).

SCANS is a microcomputer based system of computer programs developed by LLNL for evaluating safety analysis reports on spent fuel shipping casks. The system is easy to use and provides an independent check for reviews on the analyses submitted by licensees. **SCANS** calculates the global response of the shipping casks to impact loads, thermal conditions and pressure loads.

SCANS is composed of a series of menus, input programs, cask analysis programs and output display programs. An analysis is performed by preparing the necessary input data and then selecting the appropriate analysis: impact, thermal (heat transfer), thermally-induced stress, or pressure-induced stress. All data is entered through fill-in-the-blank input screens with descriptive data requests. Where possible, default values are provided as specified in Regulatory Guides published by the U.S. Nuclear Regulatory Commission (1977, 1978). The input data is evaluated for correctness before it is accepted.

Impact analyses use a one-dimensional dynamic beam model. Each node in the beam model has two translational degrees of freedom and one rotational degree of freedom. The impact code uses an explicit time-history integration scheme in which equilibrium is formulated in terms of the global external forces and internal force resultants. This formulation allows the code to track large rigid-body motion. Thus, the oblique impact problem can be calculated from initial impact through essentially rigid-body rotation to secondary impact. Lateral pressure due to lead-slump can also be calculated.

Appropriate two-dimensional finite-element meshes are automatically generated for thermal, thermal-stress, and pressure-stress analyses, based on the general geometry description. **SCANS** allows steady-state or transient thermal analyses, which may include phase change, time- and/or temperature-dependent material properties, time and/or temperature boundary conditions, and internal heat generation. Possible thermal boundary conditions include specified temperature, heat flux, convection, radiation, interface contact resistance, and nonlinear heat transfer to a bulk node. Thermal analyses use 4-node elements. Thermal-stress and pressure-stress analyses are performed using a linear-elastic

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

static structural analysis program which allows temperature-dependent material properties. Stress analyses use 9-node elements.

Output is displayed graphically and can also be printed. Graphic displays include: impact force, moment and shear time histories; impact animation; thermal/stress geometry outline; thermal/stress element outlines; temperature distributions as iso-contours or profiles; and temperature time histories.

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

SCANS requires only the press of a single key to make menu and subtask selections. **SCANS** indicates the available selections on each display screen and describes what action **SCANS** will take. For example: on the main menu **SCANS** indicates the appropriate keys to press are **1 2 3 4 5 6** 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.

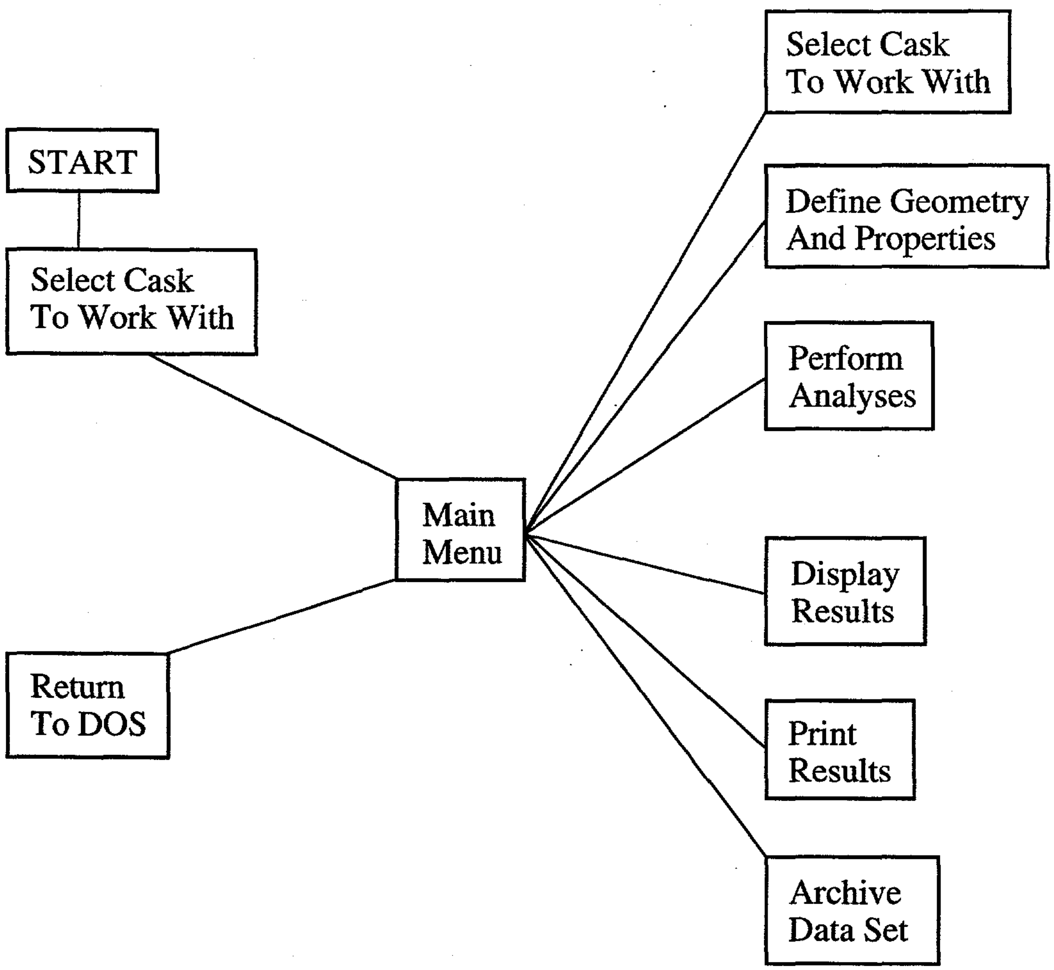


Figure 1-1. SCANS menu structure.

Introduction

Required Hardware and Software

SCANS is designed for microcomputers compatible with the IBM-PC family of computers. The minimum required hardware configuration is:

IBM "XT" or "Compatible" with the following:

- 10 Mbyte hard disk drive
- 360 Kbyte floppy disk
- 640 Kbyte RAM
- CGA Board (Color Graphics Adapter)
- Color Graphics Monitor
- 8087 Math co-processor chip
- IBM or EPSON Graphics printer

SCANS performance is improved by using new generations of machines. **SCANS** functions on MS DOS computers including the 80386, 80486, and Pentium (80586) classes of machines. A slightly upgraded confirguation using 80386 machine is:

IBM PS2 Model 80 (80386 processor)

- 40 Mbyte hard disk drive
- 1.44 Mbyte floppy disk (High Density)
- 360 Kbyte floppy disk (external)
- 640 Kbyte RAM
- VGA Board (Video Graphics Array)
- VGA Color Monitor
- 80387 Math co-processor chip
- HP LaserJet, LaserJet+, or LaserJet Series II printer

SCANS 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 **SCANS.**

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 **SCANS.**

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

The **SCANS** release package contains five 5 1/4 inch (or three 3 1/2 inch) double-density distribution diskettes (or two 5 inch high-density diskettes for AT 1.2Mb disk drives). The programs and control files on the distribution diskettes occupy approximately 2.6Mb 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 **SCANS**.

To install **SCANS**:

(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 **SCANS** 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 **SCANS** 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 **\SCANS** subdirectory, and prompts for **SCANS** 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.

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

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 **SCANS**.
(2) **INSTALL** checks the selected hard disk drive for enough space. **SCANS** 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 **\SCANS** on the selected hard disk. If an older version of **SCANS** is already installed, **\SCANS** is renamed to **\SCANSnn** (where **nn** is the previous **SCANS** version number) before **\SCANS** is created. If the same version of **SCANS** is already installed, **INSTALL** asks if you want to reinstall **SCANS**.
(4) **INSTALL** copies the program and control files from the distribution diskettes. **INSTALL** asks for each **SCANS** diskette in order.
(5) **INSTALL** unpacks the sample data set.
(6) **INSTALL** updates the **SCANS** procedure to identify the selected hard disk.
7) Select video type (max resolution for plots). Allows user to change video and printer setup.

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

SCANS (followed with Enter or Return)

SCANS will display the title and disclaimer screen shown in **Figure 1-2**. Press any key to continue. **SCANS** 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, **SCANS** 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.

When only one data set exists **SCANS** displays a summary of the data set (**Figure 1-3**). Three choices are provided:

Press **N** to select a new CASKID by direct entry
Press **P** to Proceed with the indicated CASKID (**SCANS** displays the Main Menu)
Press **Q** to QUIT and return to DOS

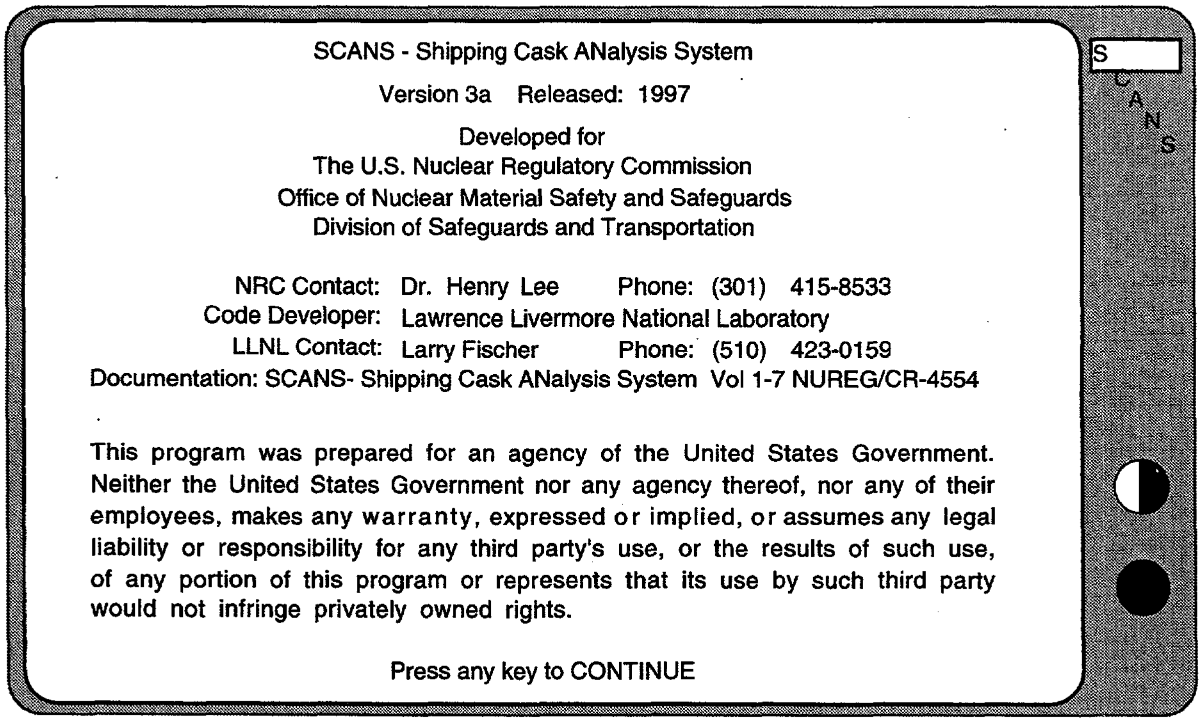


Figure 1-2. Title and disclaimer screen. Displayed when SCANS is started.

If more than one data set exists, **SCANS** displays a list of CASKIDs and indicates several options:

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

When more than one data set exists, the summary screen options are:

Press **S** to select a different CASKID (return to the CASKID list screen)
Press **P** to Proceed with the specified CASKID (**SCANS** displays the Main Menu)
Press **Q** to QUIT and return to DOS

After the CASKID is selected, **SCANS** 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 perform an analysis, display the graphical results (if applicable) and then print the results. Each of these operations is selected from the Main Menu.

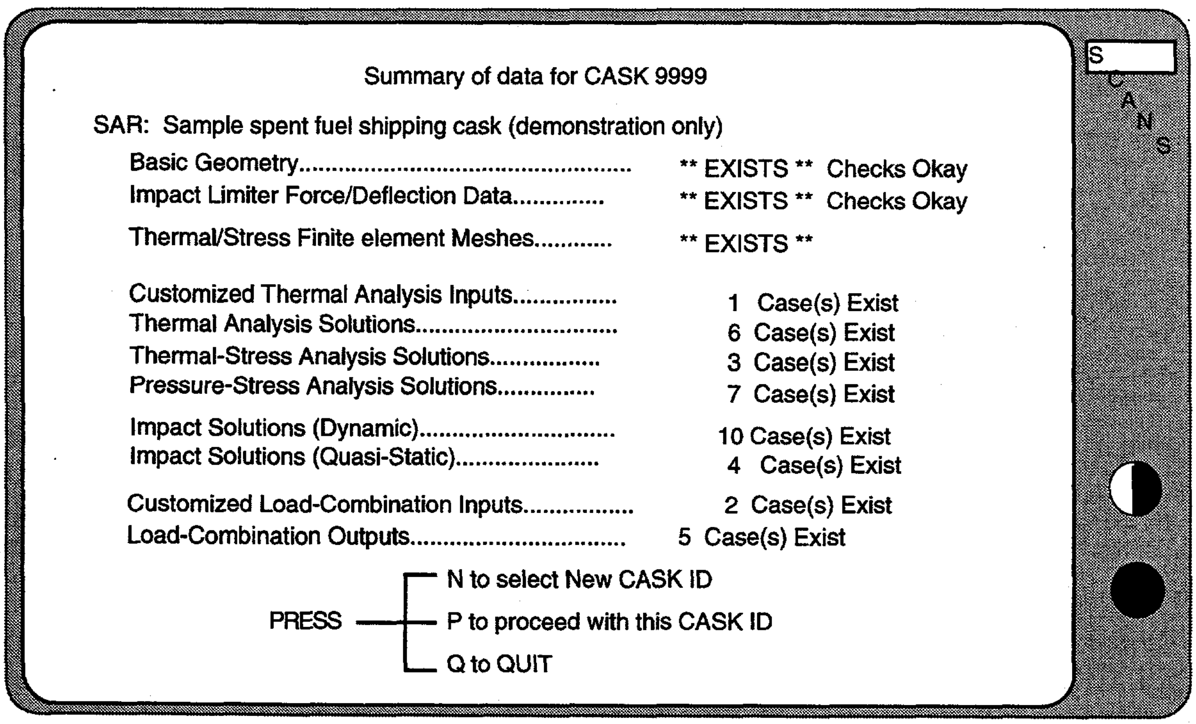


Figure 1-3. Cask data set summary screen.

NOTES:

Main Menu

The Main Menu (**Figure 2-1**) is the central hub of **SCANS**. It provides access to five 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 **SCANS** is started. The only difference is that pressing **Q** returns to the Main Menu instead of leaving **SCANS** and returning to DOS.

PRESS 2 to Create/Modify the CASK geometry model

Select this task first for a new cask data set. **SCANS** displays the Geometry Menu which provides tasks for: (1) creating new (or modifying previous) basic geometry definitions and impact limiter force-deflection curves; and (2) copying basic geometry or limiter curves from a different cask data set.

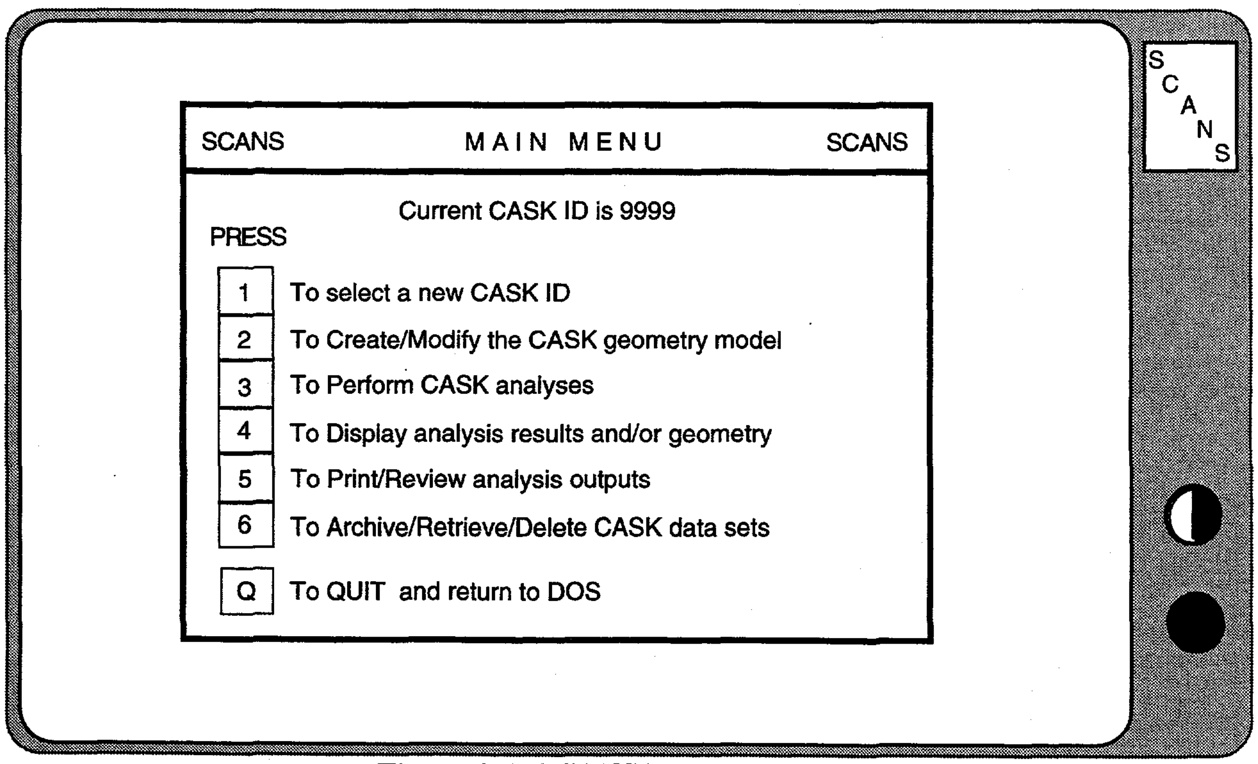


Figure 2-1. SCANS Main Menu.

Main Menu

PRESS 3 to Perform CASK analyses

CASK analyses are performed after defining the cask geometry and if necessary, the impact limiter force-deflection curves. **SCANS** displays the Analysis Menu, which provides tasks to perform analyses involving impact loads, thermal distributions and stresses, pressure loads, and load combintations.

PRESS 4 to Display analysis results and/or geometry

SCANS displays the Display Menu which provides tasks for: (1) plotting dynamic impact time-histories; (2) displaying and printing finite-element meshes used for thermal, thermal-stress and pressure-stress calculations; and (3) plotting thermal distributions as isocontours, time histories, or thermal profiles. The finite-element meshes can be displayed before any analysis is performed. Results cannot be plotted until the appropriate analysis is performed.

PRESS 5 to Print/Review analysis outputs

SCANS displays the Print/Review Menu, which provides tasks for printing or reviewing all printable outputs (analysis results or the cask summary and data check). Printing an output sends it to the printer; reviewing an output displays it on the screen.

PRESS 6 to Archive/Retrieve/Delete CASK data sets

SCANS 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 (complete data sets or just the output) from the hard disk.

PRESS Q to QUIT and return to DOS

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

Geometry Menu

The Geometry Menu (**Figure 3-1**) provides tasks for creating new (or modifying previous) basic geometry definitions and impact limiter force-deflection curves.

PRESS 1 to Create/Modify basic geometry

If the basic geometry definition data set exists, editing is initiated. If the basic geometry data does not exist, **SCANS** creates a new data set with default values, and editing is initiated. When the basic geometry is saved, **SCANS** automatically performs a data check. Basic geometry definitions must be completed and pass the data check before **SCANS** will perform any analysis.

PRESS 2 to Create/Modify impact limiter F/D curves

If the impact limiter force-deflection curve data set exists, editing is initiated. If the limiter curve data does not exist, **SCANS** creates a new data set with default values, and editing is initiated. When the limiter curve data is saved, **SCANS** automatically performs a data check. Limiter force-deflection curves must be defined and pass the data check before **SCANS** will perform an impact analysis.

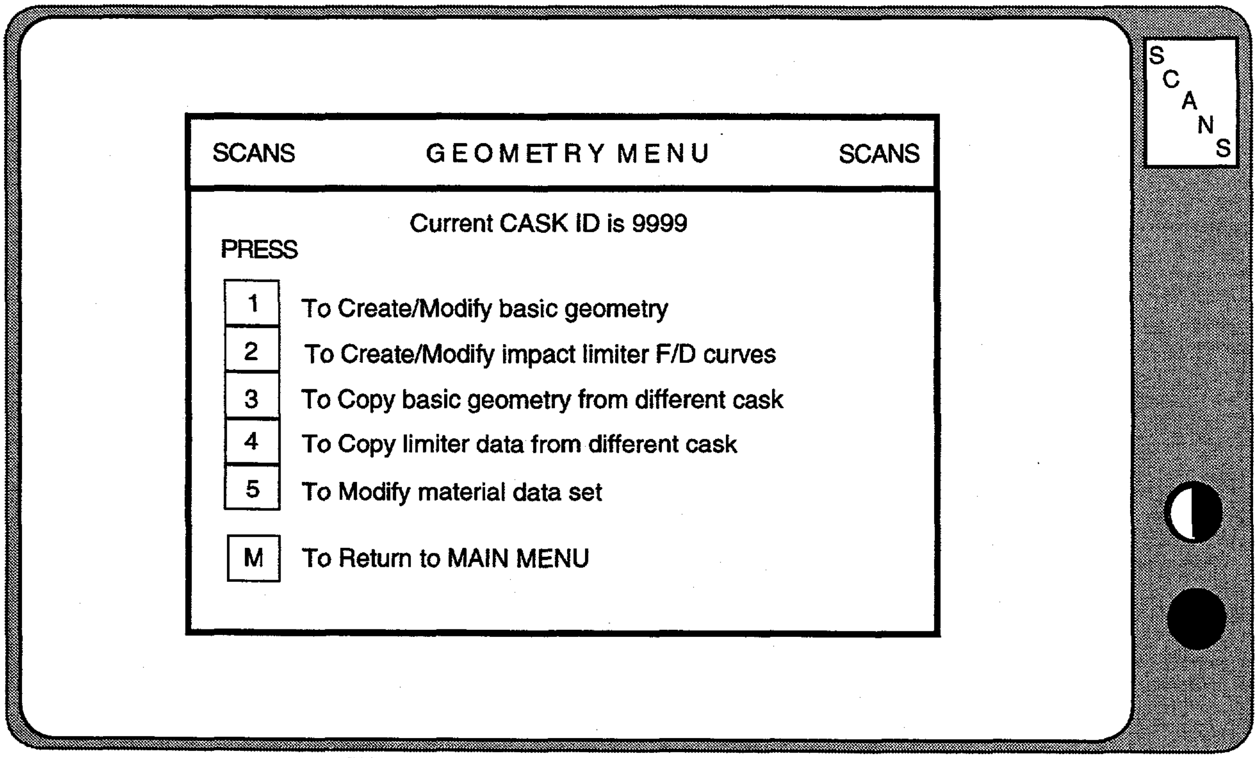


Figure 3-1. SCANS Geometry Menu.

Geometry Menu

PRESS 3 to Copy basic geometry from different cask

Use this feature to create the basic 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.

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

PRESS 4 to Copy limiter data from different cask

Use this feature to create the impact limiter force-deflection curve 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.

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

PRESS 5 to Modify material data set

Use this feature to create or modify material property data set. To create a data set, first copy it from an existing data set. Then, modify the copied set to the desired data set. Only the data sets created by the user can be modified. The built-in material data sets are locked; i.e., they cannot be modified but can be copied.

SCANS lists all available material property data sets including the built-in and user-created sets. Use the cursor keys to highlight the data set to copy, then press S. **SCANS** will ask the user to name the new material data set and identify the cask component for which the data is intended. If a data set with the same name already exists for the component, **SCANS** asks for confirmation before overwriting the old data set with the new.

PRESS M to Return to MAIN MENU

SCANS returns to the Main Menu display.

SCANS uses a general purpose fill-in-the-blank type editor to enter data for the basic geometry definition and the impact limiter force-deflection curve definitions. 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.

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, **SCANS** 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
  (Typing in the first character position clears the field)
- 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. **SCANS** 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.

SCANS uses a simplified cask model comprised of seven components: (1) cask cavity; (2) shell; (3) top end cap; (4) bottom end cap; (5) top impact limiter; (6) bottom impact limiter; and (7) neutron shield and water jacket. 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 (two or three layers). The cavity, shell and end caps must be defined for each analysis. Impact limiters are optional but are required for impact calculations. The neutron shield/water jacket is optional and, if included, used only for thermal analyses. Mesh division values are used to generate two-dimensional finite-element meshes for thermal, thermal-stress and pressure-stress analyses. The geometry definition is described in the context of the editor pages that follow.

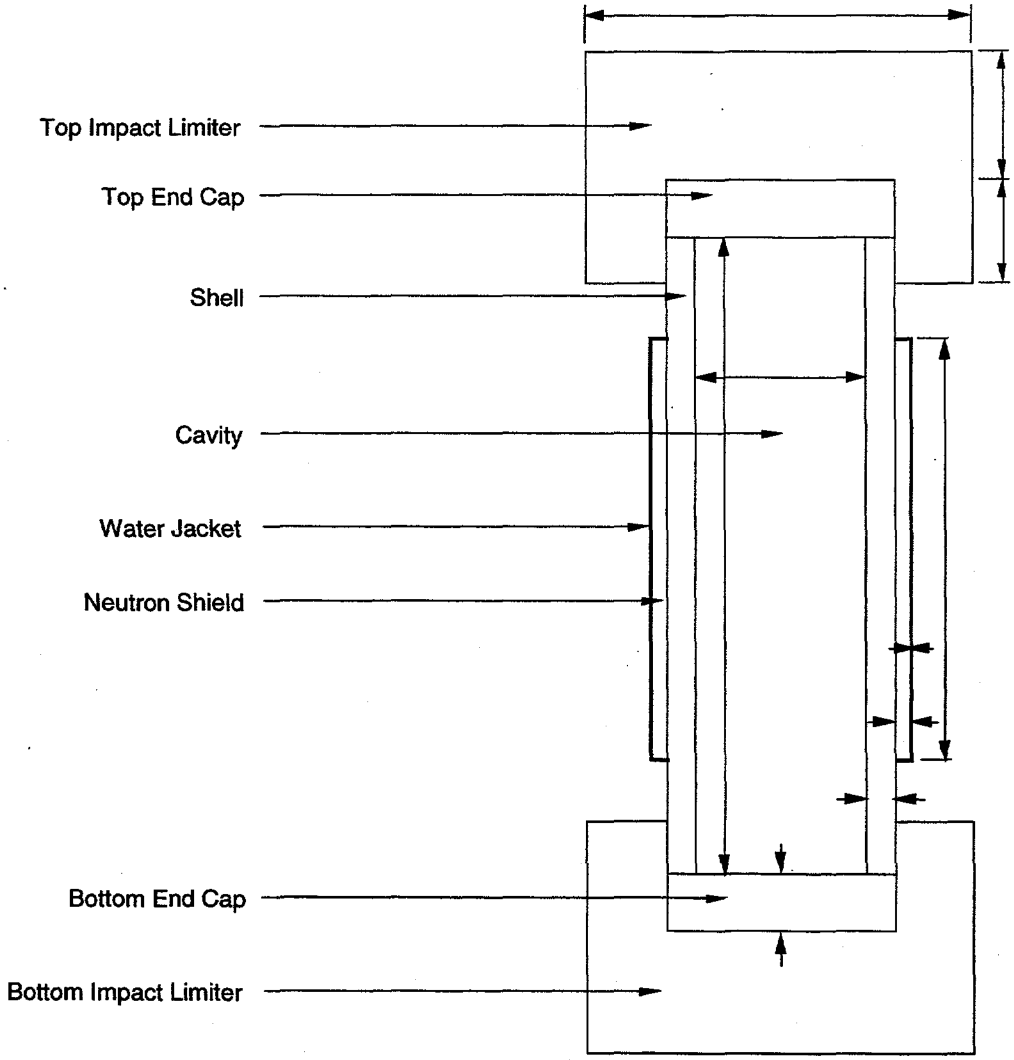


Figure 3-2. SCANS simplified cask model.

Geometry Menu

Defining the Geometry

Basic Geometry PAGE 1 General SAR Information

The SAR title is required.

Four fields are provided for other SAR information, three fields are provided for additional information, and three for the submitting company's address. All fields on this page are character type and are not checked for validity.

Basic Geometry PAGE 2 Reviewer Information

There is no required data on this page. It is provided to document the persons involved in the cask evaluation. All fields are character type and are not checked for validity.

Basic Geometry PAGE 3 Cask Cavity/Contents Specifications

The cavity dimensions and the weight specifications are required for all analyses. The maximum heat generation rate is required for thermal and thermal-stress analyses.

Cavity inner radius (inches) **Required**.
Must be positive and less than 2000.

Cavity length (inches) **Required**.
Must be positive and less than 2000.

Gross weight of package (lbs) **Required**.
Includes the cask body, impact limiters, internal structures, and spent fuel contents. Must be positive.

Weight of spent fuel contents and internal structures (lbs) **Required**.
Must be non-negative.

Maximum heat generation rate of the spent fuel contents (Btu/min).
Used for thermal and thermal-stress analyses. Must be non-negative.

Initial cavity charge pressure (psia) and temperature (degrees F).
Used during thermal analyses to estimate the change in internal pressure as a result of thermal loads. Pressure must be positive, and temperature must be greater than or equal to -100°F.

Maximum normal operating pressure (psia).
Used as one of the regulatory pressure-stress loading conditions. Must be positive.

Temperature defining stress free condition (degrees F).
Used for thermal-stress analyses. May be changed during specification of the thermal-stress analysis. Must be greater than or equal to -100°F.

Number of mesh divisions along cavity inner radius and along cavity half length.
NOTE: Specify the mesh divisions along the half length of the cavity, not the full length. Must be even and between 2 and 30.

Basic Geometry PAGE 4 Cask Component Configurations

The default cask configuration has a solid shell and solid end caps. It includes top and bottom impact limiters, neutron shield, and water jacket. Enter **L** to specify a laminated shell or end caps. Enter **N** to exclude either limiter or the neutron shield and water jacket. **Figure 3-3** shows several possible configurations.

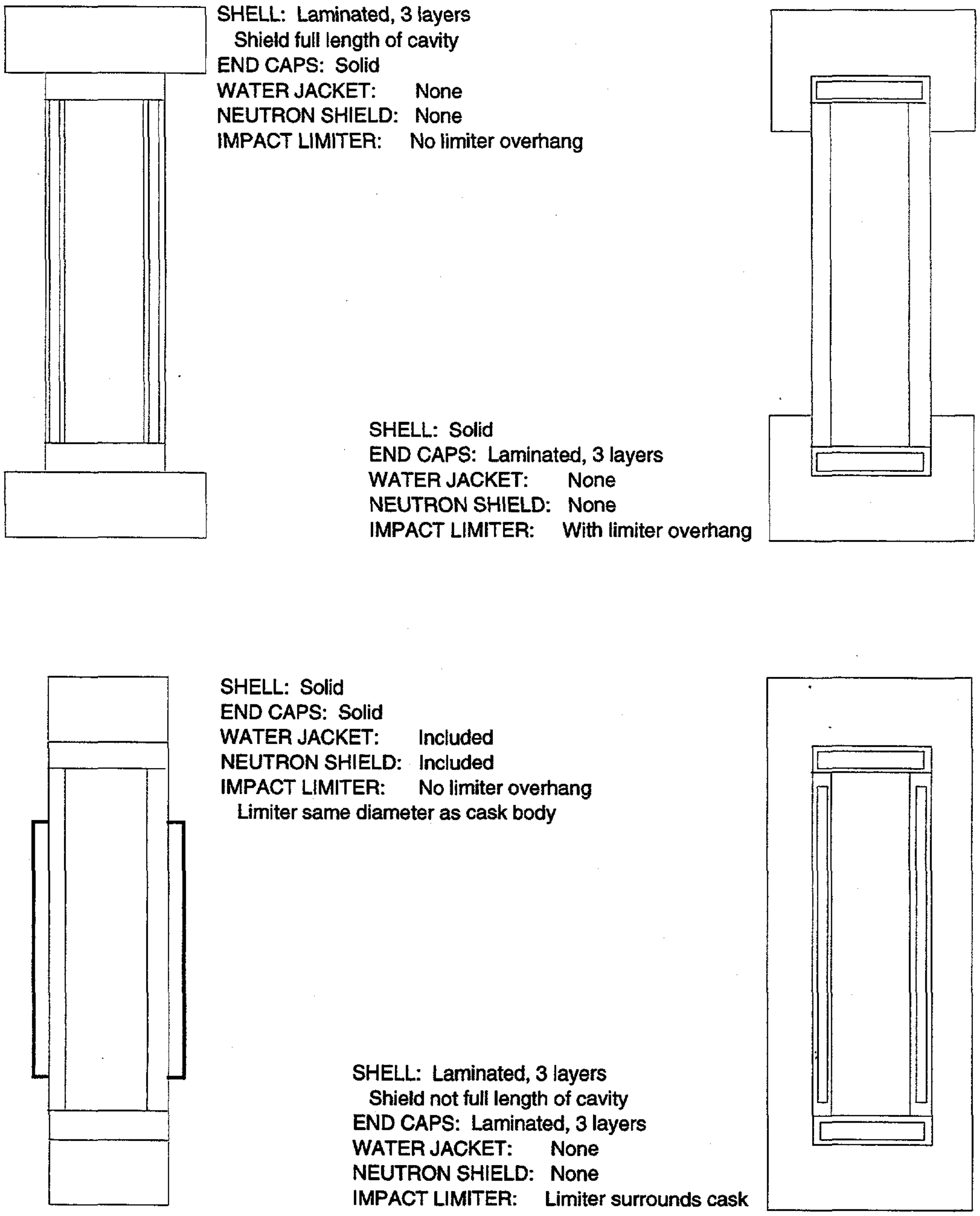


Figure 3-3. Sample cask configurations.

Geometry Menu
Defining the Geometry

Basic Geometry Page 5 Cask Shell Specifications

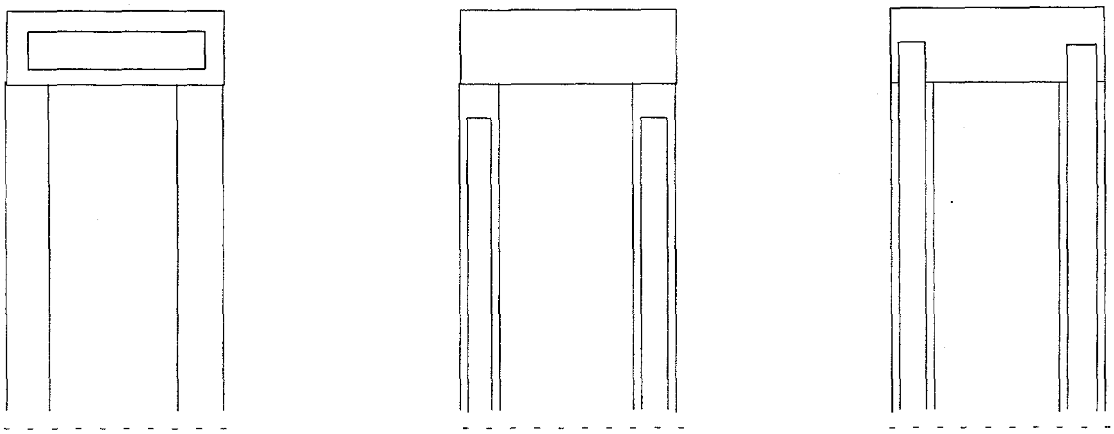
Page 5a is displayed when a solid shell is specified and page 5b is displayed when a laminated shell is specified.

Solid Shell

Shell thickness (inches) **Required.**
Total thickness of the shell. Must be positive and less than 2000.
Shell material name.
Select from the displayed list of materials.
Number of mesh divisions through shell.
Used to generate a two-dimensional finite-element mesh for thermal, thermal-stress and pressure-stress analyses. Must be even and between 2 and 10.

Laminated Shell

Shell inner layer thickness (inches) **Required.**
Must be non-negative and less than 2000. Set to 0.0 to eliminate the inner layer.
Additional thickness of inner layer in vicinity of the end caps (inches).
Must be non-negative and less than 2000. Set to 0.0 if inner shell is not thickened. Used for impact analyses with unbonded lead shielding.
Shell inner layer material name.
Select from the displayed list of materials.
Shell shield layer thickness (inches) **Required.**
Must be non-negative and less than 2000. Set to 0.0 to eliminate the shield layer.
Shell shield length (inches) **Required.**
Must be non-negative and less than 2000. Set to 0.0 to eliminate the shield layer. May be larger than the cavity length but should not exceed the cask body length (cavity length plus thickness of both end caps). **Figure 3-4** shows the effects of various shell shield lengths. **NOTE:** impact analyses assume shield length is same as cavity length.
Shell shield layer material name.
Select from the displayed list of materials.
Shell outer layer thickness (inches) **Required.**
Must be positive and less than 2000.
Additional thickness of outer layer in vicinity of the end caps (inches).
Must be non-negative and less than 2000. Set to 0.0 if outer shell is not thickened. Used for impact analyses with unbonded lead shielding.
Shell outer layer material name.
Select from the displayed list of materials.
Number of mesh divisions through inner layer, shield layer and outer layer of the shell.
If inner layer or shield layer is eliminated, number of mesh divisions is ignored. Must be even and between 2 and 10.



SHELL: Solid

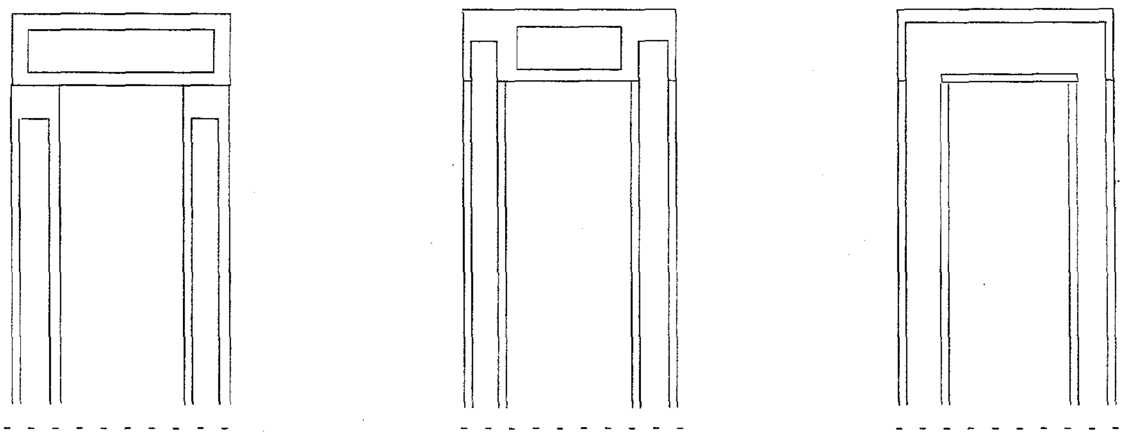
END CAPS: Laminated 3 layers
End cap shield radius greater
than cavity radius

SHELL: Laminated 3 layers
Shell Shield length less
than length of cavity

END CAPS: Solid

SHELL: Laminated 3 layers
Shell Shield length greater
than length of cavity

END CAPS: Solid



SHELL: Laminated 3 layers
Shell shield length less
than length of cavity

END CAPS: Laminated 3 layers
End cap shield radius greater
than cavity radius

SHELL: Laminated 3 layers
Shell Shield length greater
than length of cavity

END CAPS: Laminated 3 layers
End cap shield radius less
than cavity radius

SHELL: Laminated 3 layers
Shell Shield length greater
than length of cavity

END CAPS: Laminated 3 layers
End cap shield radius
greater than cavity radius

Figure 3-4. Possible shield configurations.

Geometry Menu

Defining the Geometry

Basic Geometry Pages 6-7 Cask End Cap Specifications

Page 6a is displayed when a solid top end cap is specified. Page 6b is displayed when a laminated top end cap is specified. Pages 7a and 7b are for solid and laminated bottom end caps; these pages are identical to pages 6a and 6b.

Solid End Cap

End cap thickness (inches) **Required.**
Total thickness of the end cap. Must be positive and less than 2000.

End cap material name.
Select from the displayed list of materials.

Number of mesh divisions through end cap.
Must be even and between 2 and 10.

Laminated End Cap

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

End cap inner layer material name.
Select from the displayed list of materials.

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

End cap shield radius (inches) **Required.**
Must be non-negative and less than 2000. Set to 0.0 to eliminate the shield layer. Must be larger than the cavity radius and should not exceed the cask body outer radius (cavity radius plus shell thickness). **Figure 3-4** shows the effects of various end cap shield lengths.

End cap shield layer material name.
Select from the displayed list of materials.

End cap outer layer thickness (inches) **Required.**
Must be positive and less than 2000.

End cap outer layer material name.
Select from the displayed list of materials.

Number of mesh divisions through inner layer, shield layer, and outer layer of the end cap.
If inner layer or shield layer is eliminated, number of mesh divisions is ignored. Must be even and between 2 and 10.

Basic Geometry Page 8 Cask Closure Bolts Information

Number of closure bolts **Required.**
Must be positive and less than 100.
Diameter of closure bolts (inches) **Required.**
Must be positive and less than or equal to 10.
Closure bolt circle radius (inches) **Required.**
Must be positive and less than 2000. Should be greater than the cavity radius and less than the cask body outer radius (cavity radius plus shell thickness).

Basic Geometry Page 9 Cask Neutron Shield / Water Jacket Specifications

The neutron shield and water jacket are not included in impact, thermal-stress and pressure-stress analyses. They may be included in thermal analyses if they affect heat transfer.

Neutron shield and water jacket length (inches) **Required.**
Must be non-negative and less than 2000. Should be less than the cavity length. Set to 0.0 to eliminate the neutron shield and water jacket (same as specifying on Page 4 that they are not included).
Neutron shield thickness (inches) **Required.**
Must be non-negative and less than 2000. Set to 0.0 to eliminate the neutron shield.
Neutron shield material name.
Select from the displayed list of materials.
Water jacket thickness (inches) **Required.**
Must be non-negative and less than 2000. Set to 0.0 to eliminate the water jacket.
Water jacket material name.
Select from the displayed list of materials.
Number of mesh divisions through neutron shield and water jacket.
If neutron shield or water jacket is eliminated, number of mesh divisions is ignored. Must be between 1 and 3.

Basic Geometry Pages 10-11 Cask Impact Limiter Specifications

Page 10 is displayed when a top impact limiter is included in the cask model. Page 11 is displayed when a bottom impact limiter is included. Top and bottom impact limiters are specified in a similar manner. Impact limiters are included in impact and thermal analyses. **Figure 3-5** shows possible impact limiter configurations.

Impact limiter radius (inches) **Required.**
Must be positive and less than 2000. Should be greater than or equal to the cask body outer radius (cavity radius plus shell thickness).
Impact limiter centerline thickness above the end cap (inches) **Required.**
Must be positive and less than 2000.

Impact limiter overhang thickness below the end cap (inches) **Required**.

Must be non-negative and less than 2000. Should be less than or equal to half the cask body length (cavity length plus thickness of both end caps). Set to 0.0 for no overhang. Set greater than half cask body length to surround the cask with the impact limiter. If the impact limiter radius is less than or equal to the cask body outer radius, the overhang thickness is ignored.

Impact limiter material name.

Select from the displayed material list.

Number of mesh divisions through limiter centerline thickness and overhang width (impact limiter radius minus cask body outer radius).

Must be between 1 and 10.

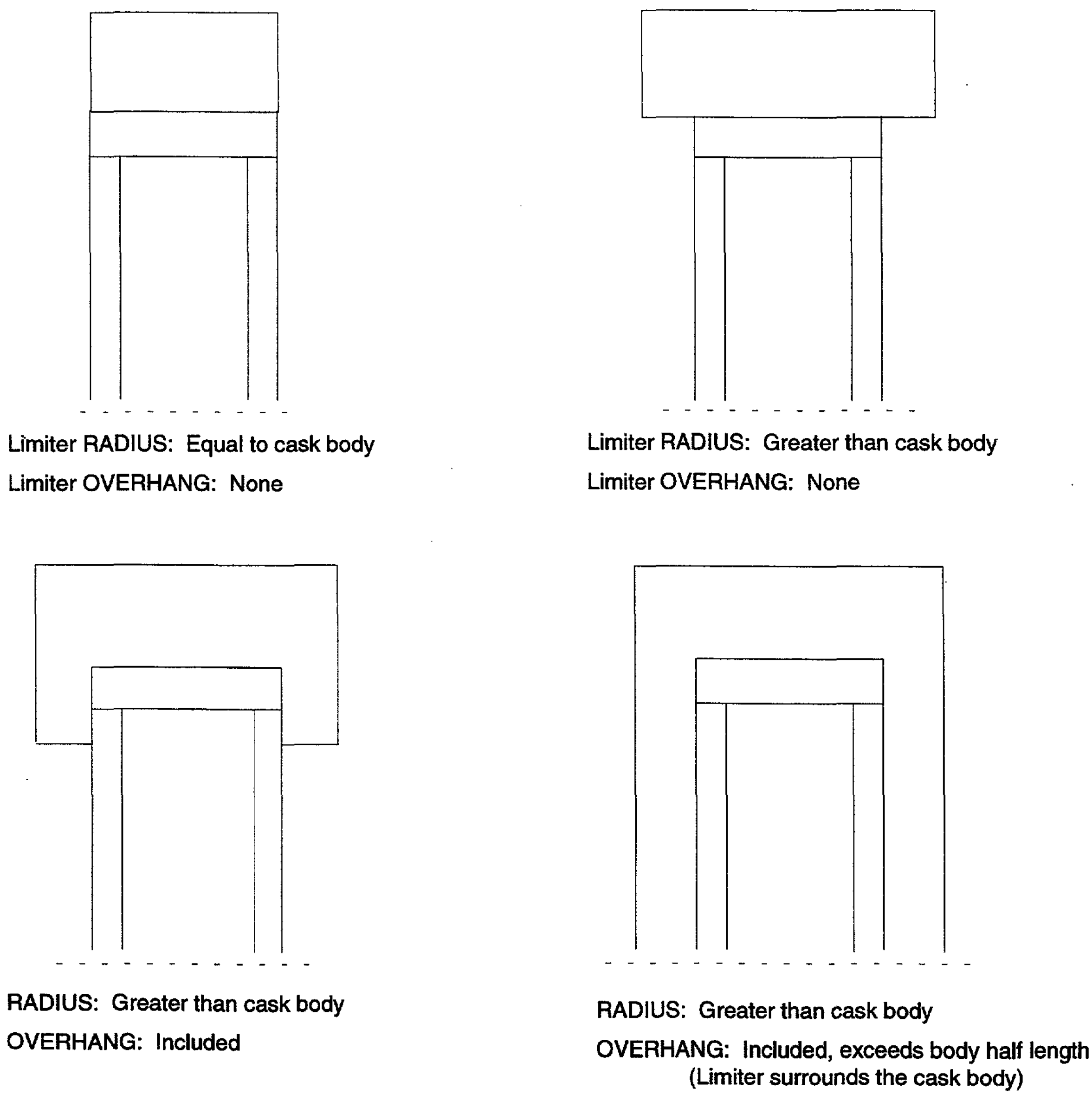


Figure 3-5. Possible impact limiter configurations.

Basic Geometry Page 12 Cask Impact Model Specifications

Define these values for impact analyses. They are not used for any other analysis.

Number of elements for the one-dimensional beam impact model.

Accuracy generally improves with increased number of elements. However, the more elements used, the higher the possibility of capturing unnecessary high frequency modes. The integration time step is inversely proportional to the maximum frequency of the model. Thus, high frequencies require small time steps which causes the computation time to lengthen. The number of elements also specifies where force and stress information is output. Set to 3 for output at third points. Set to 4 for output at quarter points. Set to 6 for 1/6th points. Set to 12 for quarter and third points (plus a few more). Must be between 3 and 20.

Top impact limiter weight (lbs).

Set to 0.0 to calculate top impact limiter weight based on limiter dimensions and density.

Bottom impact limiter weight (lbs).

Set to 0.0 to calculate bottom impact limiter weight based on limiter dimensions and density.

Define impact model with user specified properties? [Y/N].

Specify **N** to use shell, end caps, and impact limiter dimensions for impact analyses. Specify **Y** to input the following impact model properties directly. These properties are described in Volume 2, *SCANS Impact Analysis Theory Manual*, in the section discussing the theory of impact. The weight of the contents and internal structures must be specified on the basic geometry editor page 3 (cask cavity/contents specifications).

The following properties must all be positive.

Shell translational mass (lb-sec**2/inch).
Shell rotational mass (lb-sec**2-inch).
Shell inside length (inches).
Shell E*I (composite Young's Modulus *x* Moment of Inertia)
(lb-inch**2).
Shell A*E (composite Young's Modulus *x* Area) (lbs).
Shell composite Poisson's Ratio.
Top end translational mass (lb-sec**2/inch).
Top end rotational mass (lb-sec**2-inch).
Bottom end translational mass (lb-sec**2/inch).
Bottom end rotational mass (lb-sec**2-inch).
Characteristic cross-section width (inches).

Geometry Menu

Defining the Impact Limiter Force-Deflection Curve

SCANS has eight predefined oblique angles for impact analyses: 0 degrees (side drop); 15; 30; 45; 60; 75; 90 (end-on drop); and CG (center-of-gravity drop). Impact limiter force-deflection curves are related to the angle of impact because limiter crush forces are based on the contact footprint. Define any or all of the limiter curves; there are eight possible curves for the top impact limiter and eight for the bottom limiter. If curves are only defined for one limiter, **SCANS** will not allow side drop analyses, secondary impact analyses, or analyses specifying the end without an impact limiter as the primary impact end.

The impact limiter data set has 17 editor pages. Page 0 specifies the slope of the unloading path for the impact limiters (**Figure 3-6**). This slope relates the force unloaded with the amount of elastic recovery of the limiter. **SCANS** allows three choices: **C** selects the maximum slope of the limiter force-deflection curve as the unloading slope; **N** selects no elastic recovery of the impact limiter (for dynamic stability this is approximated by an unloading slope that is five times the maximum slope of the force-deflection curve); and **U** selects a user specified unloading slope (in terms of kips of unloading force per inch of elastic recover).

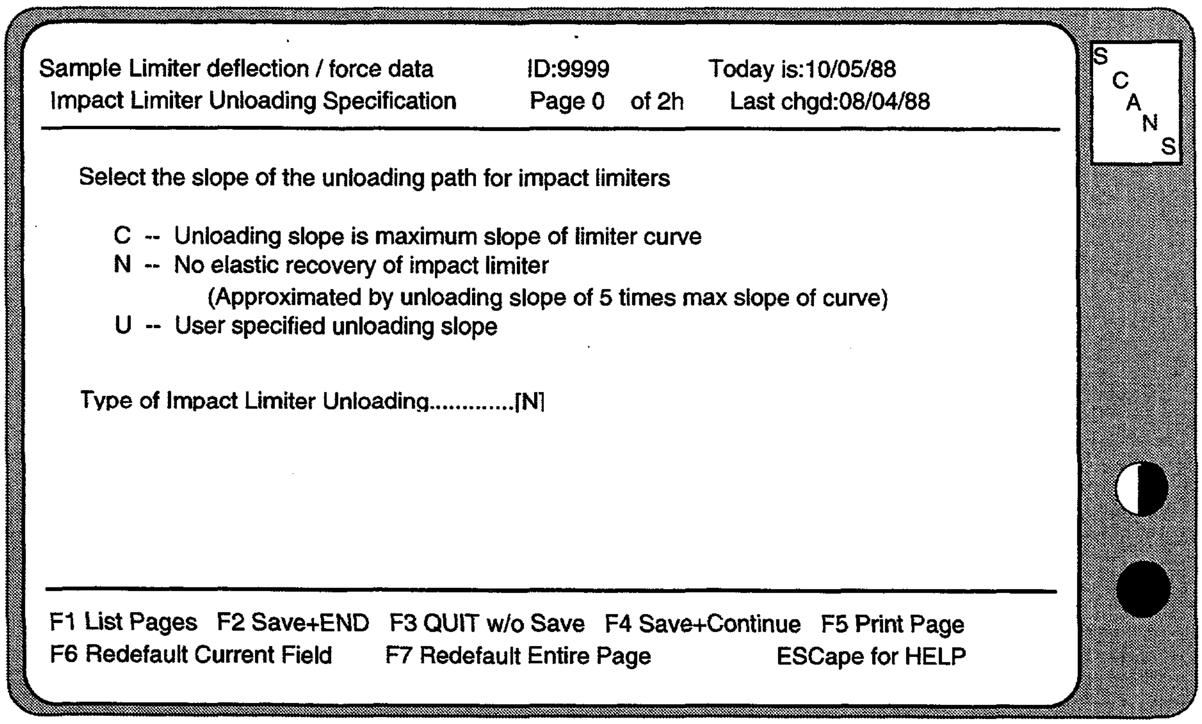


Figure 3-6. Impact limiter unloading specification.

