

Repair Assessment Procedure and Integrated Design

RAPID

Version 2.1

User's Manual

June 1998

RAPID Disclaimer

The development of the RAPID software program was funded by the Federal Aviation Administration (FAA) and the USAF and is provided to the user as is. Neither the FAA nor the U.S. Government warrants the merchantability of the software nor its fitness for a particular use. Use of RAPID or its output does not replace or change any part of the repair or alteration approval process. Users of RAPID must obtain approval of any repair or alteration designed or analyzed with RAPID with the same procedures as with any other analysis tool. A repair design from RAPID should never supersede that supplied by the original equipment manufacturer (OEM). RAPID should be considered an alternative design tool whenever a repair procedure is not provided or is not available from the OEM. In no instance will the U.S. Government be liable for any damages sustained by the user, or any third party, caused by or attributed to the use of the RAPID software.

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1. Introduction

This document provides installation and usage instructions for the Repair Assessment Procedure and Integrated Design (RAPID) program. It should be read by any user who is not already familiar with running the current version of RAPID. In the companion document, Repair Assessment Procedure and Integrated Design RAPID Version 2.1, Analysis Methodology Document, technical details of the analysis methodology used in the program are provided.

RAPID is a tool for the design and analysis of aircraft structural repairs. This version assists the user in designing mechanically fastened fuselage skin repairs with up to three doublers. RAPID performs both static and damage tolerance analyses of the repair. The static analysis determines if the doublers and fasteners are statically adequate, while the damage tolerance analysis yields inspection intervals and residual strength.

2. Requirements

The following are the minimum hardware and software requirements for installing and running the RAPID software:

- 386 PC (a 486 or better is highly recommended).
- Math coprocessor if the CPU is a 386 or 486sx. (The coprocessor reduces run times for damage tolerance analysis from hours to minutes.)
- Windows 3.1 running in enhanced mode. Although RAPID is a Windows 3.1 program, it has been tested within and runs under Windows 95 and Windows NT v4.0.
- Hard disk with 25 megabytes free disk space. The load spectra, if generated, require an additional 5 to 25 megabytes each.
- 4 megabytes random access memory (RAM) (8 megabytes or more is preferred). Windows 95 and NT require additional memory.
- 3.5 inch 1.44MB floppy disk drive.
- VGA (Super VGA, 800 by 600 dpi resolution or higher is recommended).
- Mouse or track-ball recommended.

3. RAPID Program Notes and Limitations

This section lists graphical user interface notes and program limitations for the current version of RAPID. Updated versions of this information will be available in RAPID from the **Readme Information** menu item in the **Help** pull-down menu.

3.1 RAPID Graphical User Interface Notes

3.1.1 Help Keys and Buttons

The F1 key will bring up HELP in any module. The help will be module specific. However, once in HELP, other areas of HELP can be accessed. Each module has a HELP button that acts like the F1 key.

3.1.2 Checking Cutout Properties

Checking the cutout information through the menu or cutout button after the cutout is drawn does not work. As a work around, the cutout information may be accessed by selecting the cutout with the mouse and then clicking with the right mouse button on the cutout. This problem is scheduled to be corrected in a later version of RAPID.

3.1.3 Cutout Display Problem

If the cutout is initially drawn after the display has been scrolled horizontally or vertically, the cutout will be displayed in the wrong location, although the geometry is stored correctly. Resetting the zoom to 100% will display the cutout correctly. This problem is scheduled to be corrected in a later version of RAPID.

3.1.4 Conflict with PC-Xware

RAPID will not run when PC-Xware is installed in Windows.

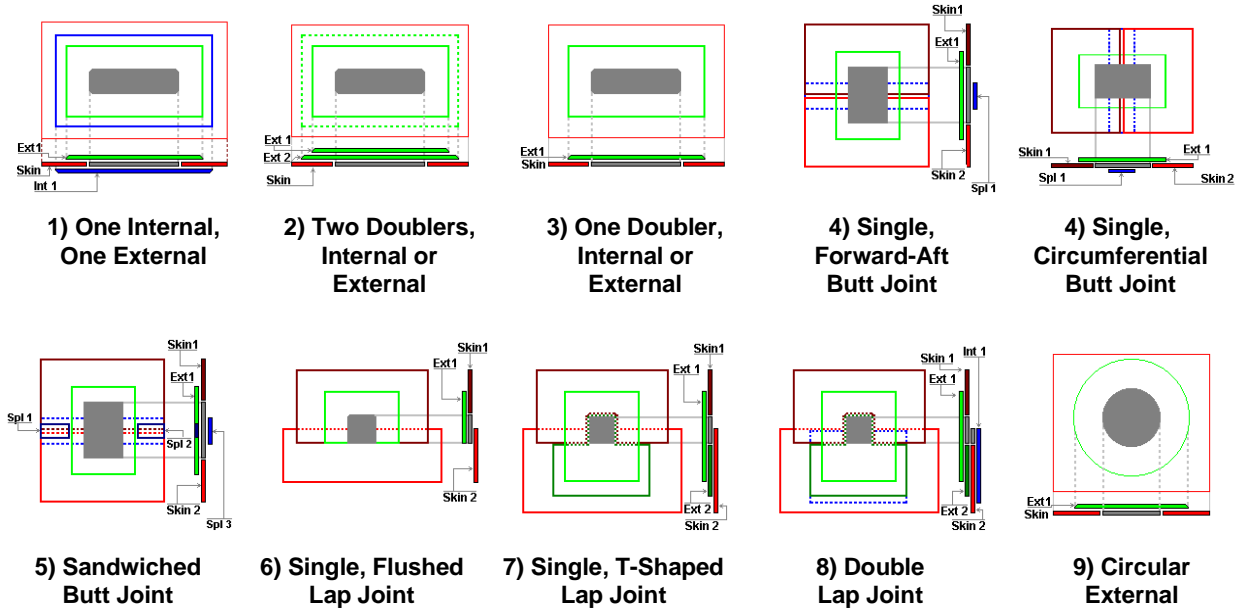
3.2 Analysis General Notes and Program Limitations

The RAPID version 2.1 program performs static strength and damage tolerance analysis of a repaired fuselage skin which involves a damage treatment of the skin cutout and replacement of the removed skin with repair doublers. The repair doublers are mechanically fastened to the skin. The following addresses the analysis capability of the current version of the program.

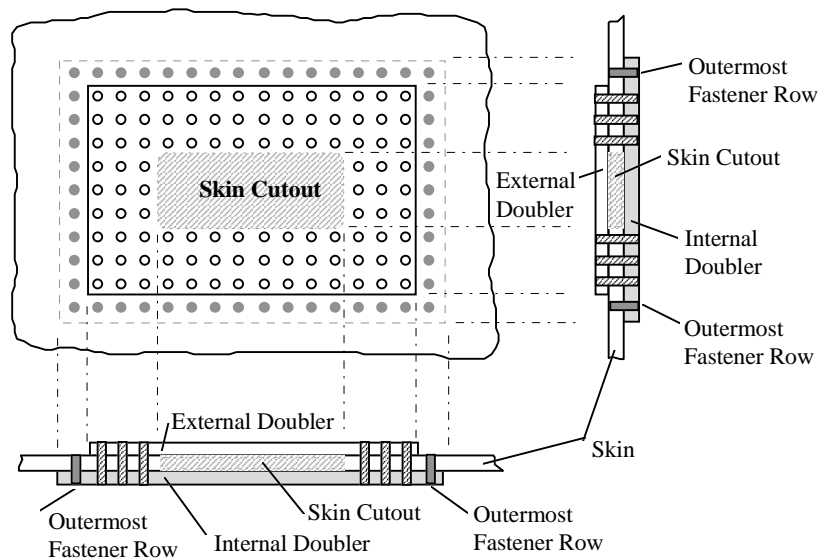
3.2.1 General

- a. Repairs are restricted to fuselage skin repairs between forward and aft pressure bulkheads, but away from door cutouts, window cutouts, and window belt structure. This is also not applicable to pressure bulkheads or flat pressure panels.
- b. The fuselage is assumed to be circular with a constant radius. The repairs are limited to areas on the airplane where the hoop stress due to pressurization can be approximated using a cylindrical pressure vessel analysis.

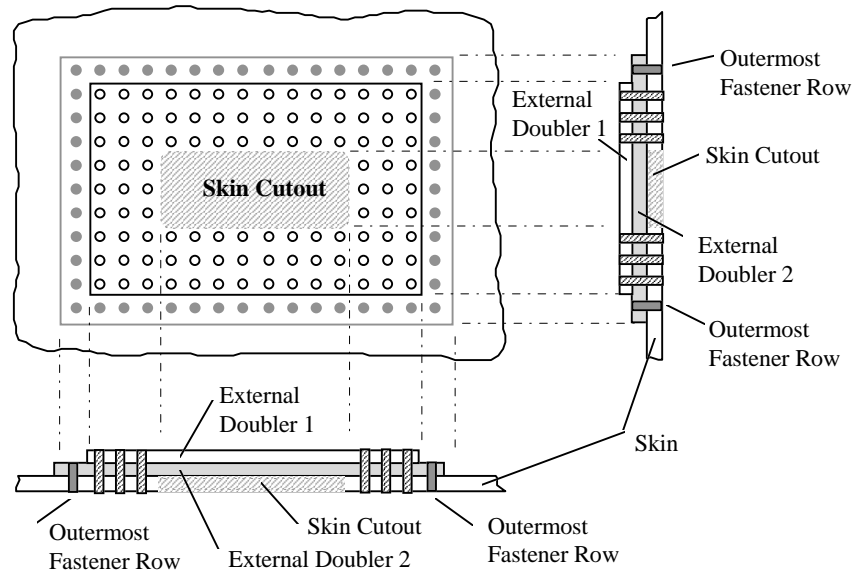
- c. Damage due to accidental or cracking causes is only in one skin layer except the lap joint repairs which both upper and lower skins may be
- d. Skin cutout and repair doublers are rectangular or circular in shape. For rectangular repairs, the orientation is such that two of the four sides are in the hoop stress direction and the other two are in the longitudinal stress direction.
- e. Nine repair configurations are included as depicted in the following figure:



- f. For Type 1 repairs, only one outstanding fastener row (beyond the external doubler) is allowed in the internal doubler.



- g. For Type 2 repairs, only one outstanding fastener row (beyond the external doubler number 1) is allowed in the external doubler next to the skin.



- h. The program is capable of assessing common repairs such as a repair near another repair, repairs near stiffeners, and repairs at joints.

- i. The following restrictions are applied to the RAPID 2.1

- For a repair near another repair:
Only Type 1, 2, and 3 repairs are considered.
- For repairs at/near stiffeners:
Only Type 1, 2, and 3 repairs and repairs over splice joints are considered.
- For a repair at/near stiffeners near another repair:
Only Type 1, 2, and 3 repairs are considered.

- j. Repairs are limited to the following sizes

- Skin cutout size (Add 3 ~ 5 fastener rows to determine the repair size)
 - Type 1,2,3 repairs: 30" (Long.) x 20" (Circumferential)
 - Circular repairs: 5" (Radius)
 - Butt joint repairs: 20" (Long.) x 10" (Circumferential)
 - Lap joint repairs: 20" (Long.) x 5" (Circumferential)
- Skin cutout size in proximate repairs

- Subject repair: 30" (Long.) x 20" (Circumferential)
- Proximate repair: 25" (Long.) x 25" (Circumferential)

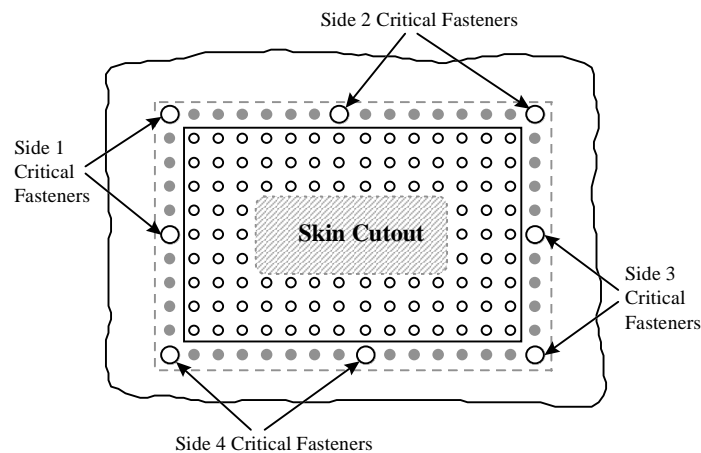
k. The static strength and damage tolerance analyses are limited to material and fastener databases available in RAPID.

3.2.2 Static Strength Analysis

- a. Static strength analysis is performed using the fastener joint allowable, the repair doubler allowable, and the shear allowable of skin and doubler. The margins of safety are calculated and flagged to testify adequacy of the repair. The stiffness ratios between the repair doublers and skin layers are checked and flagged to indicate whether the repair is too stiff or not stiff enough. Fastener bending and inter-rivet buckling guidelines are provided in the Advisory System.
- b. The load carrying capacity lost due to skin cutout is calculated using the design ultimate tensile strength and cutout size of the skin.
- c. The database of fastener joint allowables is built using the data in the MIL-HDBK-5F. [1]

3.2.3 Damage Tolerance Analysis

- a. In a repaired skin, the load transfer at the corner fastener tends to be higher than that at the center fastener. Load transfers along the critical fastener row are obtained using the two-dimensional analysis of the repaired skin with the fastener shear stiffness calculated using the Swift's equation [2]. It is noted that the fastener loads are calculated for the un-cracked repaired skin configuration; and the load transfer in each fastener remains constant in the damage tolerance analysis.
- b. Damage tolerance analysis is performed for both longitudinal and circumferential through cracks emanating from the critical fastener holes in the fastener row along all four sides of rectangular repairs, as shown in the following figure.



c. The crack geometry is assumed to be through crack. Following are cases of initial crack assumptions made in the analysis

(1) Type 1, 2, and 3 repairs:

- A through crack emanating from the center fastener hole
- Two asymmetric through cracks emanating from the center fastener hole
- A through crack emanating from the corner fastener hole

(2) Circular repairs:

- A through crack emanating from the outermost fastener hole in the applied stress direction

(3) Lap joint repairs:

For the upper skin:

- When stress is parallel to the splice direction, a through crack emanating from the critical fastener hole next to the free edge of the skin in the outermost fastener row
- When stress is normal to the splice direction, crack configurations assumed above for Type 1, 2, and 3 apply.

For the lower skin:

- When stress is parallel to the splice direction, a through crack emanating from the critical fastener hole next to the edge of the overlapped splice in the outermost fastener row
- When stress is normal to the splice direction, crack configurations assumed above for Type 1, 2, and 3 apply.

(4) Butt joint repairs:

- When stress is parallel to the splice direction, a through crack emanating from the critical fastener hole next to the free edge of the skin in the outermost fastener row
- When stress is normal to the splice direction, crack configurations assumed above for Type 1, 2, and 3 apply.

d. The default initial crack sizes are primary crack 0.05" and secondary crack 0.005" for all cases in the program. The user, however, can directly input other initial crack sizes for the analysis.

e. Crack sequences are assumed as follows:

(1) For Type 1, 2, and 3 repairs:

- For a through crack emanating from the center fastener hole, the crack grows towards the adjacent hole. When the crack tip grows into the adjacent hole, two through cracks of size equal to 0.005" are assumed to exist instantaneously, one at each outer side of the holes.
- For two asymmetric through cracks emanating from the center fastener hole, the cracks grow towards the adjacent holes. When a crack tip grows into the hole, a through crack of size equal to 0.005" is assumed to exist instantaneously at the opposite side of the hole.
- For a through crack emanating from the corner fastener hole, the initial crack grows towards the adjacent hole. When the crack tip grows into the adjacent hole, two through cracks of size equal to 0.005" are assumed to exist instantaneously, one at each outer side of the holes. In such a case, one crack tip continues to grow towards the adjacent hole; while the other crack tip grows in the skin without entering any holes.

(2) For circular repairs:

- The crack grows in the skin without entering any holes

(3) For lap joint repairs:

For upper skin:

- When stress is parallel to the splice direction, the crack grows towards the free edge. When the crack tip reaches the edge, a through crack of size equal to 0.005" is assumed to exist instantaneously at the opposite side of the hole. The crack continues to grow towards the adjacent hole.
- When stress is normal to the splice direction, crack growth scenarios assumed above for Type 1, 2, and 3 apply.

For lower skin:

- When stress is parallel to the splice direction, the crack grows towards the adjacent hole. When the crack tip enters the hole, two through cracks of size equal to 0.005" are assumed to exist instantaneously, one at each outer side of the holes.
- When stress is normal to the splice direction, crack growth scenarios assumed above for Type 1, 2, and 3 apply.

(4) For butt joint repairs:

- When stress is parallel to the splice direction, the crack grows towards the free edge. When the crack tip reaches the edge, a through crack of size equal to 0.005" is assumed to exist instantaneously at the opposite side of the hole. The crack continues to grow towards the adjacent hole.
- When stress is normal to the splice direction, crack growth scenarios assumed above for Type 1, 2, and 3 apply.

f. Two types of stress-intensity factor solutions are implemented in RAPID:

(1) Basic solutions:

- A through crack emanating from a hole in a wide plate
- Two asymmetric through cracks emanating from a hole in a wide plate
- A through crack approaching a hole in a wide plate
- An edge crack in a semi-wide plate
- A through crack growing towards a stiffener in a wide plate
- A through crack at stiffener growing towards adjacent stiffeners in a wide plate
- A through crack between two stiffeners growing towards adjacent stiffeners in a wide plate

(2) Derived solutions:

- A through crack passing through two or more holes
- An edge crack passing through one or more holes

Solutions for both uniform far field stress and pin loads are considered. The interference-fit and neat-fit-pin effects are ignored.

g. Residual strength of the skin is assessed based on the fracture toughness approach.

h. Crack growth analysis can be performed using either the simplified method, or the cycle-by-cycle method with or without the retardation effect in the analysis. When the retardation effect is considered, it is accounted for by using the generalized Willenborg retardation model.

i. Crack growth prediction using the simplified method, is based on Walker's crack growth equation [3]. Coefficients in the Walker's equation are reduced for the following 13 materials:

- 2024-T3 Clad Sheet, -T42 Bare Sheet, L-T RT LA DW
- 2024-T3 Clad Sheet, -T42 Bare Sheet, T-L RT LA DW
- 2024-T3 51 Plate, -T3511 Extrusion, L-T RT LA DW

- 7050-T7452 Forging, L-T T-L LA RT
- 7050-T74511, -T76511 Extrusion, L-T RT LA DW
- 7050-T74511, Extrusion, L-T RT STW
- 7050-T7651, -T7451 Plate, L-T T-L RT LA DW
- 7050-T76511, Extrusion, L-T RT STW
- 7475-T7351, Plate, L-T LA RT
- 7475-T7651, Plate, L-T LA RT DW
- 7475-T761, Clad Sheet, L-T RT LA DW
- 7075-T6, Clad Sheet, L-T RT LA
- 2014-T6 Sheet, T = 0.05, L-T RT LA 10Hz

In the cycle-by-cycle method, table lookup of the da/dN rate data is used in the analysis.

- j. Generic load spectra for narrow- and wide-body aircraft are generated at the fuselage c.g. location. RAPID converts the load spectrum into the stress spectrum near the repair location for the crack growth analysis. The user can also provide RAPID with the stress spectrum for analysis.
- k. Limit stress in the circumferential direction is

$$\sigma_{\text{lim } c} = \frac{1.1pR}{t} + \frac{1.1R}{t}$$

Where p is the operating pressure differential in psi, R is the fuselage radius, and t is the thickness of the fuselage skin. The second term represents an upper bound on aerodynamic pressure.

The limit stress in the longitudinal direction is

$$\sigma_{\text{lim } l} = \frac{C_1 F_{tu}}{1.5}$$

where F_{tu} is the ultimate tensile strength of the material and C_1 is the strength reduction factor obtained from manufacturer's testing data. In RAPID, C_1 takes a value of 0.88 for 2024-T3 alloy materials.

- l. The inspection threshold is established using the following formula:

$$N_{\text{Threshold}} = \frac{N_{\text{Critical}}}{2}$$

where N_{Critical} is the number of flights associated with the critical condition.

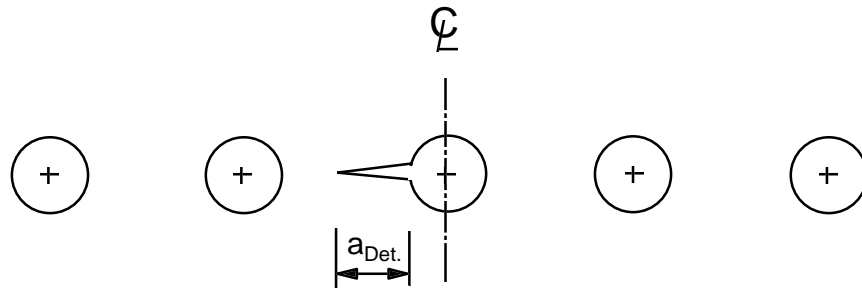
m. The inspection interval is determined using the following formula:

$$N_{\text{Interval}} = \frac{N_{\text{Critical}} - N_{\text{Detectable}}}{2}$$

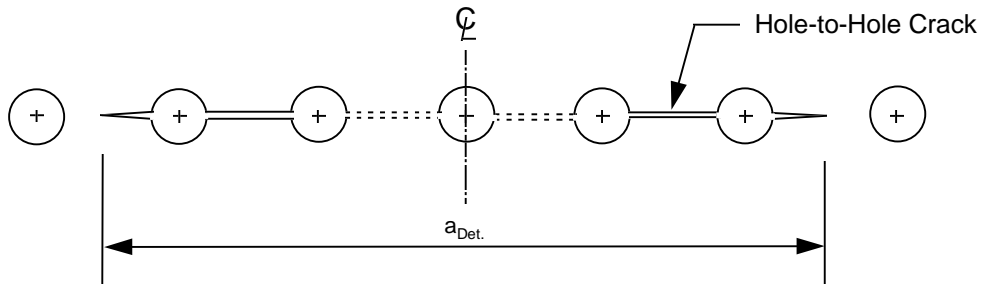
where N_{Critical} is the number of flights associated with the critical condition, and $N_{\text{Detectable}}$ is the number of flights associated with the detectable crack length for an NDI method.

n. The detectable crack length is defined as follows:

- No Hole-to-Hole crack:



- Hole-to-Hole crack:



Details of the analysis methods are provided in the companion Analysis Methods Document.

4. Document Conventions

This manual uses the following special fonts:

ALL CAPS	This type represents file categories or names and disk directories
Bold	This type represents application commands, menu items, edit fields, etc.
<i>Italic</i>	This type represents string(s) that are found in a file
Monospace	This type represents text that user types or text as it appears on the screen.

5. RAPID Support Services

5.1 Telephone Support

For technical assistance, problem reporting, or general questions regarding RAPID, please contact:

John Bakuckas
AAR-431
FAA William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405
Phone: (609) 485-4784
FAX: (609) 485-4569
e-mail: John_Bakuckas_at_ct27@admin.tc.faa.gov

or

Michael Shiao
AAR-431
FAA William J. Hughes Technical Center
Atlantic City International Airport, NJ 08405
Phone: (609) 485-4137
FAX: (609) 485-4569
e-mail: Michael_Shiao_at_ct27@admin.tc.faa.gov

Any problems or difficulties encountered while running RAPID should be reported. If you discover any problems with RAPID, fill out the RAPID Problem Description Form supplied in the subsequent section documenting the events that led up to the problem in RAPID and the manifestations of the problem. This form should be submitted as soon as the problem is discovered. The same information may be supplied using e-mail if the user so desires.

6. Installation

The following instructions are for Windows 3.1, Windows 95 and Windows NT 4.0.

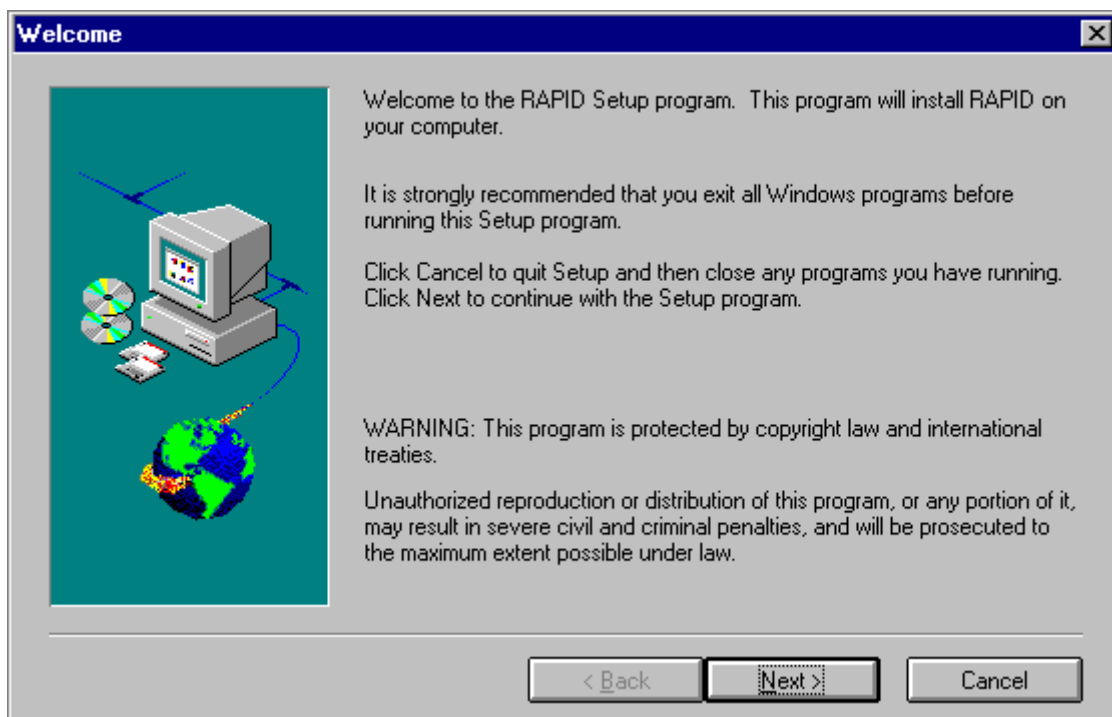
6.1 Run Setup

Exit all other Windows programs, insert Disk 1, and then run the `setup` program. Setup can be run by double-clicking the icon or by entering the following command at a DOS prompt or in a “Run...” dialog.

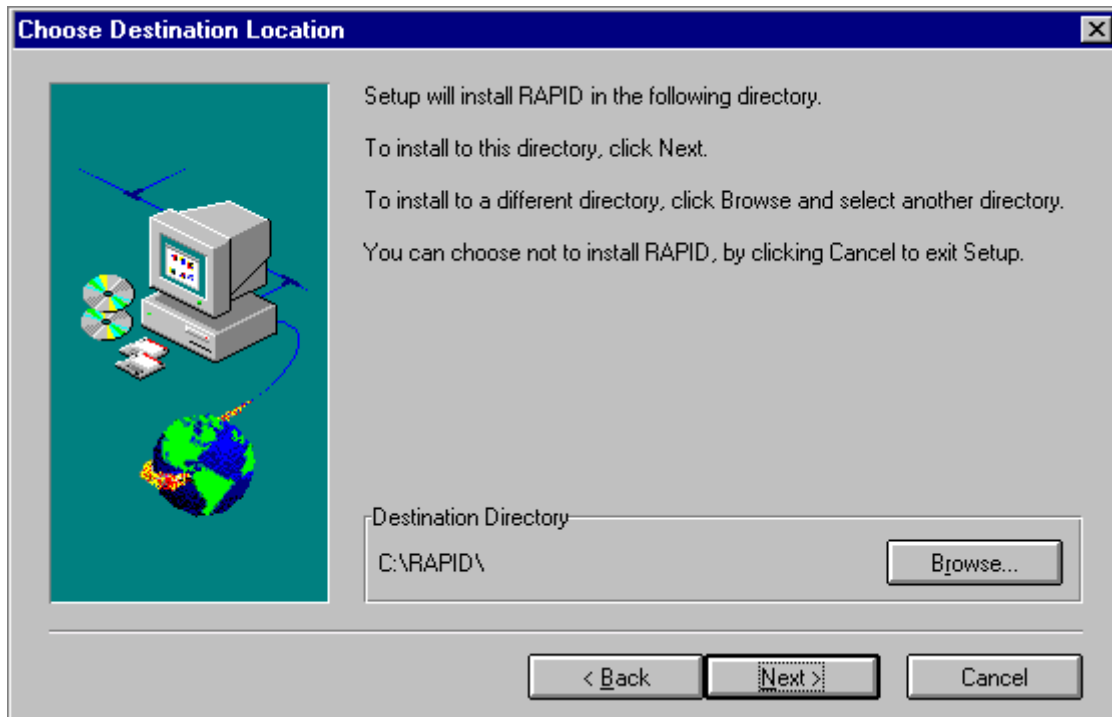
```
a:\setup
```

If a previous version of RAPID is already installed, then user created models and data files should first be backed up, and then the previous version of RAPID should be uninstalled or removed. Older versions of RAPID which do not include an uninstall utility can be removed by simply deleting the RAPID directory and its contents. Please note that repair configuration data files generated by older versions of RAPID may not be compatible with the current version.

After a few moments, the following dialog will appear. Select the **Next** button to continue.



6.2 Choose Destination Location



To install RAPID in the default C:\RAPID\ directory, select the **Next** button. To install elsewhere, select the **Browse** button and enter an alternate directory location.

When installing from disk, a dialog will appear which will prompt the insertion of the next disk. Simply remove the current disk, insert the requested disk, and press the **Enter** key on the keyboard.

The extraction process will install the following files:

PROGRAM FILES:

RAPIDMDI . EXE	The RAPID MDI Windows executable program
STATIC . PIF	The STATIC Program Information File
DADTA . PIF	The DADTA Program Information File
GENRLN . PIF	The GENRLN Program Information File
GENRLW . PIF	The GENRLW Program Information File
EQVSTRS . PIF	The EQVSTRS Program Information File
GENRSPEC . PIF	The GENRSPEC Program Information File
USRSSPEC . PIF	The USRSSPEC Program Information File
SSPECCHK . PIF	The SSPECCHK Program Information File
CHKDADN . PIF	The CHKDADN Program Information File
REPAIRD . EXE	The RAPID-callable version of the Damage Tolerance Analysis Program

REPAIRS . EXE	The RAPID-callable version of the Static Analysis Program
CTL3DV2 . DLL	The Microsoft 3-D Controls Dynamic Link Library
BIVBX30 . DLL	Allows 16 bit programs compiled in Win95 to run under Win3.1
BWCC . DLL	The Borland Windows Custom Controls Dynamic Link Library
GENRLN . EXE	The Generic Narrow Body Load Spectrum Generation Program
GENRLW . EXE	The Generic Wide Body Load Spectrum Generation Program
USRSSPEC . EXE	The User Input Stress Spectrum Generation Program
GENRSPEC . EXE	The Generic Stress Spectrum Generation Program
EQVSTRS . EXE	The Equivalent Stress Generation Program
SSPECCHK . EXE	The Stress Spectrum Format Check Program
CHKDADN . EXE	The da/dN Format Check Program
USRSSPEC . DAT	User Stress Spectrum Generation Input File Example
CHKDADN . INP	da/dN Input Format Check Program
README . WRI	Documents last minute changes and corrections
ANALYSIS . WRI	Boilerplate text included in RAPID Repair Reports
TEMPLATE . 1	Stress Report Template
DISCLAIM . DOC	RAPID Disclaimer

ADVISORY SYSTEMS FILES:

RAPID . HLP	The RAPID Help system file
ADVISE . DAT	The RAPID Advisory system data

DATABASE FILES:

MATERIAL . DAT	Material database
MATTHICK . DAT	Material database thickness parameters
MATPROP . DAT	Material properties database
MAT-FT . DAT	Fracture Toughness Database
FTYPE . DAT	Fastener database (1 of 2)
RIVET . DAT	Fastener database (2 of 2)
TEMPER . DAT	Material Temper Database
SURFACE . DAT	Material Surface Database
FORM . DAT	Material Form Database
REPAIRD . FST	Fastener Factors database
REPAIRD . JNT	Splice Joint database
REPAIRD . LCF	Life Correction Factor database
REPAIRD . STB	Stiffener database
REPAIRD . STF	Stiffener Ratio Factors database
REPAIRD . MAT	da/dN database
REPAIRD . SIF	Stress-Intensity Factors database
REPAIRD . PRX	Proximity database
RPRTYPE . DAT	Repair Configuration database
REPAIRD . CIR	Damage Tolerance Circular Repair Ratio Factors

EXAMPLE FILES:

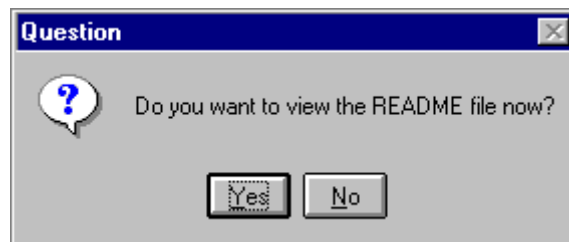
TYPE1.RPD	Type 1 repair example problem
TYPE2.RPD	Type 2 repair example problem
TYPE3.RPD	Type 3 repair example problem
TYPE41.RPD	Type 4 longitudinal butt joint repair example problem
TYPE42.RPD	Type 4 circumferential butt joint repair example problem
TYPE5.RPD	Type 5 repair example problem
TYPE6.RPD	Type 6 repair example problem
TYPE7.RPD	Type 7 repair example problem
TYPE8.RPD	Type 8 repair example problem
TYPE9.RPD	Type 9 repair example problem
PSEUDO.SSF	Sample User Defined Pseudo-Flights Stress Spectrum
CYCLE.SSF	Sample User Defined Cycle-by-Cycle Stress Spectrum

If you are replacing version 1.x of RAPID, then you will no longer need the `dosxnt.386` device driver (unless it is required by programs other than RAPID). Edit the `system.ini` file in the `windows` directory. On some systems, this file might be located in the `windows\system` directory. Search for the string `dosxnt.386`. If the string is found and it includes reference to the RAPID directory (indicating that it was installed solely for RAPID), then delete that line from SYSTEM.INI:

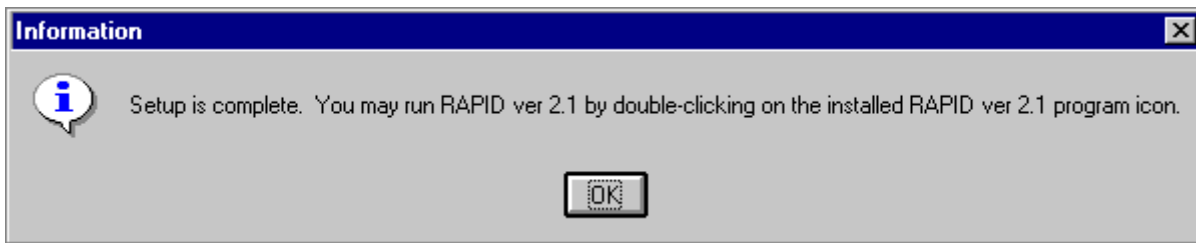
```
device=c:\rapid\dosxnt.386
```

6.3 Complete the Installation

The following dialog will appear which asks if you would like to view the README file. You may select **No** to skip, since the README file can be viewed within the RAPID program. If **Yes** is selected, then the README file will be displayed.



The following dialog will appear to verify that the installation of RAPID is complete. Click the **OK** button to exit the installation procedure. Remove the remaining disk from the floppy drive and store the disks in a safe location.



The RAPID program may then be run by double-clicking on the installed **RAPID ver 2.1** program icon. In Windows 95 and Windows NT 4.0, RAPID may also be run by selecting it from within the **Programs** section of the Windows **Start** button.

6.4 Change to Super VGA mode (recommended)

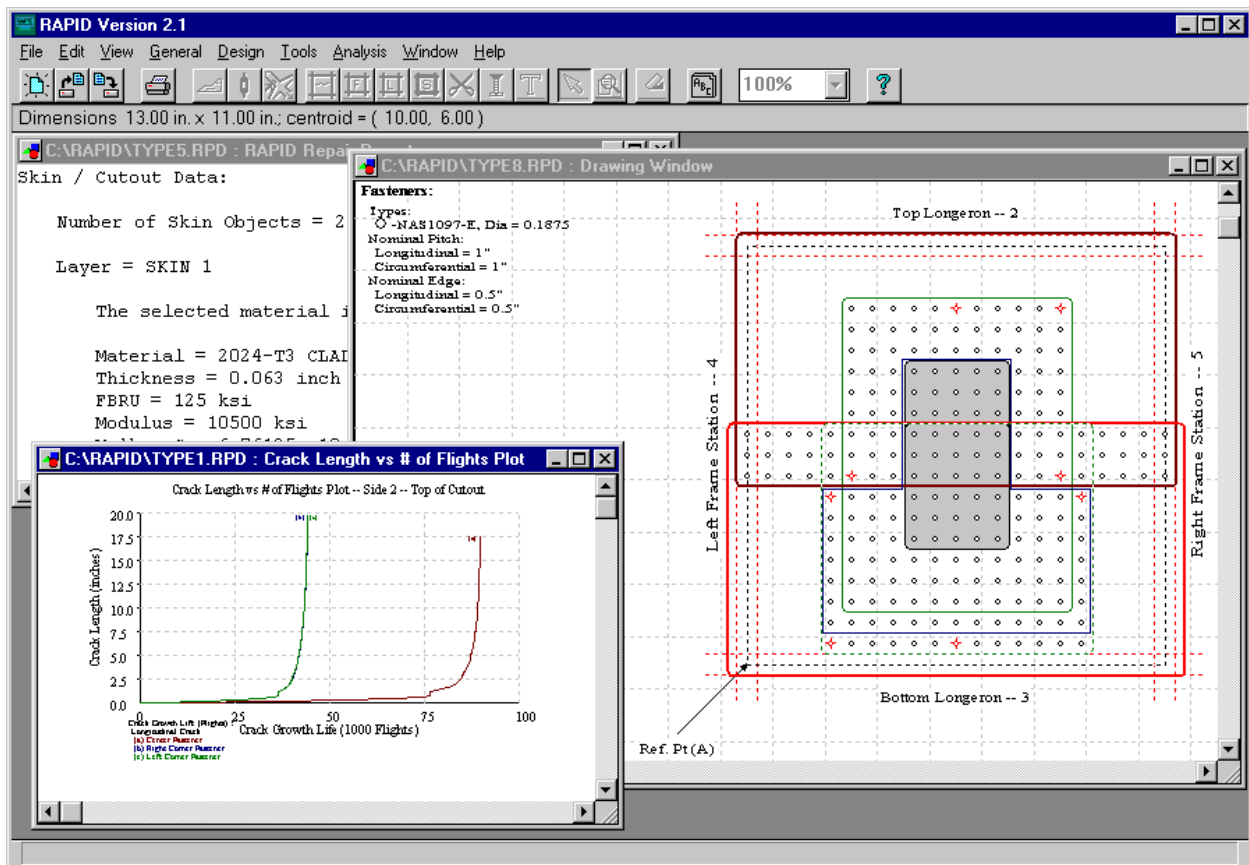
Although it is possible to use RAPID with any Windows-compatible display, it is recommended that a minimum window resolution of 800 by 600 dots per inch (Super VGA) be used so that the windows will fit the display without the use of scrolling. Most computers will support the Super VGA driver which is shipped with Windows 3.1. To change to Super VGA mode, open **WINDOWS SETUP** (in the **MAIN** program group) and select **Change System Settings** from the **Options** menu, and then select **Super VGA (800x600, 16 colors)** in the **Display** field and press the **OK** button. (Note which video mode you were using in case you need to switch back later). If prompted to use the currently installed driver, select **Current**. Otherwise, you will need to use your original Windows 3.1 installation disks when prompted. Finally, when prompted, restart Windows to switch to the new display driver. If, after changing the video mode, you are unable to restart Windows, you will need to return to your original video mode. The video mode can be reset by running the Windows Setup program from DOS, changing to the **WINDOWS** directory, and running **SETUP**.

For Windows 95 and Windows NT 4.0, please refer to the hardware and operating system documentation included with the computer. Typically, the video mode can be changed through the **Settings** tab on the **Display Properties**, accessible from both the **Control Panel**, or by clicking the right mouse button on the Windows desktop and then selecting **Properties**.

7. Running RAPID

RAPID is run by double-clicking on the installed **RAPID ver 2.1** program icon. In Windows 95 and Windows NT 4.0, RAPID may also be run by selecting it from within the **Programs** section of the Windows **Start** button. When opened, RAPID fills the screen with the RAPID Multi-Document Interface (MDI). Commonly used tools and options are available both from the icon button bar and from the pull-down menus. Other options are available only from the pull-down menus. As with most Windows applications, the pull-down menus can be accessed both by mouse selection and by holding down the “Alt” key then pressing the key-character of the menu item. (The key-character is underlined.) For use with a mouse, however, selection is simplified by the icon button bar. Each button represents a selection available in a pull-down menu. As the mouse pointer is placed over any of the buttons, a description of the button is displayed in the strip along the bottom of the RAPID MDI window.

The following figure shows an example of the RAPID MDI with several of the input windows opened.

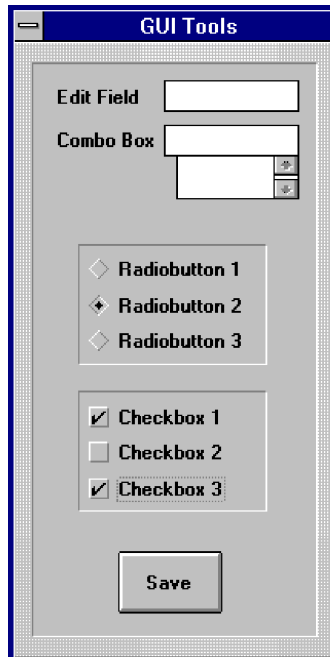


Selections can be made in any order, except for those which require prior input. For example, the **Analysis** menu items are not available for selection (and are grayed-out) until all of the data necessary for the model has been input.

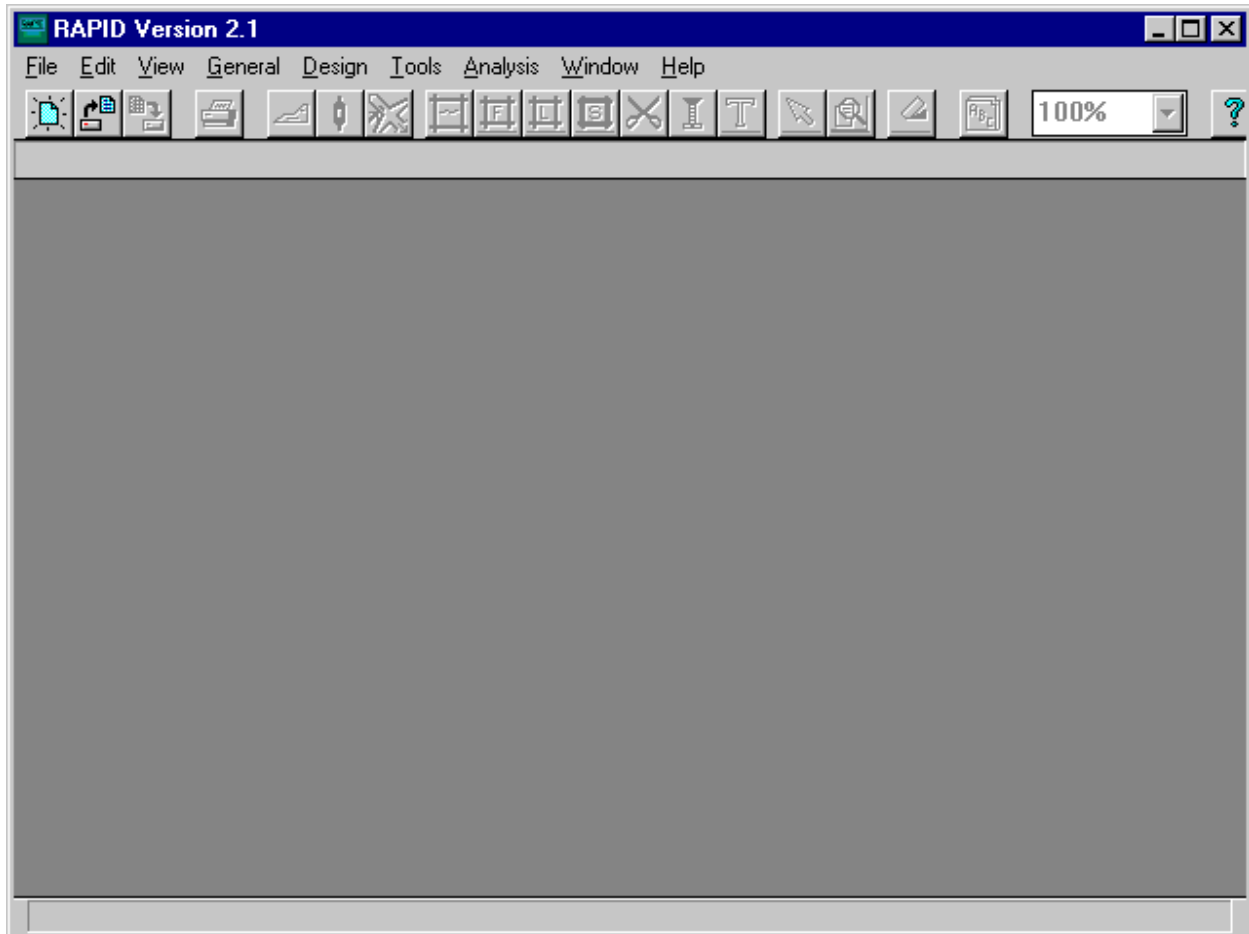
Before RAPID can be used to edit out a repair model, an existing model must be opened or a new model must be created. This is done by selecting the **New** or **Open** menu items from the **File** menu or by selecting the corresponding icon buttons. These buttons are the two buttons furthest to the left on the button bar.

For a typical text-based input, the icon buttons would be selected from left to right, beginning with the **Aircraft/General Information** dialog and culminating with the **Report** dialog. If an icon button or a menu item is grayed-out, then either the prerequisite information has not yet been entered or that option is not pertinent to the current model.

In describing the use and function of the dialog windows, it is necessary to first define several of the features common to all dialog windows, as shown below in the fictional **GUI Tools** dialog window. As depicted, an **Edit Field** is used to enter alphabetic or numeric data. A **Combo Box** is also used to enter alpha-numeric data with the added option of selecting predefined entries from an attached list, which may be scanned using its scroll bar. **Radiobuttons** are used to select among a group of mutually exclusive input options. **Checkboxes** are used to toggle independently selectable options. Finally, **Pushbuttons** (here represented by the **Save** button, and sometimes referred to simply as **buttons**) are used to invoke an action.



7.1 Opening Window



The opening window displays the RAPID Multidocument Interface. All other windows in the RAPID system are selected from and displayed in this window. The gray strip along the bottom describes the function of each button as it is pointed to by the mouse.

The icon buttons near the top of the window activate most of the capabilities within RAPID. In every case, their functions are reproduced by selections within the pull-down menus located on the line above the button bar. The icon buttons perform the functions listed below. The bold face entries are documented within this section.



Starts a **New** repair.



Opens an existing repair file.



Saves the current repair to a file.



Prints the current window.



Invokes the **Aircraft/General Information** dialog window.



Invokes the **Repair Type** dialog window.



Invokes the **Damage Location Information** dialog window.



Switches mouse to **Repair Boundary** drawing mode. This tool is used to draw the rectangular repair boundary, as defined by the two frames and two longerons which enclose the area of the repair. The repair boundary is drawn by clicking the left mouse button on one corner of the desired location of the repair boundary and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the repair boundary, at which point the left mouse button is released.



The frame tool is used to draw frames that are overlapped by the repair.



The longeron tool is used to draw longerons that are overlapped by the repair.



Invokes the **Skin Properties** dialog window.



Switches mouse to **Skin Cutout** drawing mode. The cutout tool is used to draw the rectangular cutout. The cutout is drawn by clicking the left mouse button on one corner of the desired cutout, and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the cutout, at which point the left mouse button is released.



Invokes the **Fastener Arrangement** dialog window, which then automatically generates the fastener rows and columns.



Switches mouse pointer to **Text** input mode. The text tool is used to annotate the drawing. After selecting this tool, text may be entered directly on the drawing at the location indicated by the next click of the left mouse button.



Switches mouse to **Select Object** mode. The selection tool is used to select graphical objects, such as doublers and fasteners, which are already on the screen. Once selected, objects

can be moved and resized, unless their position has been frozen due to the existence of dependent objects. For example, cutouts cannot be moved after the fasteners are defined, since that would require that the fasteners be regenerated.



Switches mouse to **Selective Zoom** mode.



Switches mouse to **Delete Object** mode. The eraser tool is used to delete graphical objects, such as the cutout and damage extent, which are already on the screen.

