Chapter 9: Stacking Strength

Introduction

As a packaging professional, you'll routinely need to calculate the stacking strength of your shipping cases. The TOPS Pro software uses the McKee formula to calculate the stacking strength of a regular slotted container (RSC). This chapter covers the stacking strength function, including the following topics:

- The McKee formula
- Edge crush test (ECT)
- Ring crush test (RCT)
- Calculate stacking strength
- Stacking strength results
- Email board combo list
- Configuration default settings

The McKee Formula

The McKee formula uses two laboratory tests performed on board components – the edge crush test (ECT) and/or the ring crush test (RCT) – to derive a box compression strength value. TOPS Pro adjusts this compression strength value (lab compression) with a variety of environmental and structural factors to calculate a box performance value.

Important Note

Even though the McKee formula is a generally accepted design formula, the packaging engineer is ultimately responsible to evaluate the degree to which this formula might apply and perform the physical tests to assure safety.

The McKee formula is defined as follows:

$(FC) \times (ECT) \times (BP)^{.4924} \times (Caliper)^{.5076}$

Lab Compression = $[(FC) \times (ECT) \times (BP)^{.4924} \times (Caliper)^{.5076}] \times$ (Shape Factor) × (Length-to-Width Ratio Factor) × (Horizontal Flute Factor) × (Printing Factor)

Box Performance = (Lab Compression) × (Flap Gap Factor) × (Humidity Factor) × (Storage Time Factor) × (Pallet Spacing Factor) × (Interlock Factor) × (Overhang Factor) + (Product Support)

The abbreviated components in the formula are outlined below:

- **FC** = Flute Constant (5.87)
- **ECT** = Edge Crush Test
- **BP** = Box Perimeter
- **Overhang Factor** = 1 – [minimum of (square root of overhang) x 32.25 ÷ 100, 1]

Note: The next three values – Horizontal Flute Factor, Shape Factor and Printing Factor – are defined and adjusted in the TOPS Configuration program. For more information, please refer to Chapter 14, Configuration.

- **Horizontal Flute Factor (HFF)** = 1, unless non-vertical flute is selected. If non-vertical flute is selected, TOPS Pro looks at HFF for the specific board grade. However, there is no generally accepted industry standard for how much a non-vertical flute's compression will degrade. TOPS Pro currently ships with a HFF of 0.9 for a 10 percent reduction.

  Note: To adjust HFF, open the Definitions menu and select Board Combinations.

- **Shape Factor** = Table lookup based on the proportions of the box – relative to box depth – and dimension vertical. To adjust the shape factor, open the Definitions menu and select Box Design Factors.
- **Printing Factor** = Table lookup based on printing type and quantity. To adjust the printing factor, open the Definitions menu and select Box Design Factors.
- **Product Support =** Additional support to the overall stacking strength provided by the products inside the shipcase.

For all other factors, TOPS Pro looks up the value in the table of environmental factors, in the Configuration program. Other factors, which the McKee formula does not account for, include rough handling, transportation conditions, workers sitting on the box, die cuts, adhesive additives, etc.

Edge Crush Test

Box compression strength is a matter of structural mechanics. Engineering formulas have been developed using various relationships to predict compression strength. The general formula used here predicts Box Compression Test (BCT) value as related to Edge Crush Test (ECT), Flexural Rigidity and box perimeter.

Edge Crush Test, also known as Short Column Test, is measured as the pounds of force per inch needed to crush a portion of the sidewall of combined corrugated board. Although not the sole criterion for box performance, ECT values are an excellent indicator of Box Compression Test values and box performance in most of today's applications.

Ring Crush Test

The Ring Crush Test (RCT) measures paper strength – specifically stiffness. RCT has been widely used and has a history of more than 20 years of data correlated to combined board strength (ECT).

In the RCT, a strip of paper is placed into a jig that curls it into a short, tubular ring. Pressure is then applied perpendicular to the exposed edge. Ring Crush is measured as the pounds of force required to crush this specimen. This value has a direct relationship to predicting Edge Crush values of the combined board and, ultimately, box compression strength.