Defining the Impact Limiter Force-Deflection Curve

Each of the remaining pages specifies a force-deflection curve for a specific limiter (bottom or top) at a specific impact angle. Pages 1a-1h define force-deflection curves for the bottom impact limiter, and pages 2a-2h define curves for the top limiter. Use the keypad **PgUp** or **PgDn** keys to display the page with the desired limiter and impact angle (or use the page list function key **F1** to select the page). The impact end and orientation angle are identified in the upper left corner of the screen. Then, type **Y** and press **ENTER** to activate the curve data. Fill in up to ten curve points; the first two points are required. If there are less than ten curve points, leave the remaining curve points 0.0. Enter deflections in **inches** and forces in **kips**. Data page 1c, which specifies the bottom impact limiter for a 30-degree impact, is shown in **Figure 3-7**. On first view of this page, only the first four lines below the title (down to the yes/no question) would appear. Upon answering yes, [Y], then the 30-degree impact page should appear as shown.

Press **F10** to copy curve data from a different impact angle or cask end. When **SCANS** displays the list of all impact angles, use the **UpArrow** and **DnArrow** keys to indicate the data to copy from and then press **C** to perform the copy.

Each force-deflection curve must be single valued and in increasing order. That is, each deflection point must be larger than the previous one. The impact limiter force-deflection model is described in Volume 2, *SCANS Impact Analysis Theory Manual.*

```
Sample Limiter deflection / force data        ID:9999       Today is:10/05/88
Bottom Impact Limiter for 30 degree impact    Page 1c  of 2h  Last chgd:10/05/88
-------------------------------------------------------------------------------
Press  F10   to copy Force/Deflection data from another impact angle

Impact angle is defined as follows:  SIDE impact angle is 0.
                                     END ON impact angle is 90.

Do you wish to define a Deflection/Force curve for this angle ?  [Y/N]........[Y]

              You must define at least 2 deflection/force pairs
  Deflection #0    (in)   .0                Force #0    (kips)   .0
  Deflection #1    (in)...[0.          ]    Force #1    (kips)...[0.          ]
  Deflection #2    (in)...[0.          ]    Force #2    (kips)...[0.          ]
  Deflection #3    (in)...[0.          ]    Force #3    (kips)...[0.          ]
  Deflection #4    (in)...[0.          ]    Force #4    (kips)...[0.          ]
  Deflection #5    (in)...[0.          ]    Force #5    (kips)...[0.          ]
  Deflection #6    (in)...[0.          ]    Force #6    (kips)...[0.          ]
  Deflection #7    (in)...[0.          ]    Force #7    (kips)...[0.          ]
  Deflection #8    (in)...[0.          ]    Force #8    (kips)...[0.          ]
  Deflection #9    (in)...[0.          ]    Force #9    (kips)...[0.          ]
  Deflection #10   (in)...[0.          ]    Force #10   (kips)...[0.          ]
-------------------------------------------------------------------------------
F1 List Pages   F2 Save+END   F3 QUIT w/o Save   F4 Save+Continue   F5 Print Page
F6 Redefault Current Field    F7 Redefault Entire Page           ESCape for HELP

SCANS
```

Figure 3-7. Sample impact limiter data page.

Geometry Menu
Defining User Material Data

SCANS has eighteen built-in material data sets which can be copied in order to create a user material data set. The built-in sets comprise five materials (carbon steel and stainless steels 304, 310, 316, and 347) for the end-cap and shell structures; one material (lead) for the radiation shield; four materials (balsa wood - cross grained, polyfoam, polyurethane, and redwood - cross grained) for the impact limiter; six materials (carbon steel, copper, stainless steels 304, 310, 316, and 347) for the water jacket; and two materials (convections in air and in water) for the neutron shield. Details of these data sets are given in Appendix B. When the option of editing material data set is selected, **SCANS** lists all existing material data files and identifies the eighteen built-in data sets as locked files which can be copied but not modified **(Figure 3-8)**.

SELECT MATERIAL FILE

FILE	NAME	CASK COMPONENT	DATE	NOTES
CARBNSTL	Carbon Steel	EndCap/Shell Structure	3-20-91	Locked
SS304	Stainless Steel 304	EndCap/Shell Structure	4-23-91	Locked
SS310	Stainless Steel 310	EndCap/Shell Structure	4-23-91	Locked
SS316	Stainless Steel 316	Endcap/Shell Structure	4-23-91	Locked
SS347	Stainless Steel 347	EndCap/Shell Structure	4-23-91	Locked
US304	Stainless Steel 304M	EndCap/Shell Structure	12-17-90	
LEAD	Cast Lead	Shielding	3-20-91	Locked
BALSAXGR	Balsa Wood Cross Grain	Impact Limiters	10-04-89	Locked
POLYFOAM	Polyfoam	Impact Limiters	10-04-89	Locked
PURETHAN	Poly urethane	Impact Limiters	10-04-89	Locked
REDWDXGR	Redwood Cross grain	Impact Limiters	10-04-89	Locked
CARBNSTL	Carbon Steel	Water Jacket	11-27-89	Locked
COPPER	Copper	Water Jacket	11-27-89	Locked
SS304	Stainless Steel 304	Water Jacket	11-27-89	Locked
SS310	Stainless Steel 310	Water Jacket	11-27-89	Locked
SS316	Stainless Steel 316	Water Jacket	11-27-89	Locked
SS347	Stainless Steel 347	Water Jacket	11-27-89	Locked
AIRCONV	Convection in Air	Neutron Shield	10-04-89	Locked
H2OCONV	Convection in Water	Neutron Shield	10-04-89	Locked

Press any of the following keys

C to Copy indicated data set — Q to QUIT — ↑ to move to previous data set

Locked files may not be edited — ↓ to move to next data set

SCANS

Figure 3-8. Material file list.

A new user material data set is created by copying one of the existing material files displayed by **SCANS**. **SCANS** uses a file name and a cask component name to identify the new data set. **SCANS** asks the user to enter a material file name of his choice and to press one of the following function keys to select a component:

F1 for end cap / shell structure
F2 for shielding
F3 for bolts
F4 for impact limiters
F5 for water jacket
F6 for neutron shield

The bolts option is for future development of **SCANS**. The current version of **SCANS** does not require material properties for bolts. If the assigned file and component names coincide with those of an existing data set, **SCANS** will ask for permission before replacing the old file with the new.

All material files except the locked files can be edited. **SCANS** uses eleven editor pages for the editing. The pages contain all the material data needed for **SCANS** analyses. For a specific material, component and analysis, only a portion of the material properties listed in the editor pages are used; input values to the unused properties are not needed and have no effect on the **SCANS** analysis results.

Page 1 of the eleven editor pages specifies the name and density of the material. The name is used to describe and identify the material. The density is used in all **SCANS** analyses. The data on this page are, therefore, required for all materials and components.

Page 2 contains properties that are used for impact and puncture analyses **(Figure 3-9)**. The impact analysis includes a buckling analysis of the inner and outer shells of the shipping cask, and a lead slump analysis of the radiation shield. The values used for the properties on this editor page should be appropriate for the temperature and strain rate of the impact or puncture phenomena being analyzed. The specific use of the properties on this page are as follows:

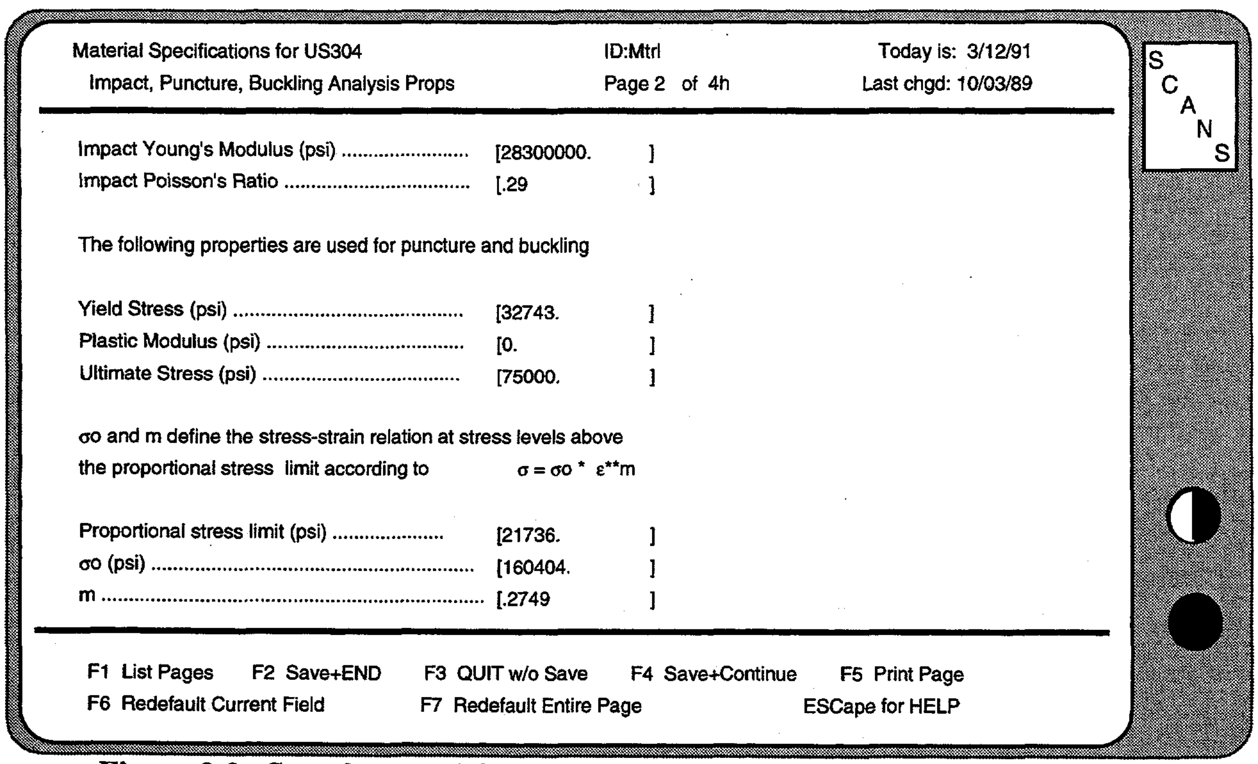


Figure 3-9. Sample material data page for impact and puncture analyses.

Geometry Menu
Defining User Material Data

The Young's modulus and Poisson's ratio are used for impact analysis and must be provided for all components of the **SCANS** impact model which includes the end caps, the cask inner and outer shells, and the radiation shield.

The yield stress is used only for buckling analysis of cask shells that are made of carbon steels or elastic-perfectly-plastic materials. It is required for cask shells made of these materials.

The plastic modulus was used in **SCANS** Version 1 for lead slump analysis and is not used in this version.

The ultimate stress is used for puncture analysis and is required for the end caps, and the outer cask shell.

The proportional limit, the material stress-strain-relation parameters, σo and m, are used for buckling analysis of cask shells that are made of austenitic steels or workhardening materials. The material properties are needed only for the cask shells made of these materials. These three material parameters are also used in the built-in lead data file for lead slump analysis. However, these lead properties cannot be modified because **SCANS** uses only the built-in lead file for lead slump analysis.

Pages 3 through 4h specify temperature-dependent material properties that are used for thermal, thermal stress, and pressure stress analyses. Page 3 identifies the number of temperatures for which the properties are given in Pages 4a through 4h; the maximum number allowed is eight. Each of Pages 4a through 4h defines the property values at a specified temperature **(Figure 3-10)**. The data must be arranged in the order of ascending temperatures and must cover the entire range of temperatures that the material experiences in the analyses. Among the material data appearing on these pages, the coefficient of thermal expansion is used for thermal stress analysis; the Young's modulus and Poisson's ratio are used for both thermal and pressure stress analyses; the thermal conductivity and specific heat are for thermal analysis, and the ASME B&PV allowable stress and tensile strength are for load combination analysis.

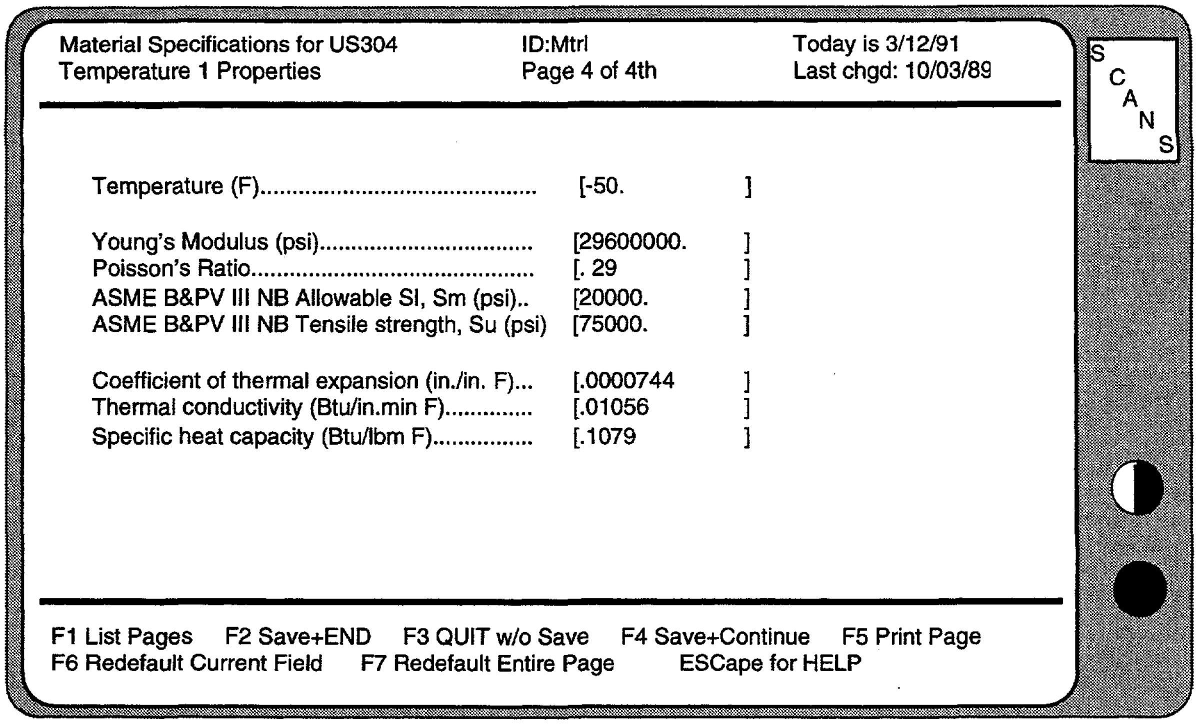


Figure 3-10. Sample temperature-dependent material data page for thermal and stress analysis.

NOTES:

Analysis Menu

The Analysis Menu (**Figure 4-1**) provides tasks to perform analyses involving impact loads, thermal distributions and stresses, and pressure loads. The basic geometry model definitions must be completed before **SCANS** can perform any analysis.

PRESS 1 to Perform Impact analysis

SCANS determines forces and stresses resulting from impact loads. Impact limiter force-deflection curves must be defined before **SCANS** can perform an impact analysis. The impact condition is specified by drop height, impact type, analysis type, shell/shield interface type, impact end, and impact angle.

PRESS 2 to Perform Thermal analysis

SCANS performs any of seven predefined regulatory thermal analyses, as well as analyses with user specified boundary conditions. These analyses include various ambient temperatures, solar effects, contents heat loads, and fire loads.

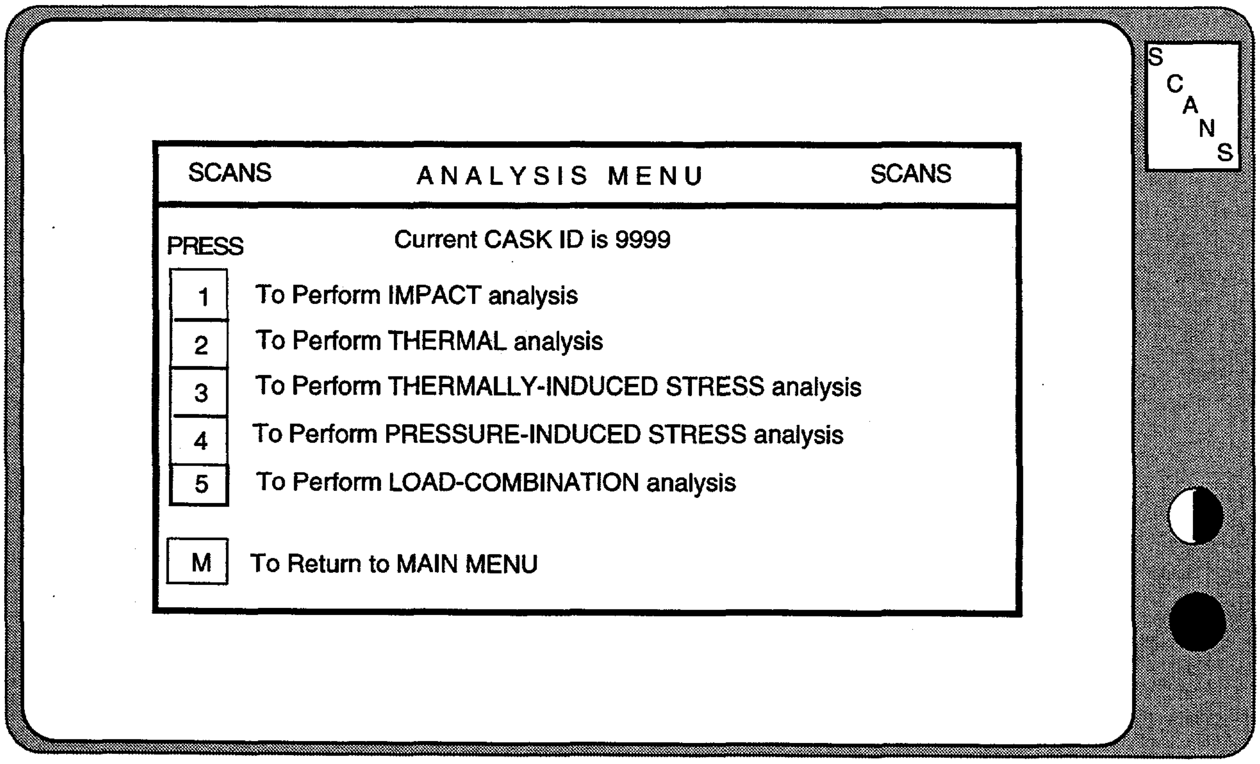


Figure 4-1. SCANS Analysis Menu.

Analysis Menu

PRESS 3 to Perform Thermally-Induced Stress analysis

SCANS determines stresses resulting from previously analyzed thermal conditions. After selecting the thermal case, specify the stress-free temperature and, for the transient case, specify the time state.

PRESS 4 to Perform Pressure-Induced Stress analysis

SCANS determines stresses resulting from the pressure difference between cavity pressure and external pressures defined by regulations.

PRESS 5 to Perform Load-Combination analysis

SCANS combines container shell stresses from three user-selected stress-analysis cases which must include one thermally-induced stress analysis case, one pressure-induced stress anaysis case, and one impact analysis case. Combined stresses are decomposed into membranes, bending, and peak stress components. These stress components are compared with corresponding ASME B&PV Section III code allowables. Regulatory Guide 7.8 explains the purpose and requirements for load combination in structural evaluation of shipping casks. Regualtory Guide 7.6 discussed the design stress criteria used by SCANS for evaluating the combined stresses.

PRESS M to Return to MAIN MENU

SCANS returns to the Main Menu display.

SCANS assumes beam-column behavior for impact analyses and determines forces and stresses for both primary and secondary impacts. **SCANS** can perform impact analyses for oblique angles between 0 degrees (side drop) and 90 degrees (end-on drop) and for drop heights from 0 to 80 feet.

Both the basic geometry and the impact limiter force-deflection curves must be defined and complete before **SCANS** can perform an impact analysis (see Geometry Menu). The basic geometry must include at least one impact limiter. The Impact Analysis Title Screen indicates any missing information required before an impact analysis can be performed.

Press **Q** to QUIT and return to MENU, or press any other key to specify the six impact analysis parameters: drop height; impact type; analysis type; shell/shield interface type; primary impact end; and impact angle (**Figure 4-2**).

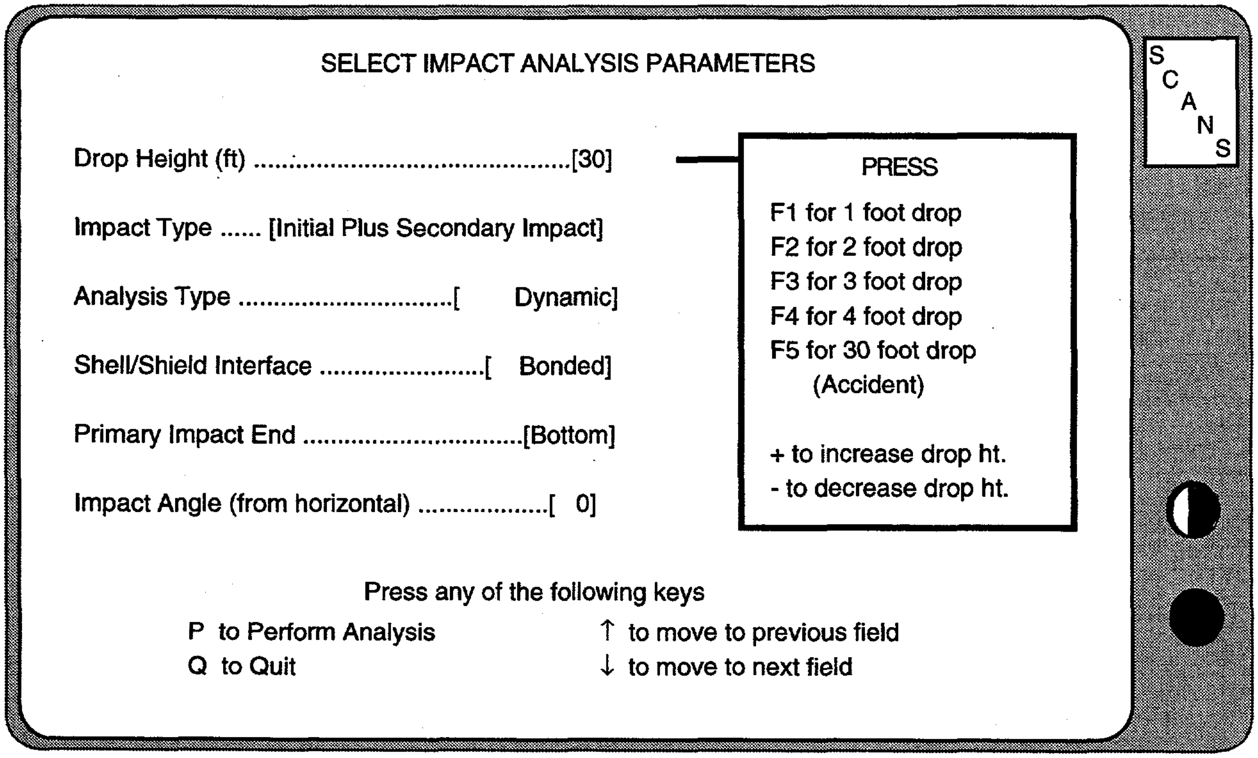


Figure 4-2. Select Impact Analysis Parameters Screen.

Analysis Menu
Perform Impact Analysis

SCANS displays the default values for each of the six parameters. Press **P** to proceed and perform the analysis with the parameters as displayed, press **Q** to QUIT and return to the Analysis Menu or modify any of the parameters before performing the analysis. To modify a parameter, use the keypad up or down arrow keys to highlight the desired field and then press the function key that selects the desired value.

Selecting the Drop Height

Highlight the *Drop Height* field and press one of the indicated function keys to change the drop height.

F1 for a 1 foot drop
F2 for a 2 foot drop
F3 for a 3 foot drop
F4 for a 4 foot drop
F5 for a 30 foot drop (accident)

To select other drop heights not listed above, press the **+** key to increase and the **-** key to decrease the drop height from the current selection. The change is in steps of 1 foot between 0 and 30 feet, 5 feet between 30 and 40 feet, 10 feet between 40 and 80 feet.

Selecting the Impact Type

Two impact types are available, impact of one end (primary impact), and impact of one end followed by rotation of the cask and impact of the other end (secondary impact). Impact limiter geometry and force-deflection curves must be defined for both ends of the cask to perform secondary impact calculations. An impact angle of 0 degrees is always a primary and secondary impact (both ends impact at the same time). Impact angles greater than or equal to the CG angle and unbonded shell/shield interface analyses are always primary impact only.

Highlight the *Impact Type* field and press one of the indicated function keys to change the type of impact.

F1 for initial plus secondary impact
F2 for initial impact only

Selecting the Analysis Type

Two analysis types can be selected: a dynamic, lumped parameter approach that accounts for the dynamic response of the cask and rigid body motion associated with oblique impact; and a quasi-static approach that treats the cask as a slender rigid bar which does not capture dynamic response. Both types are one-dimensional techniques and assume elastic response.

Highlight the *Analysis Type* field and press one of the indicated function keys to change the type of analysis.

F1 for a Dynamic analysis
F2 for a Quasi-static analysis

Selecting the Shell/Shield Interface Type

The default shell/shield interface is bonded. That is, the shield is prevented from slumping. An unbonded interface may be selected if the impact angle is greater than 0 and if the cask has a three-layer laminated shell comprised of STEEL, LEAD, and STEEL. An unbonded interface allows the lead shield to slump and contribute radial forces to the steel shells. **NOTE:** unbonded shell/shield interface analyses are always primary impact only.

Highlight the *Shell/Shield Interface Type* field and press one of the indicated function keys to change the type of shell/shield interface.

F1 for a bonded interface
F2 for an unbonded interface

Selecting the Primary Impact End

Highlight the *Primary Impact End* field and press one of the indicated function keys to change the primary impact end. The primary impact end can only be changed if the alternate end has an impact limiter and at least one force-deflection curve defined for that limiter.

F1 for primary impact on bottom of cask
F2 for primary impact on top of cask

Selecting the Impact Angle

Highlight the *Impact Angle* field and press one of the indicated function keys to change the angle of impact. The angles correspond to the force-deflection curves defined for the primary impact end that is currently specified. A 0-degree angle is a side drop, and a 90-degree impact angle is an end on drop. Side drop analyses are always a primary and secondary impact with a bonded shell/shield interface. Impact angles greater than or equal to the CG angle are always primary impact only.

Performing the Analysis

After all analysis parameters are selected, **SCANS** indicates whether a solution exists for this case. Press **P** to perform the analysis. When the analysis is complete **SCANS** displays the maximum impact force and acceleration for both primary impact and secondary impact (if included) and lists two options:

Press **P** to Perform another impact analysis (with different parameter selections)
Press **Q** to QUIT and return to the analysis menu

Analysis Menu
Perform Impact Analysis

During dynamic analyses, **SCANS** displays the current simulation time, cask orientation, and analysis status. Press **F3** to halt the analysis at any point (results are complete up to the point the analysis is halted). During primary impact, the analysis status indicates "**Calculating PRIMARY impact**". When the primary impact analysis is complete, the status is changed to "**Primary impact complete**". When a secondary impact is initiated, the analysis status indicates "**Calculating SECONDARY impact**" and displays both the cask orientation at secondary impact and the impact limiter force-deflection data set angle used for the secondary impact end. **SCANS** selects the F/D curve that is nearest to the actual secondary impact angle. When the secondary impact analysis is complete, the status is changed to "**Secondary impact complete**".

Dynamic impact analyses may indicate one of the error messages listed below:

Time limit reached
The analysis could not be completed. Probable cause is a very soft impact limiter that does not absorb all the impact energy.

Secondary impact reached, only primary requested
The secondary end of the cask impacts before the primary impact analysis is complete. Message appears only if the impact type was restricted to primary only.

Chord rotation in element "i" is too large
Indicates a numerical instability. Probable cause is a geometry or weight error.

Quasi-Static impact analyses may indicate the error message listed below:

Force becomes negative before impact energy can be dissipated
The limiter Force/deflection curve does not allow the limiter to absorb all the impact energy. Probable cause is an F/D curve that ends with a negative slope.

Thermal, thermal-stress, and pressure-stress analyses require two-dimensional finite element meshes. The first time one of these analyses is requested for a cask, **SCANS** automatically generates the F.E. meshes based on the dimensions and mesh gradings in the geometry definition (see Geometry Menu). The generated F.E. meshes are used automatically until any geometry definition is updated. When a pressure-stress or thermal analysis is selected after the geometry definition is updated, **SCANS** indicates that the F.E. mesh predates the current version of the basic geometry. **SCANS** displays the date and time for both the geometry definition and F.E. mesh and lists several options:

Press **C** to Continue (the analysis) with the current F.E. mesh
Press **G** to Generate a new F.E. mesh based on the current geometry
Press **Q** to QUIT and return to the analysis menu

SCANS displays the thermal and stress meshes after generation is complete. The thermal mesh uses 4-node elements and includes all specified cask components. The stress mesh uses 9-node elements (each 9-node element is equivalent to four 4-node elements) and includes only the cask shell and end caps. The impact limiters, neutron shield, and water jacket are low-strength components which do not affect stress distributions. After displaying the meshes, **SCANS** lists the following choices:

Press **P** to print the Graphic Display
Press **T** to print the Thermal mesh as a node/element map
Press **S** to print the Stress mesh as a node/element map
Press **D** to Display meshes again
Press **C** to Continue with the analysis
Press **Q** to QUIT and return to the Analysis Menu
(Allows abort if display indicates a potential problem)

The thermal and stress mesh node/element maps are useful for reviewing results from thermal and stress analyses. These maps can also be generated from the Display Menu.

NOTE: the video display type and printer type are selected from the Display Menu.

Analysis Menu

Perform Thermal Analysis

The basic geometry must be defined and complete before **SCANS** can perform a thermal analysis (see Geometry Menu). The Thermal Analysis Title Screen indicates any missing information required before an analysis can be performed.

Press **Q** to Quit and return to the Analysis Menu, or press any other key to display the list of available thermal analysis cases (**Figure 4-3**). The case list also indicates for each of the cases whether a solution exists and whether the case has thermal conditions that are defined by **SCANS** or by the user. **SCANS** offers seven cases with predefined thermal conditions. These cases, which are described on the next page, simulate the various normal and accident conditions required for shipping cask analyses. All cases, except the fire accident, include convection and radiation heat transfer to the environment. The fire accident case excludes convection heat transfer during the fire and reinstates it after the fire.

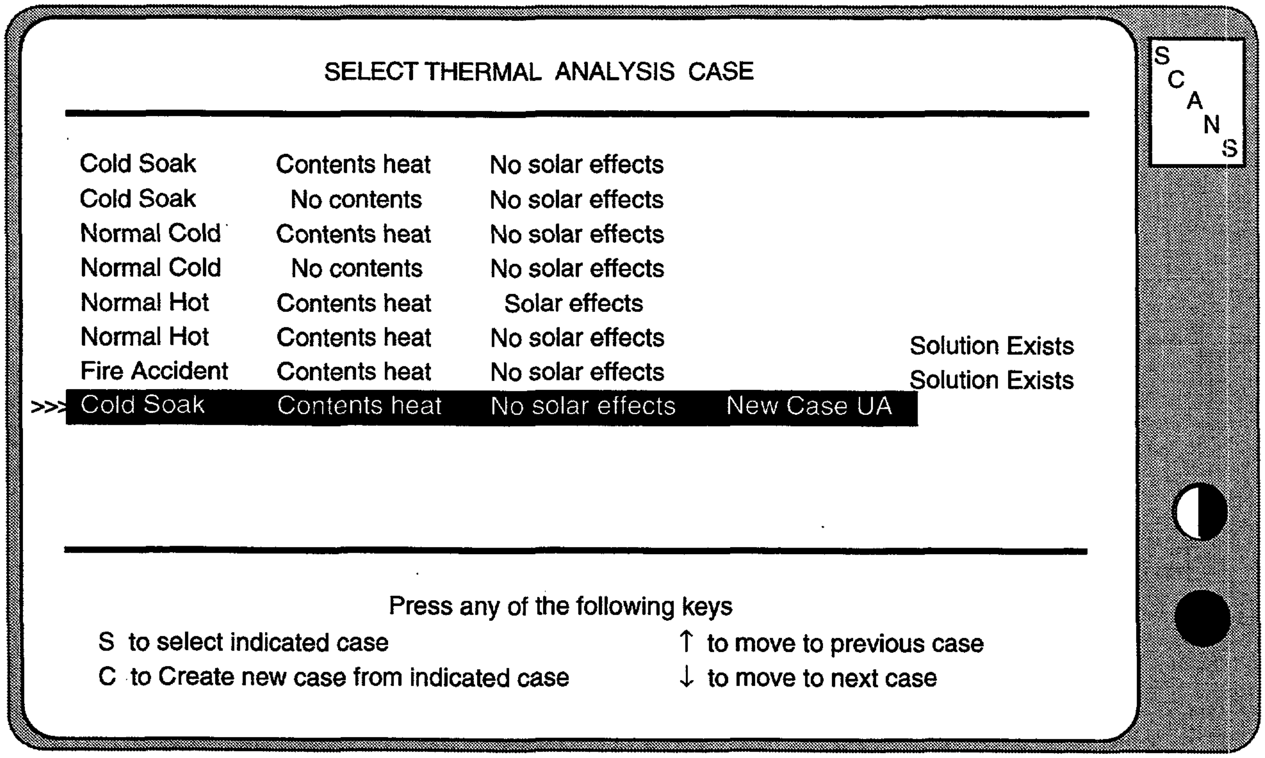


Figure 4-3. Select Thermal Analysis Case.

Cold Soak, Contents Heat, No Solar Effects

Ambient temperature: -40°F
Contents Heat: As specified in the geometry definition
Solar effects: None
Analysis type: Steady State

Cold Soak, No Contents, No Solar Effects

Ambient temperature: -40°F
Contents Heat: None
Solar effects: None
Analysis type: Steady State

Normal Cold, Contents Heat, No Solar Effects

Ambient temperature: -20°F
Contents Heat: As specified in the geometry definition
Solar effects: None
Analysis type: Steady State

Normal Cold, No Contents, No Solar Effects

Ambient temperature: -20°F
Contents Heat: None
Solar effects: None
Analysis type: Steady State

Normal Hot, Contents Heat, Solar Effects

Ambient temperature: 100°F
Contents Heat: As specified in the geometry definition
Solar effects: Included
Analysis type: Steady State

Normal Hot, Contents Heat, No Solar Effects

Ambient temperature: 100°F
Contents Heat: As specified in the geometry definition
Solar effects: None
Analysis type: Steady State
NOTE: Required as the initial condition for fire accident

Fire Accident, Contents Heat, No Solar Effects

Ambient temperature during fire: 1475°F
Ambient temperature after fire: 100°F
Contents Heat: As specified in the geometry definition
Solar effects: None
Analysis type: Transient 360 minutes in duration
Duration of fire: 30 minutes
NOTE: Requires case **Normal Hot, Contents Heat, No Solar Effects** as the initial condition before the fire

Use the keypad up or down arrow keys to highlight the desired case.

If the case can be used without any modification of the thermal conditions, press **S** to select and perform the analysis. Otherwise, press **C** to create a new case from the indicated case and to display the User Specified Thermal Input page for editing (**Figure 4-4**).

SCANS automatically assigns a case ID for the new case and displays it as the last two letters of the case title. This case ID remains unchanged even if the case title is altered. The case ID is used to name all the input and output files of this analysis case.

The Input page contains all thermal conditions, except the contents heat, that can be modified by the user. The contents heat is specified on the Basic Geometry Editor Page 3. The user should refer to Appendix D of this manual and Volume 4 of the **SCANS** theory manual for a precise definition of the parameters listed on the Editor page. To modify a parameter, use the keypad up or down arrow keys to highlight the desired field, and then enter the desired value or use the indicated key to select the desired value. After editing the Thermal Input page, press the function key, **F1**, to save and perform the thermal analysis. Otherwise, press the key **F2** or **F3**.

SCANS automatically generates the necessary finite element mesh if one has not been previously generated (see Generating Finite Element Meshes).

User Specified Thermal Input

Case Title .. [Cold Soak   Contents Heat   No Solar Effects   New Case UA]

Include the Contents Heat (0. Btu/Min) [Y/N] ....[Y]

Ambient Temperature (°F) ....[-40.   ]

Convection
- on Flat Surfaces   Coefficient (Btu/in² min °F)........ [.00002199]
- Exponent (Btu/in² min °F) .... [.3333
- on Cylindrical Surfaces   Coefficient (Btu/in² min °F) .... [.00002083]
- Exponent .... [.3333]

Radiation Emissivity of Cask .... [.5]

Solar Heat Flux (Btu/in² min) .... [0.]
(Negative flux adds heat to cask. Set to 0. for no Solar)

Press any of the following keys
- F1 to Save input and continue
- F2 to Save input and QUIT
- F3 to QUIT without saving modifications
- ↑ to move to previous field
- ↓ to move to next field

SCANS

Figure 4-4. Steady State Thermal Input Editor Page

All thermal cases, except the fire accident, are steady state analyses. **SCANS** initiates steady state analyses after the case selection is made (and after mesh generation, if necessary) and displays the steady state thermal analysis status screen (**Figure 4-5**). Since the analysis is nonlinear, **SCANS** iterates to converge on the correct solution. The iteration number and convergence achieved are updated on the display after each iteration. Also displayed is the maximum number of iterations that **SCANS** will perform.

When the solution converges, **Figure 4-5** would change—**SCANS** then displays the minimum and maximum temperatures and indicates where they occurred. To abort the steady state analysis (and delete the output) before convergence is achieved, press **F9**. **SCANS** asks for confirmation before aborting the analysis. Press **F1** to abort the analysis. Press **F9** to continue the analysis. After the analysis is finished, **SCANS** lists the following options:

Press **P** to Perform another thermal analysis (redisplays the case list screen)
Press **Q** to QUIT and return to the Analysis Menu

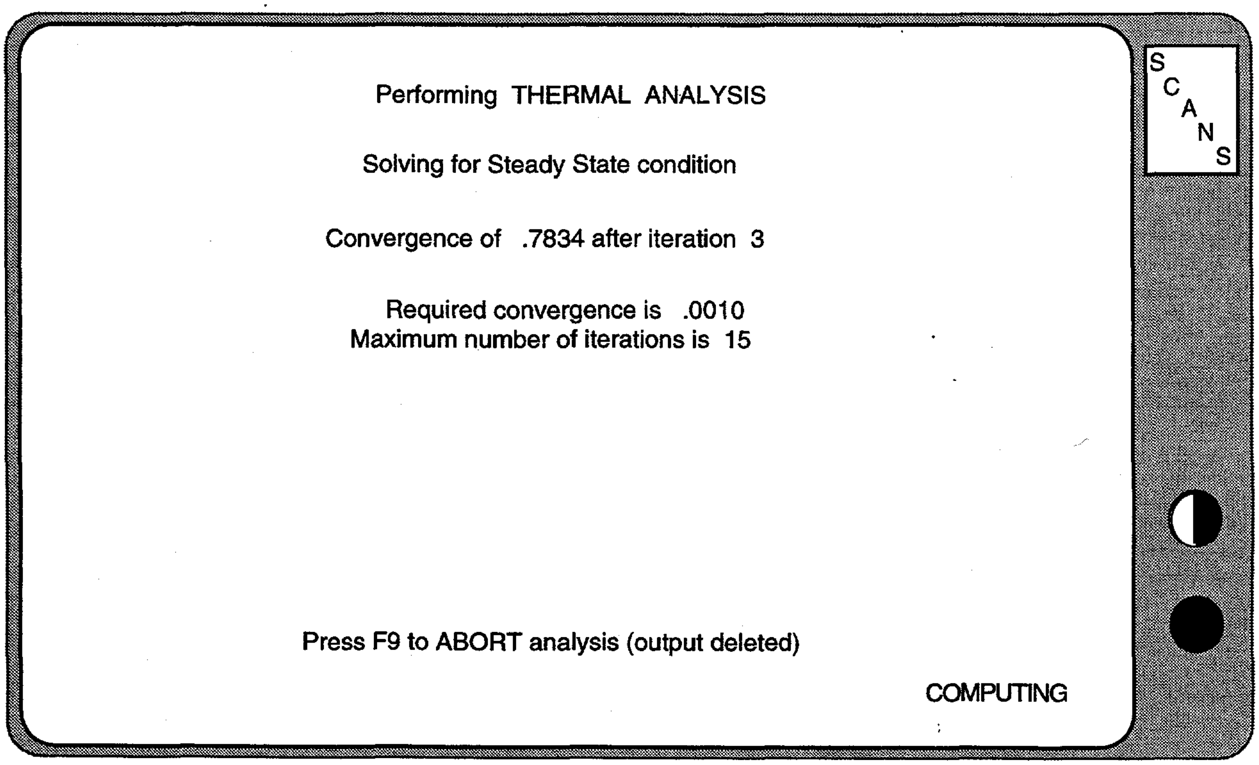


Figure 4-5. Steady State Thermal Analysis Status Screen.

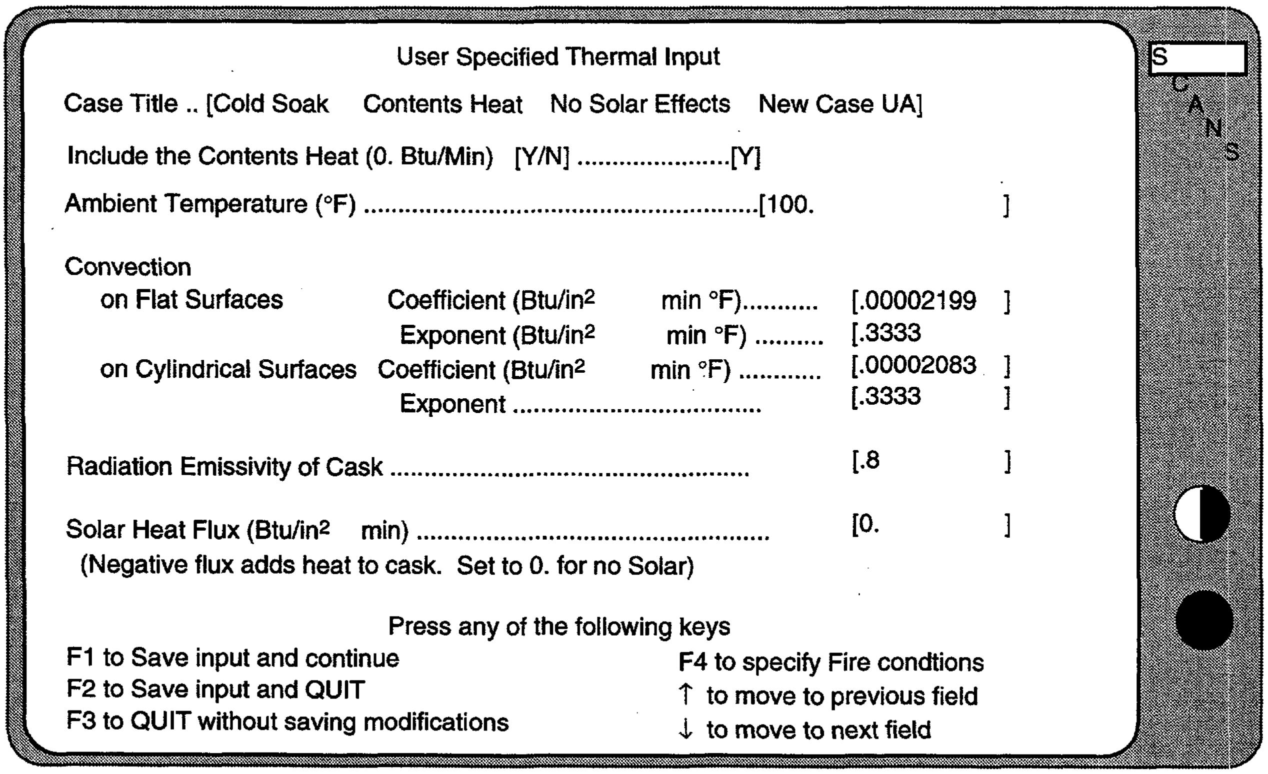
Analysis Menu
Perform Thermal Analysis

The transient fire accident analysis requires the steady state case **Normal Hot, Contents Heat, No Solar Effects** as the initial condition.

Similar to the steady state thermal analysis cases, if the transient fire accident case can be used without any modification of the predefined thermal conditions, press **S** to select the analysis. Otherwise, press **C** to create a new case and to display the User Specified Thermal Input and Fire Conditions pages for modification **(Figures 4-6 and 4-7)**.

As with the steady state case, the created transient fire case is automatically assigned a unique case ID. The contents of the Thermal Input Editor page are identical for all thermal cases. The Fire Conditions Editor page is available only for the transient fire accident case. Press the function key, **F4**, to switch between these two Editor pages.

The user should refer to Appendix D of this manual and Volume 4 of the **SCANS** theory manual for a precise definition of the parameters listed on the Editor pages. To modify a parameter, use the keypad up or down arrow keys to highlight the desired field, and then enter the desired value or use the indicated key to select the desired value. After editing, press the key **F1** to save and perform the thermal analysis. Otherwise, press the key **F2** or **F4**.


User Specified Thermal Input

Case Title .. [Cold Soak Contents Heat No Solar Effects New Case UA]

Include the Contents Heat (0. Btu/Min) [Y/N] ....[Y]

Ambient Temperature (°F) ....[100.]

Convection
- on Flat Surfaces Coefficient (Btu/in^2 min °F)........... [.00002199]
- Exponent (Btu/in^2 min °F) .... [.3333
- on Cylindrical Surfaces Coefficient (Btu/in^2 min °F) .... [.00002083]
- Exponent .... [.3333]

Radiation Emissivity of Cask .... [.8]

Solar Heat Flux (Btu/in^2 min) .... [0.]
(Negative flux adds heat to cask. Set to 0. for no Solar)

Press any of the following keys

F1 to Save input and continue
F2 to Save input and QUIT
F3 to QUIT without saving modifications
F4 to specify Fire condtions
↑ to move to previous field
↓ to move to next field

Figure 4-6. Transient Fire Thermal Input Editor Page.

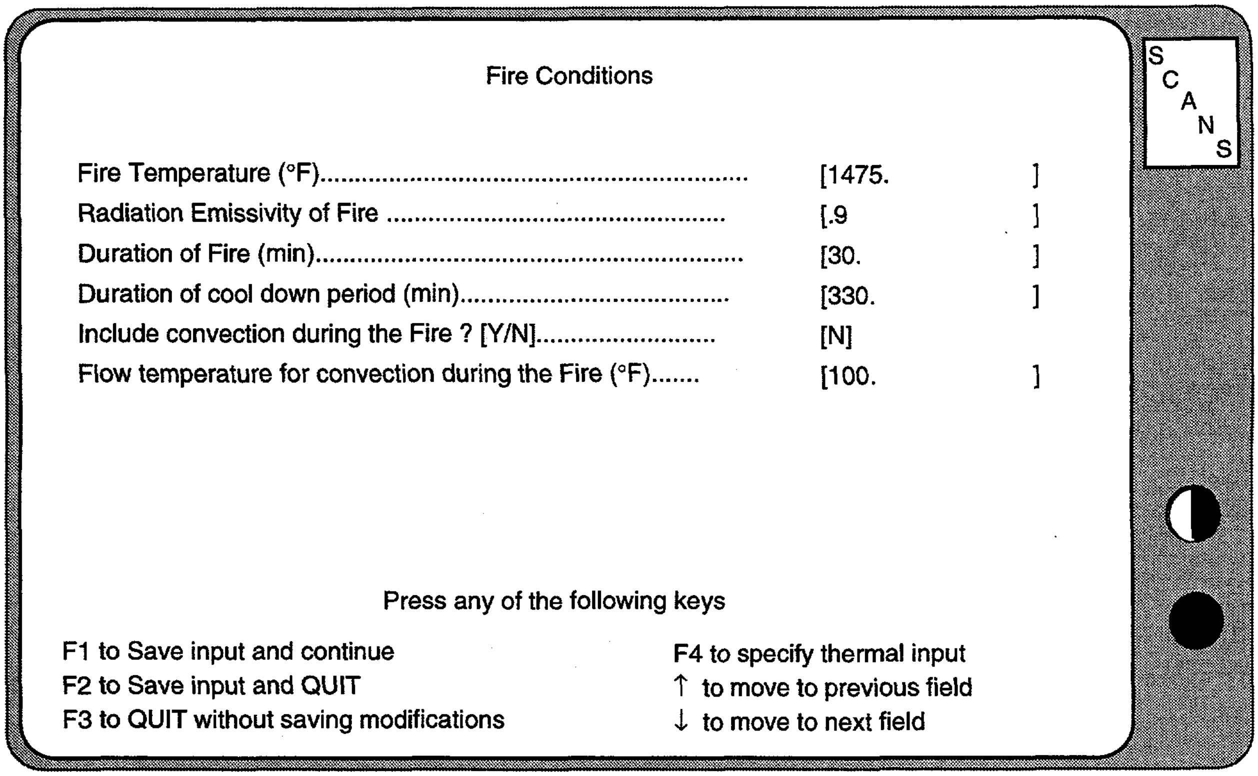


Figure 4-7. Transient Fire Conditions Editor Page.

After the analysis is selected, **SCANS** displays a list of transient analysis control parameters with their default values. **Figure 4-8** displays an example of one of these control parameter screens where the "Use variable time step?" option has been selected. The "Time between Printed output (min.)" option is the default screen.

Once all desired options are selected, press **P** to proceed and perform the analysis with the parameters as displayed, press **Q** to QUIT and return to the Analysis Menu, or modify any of the parameters before performing the analysis. To modify a parameter, use the keypad up or down arrow keys to highlight the desired field, and then use the indicated keys to select the desired value. When the displayed parameter values are correct, press **P** to perform the transient analysis. **SCANS** displays a transient analysis status screen that is similar to the steady state status screen.