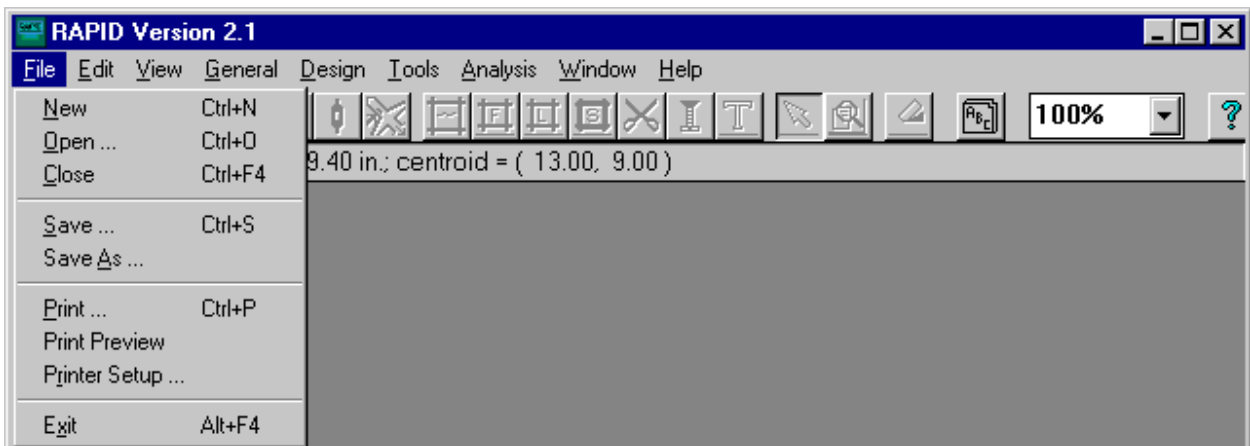


Starts the **Report** module.



Invokes the on-line **Help** system.

7.2 File Menu Listing



The **File** menu contains the typical Windows file utilities: **New**, **Open**, **Close**, **Save**, **Save As**, **Print**, **Print Preview**, **Printer Setup**, and **Exit**. **New** creates a new model. **Open** reads a saved repair model. **Close** closes the current repair model file. **Save** updates the file containing the current repair model in a RAPID **rpd** file. **Save As** creates a new repair file with a name supplied by the user. **Print** sends the currently displayed analysis plot or view of the model to the printer. **Print Preview** displays a screen representation of the printed document. **Printer Setup** invokes a standard Windows dialog for defining printer options. Finally, **Exit** closes the currently opened models (after prompting the user to save changes) and quits RAPID. Most of these utilities can also be activated from the following icon buttons.



Starts a new repair.



Opens an existing RAPID **rpd** repair file

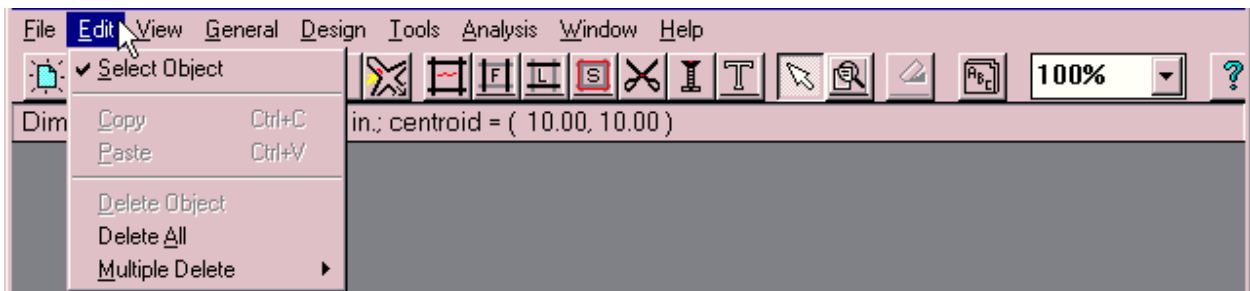


Saves the current repair to a RAPID **rpd** file.

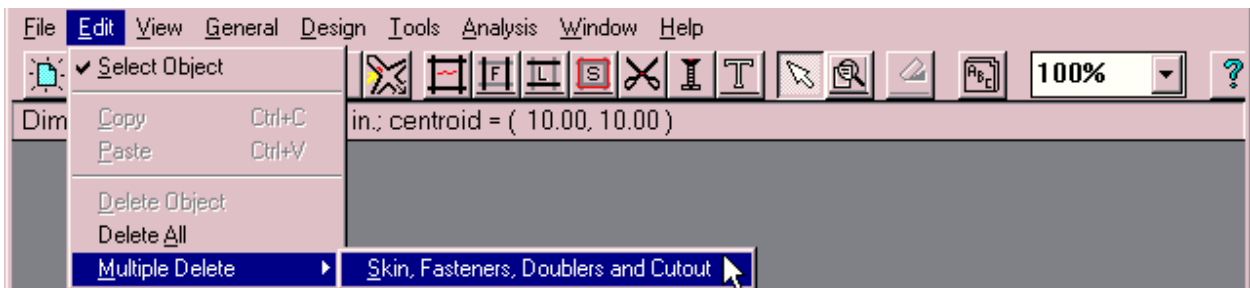


Prints the current window.

7.3 Edit Menu Listing

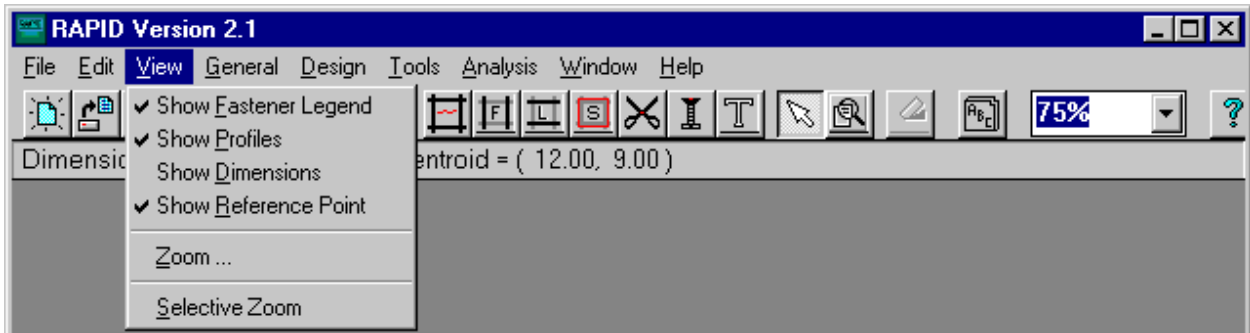


The **Edit** menu contains **Select Object**, **Copy**, **Paste**, **Delete Object**, **Delete All**, and **Multiple Delete** menu selections. **Select Object** switches the mouse to selection mode so that objects may be selected with the left mouse button. **Copy** and **Paste** are not functional in the current release but are included for completeness and will be used in future versions of RAPID to copy and paste drawing objects and text, both within RAPID and to other applications such as drawing programs and word processors. **Delete Object** deletes the currently selected drawing object. **Delete All** clears the drawing window.

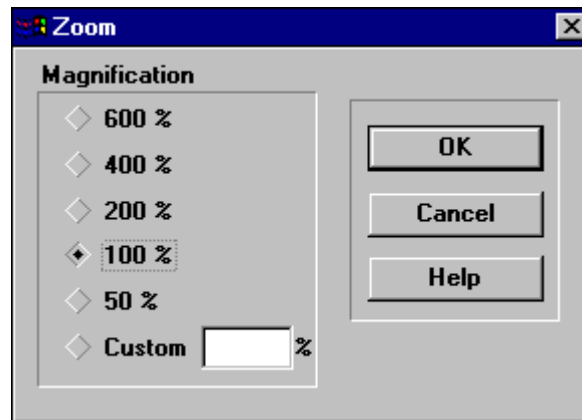


Multiple Delete currently contains one option, to delete all **Fasteners and Doublers**. If an attempt is made to delete an object upon which other objects are dependent, then an informational message will be displayed to the user.

7.4 View Menu Listing



The **View** menu contains selections for modifying how the image of the model is displayed. The **Show Fastener Legend** selection, if checked, displays information on the screen about fasteners used in the model. The **Show Profiles** selection toggles the display of cross sectional profiles. The **Show Dimensions** and **Show Reference Point** selections similarly toggle display of the model dimensions and coordinate system reference point. The **Zoom** selection invokes a dialog which prompts the user to enter a desired magnification factor (sometimes called “Zoom Scale”). Presets are provided in the dialog and on the tool bar for **50%**, **100%**, **200%**, **400%**, and **600%** magnification.



The **Selective Zoom** menu option provides a means to graphically indicate the desired magnification by depressing the left mouse button while dragging the mouse diagonally across the rectangular region to be magnified. Selective Zoom can also be activated using the icon button located on the button bar:



7.5 General Menu Listing



The **General** menu contains **Aircraft/General Information**, **Repair Type**, and **Damage Location Information** selections. Each is described in the following subsections.

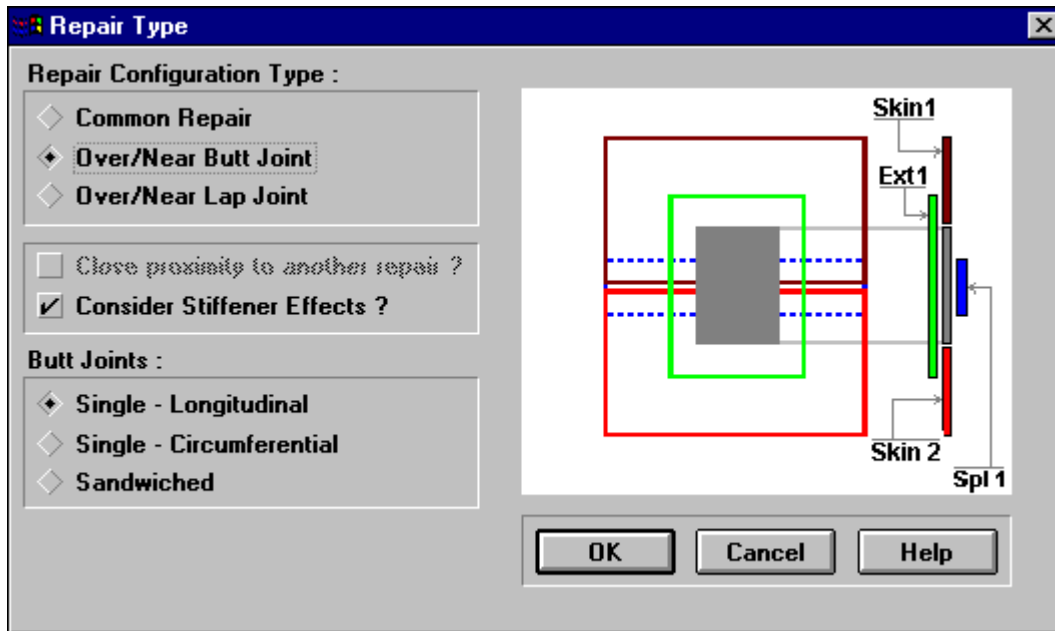
7.5.1 Aircraft/General Information Screen

A screenshot of a dialog box titled 'General/Aircraft Information'. The dialog is divided into several sections: 'Aircraft Information', 'Analyst Information', 'Aircraft ID/Registration Number', and 'Repair Identification'.
Aircraft Information:
Operator: World Wide Airlines
* Model Number: Norton 30
Series Number: 400
Flight Hours: 20000, Cycles: 4000
Analyst Information:
Name: John Doe
Company: Flight Repairs, Inc
Employee ID: 1234
Title: Technician
Aircraft ID/Registration Number:
Fuselage No.: FN-0123
* Serial No.: 98765
Airplane Registration: AR-AB134
Operator Designation: OD-987123
Repair Identification:
Repair ID: RR-01, Rev.: 33
Comment: RAPID Repair Example
Buttons: OK, Cancel, Help
* - Required Entry

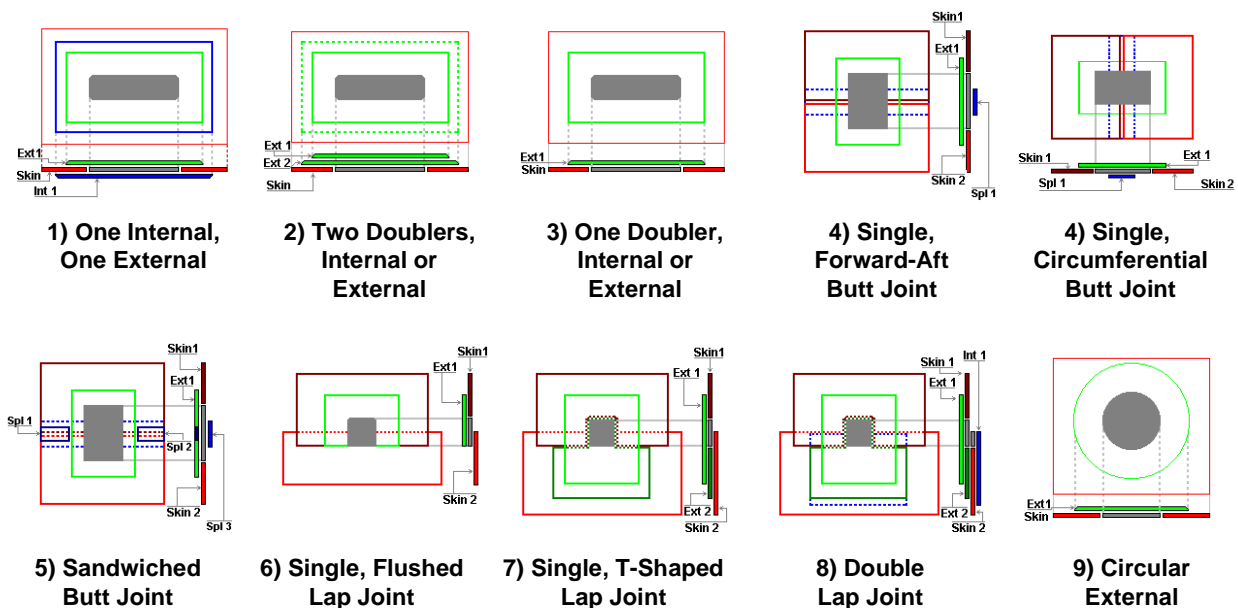
This dialog is used to store the general information about the aircraft and the analyst. Note the **OK**, **Cancel**, and **Help** buttons. The **OK** button updates the current model with any information entered in the window and then closes the window. The **Cancel** button exits the dialog window without saving any new entries. Finally, the **Help** button retrieves help appropriate to this dialog window.

Required data are indicated by an asterisk before the description of the entry, as shown above. This includes the aircraft **Model Number** and the **Serial Number**. The **Model Number** and **Serial Number** are used strictly for bookkeeping purposes.

7.5.2 Repair Type



This window is used to select among the supported repair types. For the repair type selected, a generic schematic of the cross section is depicted within the window. Currently, nine repair types are available, as depicted in the following figure:

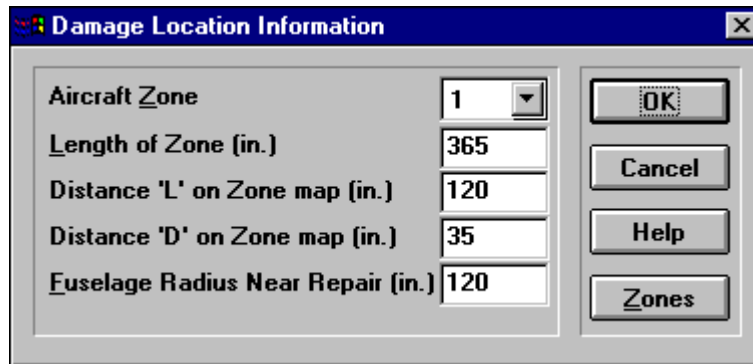


Additional **Radiobuttons** or **Checkboxes** are provided to specify repairs over existing **Lap** and **Butt Splices**, and repairs in **Close proximity to another repair**. To include the effects of a

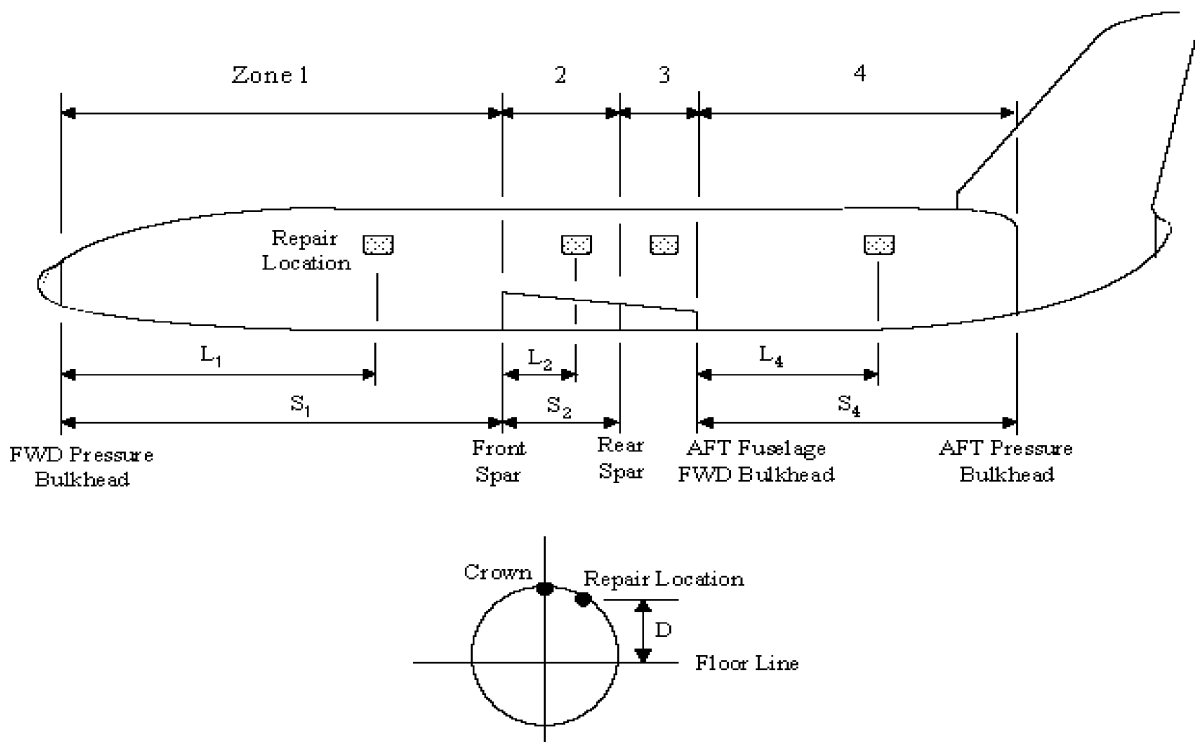
nearby repair, check the **Close proximity to another repair** box and then fill in the **Proximity Data** dialog available in the **Damage Tolerance** section of the **Analysis** pull-down menu.

The **OK** button updates the current model with any information entered in the window and then closes the window. The **Cancel** button exits the window without saving any new entries. Finally, the **Help** button retrieves help appropriate to this window.

7.5.3 Damage Location



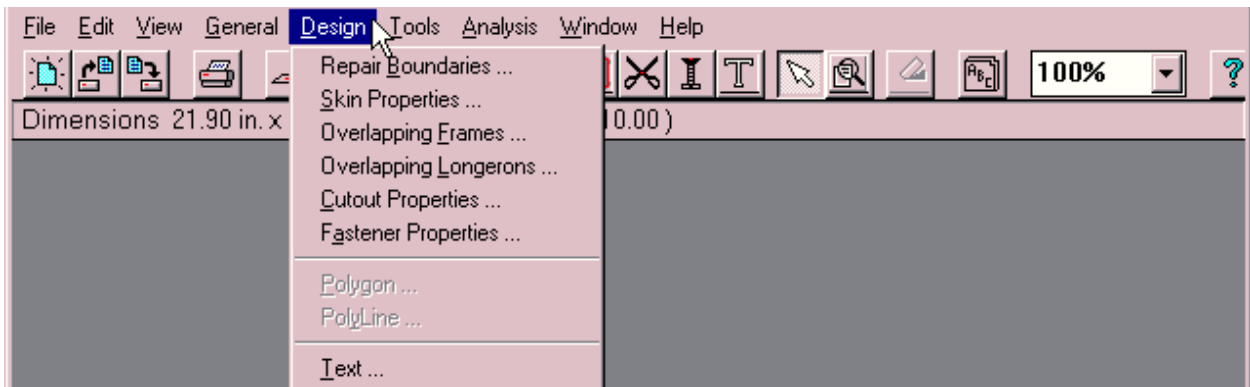
This window is used to define the location of the damage on the aircraft in relation to several pre-defined regions, which may be viewed by selecting the **ZONES** button. The entry fields are defined in the figure below which is displayed on the screen by clicking on the **ZONES** button.



This input is used to determine the appropriate stress spectrum for the repair. Repairs should be restricted to fuselage skin repairs between the forward pressure bulkhead and front wing spar and between the aft fuselage forward bulkhead and aft pressure bulkhead, Zones 1 and 4. RAPID should not be used when analyzing repairs in Zones 2 and 3 due to structural complexity of the aircraft in those regions. For repairs in these areas, the OEM should be consulted.

The **OK** button updates the current model with any information entered in the window and then closes the window. The **Cancel** button exits the window without saving any new entries. Finally, the **Help** button retrieves help appropriate to this window.

7.6 Design Menu Listing



7.6.1 Repair Boundary Information



Field	Value
Damage Type	Accidental
Overall Distances (inches)	
Longitudinal direction	20
Circumferential direction	20
Stiffeners :	
Top Longeron (stringer)	<input checked="" type="radio"/>
Bottom Longeron (stringer)	<input type="radio"/>
Left Frame Station	<input type="radio"/>
Right Frame Station	<input type="radio"/>
Stiffener Properties:	
Stiffener ID (location)	E
Number of Fasteners (overall distance)	20
Average Pitch on stiffener	1
Cross-Sectional Area (sq.in.)	0.5
Material	2024-T3 CLAD SHEET

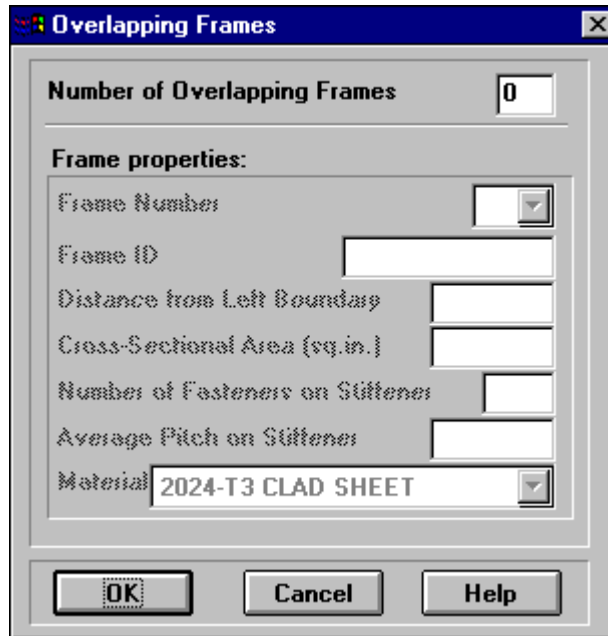
The **Repair Boundary Information** tool is used to draw the rectangular repair boundary, as defined by the two frames and two longerons which enclose the area of the repair. The repair boundary is drawn by clicking the left mouse button on one corner of the desired location of the repair boundary and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the repair boundary, at which point the left mouse button is released.

The **Repair Boundary Information** dialog window automatically appears after the repair boundary is drawn. The **Top Longeron ID**, **Bottom Longeron ID**, **Left Frame F. S.** and **Right Frame F. S.** radio buttons refer to the longerons and frames which bound the area defined by the repair. In other words, those four frames and longerons must not cross over the cutout or the doublers to be defined. The **Longitudinal direction** and **Circumferential direction** edit fields specify the distances between the right most and left most frames and the top and bottom longerons, respectively. If “**Consider Stiffener Effects**” is selected in the **Repair Type** dialog window, then the cross-sectional and material properties of the frames and longerons should be entered.

The stiffener properties are entered for each stiffener by clicking on the radio button for the stiffener and then entering the properties in the **Stiffener Properties** section.

The **OK** button updates the current model with any information entered in the window and then closes the window. The **Cancel** button exits the window without saving any new entries. Finally, the **Help** button retrieves help appropriate to this window. Data entered in this dialog window is displayed in the drawing window and is used to define coordinates of the cutout and doublers but is not otherwise used in the analysis in this version of RAPID.

7.6.2 Overlapping Frames



This window is used to define the number and position of the overlapping frames in the model. The number of frames that the repair overlaps between the damage extent bounds (between the right most and left most frames) is input in the **Number of Overlapping Frames** edit field. RAPID will automatically determine the average spacing. If stiffener effects are included in the RAPID analysis, the cross-sectional and material properties of the stiffeners should be entered.

7.6.3 Overlapping Longerons



Overlapping Longerons (stringers)

Number of Overlapping Longerons: 0

Longeron (stringer) properties:

Longeron (stringer) number: [dropdown]

Longeron (stringer) ID: [text box]

Distance from Bottom Boundary: [text box]

Cross-Sectional Area (sq. in.): [text box]

Number of Fasteners on Stiffener: [text box]

Average Pitch on Stiffener: [text box]

Material: 2024-T3 CLAD SHEET [dropdown]

OK Cancel Help

This window is used to define the number and position of the overlapping longerons in the model. The number of longerons that the repair overlaps between the damage extent bounds (between the top and bottom longerons) is input in the **Number of Overlapping** edit field. RAPID will automatically determine the average spacing. If stiffener effects are included in the RAPID analysis, the cross-sectional and material properties of the stiffeners should be entered.

7.6.4 Cutout Geometry



Cutout Geometry

Layer: SKIN 1

Distances (inches)

Start points from Damage Extent ref. point (A)

Longitudinal Direction: 7.5

Circumferential Direction: 6

Cutout Geometry (Rectangular):

Longitudinal Direction: 5

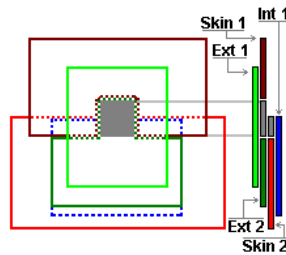
Circumferential Direction: 8

OK Cancel Help

The **Cutout Geometry** tool is used to draw the rectangular cutout in relation to the top and bottom longerons and the right most and left most frames defined in the **Repair Boundary** dialog window. The cutout is drawn by clicking the left mouse button on one corner of the desired cutout and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the cutout, at which point the left mouse button is released.

The **Cutout Geometry** dialog window is automatically invoked after the cutout is drawn with the cutout tool and can be manually displayed by clicking with the right mouse button on the cutout.

In the current version, only a single layer of skin may be cut out, except for the type 8 double lap joint repair which has two overlapping cutouts in the skin lap joint. The frames are assumed to be perpendicular to the longerons, and the angles between adjacent sides of the cutout are constrained to be right angles. The number of sides has been limited to four and the sides must be parallel and perpendicular to the frames and longerons.



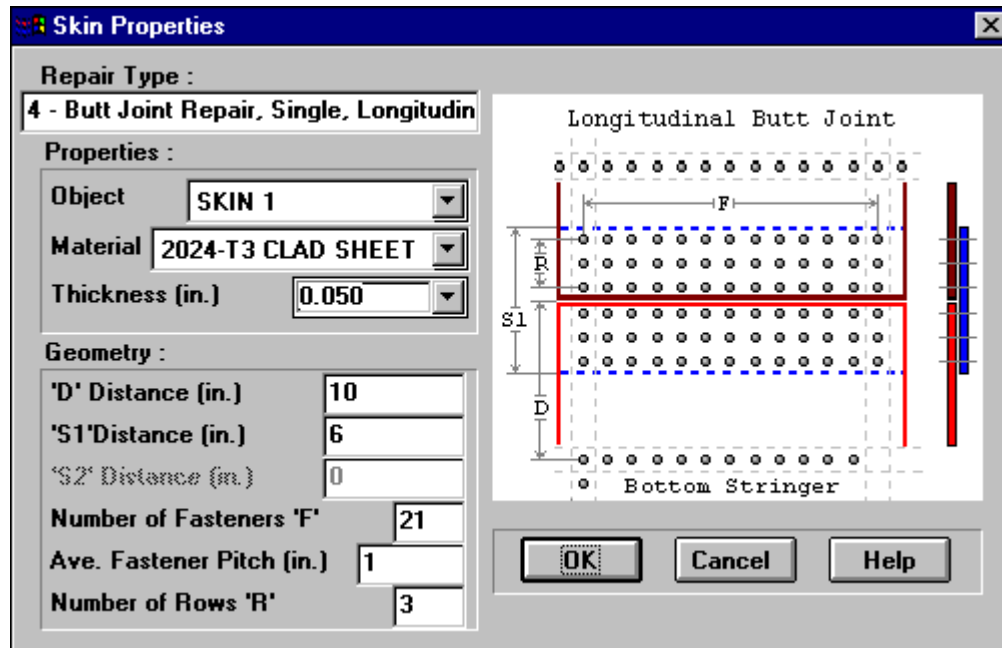
Type 8 Double Lap Joint Repair

The **Start point** refers to the lower left corner of the cutout in the coordinate system defined as starting at the lower left corner of the repair boundary (or “damage extent”). The **Cutout Geometry** is simply the size of the cutout.

The **OK** button updates the current model with any information entered in the window and then closes the window. The **Cancel** button exits the window without saving any new entries. Finally, the **Help** button retrieves help appropriate to this window.

For the type 8 repair, repair over a double lap joint, the first drawn cutout is in the upper skin. RAPID will automatically move the cutout to align with the edge of the upper skin. The user must then draw the cutout in the lower skin. RAPID adjusts the width of the lower skin cutout to match the upper skin cutout.

7.6.5 Skin Properties



This dialog window is used to define the material **Properties** of the skins and joint (if any), and is manually invoked by clicking with the right mouse button on a skin or joint or by selecting the tool bar icon. If the current **Repair Type** contains more than one skin or also contains a joint, then the properties for each of those layers must be defined before the window may be closed with the **OK** button. For repairs over splice and butt joints, the **Geometry** must be entered as indicated in the displayed drawing. This dialog window will display only those fields which are appropriate for the current repair type.

The **OK** button updates the current model with any information entered in the window and then closes the window. The **Cancel** button exits the window without saving any new entries. Finally, the **Help** button retrieves help appropriate to this window.

7.6.6 Fastener Global Properties



Fastener Global Properties

Nominal Diameter (all fasteners) -

Pitch and Edge Distances (in.)

*** RAPID Absolute Guidelines for Min / Max ***

Ranges :	Minimum (x Diam)	Nominal (inch)	Maximum (x Diam)
Longitudinal Pitch	<input type="text" value="0.375"/>	<input type="text" value="1"/>	<input type="text" value="1.5"/>
Circumferential Pitch	<input type="text" value="0.375"/>	<input type="text" value="1"/>	<input type="text" value="1.5"/>
Longitudinal Edge	<input type="text" value="0.28125"/>	<input type="text" value="0.5"/>	<input type="text" value="0.75"/>
Circumferential Edge	<input type="text" value="0.28125"/>	<input type="text" value="0.5"/>	<input type="text" value="0.75"/>

OK
Cancel
Help

Doubler Information :

Layer Object (Doubler)

Properties :

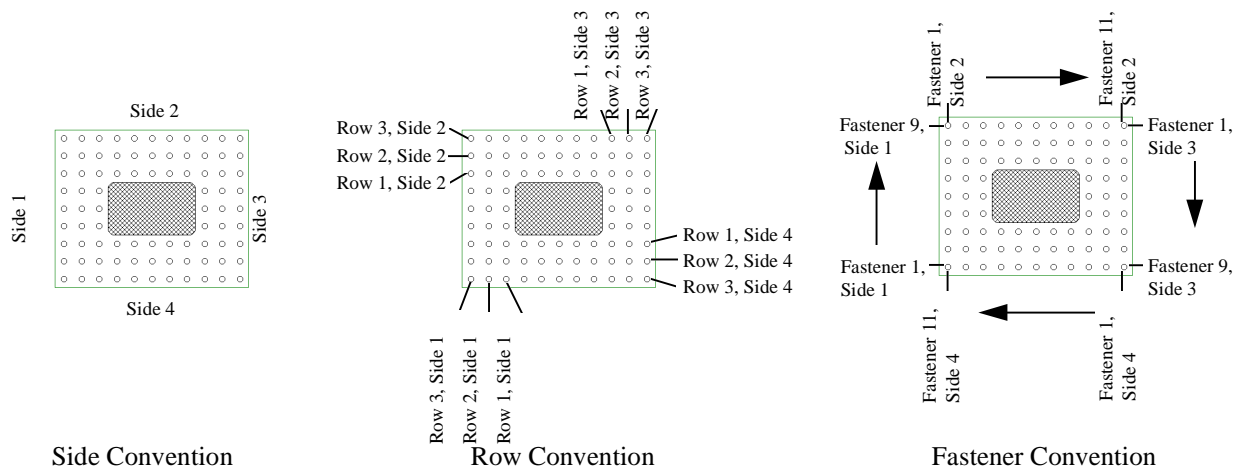
Material Thickness

Fastener Rows per Side :

Left Of Cutout	<input type="text" value="3"/>	Right Of Cutout	<input type="text" value="3"/>
Top of Cutout	<input type="text" value="3"/>	Bottom of Cutout	<input type="text" value="3"/>

Fastener Types :

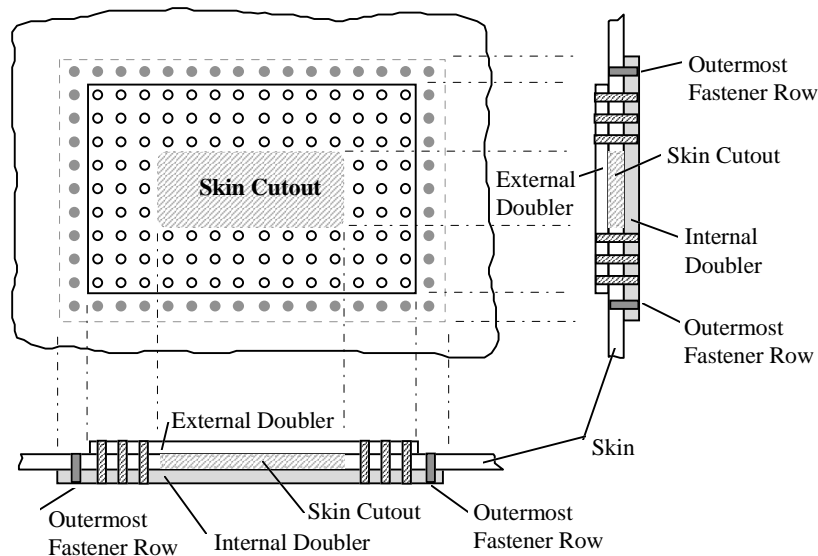
This dialog window is used to enter the fastener information for the repair. The sides are numbered starting at the left side and continuing clockwise, the rows on each side are numbered starting at the edge of the cutout and moving outward, and the fasteners are numbered in each row on each side in a clockwise fashion as shown in the figure below.



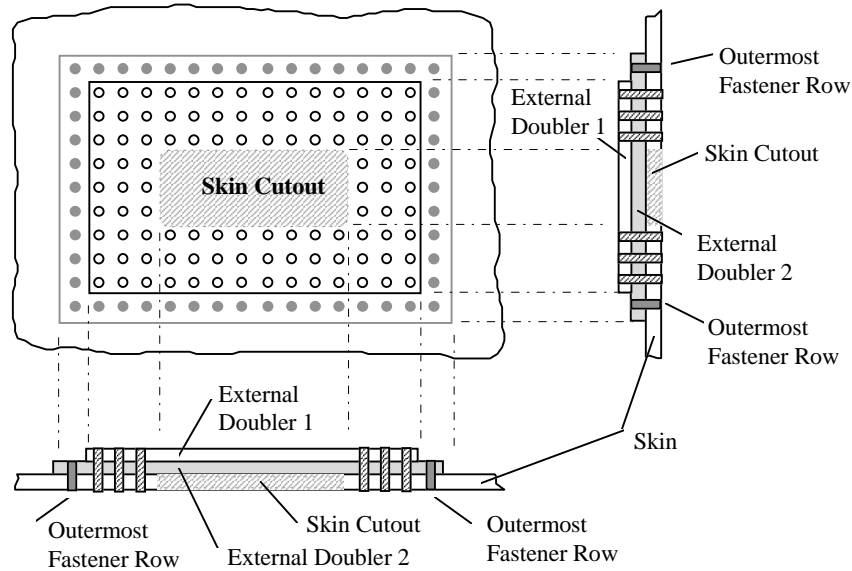
Under the **Pitch and Edge Distance (in)** section of the dialog window, the user specifies the pitch and edge distances of the fasteners, which otherwise default to the settings selected in the program setup. These values are bound by the min/max values stored in the Advisory System as determined by the fastener diameter of the type 1 fastener (defined below in the **Fastener Types** dialog). In models with stiffener effects and/or joints with existing fasteners, the pitch is fixed to that of the existing fasteners.

The doubler properties are entered in the **Doubler Information** section of this dialog window. For each doubler layer selected using the **Layer Object** combination box, the user selects the material and thickness using the **Material** and **Thickness** combination boxes, respectively. For each side of the repair listed in the **Fastener Rows per Side** section, the user enters the number of fastener rows in the associated edit field. Based on the pitch, edge distances of the fasteners, and the number of fastener rows per repair side, RAPID will automatically determine the appropriate doubler geometry. For repair configurations that must be symmetric, some of the **Fastener Rows per Side** entries will be grayed out. The **Right** and/or **Bottom** side will be grayed out and will display the same number of fastener rows per side as entered for the **Left** and/or **Top** side.

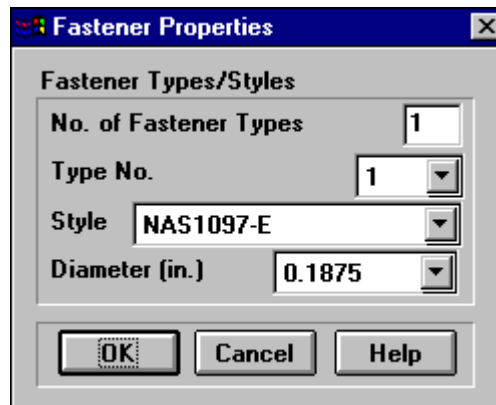
For repair type 1, the internal doubler should be larger than the external doubler. The internal doubler should be sized such that the single outermost fastener row passes through the skin and the internal doubler as shown in the figure below.



For repair type 2, the external doubler 2 should be larger than the external doubler 1. The doublers should be sized such that the single outermost fastener row passes through the skin and the external doubler 2 as shown below.

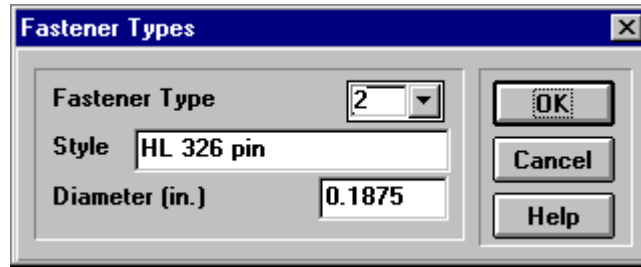


The user specifies the different types and styles of fasteners in the arrangement using the **Fastener Properties** dialog, which is invoked by selecting the **Define** button in the **Fastener Types** section of the dialog window. Fastener types are defined by first entering the number of fastener types desired in the **No. Fastener Types** edit field and then associating a type number with style and size in the **Type #**, **Style** and **Diameter** combination boxes.



7.6.6.1 Selecting and Changing Fastener Types

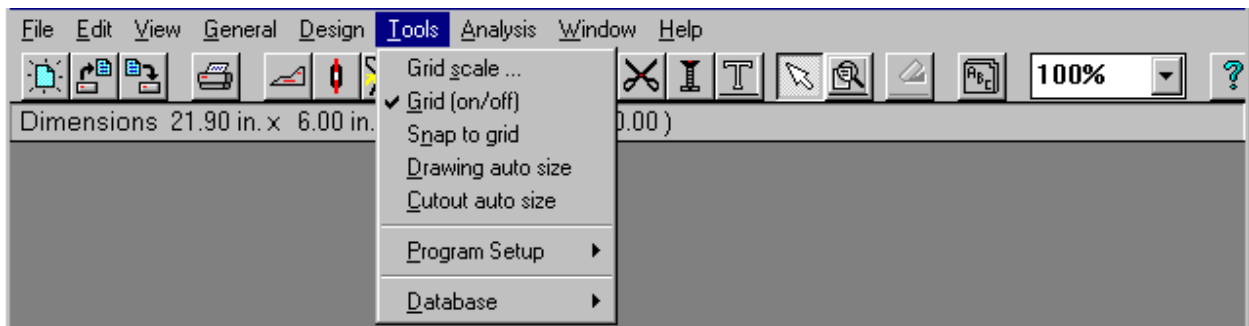
To change fastener types, they must first be defined in the **Fastener Properties** dialog which may be invoked from the **Fastener Global Properties** dialog. Any number of fasteners may be simultaneously changed to a predefined type. Multiple fasteners are selected by holding the shift key while clicking on desired fasteners. To select a rectangular region of fasteners, while holding the shift key, click and hold the left mouse button and drag the mouse to draw a rectangle around a group of fasteners. Releasing the mouse button then toggles the selection state of each of the enclosed fasteners. Subsequently clicking the right mouse button will invoke the **Fastener Types** dialog through which the new fastener type may be selected.



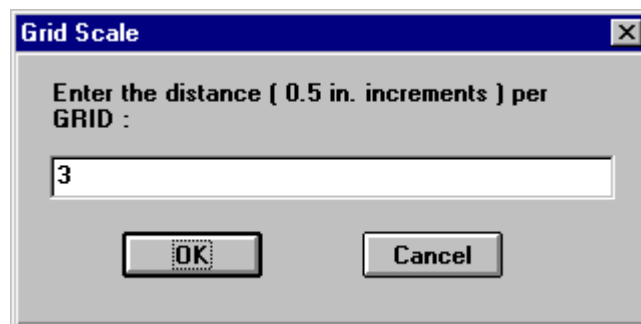
7.6.7 Text

The text tool, available both as an icon button and in the **Design** pull-down menu, switches the mouse pointer to **Text** input mode. The text tool is used to annotate the drawing. After selecting this tool, text may be entered directly on the drawing at the location indicated by the next click of the left mouse button.

7.7 Tools Menu Listing



7.7.1 Grid Scale



The grid scale can be adjusted to accommodate the size of the repair. This is done by selecting the **Grid Scale** menu item from the **Tools** pull-down menu, and then entering an appropriate number of inches per displayed grid. As a convenience, this dialog is automatically invoked the first time the repair boundary is defined.

7.7.2 Grid (on/off)

The **Grid (on/off)** option in the **Tools** pull-down menu is used to turn the display of grid lines on and off in the drawing window.

7.7.3 Snap to Grid

The **Snap to Grid** option in the **Tools** menu, if selected, causes drawing objects to “snap” to the nearest fifth of a grid when drawn, moved, or resized.

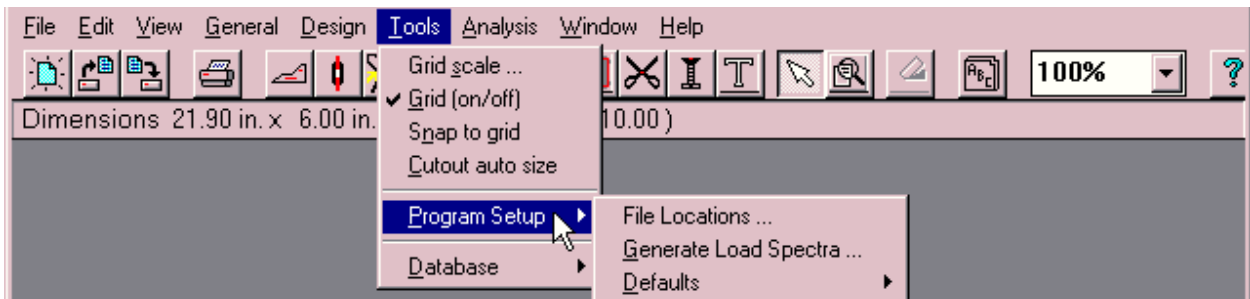
7.7.4 Drawing Auto Size

The **Drawing auto size** option in the **Tools** menu, if selected, causes drawing to automatically resize to fit the available display area.

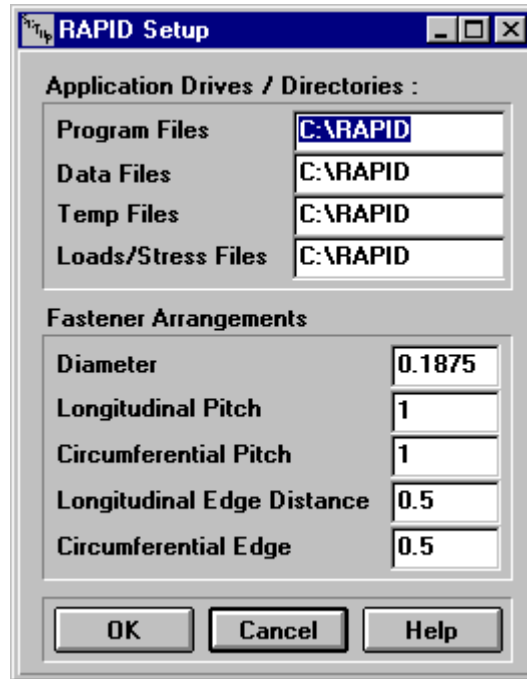
7.7.5 Cutout Auto Size

The **Cutout auto size** option in the **Tools** menu resizes the cutout to fit within the fasteners, subject to the edge distance constraint.

7.7.6 Program Setup



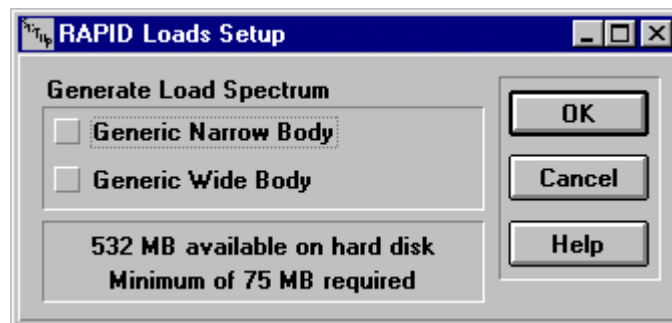
7.7.6.1 File Locations (RAPID Setup)



This window is used to set default quantities used in RAPID. It is not expected that the typical user will need to modify these values on a regular basis; thus, this dialog can only be invoked from the **Tools** pull-down menu and not from the button bar. The data entered in this dialog is stored in the RAPID.INI file which is read when RAPID is started. The **OK** button is used to update the RAPID.INI file when changes are made to the window. If the window is closed by selecting **Cancel**, then updates to the entry fields will be ignored and will not be saved.

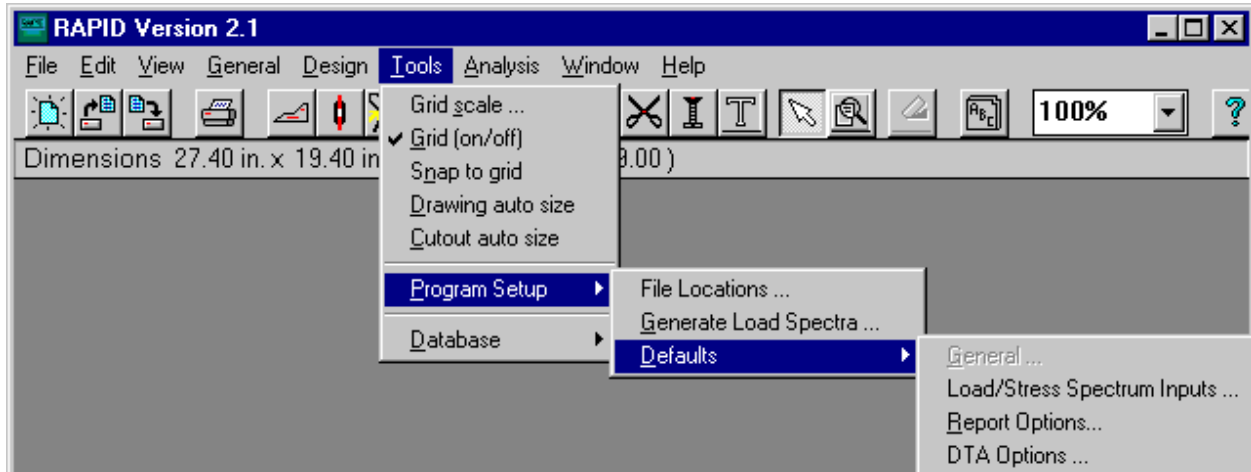
The data in the Fastener Arrangements section of this window is used in the **Fastener Arrangement Window** to determine the number and placement of the repair fasteners.