Due to industry-wide improvements in the paper-making process, industry average RCT values have gradually increased for a given Basis Weight over the years. However, across the industry, there is substantial variation in Ring Crush for a given Basis Weight – from different paper mills, even from different paper machines within the same mill.

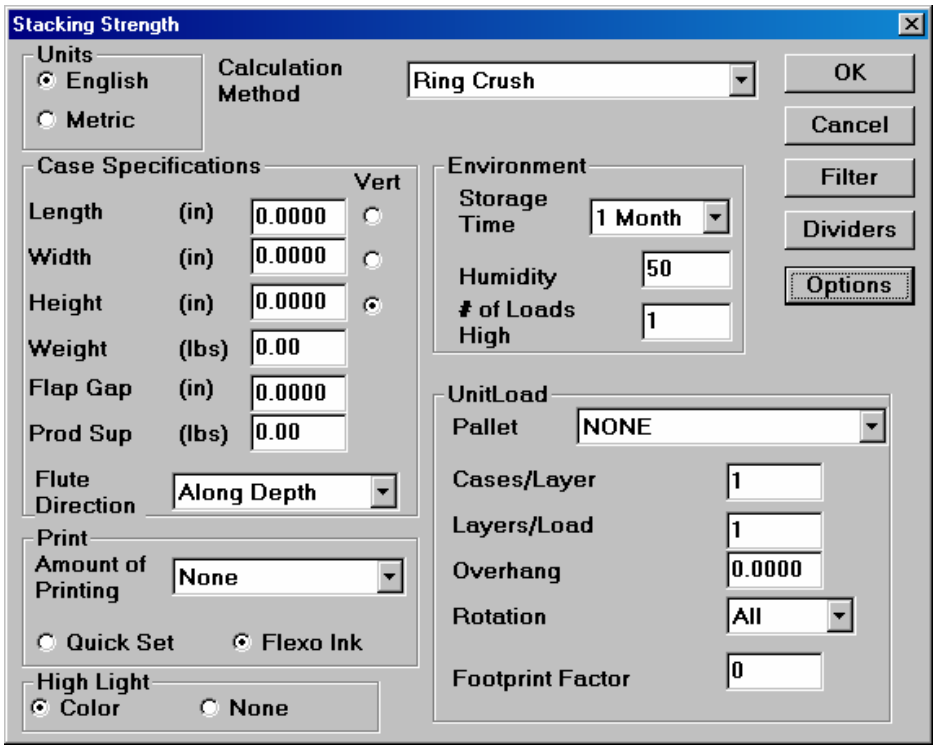
"High Ring Crush" or "High Performance" linerboard and medium are well above the industry average, at the upper end of the industry variability range for a given Basis Weight. Generally, these papers are more tightly pressed – thinner/denser/less porous – than those at the average or lower end of the range, which gives paper greater strength per pound.

Calculate Stacking Strength

In this exercise, you'll perform a shipcase-to-pallet analysis first, then calculate the stacking strength. To calculate stacking strength, start from the Control Panel and follow these instructions:

1. Perform a shipcase-to-pallet analysis and calculate solutions.
2. At the Analysis View, click on the Strength button on one of the panels. As an option, you can open the Tools menu and select Stacking Strength.

   The Stacking Strength dialog box appears, as pictured below.



Notice that the dialog box is complete with pre-defined shipcase and pallet parameters, which are grayed out (you can't change them).

3. At this point, you'll need to make decisions regarding the following parameters:

   Note: Some of these parameters are pulled from the Environment Factors dialog box in the TOPS Configuration program. This dialog box is pictured on page 9.7 for easy reference.

   - **Storage Time:** Select the target storage time for the unitloads – the period of time you expect the unitloads to be stored in a warehouse; for example, three months.

   - **Humidity:** Enter the humidity percentage that exists in the warehouse. The default is 50 percent; a typical humidity factor is 85 percent.

   - **# of Loads High:** Enter the target number of pallets high the unitload can be stacked in the warehouse.

