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TUBULAR BUCKLING AND LOCKUP MODEL (BUCKLE1)

THEORY AND USER'S MANUAL

DEA 67
PHASE I

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Tubular Buckling and Lockup Model
(BUCKLE1)

Theory and User's Manual

By

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August 1993
TR93-15

Table of Contents

Revised January 1994

Changes in BUCKLE1.2

1. The "metric units" system is added.
2. Five (5) sections of wellbores (cased-hole or open-hole) can be used.
3. Five (5) sections of tubulars can be used.
4. Developed under VISUAL BASIC 3.0.
5. Bit weight is limited to larger than or equal to zero.

Please discard the old BUCKLE1 program (Version 1.1) after you receive this updated new BUCKLE1 program (Version 1.2).

Revised October 1993

Changes in BUCKLE1.1

1. Different friction factors are now allowed for cased-hole and open-hole.

2. Wellbore size sections are now increased to 3.

3. Tubular/wellbore data file for "whole well analysis" now uses new extension name *.BT1, and section data file for "straight section analysis" now uses new extension name *.XD1. The format of the new data files has also changed a little bit from the old ones.

4. A straightness factor has been added in "straight section analysis" to simulate the effect of real wellbore tortuosity on friction/drag calculation. Straightness factor is multiplied times the actual friction factor to give the predictive friction factor.

   Different values of straightness factor are recommended for different types of wellbores as follows.

WELL TYPES	STRAIGHTNESS FACTOR RANGE	RECOMMENDED VALUE
Perfectly straight	1.0	1.0
Fairly straight	1.0 - 1.2	1.1
Typical	1.2 - 1.5	1.3
Fairly crooked	1.5 - 1.7	1.6
Very crooked	1.7 - 1.9	1.8

   User can also input any desired value for straightness factor.

1. Introduction

Tubular buckling and frictional drag are two of the more important concerns of drilling, well completion, and wireline logging operations. Tubular buckling can result in severe frictional drag with potential lockup of tubulars in the wellbore when operating in extended reach and horizontal wells. To help prevent such disasters, Maurer Engineering Inc. has developed a tubular buckling Windows application, BUCKLE1, as part of the DEA-44 project to "Develop and Evaluate Horizontal Well Technology," and the DEA-67 project to "Develop and Evaluate Slim-Hole and Coiled-Tubing Technology." This program is written in Visual Basic 1.0 for use with IBM compatible computers. The BUCKLE1 program runs in Windows 3.0 or later versions.

The program describes the complex concepts of helical buckling and lockup of tubulars. The mathematical model consists of tubular buckling analysis and frictional force calculations for buckled tubulars. The model is suitable for 3-D wellbores (vertical, inclined, and horizontal) for both inland and offshore applications. It handles both steerable drilling and running tubulars into wellbores for well completion, logging, and stimulation. The program allows the user to select either Chen's helical buckling model or Wu's helical buckling model to analyze the tubular buckling. It also considers the tubular yield strength reduction due to helical buckling bending stresses. Compressive loading of the tubular must be kept below this reduced yield strength to prevent permanent deformation of the tubular.

The program predicts the tubular axial load distributions and hook load during the process of running tubing into a well. It also presents a straight wellbore section analysis for vertical, inclined, and horizontal wellbore sections. This section analysis describes the concepts of buckling and frictional force of a buckled tubular by presenting graphs showing the axial load distribution, hook load versus slack-off weight, tubular yield strength reduction, etc.

1.1 MODEL FEATURES OF BUCKLE1

The key features of BUCKLE1 are its ability to:

1. Consider both tubular buckling and frictional drag for buckled tubular.
2. Deal with 3-D wellbores.
3. Select either Chen or Wu helical buckling model.
4. Consider inland and offshore drilling rigs.
5. Consider both drilling and tripping-in operation.
6. Consider 3 sections of tubular string and 2 well intervals currently.
7. Consider both whole well and straight section analyses.

The output window for whole well analysis is a compilation of "child" windows of text reports and graphs which include:

1. Tabulated results.
2. Axial load distribution.
3. Tubular buckling load.
4. Normal force distribution.
5. Hook load variation during tripping-in/drilling process.
6. Wellbore departure.
7. Dogleg severity.
8. Inclination angle.

The output window for the straight section analysis is also a compilation of " child" windows of text reports and graphs which include:

1. Tabulated results.
2. Axial load distribution.
3. Helical yield load.
4. Bit weight variation.
5. Maximum bit weight.
6. Maximum section length.

There is an animation window for both section analysis and whole well analysis, which illustrates the tubular buckling status and development. When the user clicks a "+" button to increase the bit weight, the tubular buckling and "lockup (yield)" are shown by different colors along the tubular goods.

1.2 REQUIRED INPUT DATA

There are four data files associated with BUCKLE1:

1. Survey data file (.SDI).
   a. Directional survey data for the well. Survey must start with zero depth, zero azimuth, and zero inclination.

2. Tubular data file (.TDI).
   a. Tubular OD, ID, weight, length, and yield strength data.
   b. Wellbore/casing ID, length data.
   c. Bit weight, starting depth for drilling.
   d. Inside and outside fluid densities.
   e. Friction factor.

3. Section data file (.XDI).
   a. Wellbore diameter, wellbore section length data.
   b. Tubular OD, ID, weight, and yield strength data.
   c. Inside and outside fluid densities.
   d. Bit weight data.
   e. Friction factor data.

4. Project data file (.PJB).

The section data file (.XDI) contains data for straight section analysis, while the survey data file (.SDI) and tubular data file (.TDI) serve for whole well analysis.

All input data saved on the disk or in memory are in the English system of units.

The project data file contains the other three data file's names, so that the user can open the project file and the computer will input the three data files automatically.

1.3 DISCLAIMER

No warranty or representation is expressed or implied with respect to these programs or documentation including their quality, performance, merchantability, or fitness for a particular purpose.

1.4 COPYRIGHT

Participants in DEA-44/67 can provide data output from this copyrighted program to third parties and can duplicate the program and manual for their in-house use, but will not give copies of the program or manual to third parties.

2. Theory and Equations

2.1 APPROACH

Figure 2-1 illustrates the conceptual approach used to model the areas of interest in the well by taking the horizontal section as an example. When drilling or tripping into the well, the tubular in a horizontal section is in compression, due to frictional force and/or bit weight. The axial compressive load increases uphole from the bottom of the tubular as a result of the frictional force.

When the axial compressive load exceeds the sinusoidal buckling load limit for the tubular, it will buckle into a sinusoidal shape. When the axial compressive load increases to its helical buckling load limit, the tubular will be buckled helically. The helical buckling of the tubular will in turn generate a large contact force between the tubular and the wellbore wall due to the confinement by the wellbore wall. This buckling produces a large frictional force. When drilling or running into the well, the frictional force is now much larger than that for an unbuckled, straight tubular. Therefore, the axial load distribution will no longer be linear, but a quickly rising non linear curve (Figure 2-1).