7.7.6.2 Generate Load Spectra



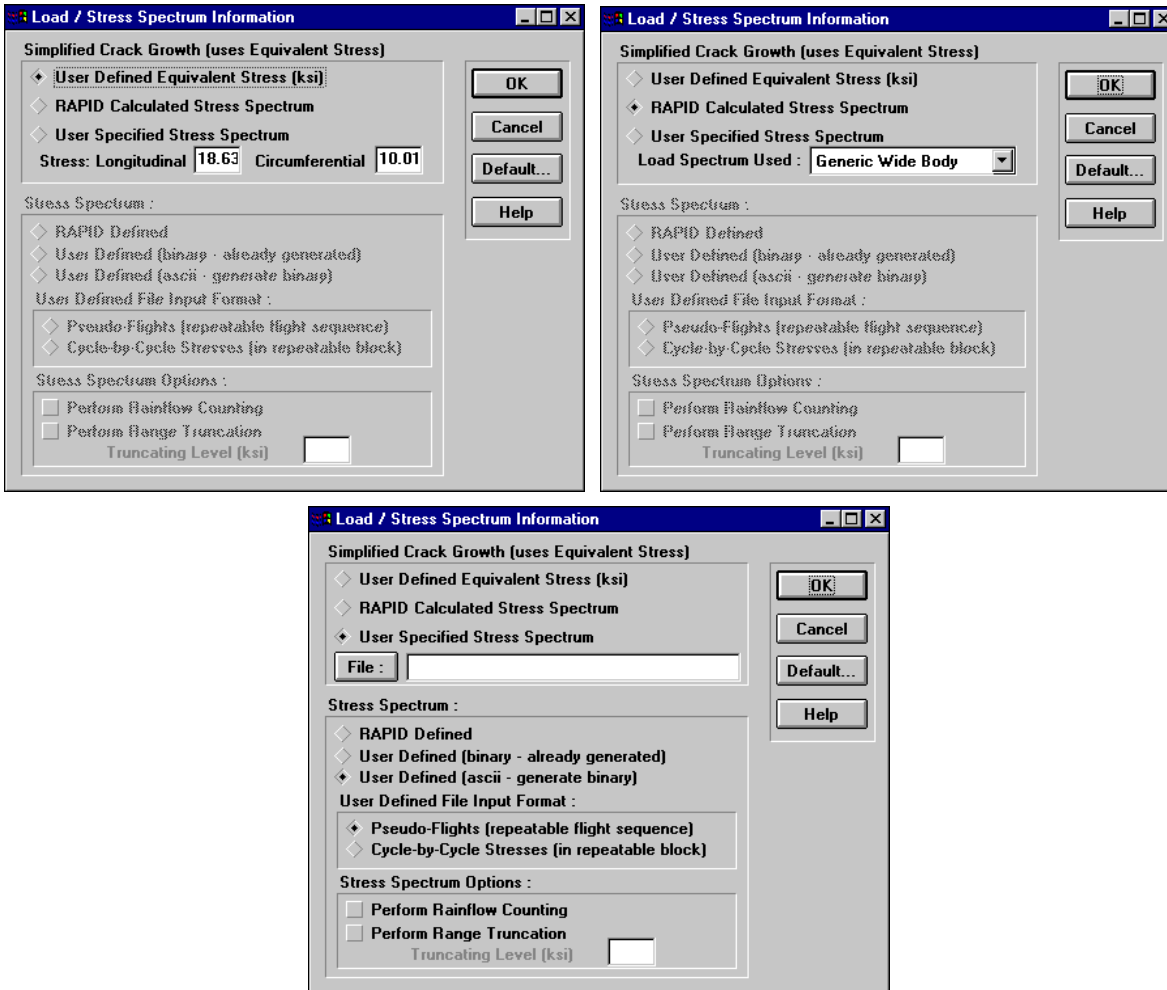
The **RAPID Loads Setup** is used to select which load spectra (generic narrow-body aircraft or generic wide-body aircraft) will be generated. These spectra can occupy considerable disk space, and so only those which are required should be generated.

7.7.6.3 Defaults



There are four selections within the **Defaults** menu in the **Program Setup** item in the **Tools** pull-down menu. The **General** selection is not currently active. The three other selections are described in the following subsections.

7.7.6.3.1 Load/Stress Spectrum Inputs



This dialog window, the three forms of which are displayed above, is used to select the stress spectrum applied during the damage tolerance analysis. The **Equivalent Stress** defines the constant stress amplitude at the repair location. See section 3 and the Analysis Methods Document for further details on the equivalent stress. If the equivalent stress is supplied, then the other input fields are not used. Otherwise, the **Stress Spectrum** is selected from one of the **RAPID Calculated** spectra or from a **User Specified** file. The user input stress spectrum must be in one of the two following ASCII text file formats. Examples of these files are included with the RAPID distribution as PSEUDO.SSF and CYCLES.SSF for pseudo-flights and cycle-by-cycle, respectively.

1. Pseudo-Flights (in repeatable flight sequence)

```
mtype
mflt
ifltseq1 ifltseq2 ifltseq3 ... ifltseqmflt
mcy1
Smin1 Smax1 Smin2 Smax2 ... Sminmcy1 Smaxmcy1
```

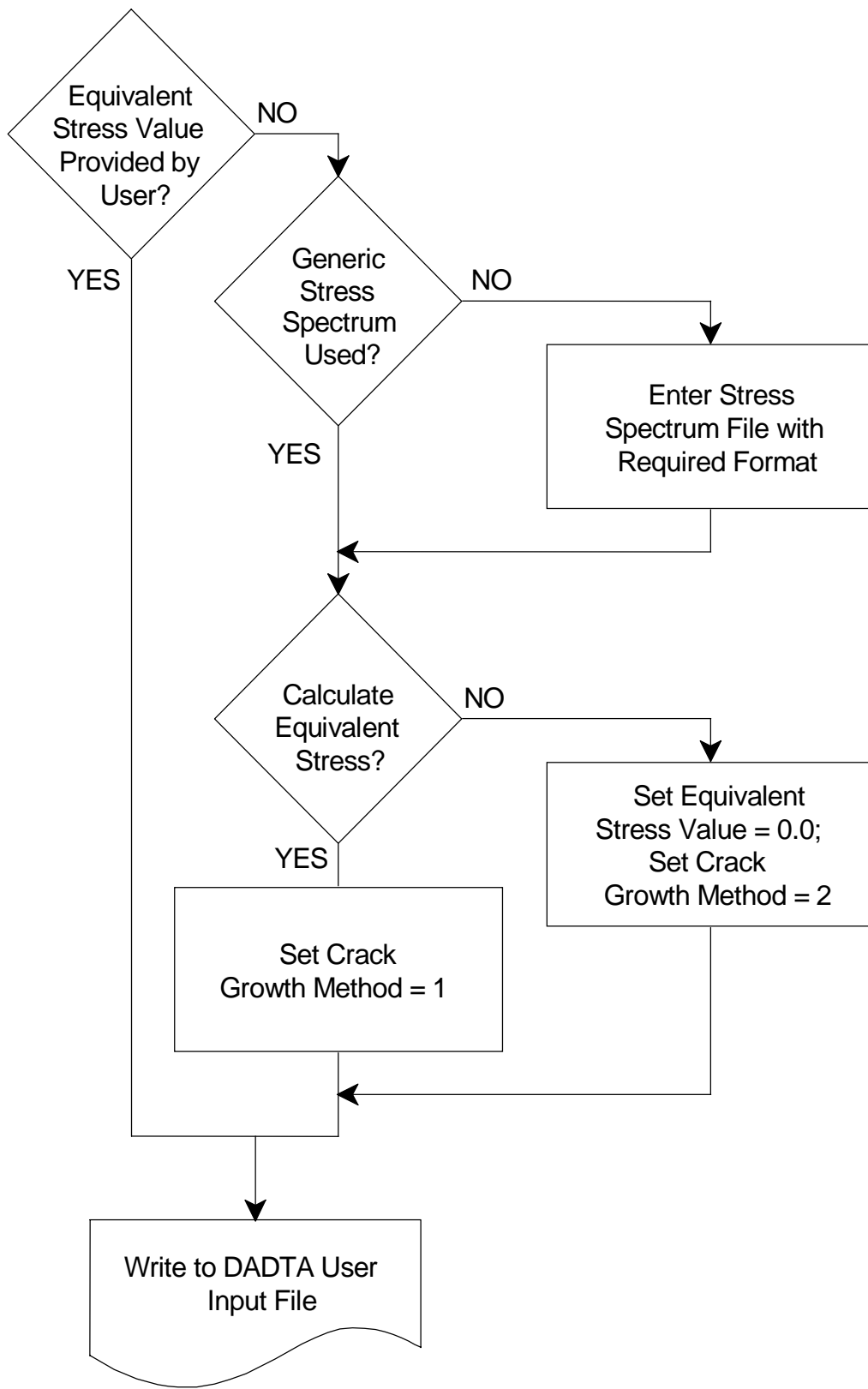

m_{cyc2}
 S_{min1} S_{max1} S_{min2} S_{max2} ... $S_{min_{m_{cyc1}}}$ $S_{max_{m_{cyc2}}}$
 ...
 $m_{cyc_{m_{type}}}$
 S_{min1} S_{max1} S_{min2} S_{max2} ... $S_{min_{m_{cyc1}}}$ $S_{max_{m_{cyc_{m_{type}}}}}$
 where m_{type} is the number of different flight types specified (maximum=20)
 m_{flt} is the number of flights in the spectrum (maximum=6000)
 $ifltseq$ contains the sequence of the flight types
 m_{cyc} is the number of cycle pairs for the flight type (maximum=1000)
 S_{min} is the minimum stress
 S_{max} is the maximum stress

2. Cycle-by-Cycle Stresses (in repeatable block)

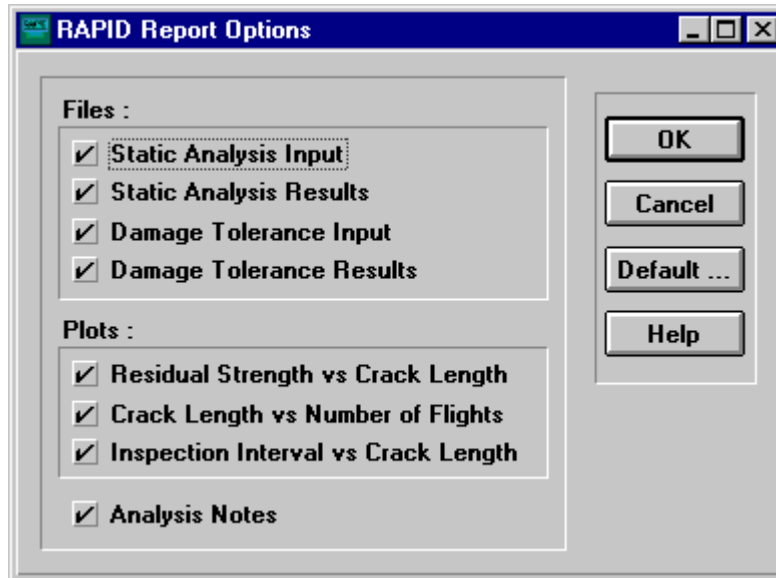
m_{flt}
 m_{cyc1}
 S_{min1} S_{max1} S_{min2} S_{max2} ... $S_{min_{m_{cyc1}}}$ $S_{max_{m_{cyc1}}}$
 m_{cyc2}
 S_{min1} S_{max1} S_{min2} S_{max2} ... $S_{min_{m_{cyc1}}}$ $S_{max_{m_{cyc2}}}$
 ...
 $m_{cyc_{m_{type}}}$
 S_{min1} S_{max1} S_{min2} S_{max2} ... $S_{min_{m_{cyc1}}}$ $S_{max_{m_{cyc_{m_{type}}}}}$
 where m_{flt} is the number of flights in the spectrum (maximum=6000)
 m_{cyc} is the number of cycle pairs for the flight type (maximum=1000)
 S_{min} is the minimum stress
 S_{max} is the maximum stress

For the user defined spectrum, **Rainflow Counting** and **Range Truncation Level** must also be specified, as documented in the Analysis Methods Document.

The input is parsed by RAPID according to the following flow chart.

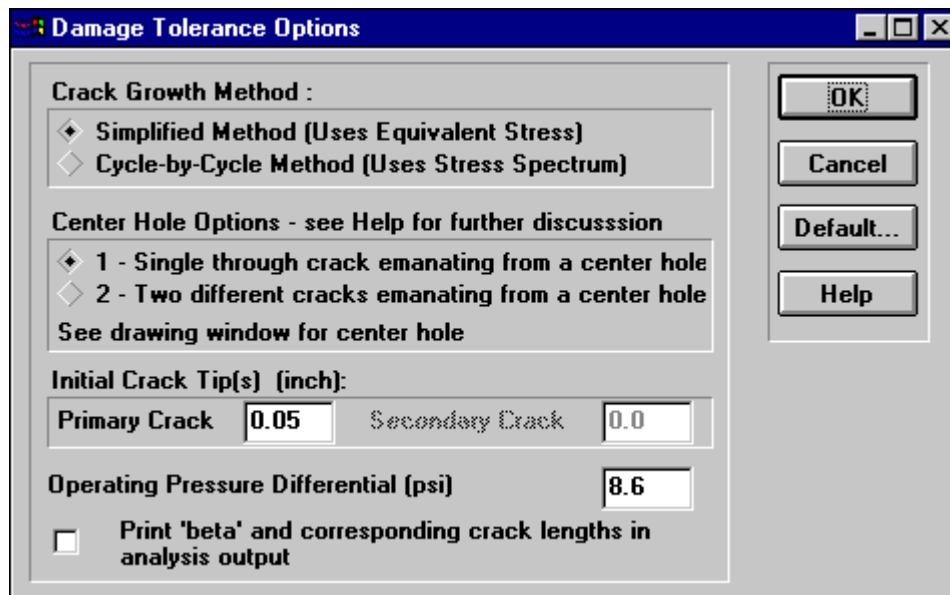


7.7.6.3.2 Report Options



The **Report Options** dialog is used to select which portions of the report will be printed. A checked box indicates that the associated item will be included in the printed RAPID repair report.

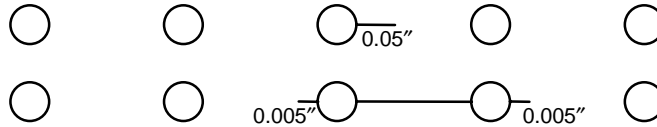
7.7.6.3.3 Damage Tolerance Options



This screen is used to set the options for damage tolerance analysis. Both **Simplified** and **Cycle-by-Cycle** methods are available.

The user may select between two **Center Hole Options** for the crack growth along with a corner hole scenario, which is always analysed, as defined below:

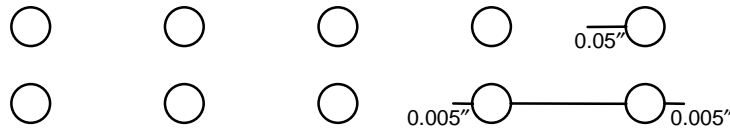
a. Scenario Type 1 (Center Hole) –



b. Scenario Type 2 (Center Hole) –



c. Scenario Type 3 (Corner Hole) - Always Performed

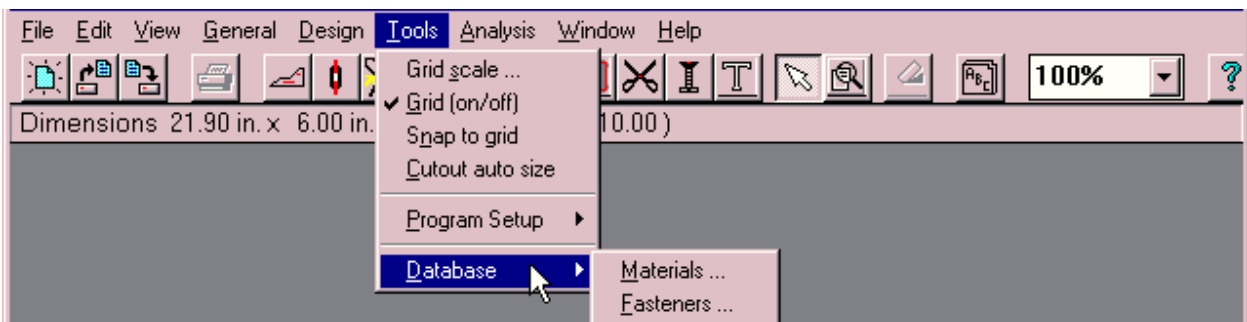


For the current version, the program is restricted to assuming a non-visual inspection method. The crack growth method and retardation flags are set as documented in the Analysis Methods Document.

The **Operating Pressure Differential** is used to define the limit load condition. See section 3 and the Analysis Methods Document for further details on the limit load condition.

A check box is provided to select output of beta values and corresponding crack lengths in the analysis output.

7.7.7 Database



The **Database** menu section of the **Tools** menu contains **Materials** and **Fasteners** menu selections, which are described in the following subsections.

7.7.7.1 Materials Database

This window is used to review and add to the database of materials available for analysis. There is no icon button on the button bar of the main RAPID MDI window for this dialog window; it must be opened from the **Database** menu item in the **Tools** menu.

A **da/dN Data File** entry is included for adding the required da/dN data for user defined records. It is grayed-out when displaying RAPID defined records.

The terms are defined as follows:

K_{Ic} = Plane strain fracture toughness

C, q, p = Coefficients of the Walker crack growth rate equation

$$\frac{da}{dN} = C \left[(1-R)^q K_{max} \right]^p$$

where

K_{max} = the stress-intensity factor associated with the maximum stress in the stress spectrum.

F_{tu} = Allowable tensile stress

- F_{ty} = Allowable tensile yield stress at permanent strain = 0.002
- F_{cy} = Allowable compressive yield stress at permanent strain = 0.002
- F_{su} = Allowable ultimate stress in pure shear (this value represents the average shearing stress over the cross section)
- F_{bru} = Allowable ultimate bearing stress
- e/D = Ratio of edge distance to hole diameter
- F_{bry} = Allowable bearing yield stress
- K_c = Critical plane stress fracture toughness, a measure of fracture toughness at point of crack growth instability

If K_c is not present, then it will be automatically calculated using the NASA/FLAGRO 2.0 equation:

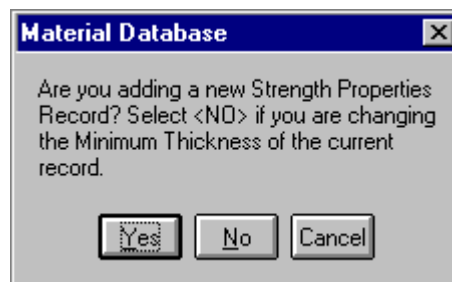
$$\frac{K_c}{K_{Ic}} = 1 + B_k e^{-(A_k / t_0)^2}$$

where

$$t_0 = 2.5 (K_{Ic} / F_{ty})^2$$

The text in the upper right of the dialog indicates whether the current material is a RAPID-defined record or a user-defined record. Only user-defined records can be deleted with the **Delete** button. The **New** button clears the entries to allow user-defined data to be entered, which can then be saved by selecting the **Save** button or discarded by selecting the **Cancel** button. The **Edit** button is used to return the dialog back to the default query and edit state after **New** has been selected. The **OK** button saves the current entry (if user defined) and closes the window.

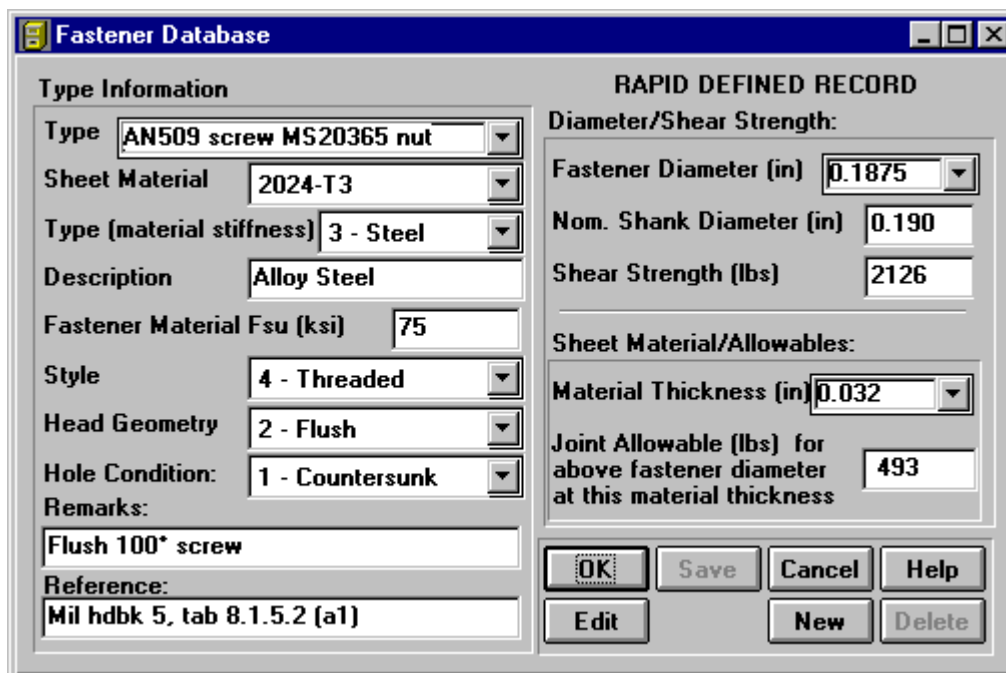
When adding a new entry, if the **Thickness (min)** field is overwritten and then that field is exited by pressing the tab key or selecting another field with the mouse, then the following dialog window will appear. This allows the user to choose between adding properties at a new minimum thickness or changing the value of the minimum thickness for the current record.



When the **Delete** button is selected, the following dialog appears to allow the user to choose between deleting the entire record or simply the material strength properties for the displayed material thickness.



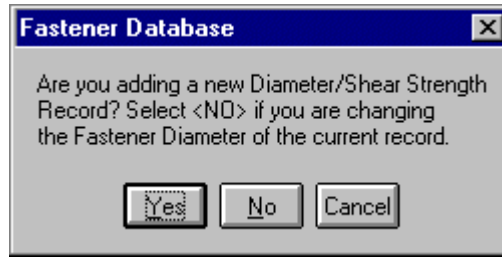
7.7.7.2 Fastener Database



This window is used to review and add to the database of fasteners available for analysis. There is no icon button on the button bar of the main RAPID MDI window for this dialog window; it must be opened from the pull-down **Database** menu item in the **Tools** menu.

The text in the upper right of the dialog indicates whether the current fastener is a RAPID-defined record or a user-defined record. Only user-defined records can be deleted with the **Delete** button. The **New** button clears the entries to allow user-defined data to be entered, which can then be saved by selecting the **Save** button or discarded by selecting the **Cancel** button. The **Edit** button is used to return the dialog back to the default query and edit state after **New** has been selected. The **OK** button saves the current entry (if user defined) and closes the window.

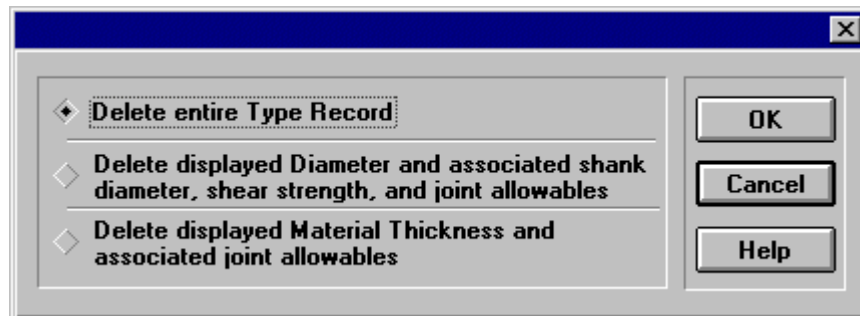
When adding a new entry, if the **Fastener Diameter** field is overwritten and then that field is exited by pressing the tab key or selecting another field with the mouse, then the following dialog window appears. This allows the user to choose between adding properties at a new fastener diameter or changing the value of the fastener diameter for the current record.



Similarly, when adding a new entry, if the **Material Thickness** field is overwritten and then that field is exited by pressing the tab key or selecting another field with the mouse, then the following dialog window appears. This allows the user to choose between adding properties at a new material thickness or changing the value of the material thickness for the current record.

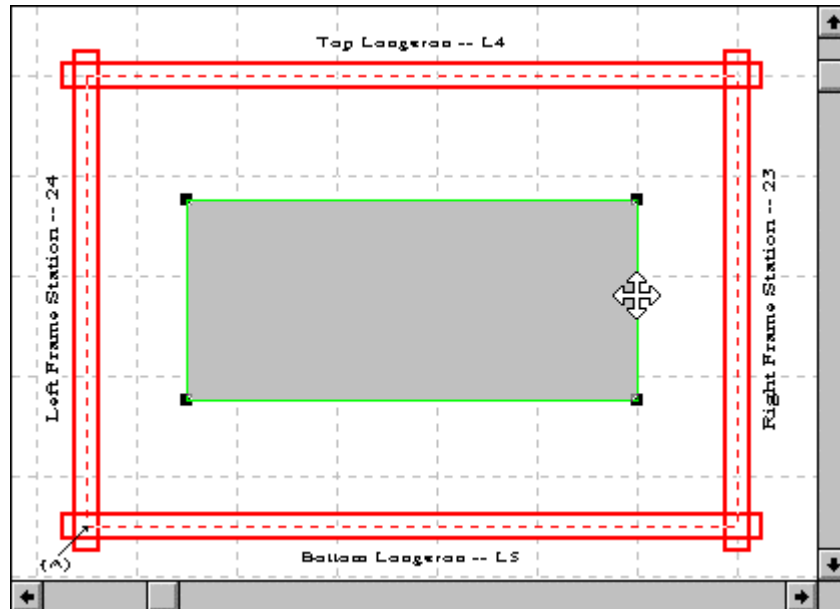


When the **Delete** button is selected, the following dialog allows the user to choose between deleting the entire record, the portion of the data associated with the displayed diameter, or the portion of the data associated with the displayed material thickness.



7.7.8 Moving and Resizing Graphical Objects

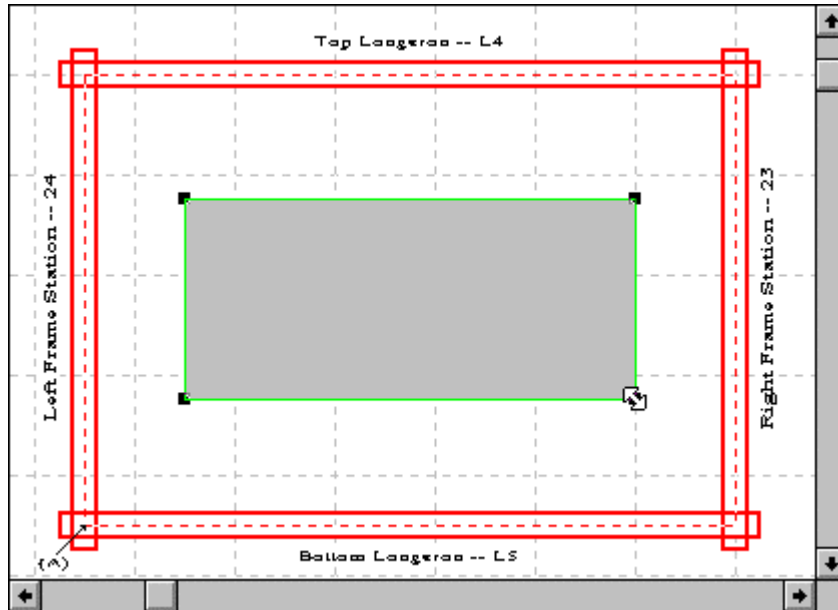
7.7.8.1 Moving an Object



Objects may be moved as follows. First, select the pointer tool from the **Tools** palette and then click within the object to select the object. Once selected, the object will display small black squares, called “handles” at its four corners. The mouse can then be moved to an edge (not a corner) of the object, at which point the cursor will change from an arrow to a cross with four arrows, as shown above. When the crossed arrow cursor is displayed, depress the left mouse button and, while continuing to depress the left mouse button, move the mouse to reposition the object. When the desired location is reached, release the left mouse button.

An object may not be moved if its position has been frozen due to the existence of dependent objects. For example, cutouts cannot be moved after fasteners are defined, since that would require that the fasteners be regenerated.

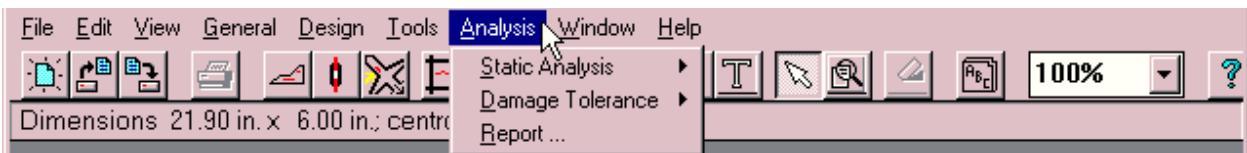
7.7.8.2 Resizing an Object



Objects may be resized as follows. First, select the pointer tool from the **Tools** palette and then click within the object to select the object. Once selected, the object will display small black squares, called “handles” at its four corners. The mouse can then be moved to a corner (not an edge) of the object, at which point the cursor will change from an arrow to a double-headed arrow, as shown above. When the double-headed arrow cursor is displayed, depress the left mouse button and, while continuing to depress the left mouse button, move the mouse to resize the object. When the desired size is achieved, release the left mouse button.

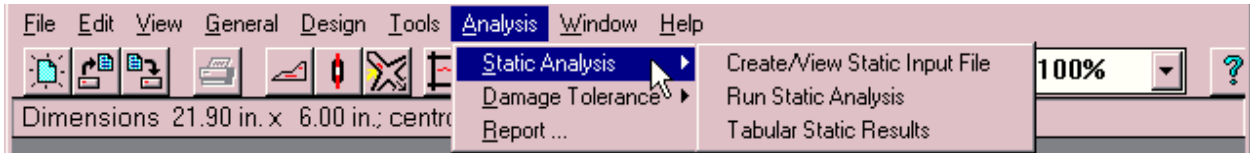
An object may not be resized if its position has been frozen due to the existence of dependent objects. For example, cutouts can not be resized after fasteners are defined, since that would require that the fasteners be regenerated.

7.8 Analysis Menu Listing



The **Analysis** menu contains selections for previewing, running, and displaying the results of the static and damage tolerance analyses. The menu items are documented in the following subsections.

7.8.1 Static Analysis



The **Static Analysis** Menu Listing contains options directly related to running the static analysis.

The input can be displayed by selecting the **Create/View Static Input File** submenu options within the **Static Analysis** menu item. The **Static Analysis** input file format is shown here (note that the RAPID GUI makes it unnecessary for the user to directly interact with this input file):

```

REPAIR CONFIGURATION TYPE (1 External Doubler)
  3
SKIN/DAMAGE : Number of Layers
  1
  SKIN : Mat.Type
    2024-T3 CLAD SHEET
    # of Sides, Thickness, FTU (ksi), Modulus (ksi)
    4      0.063      62      10500
SIDE 1      : LENGTH, FSU
              8      38
              MAX# OF FASTENER TYPES
                2
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
                1      24      1.175      0.191
                2      24      1.496      0.1875
              MAX# OF ROWS
                3
              NUMBER OF FASTENERS PER ROW
                16
                16
                16
SIDE 2      : LENGTH, FSU
              18      38
              MAX# OF FASTENER TYPES
                1
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
                1      96      1.175      0.191
              MAX# OF ROWS
                4
              NUMBER OF FASTENERS PER ROW
                24
                24
                24
                24
SIDE 3      : LENGTH, FSU
              8      38
              MAX# OF FASTENER TYPES
                2
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
                1      24      1.175      0.191
                2      24      1.496      0.1875
              MAX# OF ROWS
                3
              NUMBER OF FASTENERS PER ROW
                16
                16
                16
SIDE 4      : LENGTH, FSU
              18      38
  
```

```

MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          96          1.175    0.191
MAX# OF ROWS
4
NUMBER OF FASTENERS PER ROW
24
24
24
24
REPAIR      : Number of Layers
1
EXT DBL1    : Mat.Type
2024-T3 CLAD SHEET
# of Sides, Thickness, FTU (ksi), Modulus (ksi)
4      0.071      62      10500
SIDE 1      : LENGTH, FSU
16      38
MAX# OF FASTENER TYPES
2
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          24          1.025    0.191
2          24          1.686    0.1875
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
16
16
16
SIDE 2      : LENGTH, FSU
24      38
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          96          1.025    0.191
MAX# OF ROWS
4
NUMBER OF FASTENERS PER ROW
24
24
24
24
SIDE 3      : LENGTH, FSU
16      38
MAX# OF FASTENER TYPES
2
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          24          1.025    0.191
2          24          1.686    0.1875
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
16
16
16
SIDE 4      : LENGTH, FSU
24      38
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          96          1.025    0.191
MAX# OF ROWS
4
NUMBER OF FASTENERS PER ROW
24
24
24
24
PITCH      : Circumferential, Longitudinal
1.0000    1.0000

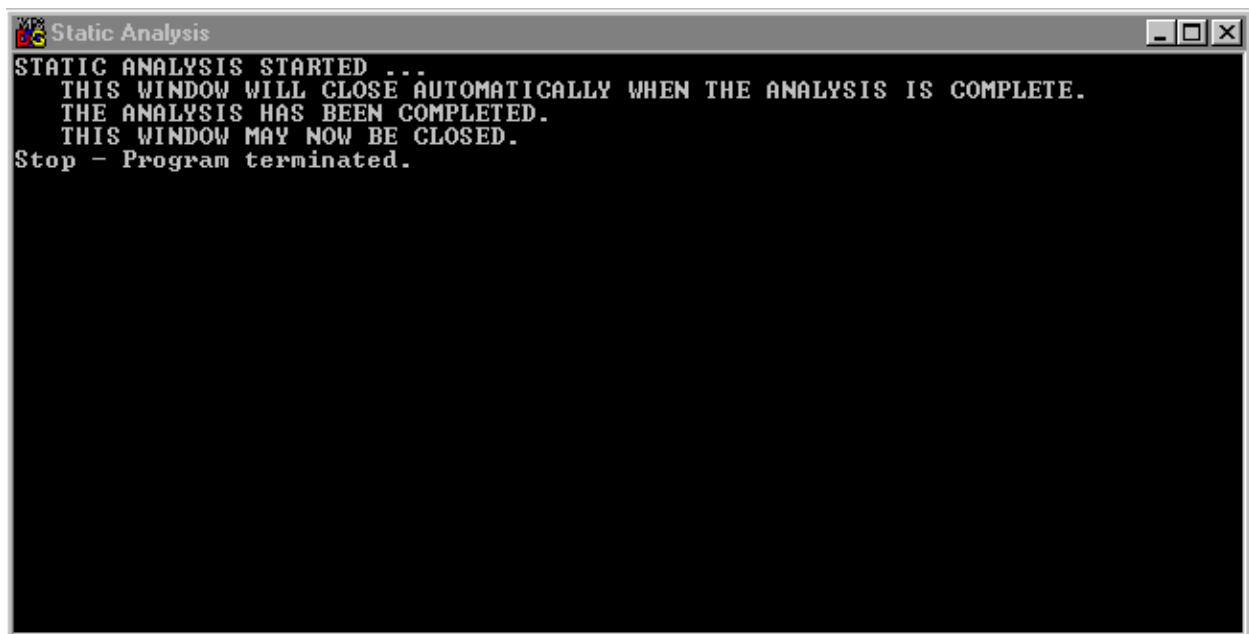
```

BENDING : Q Ratio
2.0

Definitions of Input Parameters:

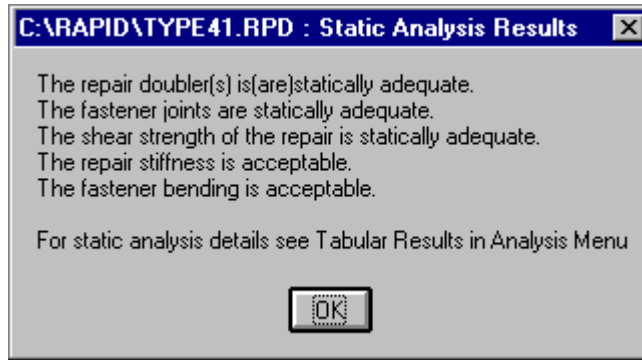
- FSU - Allowable ultimate stress in pure shear
- FTU - Allowable ultimate tension stress
- MAX # OF FASTENER TYPES - Maximum number of different types of fastener for that side (maximum = 10)
- FASTENER TYPE - Material type of that particular type of fastener
 - 1 = Aluminum
 - 2 = Titanium
 - 3 = Steel
- MAX # OF ROWS - Maximum number fastener rows on that side (maximum=4)
- Q RATIO - Use 2.0 in the present version of RAPID

The analysis is performed by selecting the **Run Static Analysis** submenu item. The analysis runs in a DOS window. The progress is automatically monitored by RAPID, while displaying the following screen.

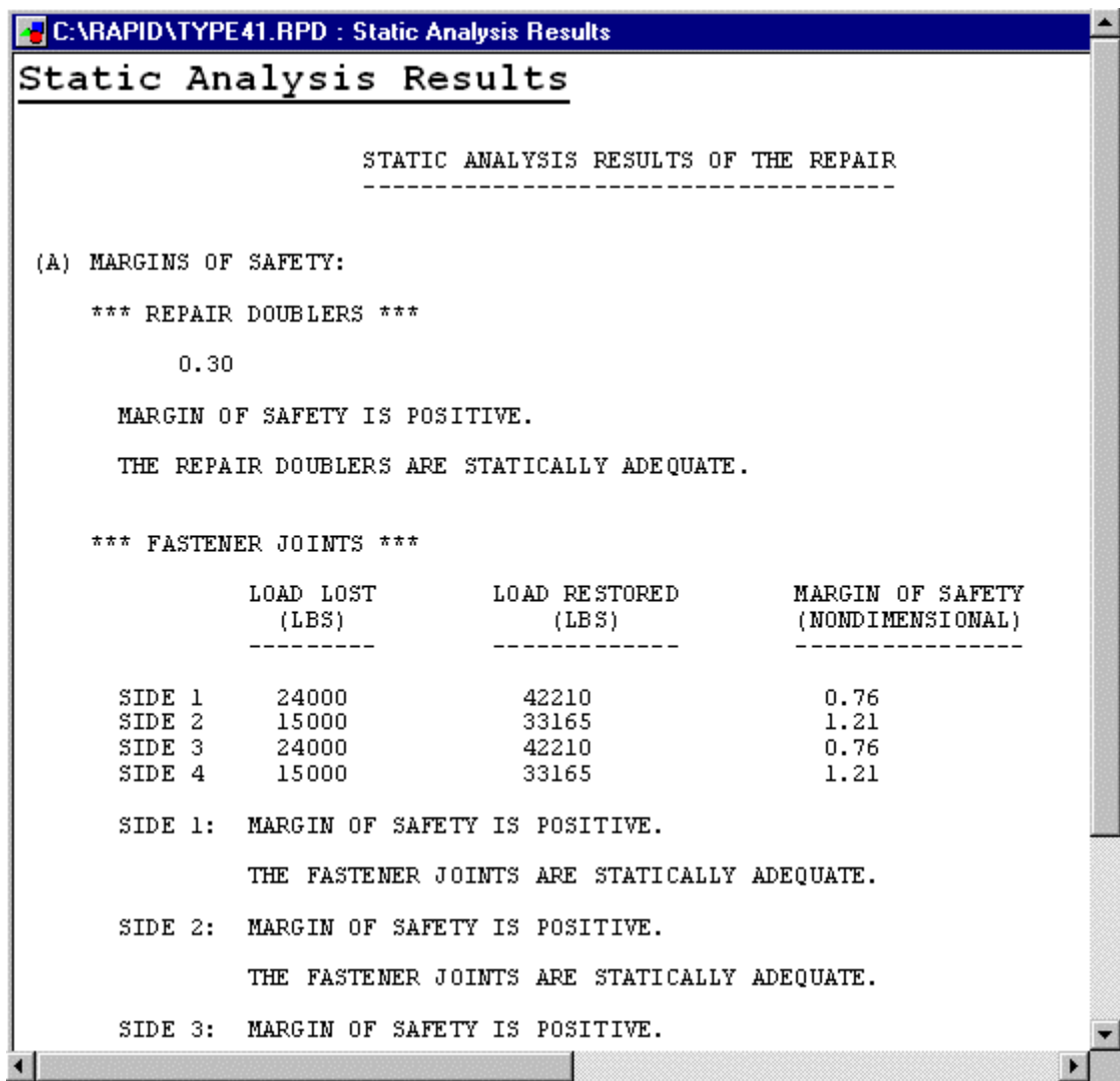


```
Static Analysis
STATIC ANALYSIS STARTED ...
THIS WINDOW WILL CLOSE AUTOMATICALLY WHEN THE ANALYSIS IS COMPLETE.
THE ANALYSIS HAS BEEN COMPLETED.
THIS WINDOW MAY NOW BE CLOSED.
Stop - Program terminated.
```

The static analysis will complete within seconds on all but the very slowest machines and then display a summary of the results.



The output can be displayed by selecting the **Tabular Results** submenu item as shown below.

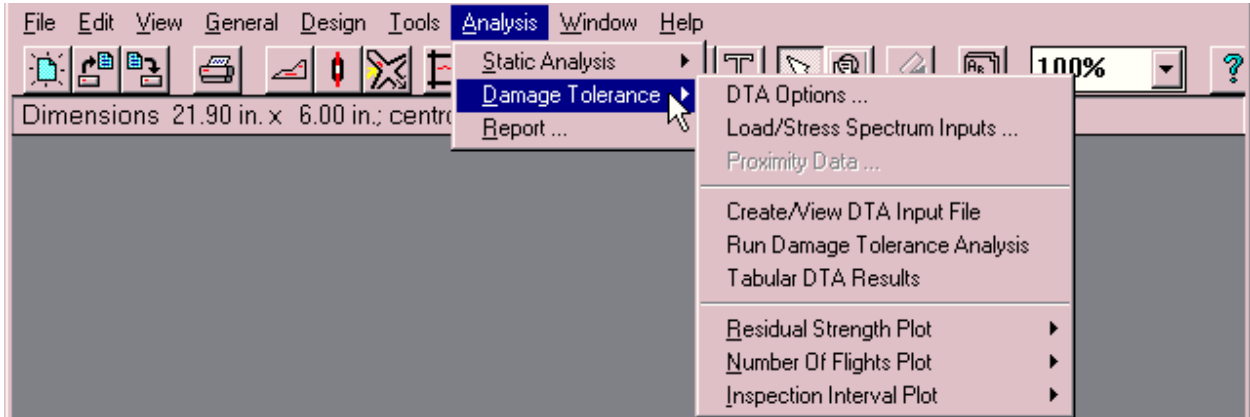


From the static analysis, the margins of safety (MS) based on the repair doubler allowable and the fastener joint allowables are calculated to determine the adequacy of the repair as follows.

- MS < 0: Repair is statically inadequate
- MS = 0: Repair is marginally adequate
- MS > 0: Repair is statically adequate

For repairs that are statically inadequate and marginally adequate, the repair should be redesigned.

7.8.2 Damage Tolerance



The **Damage Tolerance** Menu Listing contains options directly related to running the damage tolerance analysis. The damage tolerance analysis predicts the residual strength and crack length, and recommends an inspection interval. The analysis is performed for all four sides of the repair, at center, and at corner fasteners. The locations of these critical fasteners are highlighted in red in the RAPID drawing window.

The input can be displayed and edited by selecting the **Create/View DTA Input File** submenu options within the **Damage Tolerance** menu item. This selection will automatically invoke the **Damage Tolerance Options** and **Load/Stress Spectrum** dialogs if they are not yet completed for the current model. The **Damage Tolerance** input file format is shown here (note that the RAPID GUI makes it unnecessary for the user to directly interact with this input file):

```
REPAIR CONFIGURATION TYPE (1 External Doubler)
3
SKIN: Mat. Type
2024-T3 CLAD SHEET
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi),FTU
2 0.063 10500 9.01566e-10 3.68842 152.4 45 62
EDSX, EDSY
0.5 0.5
CUTOUT : X Direct., Y Direct.
18 8
EXT DBL1: Mat. Type
2024-T3 CLAD SHEET
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
2 0.071 10500 9.01566e-10 3.68842 152.4 45
```

```

PITCH : X Direct., Y Direct.
        1.0000 1.0000
FSTNR : Max # In Col
        4
        Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
        1 0.19100
        1 0.19100
        1 0.19100
        1 0.19100
        Max # In Row, Crit #, Crit #, Overlap, L2R
        24 12 24 0 0
STIFF : Max #, POS, CSA, Yng.Mod., HPit
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        Dblr Id
        1
PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
        0 0.000 0.000 1 24.000 16.000 1 0.000 0.000 0.500 0.500
FUSELAGE: Eqv.Stress, Press. Diff, Radius
        16.0381 8.6 120.000
CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL
        2 1 0 1 0 0.050 0.000 0
REPAIR CONFIGURATION TYPE (1 External Doubler)
        3
        SKIN: Mat. Type
        2024-T3 CLAD SHEET
        Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi),FTU
        1 0.063 10500 6.76125e-10 3.7198 152.4 45 62
        EDSX, EDSY
        0.5 0.5
CUTOUT : X Direct., Y Direct.
        8 18
EXT DBL1: Mat. Type
        2024-T3 CLAD SHEET
        Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
        1 0.071 10500 6.76125e-10 3.7198 152.4 45
PITCH : X Direct., Y Direct.
        1.0000 1.0000
FSTNR : Max # In Col
        3
        Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
        3 0.19000
        3 0.19000
        3 0.19000
        Max # In Row, Crit #, Crit #, Overlap, L2R
        16 9 16 0 0
STIFF : Max #, POS, CSA, Yng.Mod., HPit
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        0 0.000 0.000 0.000 0.0000
        Dblr Id
        1
PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
        0 0.000 0.000 1 16.000 24.000 1 0.000 0.000 0.500 0.500
FUSELAGE: Eqv.Stress, Press. Diff, Radius
        9.2389 8.6 120.000
CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL
        2 1 0 1 0 0.050 0.000 1

```

Definitions of Input Parameters:

- REPAIR CONFIGURATION TYPE - Type of Repair Configuration
 - 1 = One Internal Doubler, 1 External Doubler
 - 2 = Two External Doublers
 - 3 = One External Doubler

- SCENARIO TYPE - Type of Crack Scenario
 - 1 = A single through crack emanating from a center hole on a sheet, two equal length through cracks emanating from holes after first crack grew into the adjacent hole
 - 2 = Two different length through cracks emanating from a center hole on a sheet
 - 3 = A single through crack emanating from a corner hole on a sheet, two same length through cracks emanating from holes after first crack grew into the adjacent hole
- VSL.METH - Visual Inspection Flag; applicable only to Scenario Type 3
 - 0 = Inspection Method is not visual
 - 1 = Inspection Method is visual
- METHOD - Type of Crack Growth Method
 - 1 = Simplified Method
 - 2 = Cycle-by-Cycle Method (Uses Stress Spectrum)
- RETARD.FLAG - Retardation Flag; applicable only to the Cycle-by-Cycle Method
 - 0 = No Retardation (Default)
 - 1 = Retardation

The analyses are performed on all four sides of the repair at the center and corner fasteners automatically.

The analysis is performed by selecting the **Run Damage Tolerance Analysis** submenu item. The analysis runs in a DOS window. The progress is automatically monitored by RAPID, while displaying the following screen.

```

Phar Lap's 386!DOS-Extender(tm) Version 4.1L
Copyright (C) 1986-92 Phar Lap Software, Inc.
Available Memory = 15356 Kb

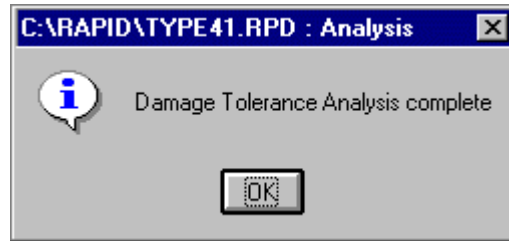
DAMAGE TOLERANCE ANALYSIS STARTED ...
FULL ANALYSIS MAY REQUIRE SEVERAL MINUTES.
THIS WINDOW WILL CLOSE AUTOMATICALLY WHEN THE ANALYSIS IS COMPLETE.

*** LONGITUDINAL CRACK(S) ***

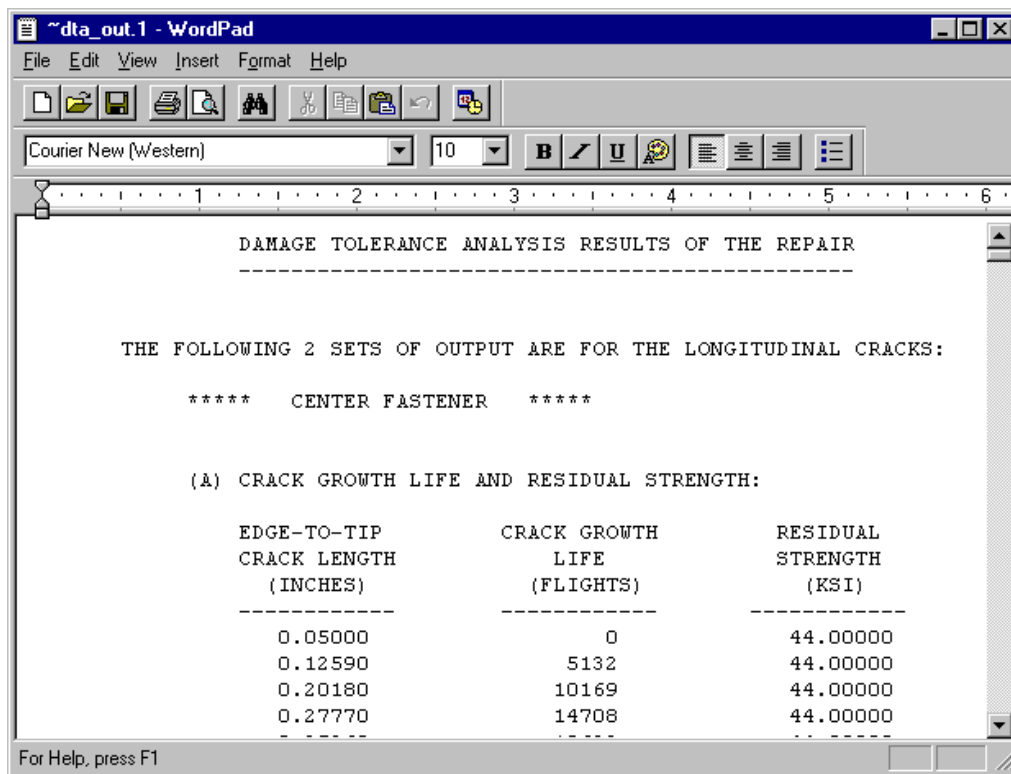
*** CENTER FASTENER ***

CRACK LENGTH          CRACK GROWTH LIFE
<INCHES>              <FLIGHTS>
-----
1.57259                40824
3.22227                44926
3.35641                45125
5.22289                46666
5.33338                46734
7.23273                47413
8.26726                47616
  
```

Depending on the computer and on the particular repair model, the damage tolerance analysis will complete within minutes or hours. On a typical Pentium-class computer, the analysis usually consumes less than 5 minutes. The progress of the crack growth can be observed by bringing the DOS window (shown above) to the foreground. When the analysis is complete, the following dialog is displayed.