   - **Rotation:** Select the rotation to be used for the unitloads. Use these guidelines:

     If the unitloads are columnar (non-interlocked), select None. This rotation yields no degradation in stacking strength.

     If the unitloads are fully interlocked, select All. This rotation yields a 30 percent degradation in stacking strength.

     If the unitloads are partially interlocked – for example, only the top two layers – select Some. This rotation yields a 15 percent degradation in stacking strength.

   - **Footprint Factor:** If you have multiple unitloads and not all shipcases help support the unitload above, specify how many shipcases do help support. Lowering this number reduces the number of bottom-most cases that help support the above unitload.

   - **Amount of Printing:** Select the amount of printing on the shipcases – usually Simple.

   - **Type of Printing:** Select the type of printing on the shipcases – usually Flexo.

   - **High Light:** Select either Color or None to specify whether you want the next screen and printouts to appear in color. If you only want to print, select None.

     Note: This has no bearing on stacking strength.

- **Calculation Method:** Select the method used to calculate stacking strength. Use these guidelines:

  The **Ring Crush method** looks up the ring crush values of the board combination's liners and mediums, then calculates the edge crush test (ECT) value from those values.

  The **Edge Crush method** uses the exact ECT value typed in for each board combination.

  The **Kellicut method** is an internationally recognized way to calculate stacking strength.

- **Dividers:** The Dividers button displays the Dividers dialog box, which displays information entered from the ShipCase Parameters dialog box. Use the Dividers dialog box to change the dividers parameters.

  Dividers provide a significant increase in stacking strength of your shipcases. For example, a 12-cell divider – if it's made of the same cardboard as the shipcase –increases stacking strength by 108 percent.

- **Options:** The Options button displays the Stacking Strength Options dialog box, which allows you to specify which columns of information will appear on the Stacking Strength Results report by selecting from a listing of board grades.

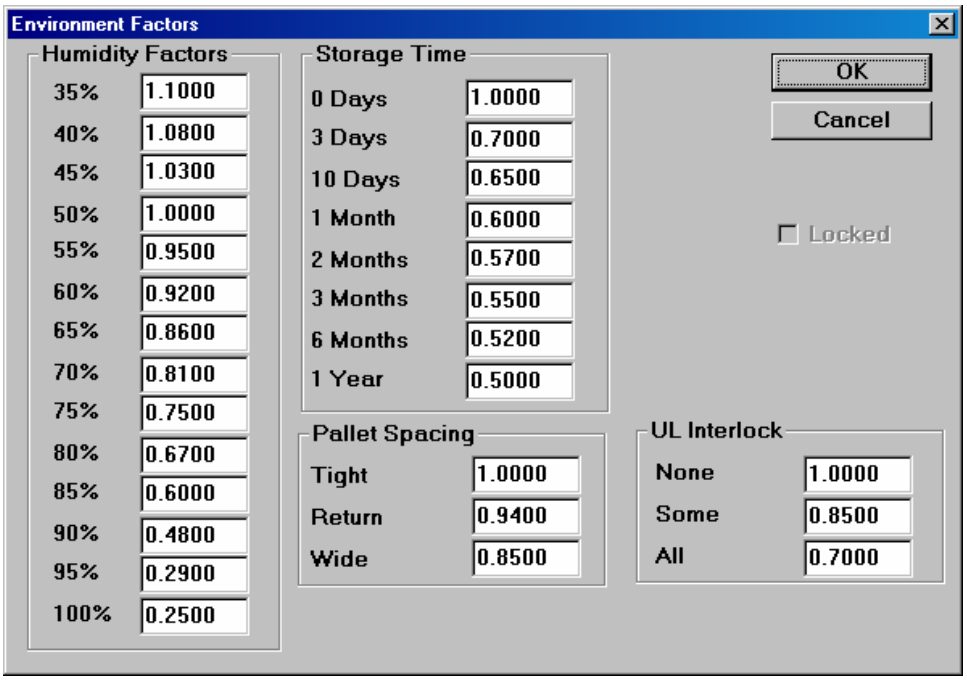
  For detailed information about the Stacking Strength Options dialog box, please refer to Appendix B, Dialog Boxes.