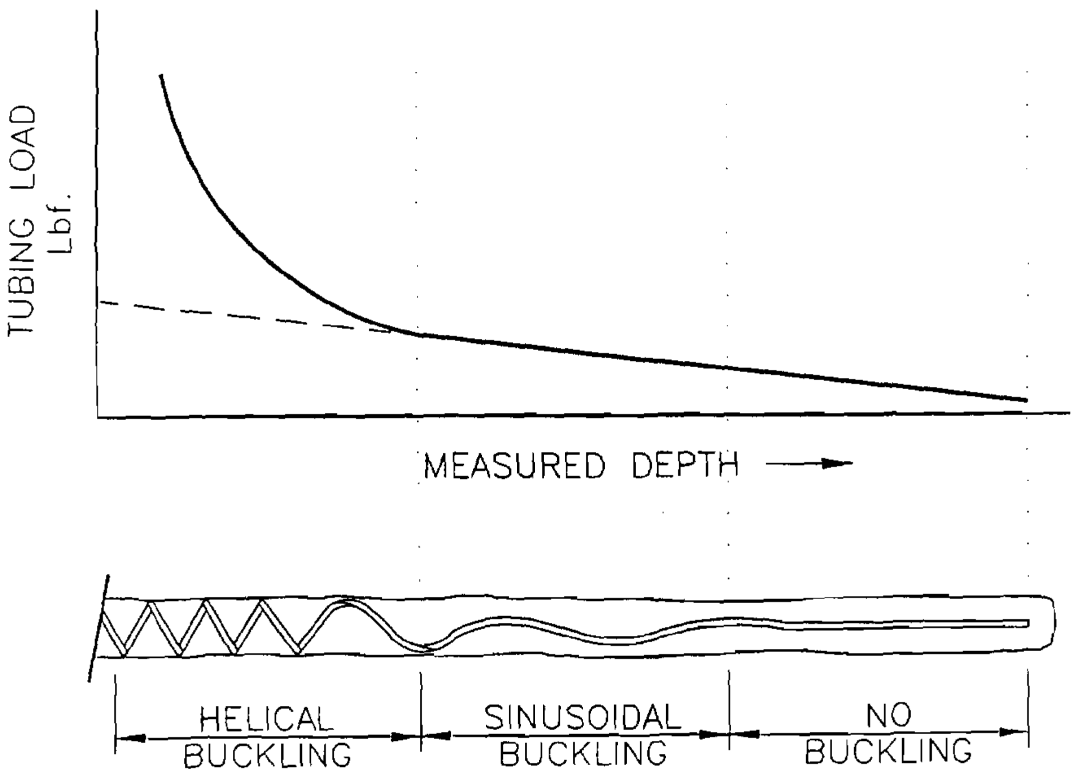

Figure 2-1. Tubular Buckling and Axial Load Distribution

For tubulars in other types of wellbores, such on a vertical or inclined wellbore, large frictional force will be generated if the tubular is helically buckled, and the axial load distribution of the tubular will be very different from that of a straight, unbuckled tubular.

Since the axial load distribution of buckled tubulars is not the same as that of the unbuckled tubular, we must develop a new model to deal with tubular buckling and the large frictional drag due to the buckling. This is necessary to correctly predict bit weight for an extended-reach and/or horizontal well when there is buckling of a tubular in some part of the wellbore. It is also very important for us to predict when and how the tubular can be locked up in the wellbore due to the extreme frictional drag resulting from tubular buckling. When the tubular is locked up, it cannot be pushed farther into the hole. No increase in bit weight will result from further slack off of weight at the surface.

2.2 TUBULAR BUCKLING MODELS

To detect the buckling of tubulars, we have to use the tubular buckling loads as the criteria.

2.2.1 Dawson and Paslay Sinusoidal Buckling Criterion

This model (Dawson and Paslay, 1984) says that when the tubular axial compressive load exceeds the following critical load, the tubular will buckle into a sinusoidal shape:

$$F_{cr} = 2\sqrt{\frac{EIWe \sin\theta}{r}} \tag{2-1}$$

where

F_{cr} = Sinusoidal buckling load, lbf
E = Young's modulus, psi
I = Moment of inertia of pipe, in^4
We = Effect weight of tubular, lb/in.
r = Radial clearance between pipe and wellbore, in.
θ = Wellbore inclination angle, rad.

2.2.2 Wu and Juvkam-Wold Sinusoidal Buckling Criterion

This model (Wu, 1992) presents different buckling load limits for the tubulars in various wellbore orientations.

For the tubulars in straight, inclined wellbores, the sinusoidal buckling limit is the same as that in the Dawson and Paslay equation:

$$F_{cr} = 2\sqrt{\frac{EIWe \sin\theta}{r}} \tag{2-2}$$

For tubulars in a vertical wellbore, the sinusoidal (initial) buckling load is:

$$F_{cr} = 2.55(EIWe^2)^{1/3} \tag{2-3}$$

For tubulars in a curved wellbore, the sinusoidal buckling load is:

$$F_{cr} = \frac{4EI}{rR}\left[1 + \sqrt{1 + \frac{rR^2 \; We \sin\theta}{4EI}}\right] \tag{2-4}$$

where

R = Radius of wellbore curvature, in.

2.2.3 Chen and Cheatham Helical Buckling Criterion

When the axial compressive load of the tubular exceeds the following compressive load, the tubular will buckle into a helical buckling shape (Chen et al., 1989):

$$F^* = 2\sqrt{\frac{EIWe\sin\theta}{r}} \tag{2-5}$$

2.2.4 Wu and Juvkam-Wold Helical Buckling Model

This model includes different buckling load equations for the tubulars in different wellbore orientations.

For the tubular in a straight, inclined wellbore, helical buckling occurs if the compressive load exceeds the critical value in Eq, 2-6 (Wu and Juvkam-Wold, 1993A).

$$F_{hel} = 2\left(2\sqrt{2} - 1\right)\sqrt{\frac{EIWe\sin\theta}{r}} \tag{2-6}$$

For the tubular in vertical wellbores, the helical buckling load limit is (Wu, 1992):

$$F_{hel} = 5.55\,(EIWe^2)^{1/3} \tag{2-7}$$

For the tubular in curved wellbore, the helical buckling load limit is (Wu, 1992):

$$F_{hel} = \left(\frac{12EI}{rR}\right)\left[1 + \sqrt{\frac{1 + rR^2 \; We\sin\theta}{8EI}}\right] \tag{2-8}$$

2.3 FRICTIONAL FORCE MODEL

2.3.1 Frictional Force Model for an Unbuckled Tubular

For an unbuckled tubular, frictional force is calculated by considering the normal force acting between the tubular and the wellbore wall. The force is composed of 1) the effects of the tubular weight, and 2) the effects of the compression or tension acting through the curved wellbore. The frictional force is the product of the normal force and the friction factor (the coefficient of friction). The effect of bending on the normal force in a curved wellbore is not considered. It is assumed that its contribution to the normal force is small.

Figure 2-2 shows the free-body diagram of a single (unit) element of the tubular for the frictional force model of unbuckled tubular running into the wellbore (Johancsik, et al., 1984).

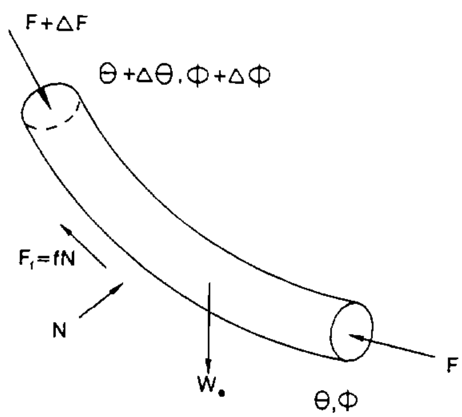

Figure 2-2. Free-Body Diagram of a Single Element

The normal force, N, is calculated as:

$$N = [(F\Delta\phi\sin\theta)^2 + (F\Delta\theta + We\sin\theta)^2]^{1/2} \tag{2-9}$$

The frictional force on this element is:

$$F_f = f \cdot N \tag{2-10}$$

The axial load increment is then:

$$\Delta F = F_f - We\cos\theta \tag{2-11}$$

2.3.2 Frictional Force Model for Buckled Tubular

Once the tubular helically buckles in the wellbore, an additional normal force will be generated due to the confinement by the wellbore wall of the buckled tubular. The additional normal force can be calculated as (Mitchell, 1986):

$$\Delta N = rF^2/4EI \tag{2-12}$$

The total normal force is then

$$N = [(F\Delta\phi \sin\theta)^2 + (F\Delta\theta + We\sin\theta)^2]^{1/2} + \frac{rF^2}{4EI} \tag{2-13}$$

Notice that for a helically buckled tubular, the contact force will increase by the square of the axial compressive load, resulting in an extremely large frictional force, which in turn increases the axial compressive load. This is just like the "snow ball" effect and eventually results in the "lockup" of the tubular in the wellbore (Wu and Juvkam-Wold, 1993B).