The transient analysis status screen also includes the current solution time, solution time limit, and minimum and maximum temperature for the previous solution time. To end the transient analysis after the current time step, press **F5**. To abort the transient analysis (and delete the output), press **F9**. **SCANS** asks for confirmation before ending or aborting the analysis. Press **F1** to end or abort the analysis. Press **F9** to continue the analysis. After the analysis is finished, **SCANS** lists the following options:

Press **P** to Perform another thermal analysis
(redisplays the case list screen)
Press **Q** to QUIT and return to the Analysis Menu

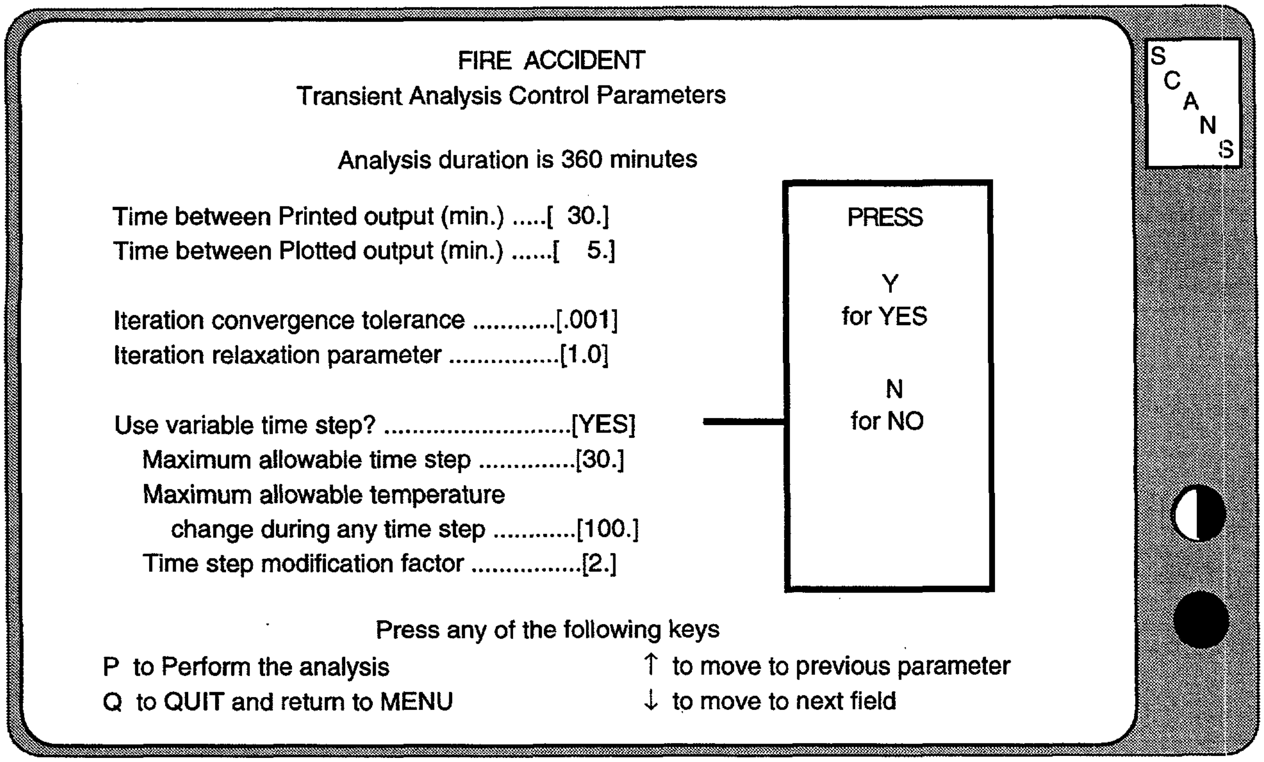


Figure 4-8. Transient Analysis Control Parameters.

Specifying the Printed Output Interval

Highlight the *Printed Output Interval* field. Use the + and - keys to change the time interval between saving thermal states for printing. Printed output can be very long. A printout interval of 30 minutes or longer is recommended.

Specifying the Plotted Output Interval

Highlight the *Plotted Output Interval* field. Use the + and - keys to change the time interval between saving thermal states for plotting.

Specifying the Iteration Convergence Tolerance

Highlight the *Iteration Convergence Tolerance* field. Use the + and - keys to change the solution convergence tolerance. Increasing the tolerance reduces the number of iterations (and computation time) for solution convergence, but may result in a less accurate solution.

Specifying the Iteration Relaxation Parameter

Highlight the *Iteration Relaxation Parameter* field. Use the + and - keys to change the relaxation parameter. The relaxation parameter guides the temperature estimate for the current iteration by using a fraction of the temperature change during the previous iteration. Decrease the relaxation parameter to 0.75 or less to dampen highly oscillatory solutions.

Specifying the Time Step Type

Highlight the *Variable Time Step* field. Press **Y** to use a variable time step or **N** to use a fixed time step. If a fixed time step is selected, **SCANS** displays the fixed time step parameter. If a variable time step is selected, **SCANS** displays maximum allowable time step, maximum allowable temperature change during any time step, and time step modification factor.

Specifying the Fixed Time Step Parameter

Select **N** for the *Use Variable Time Step* parameter and highlight the *Fixed Time Step* field. Use the + and - keys to change the fixed time step. Small time steps will converge faster, requiring fewer iterations. However, the transient analysis duration will be divided into more time steps.

Specifying the Maximum Allowable Time Step for Variable Time Step

Select **Y** for the *Use Variable Time Step* parameter and highlight the *Maximum Allowable Time Step* field. Use the + and - keys to change the maximum allowable time step. This places a ceiling on the time step size that **SCANS** can select during the transient analysis.

Specifying the Maximum Allowable Temperature Change During Any Time Step

Select **Y** for the *Use Variable Time Step* parameter and highlight the *Maximum Allowable Temperature Change During Any Time Step* field. Use the + and - keys to change the maximum allowable temperature change during any time step. **SCANS** uses the temperature change to determine when it is necessary to change the time step size.

Specifying the Maximum Allowable Temperature Change During Any Time Step

Select **Y** for the *Use Variable Time Step* parameter and highlight the *Time Step Modification Factor* field. Use the + and - keys to change the modification factor. When the time step is increased, the new time step is the current time step multiplied by the modification factor. When the time step is reduced, the new time step is the current time step divided by the modification factor.

Analysis Menu

Perform Thermally-Induced Stress Analysis

SCANS requires at least one completed thermal analysis to perform thermally-induced stress analyses. The number of thermal analysis solutions is indicated on the Thermal Stress Analysis Title Screen. The module used for stress analyses is based on SAP80 from Computers & Structures, Inc. (used by permission).

Press **Q** to QUIT and return to the Analysis Menu or press any other key to display the list of available thermal stress cases (**Figure 4-9**). The case list also indicates whether a solution exists for each case. Use the keypad up or down arrow keys to highlight the desired case, and then press **S** to select the indicated case. **SCANS** will then display the stress-free temperature as specified in the geometry definition (**Figure 4-10**). Use the keypad **+** or **-** keys to change this value (allowable range is -40°F to +400°F). For the fire accident transient analysis, the thermal stress analysis may be calculated for any thermal state (the states correspond to the temperatures saved at the plotting interval). Use the keypad up or down arrow keys to select a thermal state. **SCANS** indicates which state contains the maximum temperatures on any cask component. Press **P** to perform the analysis with the displayed stress-free temperature (and indicated thermal state, if applicable).

When the thermal stress analysis is complete, press **P** to perform another thermal stress analysis or **Q** to QUIT and return to the Analysis Menu.

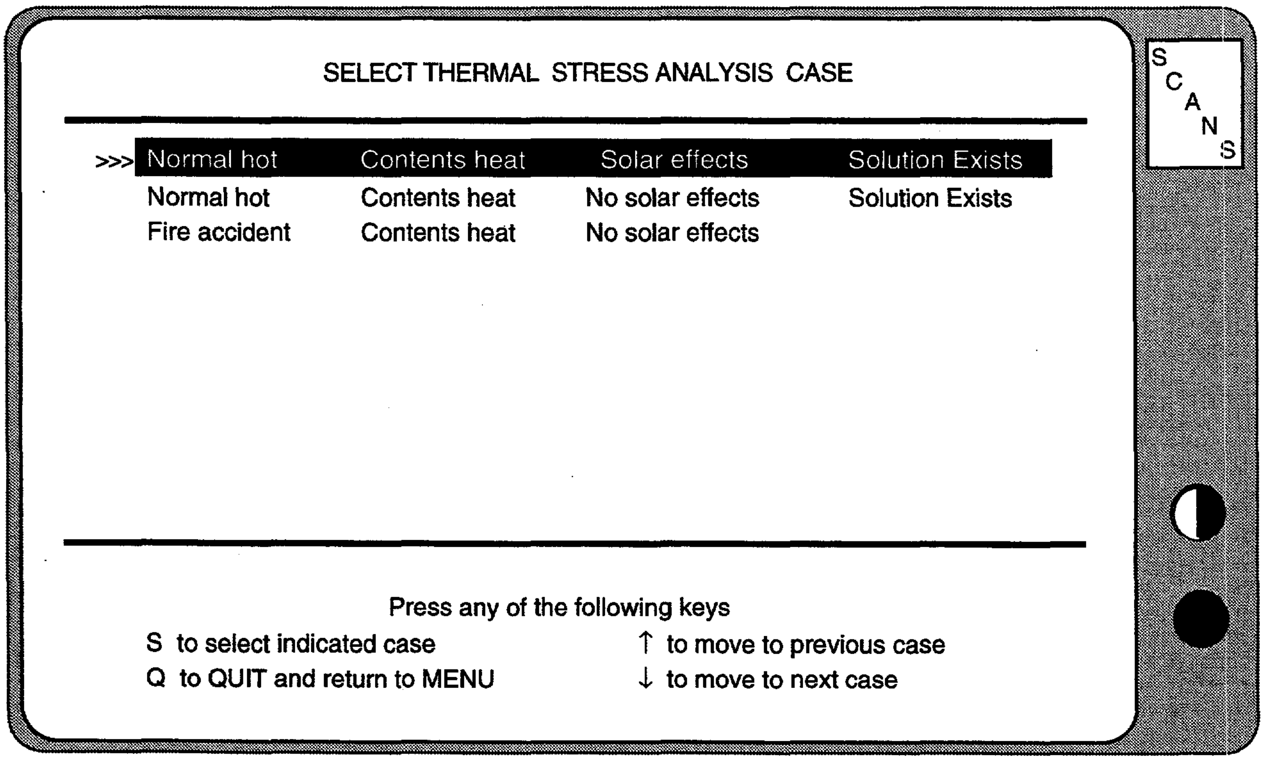


Figure 4-9. Select Thermal Stress Analysis Case.

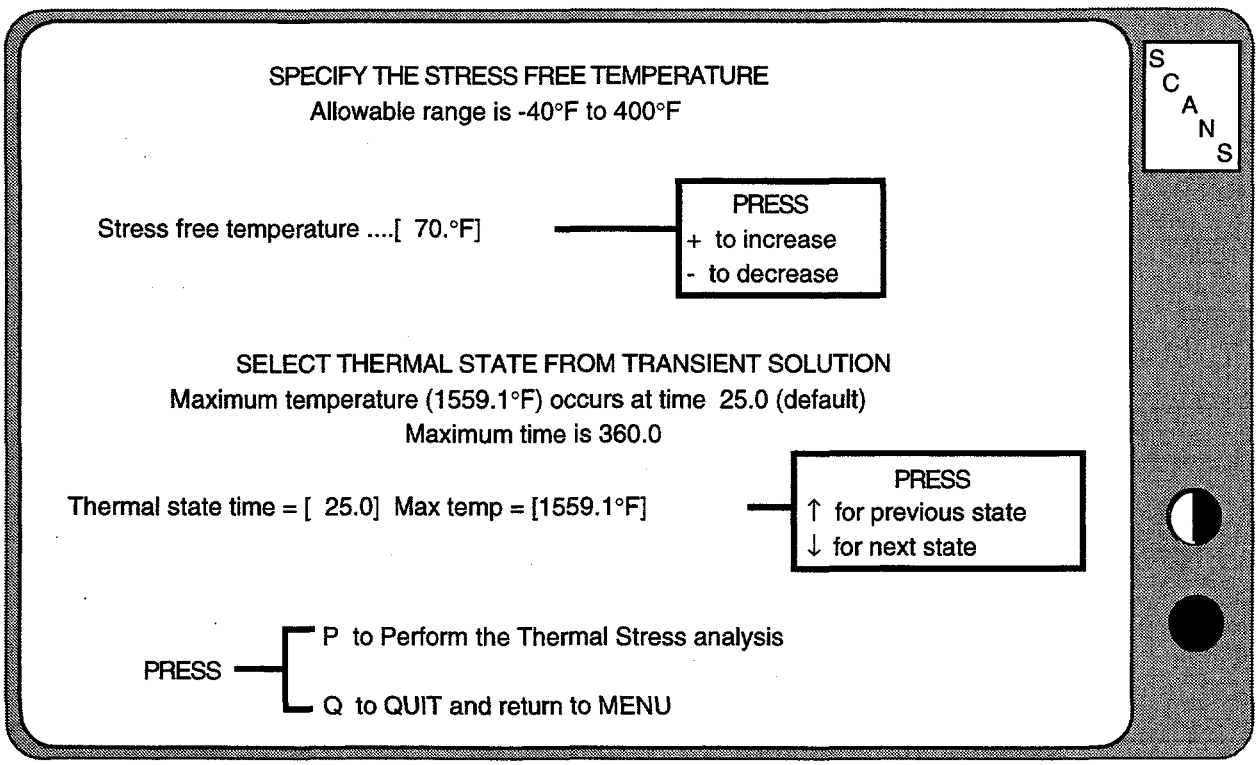


Figure 4-10. Stress Free Temperature / Thermal State.

Analysis Menu

Perform Pressure-Induced Stress Analysis

The external pressure conditions are established by the regulatory guidelines. However, the internal pressure conditions are established by the maximum normal operating pressure (input during geometry definition) or the internal pressure resulting from a thermal analysis. **SCANS** estimates the change in internal pressure using Ideal Gas Laws, based on the initial cavity charge pressure and temperature (input during geometry definition). The Pressure Stress Analysis Title Screen indicates the number of thermal solutions that exist for the cask. The module used for stress analyses is based on SAP80 from Computers & Structures, Inc. (used by permission).

Press **Q** to QUIT and return to the Analysis Menu, or press any other key to display the list of available internal pressure conditions (**Figure 4-11**). The internal pressure list consists of the Maximum Normal Operating Pressure and the internal pressures estimated by existing thermal analyses. Use the keypad up or down arrow keys to highlight the desired internal pressure. Press **S** to select the indicated internal pressure and display the list of available external pressure conditions. These pressure conditions are defined by the regulatory guidelines. Use the keypad up or down arrow keys to highlight the desired external pressure. Below the selection list, **SCANS** displays the selected internal and external pressures and whether a solution exists for this pressure condition. Press **P** to proceed with the analysis using the indicated internal and external pressure conditions; press **S** to select the indicated external pressure and display the list of available internal pressure conditions; or press **Q** to QUIT and return to the Analysis Menu.

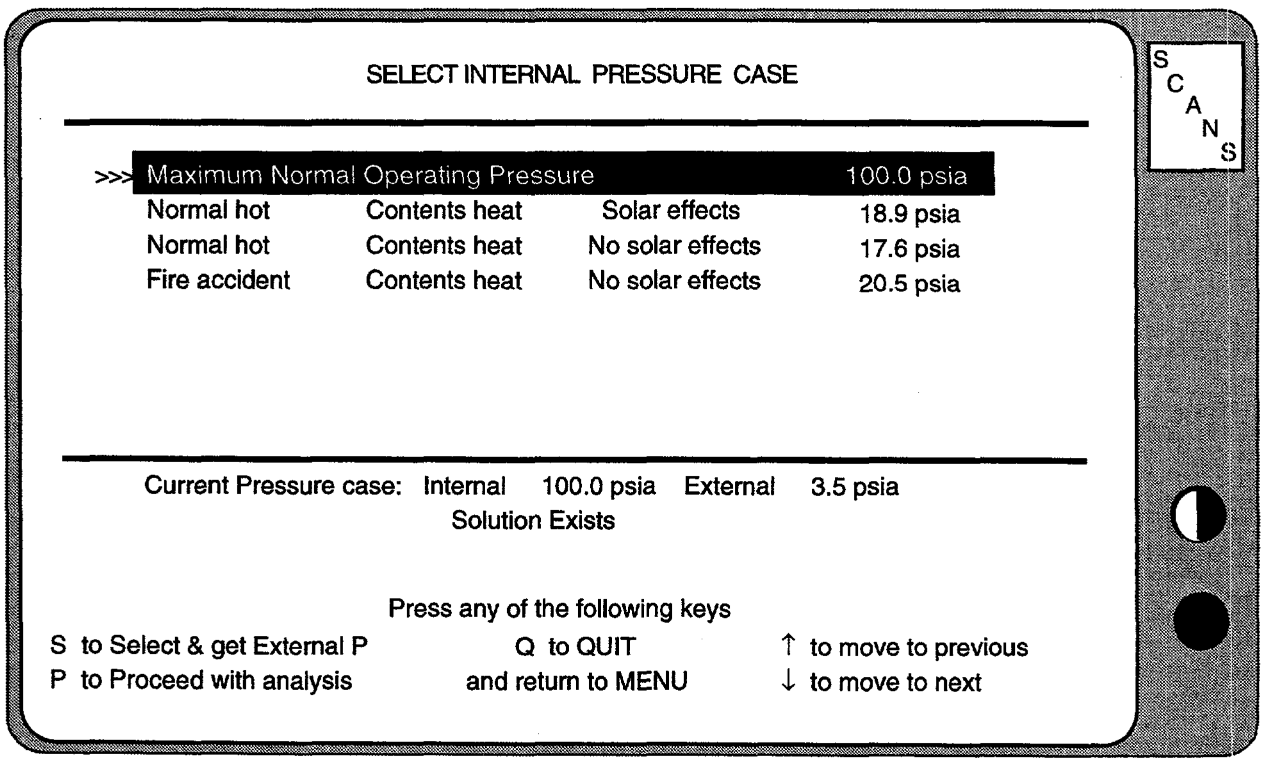


Figure 4-11. Select Internal Pressure Case.

When the pressure stress analysis is complete, press **P** to perform another pressure stress analysis or **Q** to QUIT and return to the Analysis Menu (**Figure 4-12**).

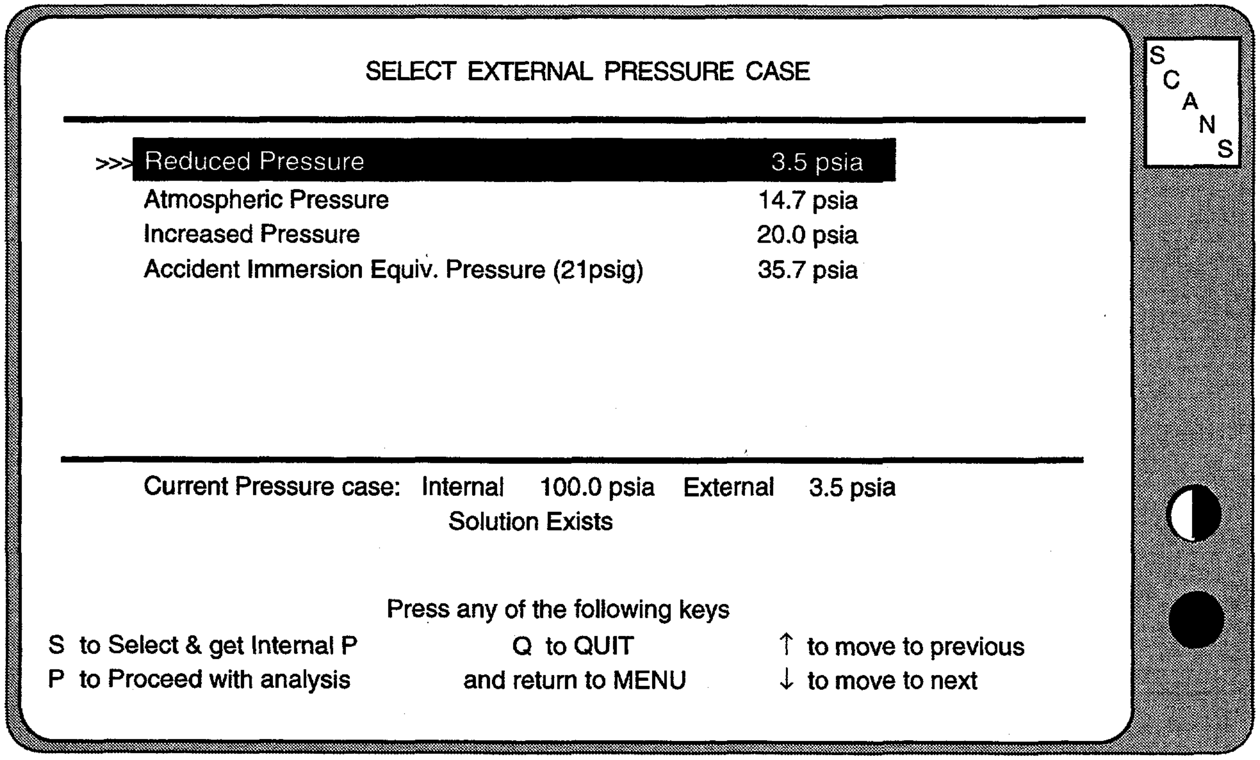


Figure 4-12. Select External Pressure Case.

Analysis Menu

Perform Load-Combination Analysis

The results of stress analysis cases to be combined must be available before SCANS can perform a load combination analysis. The Review Load Combination Analysis and Modify Load Combination screens will indicate any missing required cases.

Press Q to Quit and return to the Analysis Menu, or press any other key to display the list of load-combination cases (**Figure 4-13**). The case list also indicates for each of the cases whether a solution exists and whether the case has stress analyses that are defined by SCANS or by the user. SCANS offers nine cases with predefined stress analyses. These cases, which are described on the next page, represent some (not all) typical normal and accident conditions required for shipping-cask structural evaluation. All these cases have one pressure-induced stress analysis and one thermally-induced stress analysis. Some of the SCANS cases also include an impact analysis. The analyses in the SCANS cases may be related for an actual test condition or may be unrelated for a design load condition. The SCANS cases can not be modified directly but can be copied and then modified to create a customized case by the user. This customized case can be modified unlimited times to cover all structural-evaluation conditions and for use in all SCANS impact-analysis models (bonded or unbonded) and solutions (quasi-static or dynamic). Therefore, only a few customized cases will suffice for a complete structural evaluation.

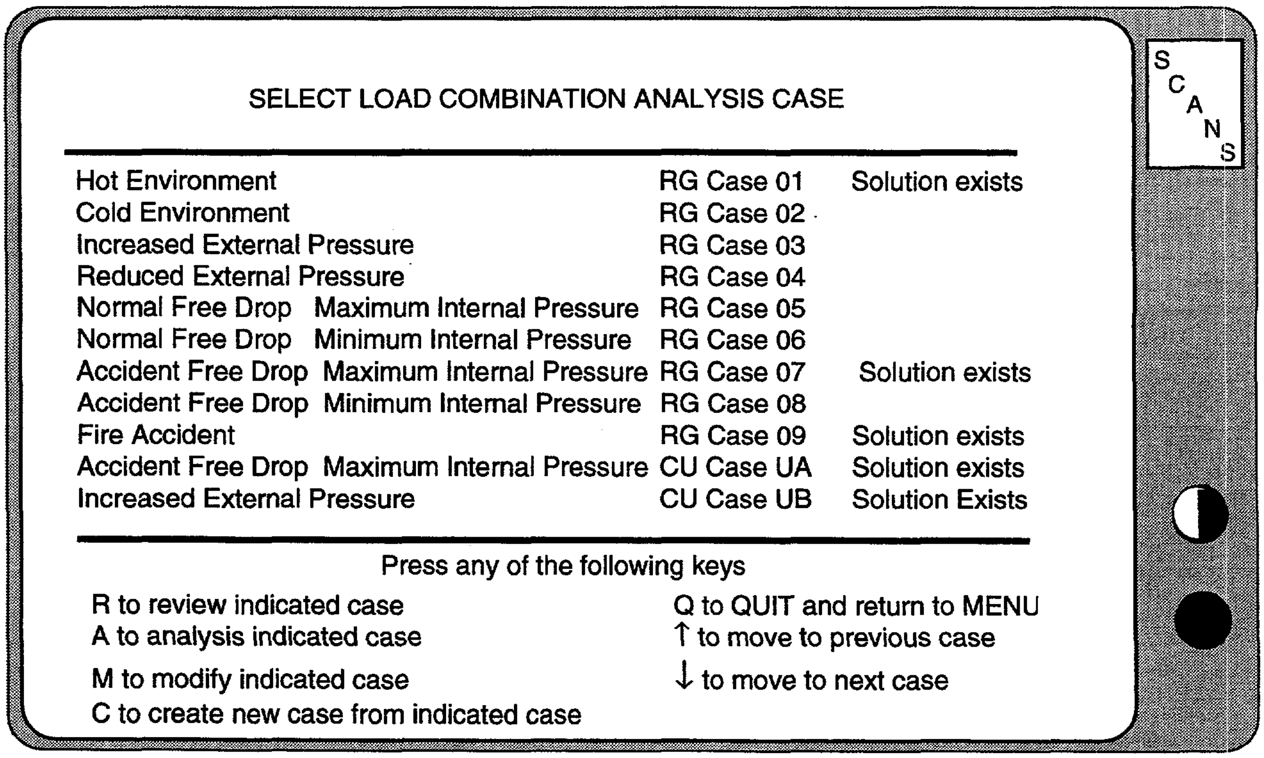


Figure 4-13. Select Load Combination Analysis Case.

Analysis Menu

Perform Load-Combination Analysis

Case 1: Hot Environment
Thermal: Normal Hot (100 F), Contents Heat, Solar Effects
Pressure: Internal = Pressure corresponding to the thermal condition
External = Atmospheric pressure (14.7 psia)
Impact: None

Case 2: Cold Environment
Thermal: Cold Soak (-40° F), No Contents Heat, No Solar Effects
Pressure: Internal = Pressure corresponding to the thermal condition
External = Atmospheric pressure (14.7 psia)
Impact: None

Case 3: Increased External Pressure
Thermal: Normal Cold (-20° F), No Contents Heat, No Solar Effects
Pressure: Internal = Pressure corresponding to the thermal condition
External = Increased Pressure (20.0 psia)
Impact: None

Case 4: Reduced External Pressure
Thermal: Normal Hot (100° F), Contents Heat, Solar Effects
Pressure: Internal = Maximum Normal Operating Pressure
External = Reduced Pressure (3.5 psia)
Impact: None

Case 5: Normal Free drop Maximum Internal Pressure
Thermal: Normal Hot (100° F), Contents Heat, Solar Effects
Pressure: Internal = Max. Normal Operating Pressure
External = Atmospheric (14.7 psia)
Impact: 1-ft c.g. over top corner drop (quasi-static bonded solution)

Case 6: Normal Free drop Minimum Internal Pressure
Thermal: Normal Cold (-20° F), No Contents Heat, No Solar Effects
Pressure: Internal = Pressure from the thermal condition
External = Atmospheric (14.7 psia)
Impact: 1-ft c.g. over top corner drop (quasi-static bonded solution)

Case 7: Accident Free drop Maximum Internal Pressure
Thermal: Normal Hot (100° F), No Contents Heat, No Solar Effects
Pressure: Internal = Maximum Normal Operating Pressure
External = Atmospheric pressure (14.7 psia)
Impact: 30-ft c.g. over top corner drop (quasi-static bonded solution)

Case 8: Accident Free drop Minimum Internal Pressure
Thermal: Normal Cold (-20° F), No Contents Heat, No Solar Effects
Pressure: Internal = Pressure corresponding to the thermal condition
External = Atmospheric pressure (14.7 psia)
Impact: 30-ft c.g. over top corner drop (quasi-static bonded solution)

Case 9: Fire Accident
Thermal: Fire Accident, Contents Heat, No Solar Effects
Pressure: Internal = Pressure corresponding to the thermal condition
External = Atmospheric pressure (14.7 psia)
Impact: None

Analysis Menu

Perform Load-Combination Analysis

Use the keypad up or down arrow keys to highlight the desired case. If the case can be used without any modification, press A to analyze the indicated case. Otherwise, press C both to create a new CUstomized Case from the indicated case and to display the Modify Load Combination Case page on the upper half of the screen for editing (**Figure 4-14**).

SCANS automatically assigns a case ID for the new case and display it as the last two letters of the case title. This case ID remains unchanged even if the case title is altered. The case ID is used to name all the input and output files of this analysis case.

The Modify page contains all the necessary inputs for a load combination analysis: the classification of the load condition (accident or normal transport conditions), the load case title, the thermal stress solution, the pressure stress solution, and sometimes the impact stress solution to be combined. Press C to change the load condition and to toggle between two displayed statements: "The case is an accident condition.", and "The case is a normal condition."

SCANS uses the input load classification to set the allowable stresses for comparison with the combined stresses. The allowable stresses are set according to the structural design criteria given in Regulatory Guide 7.6 for containment vessels of Type B packages.

Press L to edit the load case title and to display the Edit Load Case Title page on the lower half of the screen for editing (**Figure 4-15**). To modify the title, use the left or right arrow keys to move the curser to the character to be modified. After modification, press the function key F1 to save and the modified title will replace the old title on the Modify Load Combination Case page on the upper half of the screen. Press F2 to quit editing.

Upon quiting, the Edit Load Case Title page on the lower half of the screen diappears, and the control returns to the Modify Load Combination Case page on the upper half of the screen. Similar to case title editing, press T to select a different thermal stress solution and to display the Select Thermal-Stress Solutions page on the lower half of the screen (**Figure 4-16**). This figure displays all existing thermal stress solutions for selection.

Some of the existing solutions may be indicated as obsolete, if they were obtained prior to the last change of any of the analysis models for thermal, stress, and impact analyses. An obsolete solution must be re-analyzed before it can be accepted for load-combination analysis. SCANS will abort the load-combination anlaysis, if an obsolete solution is included for the analysis.

Use the up or down arrow keys to highlight the desired solution. Then press the function key F1 to select the indicated solution, and the new solution will replace the old one displayed on the Modify Load Combination Case page.

If the desired solution is not available, it must be first obtained by returning to the Analysis Menu. After selecting, press F2 to quit and return to the Modify Load Combination

Case page. A new pressure stress or impact stress solution can be similarly selected as the thermal stress solution.

After completing the modification of the load combination case, press the function F1 to save the change and to analyze the case. Otherwise, press F2 or F3.

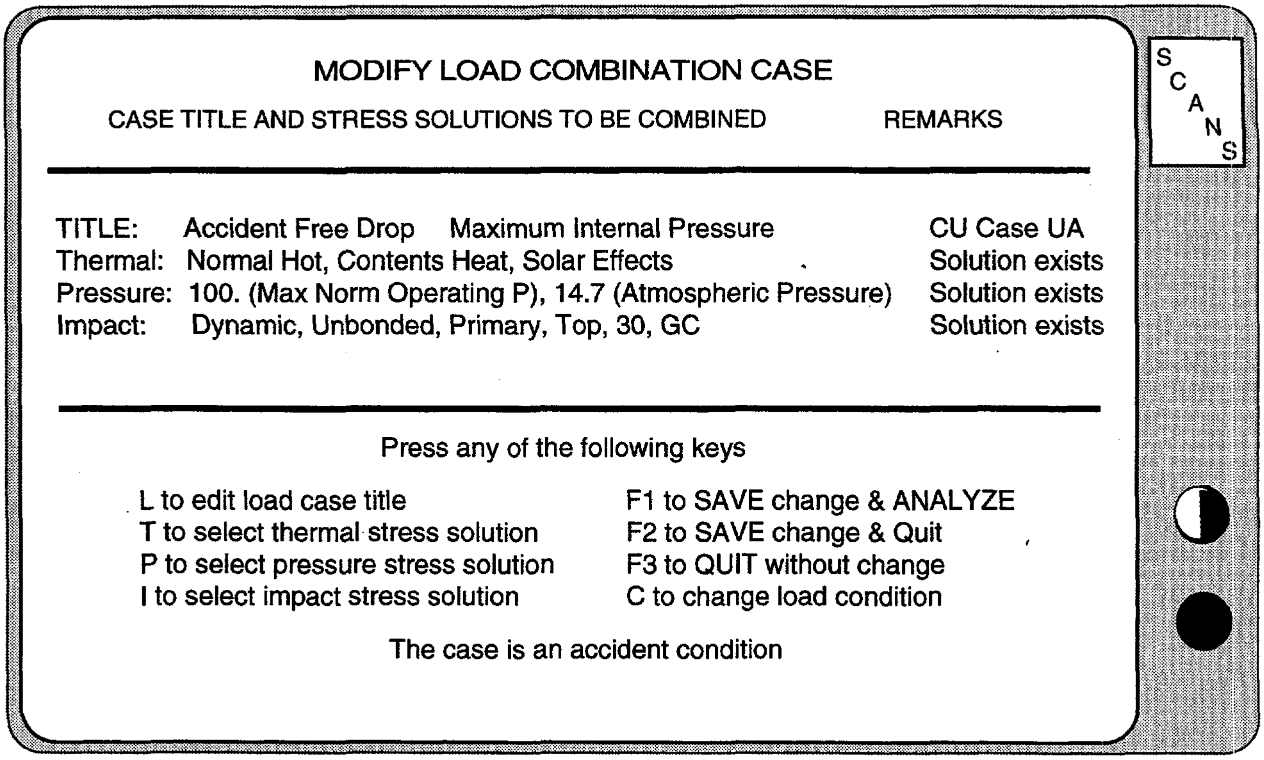


Figure 4-14. Modify Load Combination Case page.

Analysis Menu

Perform Load-Combination Analysis

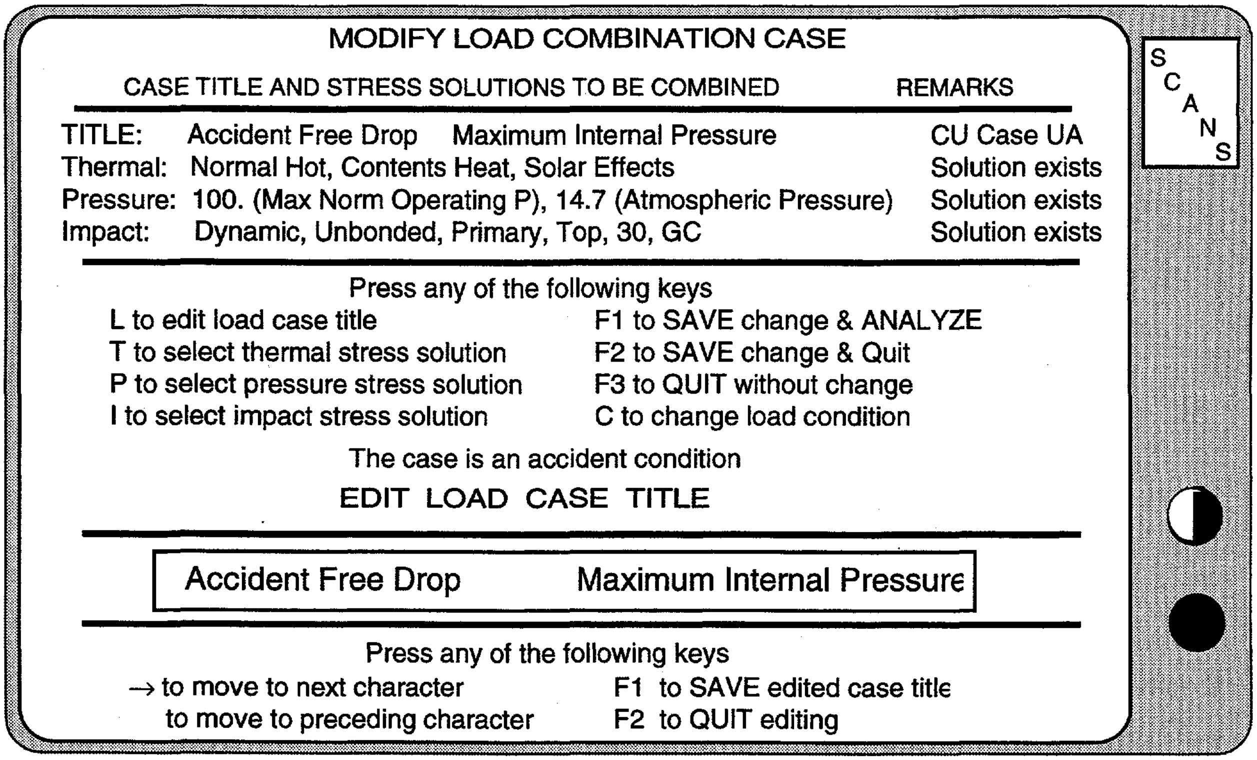


Figure 4-15. Edit Load Case Title page.

Analysis Menu

Perform Load-Combination Analysis

MODIFY LOAD COMBINATION CASE

CASE TITLE AND STRESS SOLUTIONS TO BE COMBINED REMARKS

TITLE:	Accident Free Drop Maximum Internal Pressure	CU Case UA
Thermal:	Normal Hot, Contents Heat, Solar Effects	Solution exists
Pressure:	100. (Max Norm Operating P), 14.7 (Atmospheric Pressure)	Solution exists
Impact:	Dynamic, Unbonded, Primary, Top, 30, GC	Solution exists

Press any of the following keys

L to edit load case title	F1 to SAVE change & ANALYZE
T to select thermal stress solution	F2 to SAVE change & Quit
P to select pressure stress solution	F3 to QUIT without change
I to select impact stress solution	C to change load condition

The case is an accident condition

SELECT THERMAL — STRESS SOLUTIONS

THERMAL CASE DESCRIPTION			DATE	TIME
3 solutions exist————————		Latest model	11-01-96	9:01a
Cold Soak	Contents Heat	No Solar Effects	11-01-96	1:04p
Normal Hot	Contents Heat	Solar Effects	11-01-96	12:38p
Fire Accident	Contents Heat	No Solar Effects	11-01-06	12:39p

Press any of the following keys

→ to move to next character	F1 to SAVE edited case title
to move to preceding character	F2 to QUIT editing

SCANS

Figure 4-16. Select Thermal-Stress Solutions page.

Analysis Menu

Perform Load-Combination Analysis

During a load combination analysis, SCANS displays the Performing Load Combination Analysis page. After the analysis is finished, SCANS list the following options:

Press P to Perform another load-combination analysis
(redisplays the case list screen)
Press Q to QUIT and return to the Analysis Menu

NOTES:

Display Menu

The Display Menu (**Figure 5-1**) provides options for plotting dynamic impact analysis results, displaying and printing finite element meshes, plotting thermal analysis results, and setting video and printer attributes.

PRESS 1 to Plot Dynamic Impact results

Plot the axial force, shear force, bending moment, position of cask top or bottom, cask orientation, and animation of the cask drop. For casks with an unbonded shell/shield interface, plot lead slump, and shell axial and hoop stresses.

PRESS 2 to Display/Print finite element meshes

Display the thermal and stress finite element meshes (generated during thermal or pressure stress analyses). Print the meshes as node element maps.

PRESS 3 to Plot Temperature distributions

Plot temperature distributions as iso-contours, time histories, and thermal profiles.

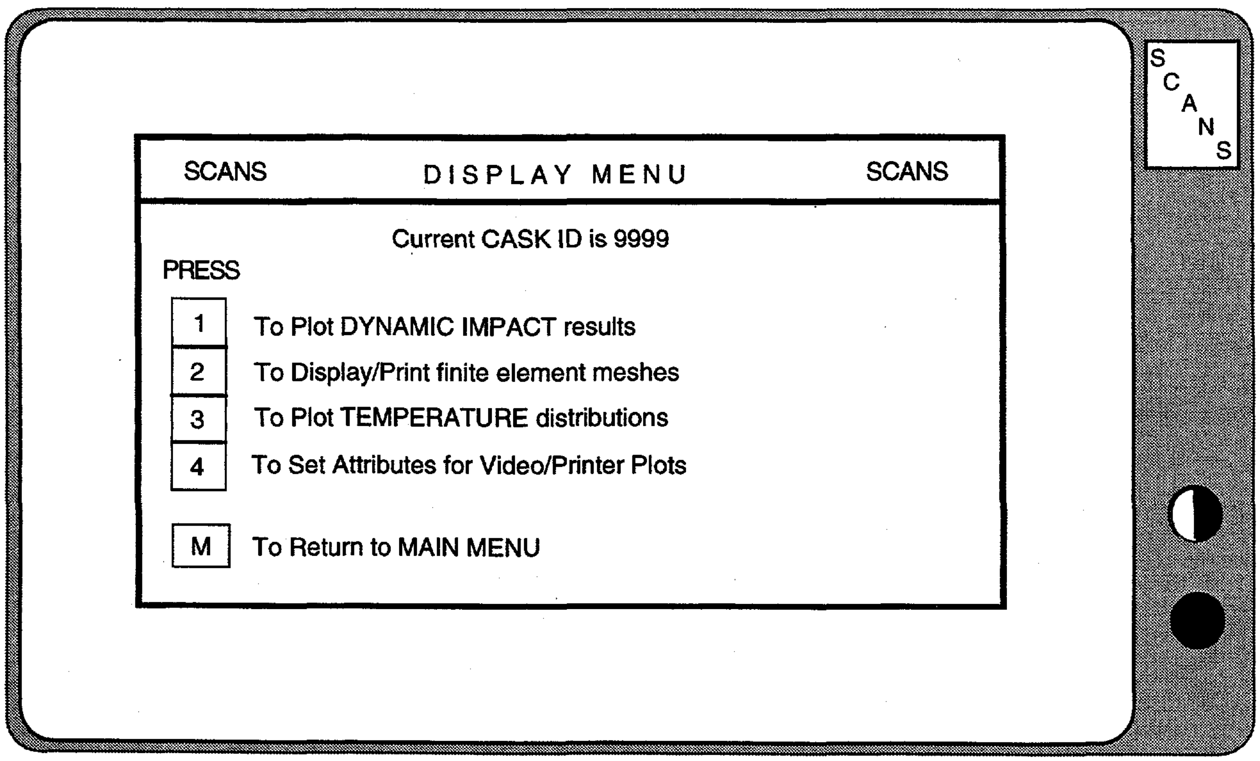


Figure 5-1. SCANS Display Menu.

Display Menu

PRESS 4 to Set Attributes for Video/Printer Plots

Select video display (CGA or EGA), printer plot resolution (low or high) and type of printer (IBM/Epson graphics printer or HP LaserJet).

PRESS M to Return to MAIN MENU

SCANS returns to the Main Menu display.

SCANS displays the Plot Dynamic Impact Results Title Screen indicating the number of dynamic impact solutions. Press **Q** to QUIT and return to the Display Menu, or press any other key to select the dynamic impact solution to plot.

SCANS lists the available dynamic impact solutions and indicates the shell/shield interface, impact type, impact end, drop height, impact angle, date, and time (**Figure 5-2**). An unbonded shell/shield interface allows the lead shield to slump. A primary/secondary impact type includes impact of both ends. The impact end indicates the end that impacts first. Impact angles are relative to the horizontal (i.e., 0 degrees is a side drop). Use the keypad up and down arrow keys to highlight the desired case. Press **S** to select the indicated solution for plotting.

SCANS displays the Select Plots and Display Parameters Screen (**Figure 5-3**; note that the options F8 to ALT-F2 only appear and are active when the "Unbounded Shell/Shield Interface" case is selected) and lists the following options:

Press **S** to Select a different dynamic impact case
Press **Q** to QUIT and return to the Display Menu
Press ↑ to move to previous choice field
Press ↓ to move to next choice field
or Press any of the keys indicated in the options box

SELECT DYNAMIC IMPACT SOLUTION TO PLOT

SHELL/SHIELD INTERFACE	IMPACT TYPE	IMPACT END	DROP HEIGHT	IMPACT ANGLE	DATE	TIME
Unbonded	Primary	Bottom	30	90	10-12-88	2:30p
Bonded	Primary/Secondary	Bottom	30	45	10-02-88	3:06p

Press any of the following keys
S to select indicated solution ↑ to move to previous solution
Q to QUIT and return to MENU ↓ to move to next solution

SCANS

Figure 5-2. Select Dynamic Impact Solution to Plot.

Display Menu
Plot Dynamic Impact Results

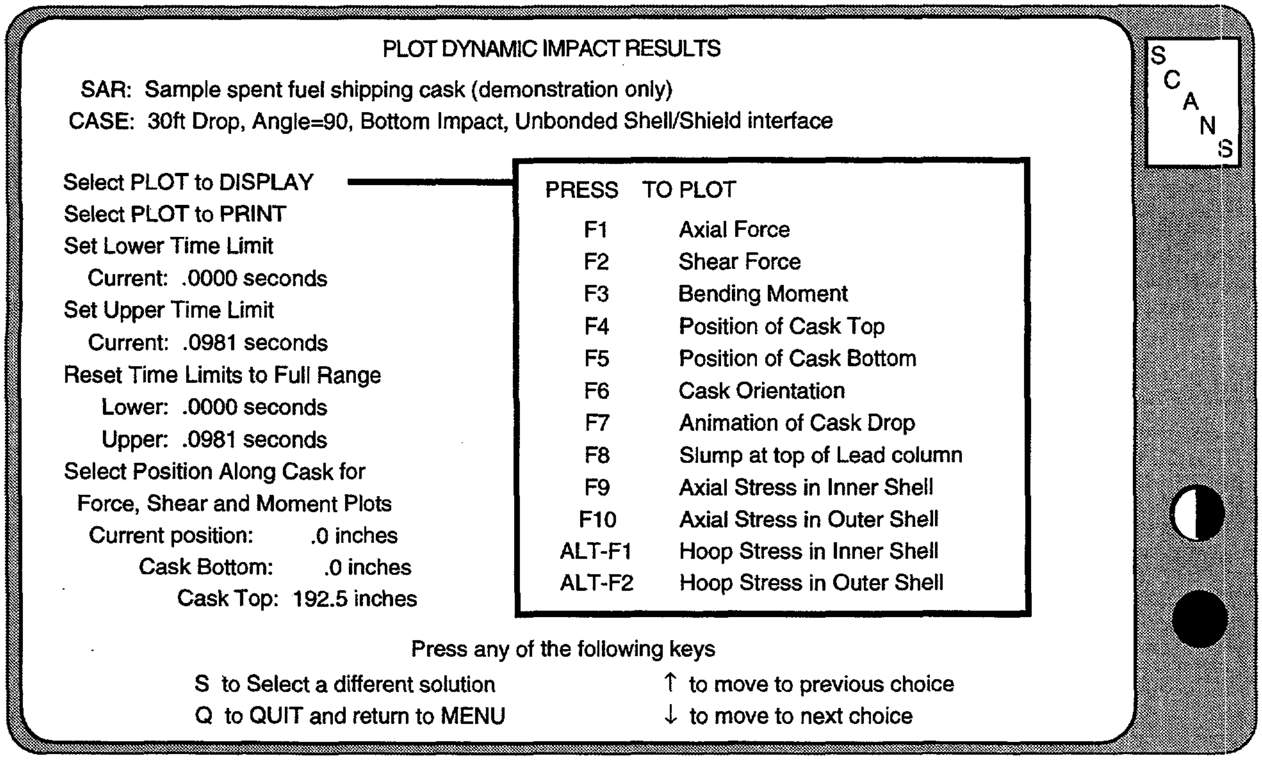


Figure 5-3. Select Plots and Display Parameters Screen.

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 Axial Force (**Figure 5-5**)
F2	to plot Shear Force
F3	to plot Bending Moment
F4	to plot Position of Cask Top
F5	to plot Position of Cask Bottom (**Figure 5-6**)
F6	to plot Cask Orientation
F7	to plot Animation of Cask Drop
F8	to plot Lead Slump in the Lead Shield (unbonded only)
F9	to plot Axial Stress in the Inner Shell (unbonded only)
F10	to plot Axial Stress in the Outer Shell (unbonded only)
ALT-F1	to plot Hoop Stress in the Inner Shell (unbonded only)
ALT-F2	to plot Hoop Stress in the Outer Shell (unbonded only) (**Figure 5-7**)

Dynamic impact results are plotted as a function of time. The axial force, shear force, and bending moment are calculated for the total cross section of the cask. Plots of force, bending moment, and stress are at the selected position along the cask. Cask orientation plots are relative to the horizontal (0 degrees). Animation of the cask drop displays the position and orientation of the cask at discrete steps during the impact analysis.

Selecting the Lower and Upper Time Limits

Adjusting the time limits will zoom in on a portion of the time history. Highlight the *Set Lower Time Limit* field to change the lower time limit. Highlight the *Set Upper Time Limit* field to change the upper time limit. Use the + and - keys to change the selected value (times are in seconds). The lower time limit must be greater than or equal to 0. and less than the upper time limit. The upper time limit must be greater than the lower time limit and less than or equal to the maximum time limit.

Resetting the Time Limits to Full Range

Highlight the *Reset Time Limits to Full Range* field and press **F1** to reset the time limits to the full range. Used to display full time histories after time limits have been adjusted.

Selecting the Position Along Cask for Plotting

Highlight the *Select Position Along Cask* field and use the + and - keys to change the position along the cask where axial force, shear force, bending moment and stresses are plotted (**Figure 5-4**). Position **0.0** corresponds to the cask bottom.

Display Menu

Plot Dynamic Impact Results

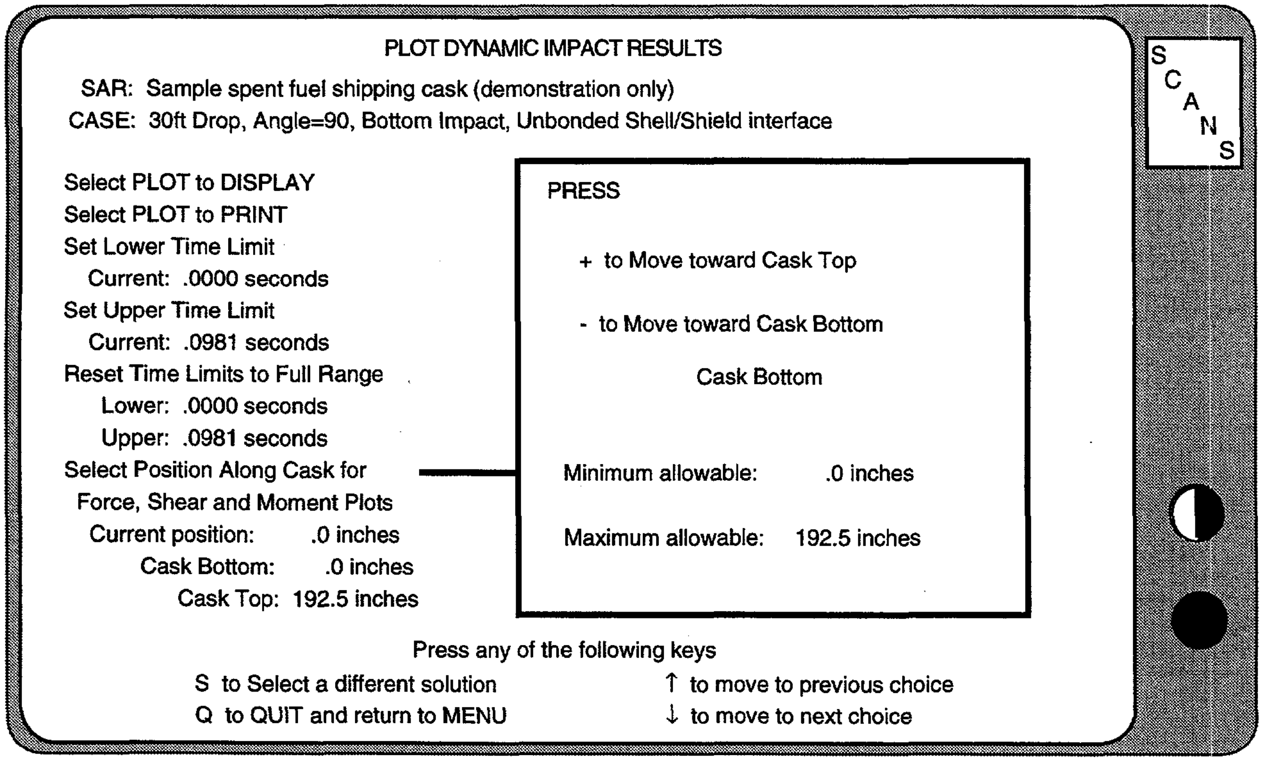


Figure 5-4. Selecting Position Along Cask for Plotting.