4. After completing the stacking strength parameters, click on OK. The Stacking Strength Results Screen appears, as pictured on page 9.8.
5. If you want to print the list of stacking strength options, open the File menu, select Print, then select Stack Strength List. TOPS Pro sends the list of stacking strength options to the printer.
6. If you want to print all the board combinations in the software, open the File menu, select Print Database, then select Stacking Strength. TOPS Pro sends the list of board combinations to the printer.

Environment Factors Dialog Box

The Environment Factors dialog box, pictured below, allows you to assign numeric safety factors to a range of environmental factors. TOPS Pro uses environmental factors to calculate stacking strength.

Note: The Environment Factors dialog box is accessed from the TOPS Pro Configuration program.

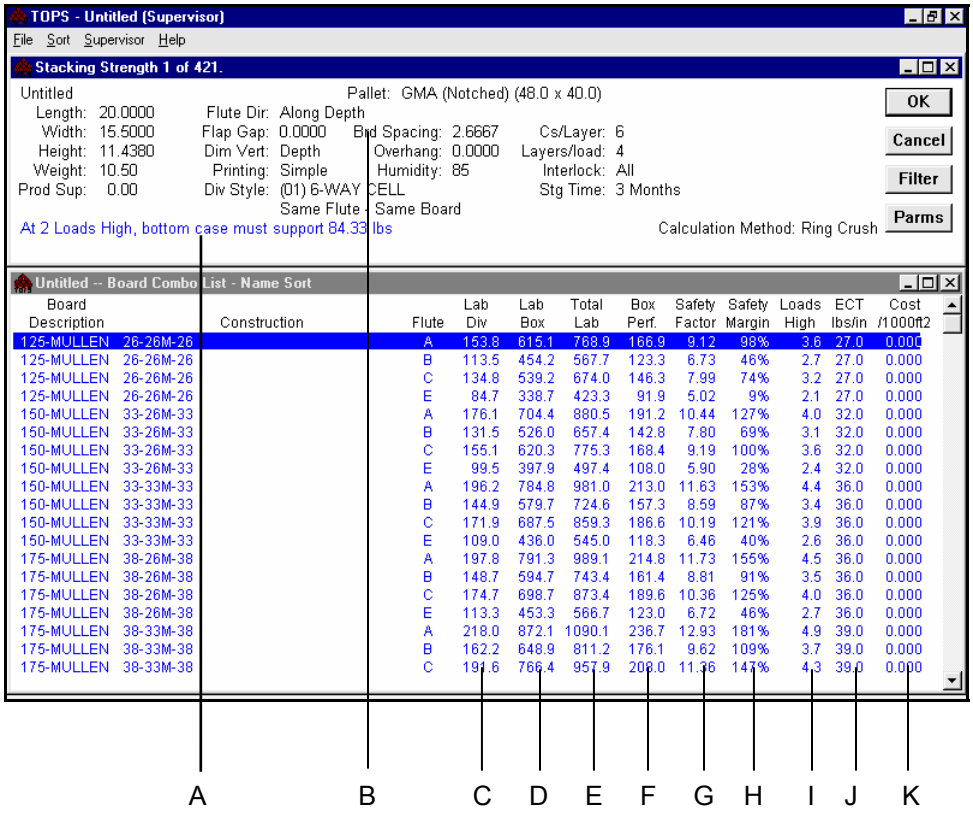


For detailed information about the Environment Factors dialog box, please refer to Appendix B, Dialog Boxes.

Stacking Strength Results

Once you've calculated a stacking strength analysis, TOPS Pro displays the Stacking Strength Results Screen, as pictured below. This screen is divided into two panes:

- **Stacking Strength Statistics Pane:** This information includes any added data related to the stacking strength option and your package design.
- **Stacking Strength List Pane:** This pane, the lower section of the screen, displays a number of columns that represent the board grades selected from the Stacking Strength Options dialog box. The default set of columns is represented in the figure below.