2.3.3 Lockup

When the axial load cannot be transmitted to the tubular bottom or the tubular cannot be pushed further into the wellbore by "slacking-off" weight at the surface, it is generally referred as "lockup" of the tubular in the wellbore.

True "lockup" is usually approached when "slacking-off" to zero hook load.

2.3.4 Yield of a Tubular

When a tubular buckles helically, it will yield at a much lower compressive load. This is because the helical buckling produces a bending stress — tensile stress on the outer convex portion of the curve and compressive stress on the inner concave portion of the curve.

The total compressive stress now becomes (Lindsey, et al., 1980):

$$\sigma_{tot} = F/A_s + D_o r F/4I$$

where

A_s = tubular net cross-section area, in.^{2}
D_o = tubular outside diameter, in.
r = radial clearance between pipe and wellbore, in.
I = moment of inertia of pipe, in.

If we consider that the tubular begins to yield when the total effective compressive stress reaches the original tubular yield strength $[\sigma]$, then the minimum compressive load that will produce a permanent deformation (yield) of the tubular due to the helical buckling is defined by Eq. 2-14.

$$F_y = [\sigma] / (1/A_s + D_o r/4I) \tag{2-14}$$

3. Program Installation

3.1 BEFORE INSTALLING

3.1.1 Hardware and System Requirements

BUCKLE1 is written in Visual Basic®. It runs in either standard or enhanced mode of Microsoft Windows 3.0 or higher. The basic requirements are:

- Any IBM-compatible machine built on the 80286 processor or higher (with math coprocessor).
- 2 megabytes of RAM; 4 megabytes is recommended.
- Hard disk.
- Mouse.
- CGA, EGA, VGA, 8514, Hercules, or compatible display. (EGA or higher resolution is recommended.)
- MS-DOS version 3.1 or higher.
- Windows version 3.0 or higher in standard or enhanced mode.

These are the minimum system requirements. We strongly suggest the program be installed on and be operated from the hard drive.

The amount of calculation (or calculation time) depends to a great extent on speed of the machine and number of calculation intervals used. Usually, calculation time is less than one minute on an 80386 processor.

For assistance with the installation or use of BUCKLE1, contact:

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Maurer Engineering Inc.
2916 West T.C. Jester Boulevard
Houston, Texas 77018-7098 U.S.A.
Telephone: (713) 683-8227 Fax: (713) 683-6418
Telex: 216556

3.1.2 Check the Program Disk

The program disk you received is a 3½-inch, 1.44 MB disk containing 20 files. These 20 files are as follows:

SETUPKIT.DL_
VBRUN100.DL_
VER.DL_
COMMDLG.DLL
GSWDLL.DLL
GSW.EXE
SETUP.EXE
SETUP1.EXE
BUCKLE1.EXE
SETUP.LST
TEST.PJB
TEST.SDI
TEST.TDI
TEST.XDI
CMDIALOG.VBX
GAUGE.VBX
GRAPH.VBX
GRID.VBX
MDICHILD.VBX
THREED.VBX

We recommend that all .VBX and .DLL files that have the potential to be used by other DEA-44/67 Windows applications be installed in your Microsoft WINDOWS/SYSTEM subdirectory. This applies to all the .VBXs and .DLLs included here. The BUCKLE1 executable (BUCKLE1.EXE) file should be placed in its own directory (default "C:/BUCKLE1") along with the example data files TEST.*. All these procedures can be done by a simple setup command explained in Section 3.2.

In order to run BUCKLE1, the user must install all the files into the appropriate directory on the hard disk. Please see Section 3.2 to set up BUCKLE1.

It is recommended that the original diskette be kept as a backup, and that working diskettes be made from it.

3.1.3 Backup Disk

It is advisable to make several backup copies of the program disk and place each in a different storage location. This will minimize the probability of all disks developing operational problems at the same time.

The user can use the COPY or DISKCOPY command in DOS, or the COPY DISKETTE on the disk menu in the File Manager in Windows.

3.2 INSTALLING BUCKLE1

The following procedure will install BUCKLE1 from the floppy drive onto working subdirectories of the hard disk (i.e., copy from A: drive onto C: drive subdirectory BUCKLE1 and WINDOWS/SYSTEM).

1. Start Windows by typing "WIN" <ENTER> at the DOS prompt.
2. Insert the program disk in drive B:\.
3. In the File Manager of Windows, choose **Run** from the **File** menu. Type **B:\setup** and press Enter.
4. Follow the on-screen instructions.

This is all the user needs to set up BUCKLE1. After set up, there will be a new Program Manager Group which contains the icon for BUCKLE1 as shown in Figure 3-1.

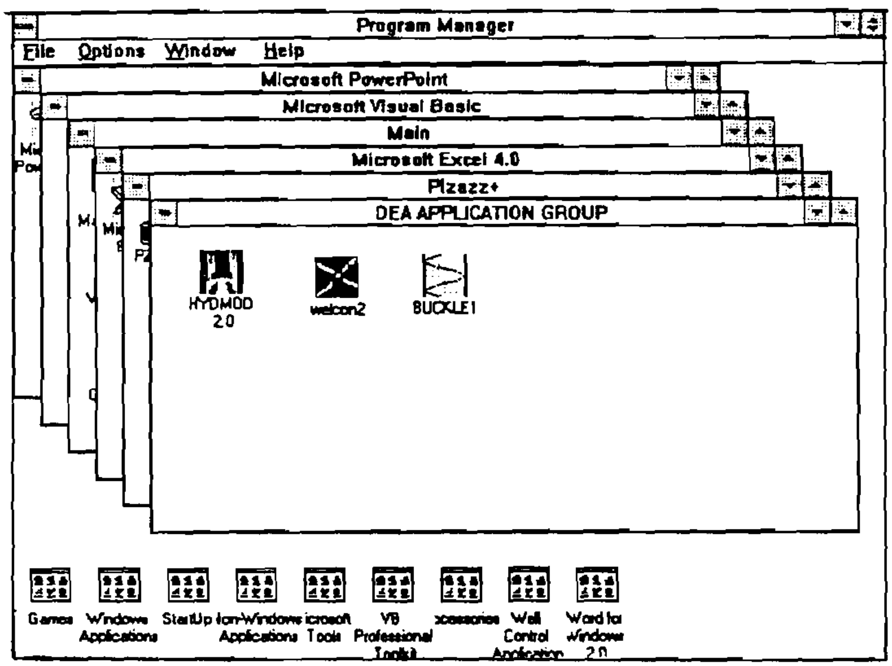

Figure 3-1. DEA APPLICATION GROUP Window Created by Setup

3.3 STARTING BUCKLE1

3.3.1 Start BUCKLE1 from Group Window

To run BUCKLE1 from Group Window, the user simply double-clicks the "BUCKLE1" icon, or when the icon is focused, press <ENTER>.

3.3.2 Use Command-Line Option from Windows

In the *Program Manager,* choose **Run** from the **File** menu. Then type C:\BUCKLE1\-BUCKLE1.EXE <ENTER>.