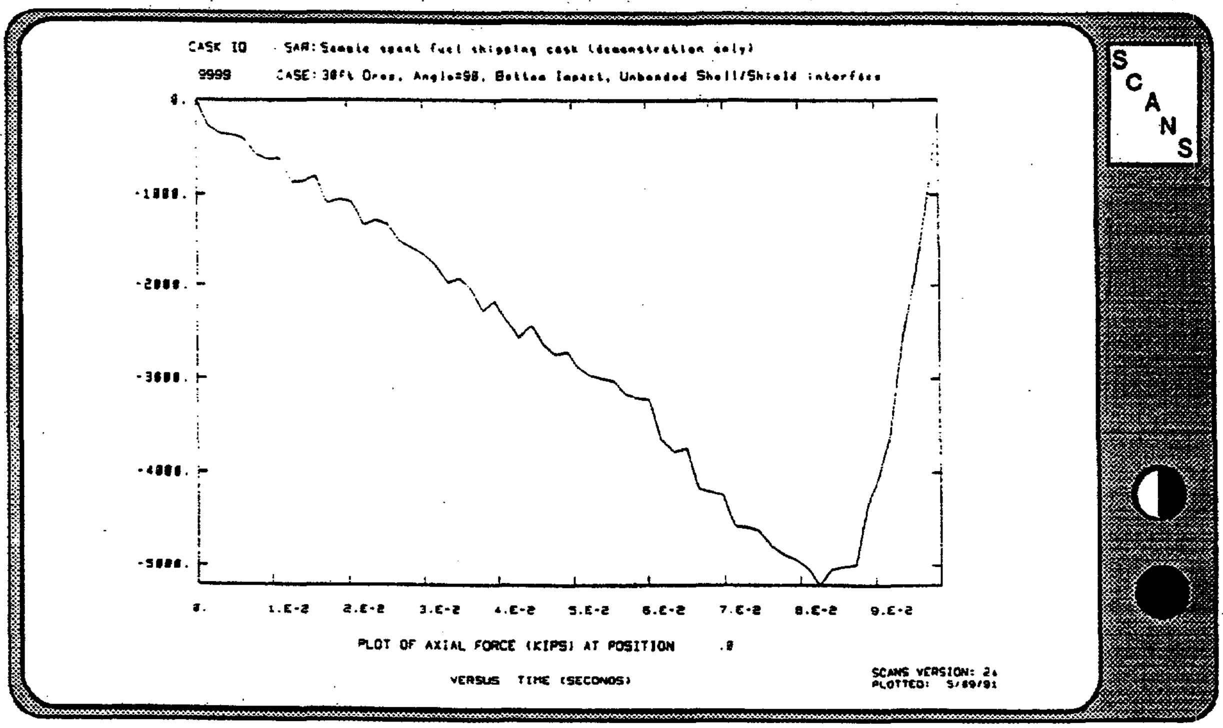


Figure 5-5. Axial Force Time History Plot.

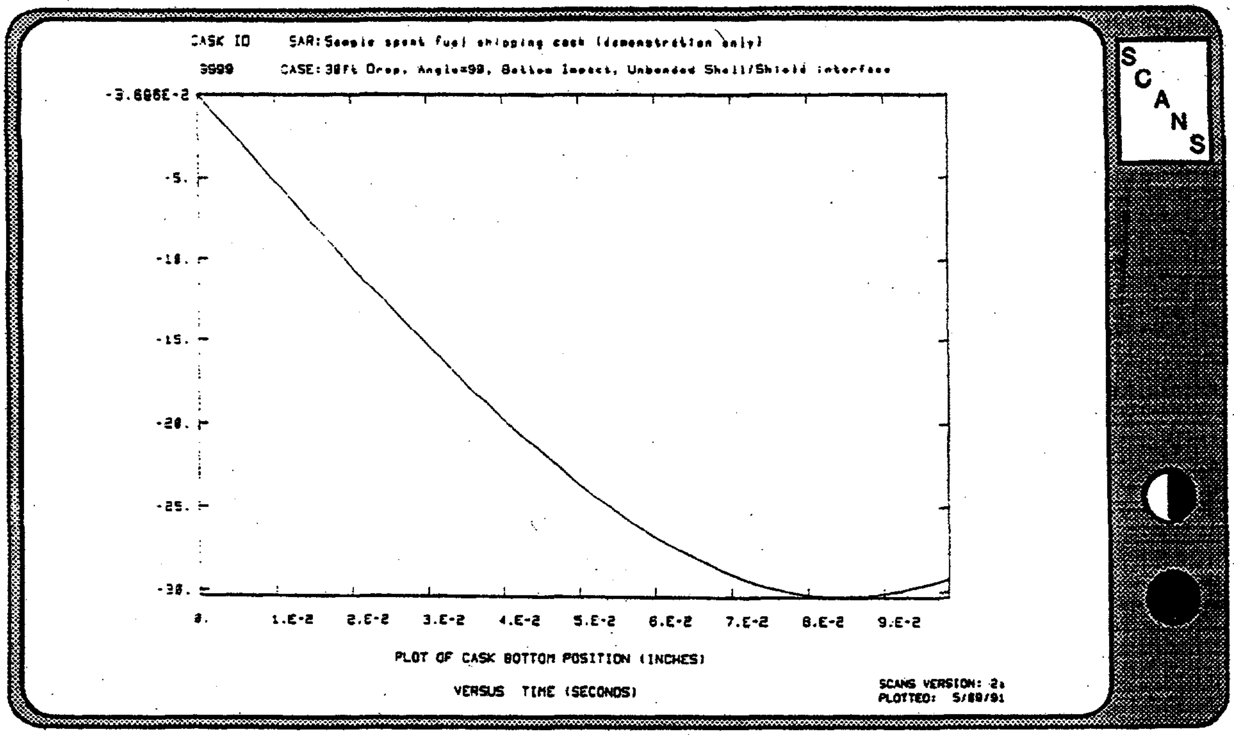


Figure 5-6. Plot of Position of Cask Bottom.

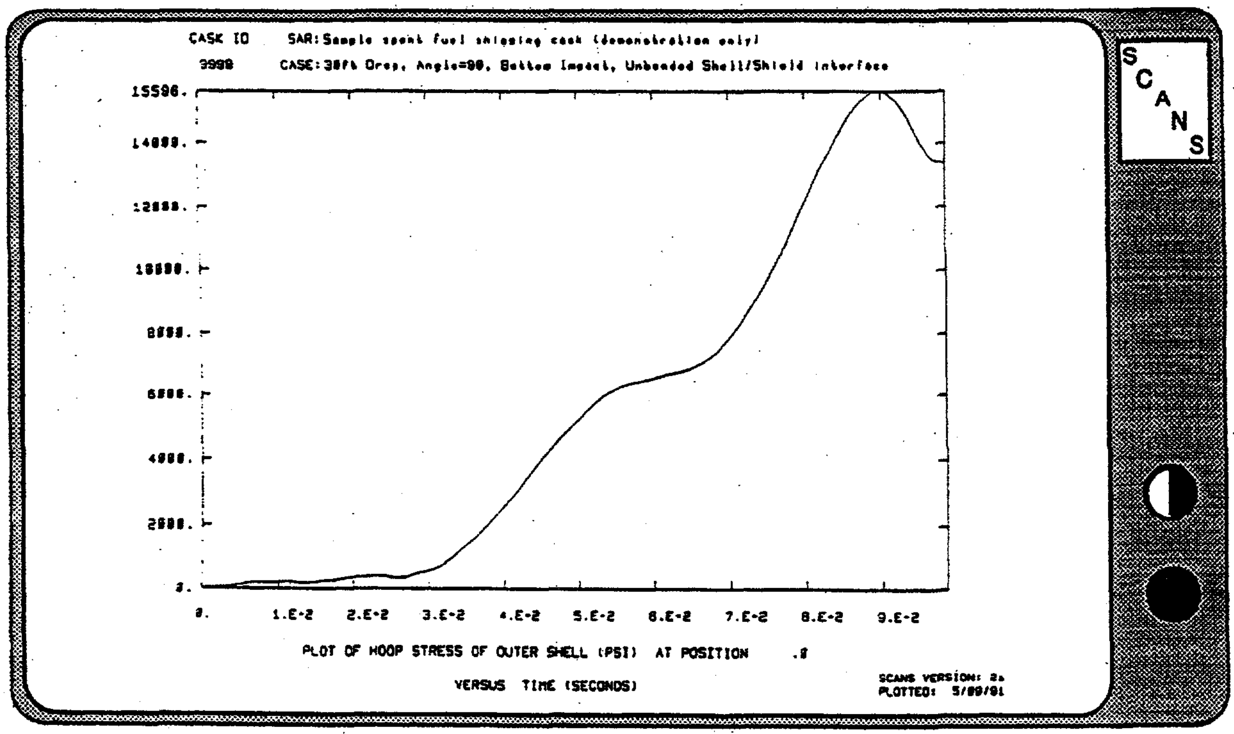


Figure 5-7. Hoop Stress Time History Plot.

Display Menu
Display/Print Finite Element Meshes

SCANS displays the Display/Print Finite Element Mesh title screen and indicates the status of the F.E. meshes. Mesh displays are always based on the basic geometry description for the TOP end of the cask and use axisymmetry. Thermal meshes use 4-node elements and include all cask components. Stress meshes use 9-node elements and include only the cask shell and end caps. Press **Q** to QUIT and return to the Display Menu or any other key to display the finite element meshes (**Figure 5-8**). Press **ENTER** after reviewing the meshes and select one of the following options:

Press **P** to print the Thermal mesh as a node/element map
Press **T** to print the Thermal mesh as a node/element map (**Figure 5-9**).
Press **S** to print the Stress mesh as a node/element map
Press **D** to Display the meshes again
Press **Q** to QUIT and return to the Display Menu

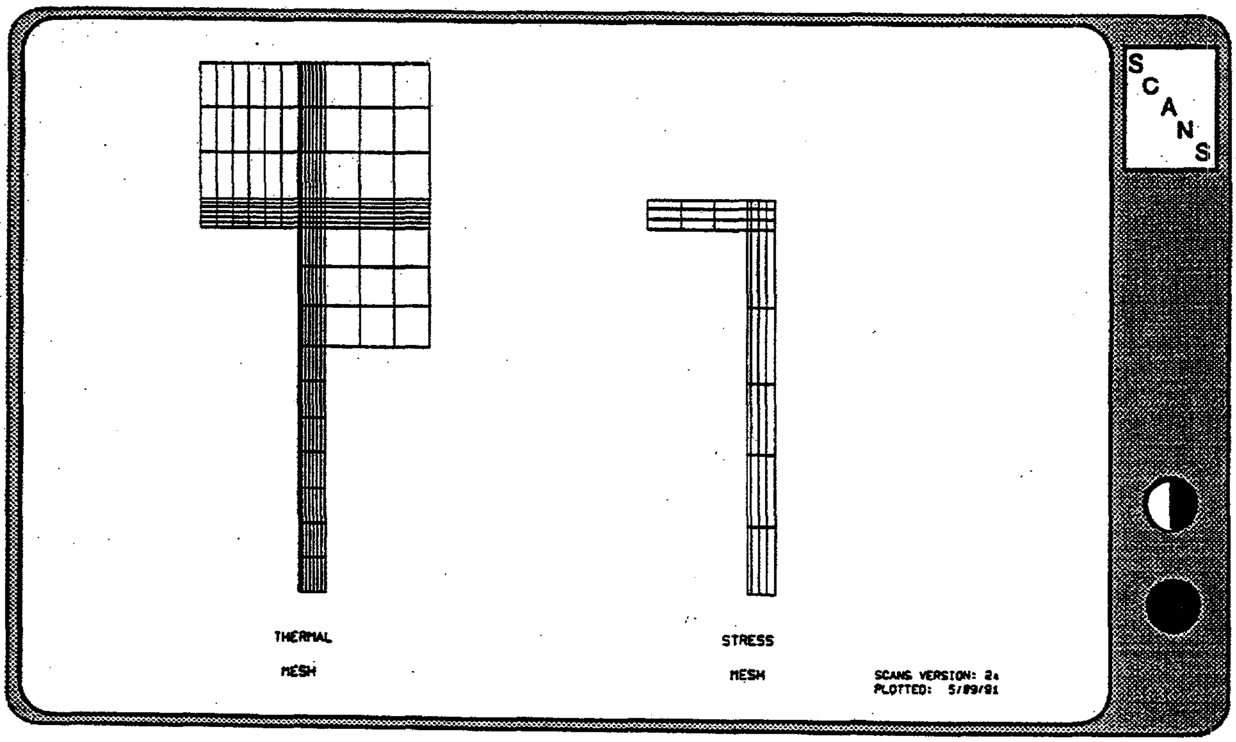


Figure 5-8. Display of Thermal and Stress Meshes.

```
CASK ID: 9999  NODE/ELEMENT map of THERMAL MESH    SCANS Version 2a
Generated on  5/09/91 at  6:57:55
SAR: Sample spent fuel shipping cask (demonstration only)

N O T   T O   S C A L E

NOTE -- Mesh is axisymmetric model for TOP half of cask

Material numbers  ... (printed in corner of each element)

1= Inner Shell     4= End cap inner layer    7= Neutron Shield
2= Shell shield    5= End cap shield layer   8= Water Jacket
3= Outer Shell     6= End cap outer layer    9= Impact Limiter
```

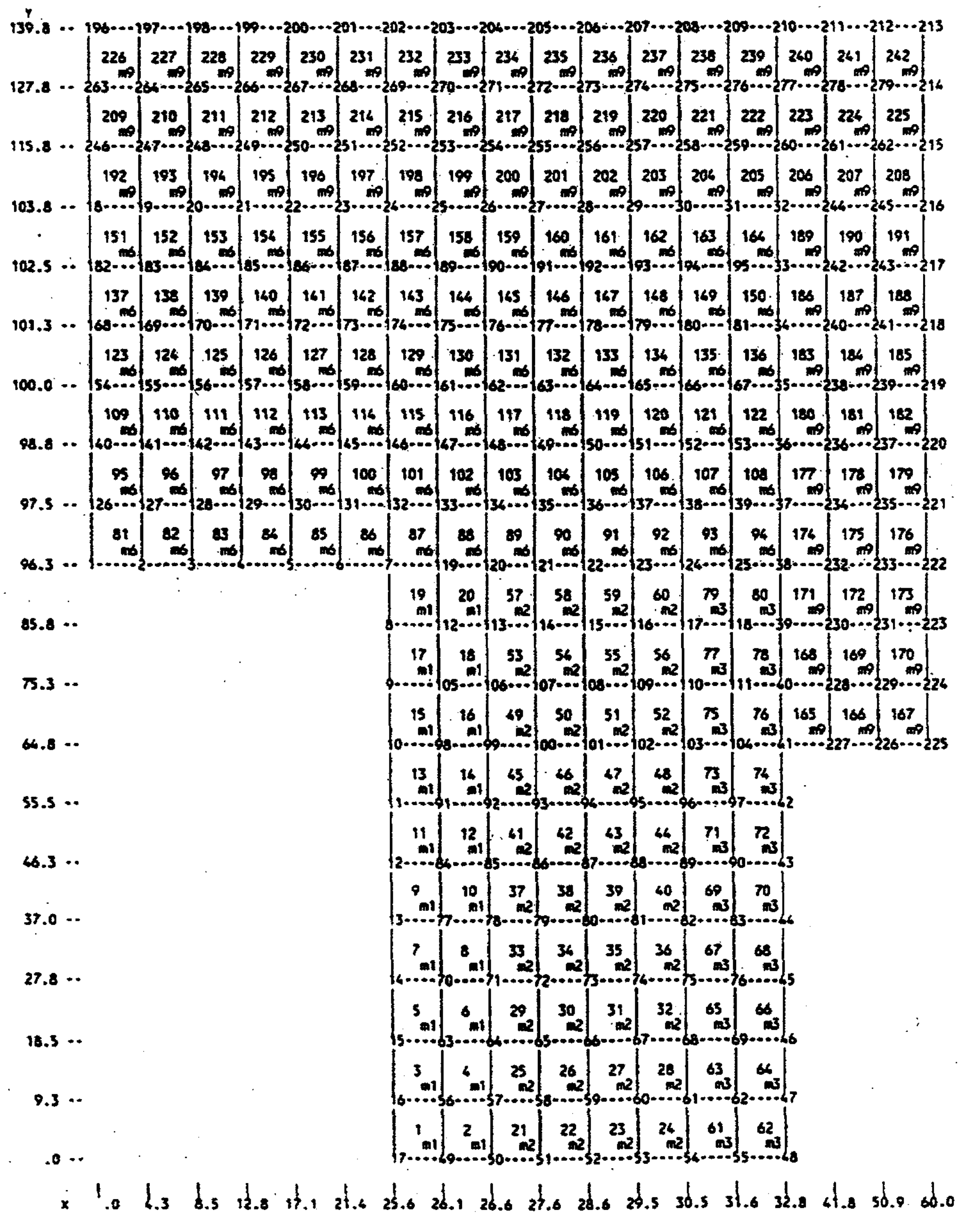


Figure 5-9. Thermal Node/Element Map.

SCANS displays the Plot Thermal Analysis Results Title Screen and indicates the number of thermal solutions. Press **Q** to QUIT and return to the Display Menu, or press any other key to select the thermal solution to plot.

SCANS lists the available thermal solutions and displays the thermal case description, contents heat, date, and time for each solution (**Figure 5-10**). The case description indicates the external temperature condition and the status of contents heat and solar effects. The applied contents heat is in Btu/min. Use the keypad up or down arrow keys to highlight the desired case and press **S** to select the indicated solution for plotting.

After the case is selected, **SCANS** displays the Select Plots and Display Parameters Screen (**Figure 5-11**; note that the options F2, F3 and F9 only appear and are active when the option is selected: "Select Profile Plot Limits" for F2 and F9, and ""Define Items for Time Hist. Plot" for F3) and lists the following options:

Press **S** to select a different thermal case
Press **Q** to QUIT and return to the Display Menu
Press ↑ to move to previous choice field
Press ↓ to move to next choice field
or Press any of the keys indicated in the options box

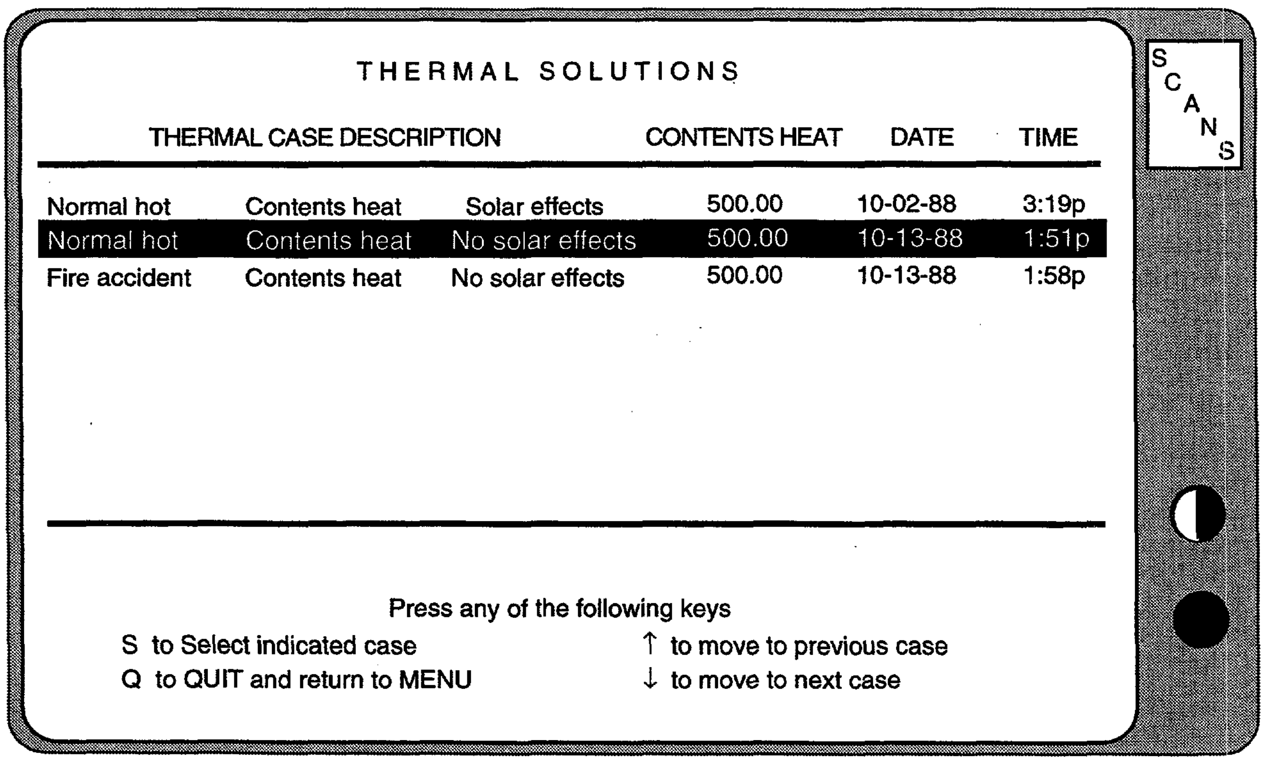


Figure 5-10. Select Thermal Solution to Plot.

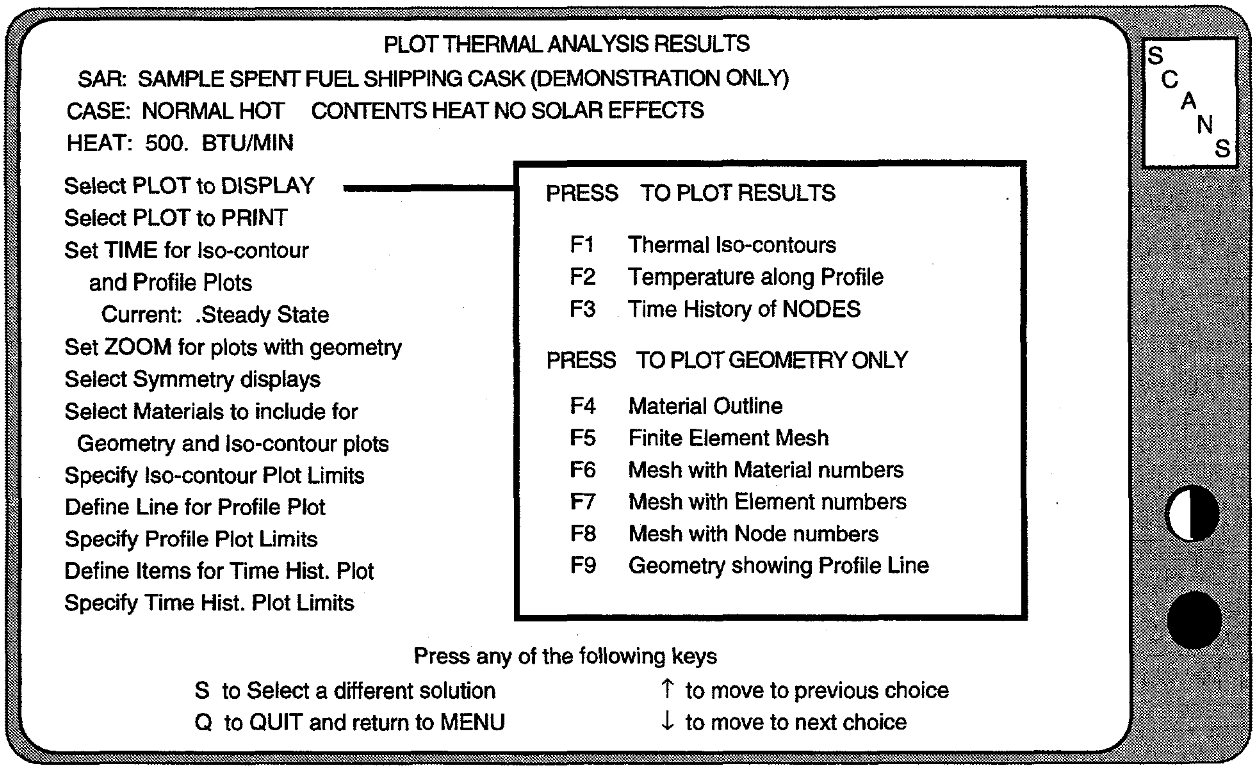


Figure 5-11. Select Plots and Display Parameters Screen.

NOTE: Enter values in the same manner as entering values when editing the geometry or impact limiter curves (see Appendix A).

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 Thermal Iso-contours (**Figure 5-16**)
- **F2** to plot Temperature along a Profile (**Figure 5-17**) (only if Line for Profile Plot is defined)
- **F3** to plot Time History of Nodes (or Elements) (**Figure 5-18**) (only if Items for Time History Plots are defined)
- **F4** to plot Material Outline (**Figure 5-19**)
- **F5** to plot Finite Element (F.E.) Mesh
- **F6** to plot F.E. Mesh with Material Numbers
- **F7** to plot F.E. Mesh with Element Numbers
- **F8** to plot F.E. Mesh with Node Numbers
- **F9** to plot Geometry showing Profile Line (**Figure 5-20**) (only if Line for Profile Plot is defined)

Display Menu
Plot Temperature Distributions

Thermal iso-contours are lines of constant temperature plotted on the geometry material outline. Plots of temperature along a profile are: (1) the temperature profile along a line cutting the geometry (the line may be defined by XY coordinates or nodes numbers); or (2) temperature plotted for specified nodes as a function of distance between the nodes. Time history plots of nodal temperatures or averaged element temperatures are only available for the transient fire case. Up to six time histories per plot are allowed. Cask components are represented as different materials. Material outline plots are composed of outlines for each component selected for display. The finite element mesh can be plotted showing the mesh only, the mesh with material numbers, the mesh with element numbers, and the mesh with node numbers. Use the ZOOM option to isolate portions of the mesh when element or node numbers overlay one another. When a temperature profile line has been defined, the line can be plotted on the cask material outline to verify its location.

Selecting the Time for Iso-contour and Profile Plots

Highlight the *Time for Iso-contour and Profile Plots* field and use the + and - keys to change the time state for plotting. If the case is a steady state solution (all cases except transient fire) the time cannot be changed.

Setting the Zoom for plots with geometry

Highlight the *Set Zoom* field and press one of the indicated function keys to change the zoom for geometry displays. Zoom on small portions of the geometry for more detailed views (**Figure 5-21**). This is helpful when displaying the finite element mesh with node or element numbers.

F1 to Automatically center and display the full geometry
F2 to ZOOM on specified coordinates
F3 to ZOOM on a specified node

For zoom on specified coordinates (**Figure 5-12**), enter the X and Y coordinates which define the center of the plot and the width of the geometry to plot around the plot center. For zoom on a specified node, enter the number of the node which defines the center of the plot instead of X Y coordinates. After specifying the zoom conditions, press one of the following keys:

Press **D** when DONE entering values
Press **A** to revert to Automatic centering and display full geometry
Press **Q** to QUIT and return to the Display Menu

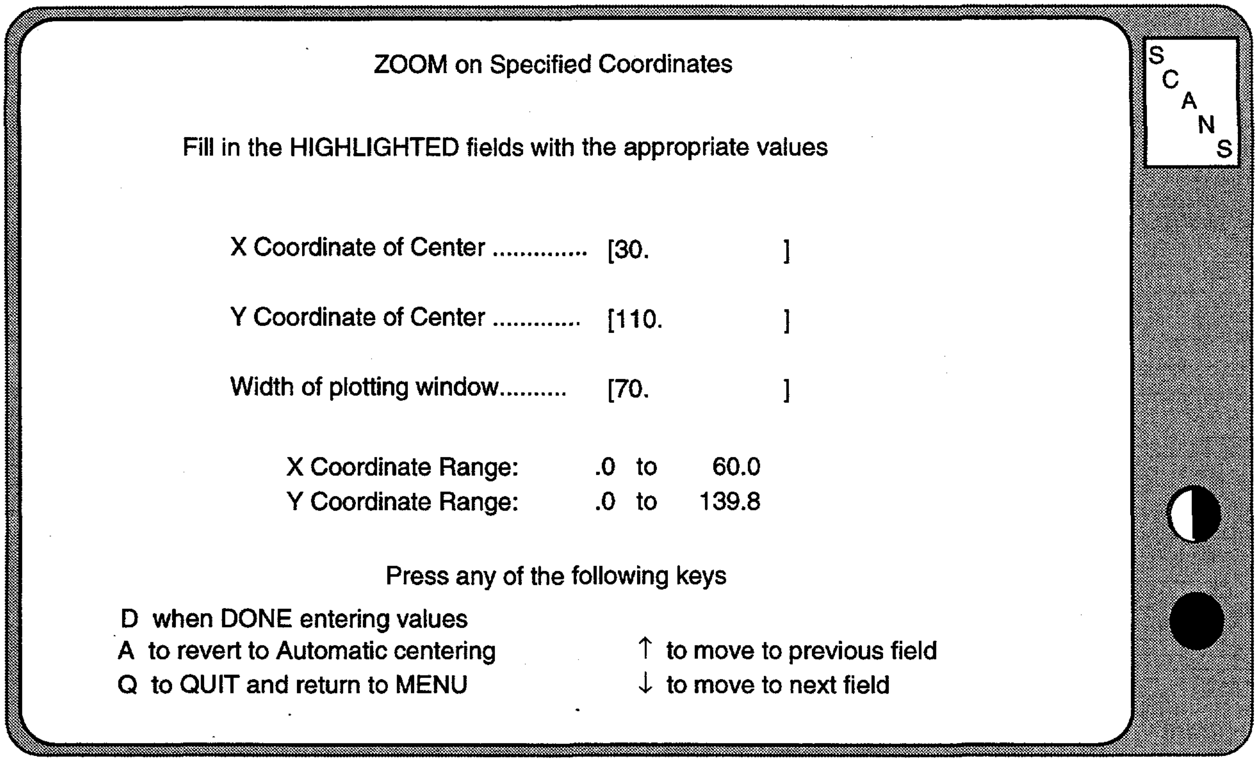


Figure 5-12. ZOOM on Specified Coordinates.

Selecting the Symmetry Displays

Highlight the *Select Symmetry Displays* field and press one of the indicated function keys. **SCANS** uses an axisymmetric model of the TOP end of the cask to represent the thermal geometry. Reflect about the Y axis to simulate the geometry full width. Reflect about the X axis to simulate the geometry full length. Reflect about both the X and Y axes to simulate the full cask geometry.

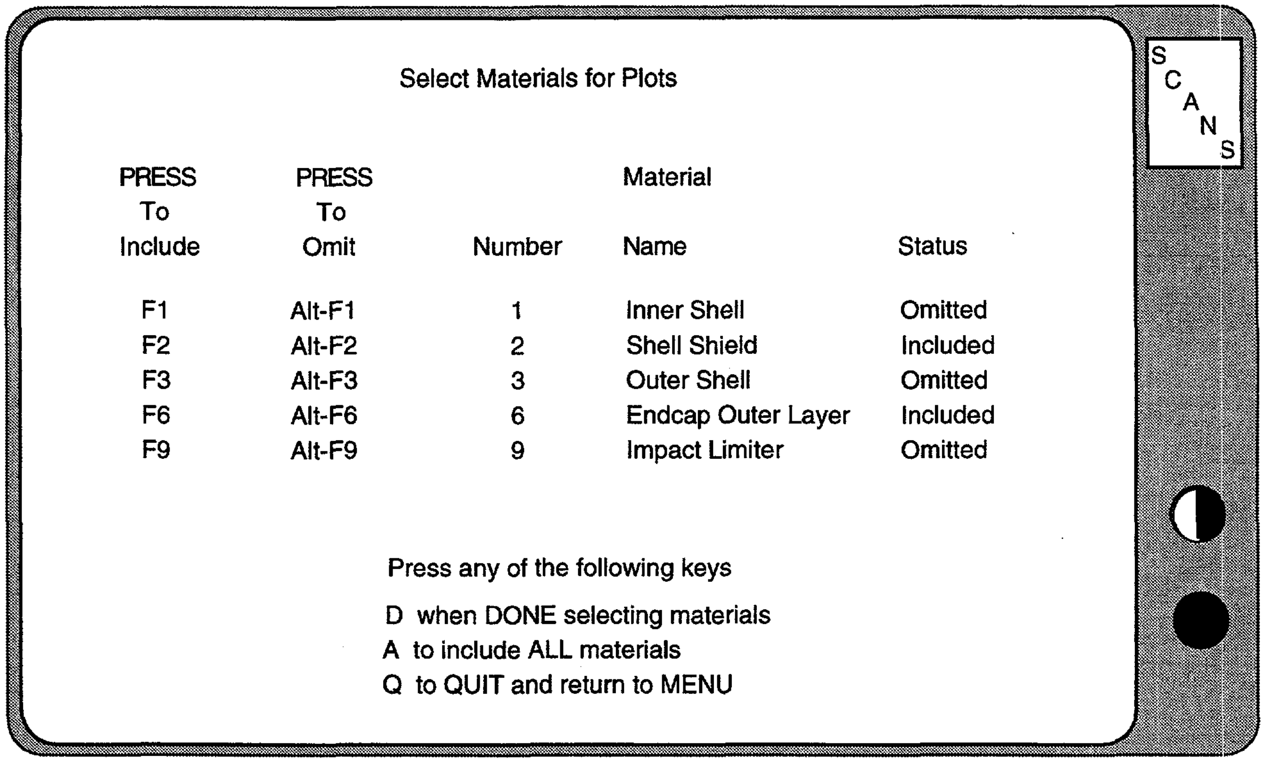
F1 for NO symmetry reflections
F2 to reflect about the Y axis (**Figure 5-22**)
F3 to reflect about the X axis
F4 to reflect about the X and Y axes

Selecting the Materials to Include for Geometry and Iso-contour Plots

Highlight the *Select the Materials to Include* field and press one of the indicated function keys. **SCANS** represents each cask component as a different material. Use this option to isolate cask components for iso-contour and outline plots.

F1 to Include ALL Materials in the Plots
F2 to Select Materials for Plots

Display Menu
Plot Temperature Distributions


Select Materials for Plots

PRESS To Include	PRESS To Omit	Number	Material Name	Status
F1	Alt-F1	1	Inner Shell	Omitted
F2	Alt-F2	2	Shell Shield	Included
F3	Alt-F3	3	Outer Shell	Omitted
F6	Alt-F6	6	Endcap Outer Layer	Included
F9	Alt-F9	9	Impact Limiter	Omitted

Press any of the following keys

D when DONE selecting materials
A to include ALL materials
Q to QUIT and return to MENU

Figure 5-13. Select Materials for Plotting.

When selecting materials, **SCANS** displays a list of all cask components indicating the material number, component name, and whether the component is included or omitted for iso-contour and outline plots (**Figure 5-13**). Press the indicated function keys to include specific components or press **ALT** and the function key to omit components. To complete material selections, press one of the following:

Press **D** when DONE selecting materials
Press **A** to include ALL materials
Press **Q** to QUIT and return to the Display Menu

Specifying the Iso-contour Plot Limits

Highlight the *Specify the Iso-contour Plot Limits* field and press one of the indicated function keys to specify the contour range. Use the + and - keys to change the number of evenly spaced contour lines.

F1 to set to Automatic ranging
F2 to specify the contour range
+ to increase the number of contour lines (maximum is 8)
- to decrease the number of contour lines (minimum is 2)

Automatic ranging sets the contour range based on the minimum and maximum temperatures of the components included for display. For a specified contour range, enter values for the FIRST and LAST contour lines. The remaining contour lines are evenly spaced in between. Enter values in the same manner as entering values when editing the geometry or impact limiter curves. **NOTE:** the value of the FIRST contour line must be less than the value for the LAST contour line. After specifying the contour range, press one of the following:

Press **D** when DONE entering values
Press **A** to revert to Automatic ranging
Press **Q** to QUIT and return to the Display Menu

Defining a Line for a Profile Plot

Highlight the *Define Line for Profile Plot* field and press one of the indicated function keys to define one of the three types of temperature profile lines. Profile lines defined between XY coordinates or between two nodes produce plots of the temperature profile along the defined line where it crosses the geometry. Profile lines defined as a series of nodes produce plots of temperature for the specified nodes as a function of the distance between the nodes. The temperature profiles between successive nodes in the series are drawn as a straight lines and do not reflect the actual temperature profiles between nodes.

F1 to Define a Line Between XY Coordinates
F2 to Define a Line Between Two Nodes
F3 to Define a Line as a Series of Nodes (**Figure 5-14**)

When defining a profile line between XY coordinates, enter X and Y coordinates for both ends of the line. **NOTE:** the line must have a finite length (the coordinates of the first point must not equal the coordinates of the second point). When defining a profile line between two nodes, enter a node number for each end. **NOTE:** the first node must not equal the second node. When defining a profile line as a series of nodes, enter node numbers for each node in the series. If the series has less than 12 nodes, terminate the list with a node number of zero. After defining the profile line, press one of the following keys:

Press **D** when DONE entering values
Press **A** to ABANDON line definition
Press **Q** to QUIT and return to the Display Menu

Display Menu
Plot Temperature Distributions

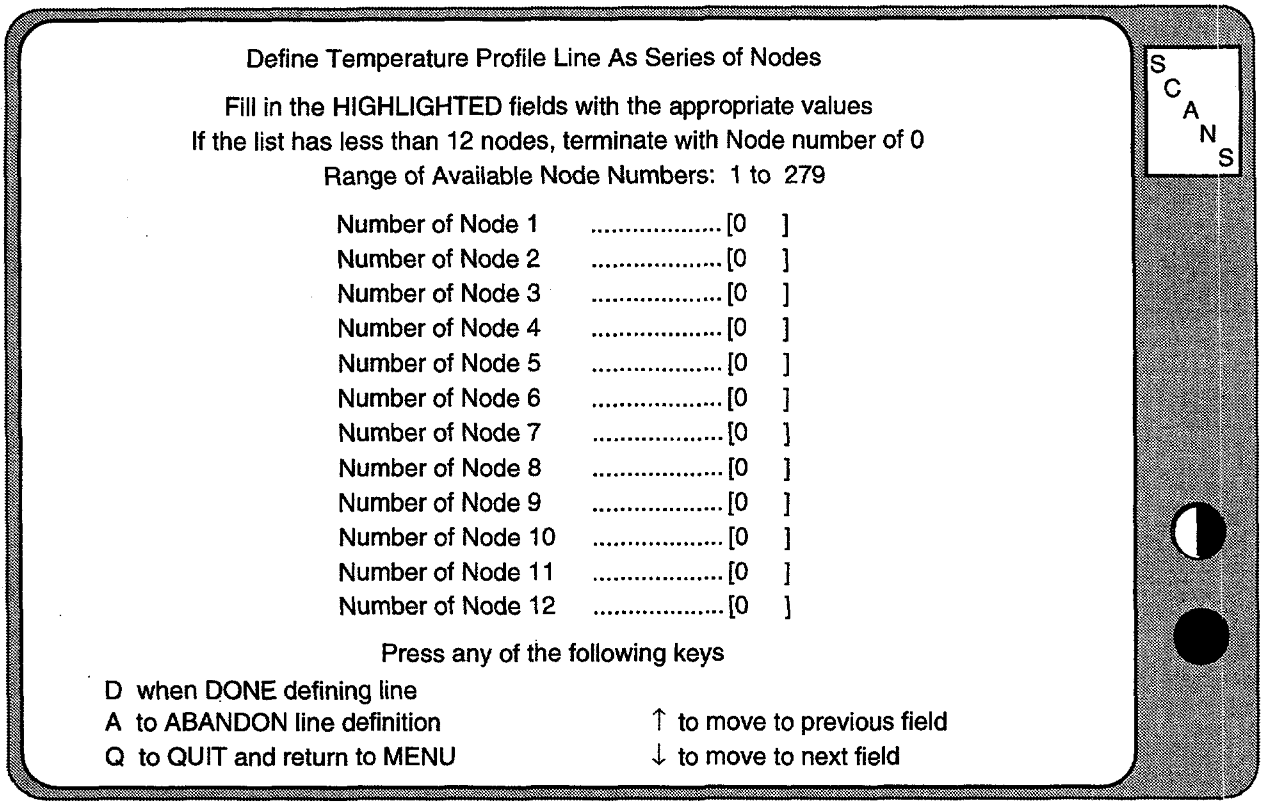


Figure 5-14. Define Profile Line Between Two Nodes.

Specifying Profile Plot Limits

Highlight the *Specify Profile Plot Limits* field and press one of the indicated function keys to specify the temperature range for the temperature profile plots.

F1 to set to Automatic ranging
F2 to specify the Temperature range

Automatic ranging sets the temperature range based on the minimum and maximum temperatures along the profile line. For a specified temperature range, enter values for the LOWER and UPPER temperature limits. **NOTE:** the value of the LOWER temperature limit must be less than the value for the UPPER temperature limit. After specifying the profile temperature range, press one of the following:

Press **D** when DONE entering values
Press **A** to revert to Automatic ranging
Press **Q** to QUIT and return to the Display Menu

Defining Items for Time History Plots

Highlight the *Define Items for Time History Plots* field and press one of the indicated function keys to select the nodes or elements for time history plots. Up to six nodes or elements may be plotted on a single time history plot. Element temperatures are calculated as the average of the temperatures of the nodes defining the element. Time history plots are only available for transient fire case solutions.

F1 to Specify NODES for Time History Plots (**Figure 5-15**)
F2 to Specify ELEMENTS for Time History Plots

Enter up to six node or element numbers. If the list has less than six node or element numbers, terminate the list with a node or element number of zero. After specifying items for time history plots, press one of the following keys:

Press **D** when DONE selecting items
Press **A** to ABANDON selections
Press **Q** to QUIT and return to the Display Menu

Specifying Time History Plot Limits

Highlight the *Specify Time History Plot Limits* field and press one of the indicated function keys to specify the temperature range for time history plots.

F1 to set to Automatic ranging
F2 to specify the Temperature range

Automatic ranging sets the temperature range based on the minimum and maximum temperatures of the nodes or element for the full time history. For a specified temperature range, enter values for the LOWER and UPPER temperature limits. **NOTE:** the value of the LOWER temperature limit must be less than the value for the UPPER temperature limit. After specifying the time history temperature range, press one of the following:

Press **D** when DONE entering values
Press **A** to revert to Automatic ranging
Press **Q** to QUIT and return to the Display Menu

Display Menu

Plot Temperature Distributions

Select NODES for Time History Plots

Fill in the HIGHLIGHTED fields with the appropriate values

NOTE: If list has less than 6 items, terminate with 0

Range of Available Node Numbers: 1 to 282

Number of Node 1 .... [196]

Number of Node 2 .... [48]

Number of Node 3 .... [0]

Number of Node 4 .... [0]

Number of Node 5 .... [0]

Number of Node 6 .... [0]

Press any of the following keys

D when DONE selecting items

A to ABANDON selections

Q to QUIT and return to MENU

↑ to move to previous field

↓ to move to next field

Figure 5-15. Select NODES for Time History Plots.

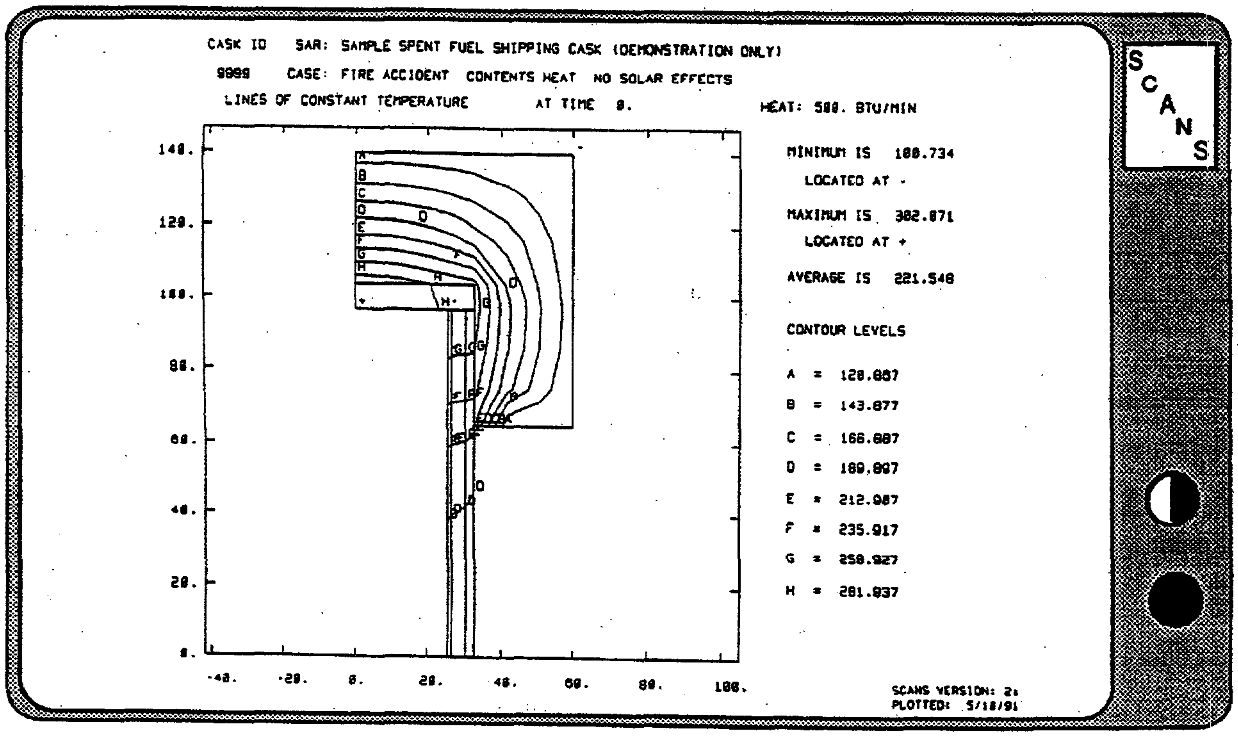


Figure 5-16. Plot of Thermal Iso-contours.

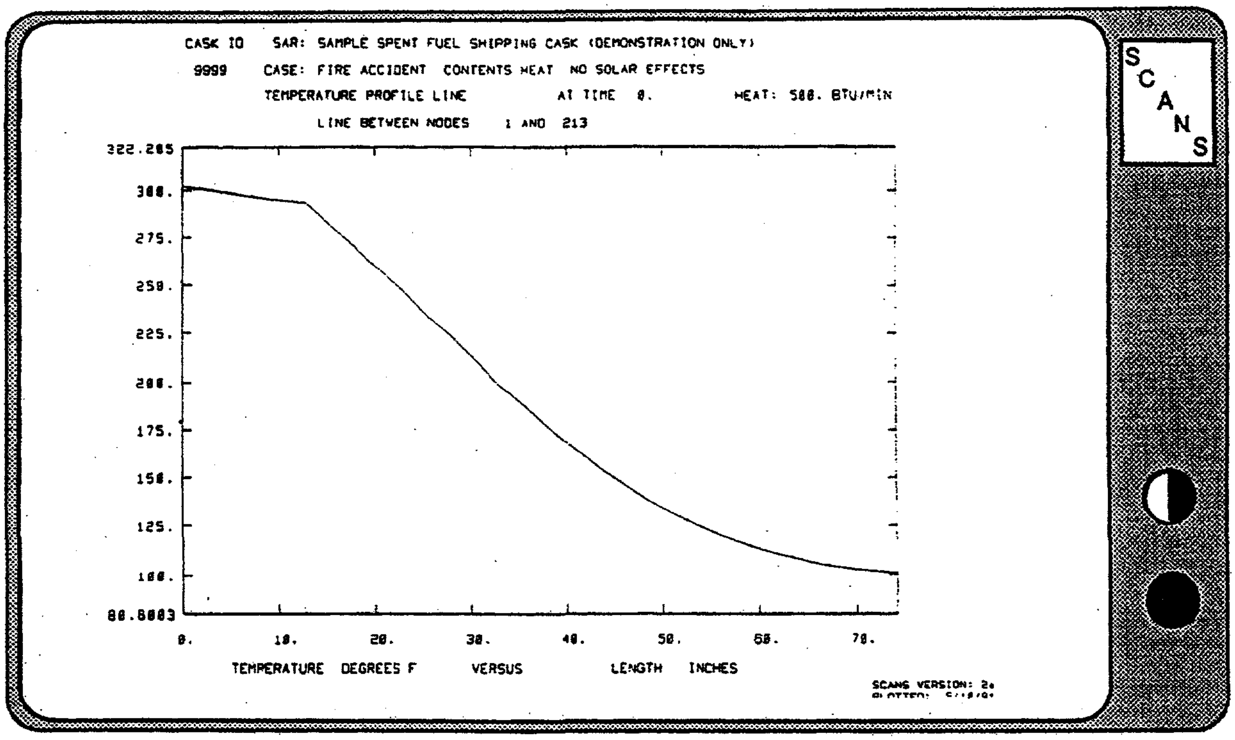


Figure 5-17. Plot of Temperature Along Profile Between Nodes 1 and 213. Profile line is shown in Figure 5-20.

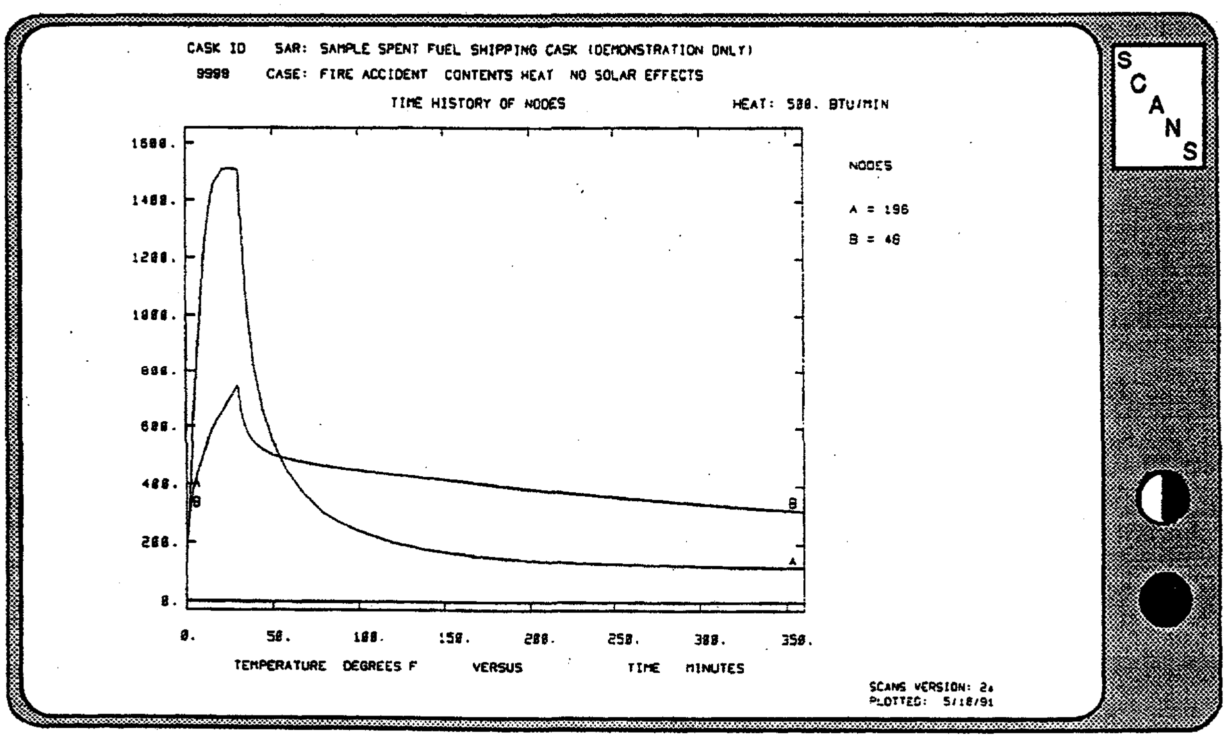


Figure 5-18. Plot of Time History of Nodes 196 and 48.