The output can be displayed by selecting the **Tabular Results** submenu item as shown below.



For the center fastener and for the corner fastener, the damage tolerance output consists of two parts. In the first part, the crack length, crack growth life, and residual strength are provided as shown below.

DAMAGE TOLERANCE ANALYSIS RESULTS OF THE REPAIR

***** CENTER FASTENER *****

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
-----	-----	-----
0.05000	0	198.83429
0.12590	15615	195.59140
0.20180	30148	189.75919
0.27770	42744	181.50046
0.35360	53320	172.89491
0.42950	62139	164.65282
0.50540	69487	156.68164
0.58130	75551	148.17274

In the second part, the inspection threshold (first inspection) is provided followed by a table with the detectable crack length and corresponding inspection interval as shown below.

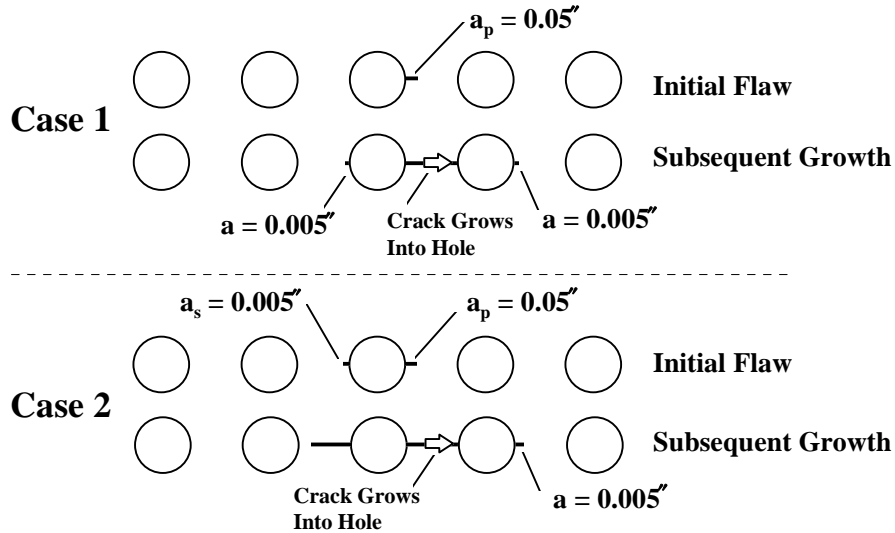
(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 50226 FLIGHTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
-----	-----
0.05000	50226
0.10000	45082
0.15000	40111
0.20000	35324
0.25000	31152
0.30000	27300
0.35000	23817
0.40000	20870
0.45000	18164
0.50000	15744
0.55000	13701
0.60000	11862
0.65000	10289
0.70000	9120
0.75000	8192

For the damage tolerance analysis, two initial flaw patterns are available:

- Case 1: A single through crack emanating from the critical fastener hole. The primary crack has a length of $a_p = 0.05''$.
- Case 2: Two asymmetric through cracks emanating from the critical fastener hole. The primary crack has a length of $a_p = 0.05''$, and the secondary crack has a length of $a_s = 0.005''$.



The analysis defaults to Case 1. To use Case 2, the user must select the **Preview** button in the **DTA** section of the dialog window. The DTA input file will be displayed in the embedded text window. In the last line of this file, the user must manually change the default entry of the crack growth configuration type from 1 to 2. The user must select the **Save** button and then the **Analysis** button to conduct a damage tolerance analysis using Case 2.

Damage tolerance results can also be viewed graphically as **Residual Strength vs. Crack Length**, **Crack Length vs. Number of Flights**, and **Inspection Interval vs. Detectable Crack Length**. These plots are available from within the **Damage Tolerance** submenu in the **Analysis** pull-down menu on the main RAPID MDI window as discussed in the following subsections.

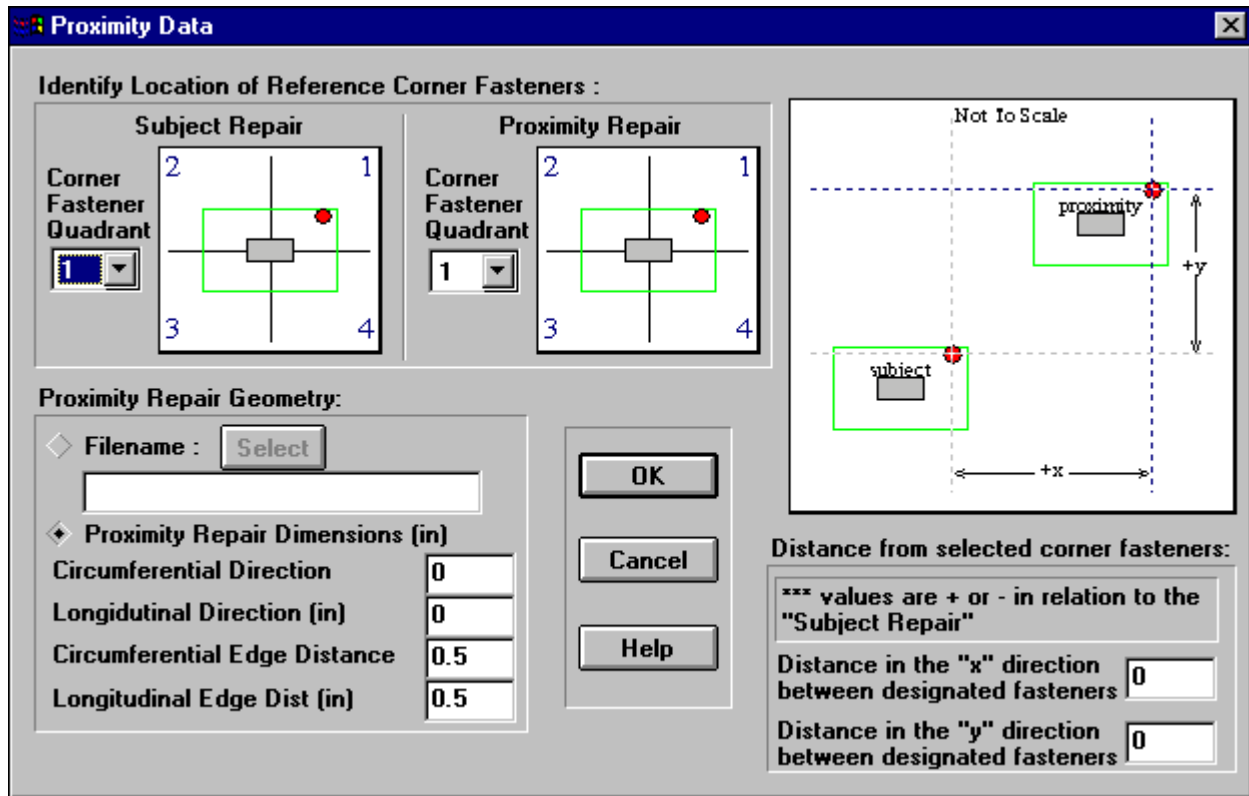
7.8.2.1 Damage Tolerance Options

The **Damage Tolerance Options** dialog is described in section 7.7.6.3.3.

7.8.2.2 Load/Stress Spectrum Information

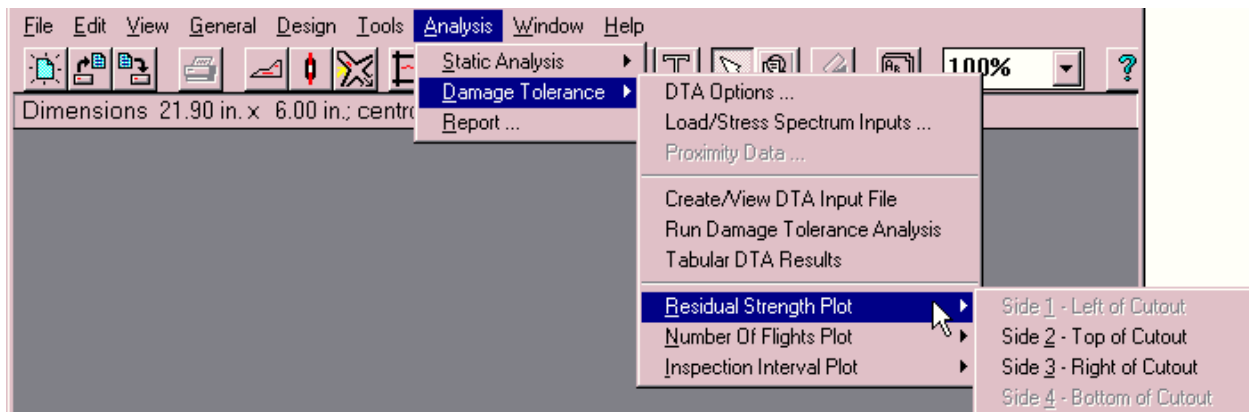
The **Load/Stress Spectrum Information** dialog is described in section 7.7.6.3.1.

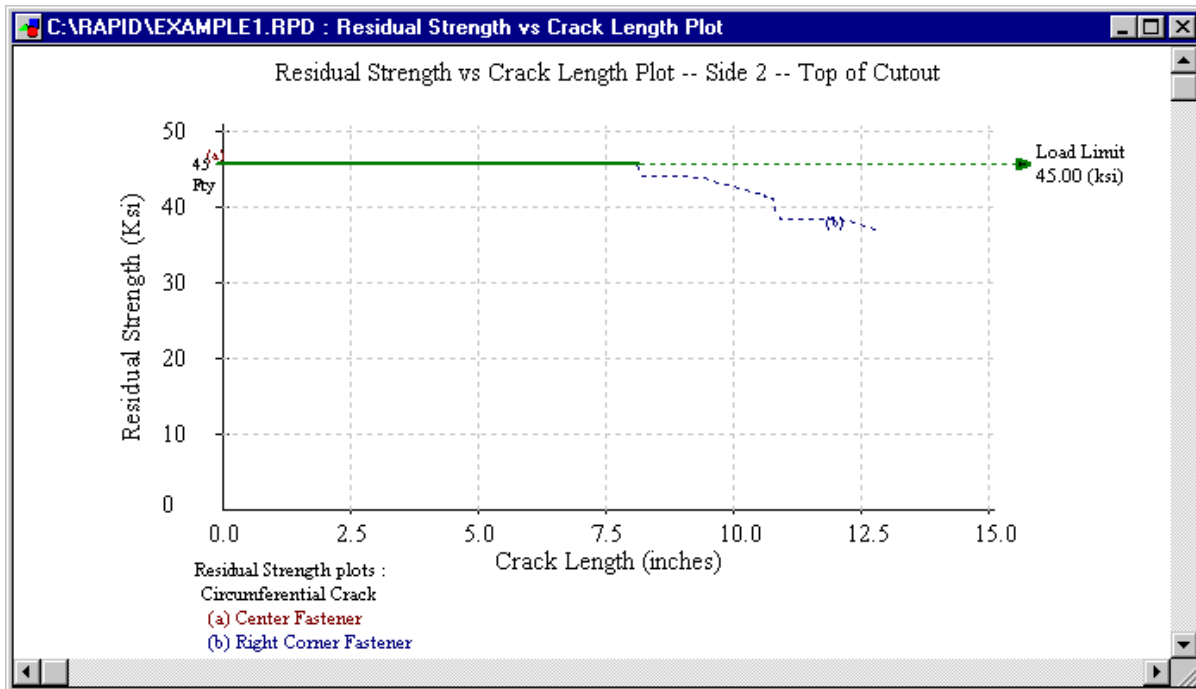
7.8.2.3 Proximity Data



The **Proximity Data** is used to define the size and location of a nearby repair so that its influence may be considered in the analysis. The location of the nearby (proximity) repair is indicated by selecting a reference corner fastener in each repair, along with the longitudinal (x) and circumferential (y) distances between those reference points. The geometry of the nearby repair can be entered directly under the **Proximity Repair Dimensions** selection or may be determined automatically via reference to an existing repair model **Filename**. The **Select** button opens a file dialog to select a file from disk.

7.8.2.4 Residual Strength vs. Crack Length Plot



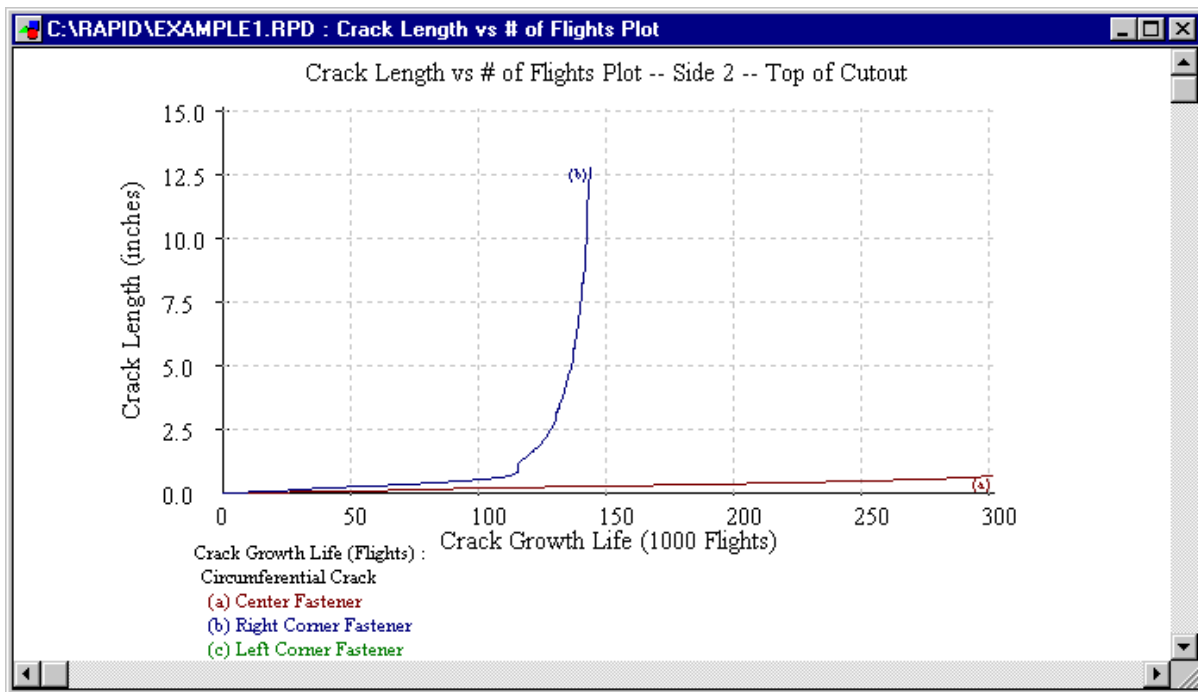
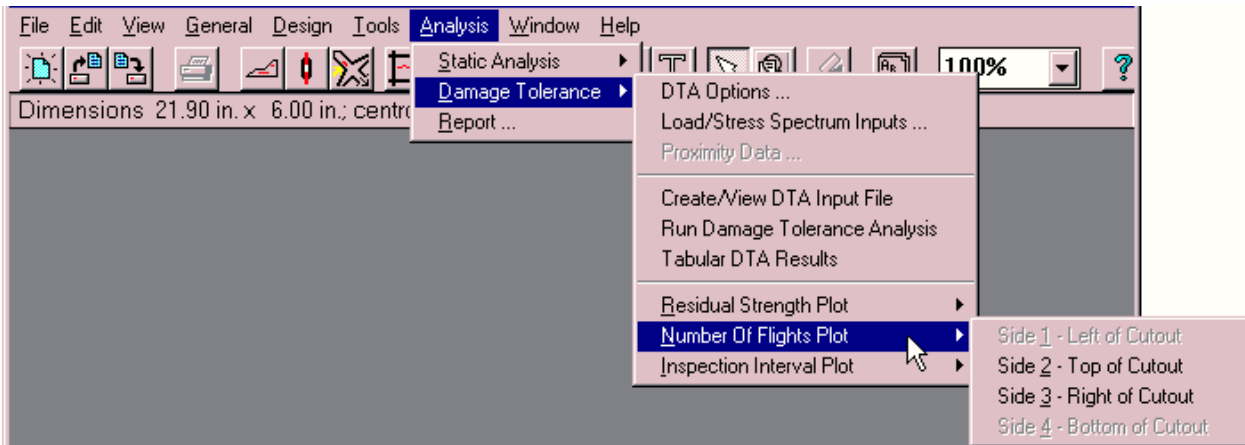


This window displays the residual strength versus crack length plot from the damage tolerance analysis for all four sides of the repair. (For a symmetrical repair, only sides 2 and 3 are available). The yield strength of the skin, F_{Ty} , is indicated by the solid horizontal line and the limit load condition is indicated in the legend key. This window can be invoked only from the **Damage Tolerance** section of the **Analysis** pull-down menu in the main RAPID MDI. The plots can be generated for longitudinal cracks in the center and corner fasteners above and below the cutout and for circumferential cracks in the center and corner fasteners to the left and right of the cutout. If there are four points, then the plot will not be generated and a message box will be displayed.

Any portion of this window may be enlarged or “zoomed” by depressing the left mouse button at one corner of the desired area and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the desired area, release the mouse button. The view will automatically enlarge the selected area to fill the plot window. To return to a non-zoomed view, simply depress the right mouse button within the plot window.

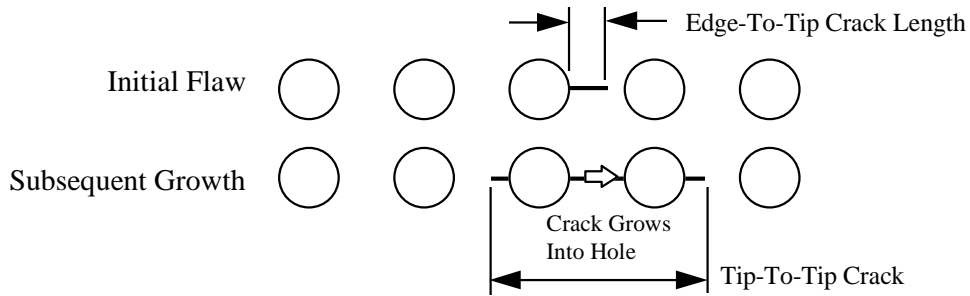
To print the plot, select the print button on the icon bar, or select the **Print** menu item within the **File** menu. The Plot window must be the active window to be printed.

7.8.2.5 Crack Length vs. # of Flights Plot



This window displays the crack length versus number of flights plot from the damage tolerance analysis for all four sides of the repair. (For a symmetrical repair, only sides 2 and 3 are available.) The predicted crack growth life at each of the critical fasteners is indicated in the legend key. This window can be invoked only from the **Damage Tolerance** section of the **Analysis** pull-down menu in the main RAPID MDI. The plots can be generated for longitudinal cracks in the center and corner fasteners above and below the cutout and for circumferential cracks in the center and corner fasteners to the left and right of the cutout. If there are four points, then the plot will not be generated and a message box will be displayed.

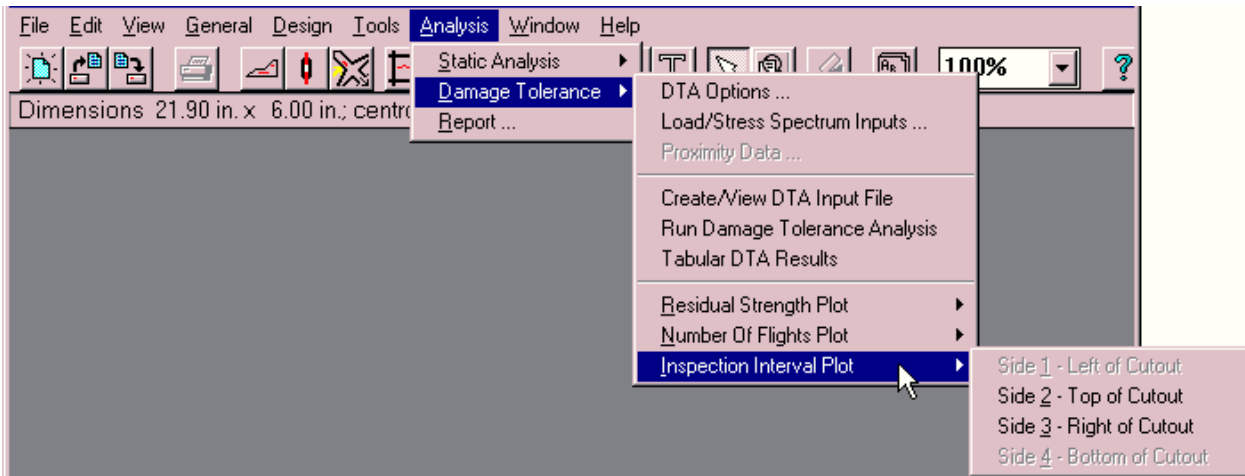
The crack grows edge to tip and then tip to tip as defined in the figure below.

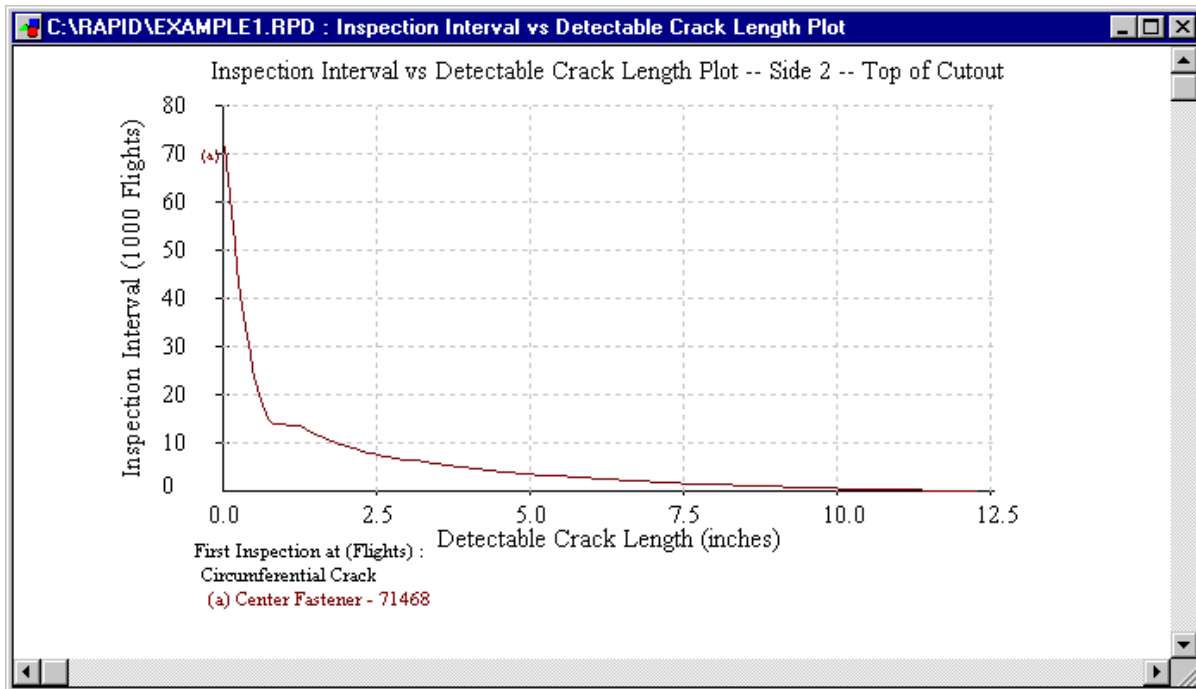


Any portion of this window may be enlarged or zoomed by depressing the left mouse button at one corner of the desired area and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the desired area, release the mouse button. The view will automatically enlarge the selected area to fill the plot window. To return to a non-zoomed view, simply depress the right mouse button within the plot window.

To print the plot, select the print button on the icon bar or select the **Print** menu item within the **File** menu. The Plot window must be the active window to be printed.

7.8.2.6 Inspection Interval vs. Detectable Crack Length Plot



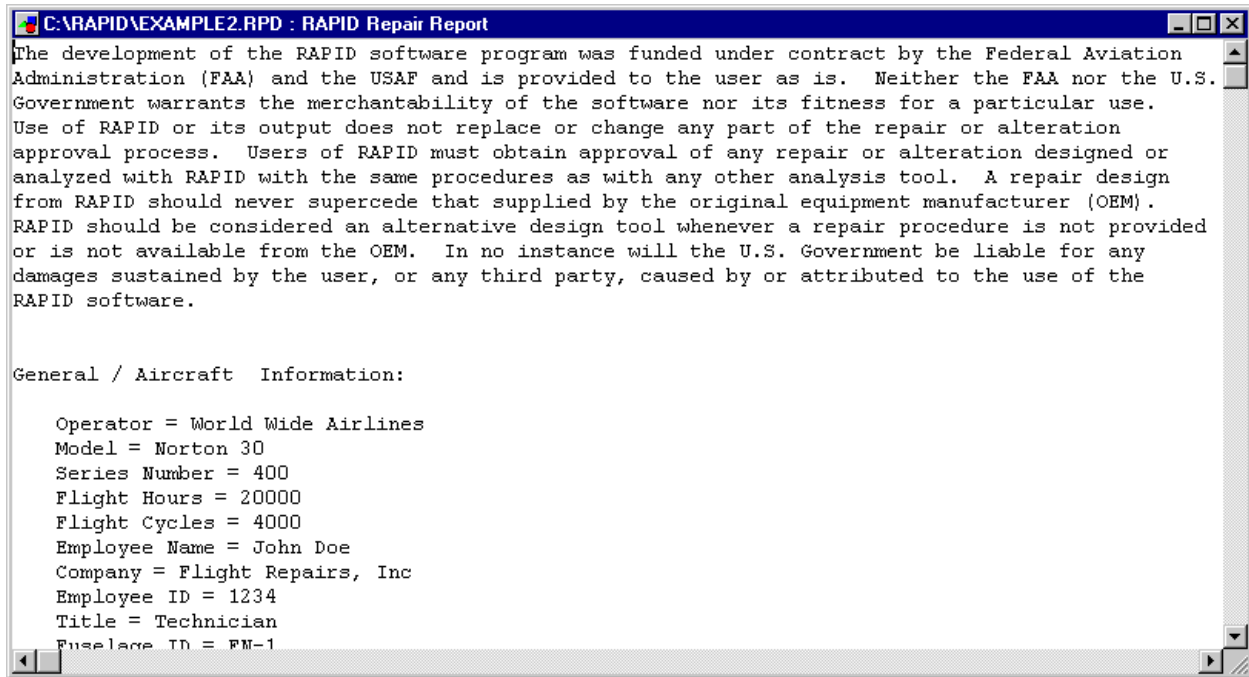


This window displays the inspection interval versus detectable crack length plot from the damage tolerance analysis for all four sides of the repair. (For a symmetrical repair, only sides 2 and 3 are available.) The first inspection as determined by the damage tolerance analysis at each of the critical fasteners is indicated in the legend key. This window can be invoked only from the **Damage Tolerance** section of the **Analysis** pull-down menu in the main RAPID MDI. The plots can be generated for longitudinal cracks in the center and corner fasteners above and below the cutout and for circumferential cracks in the center and corner fasteners to the left and right of the cutout. If there are four points, then the plot will not be generated and a message box will be displayed.

Any portion of this window may be enlarged or zoomed by depressing the left mouse button at one corner of the desired area and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the desired area, releasing the mouse button. The view will automatically enlarge the selected area to fill the plot window. To return to a non-zoomed view, simply depress the right mouse button within the plot window.

To print the plot, select the print button on the icon bar or select the **Print** menu item within the **File** menu. The Plot window must be the active window to be printed.

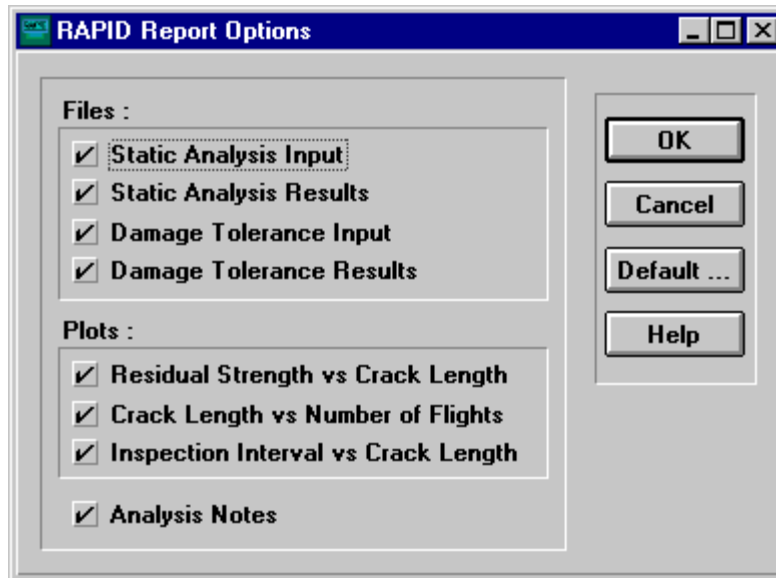
7.8.3 RAPID Repair Report



The RAPID Repair Report may be displayed (and subsequently printed) by selecting the report button on the icon bar or by selecting the **Report** menu item within the **Analysis** menu. While the report is displayed, it may be printed by selecting Print from the File menu.



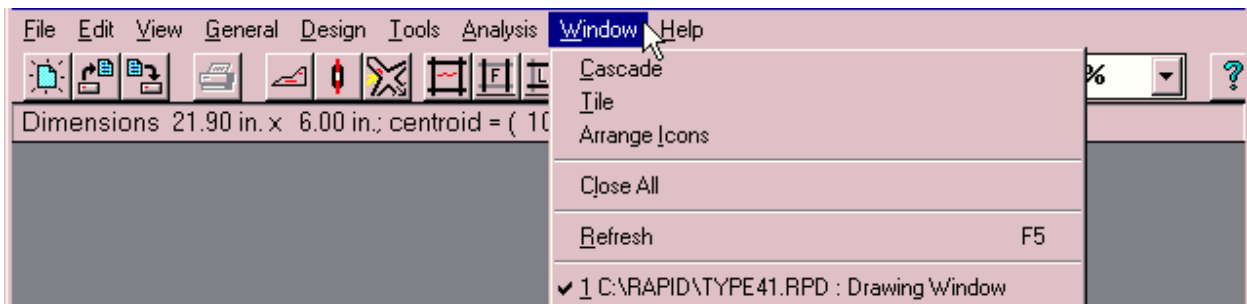
This will invoke the Report Print Options dialog through which the user may choose the components of the report to print.



For the current version, the RAPID Repair Report is read-only. The report contains the following information in sequence: the RAPID.TMP file (data input echo), the input file for the static analysis, the results from the static analysis, the input file for damage tolerance analysis, the tabular results of the damage tolerance analysis, the program limitations (section 3), and optionally, a drawing of the repair configuration and the three analysis plots for each side of the repair. It can be saved to any named file and later reopened from within the Report module.

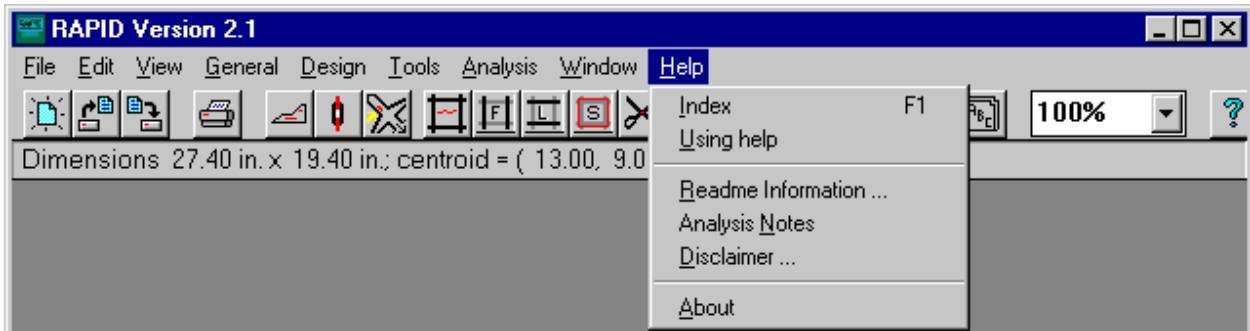
The RAPID Repair Report is formatted using Microsoft's version of Rich Text Format (RTF), which is compatible with most modern word processors.

7.9 Window Menu Listing



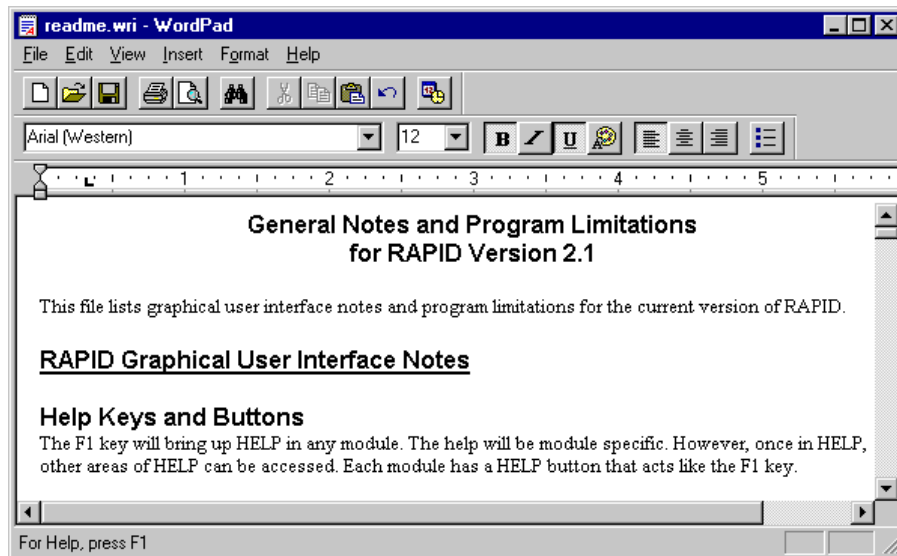
The **Window** menu contains the standard window functions of **Cascade**, **Tile**, **Arrange Icons**, and **Close All** options. **Refresh** is also provided to force a redraw of the entire RAPID window. **Cascade** arranges any open dialog windows within the RAPID MDI diagonally down the screen from left to right. **Tile** arranges dialog windows so that they are evenly distributed across the screen. **Arrange Icons** aligns minimized icons at the lower-left of the RAPID MDI screen. **Close All** closes all currently open windows within RAPID. In addition, if any RAPID models are open, they will be listed within this menu for selection by the user.

7.10 Help Menu Listing



The **Help** menu contains **Index**, **Using help**, **Readme Information**, **Disclaimer**, and **About** selections. **Index** displays the top-level help index, with links to the entire RAPID help and advisory systems. **Using help** displays general information on how to use help systems within Windows programs. **Readme Information** displays the RAPID README.WRI file which contains general notes and corrections concerning the RAPID GUI and analyses. **Disclaimer** redisplay the disclaimer statement which appears each time RAPID is started. **About** presents the RAPID copyright notice.

7.10.1 Readme Information



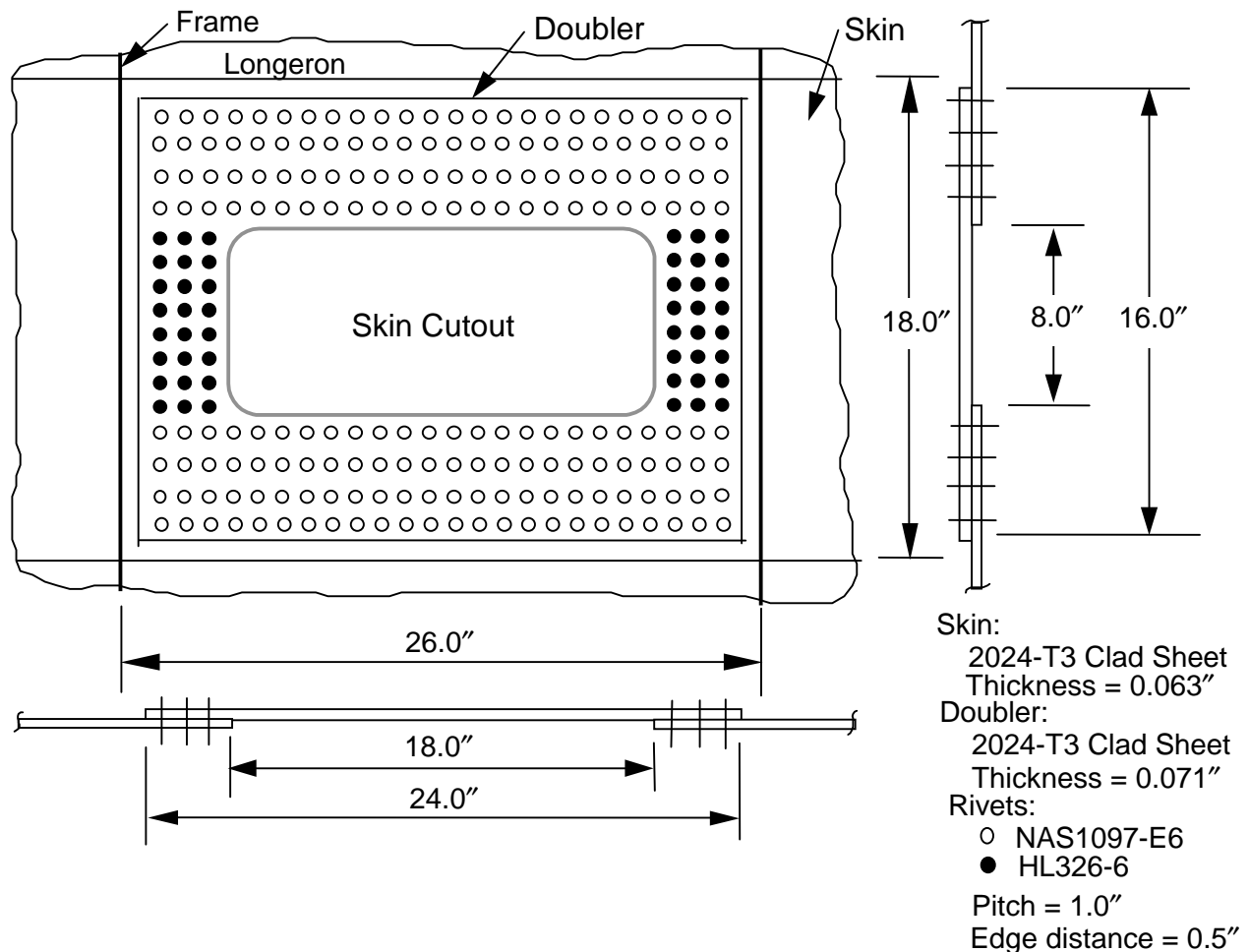
This window provides the most updated information or release notes regarding the graphical user interface and program limitations for the latest current version of RAPID. It is recommended that the user reads this information before using RAPID. The contents match those in section 3 of this manual.

8. Example Problems

Two repair examples are shown to illustrate the usage of RAPID. The first is a common skin repair with one doubler and no stiffener or joint effects. The second example is of a single doubler repair over a longitudinal butt joint.

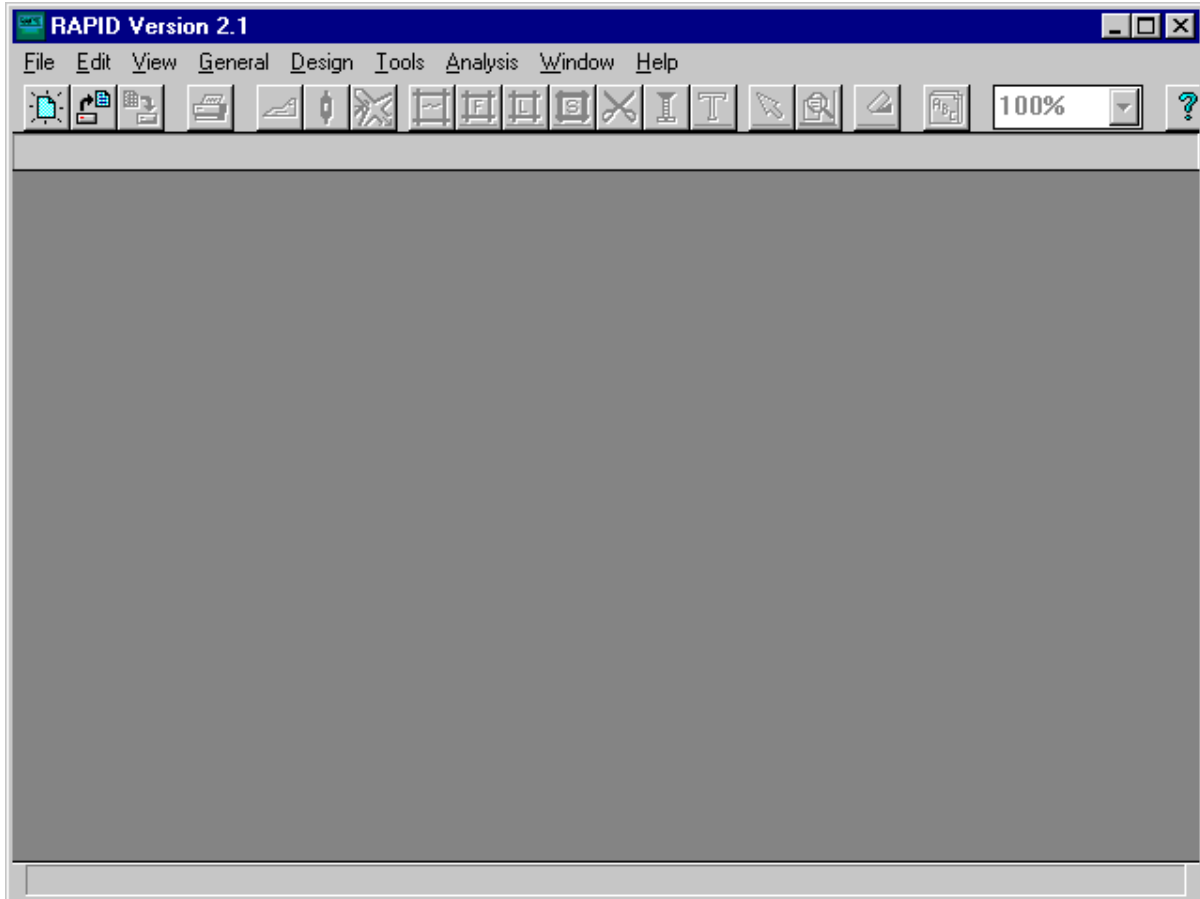
8.1 Single External Doubler Example

The following is an example of a rectangular cutout with a single external doubler repair. The cutout is 8 inches high by 18 inches wide and is located 5 inches from the adjacent bottom longeron and 4 inches from the adjacent left frame. The doubler size and fastener locations are automatically determined by the default pitch and edge distance settings together with the selected number of fastener rows per side. The layout and materials are shown in the following figure.



8.1.1 Create the New RAPID Model

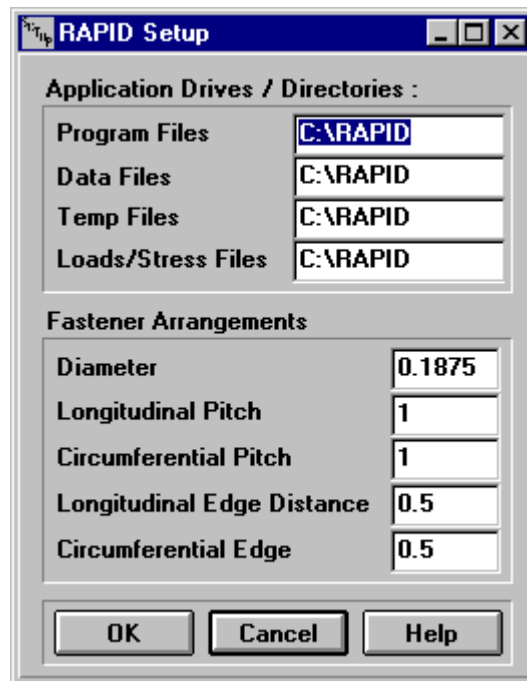
The first step is to start the RAPID program from the Windows Program Manager. Once launched, RAPID will display its main MDI window, as shown below. All of the dialog windows shown in this example appear as sub-windows within the RAPID MDI window.



To begin a new repair, select **New** from the **File** menu.



The **Setup** dialog can be selected from the **Tools --> Program Setup --> File Locations** pull-down menu and is shown below. There is no need to use the **Setup** dialog unless the user wishes to change the default RAPID configuration. The fastener pitch and edge distances will be used by the **Fastener Arrangement** dialog window to automatically determine the number and arrangement of the fasteners and the sizes of the doublers in the repair. The defaults can be changed here or on a model to model basis within the **Fastener Arrangement** dialog window which will be used later. If any of the values are changed, then the **OK** button must be selected for the values to be written to the RAPID.INI file, which stores the RAPID defaults. In this example, we will retain the defaults and simply close the window by clicking on the **Cancel** button.



The first dialog window in which data will be input is the **Aircraft/General Information** Window, shown below with example input data already entered. This dialog window can be selected either from the MDI button bar, or from the **General** pull-down menu. Once the data is entered, the **OK** button must be selected to store the data in the current model and close the dialog window.

General/Aircraft Information

Aircraft Information		Analyst Information	
Operator	World Wide Airlines	Name	John Doe
* Model Number	Norton 30	Company	Flight Repairs, Inc
Series Number	400	Employee ID	1234
Flight Hours	20000	Cycles	4000
Aircraft ID/Registration Number		Repair Identification	
Fuselage No.	FN-0123	Repair ID	RR-01
* Serial No.	98765	Rev.	33
Airplane Registration	AR-AB134	Comment	RAPID Repair Example
Operator Designation	OD-987123		

OK Cancel Help

* - Required Entry

8.1.2 Define Repair Type and Location

Next, the repair type is selected from the **Repair Type** dialog window, as show below. This dialog window can be selected either from the icon button bar or from the **General** pull-down menu. One **Rectangular External** doubler is selected from the available options, and the selection is saved and the dialog window is closed by pressing the **OK** button.

Repair Type

Repair Configuration Type :

- ◆ Common Repair
- ◇ Over/Near Butt Joint
- ◇ Over/Near Lap Joint

Close proximity to another repair ?

Consider Stiffener Effects ?