The Stacking Strength Results Screen provides the following stacking strength information:

- **(A) At 2 Loads High, bottom case must support 84.33 lbs:** Amount of weight that must be supported by a box on the bottom layer of the bottom pallet.
- **(B) Board Spacing:** Also known as pallet spacing. Use these guidelines:
  - If this value is less than 0.1 inch, you have tight pallet spacing.
  - If this value is greater than 0.1 inch and less than 3 inches, you have normal pallet spacing.
  - If this value is greater than or equal to 3 inches, you have wide pallet spacing.

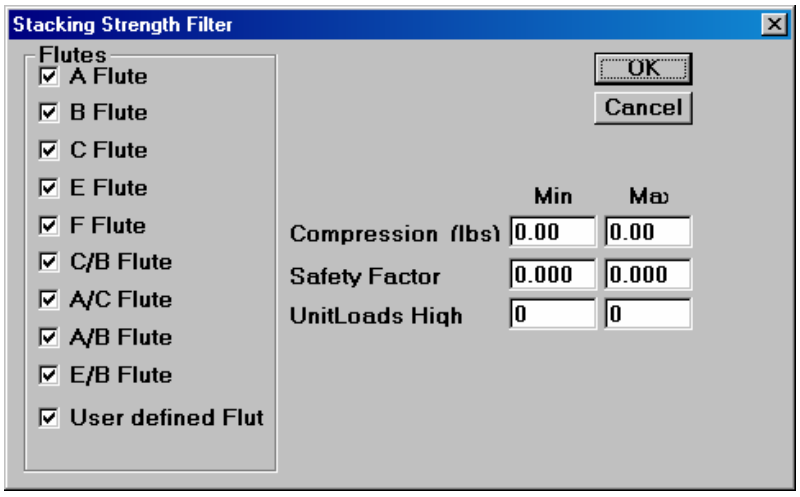
  Note: The stacking strength factors associated with pallet spacing are defined on the Environment Factors dialog box, pictured on page 9.7.
- **(C) Lab Div:** Lab Compression of the divider. This column appears only if you've specified a divider. To define new dividers, open the Definitions menu and select Dividers. Each divider has a support factor that determines the amount of additional support added by the divider. (A support factor of one (1) = no change.)
- **(D) Lab Box:** Lab Compression of the box without the divider. This column appears only if you've specified a divider.
- **(E) Total Lab:** Total Lab Compression. If you've defined a divider, this value is the sum of the divider compression and box lab compression; i.e., Total Lab Compression = Lab Compression of the divider + Lab Compression of the box without the divider.
- **(F) Box Perf:** Box Performance. The resulting compression strength, which takes into account the environmental conditions you've specified.
- **(G) Safety Factor:** Total Lab divided by the weight that must be supported by the bottom case.
- **(H) Safety Margin:** The percentage that the box performance exceeds the weight that must be supported by the bottom case; i.e., G = (F – A) ÷ A. Boards with Safety Margins that are greater than zero are highlighted in blue.

- **(I) Loads High:** How many unit loads it takes to reach the limit (box performance) of a bottom-most case.
- **(J) ECT lbs/in:** The ECT of the board. If the calculation method is Edge Crush, this value is the empirical value entered for each board in the TOPS Configuration program. If the calculation is Ring Crush, TOPS will calculate the ECT from the Ring Crush Factor (RCF) of each board's papers.
- **(K) Cost/1000ft^2:** The cost per 1000 square feet as entered into the board grade database.

Now that you've calculated stacking strength options for your analysis, you're ready to narrow down the list of options and select the one that best meets your needs. Follow these instructions:

1. Analyze the list of options and decide how you want to narrow the list. For example, you might want to narrow the list to show all options that have a safety factor of 4-7 and a compression strength of 550-665.