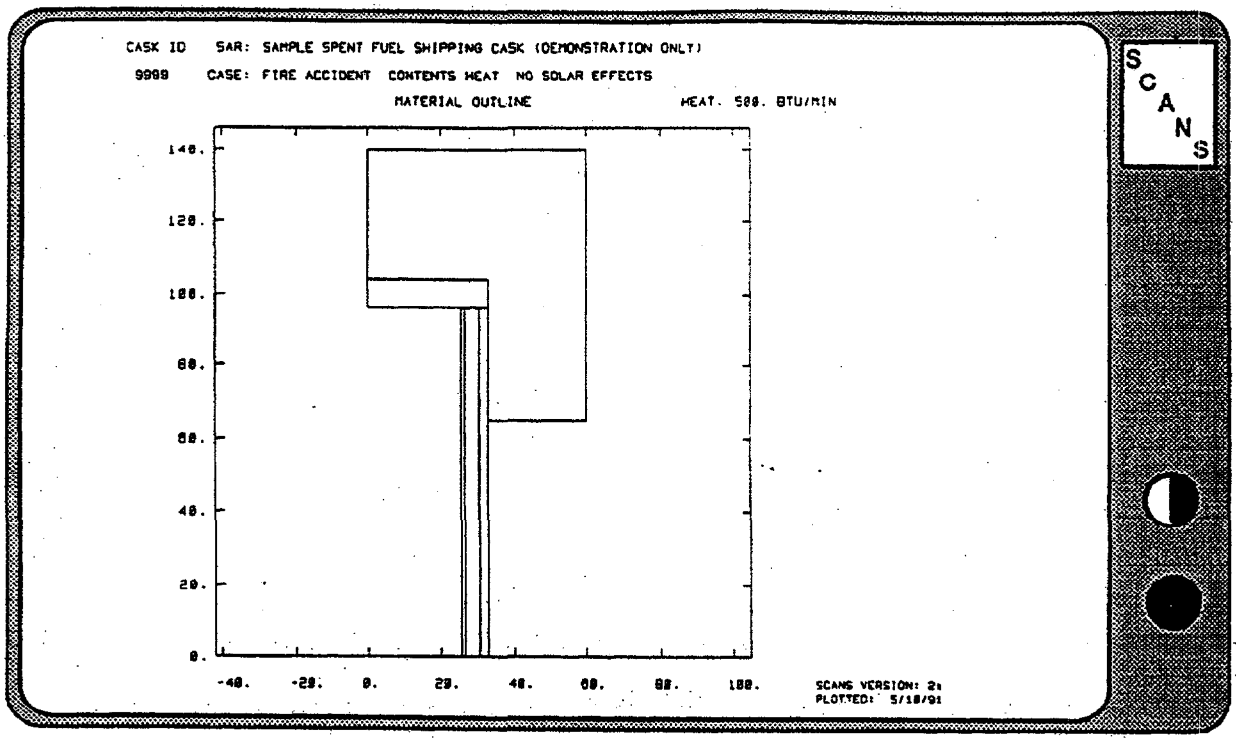


Figure 5-19. Plot of Material Outline.

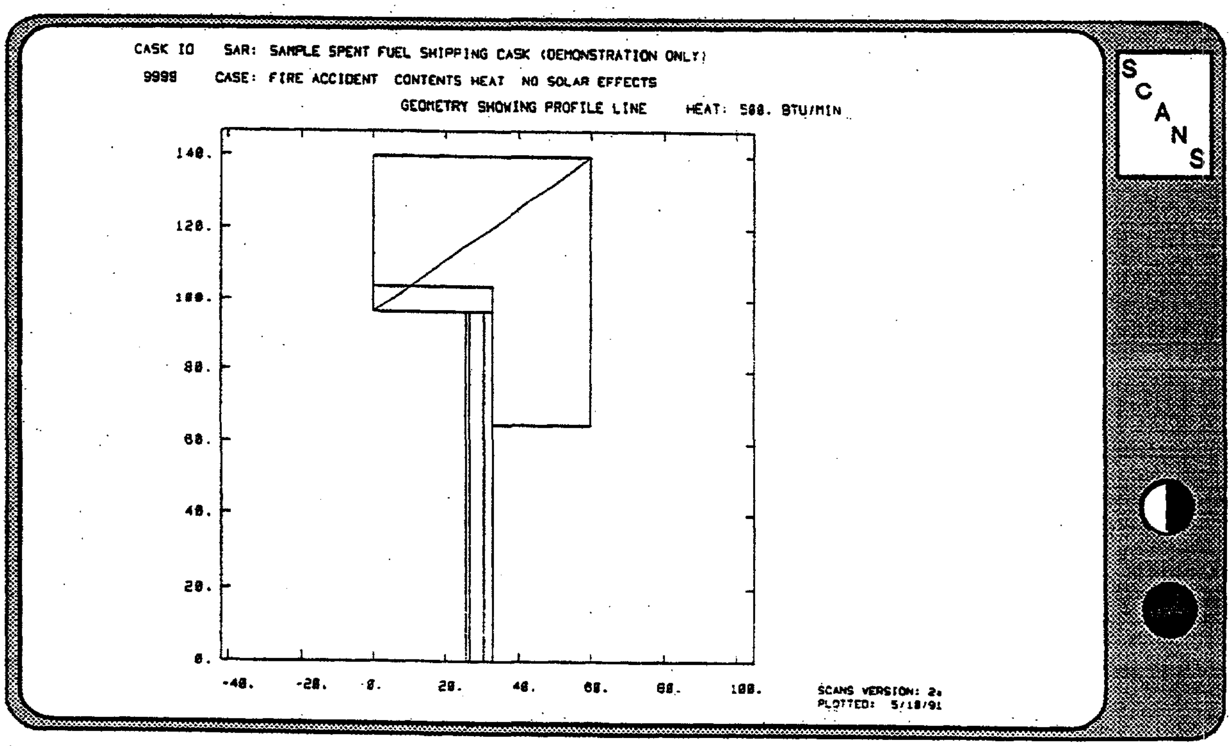


Figure 5-20. Plot of Geometry Showing Profile Line.

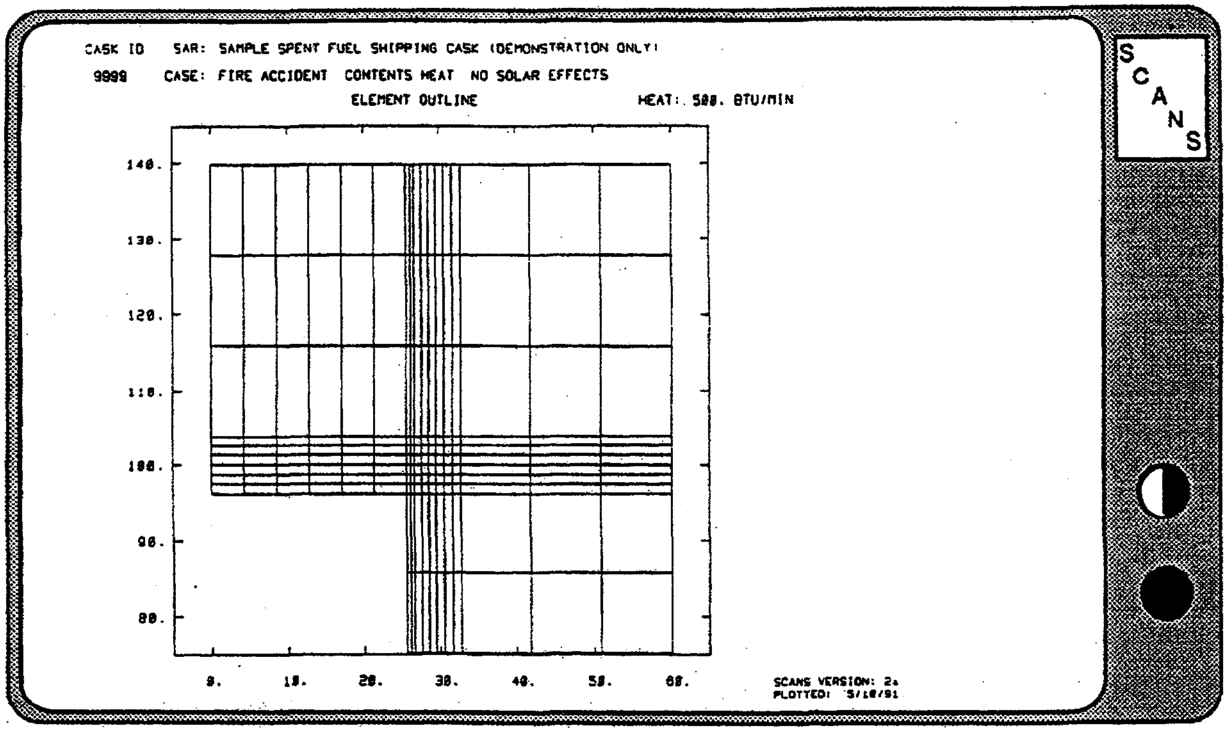


Figure 5-21. Plot of Elements Using ZOOM.

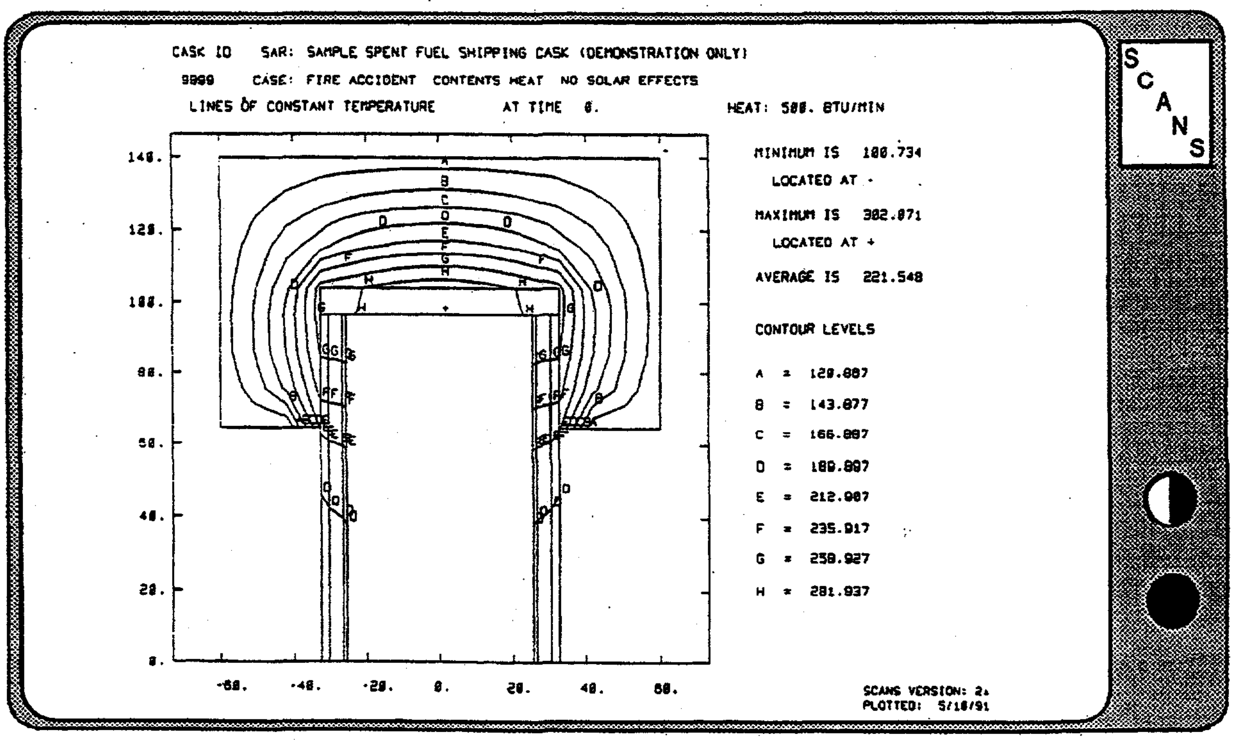


Figure 5-22. Iso-contour Plot with Y Axis Reflection.

Display Menu
Set Attributes for Video/Printer Plots

SCANS displays the Set Attributes for Video/Printer Plots Screen shown in **Figure 5-23**. To modify the current attributes, use the keypad up or down arrow keys to highlight the desired field and then use the indicated keys to select the desired attributes as follows, and press **D** when done.

Selecting the Display Type

Press **F1** for Color Graphics Adapter (one color, 640 x 200 pixels)
Press **F2** for Enhanced Graphics Adapter (three colors, 640 x 350 pixels)
Press **F3** for Video Graphics Array Display (three colors, 640 x 480 pixels)

Selecting the Printer Type

Press **F1** for Hewlett Packard LaserJet printer
Press **F2** for IBM/Epson graphics type dot matrix printer

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

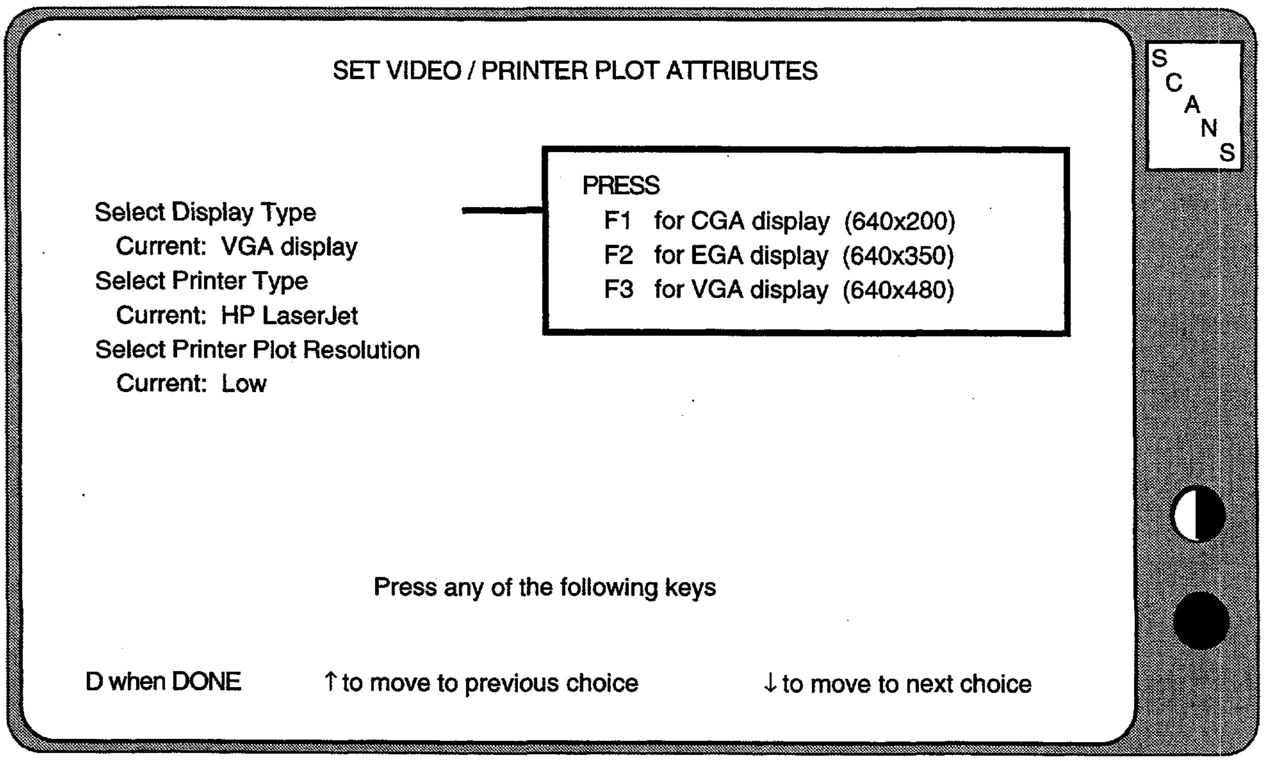


Figure 5-23. Set Video/Printer Plot Attributes.

SCANS uses the three Hewlett Packard LaserJet printer models in a limited fashion. Node/element mesh maps are printed using the standard Courier font (10 characters per inch) and the Line Printer font (16.66 characters per inch). LOW resolution plots are drawn using 150 dpi (dots per inch) graphics mode; HIGH resolution plots are drawn using 300 dpi graphics mode. Each LaserJet model is described below with its particular limitations and possible remedies.

LaserJet

(1) The Line printer font is not an internal font. Provide a font cartridge which contains the Line Printer font for mesh maps.
(2) The maximum graphics mode resolution is 75 dpi. Both LOW and HIGH resolution printer plots are printed piecemeal on several pages. If the LaserJet upgrade is installed, printer plots are printed on one page.

LaserJet+

(1) The maximum graphics mode resolution is 150 dpi. LOW resolution printer plots are printed on one page and HIGH resolution plots are printed piecemeal on several pages. If the LaserJet+ upgrade is installed, HIGH resolution plots are printed on one page.

LaserJet Series II

(1) The maximum graphics mode resolution is 150 dpi. LOW resolution printer plots are printed on one page and HIGH resolution plots are printed piecemeal on several pages. If a 1 Mbyte memory board is installed, HIGH resolution plots are printed on one page.

Selecting the Printer Plot Resolution

Press **F1** for LOW resolution printer plots
Press **F2** for HIGH resolution printer plots

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.

NOTES:

Print/Review Menu

The Print/Review Menu (**Figure 6-1**) provides options for printing and reviewing the Cask Summary/Data Check and outputs from Impact, Thermal, Thermal Stress, Pressure Stress analyses and Load Combination analyses. Output for Thermal, Thermal Stress, and Pressure Stress can also be printed as an abbreviated output summary. The review function displays the output on the screen. The outputs are discussed in Appendix C.

PRESS 1 to Print/Review Impact Output

Print or Review Dynamic or Quasi-Static Impact analysis output.

PRESS 2 to Print/Review Thermal Output

Print or Review Thermal output. Abbreviated prints skip the summary of input, printing the temperature output with flux balances.

PRESS 3 to Print/Review Thermal Stress Output

Print or Review Thermal stress output. Abbreviated prints skip nodal displacements and element stresses, printing the summary of maximum stresses and stresses corresponding to Impact nodal locations.

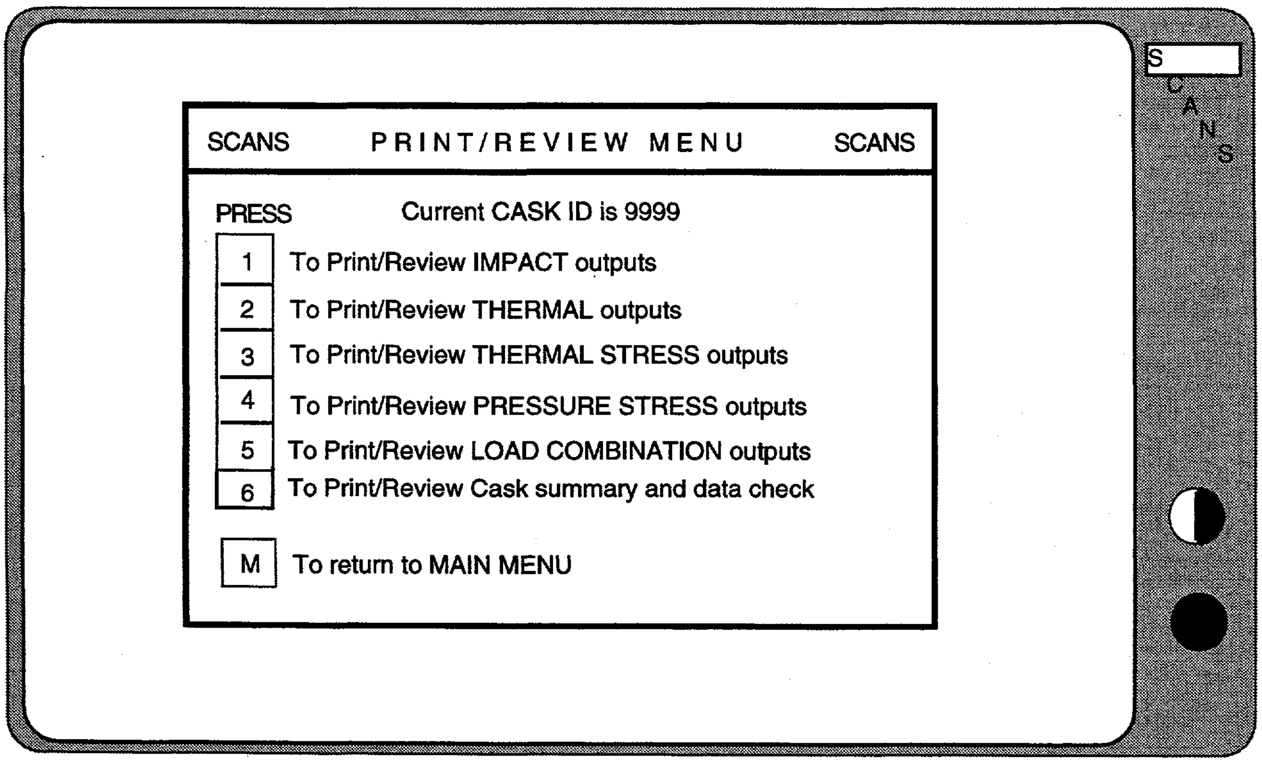


Figure 6-1. SCANS Print/Review Menu.

Print/Review Menu

PRESS 4 to Print/Review Pressure Stress output

Print or Review Pressure stress output. The abbreviated print skips the nodal displacements and element stresses and includes a table of maximum stresses and the stresses corresponding to Impact nodal locations.

PRESS 5 to Print/Review Load Combination output

Print or Review load combination output.

PRESS 6 to Print/Review Cask Summary and Data Check

Print or Review the geometry summary / data check for basic geometry and impact limiter force/deflection curve data.

PRESS M to Return to Menu

SCANS returns to the Main Menu display.

Selecting the Output to Print/Review

Press the appropriate Menu key to select the output type. **SCANS** displays the Print/Review Title Screen indicating the number of outputs available for printing or review. Press **Q** to QUIT and return to the Print/Review Menu, or press any other key to select a particular output case to print or review. **SCANS** lists an example of the available outputs and displays a description, date, and time for each output (**Figure 6-2**).

For Impact, the case descriptions indicate the analysis type, shell/shield interface, impact type, impact end, drop height, and impact angle. An unbonded shell/shield interface allows the lead shield to slump. A primary/secondary impact type includes impact of both ends. The impact end indicates the end that impacts first. Impact angles are relative to the horizontal (i.e., 0 degrees is a side drop).

For Thermal and Thermal stress, the case descriptions indicate the external temperature condition, the status of the applied contents heat, and the status of solar effects. The applied contents heat is in Btu/min.

For Pressure stress, the case descriptions indicate the internal and external pressures. The internal pressure is the maximum normal operating temperature (input during geometry definition) or the internal pressure resulting from a thermal analysis. The external pressure is established by regulatory guidelines.

For load combination, the case description contains the case title and the case number.

For Summary / Data Checks, the description indicates the basic geometry specifications or impact limiter force/deflection curves.

Use the keypad up or down arrow keys to highlight the desired case. Press **S** to select the indicated solution to print or review.

After the output is selected, **SCANS** displays an Output Summary Screen indicating the number of pages in the output, if abbreviated output is available, and the output header (**Figure 6-3**). The output header indicates the type of analysis, date and time the output was generated, and a brief description of the parameters defining the output. **SCANS** then lists the following options:

Press **P** to Print the OUTPUT
Press **R** to Review the OUTPUT on the screen
Press **S** to Select a different OUTPUT to Print/Review
Press **Q** to QUIT and return to the Print/Review Menu

IMPACT SOLUTIONS

ANALYSIS TYPE	SHELL/SHIELD INTERFACE	IMPACT TYPE	IMPACT END	DROP HEIGHT	IMPACT ANGLE	DATE	TIME
Dynamic	Unbonded	Primary	Bottom	30	90	10-12-88	2:30p
Dynamic	Bonded	Primary/Secondary	Bottom	30	45	10-02-88	3:06p

Press any of the following keys

S to Select indicated solution — ↑ to move to previous solution

Q to QUIT and return to MENU — ↓ to move to next solution

SCANS

Figure 6-2. Select Solution to Print/Review.

OUTPUT has 7 pages

OUTPUT HEADER

DYNAMIC IMPACT OUTPUT FOR CASK 9999
GENERATED ON 10/112/88 AT 14:22:45 SCANS VERSION: 1a
SAR: Sample spent fuel shipping cask (demonstration only)
30 ft accident drop on cask bottom - primary impact only
Angle of primary impact is 90 degrees - shield/shell interace is unbonded

PRESS
- P to Print the OUTPUT
- R to Review the OUTPUT on the screen
- S to Select a different OUTPUT to Print/Review
- Q to QUIT and return to MENU

SCANS

Figure 6-3. Output Summary Screen.

Printing the Output

After pressing **P** on the Output Summary Screen, **SCANS** displays a reminder to make sure the printer is ON-LINE and set to the TOP-OF-PAGE. Press one of the following keys:

Press **P** to Print the complete output
Press **A** to print the Abbreviated output (if available)
Press **Q** to QUIT and return to the Print/Review Menu

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

Press **C** to Continue
Press **Q** to QUIT and return to the Print/Review Menu

After printing is finished, **SCANS** lists the following options:

Press **P** to Print/Review another case
(redisplays the case list screen for current output type)
Press **Q** to QUIT and return to the Print/Review Menu

Print/Review Menu

Reviewing the Output

After pressing **R** on the Output Summary Screen, **SCANS** displays the first 20 lines of the full output on the screen (**Figure 6-4**). **SCANS** can review up to 4000 lines of output (the entire output 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)
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 output. **SCANS** lists the following options:

Press	**P**	to Print/Review another case (redisplays the case list screen for current output type)
Press	**Q**	to QUIT and return to the Print/Review Menu

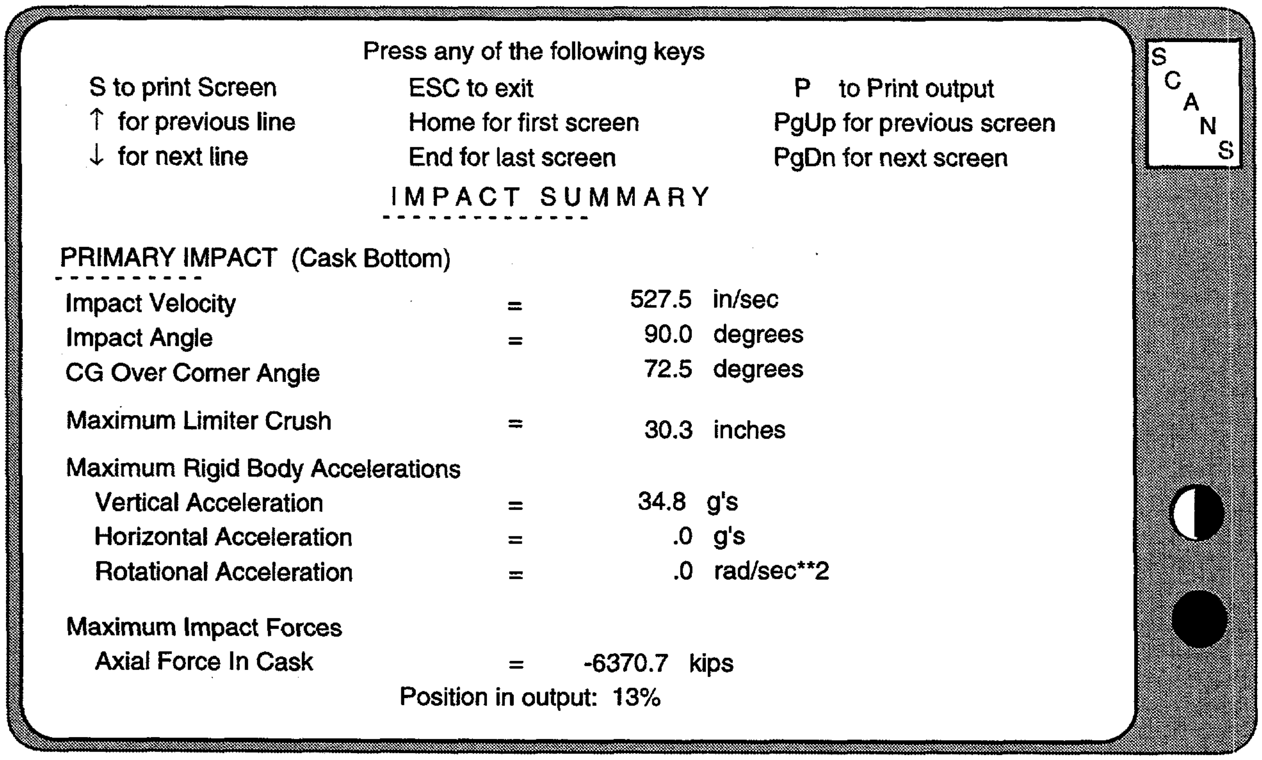


Figure 6-4. Reviewing the Output

Archive Menu

The Archive Menu (**Figure 7-1**) 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 basic geometry, impact limiter force-deflection curve data, finite-element meshes and all analysis output 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 uncompress, restoring the data set to the hard disk.

PRESS 3 to Delete CASK data set from hard disk

Deletes either a complete data set or analysis output for the selected cask.

PRESS M to Return to MAIN MENU

SCANS returns to the Main Menu display.

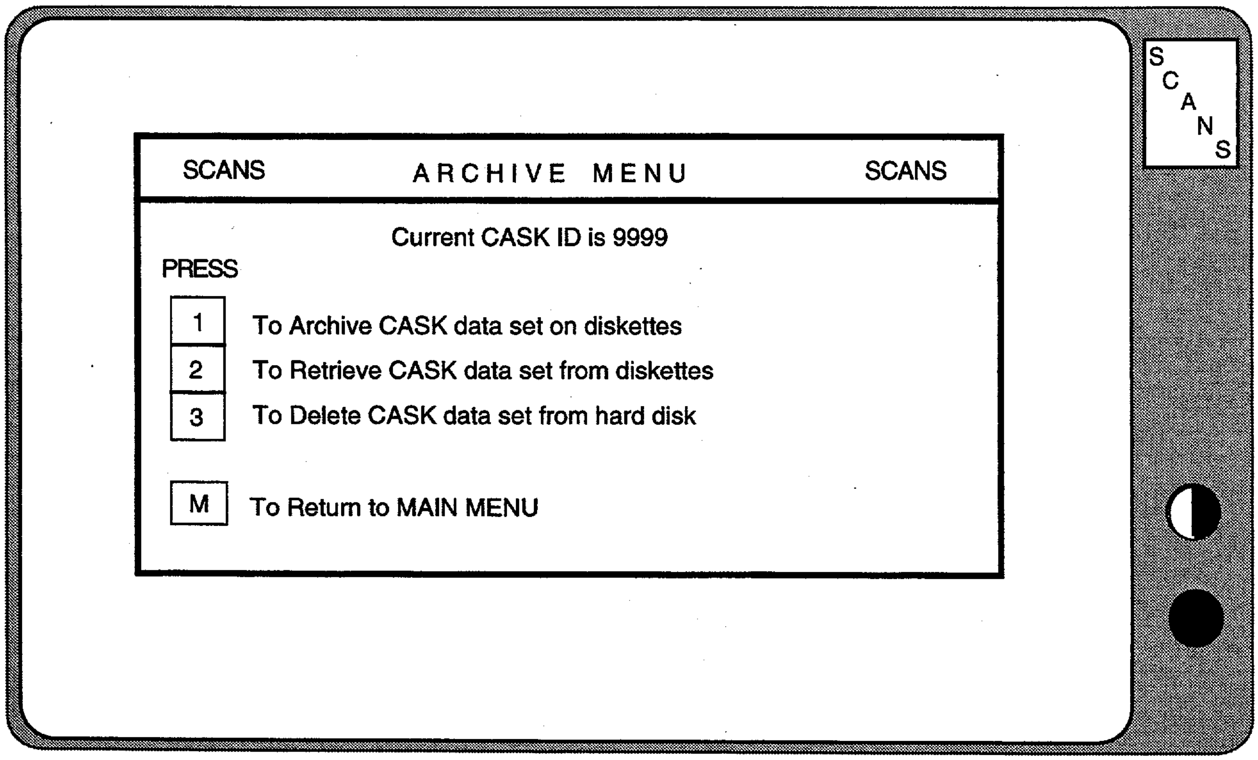


Figure 7-1. SCANS Archive Menu.

Archive Menu
Archiving Data Sets

SCANS 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, **SCANS** automatically uses the DOS utility *BACKUP* to save the archive on more than one diskette. The module used to create the compressed archive is adapted from ARC version 5.1 from System Enhancement Associates (used by permission). 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

If more than one data set exists, **SCANS** displays a list of CASKIDs and indicates several options:

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

If only one data set exists, **SCANS** selects that data set. The data set summary screen is shown in **Figure 7-2**. Summary screen options are:

Press **A** to Archive the summarized data set
Press **S** to select a different CASKID (return to the CASKID list screen-- only if more than one data set exists)
Press **Q** to QUIT and return to the Archive Menu

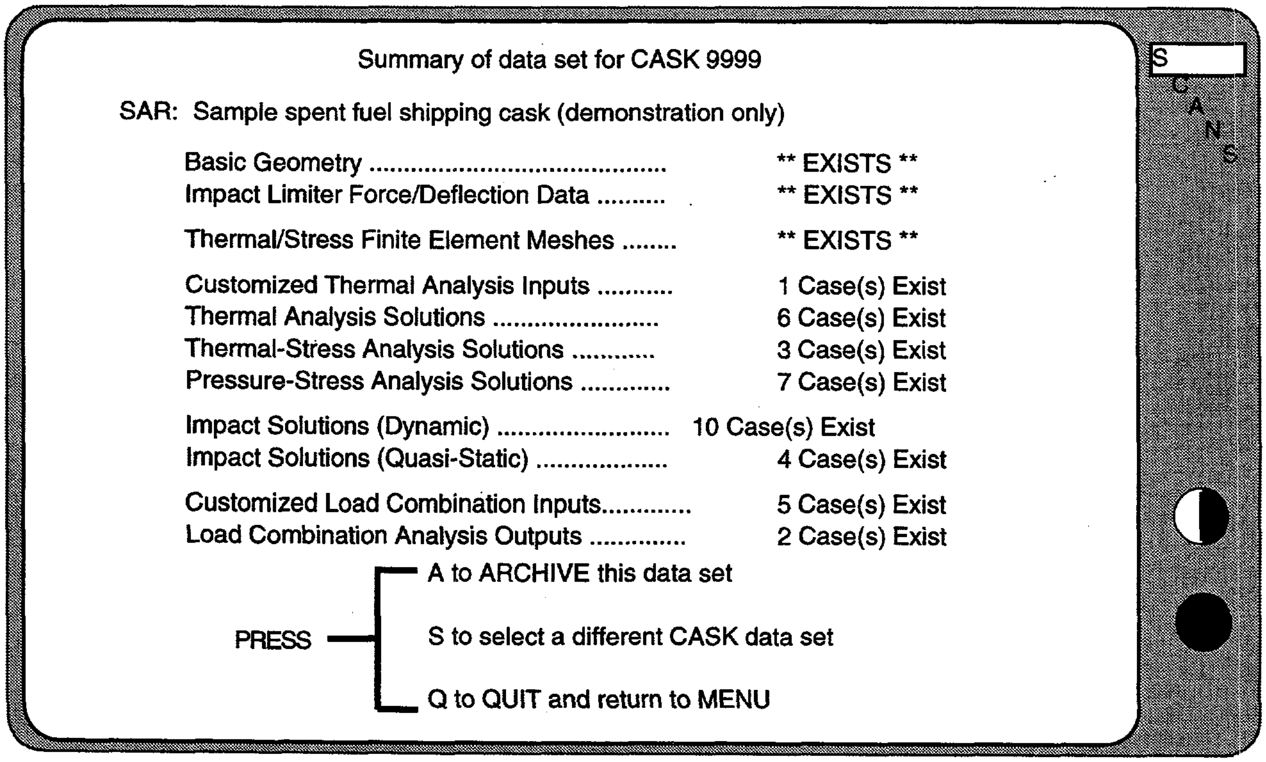


Figure 7-2. Summary of data set for Archive.

SCANS starts the archive process by creating a compressed data set archive. This process can take up to 30 minutes if the data set is large and the PC is slow (ATs are much faster). The resulting compressed archive requires only 15 to 30 percent of the space the complete data requires. After the compressed archive is created, **SCANS** 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

SCANS 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 7-1**. Archiving will not proceed until all error conditions are satisfied.

If the compressed archive will fit on a single diskette, **SCANS** will use *COPY* to write the archive to the diskette. If the archive will not fit on a single diskette, **SCANS** will use *BACKUP* to write the archive to multiple diskettes (**SCANS** indicates how many formatted diskettes of similar density are required). If the archive exists on the diskette, **SCANS** displays the date and time of the hard disk version and 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 **SCANS** 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)
(**SCANS** asks for confirmation before deleting)

SCANS 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, **SCANS** 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 7-1. 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
SCANS 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
SCANS 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.

SCANS retrieves compressed data sets from diskettes and then unpacks the archive, restoring the data set to the hard disk. The module used to unpack the compressed archive is adapted from ARC version 5.1 from System Enhancement Associates (used by permission). **SCANS** 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

SCANS checks the selected drive and searches for archived data sets. The error conditions that can occur are listed in **Table 7-2**. Retrieval will not proceed until all error conditions are satisfied.

If the diskette contains only one archived data set, **SCANS** selects that data set for retrieval. If the diskette contains more than one archived data set, **SCANS** 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

SCANS 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. **SCANS** 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

SCANS 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), **SCANS** starts retrieving the archived data set. If the archive was saved using *BACKUP*, **SCANS** 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, **SCANS** 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 7-2. 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.ARC**, where **xxxx** is the four digit CASKID. Try a different diskette.

Data sets consist of basic geometry descriptions, impact limiter force-deflection curves, and analysis outputs. **SCANS** has two options for deleting data sets: (1) delete the complete data set, or (2) delete just the analysis outputs. All existing data sets can be deleted from this menu. **SCANS** indicates the number of existing data sets and lists two choices:

Press **Q** to QUIT and return to the Archive Menu
Press any other key to select the data set to delete

If only one data set exists, **SCANS** selects that data set and displays a summary of the data set. If more than one data set exists, **SCANS** displays a list of CASKIDs and indicates several options:

Press **S** to Select the highlighted CASKID and display data set summary
Press **Q** to QUIT and return to the Archive Menu
Press ↑ to highlight the previous CASKID
Press ↓ to highlight the next CASKID

After the data set is selected, **SCANS** displays a summary of the data set. The data set summary screen options are:

Press **C** to delete COMPLETE data set
Press **O** to delete OUTPUT for the data set
Press **S** to select a different data set
(available only if more than one data set is on disk)
Press **Q** to QUIT and return to the Archive Menu

SCANS asks for confirmation before deleting the data set or output as shown in **Figure 7-3**. 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 **SCANS** has completed deleting the data set or output, if one or more data sets remain on disk, **SCANS** 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 or data set outputs.**

Hint:

Consider deleting data set outputs before archiving. **SCANS** can reproduce analysis outputs based on the basic geometry descriptions and impact limiter force/deflection curves. Archiving just the basic geometry and limiter curves is much faster than archiving a data set with numerous outputs.

Archive Menu
Deleting Data Sets

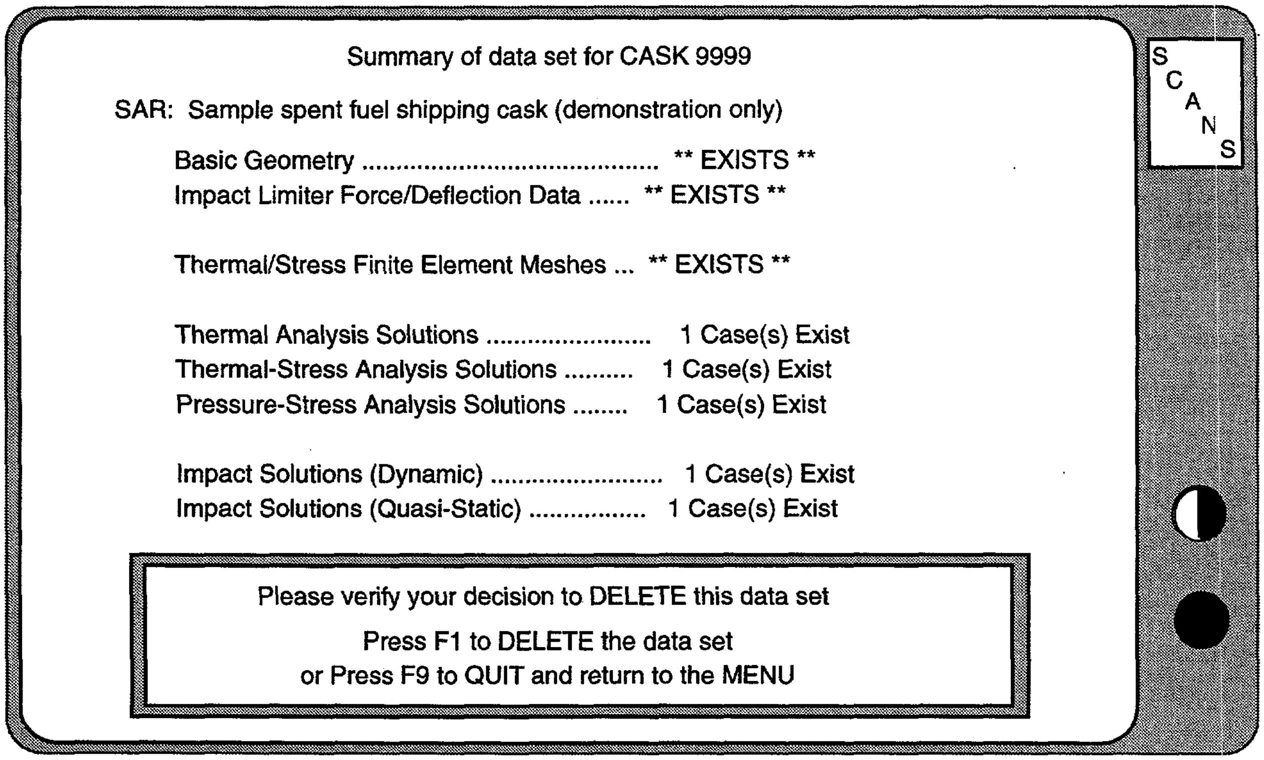


Figure 7-3. Confirm decision to DELETE screen.

NOTES:

Appendix A
The Editor

SCANS 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, **SCANS** 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 **SCANS** 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. **SCANS** 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)

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

Appendix A
The Editor

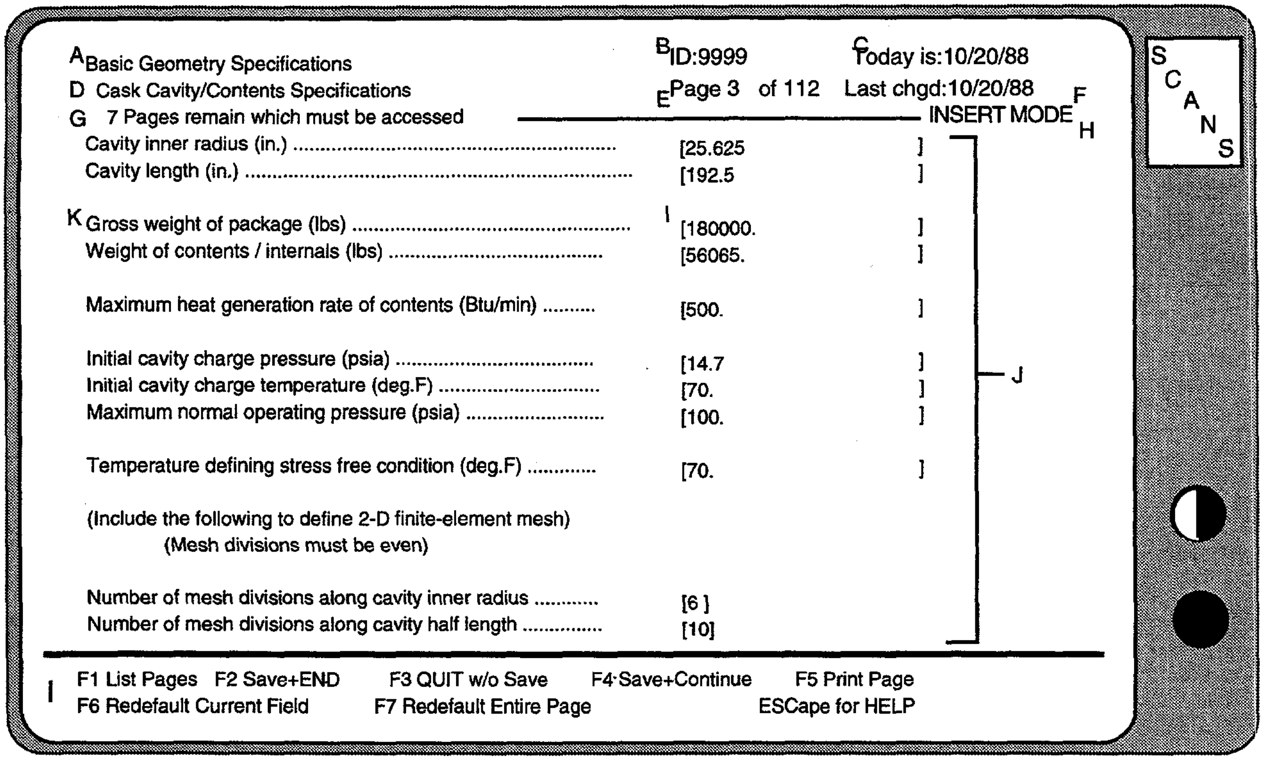


Figure A-1. SCANS Editor Page Layout.

Getting Help

Press the **ESC** key to display the *HELP* screens. The first screen indicates the 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 **SCANS** 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. **SCANS** *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. **SCANS** 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 **SCANS** 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.

Appendix A
The Editor

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, numeric digits and special character ($,%,#, etc.). Enter integer number type items using the form **nnn**. The sign is optional; **n** is any numeric digit (0-9). Enter real number type items using either the form **nn.mmm** or **nn.mmmEjj** (scientific notation). The sign, decimal point and exponent are optional; **n**, **m**, and **j** are any numeric 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 modes is off, new characters are inserted at the cursor, and they write over previous characters.

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

F7 (function key)
Set all items on the current page to the **SCANS** 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.

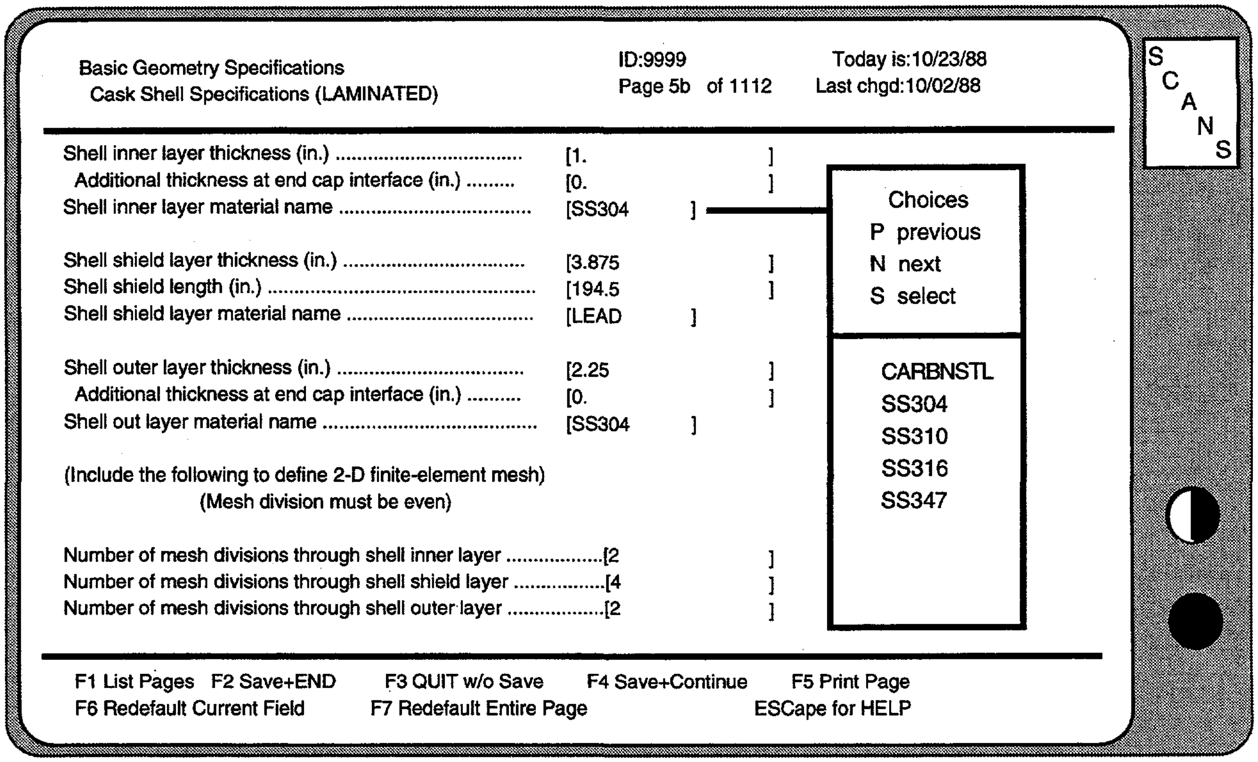


Figure A-2. Select item from a list.

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. **SCANS** 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, **SCANS** 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 A

NOTES:

Appendix B
Material Properties

The material sets used in **SCANS** contain all the information required to perform Impact, Thermal, Thermal-Stress, and Pressure-Stress analyses. These materials are built into **SCANS** and cannot be modified. The next version of **SCANS** will provide the ability to extend the material sets.

Impact analyses use dynamic Young's Modulus, Poisson's Ratio, and material density (used for component weight calculations). Puncture evaluations also use the dynamic ultimate stress. Buckling and lead slump analyses use the dynamic proportional stress limit, the dynamic plastic stress-strain parameters σ_0 and m. Thermal analyses use temperature dependent properties for thermal conductivity and specific heat capacity. Thermal stress analyses use temperature dependent properties for Young's Modulus, Poisson's Ratio and coefficient of thermal expansion. Pressure stress analyses use the thermal stress properties at 70 degrees F.