3.4 ALTERNATIVE SETUP

When the SETUP procedure described before fails, follow these steps to install the program:

1. Create a subdirectory on drive C: C:\BUCKLE1.
2. Insert source disk in drive B: (or A: may be substituted for B: in this procedure).
3. Type: C:\BUCKLE1 <ENTER>.
4. At prompt C:\BUCKLE1, type:
   Copy B:\BUCKLE1.EXE <ENTER>
   Copy B:\TEST.* <ENTER>.
5. Type: CD C:\WINDOWS <ENTER>.
6. At prompt C:\WINDOWS, type:
   Copy B:\VBRUN100.DL_ VBRUN100.DLL <ENTER>.
7. Type: CD SYSTEM.
8. At prompt C:\WINDOWS\SYSTEM, type:
   Copy B:*.DLL <ENTER>
   Copy B:\GSW.EXE <ENTER>
   Copy B:*.VBX <ENTER>.
9. Type: CD.. <ENTER>, then key in "WIN" <ENTER> to start Windows 3.0 or later version.
10. Click menu "File" under "PROGRAM MANAGER," select item "New...," click on "PROGRAM GROUP" option, then [OK] button.
11. Key in "DEA APPLICATION GROUP" after label "Description:," then click on [OK] button. A group window with the caption of "DEA APPLICATION GROUP" appears.
12. Click on menu "File" again, Select "NEW...," click on "PROGRAM ITEM" option, then [OK] button.
13. Key in "BUCKLE1" after label "Description," key in "C:\BUCKLE1\BUCKLE1.EXE" after label "COMMAND LINE," then click on [OK] button. The BUCKLE1 icon appears.
14. Double click the icon to start the program.

4. Running the Program

4.1 INTRODUCTORY REMARKS

BUCKLE1 runs in a Windows environment. It is assumed that the user is familiar with Windows, and that his or her computer is equipped with Windows 3.0 or later.

For information about Windows in a concise and convenient form, **10 Minute Guide to Microsoft Windows 3** by Katherine Murray and Doug Sabotin, published by Sams, is recommended.

In this quick start, step-by-step instructions take the user rapidly through the program. To save time and space, data will be input from prefabricated files, TEST.SDI, TEST.TDI, and TEST.XDI, which are included on the program disk and which were stored in directory C:\BUCKLE1 during the SETUP process in Section 3.

4.2 GETTING STARTED

1. Call up Windows and make DEA APPLICATION GROUP the active window, as shown in Figure 4-1.

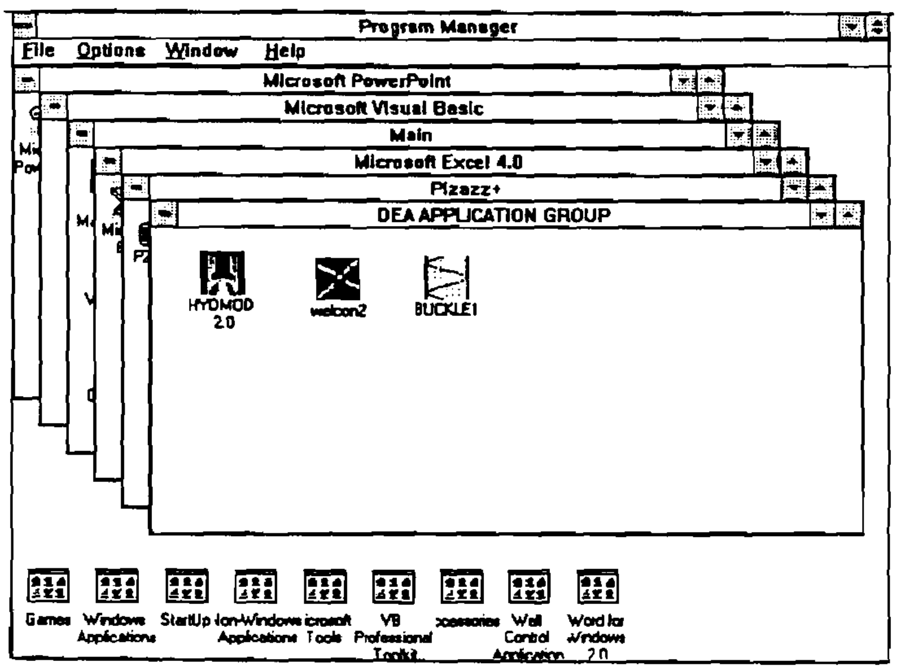

Figure 4-1. DEA APPLICATIONS GROUP Window

2. Double click on the BUCKLE1 icon. This will open the program title window (Figure 4-2). Click the [OK] button to open the information window.

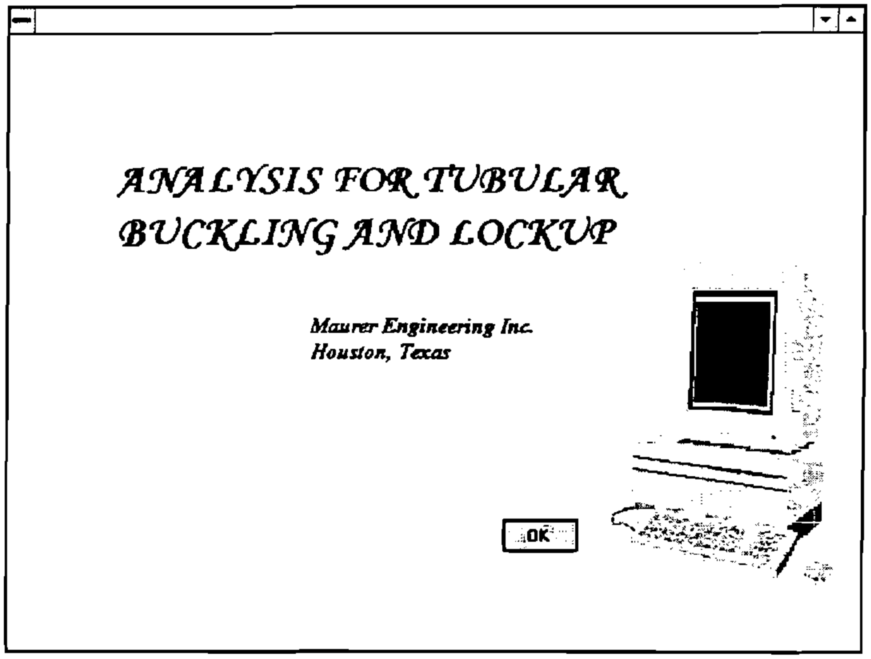

Figure 4-2. Program Title Window

3. When the information window (Figure 4-3) appears, click on the [OK] button. This will open the program Main Window, shown in Figure 4-4. Clicking [QUIT] stops the program.