2. Click on the Filter button. The Stacking Strength Filter dialog box appears, as pictured below.



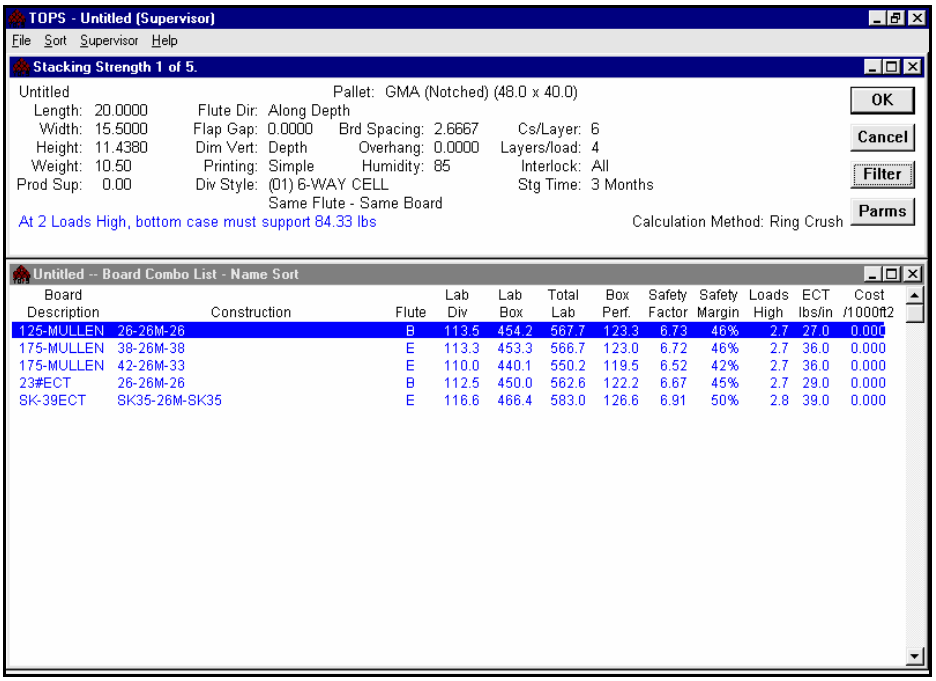
3. Use the Stacking Strength Filter dialog box to define the filter criteria. In this example, enter information in the following fields:

   - **Min Compression Str (lbs):** Enter 550.
   - **Max Compression Str (lbs):** Enter 665.
   - **Min Safety Factor:** Enter 4.
   - **Max Safety Factor:** Enter 7.

   Note: Compression is the recommended filter method because it's the most fine-tuned. For more information about the Safety Strength Filter dialog box, please refer to Appendix B, Dialog Boxes.

4. After completing the filter criteria, click on OK.

   TOPS Pro identifies all options that match your filter criteria, then redisplays the Stacking Strength Results Screen, as pictured below. The options that match your criteria are displayed in blue; the options that do not match are displayed in black.



   Notice that TOPS Pro has filtered the list of solutions from 421 down to five.

5. To sort the options by a specific criteria, open the Sort menu and select a sort option: Name, Lab Compression, ECT, Cost or Reverse Order.

   TOPS Pro redisplays the Stacking Strength Results Screen with the options sorted according to the selected sort option.

6. After you've selected a solution, print the output.

   Note: At this time, there is no way to limit the number of columns printed or displayed.

Stacking Strength Results – Menu Options

The Stacking Strength Results Screen features a menu bar with the following menus:

- File Menu
- Sort Menu
- Tools Menu
- Supervisor Menu
- Help Menu

The File, Supervisor and Help menus are identical to the File, Supervisor and Help menus that appear on the Control Panel's menu bar. For more information on these menus, please refer to Appendix C, Menu Options.

Sort Menu

The Sort menu provides the following options:

- Name
- Lab Compression
- ECT
- Cost
- Reverse Order

The Sort menu allows you to sort stacking strength results by name, lab compression, ECT, cost and reverse order.

To use the Sort function, start from the Stacking Strength Results Screen and select a Sort option (for example, ECT). The Stacking Strength List Pane redisplays with the stacking strength results sorted based on the selected option.

Tools Menu

The Tools menu provides the following options:

- Email Stacking Strength
- Select As Primary Boardgrade

Note: The Select As Primary Boardgrade option is not currently active.