Material	References
Structural and Water Jacket Materials	
Carbon Steel	1, 2, 13
Stainless Steel 304	1, 2, 8, 11, 13
Stainless Steel 310	5, 6, 7, 8, 13
Stainless Steel 316	5, 6, 7, 8, 11, 13
Stainless Steel 347	5, 6, 7, 8, 11, 13
Copper (Water Jacket Only)	5, 6, 7, 8
Shielding Materials	
Lead	1, 2, 10, 12
Impact Limiter Materials	
Polyfoam	9
Polyurethane	2
Balsa Cross-Grained	2
Redwood Cross-Grained	4
Neutron Shield Materials	
Air Convection	3
Water Convection	3

Appendix B
Material Properties

Structural and Water Jacket Materials

Carbon Steel Set name: *CARBNSTL*

Dynamic Young's Modulus:	2.800E+07 psi
Dynamic Poisson's ratio:	0.2900
Dynamic Yield Stress:	3.600E+04
Dynamic Ultimate Stress:	7.000E+04
Density:	0.2820 lb/cu.inch

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)	Design Stress Intensity (psi)	Tensile Strength (psi)
-50	0.0522	0.0941	3.08E+07	0.29	5.61E-06	23300	70000
70	0.0488	0.1036	2.95E+07	0.29	6.41E-06	23300	70000
200	0.0467	0.1125	2.88E+07	0.29	6.93E-06	21900	70000
400	0.0429	0.1238	2.77E+07	0.29	7.66E-06	20600	70000
600	0.0389	0.1327	2.67E+07	0.29	8.35E-06	17800	70000
800	0.0350	0.1457	2.42E+07	0.29	8.90E-06	16800	62700
1100	0.0290	0.1716	1.88E+07	0.29	9.680E-06		
1500	0.0218	0.1989	1.16E+07	0.29	1.072E-05		

Stainless Steel 304 Set name: *SS304*

Dynamic Young's Modulus:	2.830E+07 psi
Dynamic Poisson's ratio:	0.2900
Dynamic Yield Stress:	3.000E+04 psi
Dynamic Ultimate Stress:	7.500E+04 psi
Dynamic Proportional Stress Limit:	2.300E+04 psi
Dynamic Plastic Stress-Strain Parameter, σ_o:	9.245E+04 psi
Dynamic Plastic Stress-Strain parameter, m:	0.19955
Density:	0.2841 lb/cu.inch

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)	Design Stress Intensity (psi)	Tensile Strength (psi)
-50	0.01056	0.1079	2.96E+07	0.29	7.44E-06	20000	75000
70	0.01190	0.1160	2.83E+07	0.29	8.46E-06	20000	75000
200	0.01292	0.1214	2.76E+07	0.29	9.08E-06	20000	71000
400	0.01444	0.1284	2.66E+07	0.29	9.80E-06	18700	64400
600	0.01569	0.1323	2.53E+07	0.29	1.038E-05	16400	63500
800	0.01694	0.1351	2.41E+07	0.29	1.079E-05	15200	62700
1100	0.01889	0.1399	2.23E+07	0.29	1.136E-05		
1500	0.02125	0.1443	1.99E+07	0.29	1.212E-05		

Structural and Water Jacket Materials *(continued)*

Stainless Steel 310 Set name: *SS310*

Dynamic Young's Modulus:	2.820E+07 psi
Dynamic Poisson's ratio:	0.2900
Dynamic Yield Stress:	3.000E+04 psi
Dynamic Ultimate Stress:	7.500E+04 psi
Dynamic Proportional Stress Limit:	2.300E+04 psi
Dynamic Plastic Stress-Strain Parameter, σ_o:	9.245E+04 psi
Dynamic Plastic Stress-Strain parameter, m:	0.19955
Density:	0.2870 lb/cu.inch

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)	Design Stress Intensity (psi)	Tensile Strength (psi)
-50	0.00840	0.0996	2.96E+07	0.29	8.36E-06	20000	75000
70	0.01014	0.1132	2.83E+07	0.29	8.81E-06	20000	75000
200	0.01110	0.1186	2.76E+07	0.29	9.06E-06	20000	73600
400	0.01264	0.1257	2.65E+07	0.29	9.27E-06	20000	69500
600	0.01403	0.1297	2.53E+07	0.29	9.39E-06	18500	69500
800	0.01542	0.1332	2.41E+07	0.29	9.56E-06	17400	68100
1100	0.01750	0.1388	2.23E+07	0.29	9.83E-06		
1500	0.02014	0.1455	1.99E+07	0.29	1.019E-05		

Stainless Steel 316 Set name: *SS316*

Dynamic Young's Modulus:	2.810E+07 psi
Dynamic Poisson's ratio:	0.2900
Dynamic Yield Stress:	3.000E+04 psi
Dynamic Ultimate Stress:	7.500E+04 psi
Dynamic Proportional Stress Limit:	2.300E+04 psi
Dynamic Plastic Stress-Strain Parameter, σ_o:	9.245E+04 psi
Dynamic Plastic Stress-Strain parameter, m:	0.19955
Density:	0.2870 lb/cu.inch

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)	Design Stress Intensity (psi)	Tensile Strength (psi)
-50	0.00896	0.1049	2.96E+07	0.29	7.37E-06	20000	75000
70	0.01069	0.1159	2.83E+07	0.29	8.42E-06	20000	75000
200	0.01167	0.1201	2.76E+07	0.29	9.09E-06	20000	75000
400	0.01319	0.1269	2.65E+07	0.29	9.95E-06	19300	71800
600	0.01458	0.1307	2.53E+07	0.29	1.051E-05	17000	71800
800	0.01597	0.1340	2.41E+07	0.29	1.098E-05	15900	70900
1100	0.01792	0.1376	2.23E+07	0.29	1.164E-05		
1500	0.02028	0.1415	1.99E+07	0.29	1.252E-05		

Appendix B

Material Properties

Structural and Water Jacket Materials *(continued)*

Stainless Steel 347 Set name: *SS347*

Dynamic Young's Modulus:	2.820E+07 psi
Dynamic Poisson's ratio:	0.2900
Dynamic Yield Stress:	3.000E+04 psi
Dynamic Ultimate Stress:	7.500E+04 psi
Dynamic Proportional Stress Limit:	2.300E+04 psi
Dynamic Plastic Stress-Strain Parameter, σ_0:	9.245E+04 psi
Dynamic Plastic Stress-Strain parameter, m:	0.19955
Density:	0.2860 lb/cu.inch

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)	Design Stress Intensity (psi)	Tensile Strength (psi)
-50	0.00951	0.1042	2.96E+07	0.29	8.57E-06	20000	75000
70	0.01125	0.1146	2.83E+07	0.29	8.97E-06	20000	75000
200	0.01222	0.1195	2.76E+07	0.29	9.23E-06	20000	71800
400	0.01375	0.1268	2.65E+07	0.29	9.57E-06	20000	62000
600	0.01514	0.1313	2.53E+07	0.29	9.85E-06	19300	59400
800	0.01653	0.1353	2.41E+07	0.29	1.010E-05	18300	58500
1100	0.01847	0.1394	2.23E+07	0.29	1.046E-05		
1500	0.02083	0.1432	1.99E+07	0.29	1.094E-05		

Copper Set name: *COPPER* (Water Jacket Only)

Density: 0.3240 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-100.	.331900	.0851
68.	.320800	.0917
260.	.313900	.0951
440.	.311100	.0974
620.	.306900	.0998
800.	.302800	.1020
1160.	.291700	.1067
1340.	.286100	.1091

Shielding Materials

Cast Lead Set name: *LEAD*

Dynamic Young's Modulus:	2.420E+06 psi
Dynamic Poisson's ratio:	0.4300
Dynamic Yield Stress:	6.230E+02 psi
Dynamic Proportional Stress Limit:	2.500E+02 psi
Dynamic Plastic Stress-Strain Parameter, σ_0:	8.500E+03 psi
Dynamic Plastic Stress-Strain Parameter, m:	0.5030
Density:	0.4110 lb/cu.inch

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

Impact Limiter Materials

Polyfoam Set name: *POLYFOAM*

Density: 0.0116 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-58.	.000278	.3000
68.	.000278	.3000
1500.	.000278	.3000

Appendix B
Material Properties
Impact Limiter Materials *(continued)*

Polyurethane Set name: *PURETHAN*

Density: 0.0021 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-58.	.000034	.4200
68.	.000034	.4200
1500.	.000034	.4200

Balsa Cross-Grained Set name: *BALSAXGR*

Density: 0.0162 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-58.	.000067	.5500
68.	.000067	.5500
1500.	.000067	.5500

Redwood Cross-Grained Set name: *REDWDXGR*

Density: 0.0150 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-58.	.000088	.6900
68.	.000088	.6900
1500.	.000088	.6900

Neutron Shield Materials

Air Convection Set name: *AIRCONV*

Density: 0.0000 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-38.	.000139	.2400
68.	.000139	.2401
263.	.000139	.2421
533.	.000139	.2482
803.	.000139	.2568
983.	.000139	.2621
1253.	.000139	.2704
1523.	.000139	.2770

Water Convection Set name: *H2OCONV*

Density: 0.0347 lb/cu.inch

Temp (°F)	Thermal Conductivity (BTU/in.min°F)	Specific Heat Capacity (BTU/lbm°F)
-58.	.000182	.4100
68.	.001200	.9990
150.	.020500	1.0000
200.	.024100	1.0050
300.	.028900	1.0300
400.	.032400	1.0760
500.	.035500	1.1820
600.	.038500	1.3700

Appendix B
Material Properties
Material References

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

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

3. Turner, W. D., *HTAS1: A Two-Dimensional Heat Transfer Analysis of Fuel Casks*, Oak Ridge National Laboratory, Oak Ridge, TN, NUREG/CR-0200, Volume 1, Section H1, ORNL/NUREG/CSD-2/V1 (1985).

4. VanSant, J. H., *Conduction Heat Transfer Solutions*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52863 (1980).

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

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

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

8. 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).

9. Perry, J. H., *Chemical Engineers Handbook*, 4th edition, McGraw-Hill, NY (1963).

10. Adams, C. R., 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).

11. Rack, H. J. and Knorovsky, G. A., *An Assessment of Stress-Strain Data Suitable for Finite-Element Elastic-Plastic Analysis of Shipping Containers*, USNRC Report NUREG/CR-0481, September 1978.

12. *SCANS Theory Manual*, Vol. 3, Rev. 1 (1992).

13. *ASME Boiler & Pressure Vessel Code Section III,Division 1 Appendix I* (1991).

Appendix C
Sample Cask and Description of Output

Description of Sample Cask

This sample spent fuel shipping cask is included in the **SCANS** release. The CASKID is 9999. The cask geometry includes a long cylindrical cask body, top and bottom end caps, and top and bottom impact limiters. 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. The impact limiters overhang the cask body and are constructed of Polyfoam. This sample cask does not include a neutron shield and water jacket. Cask dimensions are shown in **Figure C-1**. Component weights, closure bolt information, and impact limiter force-deflection data are listed below:

Weights (in pounds)

Gross package:	180000
Contents/internals:	56065
Top impact limiter:	10000
Bottom impact limiter:	10000

Closure Bolts (for Top End Cap)

Number of bolts:	32
Bolt diameter:	1.5 inches
Bolt circle radius:	29.5 inches

Impact Limiter Force-Deflection Data

NOTE: The following data is for Top and Bottom limiters for all impact angles.

Deflection (inches)	Force (kips)
0.5	250.
13.0	1700.
26.5	4000.
30.0	6000.
33.5	10000.

Appendix C
Sample Cask and Description of Output

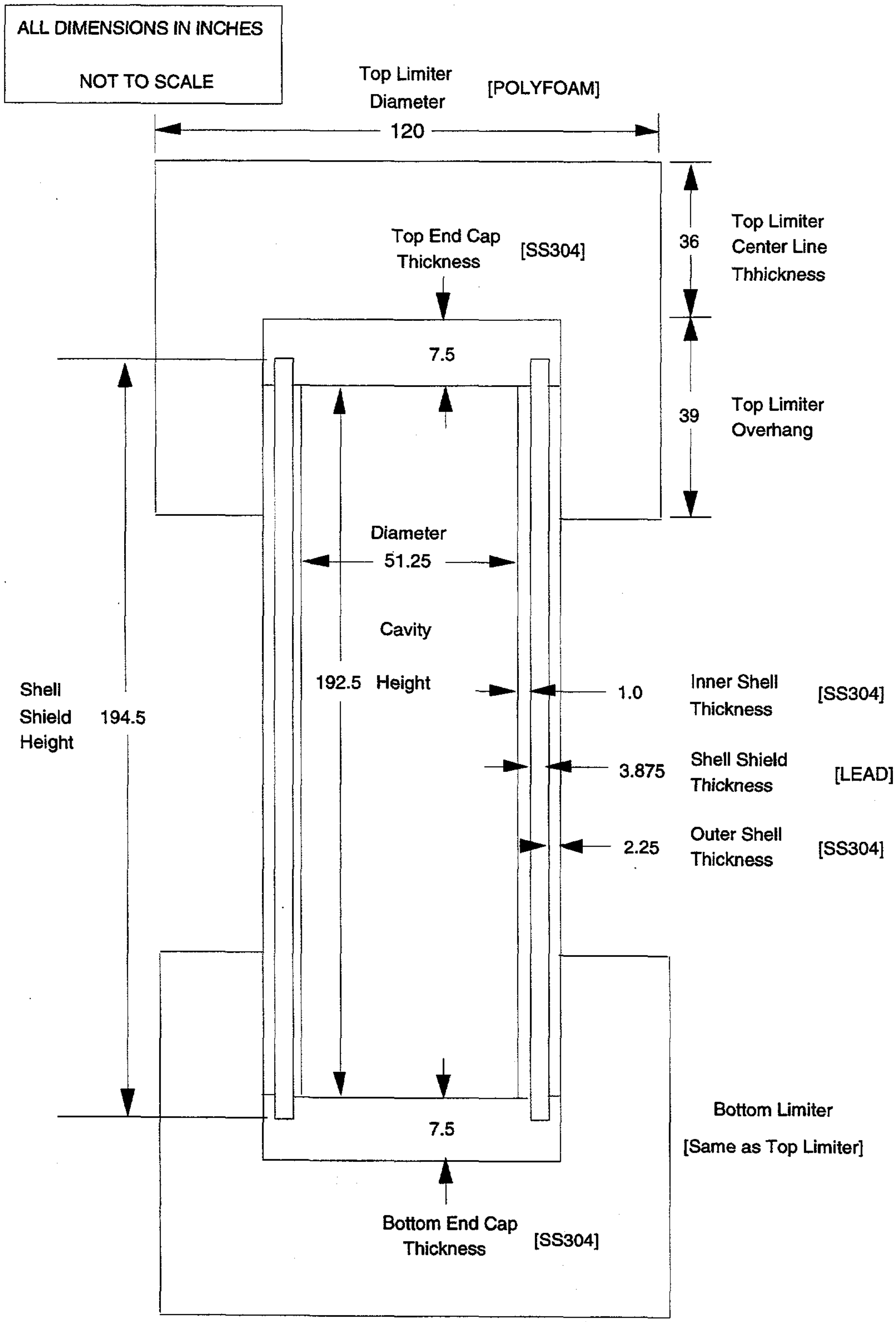


Figure C-1. Sample cask geometry and dimensions.

Appendix C

Sample Cask and Description of Output

Geometry Data Summary Output

This output is produced during the data check performed when the basic geometry is saved (Geometry Menu). It is a complete summary of all specifications for the cask. Warning and error messages appear when specified weights differ from calculated weights and 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 **SCANS** version number. The header shown in **Figure C-2** is printed at the top of every page of output.

(2) **Data Set Status**
Indicates whether the Basic Geometry data set is *COMPLETE* (**Figure C-2**). The data set has items requiring an entry if the status indicates *INCOMPLETE.*

(3) **General Information**
Lists general SAR information, general cask and contents specifications, and cask component weights (**Figure C-2**). The general SAR information includes the SAR title, report information, additional information, licensee's address, and names of review team members.

(4) **Component Specifications**
Summary of geometry specifications for each cask component (**Figure C-3**).

(5) **Closure Bolts**
Lists the number of bolts, bolt diameter, and bolt circle radius (**Figure C-4**).

(6) **Finite Element Mesh Grading**
Lists the number of mesh divisions through each cask component (**Figure C-4**). The output also indicates the status and size of the meshes. The Finite Element meshes are used for 2-D Thermal and Stress analyses.

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

(8) **Impact Model Description**
Lists the geometry of the simplified Impact model (**Figure C-5**).

(9) **Puncture Evaluation**
Tabulates results of puncture evaluation of cask exterior surfaces (**Figure C-5**).

Appendix C
Sample Cask and Description of Output

```
GEOMETRY DATA SUMMARY FOR CASK 9999                 Page  1 of  8
GENERATED ON 3/21/91 AT 9:46:20                                  SCANS VERSION: 2a


Basic geometry data set is COMPLETE


GENERAL SAR INFORMATION
------------

      SAR: Sample spent fuel shipping cask (demonstration only)

      Report number:          123 Volume 1
      Report date:            9/30/88
      Docket number:          9999
      Docket start date:      9/30/88
          . . .
           . . .
            . . .

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

      Cavity inner radius:              25.625 inches
      Cavity length:                   192.500 inches

      Cask body outer radius:           32.750 inches
      Cask body length:                207.500 inches

      Top    impact limiter       is        included in model
      Bottom impact limiter       is        included in model
      Neutron shield            is not      included in model
      Water jacket              is not      included in model

      Contents maximum heat generation rate:            500.00 Btu/minute

      Temperature defining stress free condition:            70. degrees F

      Initial cavity charge pressure:             14.70    psia
      Initial cavity charge temperature:          70.00    degrees F
      Maximum normal operating pressure:         100.00    psia

CASK WEIGHTS (By component)
----------

      Gross package:                 180000. lbs
      Contents/internals:             56065. lbs
      Top    impact limiter:          10000. lbs
      Bottom impact limiter:          10000. lbs
      Cask shell / end caps:         103935. lbs     Gross wt - (Contents+Limiters)
                 Top end cap:      7268. lbs
              Bottom end cap:      7268. lbs
                       Shell:     89398. lbs
```

Figure C-2. Cask Geometry Summary Output -- General Information.

CASK SHELL DESCRIPTION

Layer	Material Name	Thickness Inches	Inner Radius Inches	Outer Radius Inches	X-section Area Sq Inches
Inner Shell	SS304	1.000	5.625	26.625	64.148
Shield	LEAD	3.875	26.625	0.500	695.421
Outer Shell	SS304	2.250	30.500	2.750	47.088
	Total Thickness	7.125		Total Area	306.657

Inner Shell additional thickness at end cap interface: .000 inches
Outer Shell additional thickness at end cap interface: .000 inches

Shield height: 194.500 inches

TOP END CAP DESCRIPTION

Layer	Material Name	Thickness Inches
End cap	SS304	7.500

BOTTOM END CAP DESCRIPTION

Layer	Material Name	Thickness Inches
Endcap	SS304	7.500

IMPACT LIMITERS

TOP Impact Limiter
Material: POLYFOAM
Radius: 60.000 inches
Thickness above end cap: 36.000 inches
Overhang along cask body: 39.000 inches

BOTTOM Impact Limiter
Material: POLYFOAM
Radius: 60.000 inches
Thickness above end cap: 36.000 inches
Overhang along cask body: 39.000 inches

NEUTRON SHIELD

Neutron Shield is NOT included in model

WATER JACKET

Water Jacket is NOT included in model

Figure C-3. Cask Geometry Summary Output -- Component Specifications.

Appendix C
Sample Cask and Description of Output

```
CLOSURE BOLTS
-------------
        Number of bolts:              32
        Bolt diameter:             1.500
        Bolt circle radius:       29.500


FINITE ELEMENT MESH GRADING  (Applies to 2-D Thermal and Stress calculations)
--------------------------
        Cavity
            Number of mesh divisions along inner radius:                   6
            Number of mesh divisions along cavity half length:            10
        Shell
            Number of mesh divisions through inner  layer:                 2
            Number of mesh divisions through shield layer:                 4
            Number of mesh divisions through outer  layer:                 2
        Top End Cap
            Number of mesh divisions through end cap:                      6
        Bottom End Cap
            Number of mesh divisions through end cap:                      6
        Top Impact Limiter
            Number of mesh divisions through center-line thickness:        3
            Number of mesh divisions through overhang width:               3
        Bottom Impact Limiter
            Number of mesh divisions through center-line thickness:        3
            Number of mesh divisions through overhang width:               3

        Finite element meshes were generated on 10-02-88 at  3:17p

            Thermal mesh has        282    nodes and    245    4-node elements
            Stress  mesh has        195    nodes and     41    9-node elements


MATERIAL PROPERTIES
-------------------

        This model uses  3 different materials

        SS304           (SS 304     )

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

            Dynamic Young's Modulus:                          2.830E+07  psi
            Dynamic Poisson's Ratio:                           .2900
            Dynamic Yield Stress:                             3.000E+04  psi
            Dynamic Ultimate Stress:                          7.500E+04  psi
            Dynamic Proportional Stress Limit:                2.300E+04  psi
            Dynamic Plastic Stress-Strain Multiplier:         9.525E+04  psi
            Dynamic Plastic Stress-Strain Exponent:            .1996

                   Density:   .2841 lb/cu.inch
                                                                                    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
                       . . .
                       . . .
```

Figure C-4. Cask Geometry Summary Output -- Bolts, F.E. Mesh, and Materials.

IMPACT MODEL DESCRIPTION

Nodal masses and shell stiffness values

Node Number	Position inches	Translational Mass lb-sec**2/in	Rotational Mass lb-sec**2-in	AE lbs	EI lb-in**2
1 BOT	0.	74.	39578.		
2	48.	58.	24756.	1.730E+10	7.922E+12
3	96.	58.	24756.	1.730E+10	7.922E+12
4	144.	58.	24756.	1.730E+10	7.922E+12
5 TOP	193.	74.	39578.		

Shell areas and inertias for nodes 2 through 4

Layer	Area in**2	Moment of Inertia in**4
Inner Shell	164.15	56037.
Shield	695.42	284973.
Outer Shell	447.09	223858.

PUNCTURE EVALUATION OF CASK EXTERIOR SURFACES

NOTE: All thicknesses are in inches and stresses in psi.

NOTE: The recommended thickness for puncture resistance is based on the empirical formula given in the theory manual. It is valid for all SCANS built-in steels and for other user-specified ductile metals provided an average or a smaller-than-average value is used for the tensile strength.

Cask Component	Outer Layer				Recommended Thickness for puncture Resistance
	Material	Tensile Strength	Thickness	Puncture	
Cask body	SS304	89602.	2.25	likely	2.48
Top end cap	SS304	89602.	7.50	unlikely	2.48
Bottom end cap	SS304	89602.	7.50	unlikely	2.48

Figure C-5. Cask Geometry Summary Output -- Impact Model Description and Puncture Evaluation.

Appendix C
Sample Cask and Description of Output

Limiter Curve Summary Output

This output is produced during the data check performed when the impact limiter force/deflection data set is saved (Geometry Menu). It is a complete summary of all specifications for the cask. Error messages appear when impact limiter force-deflection curve definitions are incorrectly specified. The output format follows.

(1) **Header**
Indicates Limiter Curve Summary, page number of how many, date and time the output was generated, and **SCANS** version number. The header shown in **Figure C-6** is printed at the top of every page of output.

(2) **Data Set Status**
Indicates whether the Limiter F/D data set is *COMPLETE* (**Figure C-6**). The data set has items requiring an entry if the status indicates *INCOMPLETE.*

(3) **Impact Limiter Force/Deflection Curves**
Lists the impact limiter force-deflection curve specifications (**Figure C-6**). The limiter curves are specified individually for each end of the cask and for various impact orientations.

```
LIMITER CURVE SUMMARY FOR CASK 9999                    Page  1  of  2
GENERATED ON 4/24/91 AT  8:22:00                                          SCANS VERSION: 2a


Limiter  F/D    data set is COMPLETE


IMPACT LIMITER FORCE/DEFLECTION CURVES


        Bottom Limiter

          Side Impact  ( 0 degrees)

                Deflection          Force           Slope
                  inches             Kips          Kips/inch
                  ------             ----          ---------
                    0                  0
                   .500             250.00          500.00
                 13.000            1700.00          116.00
                 26.500            4000.00          170.37
                 30.000            6000.00          571.43
                 33.500           10000.00         1142.86

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

Figure C-6. Limiter Curve Summary Output.

Impact Analysis Output

This sample Impact analysis is based on a 30-foot hypothetical accident drop on the cask bottom at an initial impact angle of 45 degrees. Primary and secondary impacts are included in the analysis, and the shield/shell interface is bonded (the lead shield is not allowed to slump). The discussion of the output format includes a detailed description of output for a Dynamic Analysis. Quasi-static output is in the same format. Differences in output for an unbonded lead shield analysis are also noted.

(1) **Header**
Indicates the type of analysis, page number of how many, date and time the output was generated, **SCANS** version number, and a brief description of the parameters defining the analysis case. The header shown in **Figure C-7** is printed at the top of every page of output.

(2) **Impact Summary**
Lists the impact velocity, impact angle, CG (center-of-gravity) over corner angle, limiter crush, rigid body accelerations, maximum cask axial and shear forces, and maximum impact moment about the cask center line for both primary and secondary impacts (**Figure C-7**). For an unbonded lead shield analysis, **SCANS** lists the permanent lead slump. For secondary impacts, **SCANS** lists the secondary impact angle and the impact limiter data used (the force-deflection curve for the angle closest to the actual secondary impact angle).

(3) **Maximum Force and Moment Results**
Tables for maximum axial force, maximum shear force, and maximum bending moment are printed for each node location along the cask body and at the cask ends (**Figure C-8**). These forces and moments are beam-type values for the composite cross-section of the cask.

(4) **Impact Stress Intensity Results**
Tables for maximum stress intensity are printed for each shell layer at each node location along the cask body. Stress intensity is the absolute value of the maximum difference between the principal stresses. Principal stresses are calculated from axial, bending, shear, hoop, and radial stresses. For bonded shell/shield interface analyses the hoop stress is assumed to be zero. Axial and shear forces and bending moments are applied to the composite cross-section of the cask in order to calculate axial, bending, and shear stresses for each shell layer based on its individual stiffness. **SCANS** prints the stress intensity for the three maximum stress conditions listed below (**Figure C-9**).

A. Maximum Tension. Based on the maximum sum of the axial stress and bending stress at the extreme fiber. Shear stress is zero for this condition. This stress is the first principal stress. The second principal stress is the hoop stress.

B. Maximum Compression. Based on the maximum difference of the axial stress and bending stress. Shear stress is zero for this condition. This stress is the first principal stress. The second principal stress is the hoop stress.

C. Maximum Shear. Based on the axial stress, maximum shear stress, hoop stress and radial stress, occurring at the neutral axis. The principal stresses are calculated using Mohr's circle.

(5) **Interface Force and Moment Results** *(unbonded lead shield analysis only)*
Tables for edge moments and shear forces are printed for the inner and outer shell at the bottom end cap and top closure interfaces (**Figure C-10**). A positive moment results in compression in the outermost fiber of the shell, and a positive shear force is directed radially inward.

(6) **Buckling Analysis Results**
This section of output summarizes the results of a buckling analysis of the inner and outer cask shells (**Figure C-11**). The radius, thickness, length, Young's Modulus, and yield stress of the shells and the factor of safety used for the analysis are tabulated. The most critical impact stresses and their buckling stress ratios are printed. Based on these stress ratios, conclusions on the possibility of buckling of the cask shells are printed as 'likely' or 'unlikely'. If one of the shells is likely to buckle, additional information will be printed to provide insight into the nature and cause of the buckling. The critical impact stresses in the axial and hoop directions are compared to the corresponding theoretical elastic buckling stress and to the actual buckling stress. The capacity factor (alpha) and the plasticity reduction factor (eta) used to obtain the actual buckling from the theoretical buckling stress are also printed.

(7) **End Cap Stresses**
Lists the bending and shear stresses in the end caps (**Figure C-12**). The end caps are treated as circular plates with fixed boundary conditions for the bottom end cap and pinned boundary conditions for the top end cap. The inertial forces are evenly distributed across the end caps, and the impact limiters contribute no bending resistance. The shear stress is calculated as a maximum at the indicated radius.

(8) **Top Closure Bolt Stresses**
Indicates bolt axial and shear stresses (**Figure C-13**). Bolt axial stresses are calculated only when the bolts are in tension.

```
DYNAMIC IMPACT OUTPUT FOR CASK 9999                    Page  1 of  9
GENERATED ON 3/22/91 AT 11:14:17                                  SCANS VERSION: 2a
AR: Sample spent fuel shipping cask (demonstration only)
30 ft accident drop on cask bottom - primary & secondary impact
Angle of primary impact is 45 degrees - shield/shell interface is bonded

                         IMPACT SUMMARY

PRIMARY IMPACT (Cask Bottom)

      Impact Velocity                  =      527.5    in/sec
      Impact Angle                     =       45.0    degrees
      CG Over Corner Angle             =       72.5    degrees

      Maximum Limiter Crush            =       24.7    inches

      Maximum Rigid Body Accelerations
        Vertical Acceleration          =       19.5    g's
        Horizontal Acceleration        =         .0    g's
        Rotational Acceleration        =      -94.6    rad/sec**2

      Maximum Impact Forces
        Axial Force In Cask            =    -2362.9    kips
        Shear Force In Cask            =     2832.3    kips

      Maximum Impact Moment (C.L.)     =   -57881.5    in-kips

SECONDARY IMPACT (Cask Top)

      Impact Velocity                  =      643.6    in/sec
      Impact Angle                     =       -1.0    degrees
      Limiter Angle Used               =         .0    degrees

      Maximum Limiter Crush            =       22.1    inches

      Maximum Rigid Body Accelerations
        Vertical Acceleration          =       17.0    g's
        Horizontal Acceleration        =         .0    g's
        Rotational Acceleration        =      138.2    rad/sec**2

      Maximum Impact Forces
        Axial Force In Cask            =     -503.8    kips
        Shear Force In Cask            =    -3208.2    kips

      Maximum Impact Moment (C.L.)     =     7937.7    in-kips


Run Time For Dynamic Analysis          =       19.4    seconds
```

Figure C-7. Dynamic Impact Output -- Header and Impact Summary.

MAXIMUM FORCES AND MOMENTS

NOTE: Node 1 is at Cavity BOTTOM, Node 5 is at Cavity TOP

PRIMARY IMPACT (on cask bottom)

Node Number (Location)	Axial Position (Inches)	Max Axial Force (Kips)	Max Shear Force (Kips)	Max Moment (In-Kips)
Cask Bottom		-2362.9	2832.3	-57881.5
1	.0	-1918.4	1451.7	-63474.3
2	48.1	-1658.9	961.2	11641.4
3	96.3	-1176.1	193.3	29179.1
4	144.4	-721.8	-258.3	19622.3
5	192.5	-503.1	-349.2	6794.7
Cask Top		.0	.0	.0

SECONDARY IMPACT (on cask top)

Node Number (Location)	Axial Position (Inches)	Max Axial Force (Kips)	Max Shear Force (Kips)	Max Moment (In-Kips)
Cask Bottom		.0	.0	.0
1	.0	325.0	640.6	6206.0
2	48.1	411.8	627.4	38336.8
3	96.3	-505.6	271.1	71178.2
4	144.4	-560.1	-762.8	69852.9
5	192.5	-568.5	-1409.8	5259.3
Cask Top		-503.8	-3208.2	7937.7

Figure C-8. Dynamic Impact Output -- Maximum Forces and Moments.

STRESS INTENSITY

NOTE: SI is based on maximum combined axial & bending stress or maximum shear stress

NOTE: Node 1 is at Cavity BOTTOM, Node 5 is at Cavity TOP

PRIMARY IMPACT (on cask bottom)

Node Number (Location)	Axial Position (Inches)	STRESS INTENSITY BASED ON ... Max (P/A+Mc/I) (psi)	Max (P/A-Mc/I) (psi)	Max Shear (psi)
Inner Shell				
1	.0	2797.	8216.	9090.
2	48.1	415.	3053.	6184.
3	96.3	1450.	3958.	1908.
4	144.4	1118.	2526.	1604.
5	192.5	450.	1200.	2095.
Shield				
1	.0	282.	746.	777.
2	48.1	36.	268.	529.
3	96.3	143.	358.	163.
4	144.4	108.	229.	137.
5	192.5	40.	107.	179.
Outer Shell				
1	.0	3922.	9359.	9090.
2	48.1	434.	3233.	6184.
3	96.3	1946.	4468.	1908.
4	144.4	1452.	2877.	1604.
5	192.5	495.	1315.	2095.

SECONDARY IMPACT (on cask top)

Node Number (Location)	Axial Position (Inches)	STRESS INTENSITY BASED ON ... Max (P/A+Mc/I) (psi)	Max (P/A-Mc/I) (psi)	Max Shear (psi)
Inner Shell				
1	.0	671.	869.	3839.
2	48.1	3377.	3810.	3772.
3	96.3	6058.	6814.	1644.
4	144.4	5608.	6691.	4556.
5	192.5	701.	1083.	8425.
Shield				
1	.0	61.	78.	328.
2	48.1	315.	352.	323.
3	96.3	566.	631.	141.
4	144.4	526.	620.	390.
5	192.5	62.	95.	720.
Outer Shell				
1	.0	779.	973.	3839.
2	48.1	4069.	4502.	3772.
3	96.3	7333.	8093.	1644.
4	144.4	6844.	7946.	4556.
5	192.5	768.	1150.	8425.

Figure C-9. Dynamic Impact Output -- Stress Intensity.

```
MAXIMUM CASK SHELL / END CAP
INTERFACE FORCES AND MOMENTS
________________

A positive moment results in compression in the outermost fiber of shell.
A positive shear force is directed radially inward.

    Edge moment of inner shell at bottom end cap     =   -7.473 in-kips/in.
    Edge moment of outer shell at bottom end cap     =   24.699 in-kips/in.

    Edge shear of inner shell at bottom end cap      =   -3.765 kips/in.
    Edge shear of outer shell at bottom end cap      =    7.539 kips/in.


    Edge moment of inner shell at top closure        =     .152 in-kips/in.
    Edge moment of outer shell at top closure        =    1.189 in-kips/in.

    Edge shear of inner shell at top closure         =     .076 kips/in.
    Edge shear of outer shell at top closure         =     .363 kips/in.
```

Figure C-10. Dynamic Impact Output -- Interface Forces and Moments.
Note: Results based on unbonded shell/shield interface for primary impact only.

BUCKLING ANALYSIS OF CASK BODY

NOTE: All lengths are in inch and stresses in psi

NOTE: The factor of safety used for this buckling evaluation is 1.34 for accident condition

NOTE: The listed stresses are compressive stresses; tensile stresses are ignored in the buckling analysis and listed as 0.

NOTE: For both bonded and unbonded cask bodies, the buckling results for "Inner" and "Outer" layers are obtained by treating the layers as separate shells subjected to the stresses

Cask Body Shell Dimensions and Material Properties

Shell	Radius R	Thick. t	Length L	R/t	L/(Rt)$^{.5}$	Material	Young's Modulus E	Yield Stress Sy
Inner	26.13	1.00	192.50	26.1	37.66	SS304	28300000.	30000.
Outer	31.63	2.25	192.50	14.1	22.82	SS304	28300000.	30000.

PRIMARY IMPACT (on cask bottom)

Shell	Worst Buckling Stresses Axial	Hoop	Maximum Combined Buckling Stress Ratio	Buckling
According to ASME code Sect. III, Code Case N284				
Inner	8216.	0.	.059	unlikely
Outer	9359.	0.	.036	unlikely
According to API bulletin 2U (with residual stresses)				
Inner	8216.	0.	.000	unlikely
Outer	9359.	0.	.000	unlikely

SECONDARY IMPACT (on cask top)

Shell	Worst Buckling Stresses Axial	Hoop	Maximum Combined Buckling Stress Ratio	Buckling
According to ASME code Sect. III, Code Case N284				
Inner	6814.	0.	.049	unlikely
Outer	8093.	0.	.031	unlikely
According to API bulletin 2U (with residual stresses)				
Inner	6814.	0.	.000	unlikely
Outer	8093	0.	.000	unlikely

Figure C-11. Buckling Analysis Results.

```
                          END CAP STRESSES
                          ----------------

NOTE:  Limiters contribute no bending stiffness to the end caps
       Inertial forces are evenly distributed across the end caps

       All stresses are in PSI

PRIMARY IMPACT  (on cask bottom)
--------------

    BOTTOM END CAP  (based on inertia of end cap and contents)
    --------------
                                              Solid End Cap
                                              -------------
        Maximum Bending Stresses
            At center of end cap                 5713.8
            At edge near inner shell            -8858.5

        Average Shear Stresses                   1728.5
            At radius =  25.6 inches

    TOP END CAP  (based on inertia of end cap)
    -----------
                                              Solid End Cap
                                              -------------
        Maximum Bending Stresses
            At center of end cap                  414.8

        Average Shear Stresses                     49.2
            At radius =  25.6 inches


SECONDARY IMPACT  (on cask top)
----------------

    BOTTOM END CAP  (based on inertia of end cap)
    --------------
                                              Solid End Cap
                                              -------------
        Maximum Bending Stresses
            At center of end cap                  110.7
            At edge near inner shell             -171.6

        Average Shear Stresses                     33.5
            At radius =  25.6 inches

    TOP END CAP  (based on inertia of end cap and contents)
    -----------
                                              Solid End Cap
                                              -------------
        Maximum Bending Stresses
            At center of end cap                -7576.4

        Average Shear Stresses                    780.6
            At radius =  29.5 inches
```

Figure C-12. Dynamic Impact Output -- End Cap Stresses.

TOP CLOSURE BOLT STRESSES

Bolt Shear Stress (psi)	PRIMARY IMPACT	SECONDARY IMPACT
Applied to ALL bolts equally	6174.	24932.

Bolt Axial Tensile Stress (psi)	PRIMARY IMPACT	SECONDARY IMPACT
Case 1: Applied to ALL bolts equally	0.	19411.
Case 2: Maximum stress based on bolt position relative to impacting edge of the cask	0.	26247.

NOTE:
1. Axial load is due to mass of the contents and top end cap
2. Compressive stresses are printed as zero
3. Case 2 is best case when impact angle is less than C.G. angle

Figure C-13. Dynamic Impact Output -- Closure Bolt Stresses.

Appendix C
Sample Cask and Description of Output

Thermal Analysis Output

This Thermal analysis is based on the thermal case *Normal Hot, Contents Heat, Solar Effects*. The ambient temperature is 100°F, contents heat load is 500 Btu/min, and solar effects are included. The Thermal Analysis output format is typical for a Finite Element analysis program and is described below.

(1) **Header**
Indicates the type of analysis, page number of how many, date and time the output was generated, **SCANS** version number, and a brief description of the parameters defining the analysis case. The header shown in **Figure C-14** is printed at the top of every page of output.

(2) **Control Data**
Lists the parameters controlling the analysis. Typical control parameters are: number of materials, nodes, and elements; type of geometry; number and type of boundary and initial conditions; and non-linear solution convergence controls. A partial summary of control parameters is shown in **Figure C-14.**

(3) **Summary of Nodal Data**
Table of nodes for the Finite Element mesh, indicating the coordinates. The mesh is an axisymmetric representation of the TOP end of the cask. A partial summary of node data is shown in **Figure C-15**.

(4) **Summary of Element Data**
Table of elements for the Finite Element mesh, indicating the nodes which define the element, material number, and element volume. A partial summary of element data is shown in **Figure C-15**.

(5) **Summary of Material Data**
Table for each material used in the analysis, indicating the material name, cask component, material number for reference by element data, and material properties. A summary of Material 1 is shown in **Figure C-15**.

(6) **Summary of Temperature Initial Conditions**
Table of initial temperatures applied to nodes. A partial summary of initial temperatures is shown in **Figure C-16**.

(7) **Summary of Flux Boundary Conditions**
Table of flux boundary conditions applied to boundary segments. Each segment is defined by two nodes. Flux boundary conditions are applied to (1) the cavity surface to represent the contents heat and (2) the outer surface to represent solar effects. A partial summary of flux boundary conditions is shown in **Figure C-16**.

(8) **Summary of Convection Boundary Conditions**
Table of convection boundary conditions applied to boundary segments. Each segment is defined by two nodes. Convection boundary conditions are applied to the outer surface to transfer heat between the cask and the ambient environment. A partial summary of convection boundary conditions is shown in **Figure C-16**.

(9) **Summary of Radiation Boundary Conditions**
Table of radiation boundary conditions applied to boundary segments. Each segment is defined by two nodes. Radiation boundary conditions are applied to the outer surface to transfer heat between the cask and the ambient environment. Radiation boundary conditions are also used to represent fire conditions. A partial summary of radiation boundary conditions is shown in **Figure C-16**.

(10) **Bandwidth Minimization Information**
Summary of results of bandwidth minimization, used internally for improved calculational speed.

(11) **Summary of Output**
Table of nodal temperatures, indicating the location and magnitude of the minimum and maximum temperatures and the cavity pressure and temperature. The cavity temperature is the average cavity surface temperature. The cavity pressure is calculated using the ideal gas law. **SCANS** also prints the energy transferred across each boundary condition segment, permitting an energy balance check. For the transient Fire Accident case, temperature and energy results are printed for each time specified by the printing interval. A partial summary of temperature and energy results are shown in **Figure C-17**.

(12) **Termination Message**
Indicates the total clock time in seconds for the analysis and indicates the status of the analysis (**Figure C-17**). *Normal Termination* indicates the analysis was completed. *Error Termination* indicates the analysis was either terminated early by the user or because of an internal error condition (e.g., unable to extract values from function curves). When the analysis ends with an error termination, the resulting output can be printed but cannot be plotted.

```
THERMAL OUTPUT          FOR CASK  9999                                Page   1  of  31
GENERATED ON  5/10/91 AT  13:24:3d                                    SCANS VERSION:  2a
SAR:                Sample spent fuel shipping cask (demonstration only)
THERMAL CASE:       Normal hot              Contents heat             Solar effects
Maximum contents heat generation:                  500.00  BTU/MIN


using the TOPAZ version compiled -              1-03-91

reference - Gary L. Johnson  ph: 415-422-9323


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

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


SUMMARY  OF  INPUT

                                 *** c o n t r o l   d a t a ***



        number of materials                          =      9

        number of nodes                              =    279

        number of elements                           =    242

        temperature units                            =      3
                eq.1: dimensionless
                eq.2: centigrade
                eq.3: Fahrenheit
                eq.4: kelvin
                eq.5: rankine

        type of geometry                             =      1
                eq.1: axisymmetric
                eq.2: plane

        bandwidth minimization                       =      1
                eq.0: no minimization
                eq.1: minimization
                eq.2: minimization - nodal destination
                        vector read from input file
```

Figure C-14. Thermal Output -- Header and Control Data.

*** nodal data ***

node number	x1-coordinate	x2-coordinate	temperature (deg. f)
1	.00000	96.250	.00000
2	4.2708	96.250	.00000
3	8.5417	96.250	.00000
4	12.813	96.250	.00000
5	17.083	96.250	.00000
6	21.354	96.250	.00000

...
...
...

*** element data ***

elem. no.	i	j	k	l	matl. no.	matl. angle	volume
1	17	49	56	16	1	.00000	751.92
2	49	50	57	56	1	.00000	766.45
3	16	56	63	15	1	.00000	751.92
4	56	57	64	63	1	.00000	766.45
5	15	63	70	14	1	.00000	751.92
6	63	64	71	70	1	.00000	766.45

...
...
...

*** material data ***

SS 304 Used in the INNER SHELL

material number	=	1
material type	=	3
density	=	.28414
thermal generation rate curve number	=	0
thermal generation rate multiplier	=	.00000
material angle	=	.00000

temperature	cv	k1
-58.00	.1200	1.1250E-02
68.00	.1230	1.1400E-02
212.0	.1238	1.2083E-02
392.0	.1275	1.2083E-02
572.0	.1312	1.3056E-02
752.0	.1350	1.3889E-02
1112.	.1425	1.5278E-02
1472.	.1500	1.8056E-02

Figure C-15. Thermal Output -- Node/Element/Material Summary.

temperature initial conditions

temperature units = (deg. f)

node	temp	node	temp	node	temp	node	temp
1	100.0	71	100.0	141	100.0	211	100.0
2	100.0	72	100.0	142	100.0	212	100.0
3	100.0	73	100.0	143	100.0	213	100.0
4	100.0	74	100.0	144	100.0	214	100.0
5	100.0	75	100.0	145	100.0	215	100.0

. . .
. . .
. . .

flux boundary condition

node i	node j	curve no.	i-multiplier	j-multiplier
1	2	0	-1.42371E-02	-1.42371E-02
2	3	0	-1.42371E-02	-1.42371E-02
3	4	0	-1.42371E-02	-1.42371E-02
4	5	0	-1.42371E-02	-1.42371E-02
5	6	0	-1.42371E-02	-1.42371E-02

. . .
. . .
. . .

convection boundary condition

node i	node j	h curve	h multiplier	h exponent	free conv curve	t multiplier	temp i multiplier	temp j
196	197	0	2.1990E-05	.3333	0	100.0	100.0	
197	198	0	2.1990E-05	.3333	0	100.0	100.0	
198	199	0	2.1990E-05	.3333	0	100.0	100.0	
199	200	0	2.1990E-05	.3333	0	100.0	100.0	
200	201	0	2.1990E-05	.3333	0	100.0	100.0	

. . .
. . .
. . .

radiation boundary condition

node i	node j	f curve #	f multiplier	temp curve #	temp i multiplier	temp j multiplier
196	197	0	9.919E-14	0	100.	100.
197	198	0	9.919E-14	0	100.	100.
198	199	0	9.919E-14	0	100.	100.
199	200	0	9.919E-14	0	100.	100.
200	201	0	9.919E-14	0	100.	100.

. . .
. . .
. . .

Figure C-16. Thermal Output -- Initial/Boundary Conditions Summary.

```
SUMMARY OF OUTPUT

Steady State Solution

     Minimum temperature      =     157.7 F    at node    227
     Maximum temperature      =     348.5 F    at node      1

     Cavity pressure          =      20.1 psia
     Cavity temperature       =    265.1 deg F

node      temperature          node      temperature          node      temperature

  1          348.5               94          248.0              187         328.2
  2          347.7               95          247.4              188         322.7
  3          345.8               96          246.7              189         322.1
                            ...
                            ...

internal energy is 0. at the initial state
positive heat flow is in direction of the surface outward normal vector

                                     transfer rate          heat transfer      total heat
                                     this step              this step          transferred
     type       seg #     area       [energy/time]          [energy/step]      [energy]

     flux         1       57.303       -.81582
                            ...
                            ...
                                     ==========
     flux TOTAL        -898.03


     conv         1       57.303       .34788
                            ..
                            ...
                                     ==========
     conv TOTAL         462.93


     rad          1       57.303       .32305
                            ...
                            ...
                                     ==========
     rad TOTAL                         438.25

                          heat gen.  total heat             change in          internal
                          this step  generation             int. energy        energy
                mat #     [energy]   [energy] [energy]      [energy]

                  1                    .00000
                            ...
                            ...
                                     ==========
               TOTAL                   .00000

execution ended on  5/10/91          at   13:24:56
execution time =                 24 sec