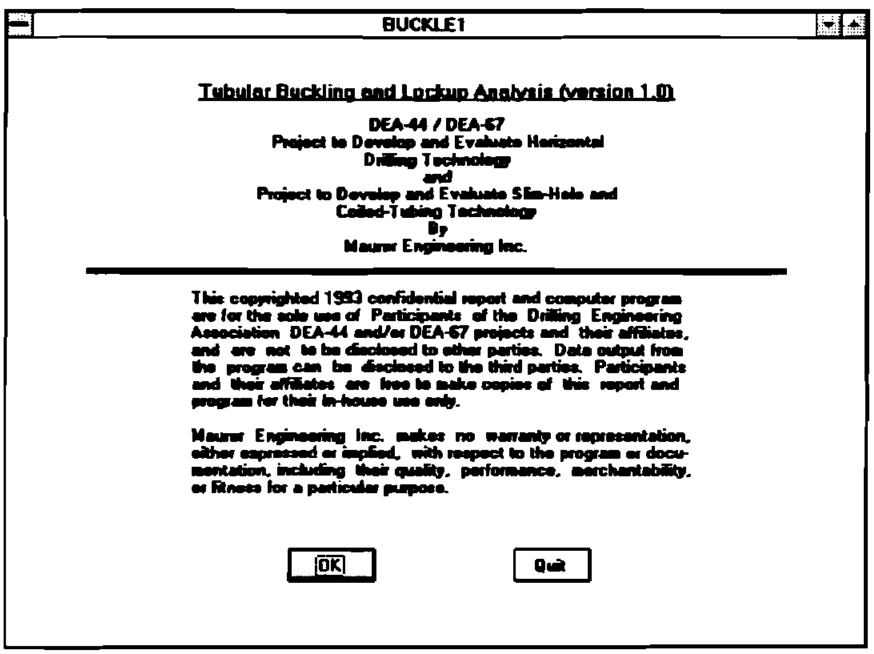

Figure 4-3. Information Window

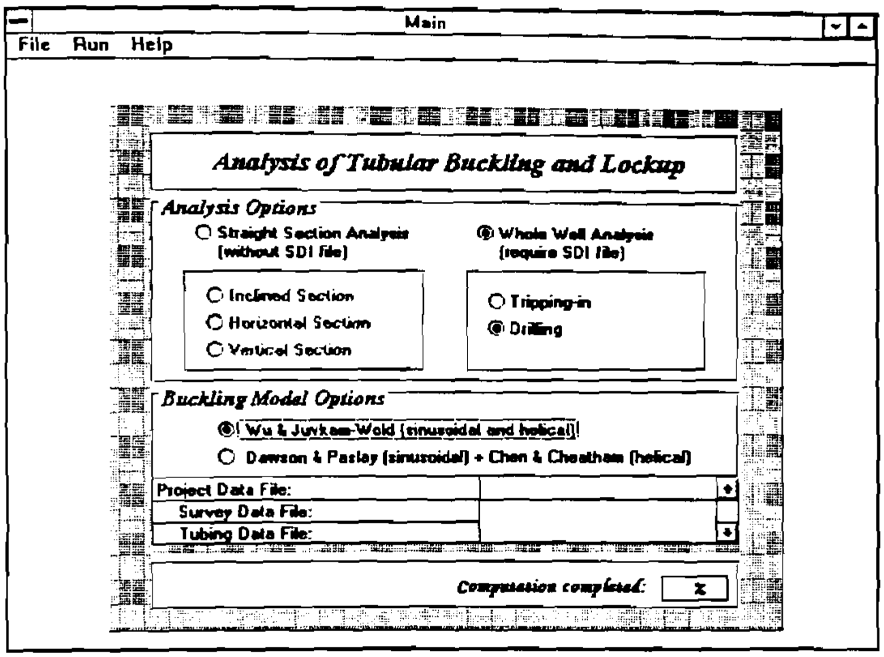

Figure 4-4. Main Menu: Data Input Window

4. When the Main Window, Figure 4-4, appears, notice that there are two major sets of choices to be made in this window. These are:

   1. Analysis options — straight section or whole well.
   2. Buckling model — Wu's or Chen's model.

The user's decision is indicated by clicking on the button in front of each listed option. The analysis option decision should be made first, so that the proper data can be input to run the calculations. The user may shift the buckling model options after data has been input. For "straight section analysis," the user can choose the straight section type: inclined, horizontal, or vertical. For "whole well analysis," the user can choose the operation type: tripping or drilling. The whole well drilling analysis and Wu's Buckling Model are the default setting.

If not using the mouse, move the cursor from one decision field to another by using the tab key. Move within a decision field by using the arrow keys.

5. After setting these options, click on "File" in the menu bar at the top of the screen. This allows the user to open the Section Data Input (XDI-file) window if the straight section analysis option is chosen (Figure 4-5), or Open Survey Data Input (SDI-file) window and Tubular Data Input (TDI-file) window if the whole well analysis option is chosen (Figure 4-15).

6. Instead of directly inputting data by the user accessing the data files, if the data file's names are saved into a project file, the user can also open/access the project file by clicking "open..." under "File" from the pull-down menu of the Main Window and the computer will read the data. Then click "start" under "Run" from the pull-down menu bar of the Main Window to start computing. This will bypass the following data input procedures.

7. If the user wants to directly input data and the "Straight Section Analysis" is selected, the user is allowed to click the "XDI file" under "File" in the menu bar at the top of the Main Window (Figure 4-5) to open/access the Section Data Input window (Figure 4-6).

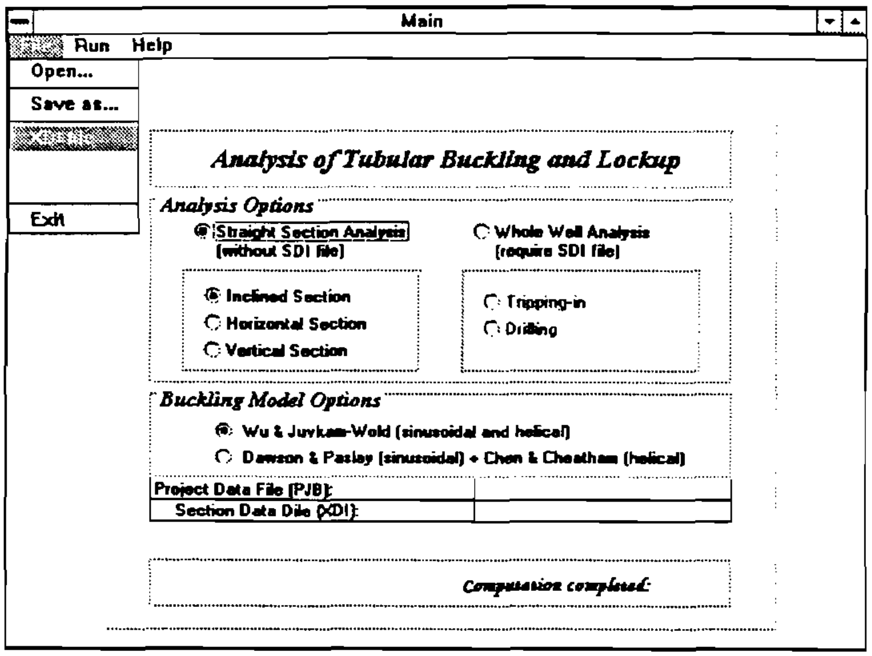

Figure 4-5. Opening the Section Data Input Window

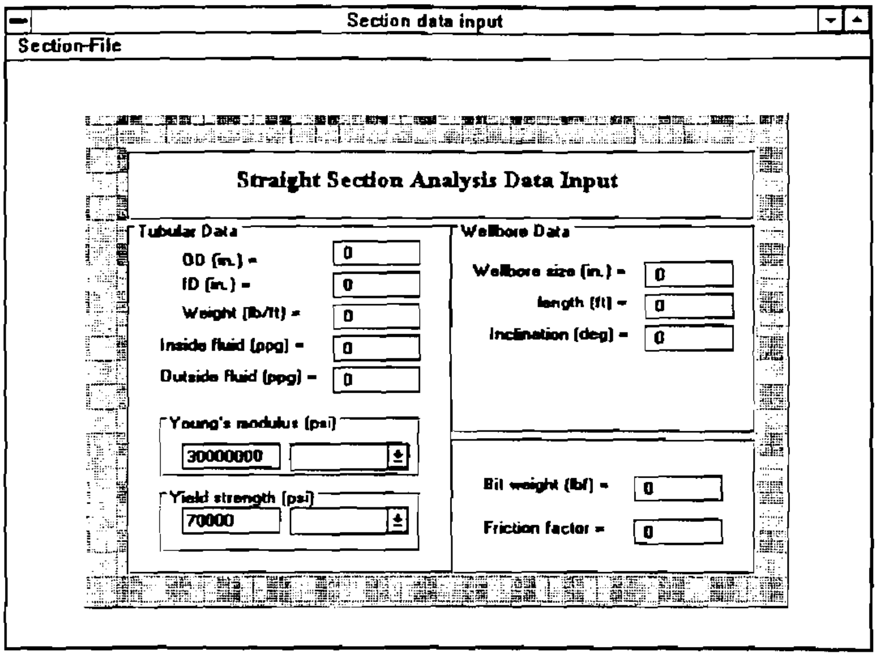

Figure 4-6. Section Data Input Window

8. When the "Section Data Input" window (Figure 4-6) appears, click "open..." under "Section File" in the menu bar at the top of the window (Figure 4-7), to input the data stored in the data file (*.XDI). The user can also input data manually.