Common Repairs

- ◆ Rectangular
- ◇ Circular

Location of Layers :

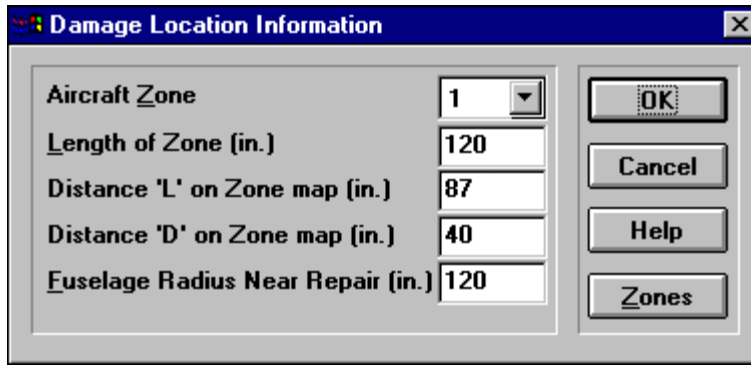
External Internal

Doubler Layers (max. 2)

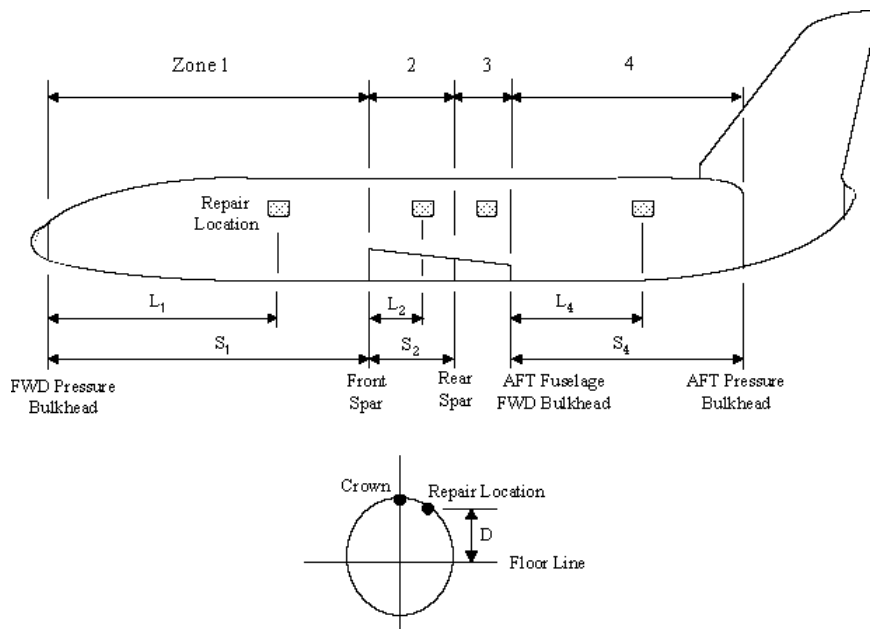
Ext1 Skin

OK Cancel Help

The **Damage Location** dialog window is invoked to enter the location of the damage on the structure and is shown below. This dialog window can be selected either from the icon button bar or from the **General** pull-down menu.

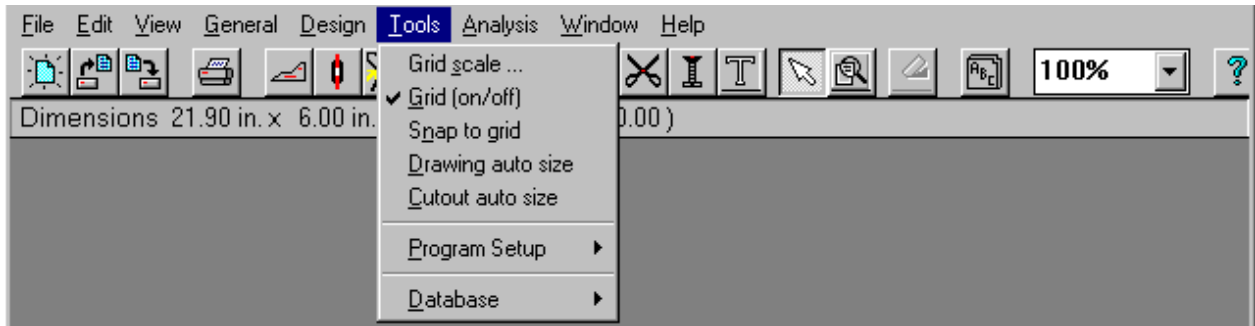


The distances entered on this dialog window refer to regions of the aircraft as depicted in the zone diagram which can be displayed by selecting the **Zones** button and which is shown in the following figure. As with all of the other dialogs with **OK** buttons, remember to save the data and close the dialog window by pressing the **OK** button after completing the entries.

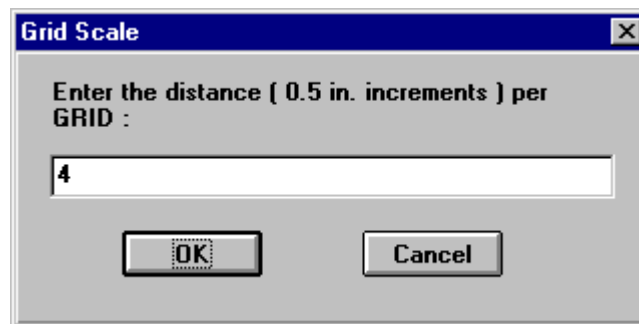


8.1.3 Draw the Repair

After entering the damage location information, the **Grid Scale** dialog window will be automatically displayed to set the drawing scale to accommodate the size of the planned repair. The grid scale can be reset at any other time by selecting the **Grid scale** menu item from the **Tools** pull-down menu.



For the depicted 640 by 480 screen resolution, a grid scale of 4 inches per grid will result in a workspace of adequate size to draw the largest included object, the damage extent, which is 26 inches wide by 18 inches high.

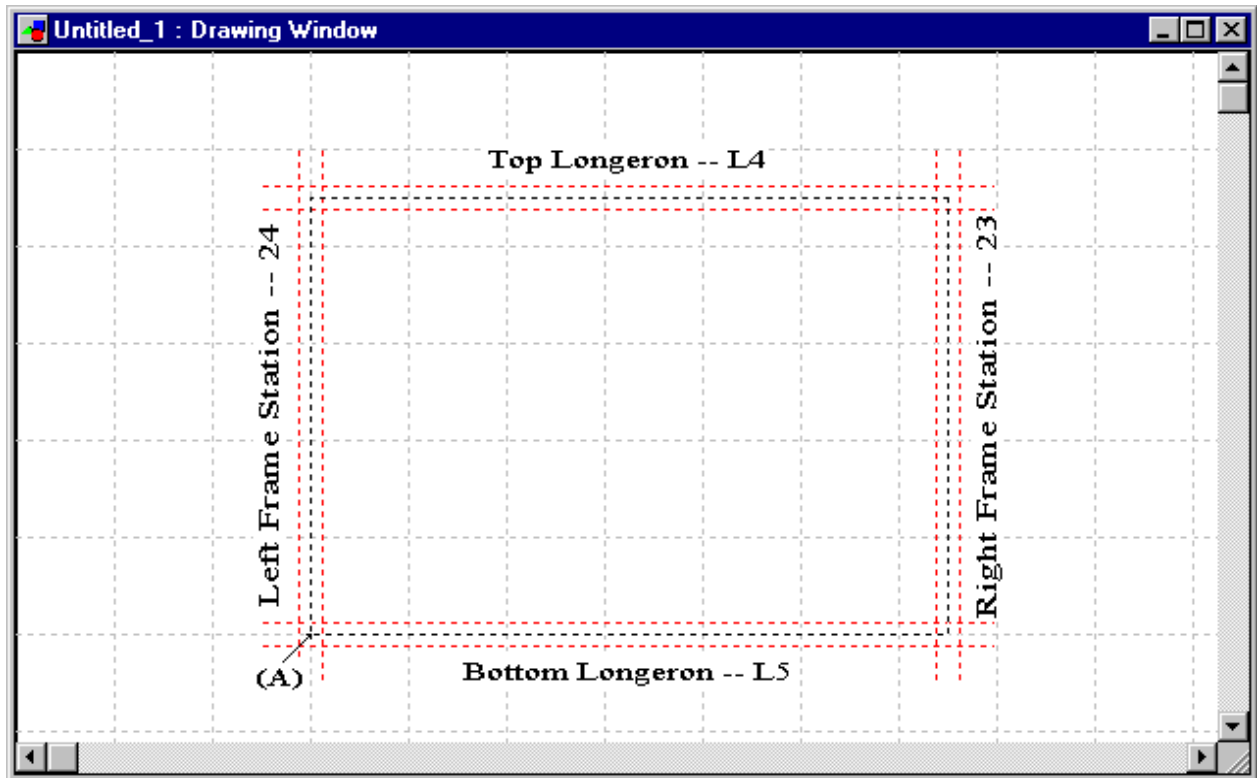


8.1.3.1 Define the Repair Boundary

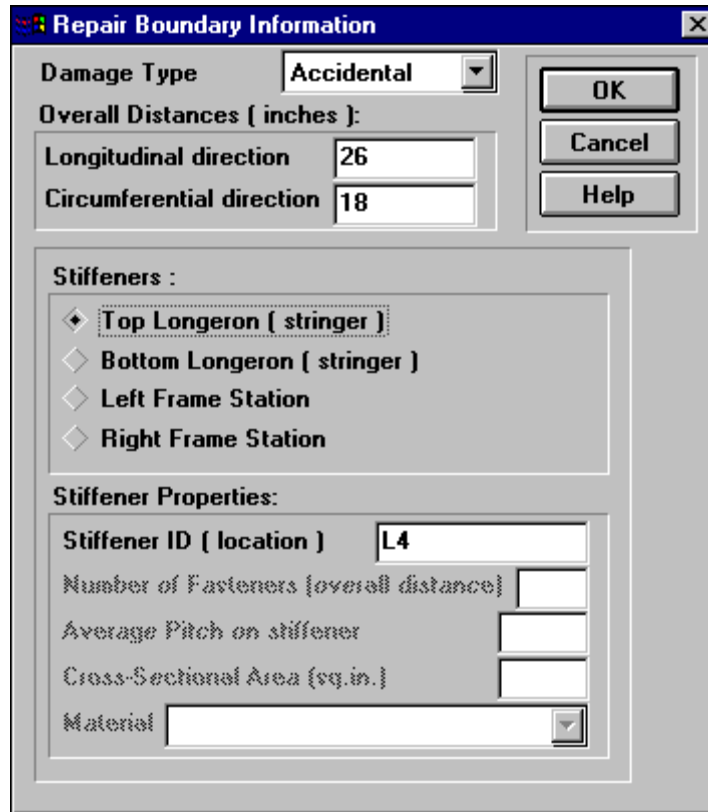
The repair boundary tool is used to draw the region defined by the two frames and two longerons which are just outside of the region of the repair, as defined by the doubler.



After selecting the repair boundary tool from the tool bar, the repair boundary is drawn by clicking the left mouse button on one corner of the repair boundary and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the repair boundary and then releasing the left mouse button. The changing size of the repair boundary is displayed in the upper left of the display as the area is drawn.



When the left mouse button is released, the **Repair Boundary Information** window is automatically displayed to input the frame and longeron labels, and to fine-tune the **Overall Distances** in the **Longitudinal** and **Circumferential** Directions. A **Stiffener ID** should be entered for each stiffener.



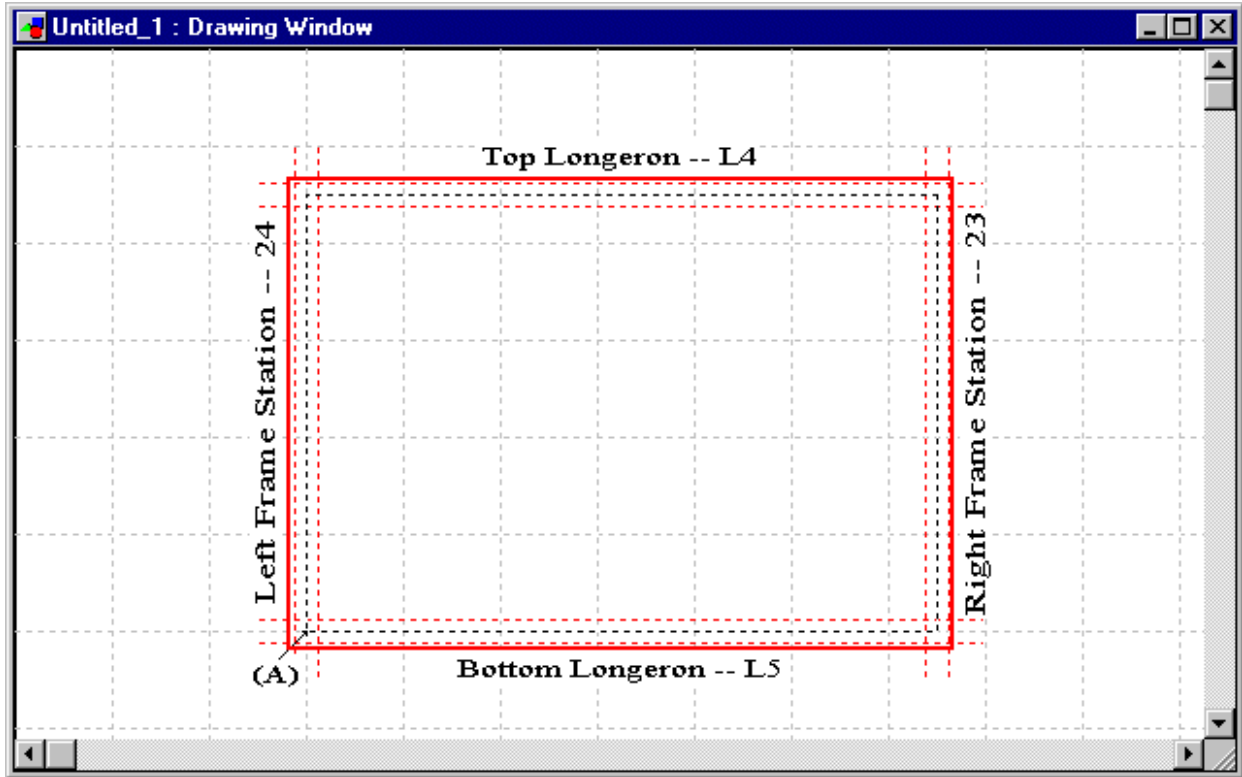
8.1.3.2 Define Skin Properties



Selecting **Skin Properties** from the **Design** menu or selecting the **Skin Properties** icon on the button bar invokes the **Skin Properties** dialog window.



After entering the properties for the skin, pressing **OK** updates the Drawing dialog window to represent the local skin area as a red rectangle.

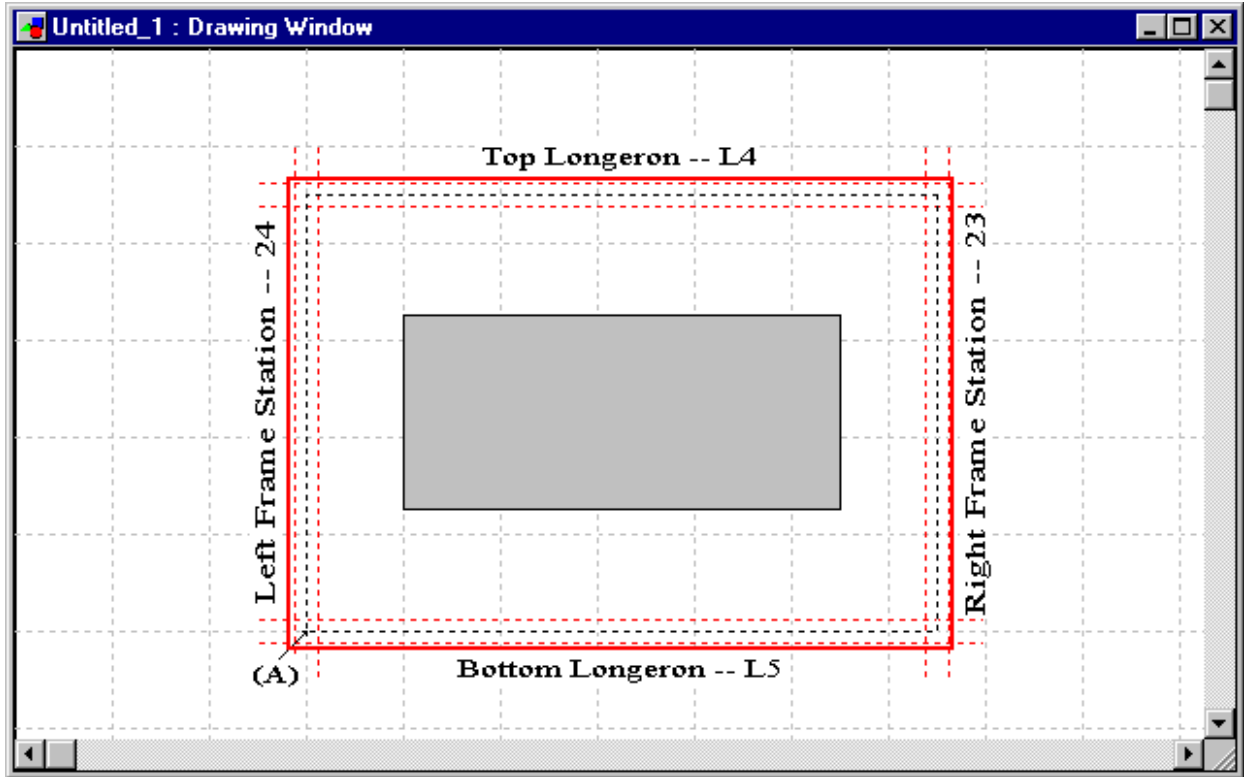


8.1.3.3 Draw the Cutout

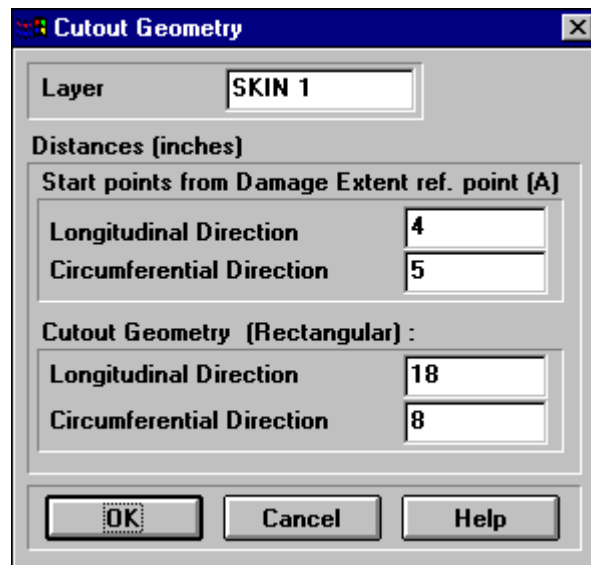
Next, the cutout is defined by selecting the cutout tool on the tool bar.



The cutout is drawn by clicking the left mouse button on one corner of the cutout, and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the cutout and then releasing the mouse button. The size and location of the centroid with respect to the left most frame and bottom longeron are displayed in the upper left of the display.



When the left mouse button is released, the **Cutout Geometry** dialog window is automatically displayed to allow manual correction of the dimensions.

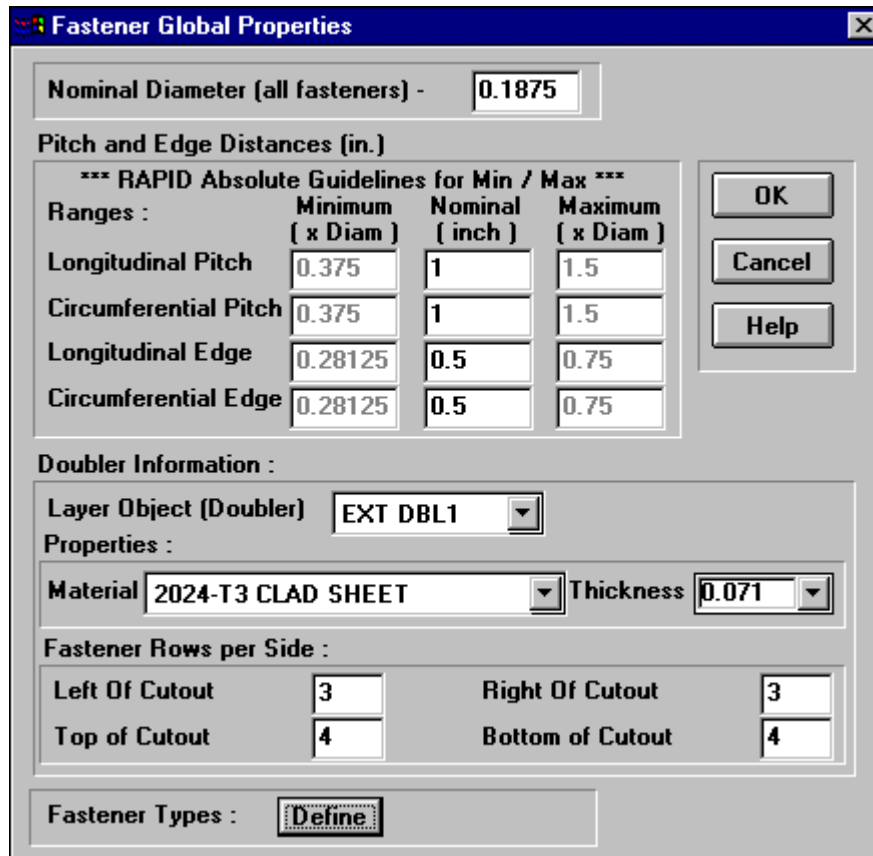


8.1.3.4 Create the Fasteners

The fastener arrangement is then defined by selecting the **Fastener Properties** tool from the button bar or from the **Design** menu.



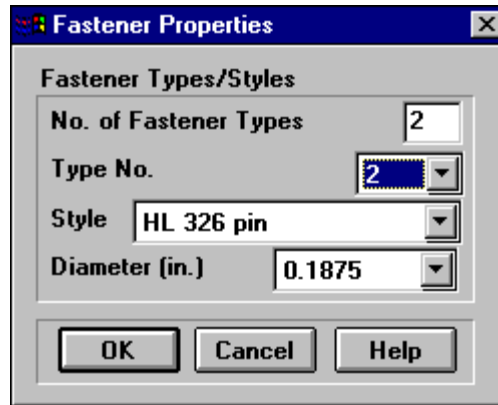
This invokes the **Fastener Global Properties** dialog window. This dialog window is used to change the default pitch and edge distances, and to enter the number of fastener rows per side of each doubler. Because this information is used by RAPID to automatically size the doublers, the material and thickness of each doubler should also be entered. For the current example, only one external doubler is included.



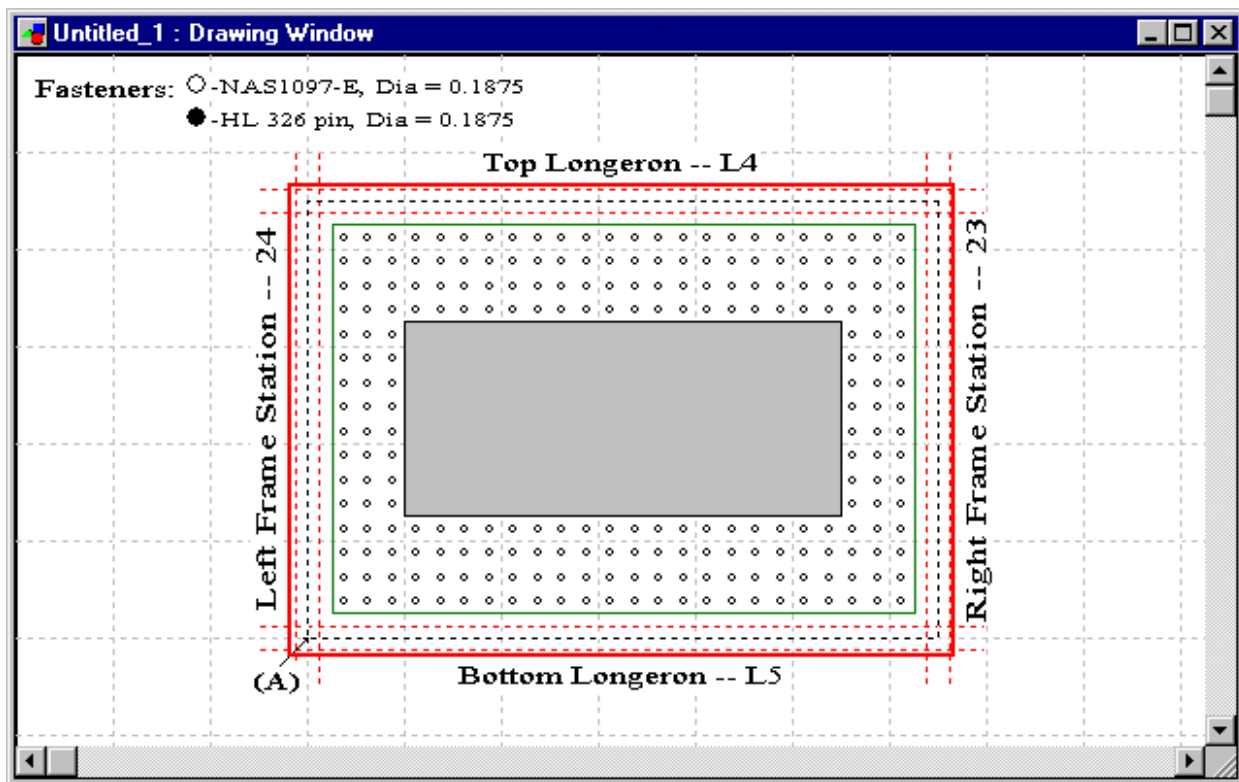
The dialog window titled "Fastener Global Properties" contains the following fields and controls:

- Nominal Diameter (all fasteners) -** 0.1875
- Pitch and Edge Distances (in.)**
 - *** RAPID Absolute Guidelines for Min / Max ***
 - Ranges :**
 - | | Minimum (x Diam) | Nominal (inch) | Maximum (x Diam) |
|-----------------------|--------------------|------------------|--------------------|
| Longitudinal Pitch | 0.375 | 1 | 1.5 |
| Circumferential Pitch | 0.375 | 1 | 1.5 |
| Longitudinal Edge | 0.28125 | 0.5 | 0.75 |
| Circumferential Edge | 0.28125 | 0.5 | 0.75 |
- Doubler Information :**
 - Layer Object (Doubler)** EXT DBL1
 - Properties :**
 - Material** 2024-T3 CLAD SHEET
 - Thickness** 0.071
 - Fastener Rows per Side :**
 - Left Of Cutout** 3
 - Right Of Cutout** 3
 - Top of Cutout** 4
 - Bottom of Cutout** 4
- Fastener Types :** Define

Each of the two fastener types in the model should now be entered by pressing the **Fastener Types Define** button to display the **Fastener Properties** input screen. Enter 2 for the **No. of Fastener Types** and then enter the **Style** and **Diameter** for each **Type No.**



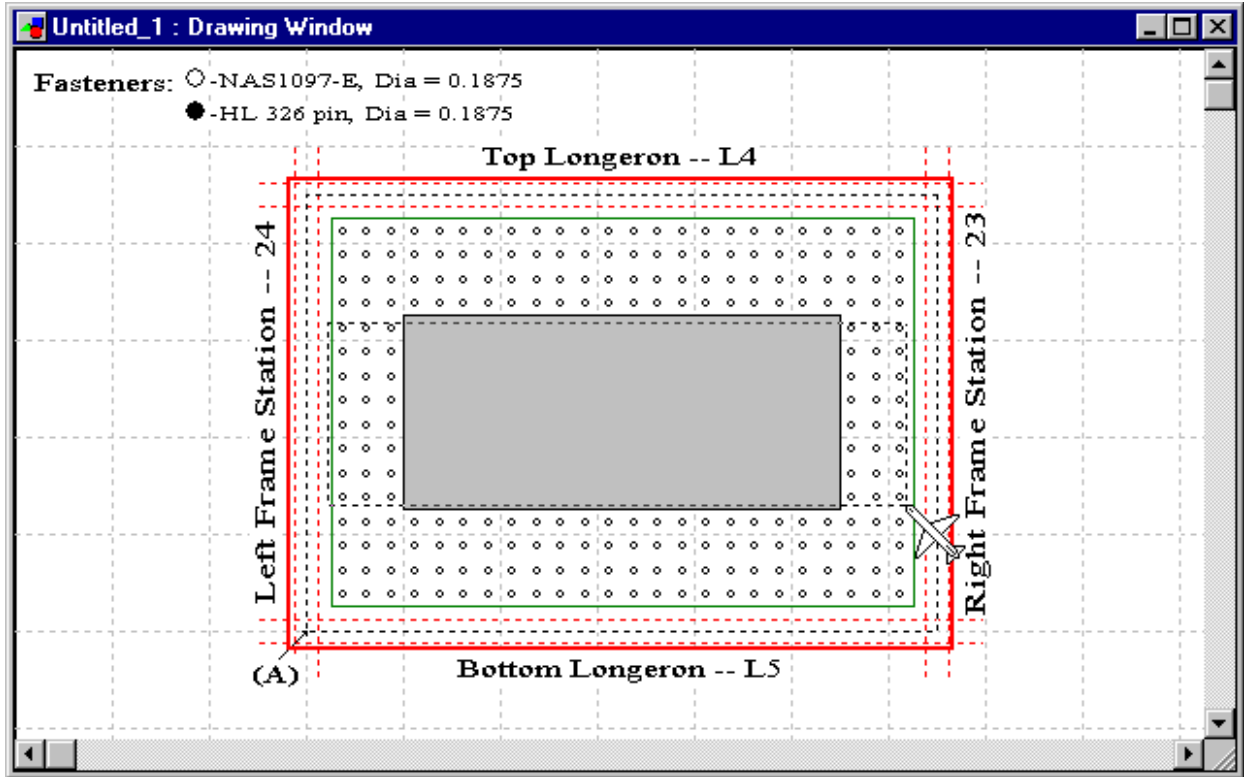
When the **OK** button is selected in the **Fastener Global Properties** screen, the fasteners and doubler are automatically generated and displayed in the workspace.



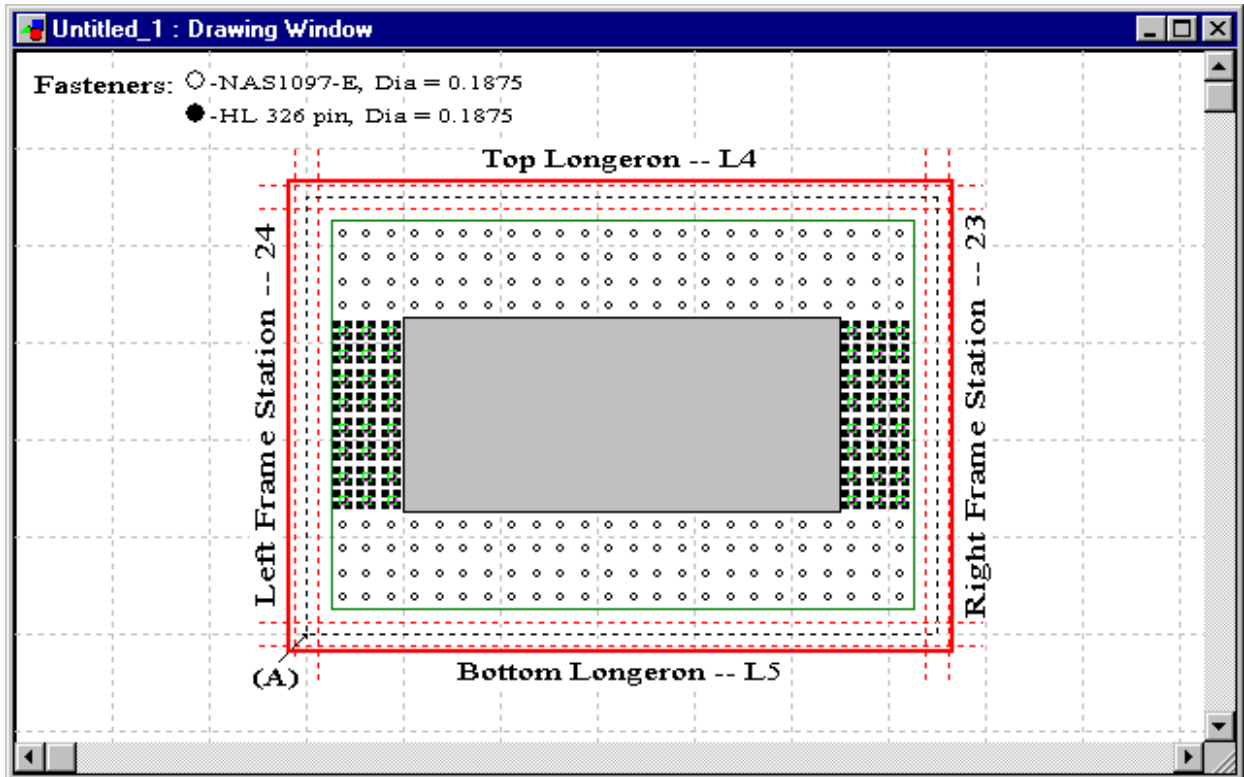
To change the desired fasteners to type 2, first select the selection tool from the **Tools** palette.



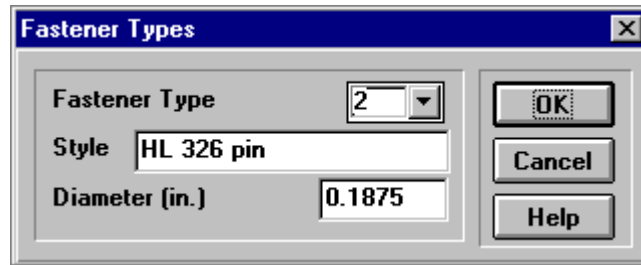
Then, while holding the shift key, click and hold the left mouse button and drag the mouse to draw a rectangle around the fasteners which should be type 2.



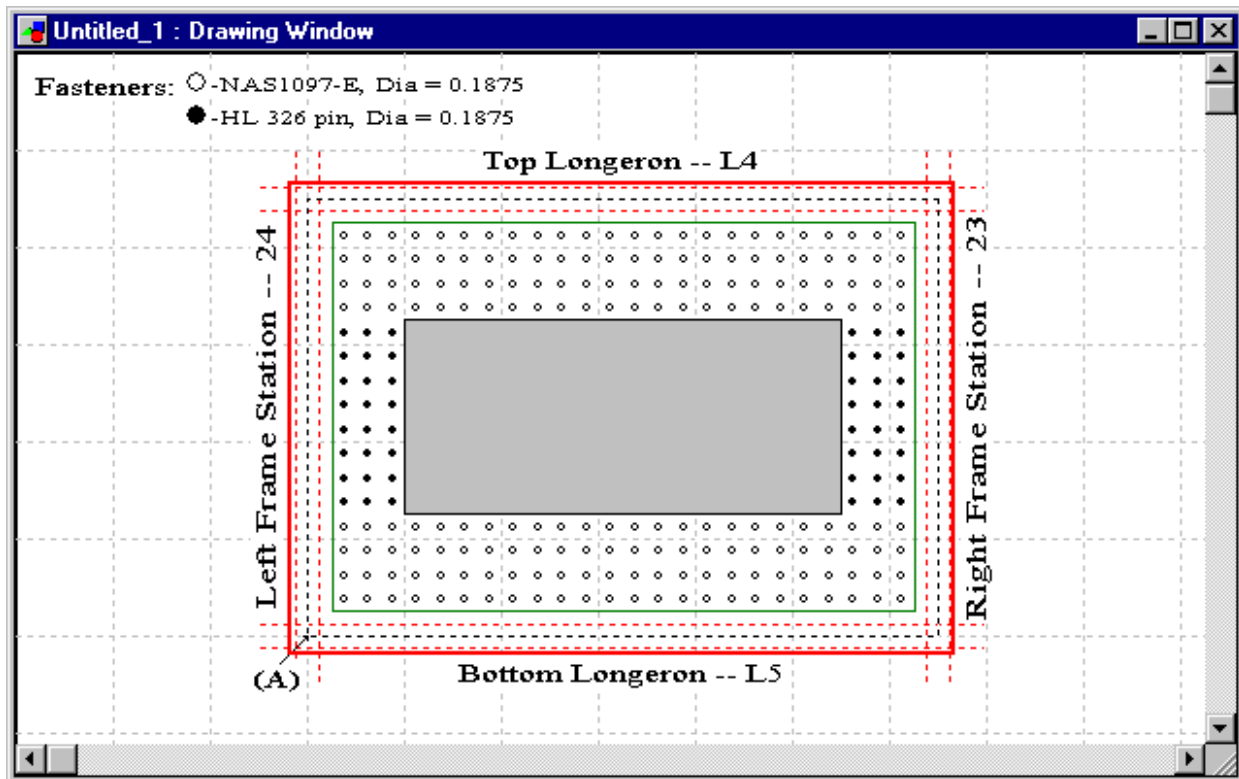
Releasing the mouse button then selects that group of fasteners.



Click the right mouse button to change the fastener type of the selected fasteners using the **Fastener Types** dialog window.

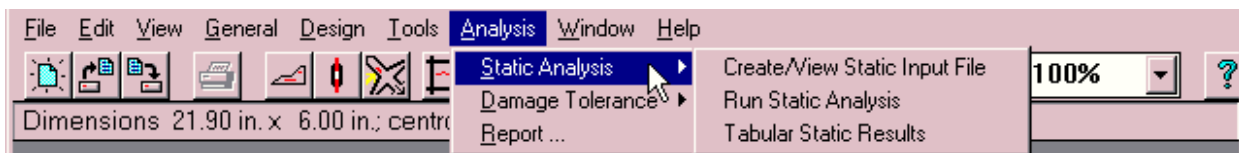


Select type 2 from the **Fastener Type** combo box, then click **OK**.



8.1.4 Run the Analyses

The analyses can then be run and the results viewed by using the **Analysis** pull-down menu.



8.1.4.1 Static Analysis

Listed below is the input to the Static module as displayed by the **Create/View Static Input File** menu item in the **Static Analysis** section of the **Analysis** pull-down menu:

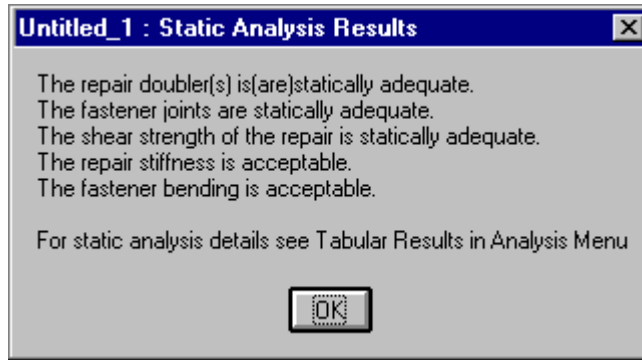
```
REPAIR CONFIGURATION TYPE (1 External Doubler)
3
SKIN/DAMAGE : Number of Layers
1
  SKIN : Mat.Type
  2024-T3 CLAD SHEET
  # of Sides, Thickness, FTU (ksi), Modulus (ksi)
  4      0.063      62      10500
SIDE 1      : LENGTH, FSU
              8      38
  MAX# OF FASTENER TYPES
  2
  FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
  1          24          1.175    0.191
  2          24          1.496    0.1875
  MAX# OF ROWS
  3
  NUMBER OF FASTENERS PER ROW
  16
  16
  16
SIDE 2      : LENGTH, FSU
              18     38
  MAX# OF FASTENER TYPES
  1
  FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
  1          96          1.175    0.191
  MAX# OF ROWS
  4
  NUMBER OF FASTENERS PER ROW
  24
  24
  24
  24
SIDE 3      : LENGTH, FSU
              8      38
  MAX# OF FASTENER TYPES
  2
  FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
  1          24          1.175    0.191
  2          24          1.496    0.1875
  MAX# OF ROWS
  3
  NUMBER OF FASTENERS PER ROW
  16
  16
  16
SIDE 4      : LENGTH, FSU
              18     38
  MAX# OF FASTENER TYPES
  1
  FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
  1          96          1.175    0.191
  MAX# OF ROWS
  4
  NUMBER OF FASTENERS PER ROW
  24
  24
  24
  24
```

```

REPAIR      : Number of Layers
              1
EXT DBL1    : Mat.Type
              2024-T3 CLAD SHEET
              # of Sides, Thickness, FTU (ksi), Modulus (ksi)
              4      0.071      62      10500
SIDE 1      : LENGTH, FSU
              16      38
              MAX# OF FASTENER TYPES
              2
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
              1      24      1.025      0.191
              2      24      1.686      0.1875
              MAX# OF ROWS
              3
              NUMBER OF FASTENERS PER ROW
              16
              16
              16
SIDE 2      : LENGTH, FSU
              24      38
              MAX# OF FASTENER TYPES
              1
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
              1      96      1.025      0.191
              MAX# OF ROWS
              4
              NUMBER OF FASTENERS PER ROW
              24
              24
              24
              24
SIDE 3      : LENGTH, FSU
              16      38
              MAX# OF FASTENER TYPES
              2
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
              1      24      1.025      0.191
              2      24      1.686      0.1875
              MAX# OF ROWS
              3
              NUMBER OF FASTENERS PER ROW
              16
              16
              16
SIDE 4      : LENGTH, FSU
              24      38
              MAX# OF FASTENER TYPES
              1
              FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
              1      96      1.025      0.191
              MAX# OF ROWS
              4
              NUMBER OF FASTENERS PER ROW
              24
              24
              24
              24
PITCH      : Circumferential, Longitudinal
              1.0000      1.0000
BENDING    : Q Ratio
              2.0

```

The static analysis is then executed by selecting the **Run Static Analysis** menu item located in the **Static Analysis** section of the **Analysis** pull-down menu. When the analysis completes, RAPID displays the **Static Analysis Results Summary**.



The following shows the textual output produced by the static analysis and displayed by selecting the **Tabular Static Results** menu item in the **Static Analysis** section of the **Analysis** pull-down. Note that the margins of safety for the doublers and the fasteners are all positive, indicating that the chosen design is statically adequate.

STATIC ANALYSIS RESULTS OF THE REPAIR

(A) MARGINS OF SAFETY :

*** REPAIR DOUBLERS ***

0.13

MARGIN OF SAFETY IS POSITIVE.

THE REPAIR DOUBLER IS STATICALLY ADEQUATE.

*** FASTENER JOINTS ***

	LOAD LOST (LBS)	LOAD RESTORED (LBS)	MARGIN OF SAFETY (NONDIMENSIONAL)
SIDE 1	31248	64104	1.05
SIDE 2	70308	98400	0.40
SIDE 3	31248	64104	1.05
SIDE 4	70308	98400	0.40

SIDE 1: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

SIDE 2: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

SIDE 3: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

SIDE 4: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

(B) SHEAR STRENGTHS:

	DOUBLER(S) (LBS)	SKIN (LBS)	MARGIN OF SAFETY (NONDIMENSIONAL)
	-----	-----	-----
SIDE 1	2698	2394	0.13
SIDE 2	2698	2394	0.13
SIDE 3	2698	2394	0.13
SIDE 4	2698	2394	0.13

SIDE 1: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

SIDE 2: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

SIDE 3: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

SIDE 4: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

(C) STIFFNESS:

	DOUBLER(S) (LBS/IN)	SKIN (LBS/IN)	STIFFNESS RATIO (NONDIMENSIONAL)
	-----	-----	-----
SIDE 1	745500	661500	1.13
SIDE 2	745500	661500	1.13
SIDE 3	745500	661500	1.13
SIDE 4	745500	661500	1.13

SIDE 1: STIFFNESS RATIO IS BETWEEN 1 AND 1.5

REPAIR STIFFNESS IS ACCEPTABLE.

SIDE 2: STIFFNESS RATIO IS BETWEEN 1 AND 1.5

REPAIR STIFFNESS IS ACCEPTABLE.

SIDE 3: STIFFNESS RATIO IS BETWEEN 1 AND 1.5

REPAIR STIFFNESS IS ACCEPTABLE.

SIDE 4: STIFFNESS RATIO IS BETWEEN 1 AND 1.5

REPAIR STIFFNESS IS ACCEPTABLE.

(D) FASTENER BENDING:

	Q RATIO (NONDIMENSIONAL)

SIDE 1	0.00
SIDE 2	0.70
SIDE 3	0.00
SIDE 4	0.70

SIDE 1: Q RATIO IS EQUAL TO 0.0

STEEL OR TITANIUM - FASTENER BENDING IS ACCEPTABLE.

SIDE 2: Q RATIO IS EQUAL TO OR LESS THAN 2.0
ALUMINUM - FASTENER BENDING IS ACCEPTABLE.

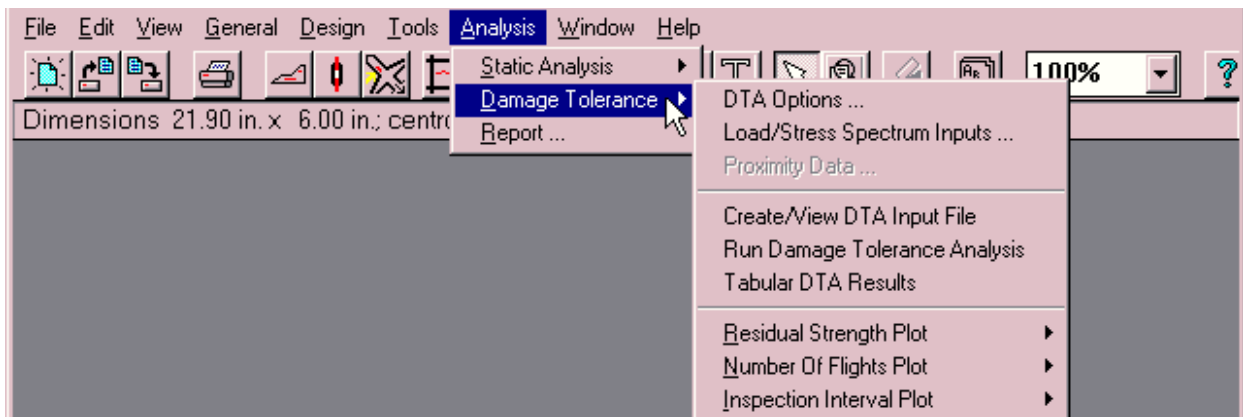
SIDE 3: Q RATIO IS EQUAL TO 0.0
STEEL OR TITANIUM - FASTENER BENDING IS ACCEPTABLE.

SIDE 4: Q RATIO IS EQUAL TO OR LESS THAN 2.0
ALUMINUM - FASTENER BENDING IS ACCEPTABLE.

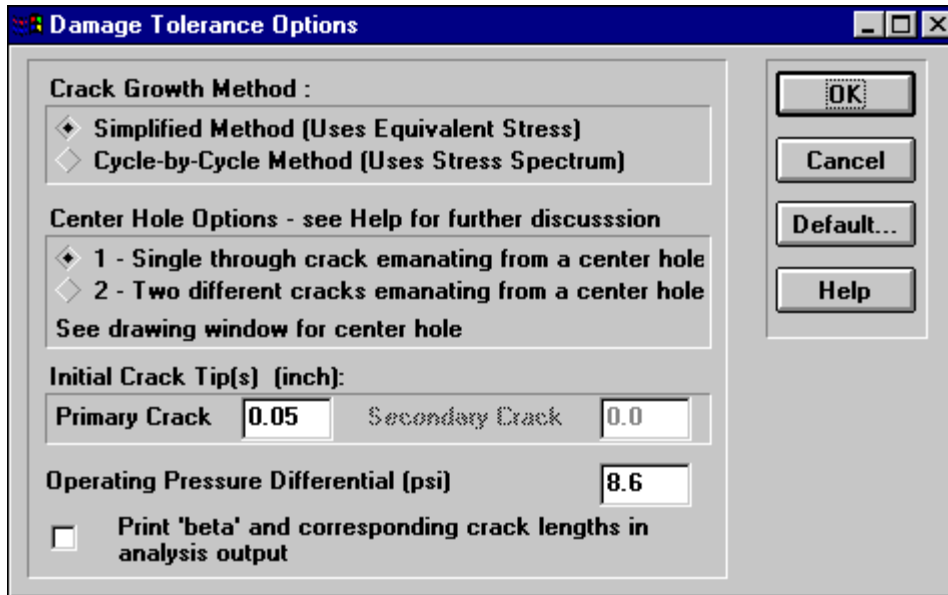
If the repair doubler or the fastener joints for any of the sides had been inadequate ($MS < 0$) or only marginally adequate ($MS = 0$), it would be necessary to return to the **Fastener Arrangement** dialog window to modify the fasteners and/or doublers.

8.1.4.2 Damage Tolerance Analysis

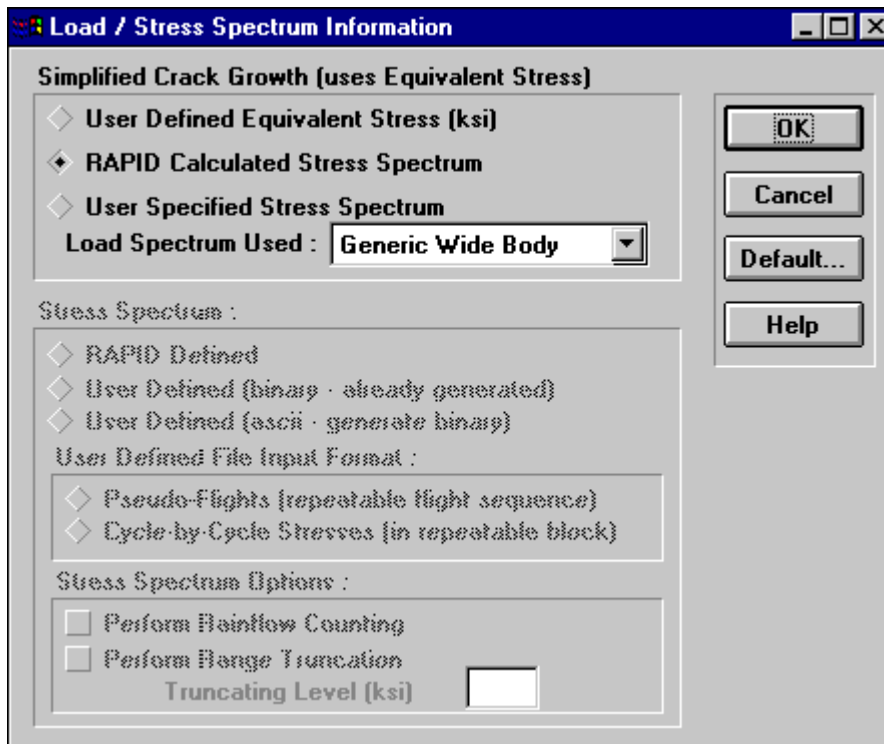
If the repair is statically adequate, the damage tolerance analysis (DTA) can be run.