*** normal termination ***
```

Figure C-17. Thermal Output -- Temperature Output and Energy Balance.

Appendix C

Sample Cask and Description of Output

Thermal and Pressure Stress Analysis Output

Thermal Stress and Pressure Stress analyses have the same output format. The sample output shown in **Figures C-18, C-19,** and **C-20** is for a Thermal Stress analysis. The analysis is based on the thermal case *Normal Hot, Contents Heat, Solar Effects*. The ambient temperature is 100°F, contents heat load is 500 Btu/min, solar effects are included, and the stress free temperature is 70°F. The output format is as follows:

(1) **Header**

Indicates the type of analysis, page number of how many, date and time the output was generated, **SCANS** version number, and a brief description of the parameters defining the analysis case. The header shown in **Figure C-18** is printed at the top of every page of output.

(2) **Nodal Results**

Table of coordinates and displacements for each node in the Finite Element mesh. The mesh is an axisymmetric representation of the TOP end of the cask. The results for the first ten nodes are shown in **Figure C-18**.

(3) **Element Stress results**

Table of stresses for each element in the mesh. Stresses are calculated at element integration points. These stress are extrapolated to the nodes which define the element and printed in the output. Stresses are not calculated for nodes which lie on the axis of symmetry. The stresses for the first two elements are shown in **Figure C-19**. The stress components are defined as follows:

Srr	Radial stress
Szz	Axial Stress
Stt	Hoop Stress
Srz	Shear stress in the axial cutting plane
S(MAX)	Maximum Principal Stress
S(MIN)	Minimum Principal Stress
ANGLE	Orientation of the principal stresses

(4) **Summary of Output**

Table of maximum and minimum stresses (radial, axial, hoop, shear), indicating the elements where they occur; table of stresses at locations corresponding to Impact model node locations. Stresses are printed for the outer radius of each shell layer along the cask body. Stresses are interpolated to the Impact node locations when necessary. The stresses at the outer radius of the Shell Inner Layer corresponding to Impact node locations are shown in **Figure C-20**.

STRESS OUTPUT FOR CASK 9999 — Page 1 of 19
GENERATED ON 5/10/91 AT 13:49:34 — SCANS VERSION: 2a
TITLE: Sample spent fuel shipping cask (demonstration only)
THERMAL CASE: Normal hot Contents heat Solar effects
Maximum contents heat generation: 500.00 BTU/MIN
Stress Free Temp= 70. Thermal State 2 at Time S.S.

NODAL RESULTS

NODE NUMBER	COORDINATES X	Y	DISPLACEMENTS DX	DY
1	.000	96.250	.000000	.173947
2	4.271	96.250	.009714	.173776
3	8.542	96.250	.019379	.173281
4	12.813	96.250	.028941	.172446
5	17.083	96.250	.038351	.171245
6	21.354	96.250	.047676	.169859
7	25.625	96.250	.055989	.168217
8	25.625	85.750	.046316	.142073
9	25.625	75.250	.045007	.119668
10	25.625	64.750	.040446	.099765

Figure C-18. Thermal Stress Output -- Header and Nodal Results.

ELEMENT STRESS RESULTS

Integration point stresses are extrapolated to the element nodes

Elem Numb	Node Numb	Srr psi	Szz psi	Stt psi	Srz psi	S(MAX) psi	S(MIN) si	ANGLE eg.
1								
	17	-3.	1486.	-3146.	9.	1486.	-3.	89.66
	49	-59.	1651.	-2901.	6.	1651.	-59.	89.82
	50	-113.	1810.	-2665.	2.	1810.	-113.	89.93
	16	1.	1559.	-3145.	-8.	1559.	1.	-89.72
	56	-54.	1721.	-2900.	-11.	1721.	-54.	-89.64
	57	-108.	1876.	-2665.	-14.	1876.	-108.	-89.58
	15	6.	1632.	-3144.	-24.	1633.	6.	-89.15
	63	-49.	1790.	-2900.	-28.	1791.	-50.	-89.13
	64	-102.	1943.	-2665.	-31.	1943.	-103.	-89.13
2								
	15	-15.	1589.	-3158.	5.	1589.	-15.	89.83
	63	-75.	1741.	-2918.	-6.	1741.	-75.	-89.81
	64	-133.	1888.	-2686.	-17.	1888.	-133.	-89.53
	14	-15.	1826.	-3157.	-51.	1827.	-16.	-88.41
	70	-59.	1958.	-2917.	-63.	1960.	-61.	-88.20
	71	-101.	2085.	-2686.	-75.	2088.	-104.	-88.04
	13	-14.	2063.	-3156.	-107.	2068.	-19.	-87.05
	77	-42.	2175.	-2917.	-121.	2181.	-49.	-86.90
	78	-70.	2282.	-2687.	-133.	2290.	-77.	-86.77

Figure C-19. Thermal Stress Output -- Typical Element Stresses.

SUMMARY OF OUTPUT

Elements with minimum and maximum stress values

Srr	minimum of	-12631.	psi	occurs in element	14 at node	122
	maximum of	49246.	psi	occurs in element	26 at node	124
Szz	minimum of	-13886.	psi	occurs in element	14 at node	120
	maximum of	24241.	psi	occurs in element	26 at node	124
Stt	minimum of	-14599.	psi	occurs in element	14 at node	120
	maximum of	25561.	psi	occurs in element	26 at node	124
Srz	minimum of	-25811.	psi	occurs in element	26 at node	124
	maximum of	21622.	psi	occurs in element	25 at node	120

Stresses along Cask body at radius of each SHELL layer
Stresses are interpolated to IMPACT node positions
Cask bottom end: Impact node is 1, position is .0 inches
Cask top end: Impact node is 5, position is 192.5 inches

SHELL INNER LAYER outer radius= 26.625 inches

Impact Model Node	Pos. inch	Srr psi	Szz psi	Stt psi	Srz psi	S(MAX) psi	S(MIN) psi	ANGLE deg.
1	.0	-4142.	11222.	1016.	3350.	11920.	-4841.	78.22
	10.5	-2286.	4388.	-2507.	207.	4394.	-2292.	88.22
	21.0	41.	25.	-4596.	520.	554.	-487.	44.56
	31.5	82.	1882.	-3116.	2285.	3438.	-1474.	55.75
	40.8	-10.	1893.	-2842.	330.	1948.	-65.	80.42
2	48.1	64.	2283.	-2692.	116.	2289.	58.	87.02
	50.0	82.	2382.	-2654.	62.	2384.	81.	88.47
	59.3	-116.	2265.	-2690.	-38.	2266.	-117.	-89.08
	68.5	-101.	2085.	-2686.	-75.	2088.	-104.	-88.04
	77.8	-118.	1915.	-2676.	-24.	1916.	-118.	-89.32
	87.0	-108.	1876.	-2665.	-14.	1876.	-108.	-89.58
3	96.3	-113.	1810.	-2665.	2.	1810.	-113.	89.93
	105.5	-108.	1876.	-2665.	-14.	1876.	-108.	-89.58
	114.8	-118.	1915.	-2676.	-24.	1916.	-118.	-89.32
	124.0	-101.	2085.	-2686.	-75.	2088.	-104.	-88.04
	133.3	-116.	2265.	-2690.	-38.	2266.	-117.	-89.08
	142.5	82.	2382.	-2654.	62.	2384.	81.	88.47
4	144.4	64.	2283.	-2692.	116.	2289.	58.	87.02
	151.8	-10.	1893.	-2842.	330.	1948.	-65.	80.42
	161.0	82.	1882.	-3116.	2285.	3438.	-1474.	55.75
	171.5	41.	25.	-4596.	520.	554.	-487.	44.56
	182.0	-2286.	4388.	-2507.	207.	4394.	-2292.	88.22
5	192.5	-4142.	11222.	1016.	3350.	11920.	-4841.	78.22

Figure C-20. Thermal Stress Output -- Summary of Stresses.

Appendix D

Thermal Analysis Boundary Conditions

SCANS uses heat flux, convection, and radiation boundary conditions to define the thermal analysis conditions. The contents heat is applied as a uniform heat flux over a portion of or the entire interior surface area of the cask cavity. The selection is set by selecting a length to represent a user-assigned length of the contents in the cask geometry definition. If the contents length is set identical to the cavity length, the contents heat will be applied evenly to the entire area (including the inner surfaces of the cask lids). Otherwise, the contents heat is applied evenly only to the center portion of the cylindrical area of the cavity which has the same length as the selcted length of the contents. Following is a list of the boundary condition values used for each **SCANS** thermal analysis.

NOTE: Refer to Volume 4, *SCANS Thermal Analysis Theory Manual* for a more complete description of the following terms and equations.

Convection Equation: $q'' = h\,(T - T_\infty)^a\,(T - T_\infty)$

Where:

- q'' = Surface heat flux due to convection
- h = Convection coefficient
- a = Free convection exponent
- T = Surface temperature
- T_∞ = Convection flow temperature

Radiation Equation: $q'' = f(T + T_\infty)(T^2 + T_\infty^2)(T - T_\infty)$

and $f = \sigma F$

Where:

- q'' = Surface heat flux due to radiation
- σ = Stefan-Boltzmann constant
- F = characteristic exchange factor (includes effects of geometry, emissivity and reflectivity)
- T = Surface temperature
- T_∞ = Radiation source temperature

Cold Soak, Contents Heat, No Solar Effects

All boundary conditions are constant

Heat Flux

Cavity: Contents heat as specified in the geometry definition

Outer Surfaces (solar): None

Convection

Flat surfaces

- h = .00002199 Btu / in.^{2} min °F
- a = .3333
- T_∞ = -40 °F

Cylindrical surfaces

- h = .00002083 Btu / in.^{2} min °F
- a = .3333
- T_∞ = -40 °F

Radiation

- f = 1.001E-13 Btu / in.^{2} min °F^4
- T_∞ = -40 °F

Appendix D

Thermal Analysis Boundary Conditions

Cold Soak, No Contents, No Solar Effects

All boundary conditions are constant

Heat Flux

Cavity: None

Outer Surfaces (solar): None

Convection

Flat surfaces

h = .00002199 Btu / in.^{2} min °F

a = .3333

T_∞ = -40 °F

Cylindrical surfaces

h = .00002083 Btu / in.^{2} min °F

a = .3333

T_∞ = -40 °F

Radiation

f = 1.001E-13 Btu / in.^{2} min °F^4

T_∞ = -40 °F

Normal Cold, Contents Heat, No Solar Effects

All boundary conditions are constant

Heat Flux

Cavity: Contents heat as specified in the geometry definition

Outer Surfaces (solar): None

Convection

Flat surfaces

h = .00002199 Btu / in.^{2} min °F

a = .3333

T_∞ = -20 °F

Cylindrical surfaces

h = .00002083 Btu / in.^{2} min °F

a = .3333

T_∞ = -20 °F

Radiation

f = 1.001E-13 Btu / in.^{2} min °F^4

T_∞ = -20 °F

Normal Cold, No Contents, No Solar Effects

All boundary conditions are constant

Heat Flux

Cavity: None

Outer Surfaces (solar): None

Convection

Flat surfaces

h = .00002199 Btu / in.^{2} min °F

a = .3333

T_∞ = -20 °F

Cylindrical surfaces

h = .00002083 Btu / in.^{2} min °F

a = .3333

T_∞ = -20 °F

Radiation

f = 1.001E-13 Btu / in.^{2} min °F^4

T_∞ = -20 °F

Normal Hot, Contents Heat, Solar Effects

All boundary conditions are constant

Heat Flux

Cavity: Contents heat as specified in the geometry definition

Outer Surfaces (solar): .01065 Btu / in.^{2} min

Convection

Flat surfaces

h = .00002199 Btu / in.^{2} min °F

a = .3333

T_∞ = 100 °F

Cylindrical surfaces

h = .00002083 Btu / in.^{2} min °F

a = .3333

T_∞ = 100 °F

Radiation

f = 1.001E-13 Btu / in.^{2} min °F^4

T_∞ = 100 °F

Appendix D

Thermal Analysis Boundary Conditions

Normal Hot, Contents Heat, No Solar Effects

All boundary conditions are constant

Heat Flux

Cavity: Contents heat as specified in the geometry definition
Outer Surfaces (solar): None

Convection

Flat surfaces

h = .00002199 Btu / in.^{2} min °F
a = .3333
T_∞ = 100 °F

Cylindrical surfaces

h = .00002083 Btu / in.^{2} min °F
a = .3333
T_∞ = 100 °F

Radiation

f = 1.001E-13 Btu / in.^{2} min °F^4
T_∞ = 100 °F

Fire Accident, Contents Heat, No Solar Effects

All boundary conditions are time dependent

Heat Flux **Applied for complete analysis**

Cavity: Contents heat as specified in the geometry definition
Outer Surfaces (solar): None

Convection **Applied after fire (30-360 minutes)**

Flat surfaces

h = .00002199 Btu / in.^{2} min °F
a = .3333
T_∞ = 100 °F

Cylindrical surfaces

h = .00002083 Btu / in.^{2} min °F
a = .3333
T_∞ = 100 °F

Radiation **Applied during fire (0-30 minutes)**

f = 1.47087E-13 Btu / in.^{2} min °F^4
T_∞ = 1475 °F

Radiation **Applied after fire (30-360 minutes)**

f = 1.6016E-13 Btu / in.^{2} min °F^4
T_∞ = 100 °F

Appendix E
Program Reference

Contents of Distribution Diskettes

The **SCANS** release package contains three 3-1/2 inch double-density (720K) distribution diskettes, listed below. Each file is identified and its function explained.

DISK 1 (5 files)

File Name	Function
SCANSV2A.D1	SCANS Disk 1 Identification File
SCANS.VER	SCANS Version File
INSTALL.EXE	Program to Install SCANS on the PC
SAMPLE.EXE	Packed Sample Cask Data Set
D1.EXE	First Set of Packed SCANS Program Files

DISK 2 (2 files)

File Name	Function
SCANSV2A.D2	SCANS Disk 2 Identification File
D2.EXE	Second Set of Packed SCANS Program Files

DISK 3 (2 files)

File Name	Function
SCANSV2A.D3	SCANS Disk 3 Identification File
D3.EXE	Third Set of Packed SCANS Program Files

DISK 4 (2 files)

File Name	Function
D4.EXE	Fourth Set of Packed SCANS Program Files
SCANSV2A.D4	SCANS Disk 4 Identification File

The **INSTALL** program automatically unpacks the packed files. The four packed sets of SCANS files produce the following sixty six SCANS program files:

File Name	Function
AIRCONV.NSM	Neutron Shield Material File, Air Convection
ALLDONE.EXE	Program for Termination Message
BALSAXGR.ILM	Impact Limiter Material File, Balsa wood cross-grained
CARBNSTL.STM	Shell/End Cap Material File, Carbon Steel
CARBNSTL.WJM	Water Jacket Material File, Carbon Steel
COPPER.WJM	Water Jacket Material File, Copper
DOT1.COM	Program for Thermal/Pressure Stress Analysis Module
DOT2.COM	Program for Thermal/Pressure Stress Analysis Module
GEOMETRY.EDT	Editor Template File for Basic Geometry
H2OCONV.NSM	Neutron Shield Material File, Water Convection
LEAD.SHM	Shield Material File, Lead
LIMITER.EDT	Editor Template File for Limiter Force-Deflection Curves
MATERIAL.EDT	Editor Template File for Material Properties
PLOTRES.LOW	Flag File for Printer Plot Resolution
POLYFOAM.ILM	Impact Limiter Material File, Polyfoam
PRINTER.EPS	Flag File for Printer Type
PURETHAN.ILM	Impact Limiter Material File, Polyurethane

Appendix E
Program Reference

REDWDXGR.ILM	Impact Limiter Material File, Redwood cross-grained
L1RGLCZI	Load Combination RG Case 1 Input File
L2RGLCZI	Load Combination RG Case 2 Input File
L3RGLCZI	Load Combination RG Case 3 Input File
L4RGLCZI	Load Combination RG Case 4 Input File
L5RGLCZI	Load Combination RG Case 5 Input File
L6RGLCZI	Load Combination RG Case 6 Input File
L7RGLCZI	Load Combination RG Case 7 Input File
L8RGLCZI	Load Combination RG Case 8 Input File
L9RGLCZI	Load Combination RG Case 9 Input File"
SCANS.BAT	SCANS Main Control Batch File
SCANSAM.COM	SCANS Analysis Menu
SCANSDM.COM	SCANS Display Menu
SCANSFM.COM	SCANS Archive Menu
SCANSGM.COM	SCANS Geometry Menu
SCANSMM.COM	SCANS Main Menu
SCANSPM.COM	SCANS Print Menu
SS304.STM	Shell/End Cap Material File, Stainless Steel 304
SS304.WJM	Water Jacket Material File, Stainless Steel 304
SS310.STM	Shell/End Cap Material File, Stainless Steel 310
SS310.WJM	Water Jacket Material File, Stainless Steel 310
SS316.STM	Shell/End Cap Material File, Stainless Steel 316
SS316.WJM	Water Jacket Material File, Stainless Steel 316
SS347.STM	Shell/End Cap Material File, Stainless Steel 347
SS347.WJM	Water Jacket Material File, Stainless Steel 347
T1RGTPZI	Thermal Analysis B.C. File, Cold Soak, Contents, No Solar
T2RGTPZI	Thermal Analysis B.C. File, Cold Soak, No Contents, No Solar
T3RGTPZI	Thermal Analysis B.C. File, Normal Cold, Contents, No Solar
T4RGTPZI	Thermal Analysis B.C. File, Normal Cold, No Contents, No Solar
T5RGTPZI	Thermal Analysis B.C. File, Normal Hot, Contents, Solar
T6RGTPZI	Thermal Analysis B.C. File, Normal Hot, Contents, No Solar
T7RGTPZI	Thermal Analysis B.C. File, Fire Accident, Contents, No Solar
VIDEO.CGA	Flag File for Video Display Type
ARCSCANS.EXE	Program to Compress/Expand Data Sets for Archive
ASOLID.EXE	Program for Thermal/Pressure Analysis module
ASOLIDF.EXE	Program for Thermal/Pressure Analysis module
COPYFL.EXE	Program to Copy Geometry/Limiter Data Files
DATACK.EXE	Program to Create Cask Summary and Data Check
DISCLAIM.EXE	Program to Display Disclaimer
EDGLP.EXE	Program to Initialize Editor for Geometry and Limiter Data
EDITOR.EXE	Program to Edit Geometry, Limiter and Material Data Files
EDMAT.EXE	Program to Initialize Editor for Material Data
GETID.EXE	Program to Select CASK ID
IMPACT.EXE	Program to Perform Impact Analysis
LOADCOM.EXE	Program to Perform Load Combination Analysis
MATCK.EXE	Program to Perform Data Check on Material
MSHDSP.EXE	Program to Generate and Display Finite Element Meshes
PLTDYN.EXE	Program to Plot Dynamic Impact Analysis Results
POSTPZ.EXE	Program to Plot Thermal Analysis Results
PRELCOM.EXE	Program to Create ot Select Load Combination Analysis
PRETOPAZ.EXE	Program to Create or Select Thermal Case and Control Thermal Analysis
PRINTIT.EXE	Program to Print and Review Outputs

SAPINPT.EXE	Program to Create Thermal Stress Analysis Input
SAPPHIRE.EXE	Program for Thermal/Pressure Analysis module
SAPRESS.EXE	Program to Create Pressure Analysis Input
SAVER.EXE	Program to Archive/Retrieve/Delete Data Sets
SETVIDEO.EXE	Program to Select Video/Printer type
SOLVE1.EXE	Program for Thermal/Pressure Analysis module
SOLVE2.EXE	Program for Thermal/Pressure Analysis module
TOPAZ.EXE	Program to Perform Thermal Analysis

Appendix E

Program Reference

System Details

SCANS 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 **SCANS** *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 *BATCH* file branches based on ERRORLEVEL, to perform the selected task.

SCANS has six menu programs. Each menu program is written in Assembly Language, making it small, fast, and flexible. All other programs in **SCANS** 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 **SCANS** *BATCH* file is listed below with comments identifying the flow of control.

```
C:                                        | Switch to hard disk containing SCANS
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 SCANS DRIVE    *****

IF EXIST \COMMAND.COM   GOTO CHNGDIR      | Go to directory change, if COMMAND.COM exists
                                          |  in root directory

ECHO
ECHO
ECHO
ECHO    ERROR  --  CANNOT INITIALIZE SCANS
ECHO
ECHO      COMMAND.COM DOES NOT EXIST IN THE ROOT DIRECTORY OF THE
ECHO      DRIVE WHICH CONTAINS SCANS
ECHO
ECHO

PROMPT  $p$g                              | If COMMAND.COM does not exist, set prompt to
GOTO END2                                 | display drive and path and go to END of session

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

:CHNGDIR
CD\SCANS                                  | Change to SCANS subdirectory
DISCLAIM                                  | Display SCANS disclaimer
GETID                                     | Select CASK ID
IF NOT EXIST CASK.ID  GOTO END            | If no CASK ID selected, go to end SCANS

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

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

:MAIN
SCANSMM                                  | Display MAIN MENU
IF ERRORLEVEL 7 GOTO END                 | Check ERRORLEVEL and branch
IF ERRORLEVEL 6 GOTO SAVE
IF ERRORLEVEL 5 GOTO PRINTER
IF ERRORLEVEL 4 GOTO DISPLAY
IF ERRORLEVEL 3 GOTO ANALYZE
IF ERRORLEVEL 2 GOTO GEOMETRY

REM             GET NEW CASK ID

: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
SCANSGM                                  | Display GEOMETRY MENU
IF ERRORLEVEL 6 GOTO MAIN
IF ERRORLEVEL 5 GOTO EDITM
IF ERRORLEVEL 4 GOTO COPYLM
IF ERRORLEVEL 3 GOTO COPYBG
IF ERRORLEVEL 2 GOTO EDITL

REM      EDIT THE CASK GEOMETRY DATA FILE AND PERFORM DATA CHECK

:EDITG
EDGLP G                                  | Setup 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 G                                 | Perform data check on basic geometry
GOTO GEOMETRY                            |  and return to GEOMETRY MENU

REM      EDIT THE IMPACT LIMITER DATA FILE AND PERFORM DATA CHECK

:EDITL
EDGLP L                                  | Setup to edit LIMITER
IF NOT EXIST EDITOR.EDM GOTO GEOMETRY    | If control file missing, return to GEOMETRY MENU
EDITOR                                   | Edit LIMITER
IF NOT EXIST DATACHCK GOTO GEOMETRY      | If not doing data check, return to GEOMETRY MENU
DATACK L                                 | Perform data check on limiter F/D curves
GOTO GEOMETRY                            |  and return to GEOMETRY MENU
```

```
REM       COPY BASIC GEOMETRY FROM DIFFERENT CASK

:COPYBG
COPYFL B                                 | Copy GEOMETRY from different data set
GOTO GEOMETRY                            | and return to GEOMETRY MENU

REM      COPY LIMITER DATA FROM DIFFERENT CASK

:COPYLM
COPYFL L                                 | Copy LIMITER from different data set
GOTO GEOMETRY                            | and return to GEOMETRY MENU

REM      EDIT MATERIAL DATA SET

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

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

REM   ***** ANALYSIS MENU *****

:ANALYZE
SCANSAM                                  | Display ANALYSIS MENU
IF ERRORLEVEL 6 GOTO MAIN                | Check ERRORLEVEL and branch
IF ERRORLEVEL 5 GOTO LOADCOM
IF ERRORLEVEL 4 GOTO PSTRESS
IF ERRORLEVEL 3 GOTO TSTRESS
IF ERRORLEVEL 2 GOTO THERMAL

REM              PERFORM IMPACT ANALYSIS

:IMPACTIT
IMPACT                                   | Perform IMPACT analysis
GOTO ANALYZE                             | and return to ANALYSIS MENU

REM              PERFORM THERMAL ANALYSIS

:THERMAL
PRETOPAZ                                 | Prepare or select case for THERMAL analysis
IF NOT EXIST TOPAZ.CMD GOTO ANALYZE      | If no case selected, return to ANALYSIS MENU
TOPAZ                                    | Perform THERMAL analysis
IF EXIST CONTINUE.TPZ GOTO THERMAL       | If performing another, go to select case
GOTO ANALYZE
```

```
REM                PERFORM THERMAL STRESS ANALYSIS

:TSTRESS
SAPINPT                                      | Select case for THERMAL STRESS analysis
IF NOT EXIST TEMPCASK GOTO ANALYZE           | If no case selected, return to ANALYSIS MENU
SAPPHIRE                                     | Perform THERMAL STRESS analysis
ASOLID
DOT1
SOLVE1 >TEMPCASK.JNK
DOT2
SOLVE2 >>TEMPCASK.JNK
ASOLIDF
DEL TEMPCASK.*                               | Delete temporary files
DEL SYSTEM
IF EXIST CONTINUE.TSO GOTO TSTRESS           | If performing another, go to select case
GOTO ANALYZE                                 | else return to ANALYSIS MENU

REM                PERFORM PRESSURE STRESS ANALYSIS

:PSTRESS
SAPRESS                                      | Select case for PRESSURE STRESS analysis
IF NOT EXIST TEMPCASK GOTO ANALYZE           | If no case selected, return to ANALYSIS MENU
SAPPHIRE                                     | Perform PRESSURE STRESS analysis
ASOLID
DOT1
SOLVE1 >TEMPCASK.JNK
DOT2
SOLVE2 >>TEMPCASK.JNK
ASOLIDF
DEL TEMPCASK.*                               | Delete temporary files
DEL SYSTEM
IF EXIST CONTINUE.TSO GOTO PSTRESS           | If performing another, go to select case
GOTO ANALYZE                                 | else return to ANALYSIS MENU
"
REM            PERFORM LOAD COMBINATION ANALYSIS

:LOADCOM
PRELCOM             /Prepare or select case for LOAD COMBINATION
analysis
IF NOT EXIST LOADCOM.CMD GO TO ANALYZE
                    /If no case selcted, return to ANALYZE MENU
LOADCOM             /Perform LOAD COMBINATION analysis
IF EXIST CONTINUE.LCM GO TO LOADCOM
                    /If performing another, go to select case
GOTO ANALYZE
```

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

REM     ***** DISPLAY MENU *****

:DISPLAY
SCANSDM                          | Display DISPLAY MENU
IF ERRORLEVEL 5 GOTO MAIN        | Check ERRORLEVEL and branch
IF ERRORLEVEL 4 GOTO ATTRIB
IF ERRORLEVEL 3 GOTO PLOTT
IF ERRORLEVEL 2 GOTO PMESH

REM       PLOT IMPACT RESULTS

:PLOTI
PLTDYN                           | Plot DYNAMIC IMPACT ANALYSIS results
GOTO DISPLAY                     |  and return to DISPLAY MENU

REM       PLOT FINITE ELEMENT MESHES

:PMESH   PLOT FINITE ELEMENT MESHES
MSHDSP D                         | Display FINITE ELEMENT meshes
GOTO DISPLAY                     |  and return to DISPLAY MENU

REM       PLOT THERMAL DISTRIBUTIONS

:PLOTT
POSTPZ                           | Plot THERMAL ANALYSIS results
GOTO DISPLAY                     |  and return to DISPLAY MENU

REM       SET VIDEO ATTRIBUTES

:ATTRIB
SETVIDEO                         | Select Video/Printer type and plot resolution
GOTO DISPLAY                     |  and return to DISPLAY MENU

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

REM     *****  PRINT/REVIEW MENU  *****

:PRINTER
SCANSPM                          | Display PRINT/REVIEW MENU
IF ERRORLEVEL 7 GOTO MAIN        | Check ERRORLEVEL and branch
IF ERRORLEVEL 6 GOTO PRINTD
IF ERRORLEVEL 5 GOTO PRINTL
IF ERRORLEVEL 4 GOTO PRINTP
IF ERRORLEVEL 3 GOTO PRINTS
IF ERRORLEVEL 2 GOTO PRINTT
```

```
REM        PRINT IMPACT RESULTS

:PRINTI
PRINTIT I                        | Print IMPACT ANALYSIS results
GOTO PRINTER                     | and return to PRINT/REVIEW MENU


REM          PRINT THERMAL RESULTS

:PRINTT
PRINTIT T                        | Print THERMAL ANALYSIS results
GOTO PRINTER                     | and return to PRINT/REVIEW MENU

REM          PRINT THERMAL STRESS RESULTS

:PRINTS
PRINTIT S                        | Print THERMAL STRESS ANALYSIS results
GOTO PRINTER                     | and return to PRINT/REVIEW MENU

REM          PRINT PRESSURE STRESS RESULTS

:PRINTP
PRINTIT P                        | Print PRESSURE STRESS ANALYSIS results
GOTO PRINTER                     | and return to PRINT/REVIEW MENU

REM          PRINT CASK SUMMARY AND DATA CHECK

:PRINTD
PRINTIT D                        | Print CASK SUMMARY/DATA CHECK
GOTO PRINTER                     | and return to PRINT/REVIEW MENU

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

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

:SAVE
SCANSFM                          | 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 SCANS PROCESS *****

:END                                      | Terminate SCANS
IF EXIST CASK.ID DEL CASK.ID              | Delete CASK ID identification file
PROMPT $p $g                              | Set prompt to display drive and path
ALLDONE                                   | Display termination message
:END2                                     | End of Session
```

Description of Databases

SCANS uses integrated databases to pass information between various programs. These databases describe the cask geometry, impact limiter force-deflection curves, material properties, boundary conditions for Thermal analyses, analysis results for plotting, and analysis results for printing. 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.

Basic Geometry Database

Purpose: Contains all geometry specifications for the cask.
Used by: IMPACT, DATACK, PRETOPAZ, SAPINPT, SAPRESS, MSHDSP
Created by: EDITOR
Modified by: EDITOR, PRETOPAZ
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	Comments
1	Scans Id			Must be 'Scans 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	Geometry.edt
14	Unused at this time			
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 45 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'

Appendix E

Program Reference

General SAR Information and Reviewer Information

Record	Description	Type	Length	Restrictions	Default
46 \					
47 |					
48 |--	SAR title	Char	54		(blank)
49 |					
50 /					
51	SAR report number	Char	12		(blank)
52	SAR report date	Char	8		(blank)
53	SAR docket number	Char	7		(blank)
54	SAR docket start date	Char	8		(blank)
55 \					
56 |					
57 |--	Additional SAR info Line 1	Char	54		(blank)
58 |					
59 /					
60 \					
61 |					
62 |--	Additional SAR info Line 2	Char	54		(blank)
63 |					
64 /					
65 \					
66 |					
67 |--	Additional SAR info Line 3	Char	54		(blank)
68 |					
69 /					
70 \					
71 |					
72 |--	Submitters address Line 1	Char	54		(blank)
73 |					
74 /					
75 \					
76 |					
77 |--	Submitters address Line 2	Char	54		(blank)
78 |					
79 /					
80 \					
81 |					
82 |--	Submitters address Line 3	Char	54		(blank)
83 |					
84 /					
85	Cask review leader name	Char	24		(blank)
86	(cont'd)				
87	Thermal analyst's name	Char	24		(blank)
88	(cont'd)				
89	Structural analyst's name	Char	24		(blank)
90	(cont'd)				
91	Nucleonics analyst's name	Char	24		(blank)
92	(cont'd)				
93-99	Unused at this time				

Cask Cavity/Contents Specifications

Record	Description	Type	Length	Restrictions	Default
100	Gross weight of package (lbs)	Real	12	Positive	0.
101	Cavity radius (inches)	Real	12	.001 ≤ X ≤ 2000	0.
102	Cavity radius mesh divisions	Int	2	Even 2 ≤ I ≤ 20	6
103	Cavity length (inches)	Real	12	.001 ≤ X ≤ 2000	0.
104	Half length mesh divisions	Int	2	Even 2 ≤ I ≤ 40	8
105	Weight of contents (lbs)	Real	12	Positive	0
117	Contents length (inches)	Real	12	.001 <= X <= 2000	0
106	Max contents heat (btu/min)	Real	12	0 ≤ X	0
107	Initial cavity pressure (psia)	Real	12	0 ≤ X ≤ 500	14.7
108	Initial cavity temperature (°F)	Real	12	-100 ≤ X ≤ 300	70
109	Maximum Normal Operating Pressure (psia)	Real	12	0 ≤ X ≤ 2000	14.7
110	Stress free temperature (°F)	Real	12	-100 ≤ X ≤ 300	70

Cask Component Configurations

Record	Description	Type	Length	Restrictions	Default
111	Shell configuration	List	1	S or L	S
112	Top end cap configuration	List	1	S or L	S
113	Bottom end cap configuration	List	1	S or L	S
114	Top limiter present?	List	1	Y or N	Y
115	Bottom limiter present?	List	1	Y or N	Y
116	Neutron shield/water jacket?	List	1	Y or N	Y

118-120 Unused at this time

Cask Shell Specifications

Record	Description	Type	Length	Restrictions	Default
	The following 3 records are for Solid Shells (1 layer)				
121	Shell thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
122	Shell material	Name	8	List from *.STM	SS304
123	Shell mesh divisions	Int	2	Even 2 ≤ I ≤ 10	4
	The following 12 records are for Laminated Shells (1-3 layers)				
124	Shell inner layer thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
125	Shell inner layer material	Name	8	List from *.STM	SS304
126	Shell inner layer mesh divisions	Int	2	Even 2 ≤ I ≤ 10	2
127	Shell shield thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
128	Shell shield length (in.)	Real	12	0. ≤ X ≤ 2000	0.
129	Shell shield material	Name	8	List from *.SHM	LEAD
130	Shell shield mesh divisions	Int	2	Even 2 ≤ I ≤ 10	4
131	Shell outer layer thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
132	Shell outer layer material	Name	8	List from *.STM	SS304
133	Shell outer layer mesh divisions	Int	2	Even 2 ≤ I ≤ 10	2
134	Inner Shell additional thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
135	Outer Shell additional thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.

Cask Top End Cap Specifications

Record	Description	Type	Length	Restrictions	Default
The following 3 records are for Solid Top End Caps (1 layer)					
136	Top End Cap thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
137	Top End Cap material	Name	8	List from *.STM	SS304
138	Top End Cap mesh divisions	Int	2	Even 2 ≤ I ≤ 10	4
The following 10 records are for Laminated Top End Caps (1-3 layers)					
139	Top End Cap inner layer thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
140	Top End Cap inner layer material	Name	8	List from *.STM	SS304
141	Top End Cap inner layer mesh divisions	Int	2	Even 2 ≤ I ≤ 10	2
142	Top End Cap shield thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
143	Top End Cap shield length (in.)	Real	12	0. ≤ X ≤ 2000	0.
144	Top End Cap shield material	Name	8	List from *.SHM	LEAD
145	Top End Cap shield mesh divisions	Int	2	Even 2 ≤ I ≤ 10	4
146	Top End Cap outer layer thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
147	Top End Cap outer layer material	Name	8	List from *.STM	SS304
148	Top End Cap outer layer mesh divisions	Int	2	Even 2 ≤ I ≤ 10	2

149-150 Unused at this time

Cask Bottom End Cap Specifications

Record	Description	Type	Length	Restrictions	Default
The following 3 records are for Solid Bottom End Caps (1 layer)					
151	Bottom End Cap thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
152	Bottom End Cap material	Name	8	List from *.STM	SS304
153	Bottom End Cap mesh divisions	Int	2	Even 2 ≤ I ≤ 10	4
The following 10 records are for Laminated Bottom End Caps (1-3 layers)					
154	Bottom End Cap inner layer thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
155	Bottom End Cap inner layer material	Name	8	List from *.STM	SS304
156	Bottom End Cap inner layer mesh divisions	Int	2	Even 2 ≤ I ≤ 10	2
157	Bottom End Cap shield thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
158	Bottom End Cap shield length (in.)	Real	12	0. ≤ X ≤ 2000	0.
159	Bottom End Cap shield material	Name	8	List from *.SHM	LEAD
160	Bottom End Cap shield mesh divisions	Int	2	Even 2 ≤ I ≤ 10	4
161	Bottom End Cap outer layer thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
162	Bottom End Cap outer layer material	Name	8	List from *.STM	SS304
163	Bottom End Cap outer layer mesh divisions	Int	2	Even 2 ≤ I ≤ 10	2

164-167 Unused at this time

Cask Closure Bolts Information

Record	Description	Type	Length	Restrictions	Default
168	Closure bolt circle radius (in.)	Real	12	.001 ≤ X ≤ 2000	0.
169	Number of closure bolts	Int	2	1 ≤ I ≤ 99	0
170	Diameter of closure bolts (in.)	Real	12	.001 ≤ X ≤ 10	0.

171-175 Unused at this time

Cask Neutron Shield / Water Jacket Specifications

Record	Description	Type	Length	Restrictions	Default
176	Neutron shield / Water Jacket length (in.)	Real	12	0. ≤ X ≤ 2000	0.
177	Neutron shield thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
178	Neutron shield material	Name	8	List from *.NSM	H2OCONV
179	Neutron shield mesh divisions	Int	2	2 ≤ I ≤ 9	1
180	Water jacket thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
181	Water jacket material	Name	8	List from *.WJM	SS304
182	Water jacket mesh divisions	Int	2	2 ≤ I ≤ 9	1

183-185 Unused at this time

Cask Top Impact Limiter Specifications

Record	Description	Type	Length	Restrictions	Default
186	Top limiter outer radius	Real	12	.001 ≤ X ≤ 2000	0.
187	Top limiter centerline thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
188	Top limiter centerline mesh divisions	Int	2	2 ≤ I ≤ 10	4
189	Top limiter overhang thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
190	Top limiter overhang mesh divisions	Int	2	2 ≤ I ≤ 10	3
191	Top limiter material	Name	8	List from *.ILM	POLYFOAM

192-195 Unused at this time

Cask Bottom Impact Limiter Specifications

Record	Description	Type	Length	Restrictions	Default
196	Bottom limiter outer radius	Real	12	.001 ≤ X ≤ 2000	0.
197	Bottom limiter centerline thickness (in.)	Real	12	.001 ≤ X ≤ 2000	0.
198	Bottom limiter centerline mesh divisions	Int	2	2 ≤ I ≤ 10	4
199	Bottom limiter overhang thickness (in.)	Real	12	0. ≤ X ≤ 2000	0.
200	Bottom limiter overhang mesh divisions	Int	2	2 ≤ I ≤ 10	3
201	Bottom limiter material	Name	8	List from *.ILM	POLYFOAM

202-205 Unused at this time

Appendix E

Program Reference

Cask Impact Model Specifications

Record	Description	Type	Length	Restrictions	Default
206	Number of elements for 1d model	Int	2	3 ≤ I ≤ 20	4
207	Top limiter weight (lbs)	Real	12	0 ≤ X	0.
208	Bottom limiter weight (lbs)	Real	12	0 ≤ X	0.
209	Define model with user properties ?	List	1	Y or N	N
210	Shell translational mass (lb-sec**2/in.)	Real	12	POSITIVE	0.
211	Shell rotational mass (lb-sec**2-in.)	Real	12	POSITIVE	0.
212	Shell inside length (in.)	Real	12	POSITIVE	0.
213	Shell composite E*I (lb-in.**2)	Real	12	POSITIVE	0.
214	Shell composite A*E (lb)	Real	12	POSITIVE	0.
215	Top End translational mass (lb-sec**2/in.)	Real	12	POSITIVE	0.
216	Top End rotational mass (lb-sec**2-in.)	Real	12	POSITIVE	0.
217	Bottom End translational mass (lb-sec**2/in.)	Real	12	POSITIVE	0.
218	Bottom End rotational mass (lb-sec**2/in.)	Real	12	POSITIVE	0.
219	Characteristic cross-section (in.)	Real	12	POSITIVE	0.
220	Unused at this time				

Thermal Transient Analysis Control Parameters

NOTE: These parameters cannot be modified using the EDITOR

Record	Description	Type	Length	Restrictions	Default
221	Allow phase change ?	List	1	Y or N	N
222	Print output interval (min)	Real	12	10 ≤ X ≤ 3603	0.
223	Plot output interval (min)	Real	12	2 ≤ X ≤ 30	5.
224	Use variable time step ?	List	1	Y or N	N
225	Iteration convergence tolerance	Real	12	.001 ≤ X ≤ .1	.001
226	Iteration relaxation parameter	Real	12	.3 ≤ X ≤ 1.	1.
227	Maximum allowable time step (min)	Real	12	5 ≤ X ≤ 30	30.
228	Maximum allowable temperature change (°F)	Real	12	25 ≤ X ≤ 50	100.
229	Time step modification factor	Real	12	2 ≤ X ≤ 6	2.
230	Fixed time step size (min)	Real	12	.25 ≤ X ≤ 5	.5

Impact Limiter Force-Deflection Curves Database

Purpose:	Contains all limiter force-deflection curve specifications
Used by:	IMPACT, DATACK
Created by:	EDITOR
Modified by:	EDITOR
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	Comments
1	Scans Id			Must be 'Scans lmi'
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	Limiter template file name	Char	12	Limiter.edt
14	Unused at this time			
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 45 mod date, PGACC, PGREQ	Char	8 1 1	Form 'mm/dd/yy AR'

Impact Limiter Unloading Specification

Record	Description	Type	Length	Restrictions	Default
48	Type of limiter unloading	List	1	N or U or C	N
49	User unloading slope (kips/in.)	Real	12	POSITIVE	0.

Bottom Impact Limiter Curve for a 0-Degree Impact

Record	Description	Type	Length	Restrictions	Default
50	Is this limiter defined ?	List	1	Y or N	N
51	Deflection #1 (in.) Real	12POSITIVE		0.	
52	Force #1 (kips)	Real	12	POSITIVE	0.
53	Deflection #2 (in.)	Real	12	POSITIVE	0.
54	Force #2 (kips)	Real	12	POSITIVE	0.
55	Deflection #3 (in.)	Real	12	0. ≤ X	0.
56	Force #3 (kips)	Real	12	0. ≤ X	0.
57	Deflection #4 (in.)	Real	12	0. ≤ X	0.
58	Force #4 (kips)	Real	12	0. ≤ X	0.
59	Deflection #5 (in.)	Real	12	0. ≤ X	0.
60	Force #5 (kips)	Real	12	0. ≤ X	0.
61	Deflection #6 (in.)	Real	12	0. ≤ X	0.
62	Force #6 (kips)	Real	12	0. ≤ X	0.
63	Deflection #7 (in.)	Real	12	0. ≤ X	0.
64	Force #7 (kips)	Real	12	0. ≤ X	0.
65	Deflection #8 (in.)	Real	12	0. ≤ X	0.
66	Force #8 (kips)	Real	12	0. ≤ X	0.
67	Deflection #9 (in.)	Real	12	0. ≤ X	0.
68	Force #9 (kips)	Real	12	0. ≤ X	0.
69	Deflection #10 (in.)	Real	12	0. ≤ X	0.
70	Force #10 (kips)	Real	12	0. ≤ X	0.
71-74	Unused at this time				

Bottom Impact Limiter Curve for a 15-Degree Impact

Record	Description	Type	Length	Restrictions	Default
75	Is this limiter defined ?	List	1	Y or N	N
76	Deflection #1 (in.)	Real	12	POSITIVE	0.
77	Force #1 (kips)	Real	12	POSITIVE	0.
78	Deflection #2 (in.)	Real	12	POSITIVE	0.
79	Force #2 (kips)	Real	12	POSITIVE	0.
80	Deflection #3 (in.)	Real	12	0. ≤ X	0.
81	Force #3 (kips)	Real	12	0. ≤ X	0.
82	Deflection #4 (in.)	Real	12	0. ≤ X	0.
83	Force #4 (kips)	Real	12	0. ≤ X	0.
84	Deflection #5 (in.)	Real	12	0. ≤ X	0.
85	Force #5 (kips)	Real	12	0. ≤ X	0.
86	Deflection #6 (in.)	Real	12	0. ≤ X	0.
87	Force #6 (kips)	Real	12	0. ≤ X	0.
88	Deflection #7 (in.)	Real	12	0. ≤ X	0.
89	Force #7 (kips)	Real	12	0. ≤ X	0.
90	Deflection #8 (in.)	Real	12	0. ≤ X	0.
91	Force #8 (kips)	Real	12	0. ≤ X	0.
92	Deflection #9 (in.)	Real	12	0. ≤ X	0.
93	Force #9 (kips)	Real	12	0. ≤ X	0.
94	Deflection #10 (in.)	Real	12	0. ≤ X	0.
95	Force #10 (kips)	Real	12	0. ≤ X	0.
96-99	Unused at this time				

Bottom Impact Limiter Curve for a 30-Degree Impact

Record	Description			Type	Length	Restrictions	Default
100	Is this limiter defined ?			List	1	Y or N	N
101	Deflection	#1	(in.)	Real	12	POSITIVE	0.
102	Force	#1	(kips)	Real	12	POSITIVE	0.
103	Deflection	#2	(in.)	Real	12	POSITIVE	0.
104	Force	#2	(kips)	Real	12	POSITIVE0.	
105	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
106	Force	#3	(kips)	Real	12	0. ≤ X	0.
107	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
108	Force	#4	(kips)	Real	12	0. ≤ X	0.
109	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
110	Force	#5	(kips)	Real	12	0. ≤ X	0.
111	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
112	Force	#6	(kips)	Real	12	0. ≤ X	0.
113	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
114	Force	#7	(kips)	Real	12	0. ≤ X	0.
115	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
116	Force	#8	(kips)	Real	12	0. ≤ X	0.
117	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
118	Force	#9	(kips)	Real	12	0. ≤ X	0.
119	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
120	Force	#10	(kips)	Real	12	0. ≤ X	0.
121-124	Unused at this time						

Bottom Impact Limiter Curve for a 45-Degree Impact

Record	Description			Type	Length	Restrictions	Default
125	Is this limiter defined ?			List	1	Y or N	N
126	Deflection	#1	(in.)	Real	12	POSITIVE	0.
127	Force	#1	(kips)	Real	12	POSITIVE	0.
128	Deflection	#2	(in.)	Real	12	POSITIVE	0.
129	Force	#2	(kips)	Real	12	POSITIVE	0.
130	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
131	Force	#3	(kips)	Real	12	0. ≤ X	0.
132	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
133	Force	#4	(kips)	Real	12	0. ≤ X	0.
134	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
135	Force	#5	(kips)	Real	12	0. ≤ X	0.
136	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
137	Force	#6	(kips)	Real	12	0. ≤ X	0.
138	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
139	Force	#7	(kips)	Real	12	0. ≤ X	0.
130	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
141	Force	#8	(kips)	Real	12	0. ≤ X	0.
142	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
143	Force	#9	(kips)	Real	12	0. ≤ X	0.
144	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
145	Force	#10	(kips)	Real	12	0. ≤ X	0.
146-149	Unused at this time						

Bottom Impact Limiter Curve for a 60-Degree Impact

Record	Description	Type	Length	Restrictions	Default
150	Is this limiter defined ?	List	1	Y or N	N
151	Deflection #1 (in.)	Real	12	POSITIVE	0.
152	Force #1 (kips)	Real	12	POSITIVE	0.
153	Deflection #2 (in.)	Real	12	POSITIVE	0.
154	Force #2 (kips)	Real	12	POSITIVE	0.
155	Deflection #3 (in.)	Real	12	0. ≤ X	0.
156	Force #3 (kips)	Real	12	0. ≤ X	0.
157	Deflection #4 (in.)	Real	12	0. ≤ X	0.
158	Force #4 (kips)	Real	12	0. ≤ X	0.
159	Deflection #5 (in.)	Real	12	0. ≤ X	0.
160	Force #5 (kips)	Real	12	0. ≤ X	0.
161	Deflection #6 (in.)	Real	12	0. ≤ X	0.
162	Force #6 (kips)	Real	12	0. ≤ X	0.
163	Deflection #7 (in.)	Real	12	0. ≤ X	0.
164	Force #7 (kips)	Real	12	0. ≤ X	0.
165	Deflection #8 (in.)	Real	12	0. ≤ X	0.
166	Force #8 (kips)	Real	12	0. ≤ X	0.
167	Deflection #9 (in.)	Real	12	0. ≤ X	0.
168	Force #9 (kips)	Real	12	0. ≤ X	0.
169	Deflection #10 (in.)	Real	12	0. ≤ X	0.
170	Force #10 (kips)	Real	12	0. ≤ X	0.
171-174	Unused at this time				

Bottom Impact Limiter Curve for a 75-Degree Impact

Record	Description	Type	Length	Restrictions	Default
175	Is this limiter defined ?	List	1	Y or N	N
176	Deflection #1 (in.)	Real	12	POSITIVE	0.
177	Force #1 (kips)	Real	12	POSITIVE	0.
178	Deflection #2 (in.)	Real	12	POSITIVE	0.
179	Force #2 (kips)	Real	12	POSITIVE	0.
180	Deflection #3 (in.)	Real	12	0. ≤ X	0.
181	Force #3 (kips)	Real	12	0. ≤ X	0.
182	Deflection #4 (in.)	Real	12	0. ≤ X	0.
183	Force #4 (kips)	Real	12	0. ≤ X	0.
184	Deflection #5 (in.)	Real	12	0. ≤ X	0.
185	Force #5 (kips)	Real	12	0. ≤ X	0.
186	Deflection #6 (in.)	Real	12	0. ≤ X	0.
187	Force #6 (kips)	Real	12	0. ≤ X	0.
188	Deflection #7 (in.)	Real	12	0. ≤ X	0.
189	Force #7 (kips)	Real	12	0. ≤ X	0.
190	Deflection #8 (in.)	Real	12	0. ≤ X	0.
191	Force #8 (kips)	Real	12	0. ≤ X	0.
192	Deflection #9 (in.)	Real	12	0. ≤ X	0.
193	Force #9 (kips)	Real	12	0. ≤ X	0.
194	Deflection #10 (in.)	Real	12	0. ≤ X	0.
195	Force #10 (kips)	Real	12	0. ≤ X	0.
196-199	Unused at this time				

Bottom Impact Limiter Curve for a 90-Degree Impact

Record	Description	Type	Length	Restrictions	Default
200	Is this limiter defined ?	List	1	Y or N	N
201	Deflection #1 (in.)	Real	12	POSITIVE	0.
202	Force #1 (kips)	Real	12	POSITIVE	0.
203	Deflection#2 (in.) Real	12POSITIVE		0.	
204	Force #2 (kips)	Real	12	POSITIVE	0.
205	Deflection #3 (in.)	Real	12	0. ≤ X	0.
206	Force #3 (kips)	Real	12	0. ≤ X	0.
207	Deflection #4 (in.)	Real	12	0. ≤ X	0.
208	Force #4 (kips)	Real	12	0. ≤ X	0.
209	Deflection #5 (in.)	Real	12	0. ≤ X	0.
210	Force #5 (kips)	Real	12	0. ≤ X	0.
211	Deflection #6 (in.)	Real	12	0. ≤ X	0.
212	Force #6 (kips)	Real	12	0. ≤ X	0.
213	Deflection #7 (in.)	Real	12	0. ≤ X	0.
214	Force #7 (kips)	Real	12	0. ≤ X	0.
215	Deflection #8 (in.)	Real	12	0. ≤ X	0.
216	Force #8 (kips)	Real	12	0. ≤ X	0.
217	Deflection #9 (in.)	Real	12	0. ≤ X	0.
218	Force #9 (kips)	Real	12	0. ≤ X	0.
219	Deflection #10 (in.)	Real	12	0. ≤ X	0.
220	Force #10 (kips)	Real	12	0. ≤ X	0.
221-224	Unused at this time				

Bottom Impact Limiter Curve for a C.G. Degree Impact

Record	Description	Type	Length	Restrictions	Default
225	Is this limiter defined ?	List	1	Y or N	N
226	Deflection #1 (in.)	Real	12	POSITIVE	0.
227	Force #1 (kips)	Real	12	POSITIVE	0.
228	Deflection #2 (in.)	Real	12	POSITIVE	0.
229	Force #2 (kips)	Real	12	POSITIVE	0.
230	Deflection #3 (in.)	Real	12	0. ≤ X	0.
231	Force #3 (kips)	Real	12	0. ≤ X	0.
232	Deflection #4 (in.)	Real	12	0. ≤ X	0.
233	Force #4 (kips)	Real	12	0. ≤ X	0.
234	Deflection #5 (in.)	Real	12	0. ≤ X	0.
235	Force #5 (kips)	Real	12	0. ≤ X	0.
236	Deflection #6 (in.)	Real	12	0. ≤ X	0.
237	Force #6 (kips)	Real	12	0. ≤ X	0.
238	Deflection #7 (in.)	Real	12	0. ≤ X	0.
239	Force #7 (kips)	Real	12	0. ≤ X	0.
230	Deflection #8 (in.)	Real	12	0. ≤ X	0.
241	Force #8 (kips)	Real	12	0. ≤ X	0.
242	Deflection #9 (in.)	Real	12	0. ≤ X	0.
243	Force #9 (kips)	Real	12	0. ≤ X	0.
244	Deflection #10 (in.)	Real	12	0. ≤ X	0.
245	Force #10 (kips)	Real	12	0. ≤ X	0.
246-249	Unused at this time				

Appendix E

Program Reference

Top Impact Limiter Curve for a 0-Degree Impact

Record	Description			Type	Length	Restrictions	Default
250	Is this limiter defined ?			List	1	Y or N	N
251	Deflection	#1	(in.)	Real	12	POSITIVE	0.
252	Force	#1	(kips)	Real	12	POSITIVE	0.
253	Deflection	#2	(in.)	Real	12	POSITIVE	0.
254	Force	#2	(kips)	Real	12	POSITIVE	0.
255	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
256	Force	#3	(kips)	Real	12	0. ≤ X	0.
257	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
258	Force	#4	(kips)	Real	12	0. ≤ X	0.
259	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
260	Force	#5	(kips)	Real	12	0. ≤ X	0.
261	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
262	Force	#6	(kips)	Real	12	0. ≤ X	0.
263	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
264	Force	#7	(kips)	Real	12	0. ≤ X	0.
265	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
266	Force	#8	(kips)	Real	12	0. ≤ X	0.
267	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
268	Force	#9	(kips)	Real	12	0. ≤ X	0.
269	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
270	Force	#10	(kips)	Real	12	0. ≤ X	0.
271-274	Unused at this time						

Top Impact Limiter Curve for a 15-Degree Impact

Record	Description			Type	Length	Restrictions	Default
275	Is this limiter defined ?			List	1	Y or N	N
276	Deflection	#1	(in.)	Real	12	POSITIVE	0.
277	Force	#1	(kips)	Real	12	POSITIVE	0.
278	Deflection	#2	(in.)	Real	12	POSITIVE	0.
279	Force	#2	(kips)	Real	12	POSITIVE	0.
280	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
281	Force	#3	(kips)	Real	12	0. ≤ X	0.
282	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
283	Force	#4	(kips)	Real	12	0. ≤ X	0.
284	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
285	Force	#5	(kips)	Real	12	0. ≤ X	0.
286	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
287	Force	#6	(kips)	Real	12	0. ≤ X	0.
288	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
289	Force	#7	(kips)	Real	12	0. ≤ X	0.
290	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
291	Force	#8	(kips)	Real	12	0. ≤ X	0.
292	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
293	Force	#9	(kips)	Real	12	0. ≤ X	0.
294	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
295	Force	#10	(kips)	Real	12	0. ≤ X	0.
296-299	Unused at this time						

Top Impact Limiter Curve for a 30-Degree Impact

Record	Description			Type	Length	Restrictions	Default
300	Is this limiter defined ?			List	1	Y or N	N
301	Deflection	#1	(in.)	Real	12	POSITIVE	0.
302	Force	#1	(kips)	Real	12	POSITIVE	0.
303	Deflection	#2	(in.)	Real	12	POSITIVE	0.
304	Force	#2	(kips)	Real	12	POSITIVE0.	
305	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
306	Force	#3	(kips)	Real	12	0. ≤ X	0.
307	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
308	Force	#4	(kips)	Real	12	0. ≤ X	0.
309	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
310	Force	#5	(kips)	Real	12	0. ≤ X	0.
311	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
312	Force	#6	(kips)	Real	12	0. ≤ X	0.
313	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
314	Force	#7	(kips)	Real	12	0. ≤ X	0.
315	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
316	Force	#8	(kips)	Real	12	0. ≤ X	0.
317	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
318	Force	#9	(kips)	Real	12	0. ≤ X	0.
319	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
320	Force	#10	(kips)	Real	12	0. ≤ X	0.
321-324	Unused at this time						

Top Impact Limiter Curve for a 45-Degree Impact

Record	Description			Type	Length	Restrictions	Default
325	Is this limiter defined ?			List	1	Y or N	N
326	Deflection	#1	(in.)	Real	12	POSITIVE	0.
327	Force	#1	(kips)	Real	12	POSITIVE	0.
328	Deflection	#2	(in.)	Real	12	POSITIVE	0.
329	Force	#2	(kips)	Real	12	POSITIVE	0.
330	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
331	Force	#3	(kips)	Real	12	0. ≤ X	0.
332	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
333	Force	#4	(kips)	Real	12	0. ≤ X	0.
334	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
335	Force	#5	(kips)	Real	12	0. ≤ X	0.
336	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
337	Force	#6	(kips)	Real	12	0. ≤ X	0.
338	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
339	Force	#7	(kips)	Real	12	0. ≤ X	0.
330	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
341	Force	#8	(kips)	Real	12	0. ≤ X	0.
342	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
343	Force	#9	(kips)	Real	12	0. ≤ X	0.
344	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
345	Force	#10	(kips)	Real	12	0. ≤ X	0.
346-349	Unused at this time						

Appendix E

Program Reference

Top Impact Limiter Curve for a 60-Degree Impact

Record	Description			Type	Length	Restrictions	Default
350	Is this limiter defined ?			List	1	Y or N	N
351	Deflection	#1	(in.)	Real	12	POSITIVE	0.
352	Force	#1	(kips)	Real	12	POSITIVE	0.
353	Deflection	#2	(in.)	Real	12	POSITIVE	0.
354	Force	#2	(kips)	Real	12	POSITIVE	0.
355	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
356	Force	#3	(kips)	Real	12	0. ≤ X	0.
357	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
358	Force	#4	(kips)	Real	12	0. ≤ X	0.
359	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
360	Force	#5	(kips)	Real	12	0. ≤ X	0.
361	Deflection	#6	(in.)	Real	12	0. ≤ X	0,
362	Force	#6	(kips)	Real	12	0. ≤ X	0.
363	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
364	Force	#7	(kips)	Real	12	0. ≤ X	0.
365	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
366	Force	#8	(kips)	Real	12	0. ≤ X	0.
367	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
368	Force	#9	(kips)	Real	12	0. ≤ X	0.
369	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
370	Force	#10	(kips)	Real	12	0. ≤ X	0.
371-374	Unused at this time						

Top Impact Limiter Curve for a 75-Degree Impact

Record	Description			Type	Length	Restrictions	Default
375	Is this limiter defined ?			List	1	Y or N	N
376	Deflection	#1	(in.)	Real	12	POSITIVE	0.
377	Force	#1	(kips)	Real	12	POSITIVE	0.
378	Deflection	#2	(in.)	Real	12	POSITIVE	0.
379	Force	#2	(kips)	Real	12	POSITIVE	0.
380	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
381	Force	#3	(kips)	Real	12	0. ≤ X	0.
382	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
383	Force	#4	(kips)	Real	12	0. ≤ X	0.
384	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
385	Force	#5	(kips)	Real	12	0. ≤ X	0.
386	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
387	Force	#6	(kips)	Real	12	0. ≤ X	0.
388	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
389	Force	#7	(kips)	Real	12	0. ≤ X	0.
390	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
391	Force	#8	(kips)	Real	12	0. ≤ X	0.
392	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
393	Force	#9	(kips)	Real	12	0. ≤ X	0.
394	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
395	Force	#10	(kips)	Real	12	0. ≤ X	0.
396-399	Unused at this time						

Top Impact Limiter Curve for a 90-Degree Impact

Record	Description			Type	Length	Restrictions	Default
400	Is this limiter defined ?			List	1	Y or N	N
401	Deflection	#1	(in.)	Real	12	POSITIVE	0.
402	Force	#1	(kips)	Real	12	POSITIVE	0.
403	Deflection	#2	(in.)	Real	12	POSITIVE	0.
404	Force	#2	(kips)	Real	12	POSITIVE	0.
405	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
406	Force	#3	(kips)	Real	12	0. ≤ X	0.
407	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
408	Force	#4	(kips)	Real	12	0. ≤ X	0.
409	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
410	Force	#5	(kips)	Real	12	0. ≤ X	0.
411	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
412	Force	#6	(kips)	Real	12	0. ≤ X	0.
413	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
414	Force	#7	(kips)	Real	12	0. ≤ X	0.
415	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
416	Force	#8	(kips)	Real	12	0. ≤ X	0.
417	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
418	Force	#9	(kips)	Real	12	0. ≤ X	0.
419	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
420	Force	#10	(kips)	Real	12	0. ≤ X	0.
421-424	Unused at this time						

Top Impact Limiter Curve for a C.G. Degree Impact

Record	Description			Type	Length	Restrictions	Default
425	Is this limiter defined ?			List	1	Y or N	N
426	Deflection	#1	(in.)	Real	12	POSITIVE	0.
427	Force	#1	(kips)	Real	12	POSITIVE	0.
428	Deflection	#2	(in.)	Real	12	POSITIVE	0.
429	Force	#2	(kips)	Real	12	POSITIVE	0.
430	Deflection	#3	(in.)	Real	12	0. ≤ X	0.
431	Force	#3	(kips)	Real	12	0. ≤ X	0.
432	Deflection	#4	(in.)	Real	12	0. ≤ X	0.
433	Force	#4	(kips)	Real	12	0. ≤ X	0.
434	Deflection	#5	(in.)	Real	12	0. ≤ X	0.
435	Force	#5	(kips)	Real	12	0. ≤ X	0.
436	Deflection	#6	(in.)	Real	12	0. ≤ X	0.
437	Force	#6	(kips)	Real	12	0. ≤ X	0.
438	Deflection	#7	(in.)	Real	12	0. ≤ X	0.
439	Force	#7	(kips)	Real	12	0. ≤ X	0.
430	Deflection	#8	(in.)	Real	12	0. ≤ X	0.
441	Force	#8	(kips)	Real	12	0. ≤ X	0.
442	Deflection	#9	(in.)	Real	12	0. ≤ X	0.
443	Force	#9	(kips)	Real	12	0. ≤ X	0.
444	Deflection	#10	(in.)	Real	12	0. ≤ X	0.
445	Force	#10	(kips)	Real	12	0. ≤ X	0.
446-450	Unused at this time						

Appendix E

Program Reference

Finite Element Mesh Node Database

Purpose:	Contains all Finite Element mesh nodes, all boundary specifications
Used by:	TOPAZ, SAPRESS
Created by:	MSHDSP
Record Length:	65

NOTES:

1. Node/element lists are defined by number of first node/element, number of additional nodes/elements, and increment between nodes/elements.