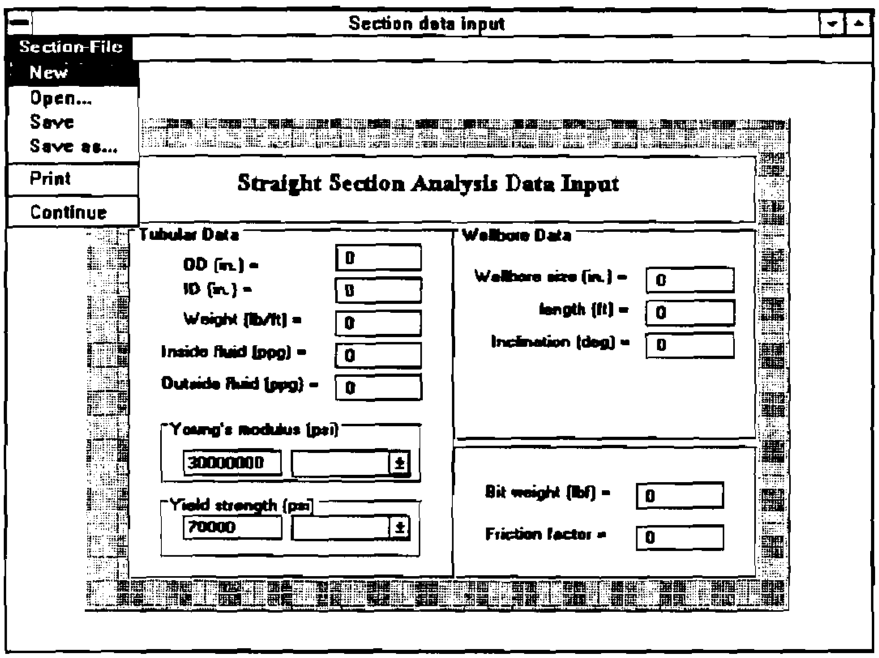

Figure 4-7. Section Data Input Window

9. Once "open..." is clicked, the following file open dialog box appears on the screen (Figure 4-8).

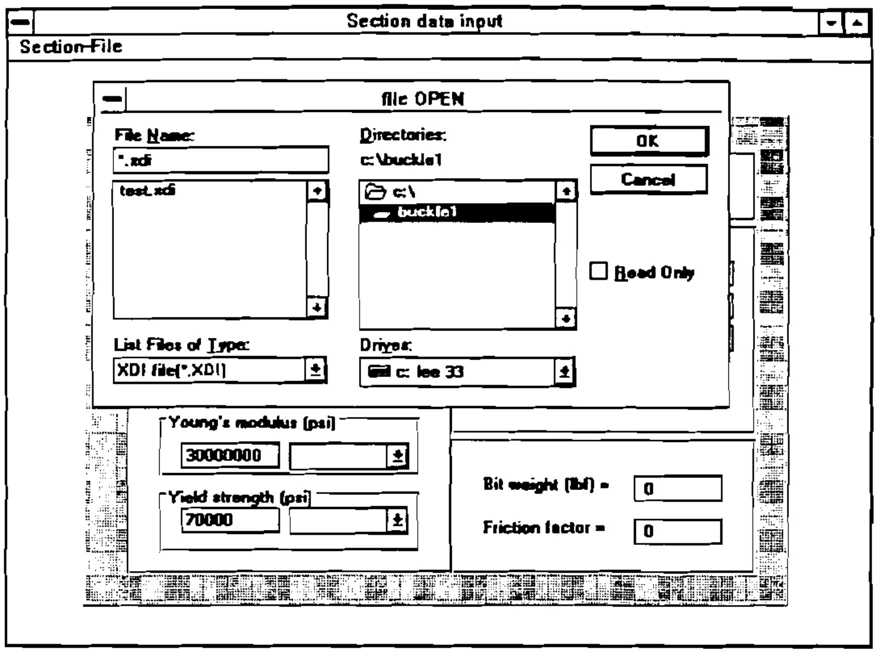

Figure 4-8. File Open Dialog Box

10. When the file open dialog box opens, click on C:\ in the Drive box. This causes the list of *.XDI files stored in drive C:\BUCKLE1\ to appear in the File Name box at the upper left of the window, as shown in Figure 4-8. Click on Test.XDI, then click [OK]. This fills the section data input window with the data stored in Test.XDI as shown in Figure 4-9.

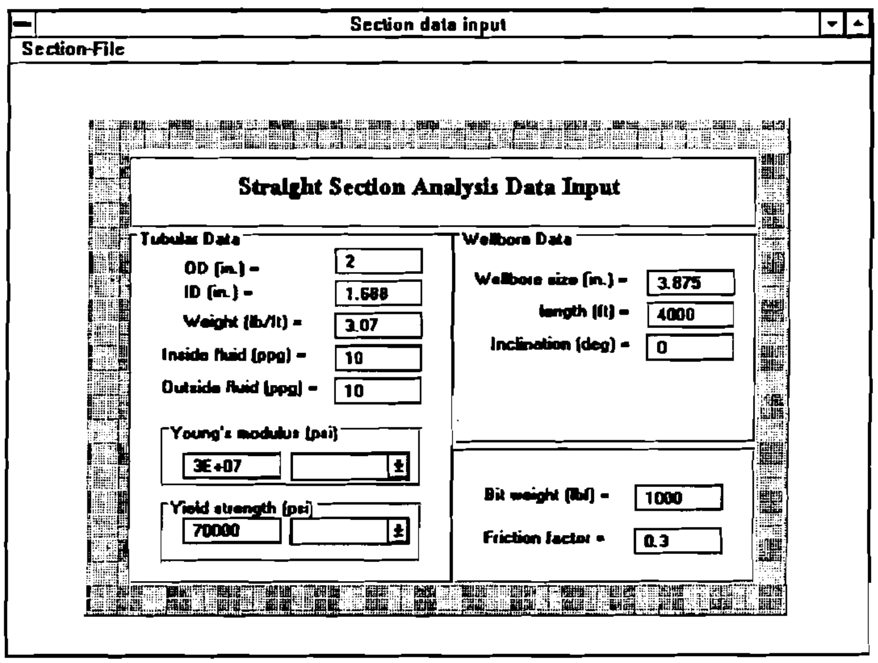

Figure 4-9. Section Data Input Window — Filled

11. Click on Section File in the menu bar above. When the Section File window opens, click on Exit. This takes the user back to Main Window as shown in Figure 4-10. **Note: the section data file name is now filled into the lower part of the Main Window.**