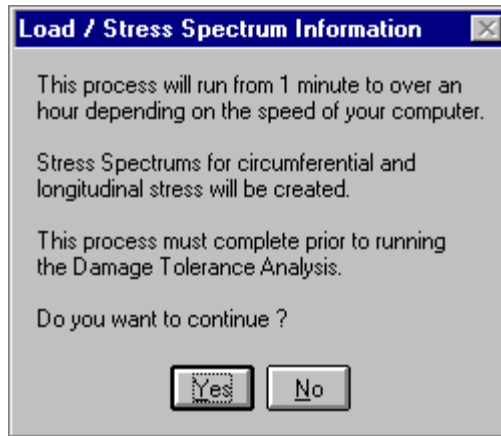
Selecting the **Create/View DTA Input File** menu item automatically invokes the **Damage Tolerance Options** dialog window. For this example, select the **Simplified Method** for **Crack Growth**, the **Single through crack emanating from a center hole** option, and an **Operating Pressure Differential** of 8.6 psi.



After closing the dialog window by selecting the **OK** button, select the **Load/Stress Spectrum Information** window from the **Load Stress Spectrum Inputs** menu item on the **Damage Tolerance** submenu of the **Analysis Menu**. For this example, select the **Generic Wide-Body Load Spectrum**. RAPID will automatically convert the stress spectrum at the repair location to an equivalent, constant amplitude stress cycle for use in the simplified analysis.



Clicking the **OK** button starts the stress spectrum generation program after displaying the following warning.



If the selected load spectrum has not previously been generated then the following message will be displayed.



In this occurs, then press the **OK** button, cancel the **Load/Stress Spectrum Information** dialog window, select the **Generate Load Spectra** menu item from the **Program Setup** submenu of the **Tools** menu, and generate the desired spectrum. Then, return to the **Load/Stress Spectrum Information** dialog window and continue.

Listed below is the input to the DTA module that may be displayed after the stress spectra are generated:

```

2
REPAIR CONFIGURATION TYPE (1 External Doubler) - Side 2 - for Longitudinal Crack direction
3
  SKIN: Mat. Type
    2024-T3 Clad Sheet
    Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi),FTU
    2 0.063 10500 9.01566e-10 3.68842 152.4 45 62
    EDSX, EDSY
    0.5 0.5
CUTOUT : X Direct., Y Direct.
    18 8
EXT DBL1: Mat. Type
    2024-T3 Clad Sheet
    Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
    2 0.071 10500 9.01566e-10 3.68842 152.4 45
PITCH : X Direct., Y Direct.
    1 1
FSTNR : Max # In Col
    4
    Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
    1 0.19100
    1 0.19100
    1 0.19100

```

```

1      0.19100
Max # In Row, Crit #, Crit #, Overlap, L2R
24      12      24      0      0
STIFF : Max #, POS, CSA, Yng.Mod., HPit
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
Dblr Id
1
PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
0      0.000 0.000 1 24.000 16.000 1 0.000 0.000 0.500 0.500
FUSELAGE: Eqv.Stress, Press. Diff, Radius
17.0000      8.6      120.000
CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL,KBFLG
2      1      0      1      0      0.050 0.000 0 0
REPAIR CONFIGURATION TYPE (1 External Doubler) - Side 3 - for Circumferential Crack direction
3
SKIN: Mat. Type
2024-T3 Clad Sheet
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi),FTU
1      0.063      10500      6.76125e-10      3.7198      152.4      45      62
EDSX, EDSY
0.5      0.5
CUTOOUT : X Direct., Y Direct.
8      18
EXT DBL1: Mat. Type
2024-T3 Clad Sheet
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
1      0.071      10500      6.76125e-10      3.7198      152.4      45
PITCH : X Direct., Y Direct.
1      1
FSTNR : Max # In Col
3
Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
3      0.19000
3      0.19000
3      0.19000
Max # In Row, Crit #, Crit #, Overlap, L2R
16      9      16      0      0
STIFF : Max #, POS, CSA, Yng.Mod., HPit
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
0      0.000 0.000      0.000 0.0000
Dblr Id
1
PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
0      0.000 0.000 1 16.000 24.000 1 0.000 0.000 0.500 0.500
FUSELAGE: Eqv.Stress, Press. Diff, Radius
8.0000      8.6      120.000
CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL,KBFLG
2      1      0      1      0      0.050 0.000 1 0

```

The damage tolerance analysis is then executed by selecting the **Run Damage Tolerance Analysis** menu item located in the **Damage Tolerance** section of the **Analysis** pull-down menu. The following shows a condensed version of the textual output produced by the DTA module and displayed by selecting the **Tabular DTA Results** menu item in the **Damage Tolerance** section of the **Analysis** pull-down menu:

DAMAGE TOLERANCE ANALYSIS RESULTS OF THE REPAIR

THE FOLLOWING 2 SETS OF OUTPUT ARE FOR THE LONGITUDINAL CRACKS OF SIDE 2:

***** CENTER FASTENER *****

FASTENER LOAD = 17.17707 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	45.00000
0.12590	7862	45.00000
0.20180	15182	45.00000
0.27770	21532	45.00000
0.35360	26872	45.00000
0.42950	31331	45.00000
0.50540	35050	45.00000
0.58130	38126	45.00000
0.65720	40552	45.00000
0.73310	42257	45.00000
0.80900	43170	45.00000
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
1.19100	43170	45.00000
1.40747	44320	45.00000
1.42798	44402	45.00000
1.45198	44492	45.00000
1.47841	44591	45.00000
	.	
	. (etc...)	
	.	
17.80900	50801	20.52188
18.19100	50801	20.52188
18.21032	50801	20.11429

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 25400 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
0.05000	25400
0.10000	22811
0.15000	20307
0.20000	17896
0.25000	15793
	.
	. (etc...)
	.
11.86189	104
11.91189	102
11.96189	100

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE HELP FILE.

***** RIGHT CORNER FASTENER *****

FASTENER LOAD = 22.12082 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	45.00000
0.12590	3104	45.00000
0.20180	5995	45.00000
0.27770	8503	45.00000
0.35360	10612	45.00000
0.42950	12373	45.00000
0.50540	13843	45.00000
0.58130	15059	45.00000
0.65720	16018	45.00000
0.73310	16691	45.00000
0.80900	17052	45.00000
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
1.19100	17052	45.00000
1.49024	17675	45.00000
1.51853	17721	45.00000
1.55172	17771	45.00000
1.58583	17825	45.00000
	.	
	. (etc...)	
	.	
18.96424	21070	20.83612
19.13749	21072	20.42561
19.27160	21073	20.11429

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 10536 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
0.05000	10536
0.10000	9514
0.15000	8525
0.20000	7573
0.25000	6743
	.
	. (etc...)
	.
12.52449	104
12.57449	102
12.62449	100

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE
CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE
HELP FILE.

THE FOLLOWING 2 SETS OF OUTPUT ARE FOR THE CIRCUMFERENTIAL CRACKS OF SIDE 3:

***** CENTER FASTENER *****

FASTENER LOAD = 20.84483 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	45.00000
0.12600	149606	45.00000
0.20200	296284	45.00000
0.20414	300000	45.00000

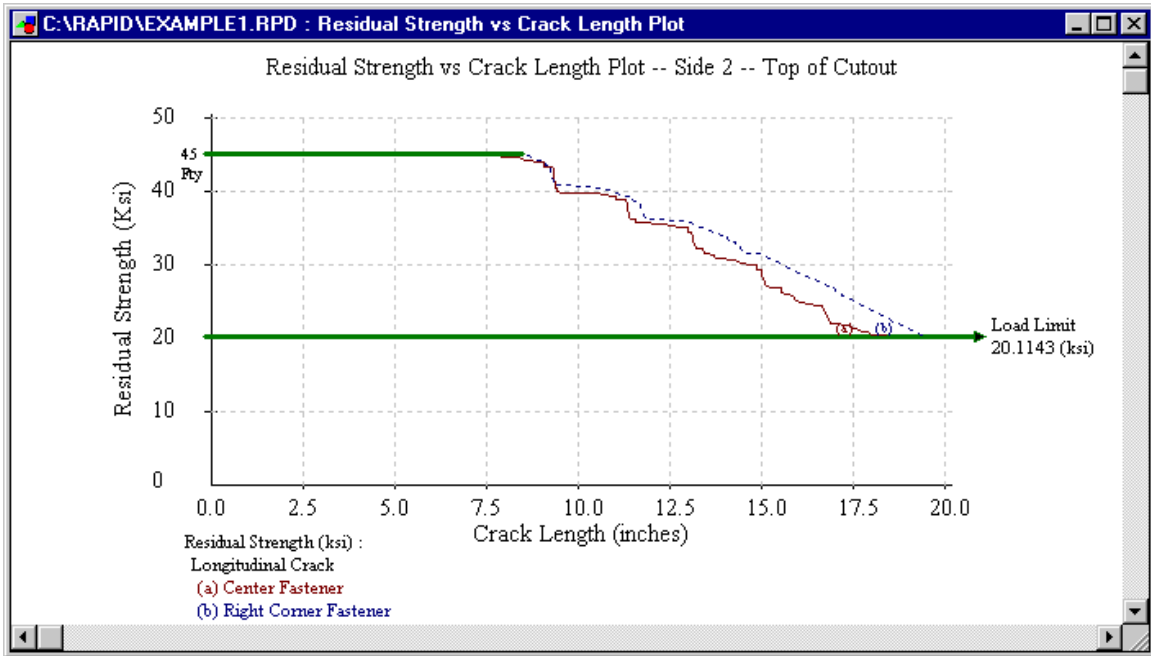
***** BOTTOM CORNER FASTENER *****

FASTENER LOAD = 23.06234 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

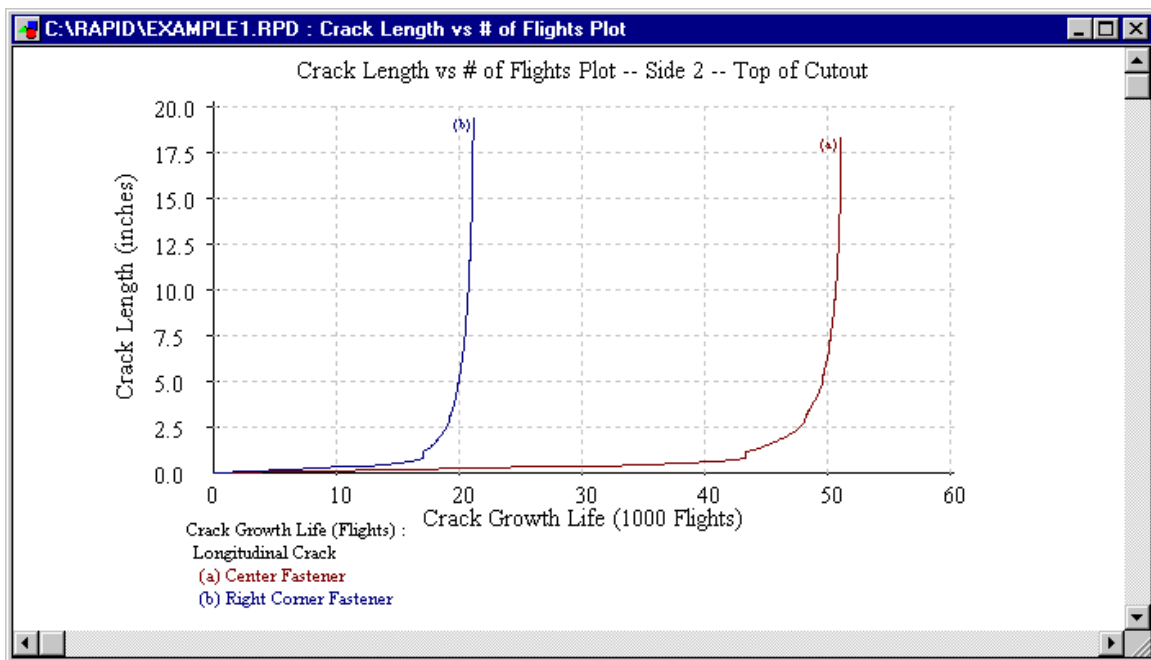
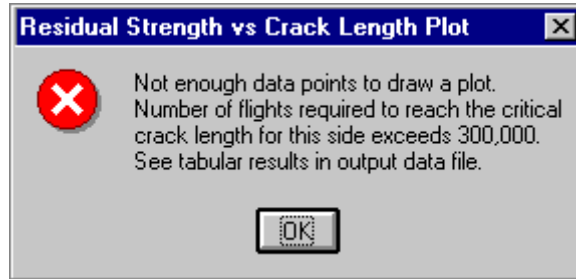
(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

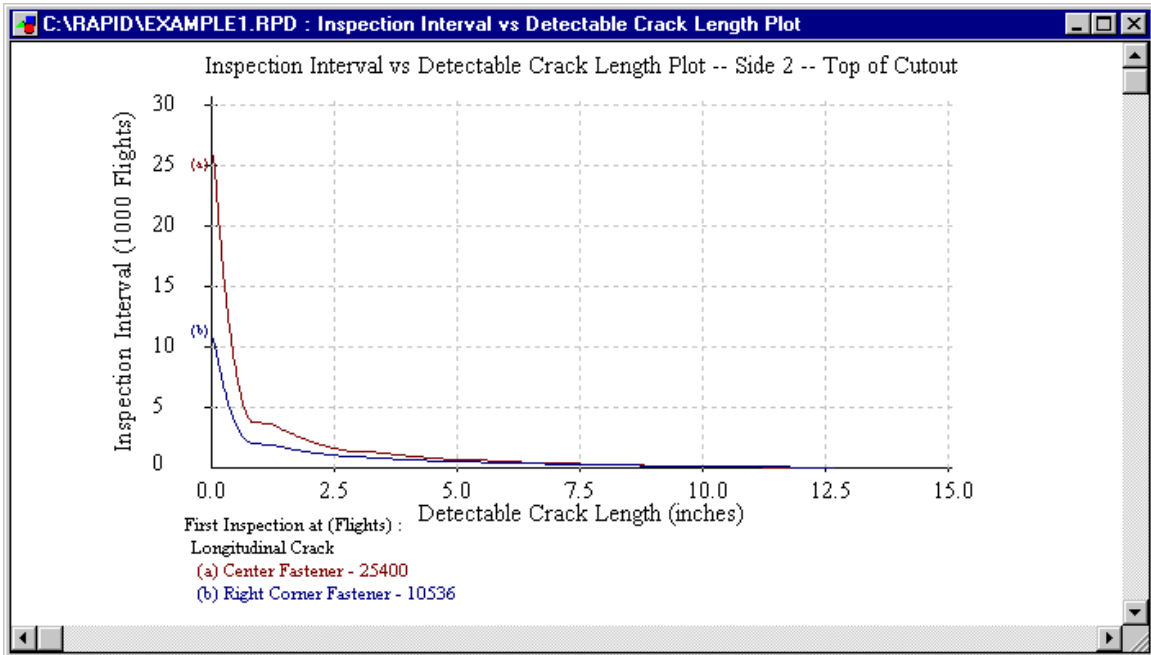
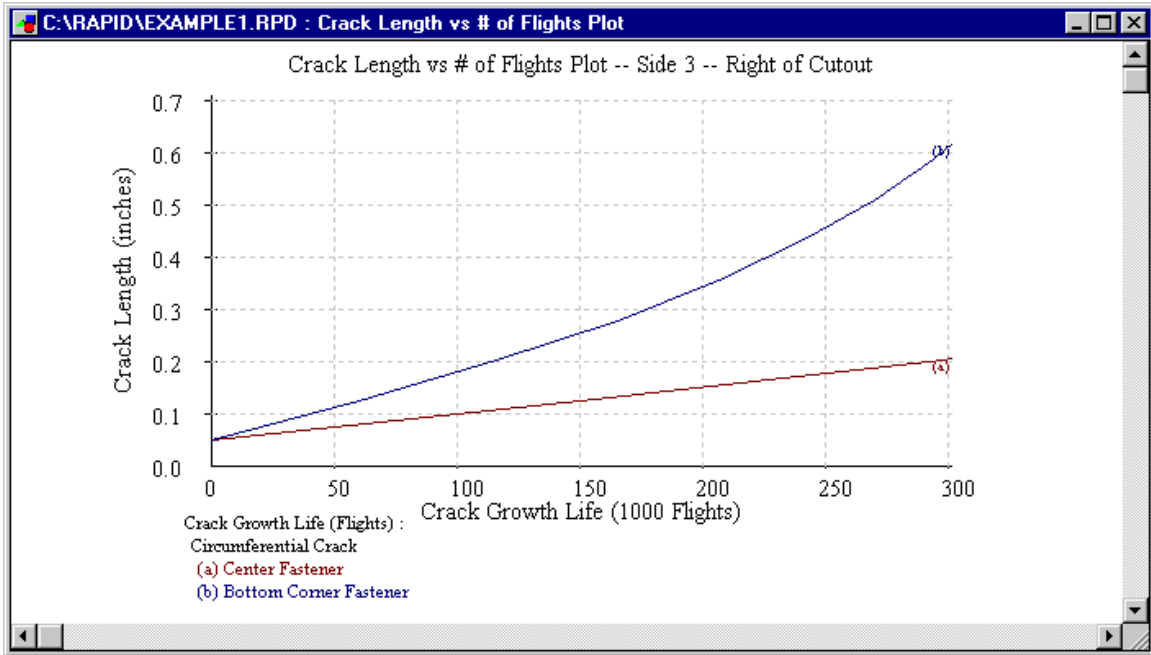
EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	45.00000
0.12600	59745	45.00000
0.20200	115796	45.00000
0.27800	164608	45.00000
0.35400	205717	45.00000
0.43000	240066	45.00000
0.50600	268730	45.00000
0.58200	292424	45.00000
0.61282	300000	45.00000

These results can be displayed graphically as **Residual Strength vs. Crack Length**, **Crack Length vs. Number of Flights**, and **Inspection Interval vs. Detectable Crack Length** plots. Each of these plots, which are shown below, is generated for longitudinal cracks in the center and corner fasteners above the cutout and for circumferential cracks in the center and corner fasteners to the right of the cutout. The plots can be selected from the **Damage Tolerance** section of the **Analysis** pull-down menu in the main RAPID MDI.

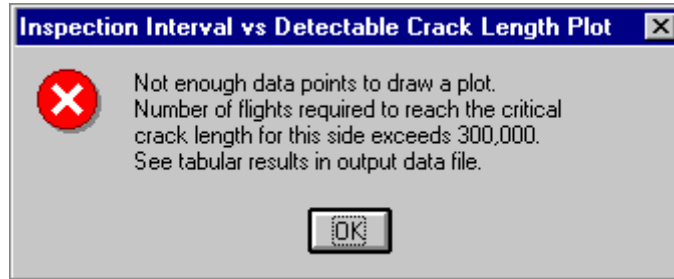


Selecting the plot for side three will display the following informational message to indicate that the plot is not available because the critical crack length was not reached within the program limit of 300,000 flights.



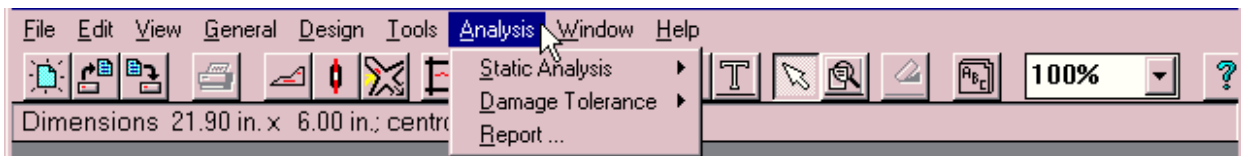


Selecting the plot for side three will display the following informational message to indicate that the plot is not available because the critical crack length was not reached within the program limit of 300,000 flights.

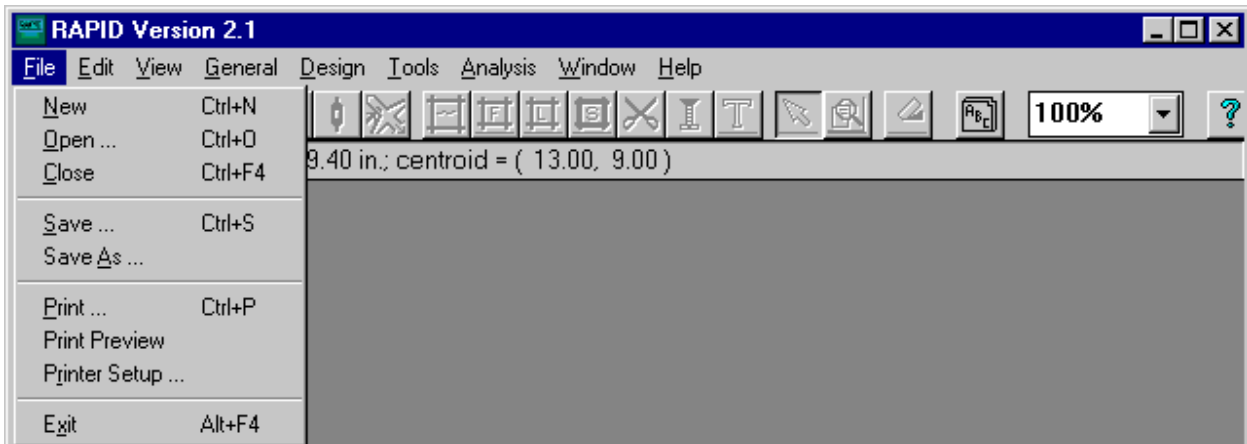


8.1.5 View and Print the Report

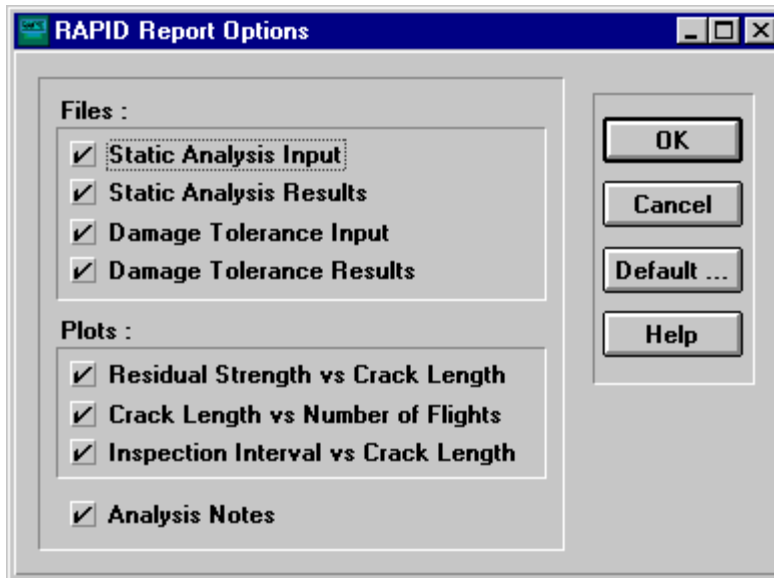
To view the report, select **Report** from the **Analysis** menu.



While the report is displayed, it may be printed by selecting **Print** from the **File** menu.



This will invoke the **Report Print Options** dialog window, through which the user may choose which components of the report to print.

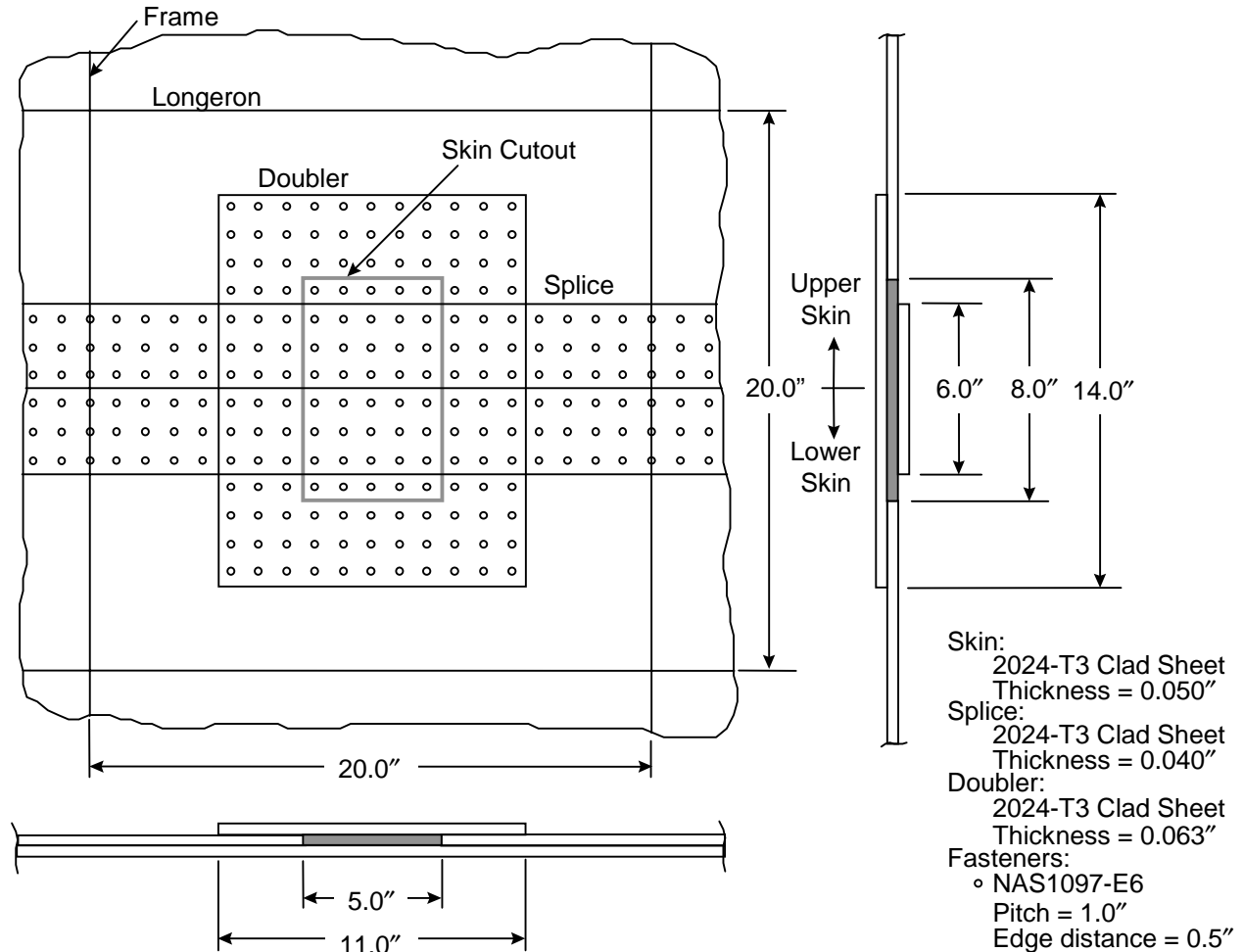


8.1.6 Save the Repair Model

This completes the example problem. To save the model, select either the **Save** or **Save As** menu item from the **File** pull down menu. Once saved, the model can be opened and modified in a subsequent RAPID session by selecting the file open button on the button bar or the **Open** menu item in the **File** pull-down menu.

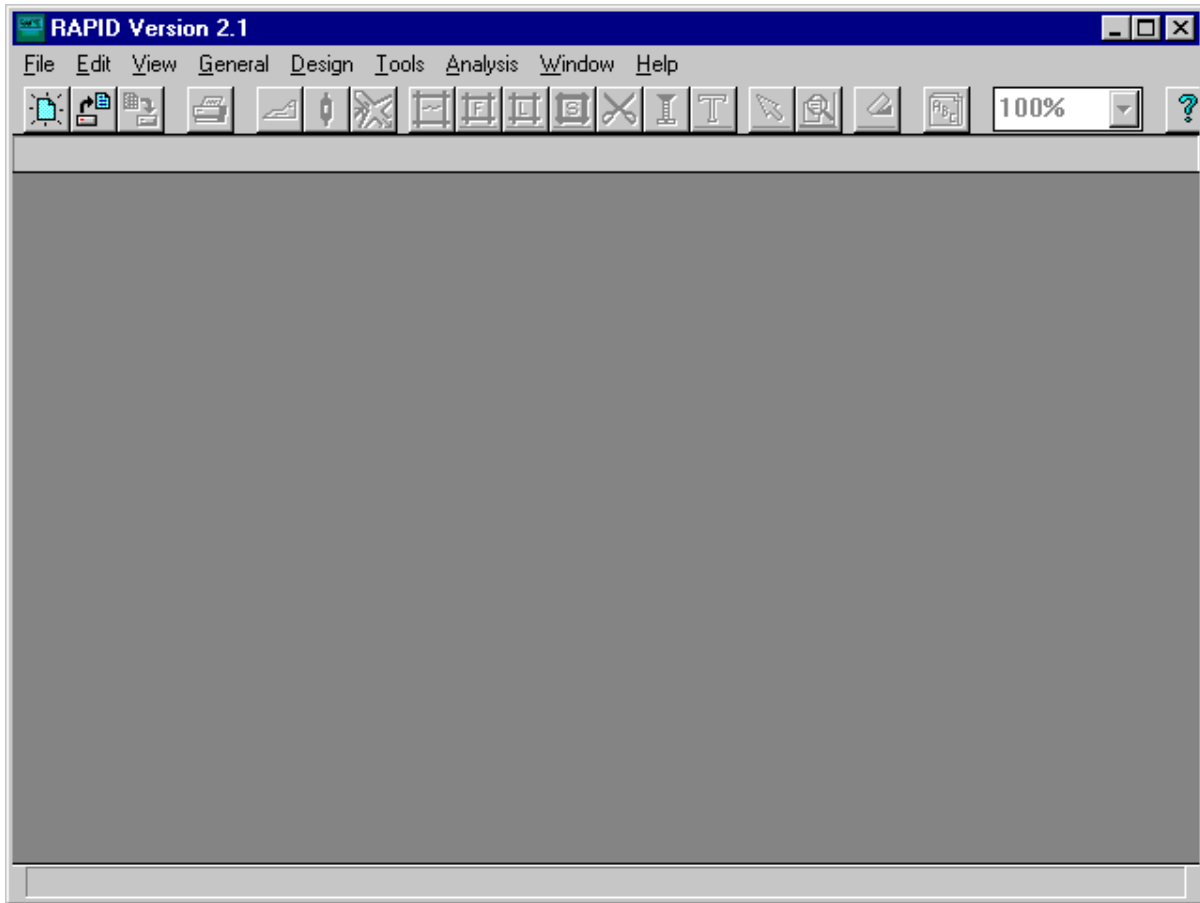
8.2 Longitudinal Butt Joint Example

The following is an example of a rectangular cutout with a single external doubler repair over a longitudinal butt joint. The cutout is 8 inches high by 5 inches wide and is centered between frames and longerons spaced on 20-inch centers. The doubler size and fastener locations are automatically determined by the default pitch and edge distance settings, together with the selected number of fastener rows per side. The layout and materials are shown in the following figure.

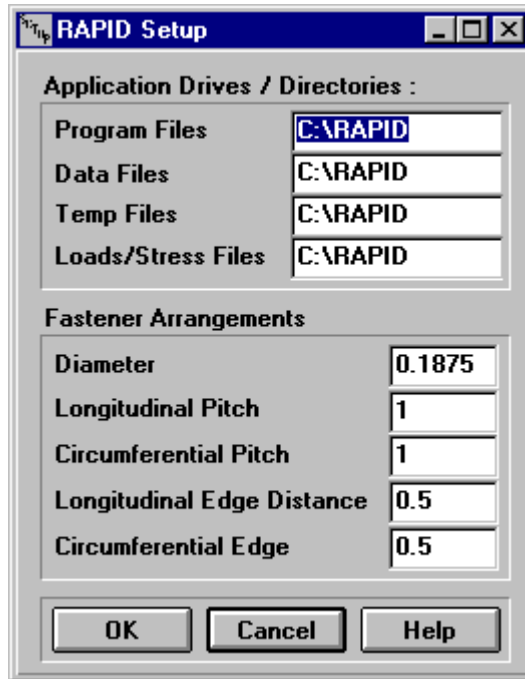


8.2.1 Create the New RAPID Model

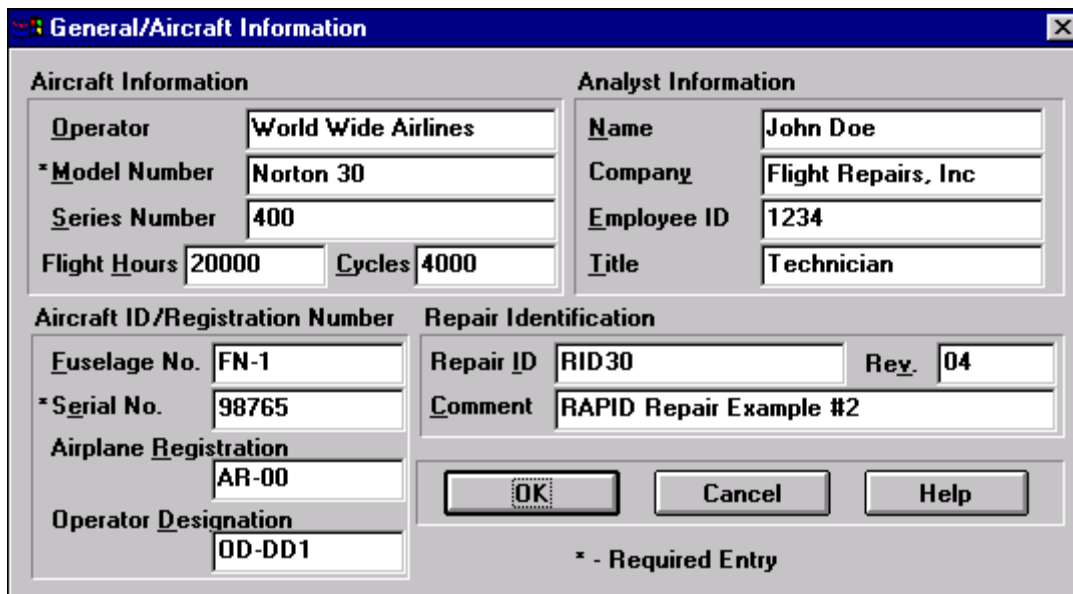
The first step is to start the RAPID program from the Windows Program Manager. Once launched, RAPID will display its main MDI window, as shown below. All of the dialog windows shown in this example appear as subwindows within the RAPID MDI window. To begin a new repair, select **New** from the **File** menu.



The **Setup** dialog window can be selected from the **Tools --> Program Setup --> File Locations** pull-down menu and is shown below. There is no need to use the **Setup** dialog window unless there is a need to change the default RAPID configuration. The fastener pitch and edge distances will be used by the **Fastener Arrangement** dialog window to automatically determine the number and arrangement of the fasteners in the repair. The defaults can be changed here or, on a model to model basis, within the **Fastener Arrangement** dialog window which will be used later. If any of the values are changed, then the **OK** button must be selected for the values to be written to the RAPID.INI file, which stores the RAPID defaults. In this example, we will retain the defaults and simply close the dialog window by clicking on the **Cancel** button.



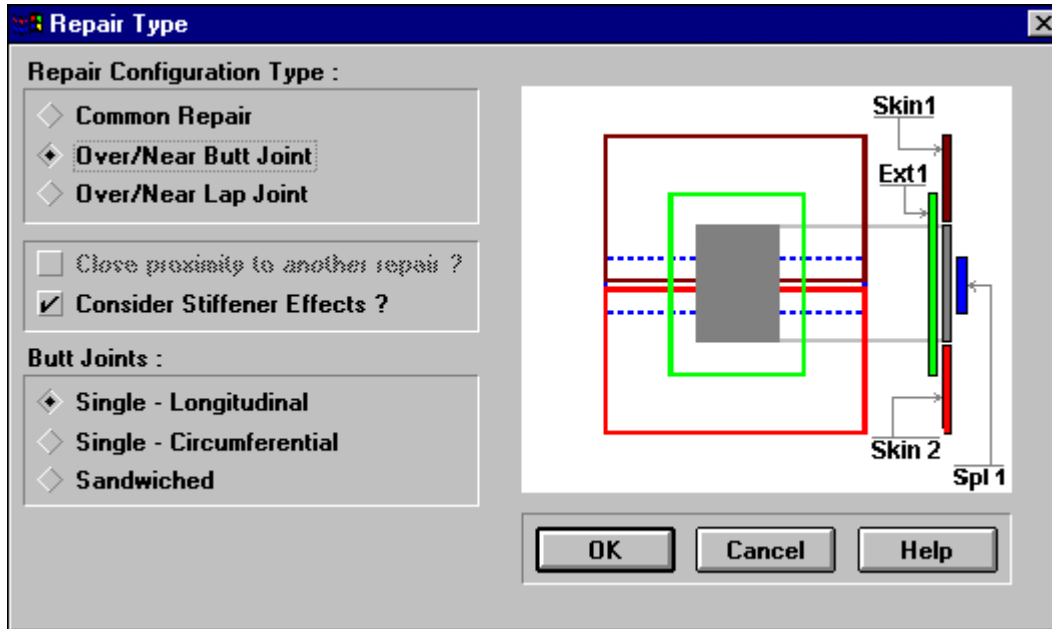
The first dialog window in which data will be input is the **Aircraft/General Information** window, shown below with example input data already entered. This window can be selected either from the MDI button bar or from the **General** pull-down menu. Once the data is entered, the **OK** button must be selected to store the data in the current model and close the dialog window.



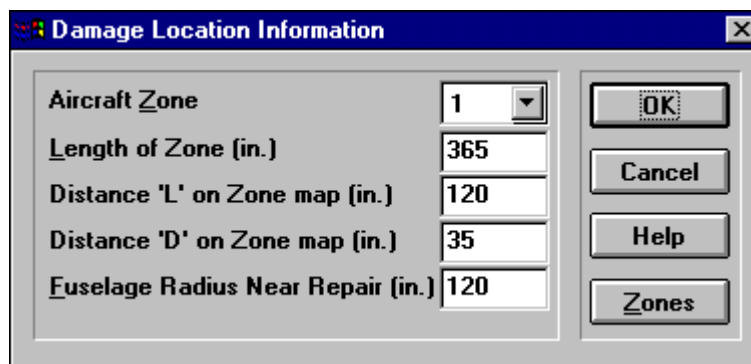
8.2.2 Define Repair Type and Location

Next, the repair type is selected from the **Repair Type** dialog window, as shown below. This dialog window can be selected either from the icon button bar or from the **General** pull-down

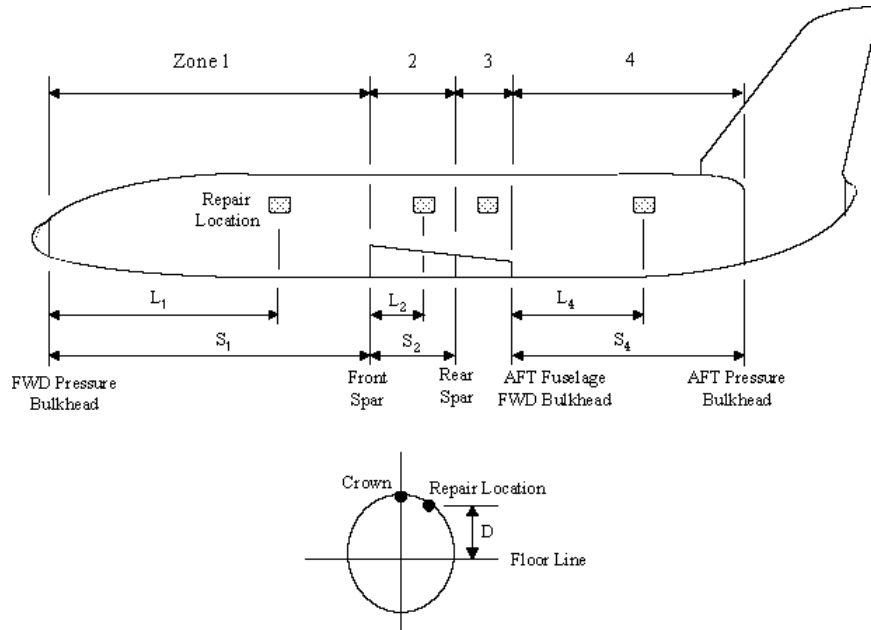
menu. The **Over/Near Butt Joint Repair Configuration Type** is selected, along with **Stiffener Effects**, in a **Single - Longitudinal** configuration. The selection is saved and the dialog window is closed by pressing the **OK** button.



The **Damage Location** dialog window is invoked to enter the location of the damage on the structure and is shown below. This window can be selected either from the icon button bar or from the **General** pull-down menu.

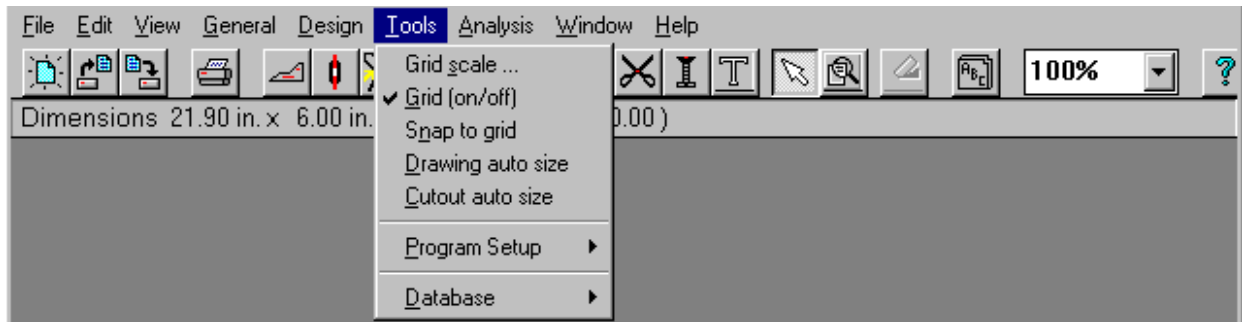


The distances entered on this dialog window refer to regions of the aircraft as depicted in the zone diagram which can be displayed by selecting the **Zones** button and which is shown in the following figure. As with all of the other dialogs with **OK** buttons, remember to save the data and close the dialog by pressing the **OK** button after completing the entries.

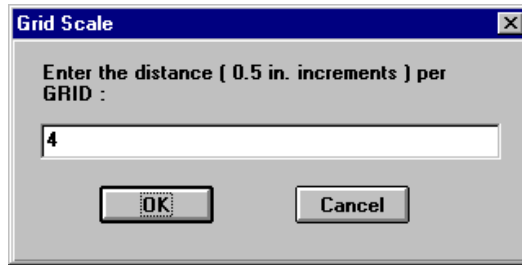


8.2.3 Draw the Repair

After entering the damage location information, the **Grid Scale** dialog window will be automatically displayed to set the drawing scale to accommodate the size of the planned repair. The grid scale can be reset at any other time by selecting the **Grid scale** menu item from the **Tools** pull-down menu.



For the depicted 640 x 480 screen resolution, a grid scale of 4 inches per grid will result in a workspace of adequate size to draw the largest included object, the repair boundary which is 20 inches wide by 20 inches high.

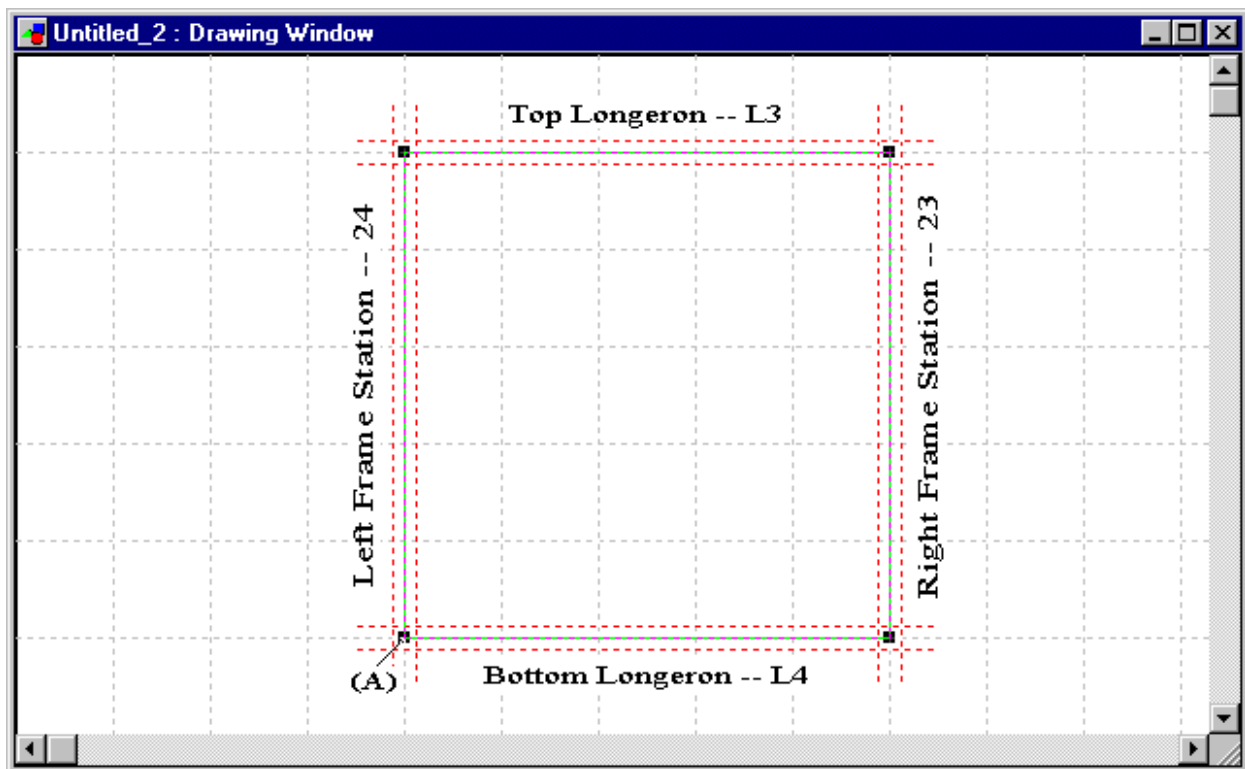


8.2.3.1 Define the Repair Boundary

The repair boundary tool is used to draw the region defined by the two frames and two longerons which are just outside of the region of the repair, as defined by the doubler.



After selecting the repair boundary tool from the tool bar, the repair boundary is drawn by clicking the left mouse button on one corner of the repair boundary and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the repair boundary and then releasing the left mouse button. The changing size of the repair boundary is displayed in the upper left of the display as the area is drawn.



When the left mouse button is released, the **Repair Boundary Information** dialog window is automatically displayed to input the frame and longeron labels and the **Number of Fasteners**

and the **Cross-Sectional Area** and to fine-tune the **Overall Distances** in the **Longitudinal** and **Circumferential** directions. Remember to enter data for each of the four stiffeners by clicking on each of the four **Stiffener** buttons in turn.