2. Surface segment lists are defined by first node pair, number of additional segments and increment between node pairs.

3. Slideline surfaces defined by first node, last node, and increment between node identified by positive length of list. Slideline surfaces defined by list of nodes, separated by commas identified by negative length of list.

4. FORTRAN read/write format for each data item follows the description.

Header

Record	Description *[format]*	
1	Scans Id. 'Scans geo'	*[9a1]*
2	Title	*[65a1]*
3	Date of Mesh Generation	*[9a1]*
4	Time of Mesh Generation	*[9a1]*
5	Geometry DB Basic Dimensions Filename	*[12a1]*
6-10	Unused at this time	

Node Control Data

Record	Description *[format]*	
11	Number of Nodes (thermal)	*[i6]*
12	Number of Nodes (stress)	*[i6]*
13-21	Unused at this time	

Slide Line Control Data Data

Record	Description [*format*]	
22	Number of Slidelines	[*i6*]
23	Total Number of Slave Nodes	[*i6*]
24	Total Number of Master Nodes	[*i6*]
25	Number of Slave Nodes in Slideline 1	[*i6*]
26	Number of Master Nodes in Slideline 1	[*i6*]
26	Number of Slave Nodes in Slideline 2	[*i6*]
28	Number of Master Nodes in Slideline 2	[*i6*]
29	Unused at this time	

Boundary and Initial Conditions Control Data Data

Record	Description [*format*]	
30	Number of Elements with Heat Generation	[*i6*]
31	Number of Nodes with Non-Zero Temperature Initial Conditions	[*i6*]
32	Number of Nodes with Temperature Boundary Conditions	[*i6*]
33	Number of Cavity Boundary Segments	[*i6*]
34	Number of Outer Boundary Segments (Sections 2,3,4-Limiter)	[*i6*]
35	Number of Outer Boundary Segments (Section 2-Limiter Top)	[*i6*]
36	Number of Outer Boundary Segments (Section 3-Limiter Side)	[*i6*]
37	Number of Outer Boundary Segments (Section 4-Limiter Bot.)	[*i6*]
38	Number of Outer Boundary Segments (Section 5-H2OJkt. Side)	[*i6*]
39	Number of Outer Boundary Segments (Section 6-Limiter Bot. to shell)	[*i6*]
40	Number of Outer Boundary Segments (Sections 1->10-All Surf)	[*i6*]
41	Number of Outer Boundary Segments (Sections 2->10-Conv Surf)	[*i6*]
42	Number of Outer Boundary Segments (Sections 2->10-Rad Surf)	[*i6*]
43	Number of Outer Boundary Segments (Section 7-Limiter side to cask)	[*i6*]
44	Number of Outer Boundary Segments (Section 8-NS/WJ top to shell)	[*i6*]
45	Number of Outer Boundary Segments (Sections 9-NS/WJ top)	[*i6*]
46	Number of Outer Boundary Segments (Sections 10-Cask side)	[*i6*]
47-50	Unused at this time	

Slideline No. 1 Node Description

Record	Description [*format*]	
51	First Slave Node	[*i6*]
52	Last Slave Node	[*i6*]
53	Increment between Slave Nodes	[*i6*]
54	List of Slave Nodes separated by commas	[*65a1*]
55	First Master Node	[*i6*]
56	Last Slave Node	[*i6*]
57	Increment between Master Nodes	[*i6*]
58	List of Master Nodes separated by commas	[*65a1*]

Appendix E

Program Reference

Slideline No. 2 Node Description

Record	Description [*format*]	
59	First Slave Node	[*i6*]
60	Last Slave Node	[*i6*]
61	Increment between Slave Nodes	[*i6*]
62	List of Slave Nodes separated by commas	[*65a1*]
63	First Master Node	[*i6*]
64	Last Slave Node	[*i6*]
65	Increment between Master Nodes	[*i6*]
66	List of Master Nodes separated by commas	[*65a1*]

List of Elements With Heat Generation

Record	Description [*format*]	
67	First element	[*i6*]
68	Number of additional element	[*i6*]
69	Increment between elements	[*i6*]

List of Nodes With Non-Zero Temperature Initial Conditions

Record	Description [*format*]	
70	First node	[*i6*]
71	Number of additional nodes	[*i6*]
72	Increment between nodes	[*i6*]

List of Nodes Temperature Boundary Conditions

Record	Description [*format*]	
73	First node	[*i6*]
74	Number of additional nodes	[*i6*]
75	Increment between nodes	[*i6*]

Cavity Boundary Surface Segments

Record	Description [*format*]	
76	Node A of First Surface Segment	[*i6*]
77	Node B of First Surface Segment	[*i6*]
78	Number additional segments defined	[*i6*]
79	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Sections 2,3,4-Limiter)

Record	Description [*format*]	
80	Node A of First Surface Segment	[*i6*]
81	Node B of First Surface Segment	[*i6*]
82	Number additional segments defined	[*i6*]
83	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Section 2-Limiter Top)

Record	Description [*format*]	
84	Node A of First Surface Segment	[*i6*]
85	Node B of First Surface Segment	[*i6*]
86	Number additional segments defined	[*i6*]
87	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Section 3-Limiter Side)

Record	Description [*format*]	
88	Node A of First Surface Segment	[*i6*]
89	Node B of First Surface Segment	[*i6*]
90	Number additional segments defined	[*i6*]
91	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Section 4-Limiter Bottom)

Record	Description [*format*]	
92	Node A of First Surface Segment	[*i6*]
93	Node B of First Surface Segment	[*i6*]
94	Number additional segments defined	[*i6*]
95	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Section 5-Water Jacket Side)

Record	Description [*format*]	
96	Node A of First Surface Segment	[*i6*]
97	Node B of First Surface Segment	[*i6*]
98	Number additional segments defined	[*i6*]
99	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Section 6-Limiter Bot. to shell)

Record	Description [*format*]	
100	Two nodes separated by a comma	[*i3, 1x, i3*]

List of Inner Boundary Nodes With Pressure Conditions

Record	Description [*format*]	
101	First node	[*i6*]
102	Number of additional nodes	[*i6*]
103	Increment between nodes	[*i6*]

List of Outer Boundary Nodes With Pressure Conditions

Record	Description [*format*]	
104	First node	[*i6*]
105	Number of additional nodes	[*i6*]
106	Increment between nodes	[*i6*]

Outer Boundary Surface Segments (Section 7-Limiter Side to Cask Top)

Record	Description [*format*]	
107	Two nodes separated by a comma	[*i3, 1x, i3*]

Outer Boundary Surface Segments (Section 8-NS/WJ Top to Shell)

Record	Description [*format*]	
108	Two nodes separated by a comma	[*i3, 1x, i3*]

Outer Boundary Surface Segments (Section 9-NS/WJ Top)

Record	Description [*format*]	
109	Node A of First Surface Segment	[*i6*]
110	Node B of First Surface Segment	[*i6*]
111	Number additional segments defined	[*i6*]
112	Nodal increment between Node Pairs	[*i6*]

Outer Boundary Surface Segments (Section 10-Exposed Cask Side)

Record	Description [*format*]	
113	Node A of First Surface Segment	[*i6*]
114	Node B of First Surface Segment	[*i6*]
115	Number additional segments defined	[*i6*]
116	Nodal increment between Node Pairs	[*i6*]
117-120	Unused	

Nodal Description

Record	Description [*format*]
121	Node Coordinates (2 nodes per record for remainder of file)

i x(i) y(i) i+1 x(i+1) y(i+1) (each record)
format [*(i4, 1p2e14.7, 1x, i4, 1p2e14.7)*]

Finite Element Mesh Element Database

Purpose:	Contains all Finite Element mesh elements for Thermal and Stress analyses, and contains names of materials for each cask component
Used by:	TOPAZ, SAPRESS
Created by:	MSHDSP
Record Length:	65

NOTES:

1. FORTRAN read/write format for each data item follows the description.

Header

Record	Description [*format*]	
1	Scans Id. 'Scans geo'	[*9a1*]
2	Title [*65a1*]	
3	Date of Mesh Generation	[*9a1*]
4	Time of Mesh Generation	[*9a1*]
5	Geometry DB Basic Dimensions Filename	[*12a1*]
6-10	Unused at this time	

Node Control Data

Record	Description [*format*]	
11	Number of Elements (stress) NELS	[*i6*]
12	Number of Elements (thermal) NELT	[*i6*]
13	Number of Materials	[*i6*]
14	Material No. 1 ID Shell inner layer	[*8a1*]
15	Material No. 2 ID Shell shield layer	[*8a1*]
16	Material No. 3 ID Shell outer layer	[*8a1*]
17	Material No. 4 ID End cap inner layer	[*8a1*]
18	Material No. 5 ID End cap shield layer	[*8a1*]
19	Material No. 6 ID End cap outer layer	[*8a1*]
20	Material No. 7 ID Neutron shield	[*8a1*]
21	Material No. 8 ID Water jacket	[*8a1*]
22	Material No. 9 ID Impact limiter	[*8a1*]
23-30	Unused at this time	

Appendix E
Program Reference

4-Node Elements For Thermal Analyses

Record **Description** [*format*]
31 4-Node elements (2 per record) [*6i5,5x,6i5*]

en(n) m(n) i(n) j(n) k(n) l(n) en(n+1) m(n+1) i(n+1) j(n+1) k(n+1) l(n+1)

9-Node Elements For Stress Analyses

Record **Description** [*format*]
ii 9-Node elements (1 per record) [*11i5*]

en(n) m(n) n1(n) n2(n) n3(n) n4(n) n5(n) n6(n) n7(n) n8(n) n9(n)

The start of 9-node elements (ii) is calculated as follows

ii = 31 + (NELT+1)/2

Material Database

Purpose: Contains thermal/structural material properties
Used by: MATCK, IMPACT, TOPAZ, SAPRESS, SAPINPT, DATACK
Created by: EDITOR
Modified by: EDITOR
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	I d			Must be 'ACASK mat'	
2 \					
3 |					
4 |	-- Database name	Char	60		
5 |					
6 /					
8	File creation data	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 at this time				
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'	
46 \					
	Material name	Char	24		(blank)
47 /					
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	Dynamic Young's Modulus (psi)	Real	12	Positive	1.
53	Dynamic Poisson's Ratio	Real	12	$.001 \leq X \leq .499$	.3
54	Dynamic Yield Stress (psi)	Real	12	$0. \leq X$	0.
55	Dynamic Plastic Modulus (psi)	Real	12	$0. \leq X$	0.
56	Dynamic Ultimate Stress (psi)	Real	12	Yield stress $\leq X$	0.

Record	Description	Type	Length	Restrictions	Default
57	Dynamic Proportional Stress Limit (psi)	Real	12	Yield stress≥X	0.
58	Dynamic plastic Stress-Strain parameter σ_o (psi)+	Real	12	0. ≤X	0.
59	Dynamic plastic Stress-Strain parameter m+	Real	12	0.≤X	0.
60	***Unused***				
61	Melt Temperature (F)	Real	12	-459.≤X	10000.
62	Heat of Fusion (Btu/lbm)	Real	12	Positive	1.
63	Internal heat generation (Btu/in.**3 min)	Real	12	0.≤X	0.
64	***Unused***				
65	Material type	Int	1	x = 3	3.
66	Number of temperatures	Int	1	1≤X≤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.≤X	0.
72	Young's Modulus (psi)	Real	12	Positive	1.
73	Poisson's Ratio	Real	12	.001≤X≤.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.≤X≤1.	1.
78	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
79	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
80	***Unused***				
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
89	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
99	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
100	***Unused***				

+ σ_o and m are parameters in the analytical expressions, $\sigma = \sigma_o \varepsilon^m$ and $\sigma = \sigma_o \varepsilon_p{}^m + \sigma_p$, which define the dynamic-stress relation of the stainless steel and lead, respectively, at stress levels above the proportional stress limit. σ is the total stress corresponding to the total strain ε; ε_p is the plastic component of ε and σ_p is the proportional stress limit.

Record	Description	Type	Length	Restrictions	Default
91	Temperature 4 (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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
99	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
109	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
119	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
120	***Unused***				
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
129	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
139	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
140	***Unused***				

Record	Description	Type	Length	Restrictions	Default
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	ASME B&PV III NB Allowable SI, Sm (psi)	Real	12	Positive	1.
149	ASME B&PV III NB Tensile Strength, Su (psi)	Real	12	Positive	1.
150	***Unused***				

Impact Analysis Plot Database

Purpose:	Contains time history results for Impact Analysis
Used by:	PLTDYN
Created by:	IMPACT
Record Length:	36

NOTES:

1. FORTRAN read/write format for each data item follows the description.

2. Maximum number of nodal variables (NVAR) is 8.
   If NVAR=3, variables are:
   (1) FORCE, (2) SHEAR, (3) MOMENT
   If NVAR=8, variables are:
   (1) FORCE, (2) SHEAR, (3) MOMENT, (4) PERM. LEAD SLUMP
   (5) AXIAL STRESS (inner shell), (6) AXIAL STRESS (outer shell)
   (7) HOOP STRESS (inner shell), (8) HOOP STRESS (outer shell)

Header

Record	Description *[format]*	
1	Scans Id. 'Scans Imp'	*[9a1]*
2	Title	*[36a1]*
3	Title (continued)	*[29a1]*

Control Data

Record	Description *[format]*	
4	Number of time states (NTS)	*[2i5,f10.0,i5]*
	Number of nodes (NNODE)	
	Length of Cask (CLEN)	
	Number of nodal variables per node (NVAR)	

Plot Variable Data *(repeat for each time state)*

Record	Description *[format]*	
ii	Time, X(bottom),Y(bottom)	*[3f12.0]*
ii+1	Angle, X(top), Y(top)	*[3f12.0]*
ii+2	Node 1 Variables	*[(3f12.0)]*
	...	
jj	Node i Variables	*[(3f12.0)]*
	...	
kk	Node NNODE Variables	*[(3f12.0)]*

Start of time history for any node N: jj = 7 + (N-1)*((NVAR+2)/3)
Increment between time states for node: inc = 2 + NNODES*((NVAR+2)/3)

Appendix E
Program Reference
Thermal Analysis Plot Database

Purpose:	Contains Finite Element mesh elements for Thermal and Stress analyses. Also contains Thermal Analysis results (nodal temperatures)
Used by:	POSTPZ, SAPINPT
Created by:	TOPAZ
Record Length:	65

NOTES:

1. FORTRAN read/write format for each data item follows the description.
2. Number of states is 2 for steady state and is greater than 2 for transient.
3. Maximum number of model global variables is 5.
4. Maximum number of material global variables is 5 for each material.
5. Maximum number of nodal distribution variables is 5.
6. Global variables can be maximums, minimums, averages, etc.

Header

Record	Description [*format*]	
1	Scans Id. 'Scans tpp'	[*9a1*]
2	Title	[*65a1*]
3	Date of Analysis	[*9a1*]
4	Time of Analysis	[*9a1*]
5	Geometry DB Basic dimensions filename	[*12a1*]
6-10	Unused at this time	

Control Data

Record	Description [*format*]		
11	Number of Nodes (thermal)	[*i6*]	NODT
12	Number of Nodes (stress)	[*i6*]	NODS
13	Number of Elements (thermal)	[*i6*]	NELT
14	Number of Elements (stress)	[*i6*]	NELS
15	Number of Materials	[*i6*]	NMAT
16	Material No. 1 ID Shell inner layer	[*a8*]	
17	Material No. 2 ID Shell shield layer	[*a8*]	
18	Material No. 3 ID Shell outer layer	[*a8*]	
19	Material No. 4 ID End cap inner layer	[*a8*]	
20	Material No. 5 ID End cap shield layer	[*a8*]	
21	Material No. 6 ID End cap outer layer	[*a8*]	
22	Material No. 7 ID Neutron shield	[*a8*]	
23	Material No. 8 ID Water jacket	[*a8*]	
24	Material No. 9 ID Impact limiter	[*a8*]	

Control Data *(continued)*

Record	Description *[format]*	
25	Unused at this time	
26	Number of Time States	*[i6]* NTS
27	Maximum time of analysis	*[f12.0]*
28	Maximum temperature, state number, time	*[f12.0,i6,f12.0]*
29	Minimum pressure, state number, time Maximum pressure, state number, time	*[2(f12.0,i6,f12.0)]*
30	Number of Model Global Variables	*[i6]* NUMGV
31	Number of Material Global Variables	*[i6]* NUMMV
32	Number of Nodal Distribution Variables	*[i6]* NUMNV
33	Unused at this time	

Variable Descriptors

Record	Description *[format]*	
34	Time Descriptor and units	*[2a12]*
35	Length Descriptor and units	*[2a12]*
36	Model Global Var 1 Descriptor/units	*[2a12]*
37	Model Global Var 2 Descriptor/units	*[2a12]*
38	Model Global Var 3 Descriptor/units	*[2a12]*
39	Model Global Var 4 Descriptor/units	*[2a12]*
40	Model Global Var 5 Descriptor/units	*[2a12]*
41	Material Global Var 1 Descriptor/units	*[2a12]*
42	Material Global Var 2 Descriptor/units	*[2a12]*
43	Material Global Var 3 Descriptor/units	*[2a12]*
44	Material Global Var 4 Descriptor/units	*[2a12]*
45	Material Global Var 5 Descriptor/units	*[2a12]*
46	Nodal Variable 1 Descriptor/units	*[2a12]*
47	Nodal Variable 2 Descriptor/units	*[2a12]*
48	Nodal Variable 3 Descriptor/units	*[2a12]*
49	Nodal Variable 4 Descriptor/units	*[2a12]*
50	Nodal Variable 5 Descriptor/units	*[2a12]*

Nodal Description

Record	Description *[format]*	
51	Node Coordinates (2 nodes per record) i x(i) y(i) i+1 x(i+1) y(i+1) (each record)	*[i4,2f14.0,1x,i4,2f14.0]*

4-Node Elements for Thermal Analyses

Record	Description *[format]*	
ii	4-Node elements (2 per record) en(n) m(n) i(n) j(n) k(n) l(n) en(n+1) m(n+1) i(n+1) j(n+1) k(n+1) l(n+1) The start of 4-node elements (ii) is calculated as follows: ii = 51 + (NODT+1)/2	*[6i5,5x,6i5]*

9-Node Elements for Thermal Stress Analyses

Record	Description [*format*]
jj	9-Node elements 1 element per record [*11i5*] en(n) m(n) n1(n) n2(n) n3(n) n4(n) n5(n) n6(n) n7(n) n8(n) n9(n)

The start of 9-node elements (jj) is calculated as follows:

jj = ii + (NELT+1)/2

Plot Variable Data *(repeat for each time state)*

Record — **Description** [*format*]

kk — Time for state [*f12.0*]

The start of state data is calculated as follows:

kk = jj + NELS

ll — NUMGV model global variables 1 per record [*f12.0*]

Model Variable 1 = Maximum temperature
Model Variable 2 = Maximum pressure

The start of model global variables is calculated as follows:

ll = kk + 1

mm — NUMMV material global variables [*5f12.0*]

Each material variable is entered for all materials
Number of records for each variable is (NMAT+4)/5

The start of material global variables is calculated as follows:

mm = kk + 1 + NUMGV

nn — NUMNV nodal variables 5 nodes per record [*5f12.0*]

Nodal Variable 1 = Nodal temperature
Nodal Variable 2 = Nodal flux in global X direction
Nodal Variable 3 = Nodal flux in global Y direction

The start of a nodal variable is calculated as follows:

nn = kk + 1 + NUMGV + NUMMV*(NMAT+4)/5 + (NV-1)*(NODT+4)/5
where NV is the nodal variable number

Length of state is calculated as follows:

LEN = 1 + NUMGV + NUMMV*(NMAT+4)/5 + NUMNV*(NODT+4)/5

Description of Editor Templates

The **SCANS** 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 ≥ 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)

Appendix E

Program Reference

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)

Basic Geometry Template

```
Scans get
Template for SCANS basic geometry
06/23/88 at  1:12pm by Michael A. Gerhard
   143    16   163   230    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     General SAR Information             \  11          Y R  0  0
  2 2     Reviewer Information                \   4          Y O  0  0
  3 3     Cask Cavity/Contents Specifications \  13          Y R  0  0
  4 4     Cask Component Configurations       \   9          Y O  0  0
  5 5a    Cask Shell Specifications (SOLID)   \   5          N R  4  1 S
  6 5b    Cask Shell Specifications (LAMINATED) \ 14         N R  4  1 L
  7 6a    Cask Top End Cap Specifications (SOLID)  \  6    Y N R  4  3 S
  8 6b    Cask Top End Cap Specifications (LAMINATED)\ 13  Y N R  4  3 L
  9 7a    Cask Bottom End Cap Specifications (SOLID) \ -7  Y N R  4  5 S      15
 10 7b    Cask Bottom End Cap Specs (LAMINATED)    \ -8    Y N R  4  5 L      15
 11 8     Cask Closure Bolts Information      \   3          Y R  0  0
 12 9     CASK Neutron Shield / Water Jacket Specs  \  8     N R  4  9 Y
 13 10    CASK Top Impact Limiter Specifications    \  8   Y N R  4  7 Y
 14 11    CASK Bottom Impact Limiter Specifications \ -13  Y N R  4  8 Y      10
 15 12    Cask Impact Model Specifications    \  18          Y O  0  0
 16 12    Thermal transient analysis control params \ 10     N O  0  0
 1  1  46 R    3  0 SAR title\                                          c 54    14                                   0
 1  2  53      5  0 SAR docket number\                                  c  7  5 29                                   0
 1  3  51      5 40 SAR report number\                                  c 12  5 65                                   0
 1  4  54      7  0 SAR docket start date\                              c  8  7 29                                   0
 1  5  52      7 40 SAR report date\                                    c  8  7 65                                   0
 1  6  55      9  0 Add. info\                                          c 54    14                                   0
 1  7  60     11  0 Add. info\                                          c 54    14                                   0
 1  8  65     13  0 Add. info\                                          c 54    14                                   0
 1  9  70     15  0 Comp addr\                                          c 54    14                                   0
 1 10  75     17  0 Comp addr\                                          c 54    14                                   0
 1 11  80     19  0 Comp addr\                                          c 54    14                                   0
 2  1  85      3  0 Cask review leader name\                            c 24    35                                   0
 2  2  87      5  0 Thermal analyst name\                               c 24    35                                   0
 2  3  89      7  0 Structural analyst name\                            c 24    35                                   0
 2  4  91      9  0 Nucleonics analyst name\                            c 24    35                                   0
 3  1 101 R    3  0 Cavity inner radius (in.)\                          r 12    58 RG .001      2000.     0.0        0
 3  2 103 R    4  0 Cavity length (in.)\                                r 12    58 RG .001      2000.     0.0        0
 3  3 100 R    6  0 Gross weight of package (lbs)\                      r 12    58 PS                     0.0        0
 3  4 105 R    7  0 Weight of contents / internals (lbs)\               r 12    58 PS                     0.0        0
 3  5 106      9  0 Maximum heat generation rate of contents (Btu/min)\ r 12    58 GE 0.                  0.0        0
 3  6 107     11  0 Initial cavity charge pressure (psia)\              r 12    58 RG 0.        500.      14.7       0
```

Basic Geometry Template

```
3  7 108    12  0 Initial cavity charge temperature (deg.F)\                  r 12   58 RG -100.    300.    70.     0
3  8 109    13  0 Maximum normal operating pressure (psia)\                   r 12   58 RG 0.       2000.   14.7    0
3  9 110    15  0 Temperature defining stress free condition (deg.F)\         r 12   58 RG -100.    300.    70.     0
3 10   0    17  0 (Include the following to define 2-D finite-element mesh)\                                          0
3 11   0    18  0               (Mesh divisions must be even)\                                                        0
3 12 102    20  0 Number of mesh divisions along cavity inner radius\         i  2   58 ER 2.       20.     6.      0
3 13 104    21  0 Number of mesh divisions along cavity half length\          i  2   58 ER 2.       40.     8.      0
4  1 111     3  0 Shell configuration\                                        l  1   36    SL               S       0
4  2   0     4  0     [S=solid, L=laminated]\                                                                     0
4  3 112     6  0 Top end cap configuration\                                  l  1   36    SL               S       0
4  4   0     7  0     [S=solid, L=laminated]\                                                                     0
4  5 113     9  0 Bottom end cap configuration\                               l  1   36    SL               S       0
4  6   0    10  0     [S=solid, L=laminated]\                                                                     0
4  7 114    13  0 Is Top impact limiter present?          [Y/N]\              l  1   55    YN               Y       0
4  8 115    15  0 Is Bottom impact limiter present?       [Y/N]\              l  1   55    YN               Y       0
4  9 116    17  0 Is Neutron shield / water jacket present? [Y/N]\            l  1   55    YN               Y       0
5  1 121 R   3  0 Shell thickness (in.)\                                      r 12   32 RG .001     2000.   0.      0
5  2 122     5  0 Shell material name\                                        n  8   32    *.stm            SS304   0
5  3   0    10  0 (Include the following to define 2-D finite-element mesh)\                                          0
5  4   0    11  0               (Mesh divisions must be even)\                                                        0
5  5 123    13  0 Number of mesh divisions through shell\                     i  2   46 ER 2.       10.     4.      0
6  1 124 R   3  0 Shell inner  layer thickness (in.)\                         r 12   52 RG 0.       2000.   0.      0
6  2 134     4  0  Additional thickness at end cap interface (in.)\           r 12   52 RG 0.       2000.   0.      0
6  3 125     5  0 Shell inner  layer material name\                           n  8   52    *.stm            SS304   0
6  4 127 R   7  0 Shell shield layer thickness (in.)\                         r 12   52 RG 0.       2000.   0.      0
6  5 128 R   8  0 Shell shield length (in.)\                                  r 12   52 RG 0.       2000.   0.      0
6  6 129     9  0 Shell shield layer material name\                           n  8   52    *.shm            LEAD    0
6  7 131 R  11  0 Shell outer  layer thickness (in.)\                         r 12   52 RG .001     2000.   0.      0
6  8 135    12  0  Additional thickness at end cap interface (in.)\           r 12   52 RG 0.       2000.   0.      0
6  9 132    13  0 Shell outer  layer material name\                           n  8   52    *.stm            SS304   0
6 10   0    16  0 (Include the following to define 2-D finite-element mesh)\                                          0
6 11   0    17  0               (Mesh divisions must be even)\                                                        0
6 12 126    19  0 Number of mesh divisions through shell inner  layer\        i  2   62 ER 2.       10.     2.      0
6 13 130    20  0 Number of mesh divisions through shell shield layer\        i  2   62 ER 2.       10.     4.      0
6 14 133    21  0 Number of mesh divisions through shell outer  layer\        i  2   62 ER 2.       10.     2.      0
7  1 136 R   3  0 End cap thickness (in.)\                                    r 12   31 RG .001     2000.   0.      0
7  2 137     5  0 End cap material name\                                      n  8   31    *.stm            SS304   0
7  3   0    10  0 (Include the following to define 2-D finite-element mesh)\                                          0
7  4   0    11  0               (Mesh divisions must be even)\                                                        0
7  5 138    13  0 Number of mesh divisions through end cap\                   i  2   45 ER 2.       10.     4.      0
7  6   0    19  0 Press  F10  to copy data from other end cap (if it is SOLID)\                                       0
8  1 139 R   3  0 End cap inner layer thickness (in)\                         r 12   44 RG 0.       2000.   0.      0
8  2 140     4  0 End cap inner layer material name\                          n  8   44    *.stm            SS304   0
```

Basic Geometry Template

```
 8  3 142 R    6  0 End cap shield layer thickness (in.)\                              r 12   44 RG 0.      2000.    0.        0
 8  4 143 R    7  0 End cap shield layer radius (in.)\                                 r 12   44 RG 0.      2000.    0.        0
 8  5 144      8  0 End cap shield layer material name\                                n  8   44    *.shm           LEAD      0
 8  6 146 R   10  0 End cap outer layer thickness (in.)\                               r 12   44 RG .001    2000.    0.        0
 8  7 147     11  0 End cap outer layer material name\                                 n  8   44    *.stm           SS304     0
 8  8   0     13  0 (Include the following to define 2-D finite-element mesh)\                                              0
 8  9   0     14  0            (Mesh divisions must be even)\                                                               0
 8 10 141     16  0 Number of mesh divisions through end cap inner layer\              i  2   61 ER 2.      10.      2.        0
 8 11 145     17  0 Number of mesh divisions through end cap shield layer\             i  2   61 ER 2.      10.      4.        0
 8 12 148     18  0 Number of mesh divisions through end cap outer layer\              i  2   61 ER 2.      10.      2.        0
 8 13   0     21  0 Press  F10  to copy data from other end cap (if it is LAMINATED)\                                       0
11  1 169 R    3  0 Number of closure bolts\                                           i  2   50 RG 1.      99.      0.        0
11  2 170 R    5  0 Diameter of closure bolts (in.)\                                   r 12   50 RG .001    10.      0.        0
11  3 168 R    7  0 Closure bolt circle radius (in.)\                                  r 12   50 RG .001    2000.    0.        0
12  1 176 R    3  0 Neutron shield/waterjacket length (in.)\                           r 12   52 RG 0.      2000.    0.        0
12  2 177 R    5  0 Neutron shield thickness (in.)\                                    r 12   52 RG 0.      2000.    0.        0
12  3 178      6  0 Neutron shield material name\                                      n  8   52    *.nsm           H2OCONV   0
12  4 180 R    8  0 Water jacket thickness (in.)\                                      r 12   52 RG 0.      2000.    0.        0
12  5 181      9  0 Water jacket material name\                                        n  8   52    *.wjm           SS304     0
12  6   0     14  0 (Include the following to define 2-D finite-element mesh)\                                              0
12  7 179     16  0 Number of mesh divisions through neutron shield\                   i  2   55 RG 1.      9.       1.        0
12  8 182     17  0 Number of mesh divisions through water jacket\                     i  2   55 RG 1.      9.       1.        0
13  1 186 R    3  0 Impact limiter radius (in.)\                                       r 12   50 RG .001    2000.    0.        0
13  2 187 R    5  0 Impact limiter center line thickness (in.)\                        r 12   50 RG .001    2000.    0.        0
13  3 189 R    7  0 Impact limiter overhang thickness (in.)\                           r 12   50 RG 0.      2000.    0.        0
13  4 191      9  0 Impact limiter material name\                                      n  8   50    *.ilm           POLYFOAM  0
13  5   0     12  0 (Include the following to define 2-D finite-element mesh)\                                              0
13  6 188     14  0 Number of mesh divisions through limiter CL thickness\             i  2   63 RG 1.      10.      4.        0
13  7 190     16  0 Number of mesh divisions through limiter overhang width\           i  2   63 RG 1.      10.      3.        0
13  8   0     20  0 Press  F10  to copy data from other impact limiter\                                                     0
15  1 206      3  0 Number of elements for 1-D impact model\                           i  2   47 RG 3.      20.      4.        0
15  2 207      4  0 TOP Impact limiter weight (lbs)\                                   r 12   47 GE 0.               0.        0
15  3 208      5  0 BOTTOM Impact limiter weight (lbs)\                                r 12   47 GE 0.               0.        0
15  4   0      6  0 (If omitted, weights are calculated based on volume and density)\                                       0
15  5 209   Y  8  0 Define impact model with user specified properties? [Y/N]\         1  1   65    YN              N         0
15  6   0      9  0   NOTE - Weight of contents must be defined (Page 3)\                                                   0
15  7   0     10  0          No stress recovery is available for user defined casks\                                        0
15  8 210 R   11  5 Shell translational mass (lb-sec**2/in)\                           r 12   57 PS                  0.        0
15  9 211 R   12  5 Shell rotational mass (lb-sec**2-in)\                              r 12   57 PS                  0.        0
15 10 212 R   13  5 Shell inside length (in.)\                                         r 12   57 PS                  0.        0
15 11 213 R   14  5 Shell E*I (lb-in**2)\                                              r 12   57 PS                  0.        0
15 12 214 R   15  5 Shell A*E (lb)\                                                    r 12   57 PS                  0.        0
15 13 220 R   16  5 Shell composite Poisson's Ratio\                                   r 12   57 PS                  0.        0
```

Basic Geometry Template

```
15 14 215 R   17  5 Top end translational mass (lb-sec**2/in)\              r 12   57 PS                     0.     0
15 15 216 R   18  5 Top end rotational mass (lb-sec**2-in)\                 r 12   57 PS                     0.     0
15 16 217 R   19  5 Bottom end translational mass (lb-sec**2/in)\           r 12   57 PS                     0.     0
15 17 218 R   20  5 Bottom end rotational mass (lb-sec**2-in)\              r 12   57 PS                     0.     0
15 18 219 R   21  5 Characteristic cross-section width (in)\                r 12   57 PS                     0.     0
16  1 221      3  0 Allow phase change? [Y/N]\                              l  1   57    YN                  N      0
16  2 222      5  0 Time between printed output (min.)\                     r 12   57 RG 10.      360.       30.    0
16  3 223      6  0 Time between plotted output (min.)\                     r 12   57 RG 2.       30.        5.     0
16  4 224      8  0 Use variable time step? [Y/N]\                          l  1   57    YN                  Y      0
16  5 225     10  0 Iteration convergence tolerance\                        r 12   57 RG .001     .1         .001   0
16  6 226     11  0 Iteration relaxation parameter\                         r 12   57 RG .3       1.         1.     0
16  7 227     13  0 Maximum allowable time step for variable TS (min.)\     r 12   57 RG 5.       30.        30.    0
16  8 228     14  0 Maximum temperature change per time step (F)\           r 12   57 RG 25.      100.       100.   0
16  9 229     15  0 Time step modification factor for variable TS\          r 12   57 RG 2.       6.         2.     0
16 10 230     17  0 Fixed time step size for fixed TS (min.)\               r 12   57 RG .25      5.         .5     0
```

Impact Limiter Force-D 'emplate

```
Scans lmt
Template file for LIMITER  editor
05/05/88 at  4:47pm  by Michael Gerhard
   56    17   150    450    12
(bn,5x,i4,2(1x,a1),2(1x,i2),1x,a74,1x,a1,3(1x,i2),1x,a2,1x,a21,1x,a14,1x
  1 0     Impact Limiter Unloading Specification     \  8            Y C
  2 1a    Bottom Impact Limiter for 0 degree impact  \ 26          Y Y C
  3 1b    Bottom Impact Limiter for 15 degree impact \ -2          Y Y C
  4 1c    Bottom Impact Limiter for 30 degree impact \ -2          Y Y C
  5 1d    Bottom Impact Limiter for 45 degree impact \ -2          Y Y C
  6 1e    Bottom Impact Limiter for 60 degree impact \ -2          Y Y C
  7 1f    Bottom Impact Limiter for 75 degree impact \ -2          Y Y C
  8 1g    Bottom Impact Limiter for 90 degree impact \ -2          Y Y C
  9 1h    Bottom Impact Limiter for C.G. impact      \ -2          Y Y C
 10 2a    Top Impact Limiter for 0 degree impact     \ -2          Y Y C
 11 2b    Top Impact Limiter for 15 degree impact    \ -2          Y Y C
 12 2c    Top Impact Limiter for 30 degree impact    \ -2          Y Y C
 13 2d    Top Impact Limiter for 45 degree impact    \ -2          Y Y C
 14 2e    Top Impact Limiter for 60 degree impact    \ -2          Y Y C         300
 15 2f    Top Impact Limiter for 75 degree impact    \ -2          Y Y C         325
 16 2g    Top Impact Limiter for 90 degree impact    \ -2          Y Y C         350
 17 2h    Top Impact Limiter for C.G. impact         \ -2          Y Y C         375
 0 1          4  2  Select the slope of the unloading path for impact limiters\
```

Impact Limiter Force-Deflection Curves Template

```
0  2          6  4  C -- Unloading slope is maximum slope of limiter curve\                                                          0
0  3          7  4  N -- No elastic recovery of impact limiter\                                                                      0
0  4          8  4       (Approximated by unloading slope of 5 times max slope of curve)\                                           0
0  5          9  4  U -- User specified unloading slope\                                                                             0
0  6   48   U 11  3 Type of Impact Limiter Unloading\                                  1  1    50    UNC              N             0
0  7   49 R   13  3 User specified unloading slope (kips/inch)\                        r 12    50 PS                  0.            0
0  8          15  4  Unloading slope is KIPS of unloading per inches elastic recovery\                                               0
1  1           3  0 Press  F10  to copy Force/Deflection data from another impact angle\                                             0
1  2           5  0 Impact angle is defined as follows:  SIDE impact angle is 0.\                                                    0
1  3           6  0                                   END ON impact angle is 90.\                                                    0
1  4   50   Y  8  0 Do you wish to define a Deflection/Force curve for this angle ? [Y/N]\   1  1    77    YN               N             0
1  5          10 13   You must define at least 2 deflection/force pairs\                                                             0
1  6          11  4 Deflection #0  (in)    .0              Force #0  (kips)    .0\                                                   0
1  7   51 R   12  4 Deflection #1  (in)\                                               r 12    27 PS                  0.            0
1  8   52 R   12 45 Force #1  (kips)\                                                  r 12    65 PS                  0.            0
1  9   53 R   13  4 Deflection #2  (in)\                                               r 12    27 PS                  0.            0
1 10   54 R   13 45 Force #2  (kips)\                                                  r 12    65 PS                  0.            0
1 11   55     14  4 Deflection #3  (in)\                                               r 12    27 GE 0.               0.            0
1 12   56     14 45 Force #3  (kips)\                                                  r 12    65 GE 0.               0.            0
1 13   57     15  4 Deflection #4  (in)\                                               r 12    27 GE 0.               0.            0
1 14   58     15 45 Force #4  (kips)\                                                  r 12    65 GE 0.               0.            0
1 15   59     16  4 Deflection #5  (in)\                                               r 12    27 GE 0.               0.            0
1 16   60     16 45 Force #5  (kips)\                                                  r 12    65 GE 0.               0.            0
1 17   61     17  4 Deflection #6  (in)\                                               r 12    27 GE 0.               0.            0
1 18   62     17 45 Force #6  (kips)\                                                  r 12    65 GE 0.               0.            0
1 19   63     18  4 Deflection #7  (in)\                                               r 12    27 GE 0.               0.            0
1 20   64     18 45 Force #7  (kips)\                                                  r 12    65 GE 0.               0.            0
1 21   65     19  4 Deflection #8  (in)\                                               r 12    27 GE 0.               0.            0
1 22   66     19 45 Force #8  (kips)\                                                  r 12    65 GE 0.               0.            0
1 23   67     20  4 Deflection #9  (in)\                                               r 12    27 GE 0.               0.            0
1 24   68     20 45 Force #9  (kips)\                                                  r 12    65 GE 0.               0.            0
1 25   69     21  4 Deflection #10 (in)\                                               r 12    27 GE 0.               0.            0
1 26   70     21 45 Force #10 (kips)\                                                  r 12    65 GE 0.               0.            0
```

Material Properties Template

```
ACASK mat
Template for AUTOCASK  Cask Geometry
Modified on 03 Nov 93  at  9:15am by Gerald Mok
    51    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-Dependent Properties           \   2         Y R  0  0
  4 4a   Temperature 1 Properties                   \   7         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
 12 4h   Dummy page for hidden properties           \  11         N O  0  0
 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 buckling\                                     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 \                                                                                            0
 2  8         14  0 Åo and m define the stress-strain relation at stress levels\                                 0
 2  9         15  0 above the proportional stress limit according to  Å = Åo * Ó**m\                            0
 2 10  57     17  0 Proportional stress limit (psi)\                            r 12   45 GE 0.             0.0      0
 2 11  58     18  0 Åo (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  77 R    8  0 ASME B&PV III NB Allowable SI, Sm (psi)\                    r 12   45 GE 0.             0.       0
 4  5  78 R    9  0 ASME B&PV III NB Tensile Strength, Su (psi)\                r 12   45 GE 0.             0.       0
 4  6  74     11  0 Coefficient of thermal expansion (in./in.F)\                r 12   45                   0.       0
 4  7  75     12  0 Thermal conductivity (Btu/in.min F)\                        r 12   45 PS                1.       0
 4  8  76     13  0 Specific heat capacity (Btu/lbm F)\                         r 12   45 PS                1.       0
```

Material Properties Template

```
12  1  61     4  0 Melt Temperature (F)\                                r 12    45 GE -459.             10000.      0
12  2  62     5  0 Heat of Fusion (Btu/lbm)\                            r 12    45 PS                    1.         0
12  3  63     6  0 Internal heat generation (Btu/in.**3 min)\           r 12    45 GE 0.                 0.         0
12  4  77     7  0 Thermal emissivity for radiation\  temp 1            r 12    45 RG 0.        1.       1.         0
12  5  87     8  0 Thermal emissivity for radiation\  temp 2            r 12    45 RG 0.        1.       1.         0
12  6  97     9  0 Thermal emissivity for radiation\  temp 3            r 12    45 RG 0.        1.       1.         0
12  7 107    10  0 Thermal emissivity for radiation\  temp 4            r 12    45 RG 0.        1.       1.         0
12  8 117    11  0 Thermal emissivity for radiation\  temp 5            r 12    45 RG 0.        1.       1.         0
12  9 127    12  0 Thermal emissivity for radiation\  temp 6            r 12    45 RG 0.        1.       1.         0
12 10 137    13  0 Thermal emissivity for radiation\  temp 7            r 12    45 RG 0.        1.       1.         0
12 11 147    14  0 Thermal emissivity for radiation\  temp 8            r 12    45 RG 0.        1.       1.         0
```

Appendix E
Program Reference

Data Set File Naming Conventions

SCANS data set files have 12 character names which specify the CASK ID, the analysis case, and the file type. File names are of the form:

```
IIIICCCC·TTT
____ ____ ___
  |    |    |
  |    |    * File Type
  |    * Analysis Case (or data name)
  * CASKID
```

Data Files

CCCC.TTT identifies the data type database:

BASE.GEI	=	Basic Geometry Database
BASE.CHK	=	Basic Geometry Data Check Output
LMTR.LMI	=	Limiter Force-Deflection Curves Database
LMTR.CHK	=	Limiter Force-Deflection Curves Data Check Output
DATA.FLG	=	Data Check Flags for Basic Geometry and Limiter Databases
NODE.GEO	=	Finite Element Mesh Node Database
ELEM.GEO	=	Finite Element Mesh Element Database

Impact Analysis Files

CCCC.TTT identifies the analysis parameters and type and is of the form

```
HETD·AAO
_ _ _ _ __ _
| | | | |  |
| | | | |  * Output Type
| | | | * Analysis Type
| | | * Impact Angle
| | * Impact Type
| * Primary Impact End
* Drop Height
```

where the individual parameters are

Drop Height	**Impact End**	**Impact Type**	**Impact Angle**	**Analysis Type**	**Output Type**
A=30 ft	**T**=Top	**P**=Primary only	**0**= 0 deg	**QB**=Quasi-Static (bonded)	**O**=Printable
1= 1 ft	**B**=Bottom	**S**=Primary with Secondary	**1**=15 deg	**QU**=Quasi-Static (unbonded)	**P**=Plot file
2= 2 ft			**3**=30 deg	**IB**=Dynamic (bonded)	
3= 3 ft			**4**=45 deg	**IU**=Dynamic (unbonded)	
4= 4 ft			**6**=60 deg		
5= 5 ft			**7**=75 deg		
:			**9**=90 deg		
9 = 9 ft			**C**=C.G. drop		
B=11 ft					

C=12 ft
:
T=29 ft
U=10 ft
V=35 ft
W=40 ft
X=50 ft
Y=60 ft
Z=80 ft

Thermal Analysis Files

CCCC identifies the analysis case:

- **T1RG** = Cold Soak, Contents Heat, No Solar Effects
- **T2RG** = Cold Soak, No Contents Heat, No Solar Effects
- **T3RG** = Normal Cold, Contents Heat, No Solar Effects
- **T4RG** = Normal Cold, No Contents Heat, No Solar Effects
- **T5RG** = Normal Hot, Contents Heat, Solar Effects
- **T6RG** = Normal Hot, Contents Heat, No Solar Effects
- **T7RG** = Fire Accident, Contents Heat, No Solar Effects

- **UACU** = Customized thermal analysis case UA

TTT identifies the output type:

- **TPO** = Printable output
- **TPP** = Plot file for POSTPZ

Thermal Stress Analysis Files

CCCC identifies the analysis case:

- **T1RG** = Cold Soak, Contents Heat, No Solar Effects
- **T2RG** = Cold Soak, No Contents Heat, No Solar Effects
- **T3RG** = Normal Cold, Contents Heat, No Solar Effects
- **T4RG** = Normal Cold, No Contents Heat, No Solar Effects
- **T5RG** = Normal Hot, Contents Heat, Solar Effects
- **T6RG** = Normal Hot, Contents Heat, No Solar Effects
- **T7RG** = Fire Accident, Contents Heat, No Solar Effects

- **UACU** = Customized thermal analysis case UA

TTT identifies the output type:

- **TSO** = Printable output

Pressure Stress Analysis Files

CCCC identifies the internal and external pressure conditions and is of the form:

IIEE

* External Pressure
* Internal Pressure

Where the internal and external pressures are identified as follows:

Internal Pressure	External Pressure	
MX=Maximum Normal Operating Pressure	**RP**=Reduced pressure	(3.5 psia)
Tn=Pressure from Thermal case n	**AP**=Atmospheric pressure	(14.7 psia)
UA=Pressure from Customized Thermal case UA	**IP**=Increased Pressure	(20.0 psia)
	IM=Accident Immersion	(35.7 psia)

TTT identifies the output type:
- **PSO** = Printable output

Load Combination Analysis Files

CCCC identifies the analysis case:
- L1RG = Hot environment
- L2RG = Cold environment
- L3RG = Increased external pressure
- L4RG = Reduced external pressure
- L5RG = Normal free drop, maximum internal pressure
- L6RG = Normal free drop, minimum internal pressure
- L7RG = Accident free drop, maximum internal pressure
- L8RG = Accident free drop, minimum internal pressure
- L9RG = Fire accident

- UACU = Customized load combination case UA

TTT identifies the output type
- LCO = Printable output

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

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

(See instructions on the reverse)

1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.)

NUREG/CR-4554, Vol. 1, Rev. 2
UCID-20674

2. TITLE AND SUBTITLE

SCANS (Shipping Cask ANalysis System) A Microcomputer Based Analysis System for Shipping Cask Design Review

User's Manual to Version 3a

3. DATE REPORT PUBLISHED

MONTH	YEAR
March	1998

4. FIN OR GRANT NUMBER

A0291

5. AUTHOR(S)

G.C. Mok, G.R. Thomas, M.A. Gerhard, D.J. Trummer, G.L. Johnson

6. TYPE OF REPORT

Technical

7. PERIOD COVERED *(Inclusive Dates)*

8. PERFORMING ORGANIZATION - NAME AND ADDRESS *(If NRC, provide Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address; if contractor, provide name and mailing address.)*

Lawrence Livermore National Laboratory
7000 East Avenue
Livermore, CA 94550

9. SPONSORING ORGANIZATION - NAME AND ADDRESS *(If NRC, type "Same as above"; if contractor, provide NRC Division, Office or Region, U.S. Nuclear Regulatory Commission, and mailing address.)*

Spent Fuel Project Office
Office of Nuclear Materials Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

SCANS (Shipping Cask ANalysis System) is a microcomputer based system of computer programs and databases developed at the Lawrence Livermore National Laboratory (LLNL) for evaluating safety analysis reports on spent fuel shipping casks. SCANS is an easy-to-use system that calculates the global response to impact loads, pressure loads and thermal conditions, providing reviewers with an independent check on analyses submitted by licensees. SCANS is based on microcomputers compatible with the IBM-PC family of computers. The system is composed of a series of menus, input programs, cask analysis programs, and output display programs. All data is entered through fill-in-the blank input screens that contain descriptive data requests. Analysis options are based on regulatory cases described in the Code of Federal Regulations 10 CFR 71 and Regulatory Guides published by the U.S. Nuclear Regulatory Commission in 1977 and 1978.

12. KEY WORDS/DESCRIPTORS *(List words or phrases that will assist researchers in locating the report.)*

SCANS (Shipping Cask ANalysis System)
Packaging for transport of radioactive materials
10 CFR 71
Normal conditions of transport
Hypothetical accident conditions
Evaluating packaging safety analysis reports

13. AVAILABILITY STATEMENT

unlimited

14. SECURITY CLASSIFICATION

(This Page) unclassified

(This Report) unclassified

15. NUMBER OF PAGES

16. PRICE