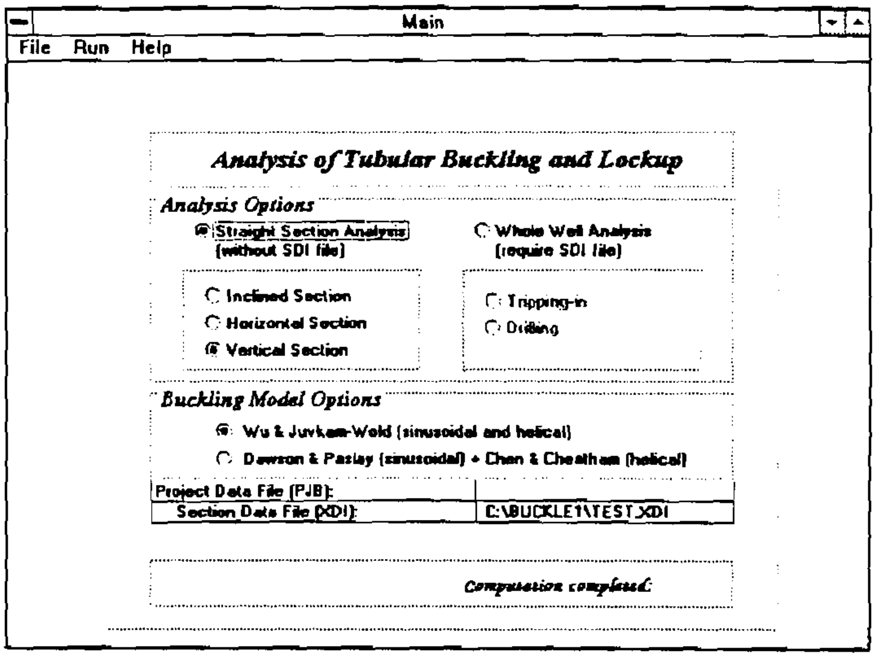

Figure 4-10. Main Window — Filled with Data File Name

12. Click "Start" under "Run" from the pull-down menu bar of the Main Window to start computing. An indicator will display the percent of computation completed as a function of time. When the indicator reaches 100%, the Main Window disappears and the result output window appears (Figure 4-11) with eight graphs and one table being displayed on Tile mode.

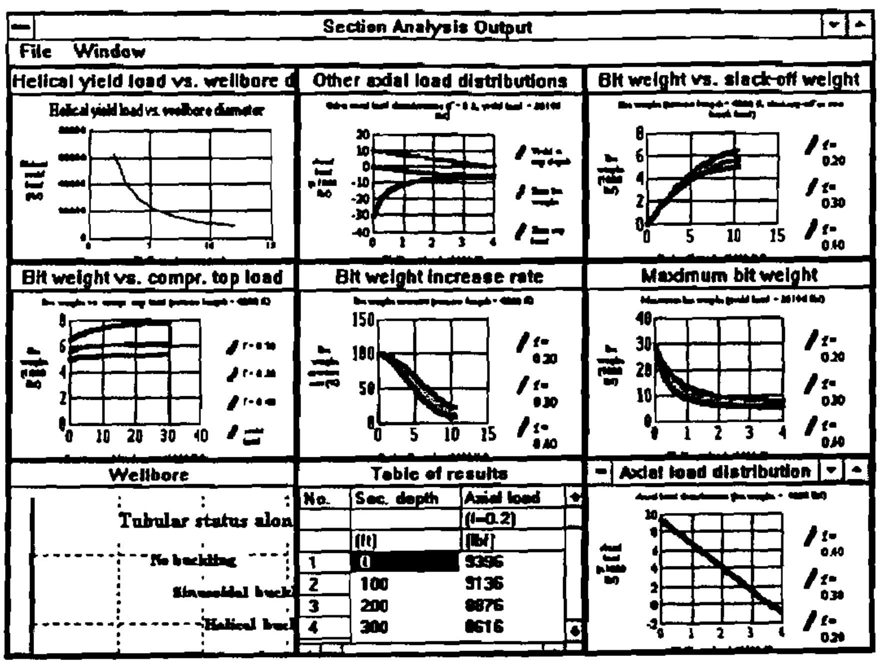

Figure 4-11. Section Analysis Result Output Window

13. Each graph or table can be pulled-up to full screen (Figure 4-12) by clicking the right-top corner of the graph or table. The table shows the numerical values of the graph, which are active by a single click.

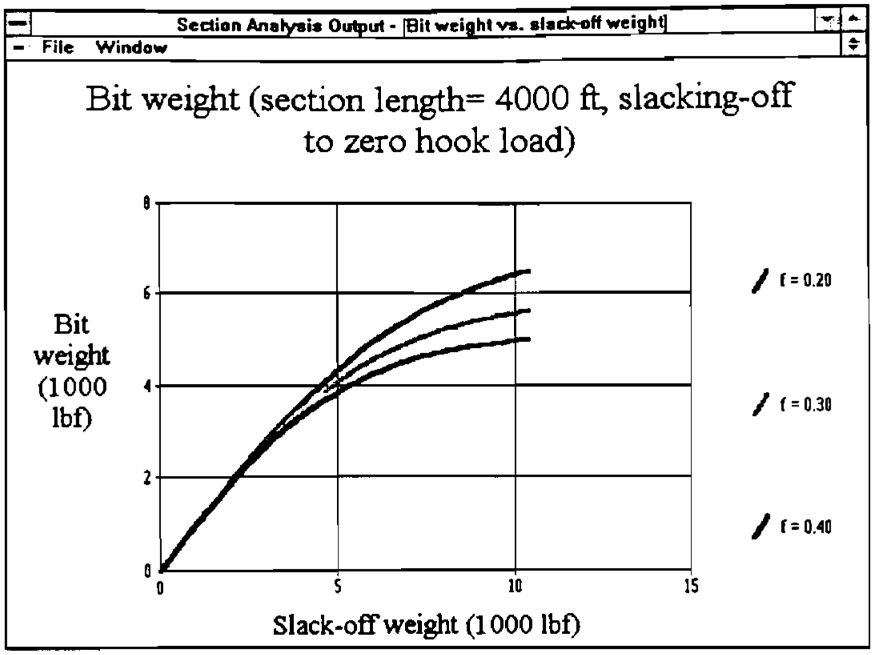

Figure 4-12. Full-Screen Graphs

14. By clicking the down triangle in the top-right corner of the full-screen graph, it returns to its original small size.

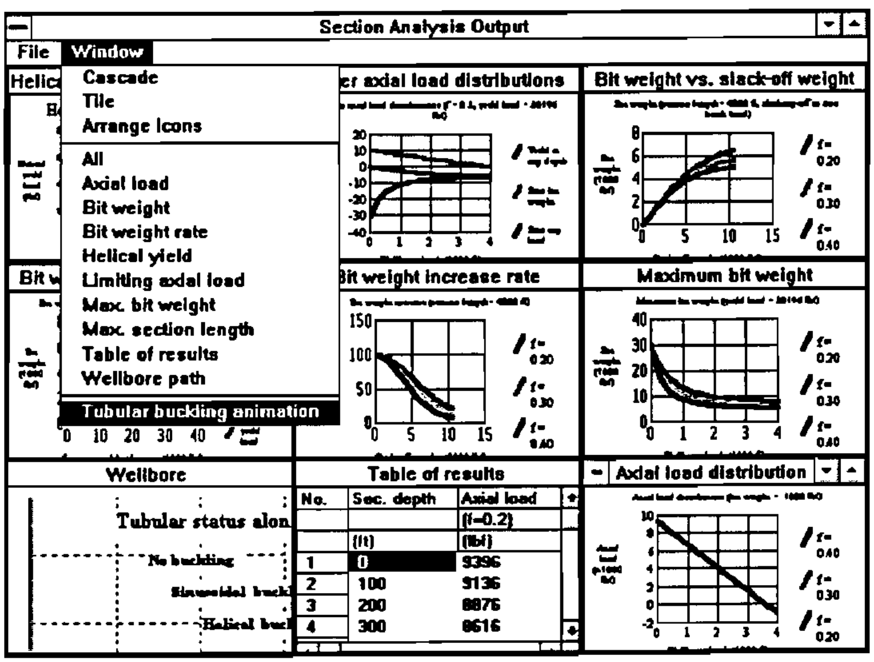

Figure 4-13. Section Analysis Result Output Window

15. By clicking "Tubular Buckling Animation" under "window" in the menu bar of the Section Analysis Result Output window above (Figure 4-13), the "Tubular Buckling Animation" screen (Figure 4-14) appears. The axial load distribution of the tubular is shown in the left graph, and the buckling status of the tubular is shown in the right graph.