The screenshot shows a dialog box titled "Repair Boundary Information". It contains the following fields and controls:

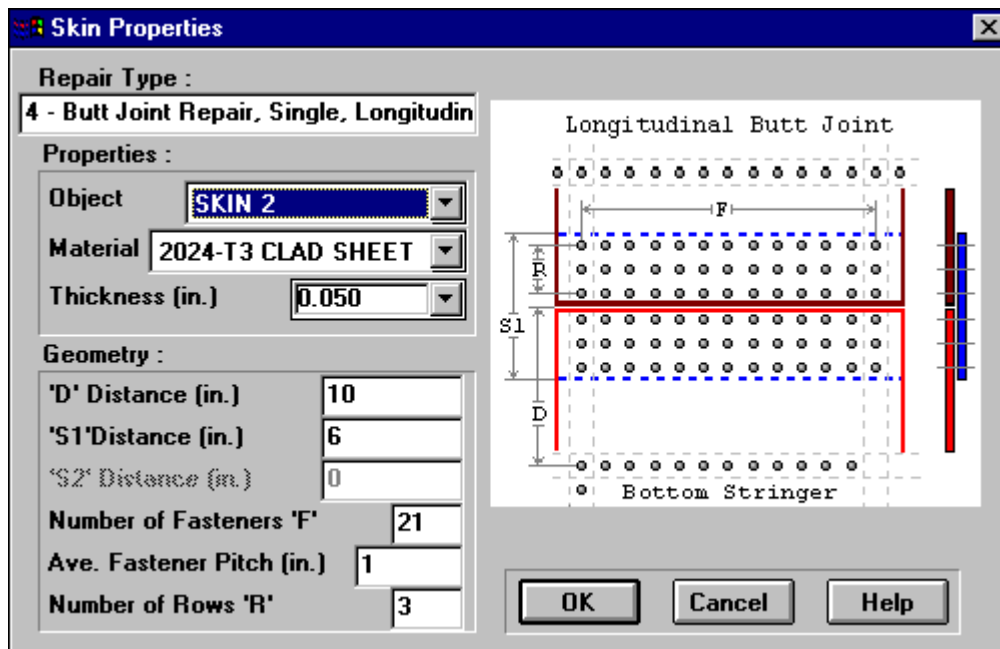
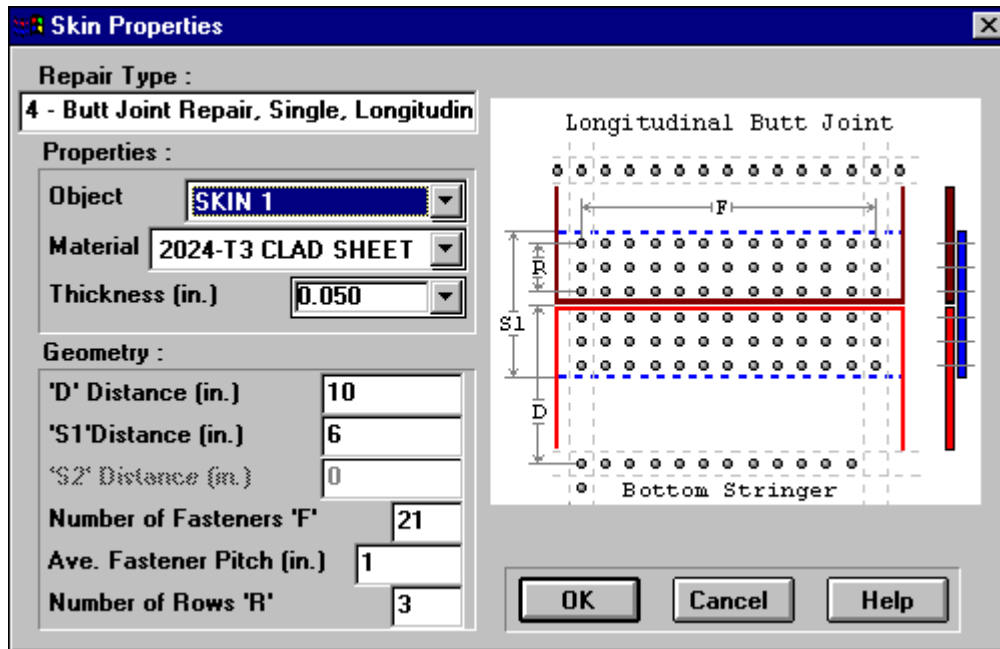
- Damage Type:** A dropdown menu set to "Accidental".
- Overall Distances (inches):**
 - Longitudinal direction:** A text box containing "20".
 - Circumferential direction:** A text box containing "20".
- Stiffeners :** A list of four items, each with a diamond-shaped selection icon:
 - Top Longeron (stringer)
 - Bottom Longeron (stringer)
 - Left Frame Station
 - Right Frame Station
- Stiffener Properties:**
 - Stiffener ID (location):** A text box containing "E".
 - Number of Fasteners (overall distance):** A text box containing "20".
 - Average Pitch on stiffener:** A text box containing "1".
 - Cross-Sectional Area (sq.in.):** A text box containing "0.5".
 - Material:** A dropdown menu set to "2024-T3 CLAD SHEET".

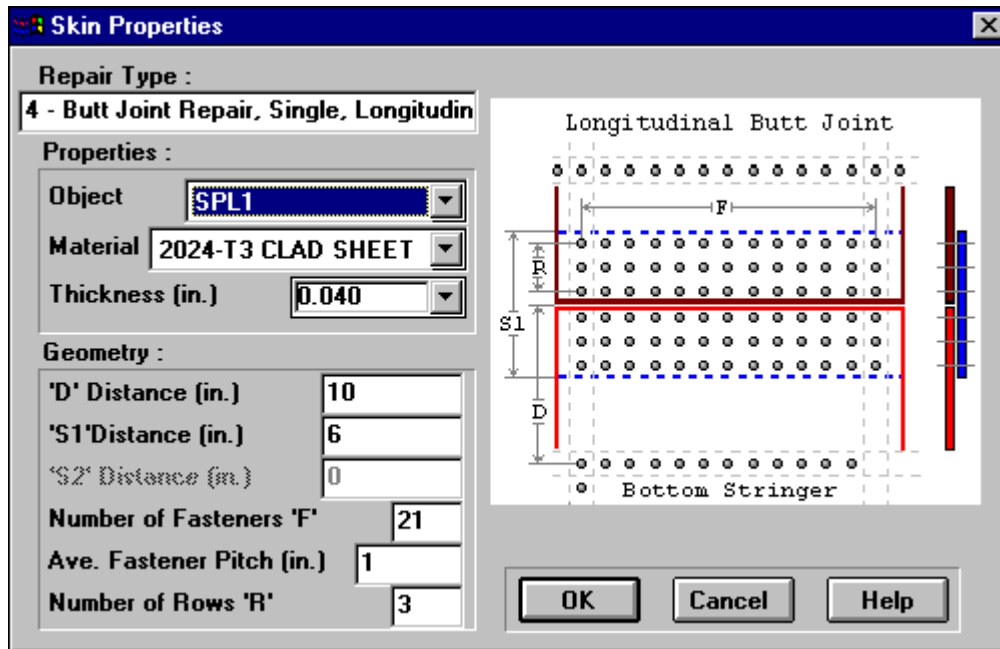
On the right side of the dialog, there are three buttons: "OK", "Cancel", and "Help".

8.2.3.2 Define Skin Properties

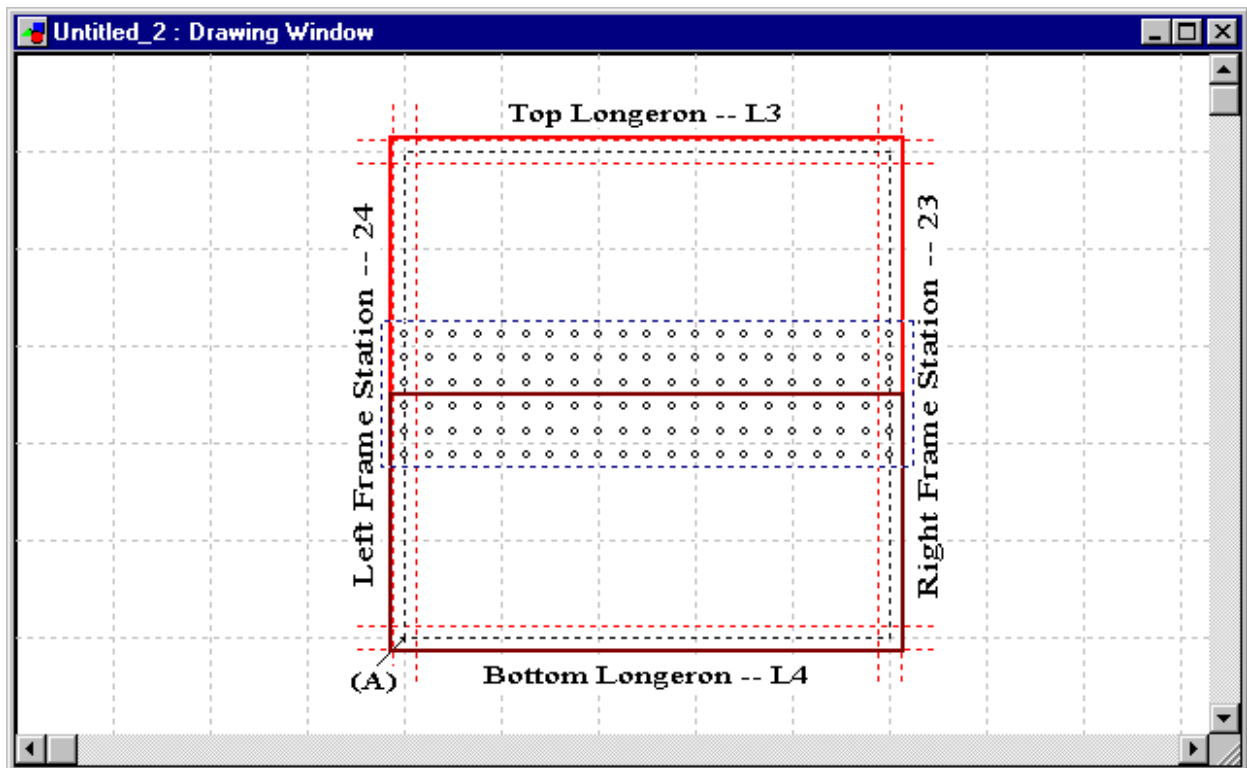
Selecting **Skin Properties** from the **Design** menu or selecting the **Skin Properties** icon on the button bar invokes the **Skin Properties** dialog window. Because the repair is over a butt joint, the existing geometry of the joint must also be entered.

For the two skin layers and the splice layer listed in the **Object** combo-box in the **Properties** section, select the **Material** and **Thickness**. In the **Geometry** section, enter the dimensions of the splice and the existing fastener geometry.





Pressing **OK** updates the Drawing window to represent the local skin areas as rectangles extending just beyond the repair boundary frames and longerons. The existing butt joint and fasteners are also displayed.

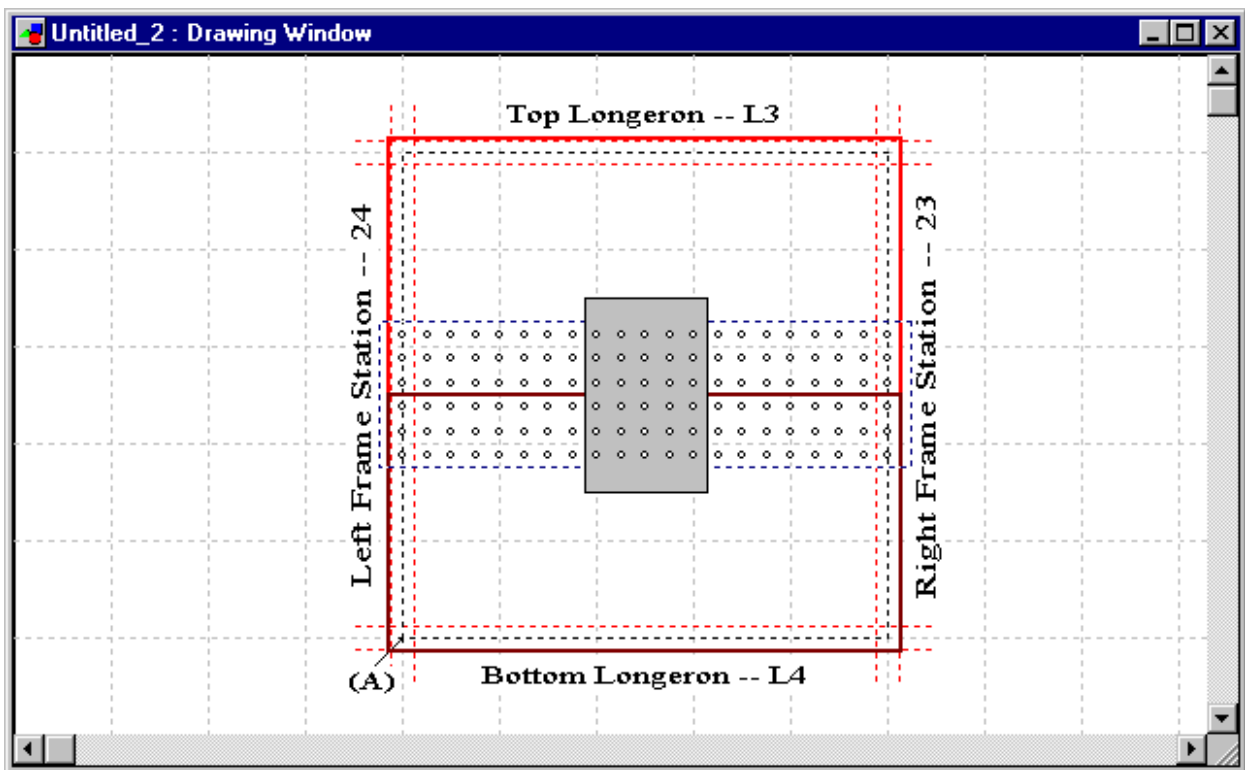


8.2.3.3 Draw the Cutout

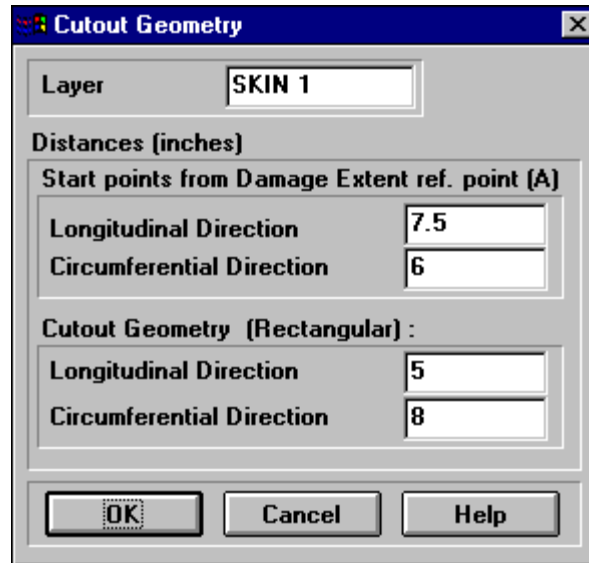
Next, the cutout is defined by selecting the cutout tool on the tool bar.



The cutout is drawn by clicking the left mouse button on one corner of the cutout and then, while continuing to depress the left mouse button, dragging the mouse to the opposite corner of the cutout and then releasing the mouse button. The size and location of the centroid with respect to the left most frame and bottom longeron are displayed in the upper left of the display.



When the left mouse button is released, the **Cutout Geometry** window is automatically displayed to allow manual correction of the dimensions.

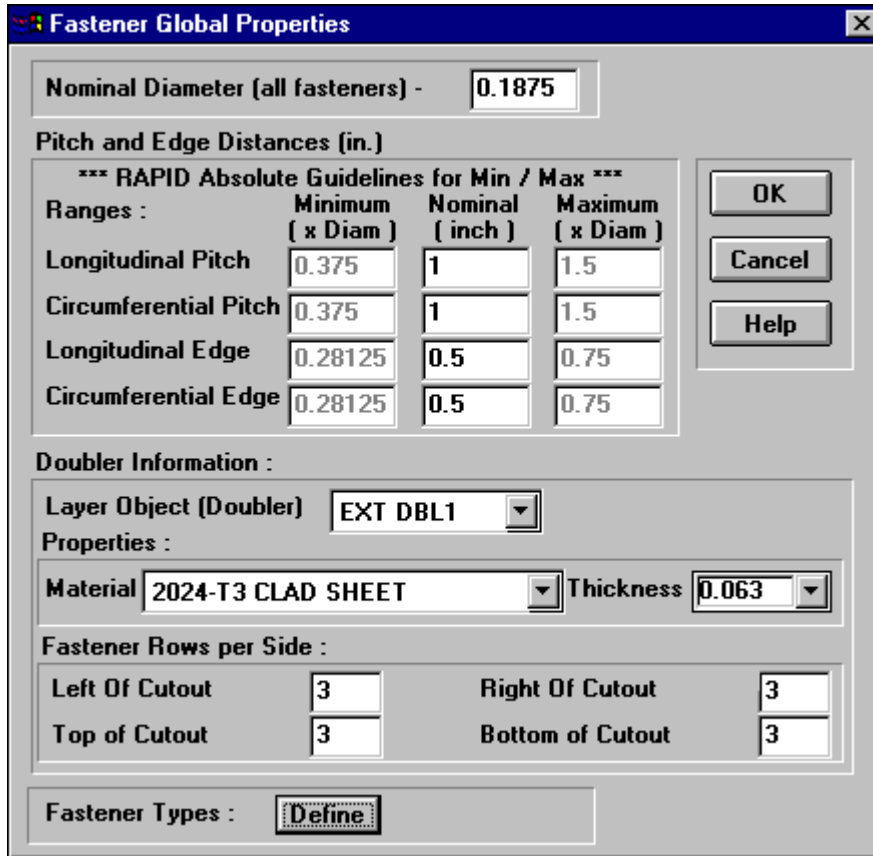


8.2.3.4 Create the Fasteners

The fastener arrangement is then defined by selecting the **Fastener Properties** tool from the button bar or from the **Design** menu.



This invokes the **Fastener Global Properties** dialog window. This dialog window is used to change the default pitch and edge distances and to enter the number of fastener rows per side of each doubler. Because this information is used by RAPID to automatically size the doublers, the material and thickness of each doubler should also be entered. For the current example, only one external doubler is included.



Fastener Global Properties

Nominal Diameter (all fasteners) - 0.1875

Pitch and Edge Distances (in.)

*** RAPID Absolute Guidelines for Min / Max ***

Ranges :	Minimum (x Diam)	Nominal (inch)	Maximum (x Diam)
Longitudinal Pitch	0.375	1	1.5
Circumferential Pitch	0.375	1	1.5
Longitudinal Edge	0.28125	0.5	0.75
Circumferential Edge	0.28125	0.5	0.75

OK
Cancel
Help

Doubler Information :

Layer Object (Doubler) EXT DBL1

Properties :

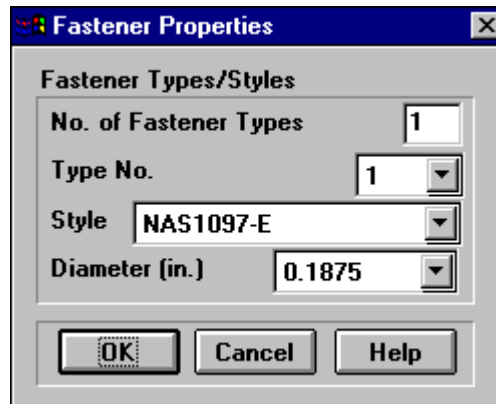
Material 2024-T3 CLAD SHEET Thickness 0.063

Fastener Rows per Side :

Left Of Cutout	3	Right Of Cutout	3
Top of Cutout	3	Bottom of Cutout	3

Fastener Types : Define

The one fastener type in the model should now be entered by pressing the **Fastener Types Define** button to display the **Fastener Properties** input screen. Enter 1 for the **No. of Fastener Types** and then enter the **Style** and **Diameter** for that **Type No.**



Fastener Properties

Fastener Types/Styles

No. of Fastener Types 1

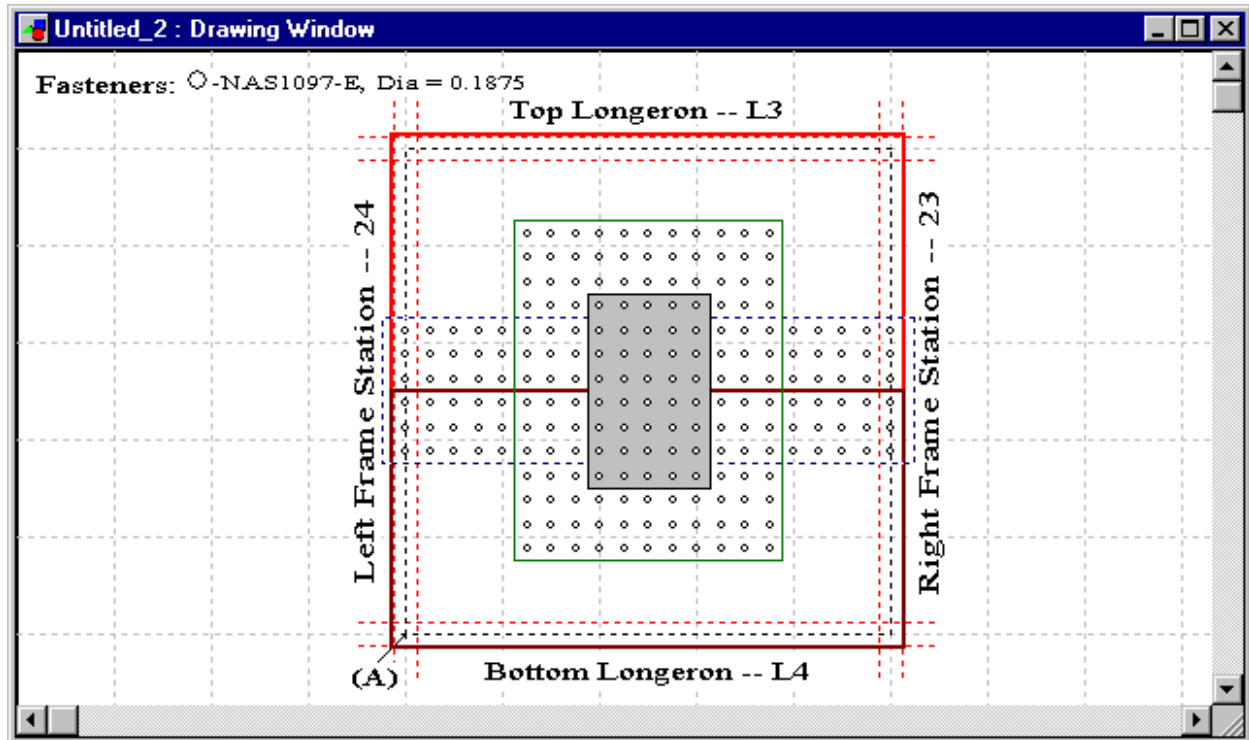
Type No. 1

Style NAS1097-E

Diameter (in.) 0.1875

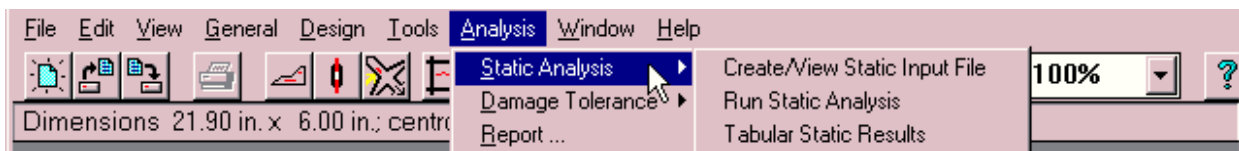
OK Cancel Help

When the **OK** button is selected in the **Fastener Global Properties** screen, the fasteners and doubler are automatically generated and displayed in the workspace.



8.2.4 Run the Analyses

The analyses can then be run and the results viewed by using the **Analysis** pull-down menu.



8.2.4.1 Static Analysis

Listed below is the input to the Static module as displayed by the **Create/View Static Input File** menu item in the **Static Analysis** section of the **Analysis** pull-down menu:

```

REPAIR CONFIGURATION TYPE (Single Butt Joint)
4
SKIN/DAMAGE : Number of Layers
1
SKIN : Mat.Type
2024-T3 CLAD SHEET
# of Sides, Thickness, FTU (ksi), Modulus (ksi)
4 0.05 60 10500
SIDE 1 : LENGTH, FSU
8 37
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1 42 1.139 0.191
MAX# OF ROWS
3

```

```

NUMBER OF FASTENERS PER ROW
14
14
14
SIDE 2 : LENGTH, FSU
5 37
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1 33 1.139 0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
11
11
11
SIDE 3 : LENGTH, FSU
8 37
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1 42 1.139 0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
14
14
14
SIDE 4 : LENGTH, FSU
5 37
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1 33 1.139 0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
11
11
11
REPAIR : Number of Layers
1
EXT DBL1 : Mat.Type
2024-T3 CLAD SHEET
# of Sides, Thickness, FTU (ksi), Modulus (ksi)
4 0.063 62 10500
SIDE 1 : LENGTH, FSU
14 38
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1 42 1.005 0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
14
14
14
SIDE 2 : LENGTH, FSU
11 38
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1 33 1.005 0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
11
11
11
SIDE 3 : LENGTH, FSU

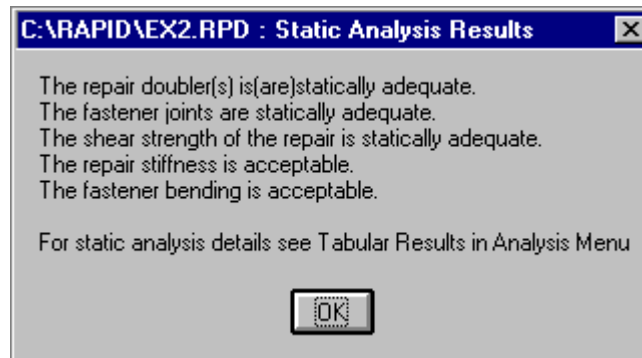
```

```

          14    38
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          42          1.005    0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
14
14
14
SIDE 4    : LENGTH, FSU
          11    38
MAX# OF FASTENER TYPES
1
FASTENER TYPE, AMOUNT, JOINT ALLOWABLE, DIAMETER
1          33          1.005    0.191
MAX# OF ROWS
3
NUMBER OF FASTENERS PER ROW
11
11
11
PITCH    : Circumferential, Longitudinal
          1.0000    1.0000
BENDING  : Q Ratio
          2.0

```

The static analysis is then executed by selecting the **Run Static Analysis** menu item located in the **Static Analysis** section of the **Analysis** pull-down menu. When the analysis is complete, RAPID displays the **Static Analysis Results Summary**.



The following shows the textual output produced by the static analysis and displayed by selecting the **Tabular Static Results** menu item in the **Static Analysis** section of the **Analysis** pull-down. Note that the margins of safety for the doublers and the fasteners are all positive, indicating that the chosen design is statically adequate.

STATIC ANALYSIS RESULTS OF THE REPAIR

```

(A) MARGINS OF SAFETY:
*** REPAIR DOUBLERS ***
0.30
MARGIN OF SAFETY IS POSITIVE.

```


THE REPAIR DOUBLERS ARE STATICALLY ADEQUATE.

*** FASTENER JOINTS ***

	LOAD LOST (LBS)	LOAD RESTORED (LBS)	MARGIN OF SAFETY (NONDIMENSIONAL)
	-----	-----	-----
SIDE 1	24000	42210	0.76
SIDE 2	15000	33165	1.21
SIDE 3	24000	42210	0.76
SIDE 4	15000	33165	1.21

SIDE 1: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

SIDE 2: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

SIDE 3: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

SIDE 4: MARGIN OF SAFETY IS POSITIVE.

THE FASTENER JOINTS ARE STATICALLY ADEQUATE.

(B) SHEAR STRENGTHS:

	DOUBLER(S) (LBS)	SKIN (LBS)	MARGIN OF SAFETY (NONDIMENSIONAL)
	-----	-----	-----
SIDE 1	2394	1850	0.29
SIDE 2	2394	1850	0.29
SIDE 3	2394	1850	0.29
SIDE 4	2394	1850	0.29

SIDE 1: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

SIDE 2: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

SIDE 3: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

SIDE 4: MARGIN OF SAFETY IS POSITIVE.

THE SHEAR STRENGTH OF THE REPAIR IS STATICALLY ADEQUATE.

(C) STIFFNESS:

	DOUBLER(S) (LBS/IN)	SKIN (LBS/IN)	STIFFNESS RATIO (NONDIMENSIONAL)
	-----	-----	-----
SIDE 1	661500	525000	1.26
SIDE 2	661500	525000	1.26
SIDE 3	661500	525000	1.26
SIDE 4	661500	525000	1.26

SIDE 1: STIFFNESS RATIO IS BETWEEN 1 AND 1.5
 REPAIR STIFFNESS IS ACCEPTABLE.

SIDE 2: STIFFNESS RATIO IS BETWEEN 1 AND 1.5
 REPAIR STIFFNESS IS ACCEPTABLE.

SIDE 3: STIFFNESS RATIO IS BETWEEN 1 AND 1.5
 REPAIR STIFFNESS IS ACCEPTABLE.

SIDE 4: STIFFNESS RATIO IS BETWEEN 1 AND 1.5
 REPAIR STIFFNESS IS ACCEPTABLE.

(D) FASTENER BENDING:

Q RATIO
 (NONDIMENSIONAL)

SIDE 1 0.59
 SIDE 2 0.59
 SIDE 3 0.59
 SIDE 4 0.59

SIDE 1: Q RATIO IS EQUAL TO OR LESS THAN 2.0
 ALUMINUM - FASTENER BENDING IS ACCEPTABLE.

SIDE 2: Q RATIO IS EQUAL TO OR LESS THAN 2.0
 ALUMINUM - FASTENER BENDING IS ACCEPTABLE.

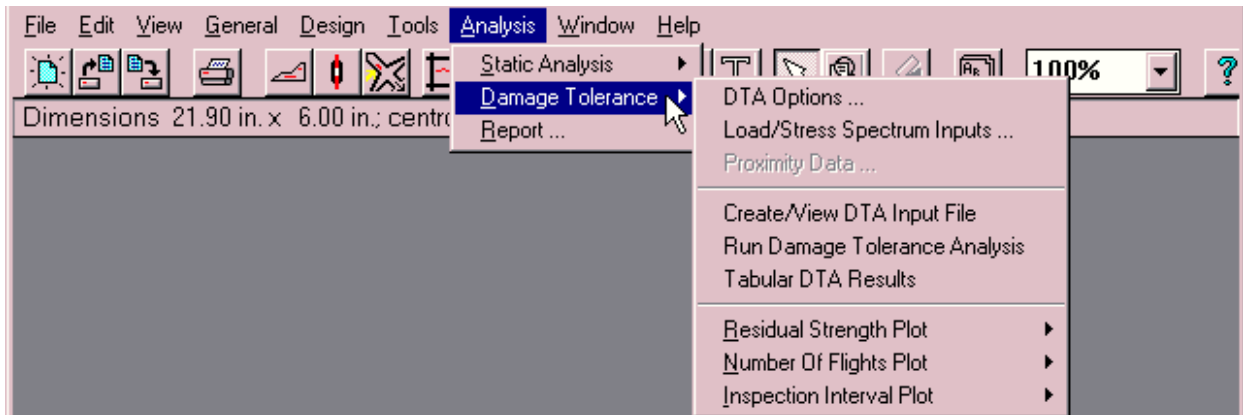
SIDE 3: Q RATIO IS EQUAL TO OR LESS THAN 2.0
 ALUMINUM - FASTENER BENDING IS ACCEPTABLE.

SIDE 4: Q RATIO IS EQUAL TO OR LESS THAN 2.0
 ALUMINUM - FASTENER BENDING IS ACCEPTABLE.

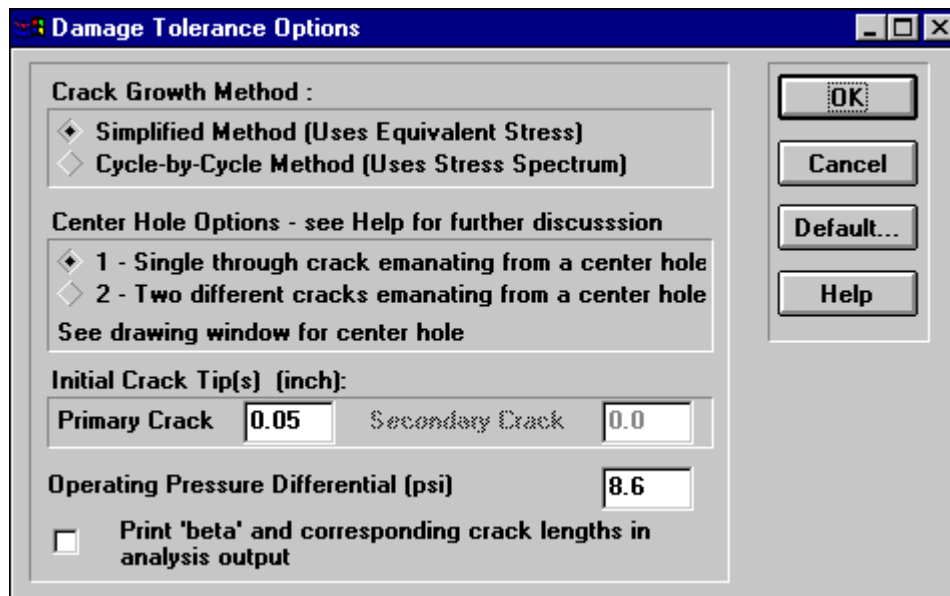
If the repair doubler or the fastener joints for any of the sides had been inadequate ($MS < 0$) or only marginally adequate ($MS = 0$), it would be necessary to return to the **Fastener Arrangement** dialog window to modify the fasteners and/or doublers.

8.2.4.2 Damage Tolerance Analysis

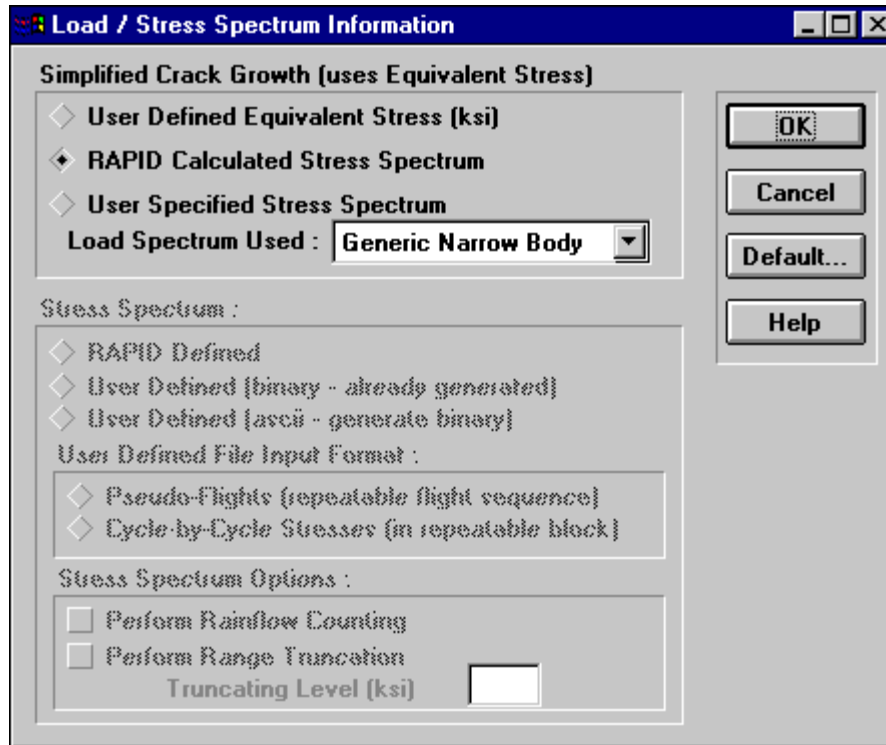
Now that it has been determined that the repair is statically adequate, the damage tolerance analysis (DTA) can be run.



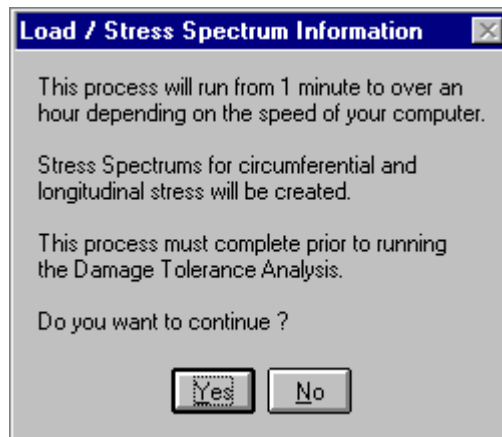
Select the **DTA Options** dialog window. For this example, select the **Simplified Method** for **Crack Growth**, the **Single through crack center hole** Option, and an **Operating Pressure Differential** of 8.6 psi.



Close the window by selecting the **OK** button, then select the **Create/View DTA Input File** menu item which will automatically invoke the **Load/Stress Spectrum Information** dialog window. For this example, select the **Generic Narrow-Body Load Spectrum**.



Clicking the **OK** button starts the stress spectrum generation program after displaying the following warning.



If the selected load spectrum has not previously been generated, then the following message will be displayed.



In this occurs, then press the **OK** button, cancel the **Load/Stress Spectrum Information** dialog window, select the **Generate Load Spectra** menu item from the **Program Setup** submenu of the **Tools** menu, and generate the desired spectrum. Then, return to the **Load/Stress Spectrum Information** dialog and continue.

Listed below is the input to the DTA module which is displayed after the stress spectra are generated:

```

4
REPAIR CONFIGURATION TYPE (Single Butt Joint) - Side 1 - for Circumferential Crack direction
4
  SKIN: Mat. Type
        2024-T3 Clad Sheet
        Mat.Type, Thickness, Modulus(ksi), C,      P,      Kc(ksi*sqrt(in)),Yield S(ksi),FTU
          1      0.05      10500      6.76125e-10      3.7198      153      44      60
        EDSX, EDSY
          0.5      0.5
  CUTOUT : X Direct., Y Direct.
            8      5
  EXT DBL1: Mat. Type
            2024-T3 Clad Sheet
            Mat.Type, Thickness, Modulus(ksi), C,      P,      Kc(ksi*sqrt(in)),Yield S(ksi)
              1      0.063      10500      6.76125e-10      3.7198      152.4      45
  PITCH : X Direct., Y Direct.
            1      1
  FSTNR : Max # In Col
            3
            Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
              1      0.19100
              1      0.19100
              1      0.19100
            Max # In Row, Crit #, Crit #, Overlap, L2R
              14      8      0      0      0
  STIFF : Max #, POS, CSA, Yng.Mod., HPit
            1      3.000 0.500 10500.000 1.0000
            0      0.000 0.000      0.000 0.0000
            0      0.000 0.000      0.000 0.0000
            0      0.000 0.000      0.000 0.0000
            0      0.000 0.000      0.000 0.0000
            2      3.000 0.500 10500.000 1.0000      23.000 0.500 10500.000 1.0000
            Dblr Id
              1
  PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
            0      0.000 0.000 1 14.000 11.000 1 0.000 0.000 0.500 0.500
  FUSELAGE: Eqv.Stress, Press. Diff, Radius
            10.0120      8.6      120.000
  CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL,KBFLG
            1      4      0      1      0      0.050 0.000 1 0
REPAIR CONFIGURATION TYPE (1 External Doubler) - Side 2 - for Longitudinal Crack direction
3
  SKIN: Mat. Type
        2024-T3 Clad Sheet
        Mat.Type, Thickness, Modulus(ksi), C,      P,      Kc(ksi*sqrt(in)),Yield S(ksi),FTU
          2      0.05      10500      9.01566e-10      3.68842      153      44      60
        EDSX, EDSY
          0.5      0.5
  CUTOUT : X Direct., Y Direct.

```

5 8

EXT DBL1: Mat. Type
2024-T3 Clad Sheet
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
2 0.063 10500 9.01566e-10 3.68842 152.4 45

PITCH : X Direct., Y Direct.
1 1

FSTNR : Max # In Col
3
Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
1 0.19100
1 0.19100
1 0.19100
Max # In Row, Crit #, Crit #, Overlap, L2R
11 6 11 0 0

STIFF : Max #, POS, CSA, Yng.Mod., HPit
1 4.500 0.500 10500.000 1.0000
0 0.000 0.000 0.000 0.0000
0 0.000 0.000 0.000 0.0000
0 0.000 0.000 0.000 0.0000
0 0.000 0.000 0.000 0.0000
2 4.500 0.500 10500.000 1.0000 24.500 0.500 10500.000 1.0000

Dblr Id
1

PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
0 0.000 0.000 1 11.000 14.000 1 0.000 0.000 0.500 0.500

FUSELAGE: Eqv.Stress, Press. Diff, Radius
18.6360 8.6 120.000

CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL,KBFLG
3 1 0 1 0 0.050 0.000 0 0

REPAIR CONFIGURATION TYPE (Single Butt Joint) - Side 3 - for Circumferential Crack direction
4

SKIN: Mat. Type
2024-T3 Clad Sheet
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi),FTU
1 0.05 10500 6.76125e-10 3.7198 153 44 60

EDSX, EDSY
0.5 0.5

CUTOUT : X Direct., Y Direct.
8 5

EXT DBL1: Mat. Type
2024-T3 Clad Sheet
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
1 0.063 10500 6.76125e-10 3.7198 152.4 45

PITCH : X Direct., Y Direct.
1 1

FSTNR : Max # In Col
3
Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
1 0.19100
1 0.19100
1 0.19100
Max # In Row, Crit #, Crit #, Overlap, L2R
14 8 0 0 0

STIFF : Max #, POS, CSA, Yng.Mod., HPit
1 3.000 0.500 10500.000 1.0000
0 0.000 0.000 0.000 0.0000
0 0.000 0.000 0.000 0.0000
0 0.000 0.000 0.000 0.0000
0 0.000 0.000 0.000 0.0000
2 3.000 0.500 10500.000 1.0000 23.000 0.500 10500.000 1.0000

Dblr Id
1

PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
0 0.000 0.000 1 14.000 11.000 1 0.000 0.000 0.500 0.500

FUSELAGE: Eqv.Stress, Press. Diff, Radius
10.0120 8.6 120.000

CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL,KBFLG
1 4 0 1 0 0.050 0.000 1 0

REPAIR CONFIGURATION TYPE (1 External Doubler) - Side 4 - for Longitudinal Crack direction
3

SKIN: Mat. Type
2024-T3 Clad Sheet
Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi),FTU
2 0.05 10500 9.01566e-10 3.68842 153 44 60

EDSX, EDSY

```

      0.5    0.5
CUTOOUT : X Direct., Y Direct.
          5      8
EXT DBL1: Mat. Type
          2024-T3 Clad Sheet
          Mat.Type, Thickness, Modulus(ksi), C, P, Kc(ksi*sqrt(in)),Yield S(ksi)
          2      0.063    10500    9.01566e-10    3.68842    152.4    45
PITCH   : X Direct., Y Direct.
          1      1
FSTNR   : Max # In Col
          3
          Material, Hole Diameter *(1-AL, 2-TI, 3-Steel)
          1      0.19100
          1      0.19100
          1      0.19100
          Max # In Row, Crit #, Crit #, Overlap, L2R
          11     6      11     0      0
STIFF   : Max #, POS, CSA, Yng.Mod., HPit
          1      4.500 0.500 10500.000 1.0000
          0      0.000 0.000    0.000 0.0000
          0      0.000 0.000    0.000 0.0000
          0      0.000 0.000    0.000 0.0000
          0      0.000 0.000    0.000 0.0000
          2      4.500 0.500 10500.000 1.0000      24.500 0.500 10500.000 1.0000
          Dblr Id
          1
PROXMTY : Flag,Delta X,Delta Y,IQS, Sub.X, Sub.Y,IQP, Prx.X, Prx.Y, EDPX, EDPY
          0      0.000 0.000 1 11.000 14.000 1 0.000 0.000 0.500 0.500
FUSELAGE: Eqv.Stress, Press. Diff, Radius
          18.6360      8.6    120.000
CRK GRW : RunType,Crk.Scnr,Vsl.Meth,Method,Rtd.Flag,TipA,TipB,ICL,KBFLG
          3      1      0      1      0      0.050 0.000 0 0

```

The damage tolerance analysis is then executed by selecting the **Run Damage Tolerance Analysis** menu item located in the **Damage Tolerance** section of the **Analysis** pull-down menu. The following shows the textual output produced by the DTA module and displayed by selecting the **Tabular DTA Results** menu item in the **Damage Tolerance** section of the **Analysis** pull-down menu:

DAMAGE TOLERANCE ANALYSIS RESULTS OF THE REPAIR

THE FOLLOWING 1 SET OF OUTPUT IS FOR THE CIRCUMFERENTIAL CRACK OF SIDE 1:

***** BUTT JOINT FASTENER *****

FASTENER LOAD = 16.73764 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	44.00000
0.08545	19513	44.00000
0.12090	38236	44.00000
0.15635	56193	44.00000
0.19180	73489	44.00000
0.22725	89240	44.00000
0.26270	102306	44.00000
0.29815	112438	44.00000
0.33360	119651	44.00000
0.36905	123712	44.00000
0.40450	124900	39.65282

TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.59550	124900	39.65282
0.60050	124900	44.00000
0.61122	126188	44.00000
0.62194	126712	44.00000
0.63266	127148	44.00000
0.64338	127516	44.00000
0.65410	127859	44.00000
0.92210	136003	44.00000
1.08290	140030	44.00000
1.24370	142932	44.00000
1.40450	144575	44.00000
1.59550	144575	44.00000
1.60050	144575	44.00000
1.60521	144585	44.00000
1.60922	144593	35.20000

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 72296 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
0.05000	72296
0.10000	58697
0.15000	45808
0.20000	33730
0.25000	23484
.	.
(etc...)	.
.	.
1.24550	821
1.29550	566
1.34550	310

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE
CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE
HELP FILE.

THE FOLLOWING 3 SETS OF OUTPUT ARE FOR THE LONGITUDINAL CRACKS OF SIDE 2:

***** CENTER FASTENER *****

FASTENER LOAD = 16.73764 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	44.00000
0.27770	16728	44.00000
0.35360	21565	44.00000
0.42950	25852	44.00000
0.50540	29636	44.00000
0.58130	32935	44.00000
0.65720	35675	44.00000

0.73310	37699	44.00000
0.80900	38838	44.00000
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
-----	-----	-----
1.19100	38838	44.00000
1.28294	39572	44.00000
1.29226	39616	44.00000
1.30184	39663	44.00000
1.31307	39714	44.00000
.		
. (etc...)		
.		
21.49009	48421	31.44543
22.57077	48443	27.55699
23.22652	48451	25.34400

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 24225 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
-----	-----
0.05000	24225
0.10000	22389
0.15000	20552
0.20000	18715
0.25000	16879
.	
. (etc...)	
.	
16.95961	102
17.00961	101
17.05961	100

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE
CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE
HELP FILE.

***** RIGHT CORNER FASTENER *****

FASTENER LOAD = 19.28462 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
-----	-----	-----
0.05000	0	44.00000
0.20180	4522	44.00000
0.27770	6584	44.00000
0.35360	8409	44.00000
0.42950	10010	44.00000
0.50540	11411	44.00000
0.58130	12625	44.00000
0.65720	13628	44.00000
0.73310	14367	44.00000
0.80900	14782	44.00000

TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
1.19100	14782	44.00000
1.94715	16792	44.00000
2.02383	16950	44.00000
2.10828	17117	44.00000
2.20130	17290	44.00000
.		
. (etc...)		
.		
23.41755	23332	25.71043
23.47536	23333	25.51849
23.53229	23334	25.34400

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 11667 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
0.05000	11667
0.10000	10922
0.15000	10177
0.20000	9432
0.25000	8751
.	
. (etc...)	
.	
18.79217	104
18.84217	102
18.89217	100

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE HELP FILE.

***** LEFT CORNER FASTENER *****

FASTENER LOAD = 19.28462 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	44.00000
0.20180	4522	44.00000
0.27770	6584	44.00000
0.35360	8409	44.00000
0.42950	10010	44.00000
0.50540	11411	44.00000
0.58130	12625	44.00000
0.65720	13628	44.00000
0.73310	14367	44.00000
0.80900	14782	44.00000
.		
.		
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)

-----	-----	-----
1.19100	14782	44.00000
1.93844	16803	44.00000
1.97582	16885	44.00000
2.01506	16969	44.00000
2.05626	17056	44.00000
.		
. (etc...)		
.		
22.45173	23406	28.91621
23.26524	23422	26.06554
23.49343	23426	25.34400

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 11713 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
-----	-----
0.05000	11713
0.10000	10968
0.15000	10223
0.20000	9478
0.25000	8797
.	
. (etc...)	
.	
18.73218	104
18.78218	103
18.83217	101

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE
CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE
HELP FILE.

THE FOLLOWING 1 SET OF OUTPUT IS FOR THE CIRCUMFERENTIAL CRACK OF SIDE 3:

***** BUTT JOINT FASTENER *****

FASTENER LOAD = 16.73764 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
-----	-----	-----
0.05000	0	44.00000
0.08545	19513	44.00000
0.12090	38236	44.00000
0.15635	56193	44.00000
0.19180	73489	44.00000
0.22725	89240	44.00000
0.26270	102306	44.00000
0.29815	112438	44.00000
0.33360	119651	44.00000
0.36905	123712	44.00000
0.40450	124900	39.65282
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)

CRACK LENGTH (INCHES)	FLIGHTS	RESIDUAL STRENGTH (KSI)
0.59550	124900	39.65282
0.60050	124900	44.00000
0.61122	126188	44.00000
0.62194	126712	44.00000
0.63266	127148	44.00000
0.64338	127516	44.00000
0.65410	127859	44.00000
0.92210	136003	44.00000
1.08290	140030	44.00000
1.24370	142932	44.00000
1.40450	144575	44.00000
1.59550	144575	44.00000
1.60050	144575	44.00000
1.60521	144585	44.00000
1.60922	144593	35.20000

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 72296 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
0.05000	72296
0.10000	58697
0.15000	45808
0.20000	33730
0.25000	23484
.	.
(etc...)	.
.	.
1.24550	821
1.29550	566
1.34550	310

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE HELP FILE.

THE FOLLOWING 3 SETS OF OUTPUT ARE FOR THE LONGITUDINAL CRACKS OF SIDE 4:

***** CENTER FASTENER *****

FASTENER LOAD = 16.73764 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	44.00000
0.27770	16728	44.00000
0.35360	21565	44.00000
0.42950	25852	44.00000
0.50540	29636	44.00000
0.58130	32935	44.00000
0.65720	35675	44.00000
0.73310	37699	44.00000
0.80900	38838	44.00000

TIP-TO-TIP	CRACK GROWTH	RESIDUAL
------------	--------------	----------

CRACK LENGTH (INCHES)	LIFE (FLIGHTS)	STRENGTH (KSI)
1.19100	38838	44.00000
1.28294	39572	44.00000
1.29226	39616	44.00000
1.30184	39663	44.00000
1.31307	39714	44.00000
.		
. (etc...)		
.		
21.49009	48421	31.44543
22.57077	48443	27.55699
23.22652	48451	25.34400

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 24225 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
0.05000	24225
0.10000	22389
0.15000	20552
0.20000	18715
0.25000	16879
.	
. (etc...)	
.	
16.95961	102
17.00961	101
17.05961	100

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE HELP FILE.