The Email Stacking Strength option allows you to email the Stacking Strength Board Combo List to other users. This function is discussed in the next section.

Email Stacking Strength Combo Board List

After you've calculated stacking strength results, TOPS Pro allows you to email the Stacking Strength Board Combo List to other users. To use this feature, start from the Stacking Strength Results Screen and follow these instructions:

1. Go to the Windows Toolbar and open the Tools Menu.

2. Select the Email Stacking Strength option. TOPS Pro automatically launches your email application, converts the Stacking Strength Board Combo List to an HTML file and attaches it to the email.

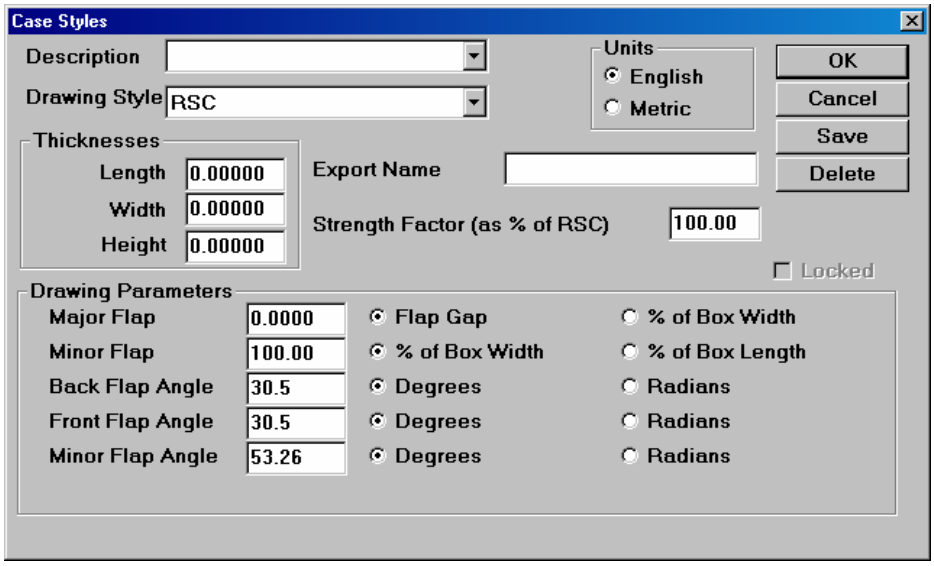
3. Send the email to the appropriate users. TOPS Pro closes the email application and returns you to the Stacking Strength Results Screen.

Define Stacking Strength Factor for a Non-RSC Box

When defining parameters for a new, non-RSC box, TOPS Pro includes a feature that defines stacking strength in relation to an RSC box. For example, you can define stacking strength for the non-RSC box as 80 percent or 120 percent of the stacking strength of an RSC box. To use this feature, follow these instructions:

1. Go to the Menu Bar and open the Define Menu.

2. From the Define Menu, select the Box Styles option. The Case Styles dialog box appears, as pictured below.



3. In the Strength Factor field, enter a stacking strength factor as a percentage. For example, if stacking strength for this box is 90 percent compared to that of an RSC box, enter 90.00.

4. Complete the remaining fields to define the new box.

5. After defining the new box parameters, click on the OK button.

   TOPS Pro saves the new box, including stacking strength factor, to the database.

Configuration Default Settings

The TOPS Configuration program allows you to define defaults for the various stacking strength variables used in the system, including the following:

- **Board Combinations:** Adjusts board grades, including changing, deleting or marking them unavailable. Use this option to adjust a board's ECT or cost per 1,000 square feet.
- **Flutes:** Adjusts base flutes, such as the default thickness or flute constant.
- **Environmental Factors:** Adjusts humidity, storage time, interlock and pallet spacing lookup values.
- **Paper:** Adjusts paper ring crush values.
- **Dividers:** Adjusts divider definitions, which reside in the primary TOPSWIN program.

For more information about defining stacking strength default values, please refer to Chapter 14, Configuration.