***** LEFT CORNER FASTENER *****

FASTENER LOAD = 19.28462 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
0.05000	0	44.00000
0.20180	4522	44.00000
0.27770	6584	44.00000
0.35360	8409	44.00000
0.42950	10010	44.00000
0.50540	11411	44.00000
0.58130	12625	44.00000
0.65720	13628	44.00000
0.73310	14367	44.00000
0.80900	14782	44.00000
.		
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)

1.19100	14782	44.00000
1.94715	16792	44.00000
2.02383	16950	44.00000
2.10828	17117	44.00000
2.20130	17290	44.00000
.		
. (etc...)		
.		
23.41755	23332	25.71043
23.47536	23333	25.51849
23.53229	23334	25.34400

(B) NDI INSPECTION INTERVAL:

AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 11667 FLTS.

DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
-----	-----
0.05000	11667
0.10000	10922
0.15000	10177
0.20000	9432
0.25000	8751
.	
. (etc...)	
.	
18.79217	104
18.84217	102
18.89217	100

NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE
CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE
HELP FILE.

***** RIGHT CORNER FASTENER *****

FASTENER LOAD = 19.28462 POUNDS (BASED ON 1000.0 PSI FAR FIELD REFERENCE STRESS)

(A) CRACK GROWTH LIFE AND RESIDUAL STRENGTH:

EDGE-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
-----	-----	-----
0.05000	0	44.00000
0.20180	4522	44.00000
0.27770	6584	44.00000
0.35360	8409	44.00000
0.42950	10010	44.00000
0.50540	11411	44.00000
0.58130	12625	44.00000
0.65720	13628	44.00000
0.73310	14367	44.00000
0.80900	14782	44.00000
TIP-TO-TIP CRACK LENGTH (INCHES)	CRACK GROWTH LIFE (FLIGHTS)	RESIDUAL STRENGTH (KSI)
-----	-----	-----
1.19100	14782	44.00000
1.93844	16803	44.00000
1.97582	16885	44.00000

2.01506	16969	44.00000
2.05626	17056	44.00000
.		
. (etc...)		
.		
22.45173	23406	28.91621
23.26524	23422	26.06554
23.49343	23426	25.34400

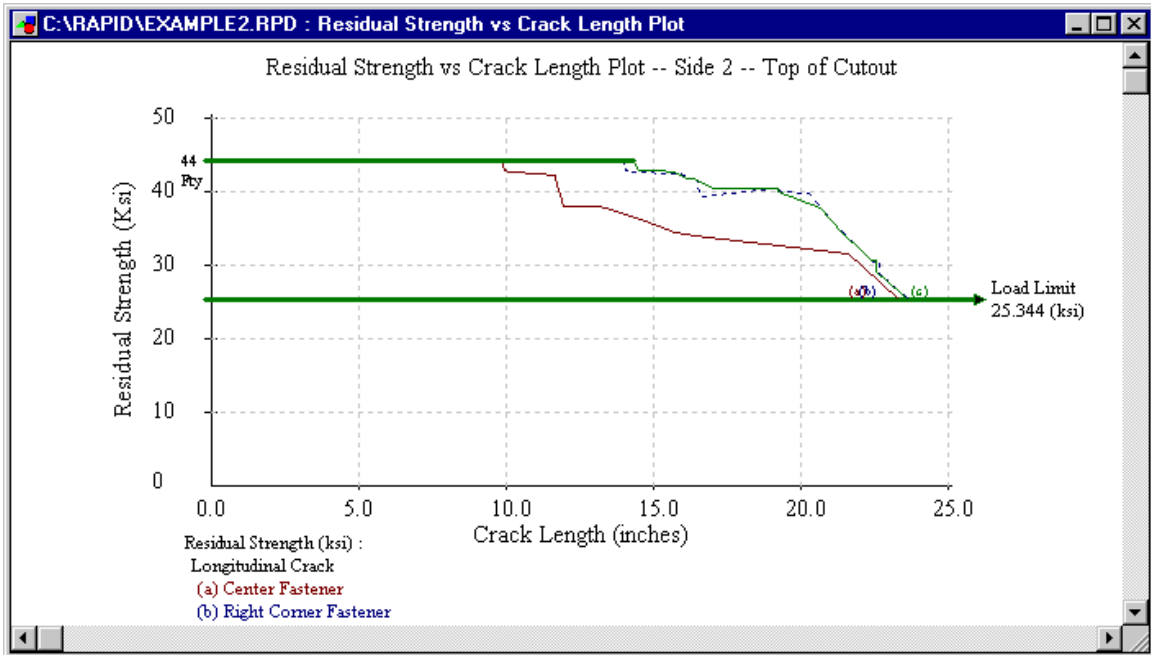
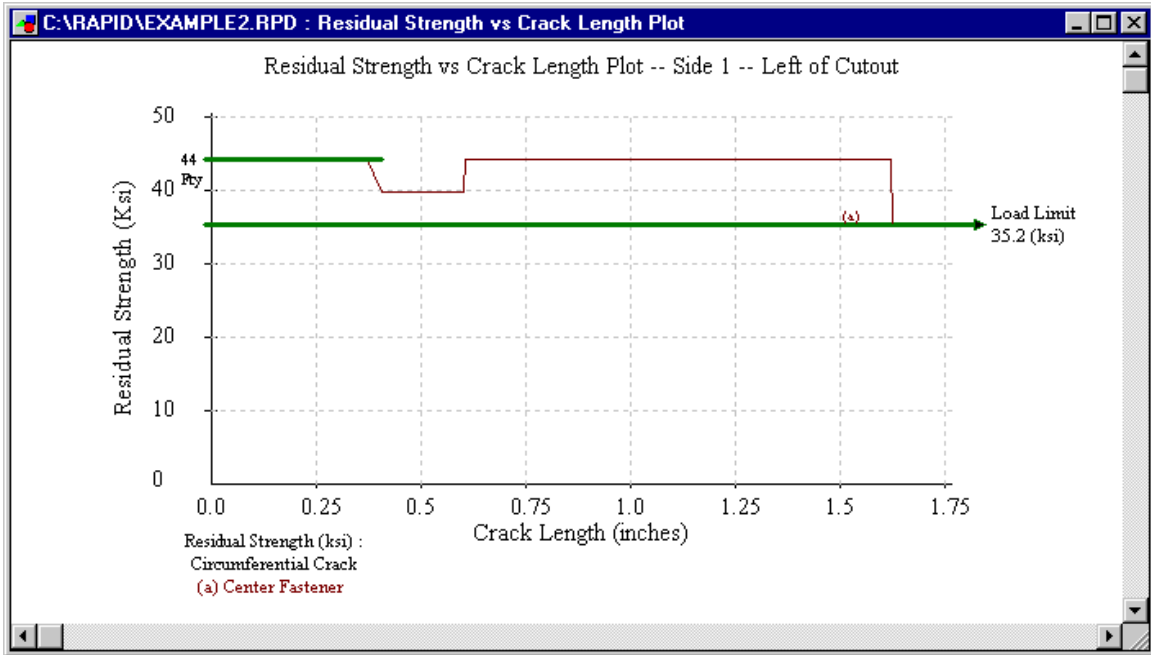
(B) NDI INSPECTION INTERVAL:

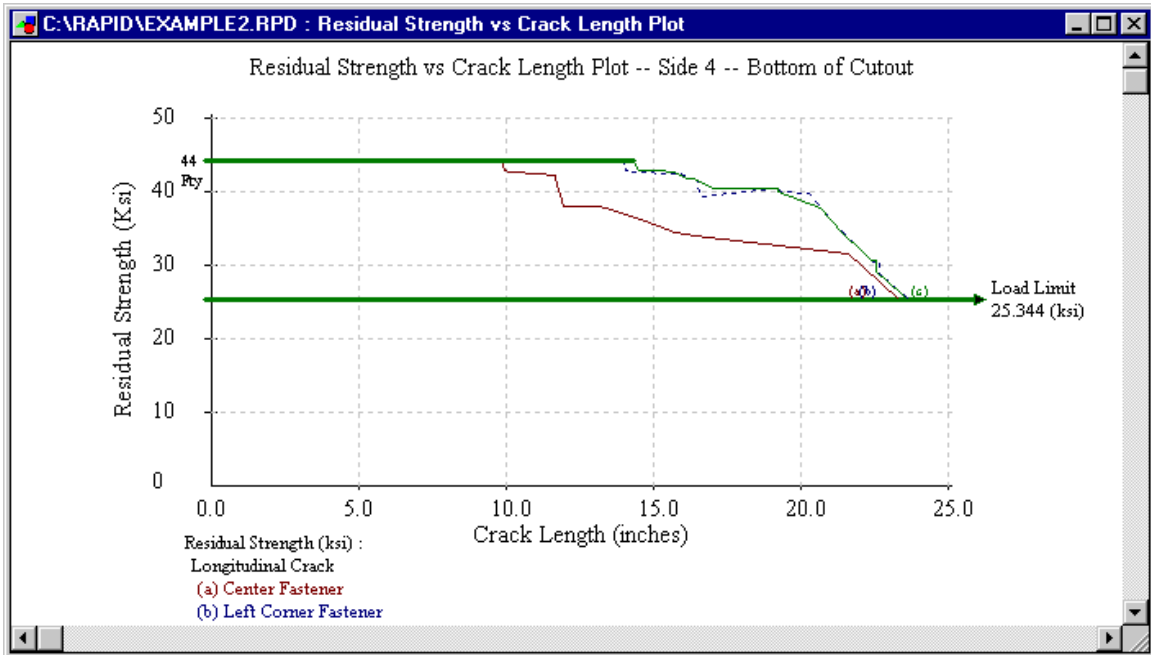
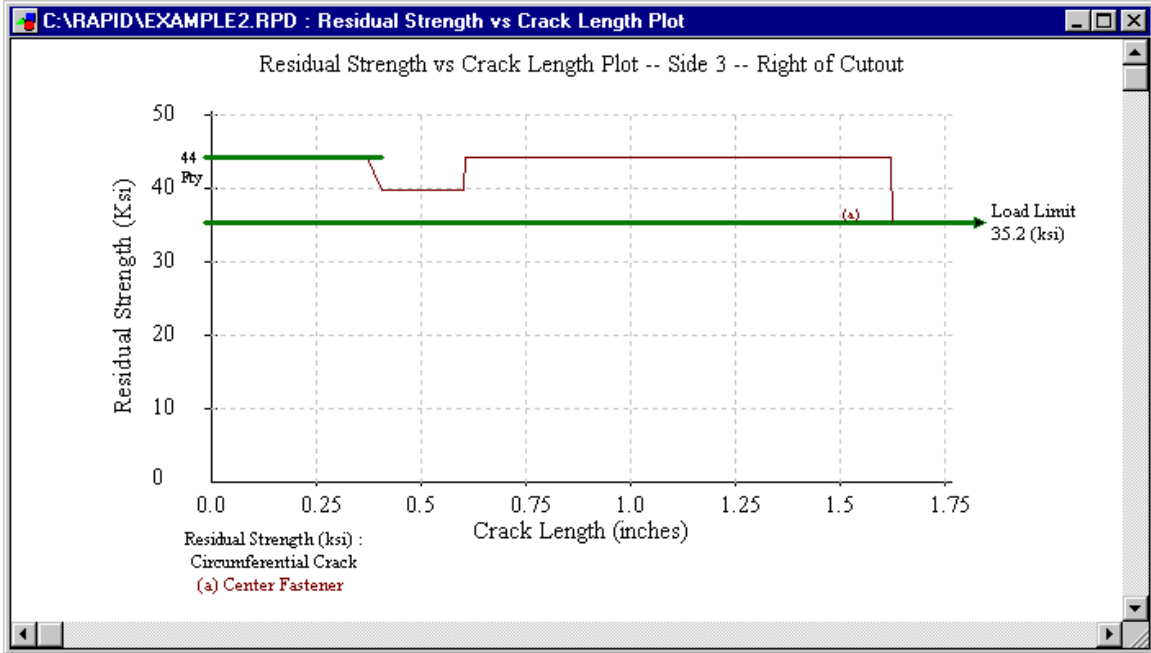
AFTER REPAIR INSTALLATION, FIRST INSPECTION IS AT 11713 FLTS.

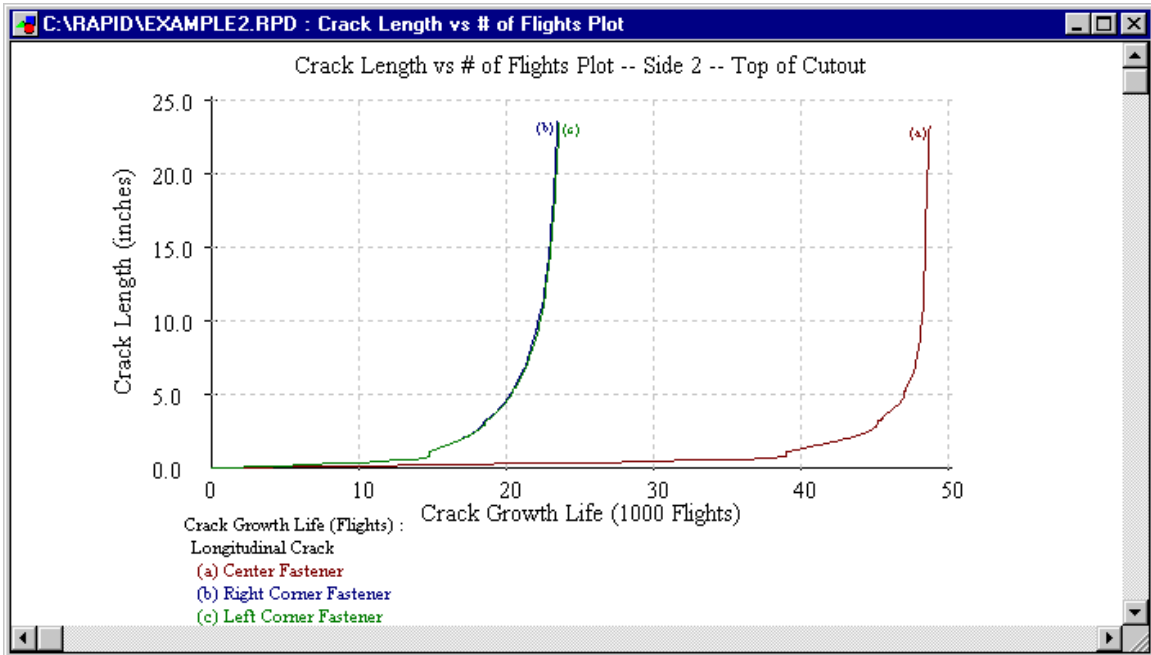
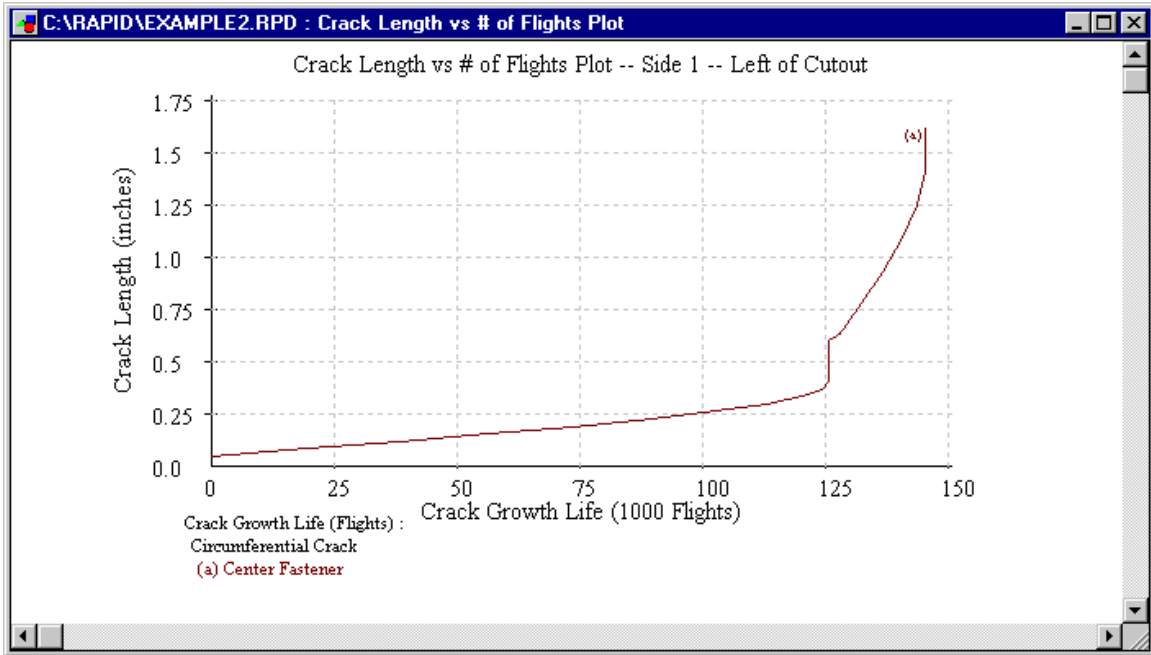
DETECTABLE CRACK LENGTH (INCHES)	INSPECTION INTERVAL (FLIGHTS)
-----	-----
0.05000	11713
0.10000	10968
0.15000	10223
0.20000	9478
0.25000	8797
.	
. (etc...)	
.	
18.73218	104
18.78218	103
18.83217	101

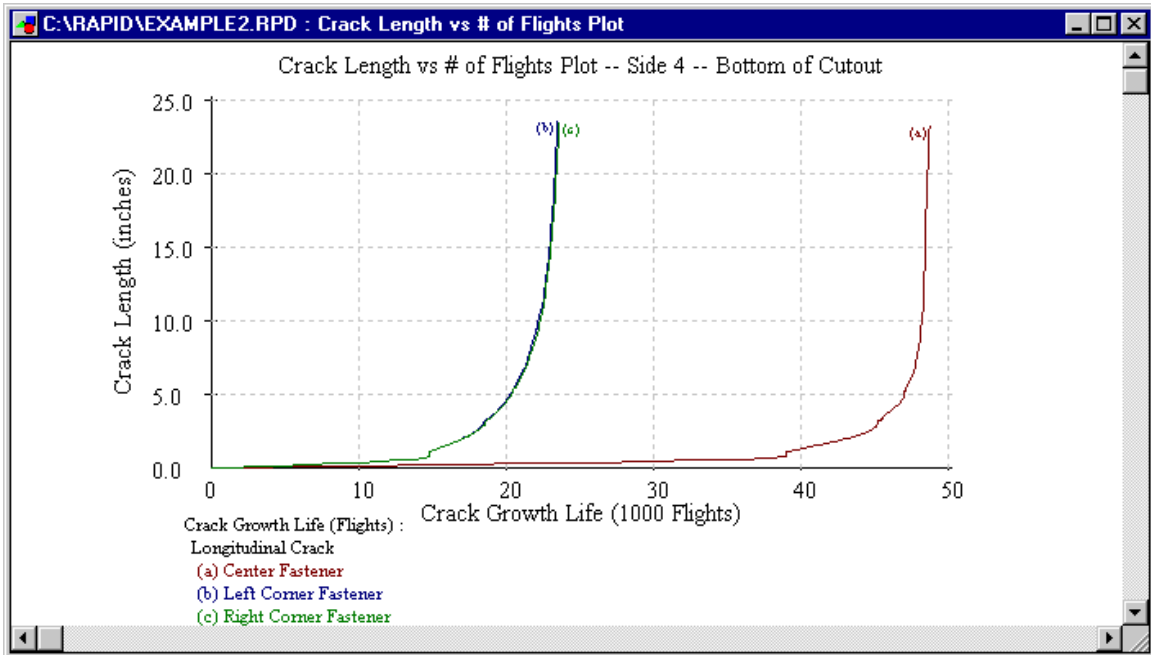
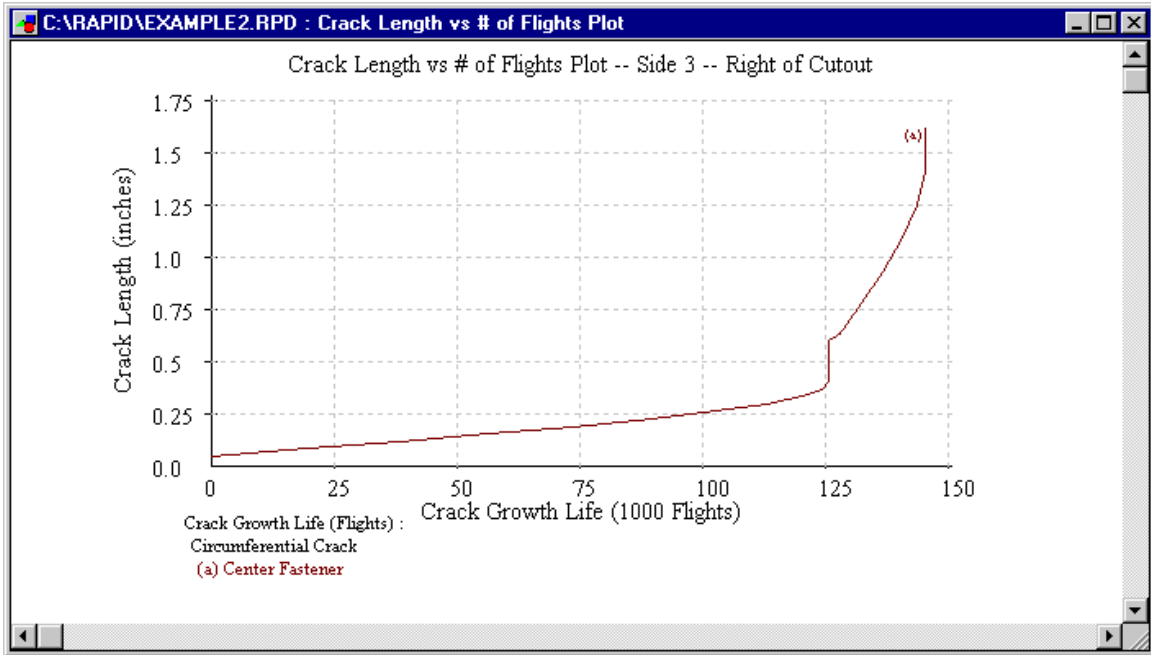
NOTE: FOR DEFINITION AND SKETCH OF THE DETECTABLE
CRACK LENGTHS, PLEASE SEE THE ANALYSIS MODULE
HELP FILE.

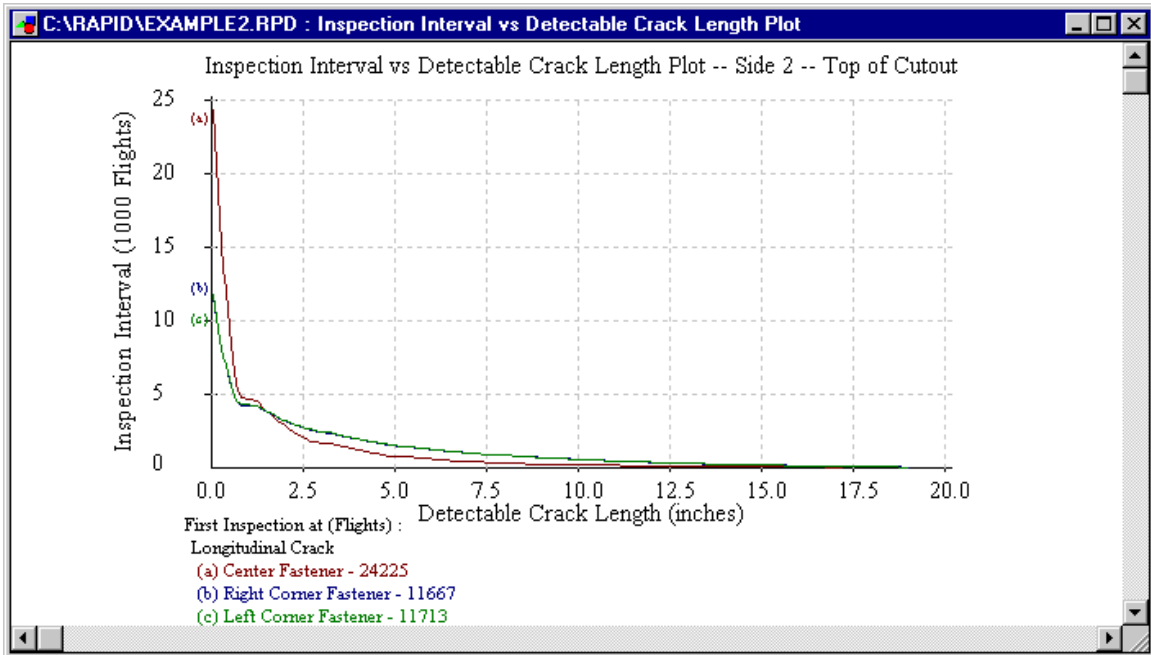
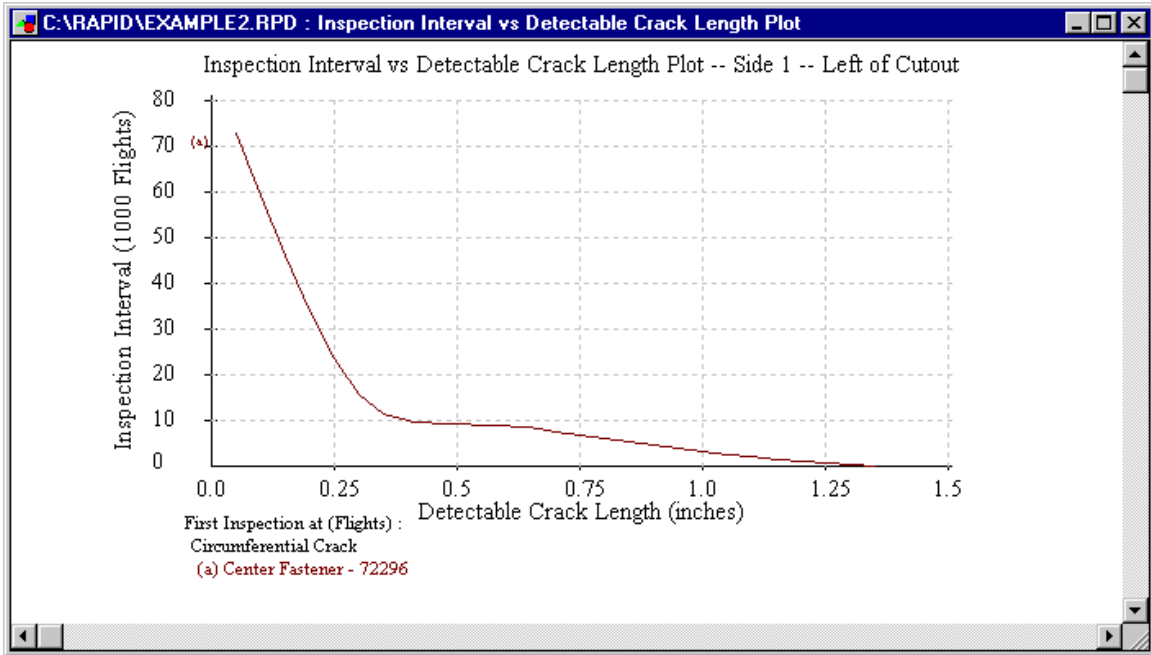
These results can be displayed graphically as **Residual Strength vs. Crack Length**, **Crack Length vs. Number of Flights**, and **Inspection Interval vs. Detectable Crack Length** plots for each side of the repair. Each of these plots, which are shown below, is generated for longitudinal cracks in the center and corner fasteners above the cutout and for circumferential cracks in the center and corner fasteners to the right of the cutout. The plots can be selected from the **Damage Tolerance** section of the **Analysis** pull-down menu in the main RAPID MDI.

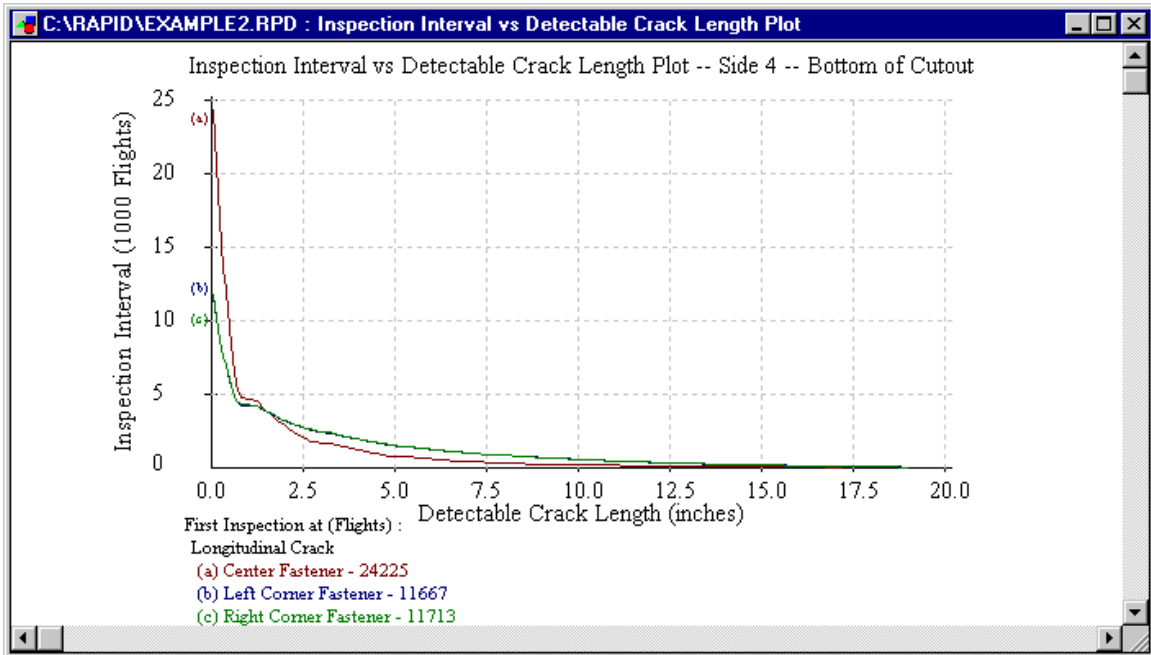
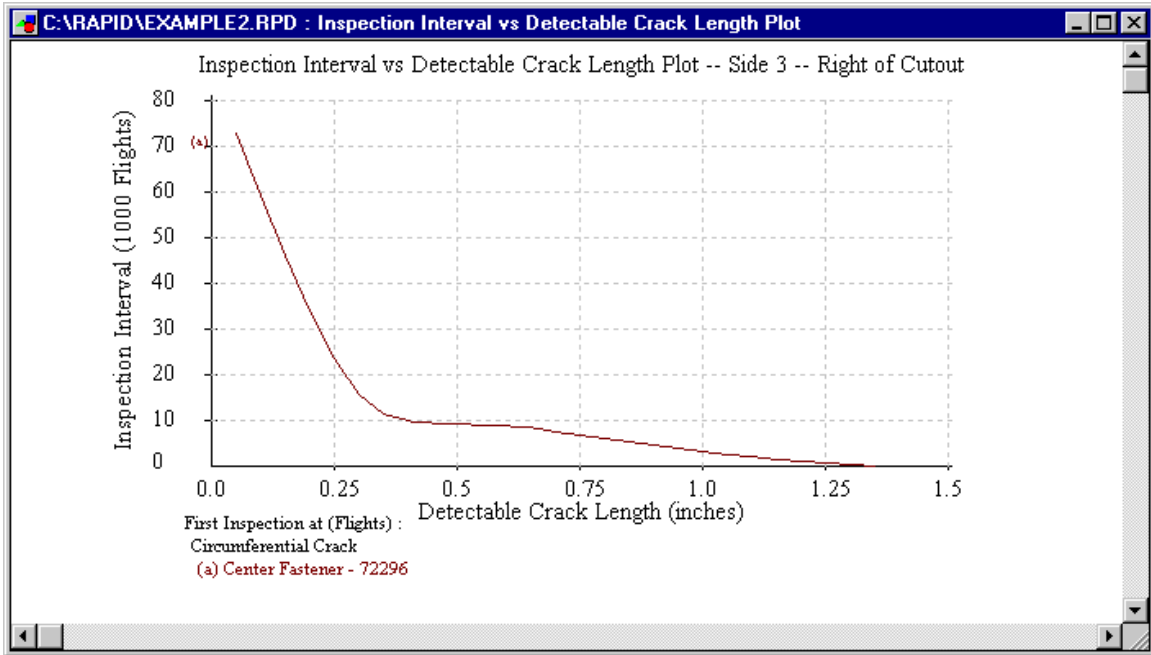






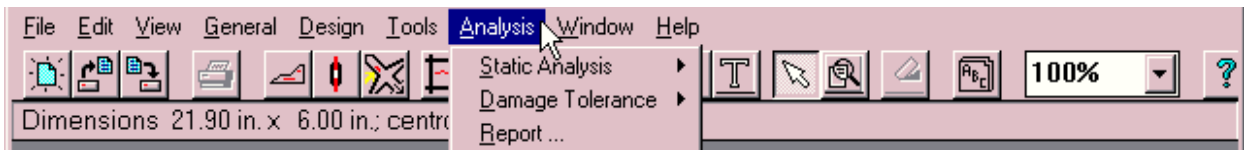




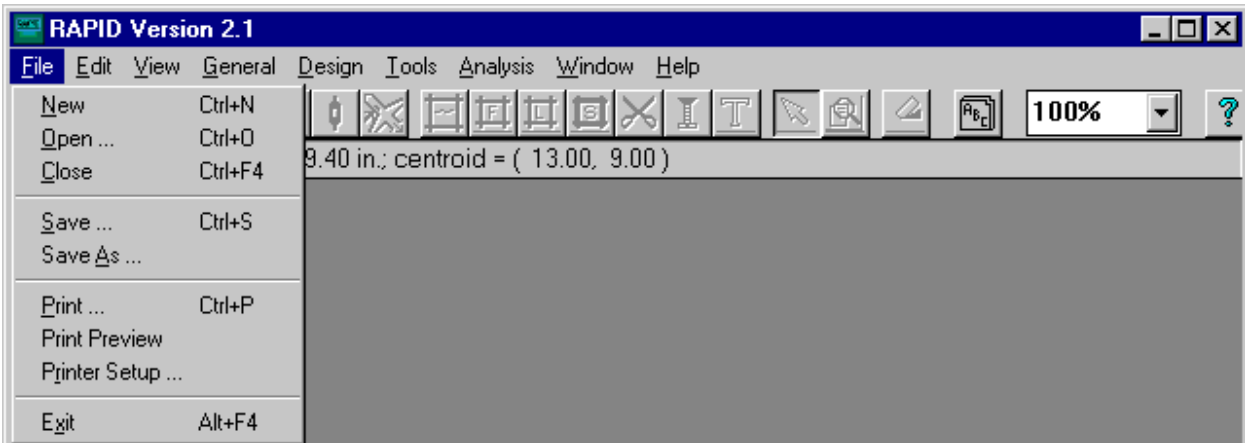


8.2.5 View and Print the Report

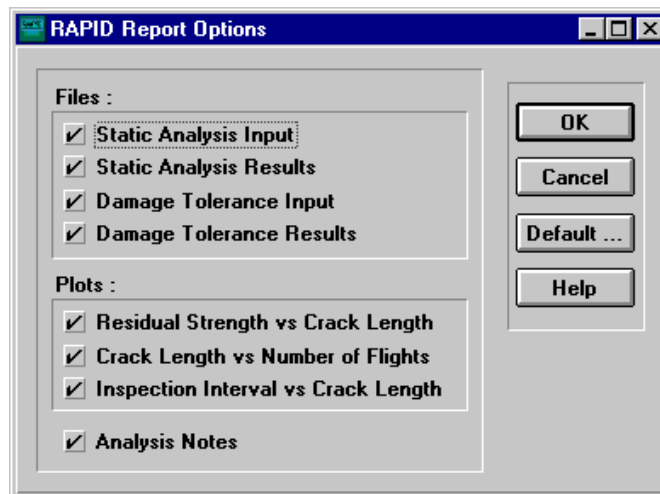
To view the report, select **Report** from the **Analysis** menu.



While the report is displayed, it may be printed by selecting **Print** from the **File** menu.



This will invoke the **Report Options** dialog window, in which the user may choose which components of the report to print.



8.2.6 Save the Repair Model

This completes the example problem. To save the model, select either the **Save** or **Save As** menu item from the **File** pull down menu. Once saved, the model can be opened and modified in a subsequent RAPID session by selecting the file open button on the button bar or the **Open** menu item in the **File** pull-down menu.

9. References

1. Military Handbook, "Metallic Materials and Elements for Aerospace Vehicle Structures," Wright-Patterson AFB 45433-6533, MIL-HDBK-5F, November 1990.
2. Swift, T., "Fracture Analysis of Stiffened Structure," Damage Tolerance of Metallic Structure: Analysis Methods and Application, ASTM STP 842, J.B. Chang and J.L. Rudd, Eds., American Society for Testing and Materials, 1984.
3. Swift, T., "Repairs to Damage Tolerant Aircraft," Structural Integrity of Aging Airplanes, S.N. Atluri, S.G. Sampath, and P. Tong, Eds., Springer-Verlag, 1991.

Appendix A. Run Analysis From the DOS Prompt

The RAPID analysis programs are compiled FORTRAN programs:

Static Analysis	- REPAIRS.EXE
Damage Tolerance	- REPAIRD.EXE

Both programs read “initialization files” – these files contain the input, output, error, and database filenames that are read by the analysis programs (the following 2 filenames are hard-coded into the program) :

Static Analysis	- REPAIRS.@#\$
Damage Tolerance	- REPAIRD.@#\$

There is a 3 step process for running the analysis programs in the DOS mode:

1. Obtain the input data from the “saved” repair configuration file.
2. Modify the analysis initialization file.
3. Run the desired analysis program (the initialization file will be read by the analysis program)

Obtain the Data

The Static Analysis input is stored in the [~STA_INP] section of the saved repair configuration.

1. Open the saved file using any ASCII text word processor
2. Search for [~STA_INP]
3. Block this section and copy it to the clipboard
4. Paste from the clipboard to your input file

Example of the start of the section:

```
:  
;[~STA_INP]  
REPAIR CONFIGURATION TYPE (1 External Doubler)  
3  
SKIN/DAMAGE : Number of Layers  
:
```

The Damage Tolerance Analysis input is stored in the [~DTA_INP] section of the saved repair configuration.

Use the above procedure to cut and paste to your document.

Example of the start of the section:

```
:  
;[~DTA_INP]  
4  
  
REPAIR CONFIGURATION TYPE (1 External Doubler)  
3  
SKIN: Mat. Type
```


NOTE -- The input decks for both the static and damage tolerance files must NOT contain any blank lines.

The binary stress spectrum files used by damage tolerance analysis can be found by searching for the [~RPD_SP0] and [~RPD_SP1] sections of the saved repair configuration. The entries in these sections give the files names of the stored data.

Example of the sections:

```
:[~RPD_SP0]
TYPE31._S0

:[~RPD_SP1]
TYPE31._S1
```

These file names are required for the initialization file described below.

Modify the Initialization File

STATIC Analysis

The static analysis program, REPAIRS.EXE, reads the initialization file, REPAIRS.@\$
File specification for [REPAIRS.@\\$](#)

```
repairs.inp          // input deck created by RAPID GUI
repairs.out          // output deck created by REPAIRD.EXE
repairs.err          // error file created by REPAIRD.EXE
```

These files can be named anything you wish, the program names them:

```
repairs.inp          ~sta_inp.<#>
repairs.out          ~sta_out.<#>
repairs.err          ~sta_err.<#>
```

The extension, <#>, is an integer the program assigns when it opens a file or starts a new file.

DAMAGE TOLERANCE Analysis

The damage tolerance analysis program, REPAIRD.EXE, reads the initialization file, [REPAIRD.@\\$](#)

File specification for [REPAIRD.@\\$](#)

```
repaird.inp          // input deck created by RAPID GUI
repaird.out          // output deck created by REPAIRD.EXE
repaird.err          // output deck created by REPAIRD.EXE
repaird.sif          // *beta factors for baseline repairs
repaird.mat          // *material database factors
repaird.fst          // *skin stress factors for baseline repairs
1                    // flag to indicate the next 2 files are the spectrum files to be used
repaird.sp0          // binary spectrum file(circumferential stress)created by
RAPID GUI
repaird.sp1          // binary spectrum file(longitudinal stress) created by
RAPID GUI
```

```

1          // flag to indicate the next file is the proximity file to be used
repaird.prx          // *fastener load transfer factors due to proximity effect
1          // flag to indicate the next file is the splice joint file to be used
repaird.jnt          // *skin stress factors for splice joint repairs
1          // flag to indicate the next 3 files are the stiffener files to be used
repaird.stf          // *skin stress factors due to stiffener effect
repaird.stb          // *stiffener beta factors
repaird.lcf          // *life correction factor database for splice joints
1          // flag to indicate the next file is the circular file to be used
repaird.cir          // *circular repair ratio factors

```

Note: 0=Do not read filename on next line; 1=read filename on next line.
 * Do not change these file names

User may execute analysis with either proximity effect, stiffener effect, or splice joint. These effects cannot be combined yet. So only **one** of the flags may be set to 1.

The following files can be named anything you wish, the program names them:

```

repaird.inp          ~dta_inp.<#>
repaird.out          ~dta_out.<#>
repaird.err          ~dta_err.<#>
repaird.sp0          ~rpd_sp0.<#> // binary spectrum file - circumferential
stress
repaird.sp1          ~rpd_sp1.<#> // binary spectrum file - longitudinal stress

```

The extension, <#>, is an integer the program assigns when it opens a file or starts a new file.

Appendix B. Save Output Data to be Used by Other Programs

The static analysis output is stored in the [~STA_OUT] section of the saved repair configuration.

1. Open the saved file using any ASCII text word processor
2. Search for [~STA_OUT]
3. Block this section, and copy it to the clipboard
4. Paste from the clipboard to your document

Example of the start of the section:

```
:  
:  
:  
; [~STA_OUT]
```

STATIC ANALYSIS RESULTS OF THE REPAIR

(A) MARGINS OF SAFETY:

```
:  
:  
:
```

The damage tolerance analysis output is stored in the [~DTA_OUT] section of the saved repair configuration.

Use the above procedure to cut and paste to you document.

Example of the start of the section:

```
:  
:  
:  
; [~DTA_OUT]
```

DAMAGE TOLERANCE ANALYSIS RESULTS OF THE REPAIR

THE FOLLOWING 2 SETS OF OUTPUT ARE FOR THE CIRCUMFERENTIAL CRACKS:

```
:  
:  
:
```

Appendix C. Description of RAPID.INI File

The RAPID.INI file is used to provide initialization and default data for the application.

It is structured like a generic Windows' INI file. The text within the brackets [...] is called the "section" and the text under each "section" are called "entries." RAPID accesses and updates this file through the Tools | Setup menu. RAPID is shipped without this INI file. With the initial run of RAPID, an INI file is constructed with hard-coded data and file location entries on the current drive/directory.

The section/entry names **must not** be changed!!!

```
[Version]
Number=2.0

[File_Locations]
Prog_Dir=D:\RAPID2C
Data_Dir=D:\RAPID2C
Temp_Dir=D:\RAPID2C
Loads_Dir=D:\RAPID2C\LOADS

[RepairType]
Type=TYPE30
ProximityFlag=0 // 0-false 1-true
StiffenerFlag=0 // 0-false 1-true
LapReversedFlag=0 // 0-false 1-true

[Report_Options] // parts to be printed on the report
Static_Input=0 // 0-false 1-true
Static_Results=1 // 0-false 1-true
DTA_Input=1 // 0-false 1-true
DTA_Results=0 // 0-false 1-true
Residual_Plot=0 // 0-false 1-true
Flights_Plot=0 // 0-false 1-true
Inspection_Plot=0 // 0-false 1-true
Analysis_Notes=0 // 0-false 1-true

[Fastener_Data]
Long_Pitch=1.0
Circum_Pitch=1.0
Long_Edge=0.5
Circum_Edge=0.5
Style=NAS1097-E
Diameter=0.1875
Rows=3

[DTA_Options]
Run_Type=2
Crack_Growth=1
Hole_Options=1
Visual_Method=0 // 0-false 1-true
Retardation=0 // 0-false 1-true
PrimaryTip=0.05
SecondaryTip=0.0
```

OperatingPressure=

[Stress_Data]

```
EquivStress=1      // 1-RAPID calculated with RAPID data
                  // 2- User entered value
                  // 3- RAPID calculated with User data
EquivStressValue= // Equivalent Stress value
SpectrumUsed=3    // 1-RAPID defined 2-User defined (binary)
                  // 3-User defined (ascii)
SpectrumName=Generic Narrow Body
InputFormat=1     // 1-Pseudo-Flights (repeatable flight sequence)
                  // 2-Cycle-by-Cycle Stresses (repeatable block)
RainFlow=0        // 0-false    1-true
Truncation=0      // 0-false    1-true
TruncRange=2.0
```

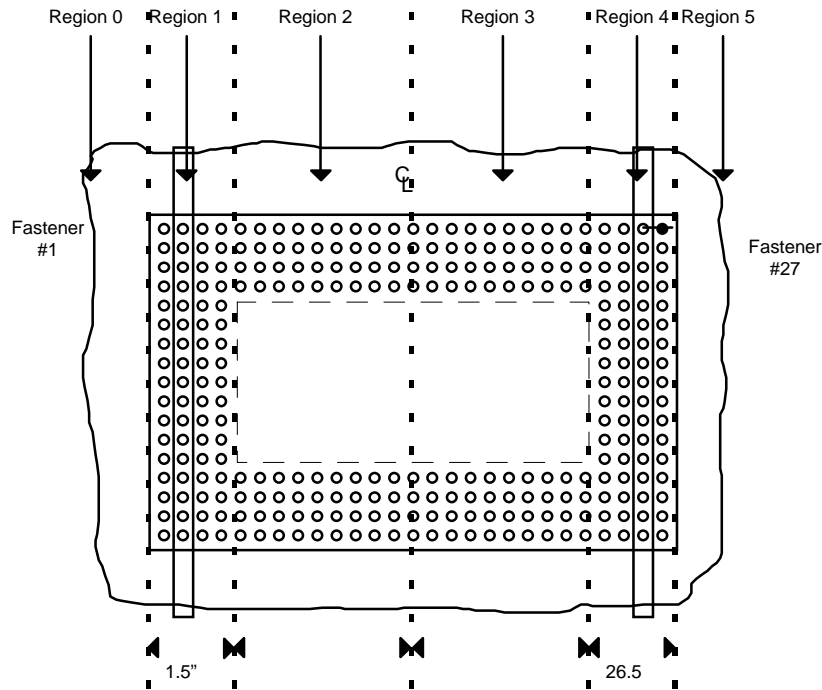
Appendix D. Description of Stiffener Effects Regions

Damage Tolerance Input File

```

.
.
.
.
.
STIFF : MAX #, POS, CSA, YNG.MOD, HPIT
0      0.0  0.0  0.0  0.0
1      1.5  0.5  10500 0.909
0      0.0  0.0  0.0  0.0
0      0.0  0.0  0.0  0.0
1      26.5 0.5  10500 0.909
0      0.0  0.0  0.0  0.0
.
.
.

```



Regions -Each repair has 6 regions numbered from left to right:

- Region 0: Outside left (repair boundary) of the repair to the left most side of the repair (absolute distance)
- Region I: Left most side of the repair to the left most side of the cutout
- Region II: Left most side of the cutout to the center line of the repair
- Region III: Center line of the repair to the right most side of the cutout
- Region IV: Right most side of the cutout to the right most side of the repair
- Region V: Outside right (repair boundary) of the repair to the right most side of the repair

Stiffener Input Line fields:

MAX # Number of stiffeners in region; maximum of 8 stiffeners per region

POS Absolute position of the stiffeners in relation to the whole repair (from the left edge of the repair); for:

REGIONS 1-4, $0.0 \leq \text{POS} \leq \text{Max.DoublerSize}$;

REGION 0, POS is the absolute distance of the stiffener away from the left edge of the repair;

REGION 5, POS is the absolute distance of the stiffener away from the right edge of the repair.

CSA Cross-sectional area of the stiffener

YNG.MOD Young's modulus of the stiffener

HPIT Pitch of the fasteners in the stiffener

DBLR ID - If more than 1 repair doubler, indicate which repair doubler is being used in referencing the stiffener's positions, 1=first doubler and 2= second doubler. If there is only 1 repair doubler, then DBLR ID=1.

Note: Each stiffener in a region has a position, cross-sectional area, Young's modulus, and fastener pitch in the stiffener parameters associated with it.

Although there might not be any stiffeners in the repair or region, enter 0 (or 0.0) in the number of stiffeners, position, cross-sectional area, Young's modulus and pitch parameters.