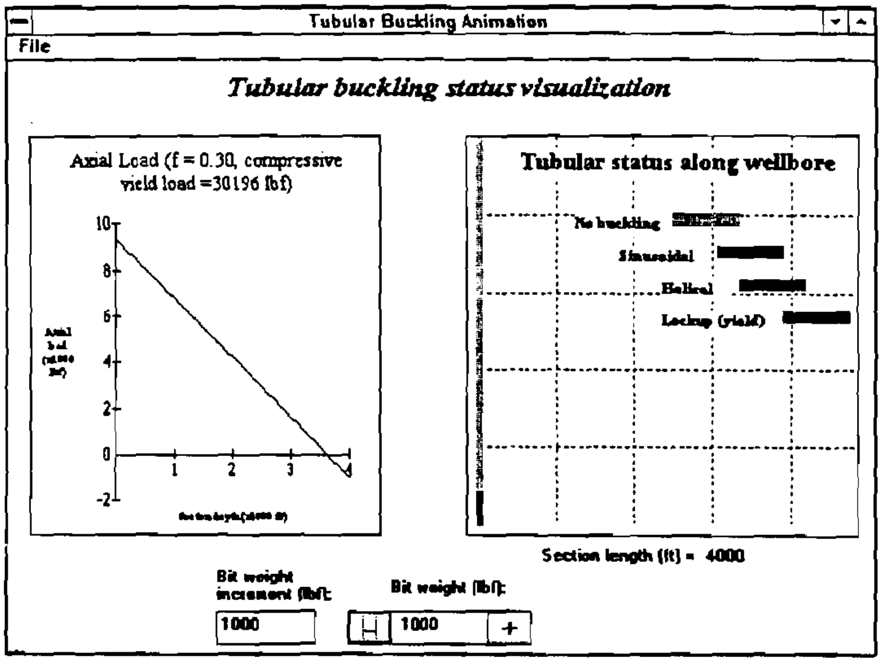

Figure 4-14. Tubular Buckling Animation Window

16. Click the "+" or "-" buttons (Figure 4-14) to increase or decrease bit weight. The bit weight increment, by one click of the buttons, can be reset by changing the default value (1000 lbf). Bit weight can also be input directly. The buckling development can be seen by the color change on the right graph and shape change on the left graph. Clicking "Back to Main" under "File" in the menu bar of the "Animation Window" takes the user back to the Main Window.

17. When the "Whole Well Analysis" option is selected and the user is ready to input data, survey data (SDI-file) and tubular data (TDI-file) must be input (Figure 4-15).

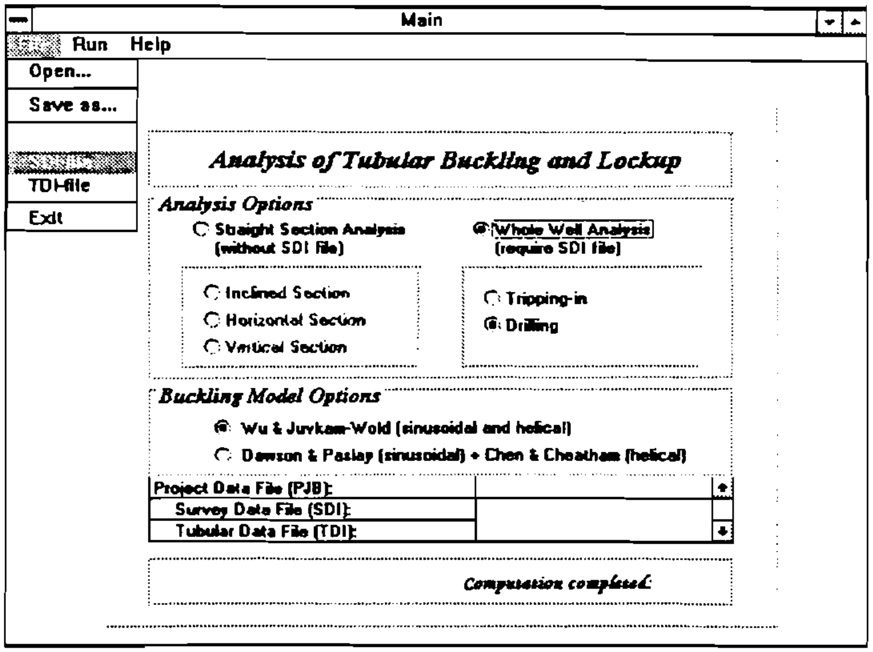

Figure 4-15. Main Window

18. Click "SDI-file" under "File" in the menu bar at the top of the Main Window to go to the well survey data input window (Figure 4-16).

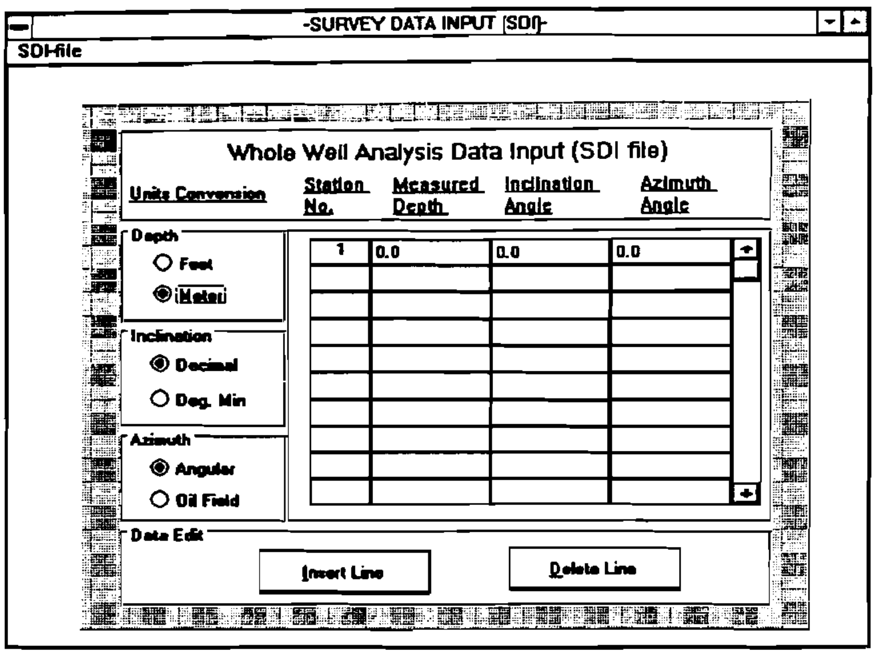

Figure 4-16. Survey Data Input Window

19. Once the Survey Data Input window displays, click "open..." under "SDI File" in the menu bar at the top of the window (Figure 4-17) to input the survey data stored in a data file.

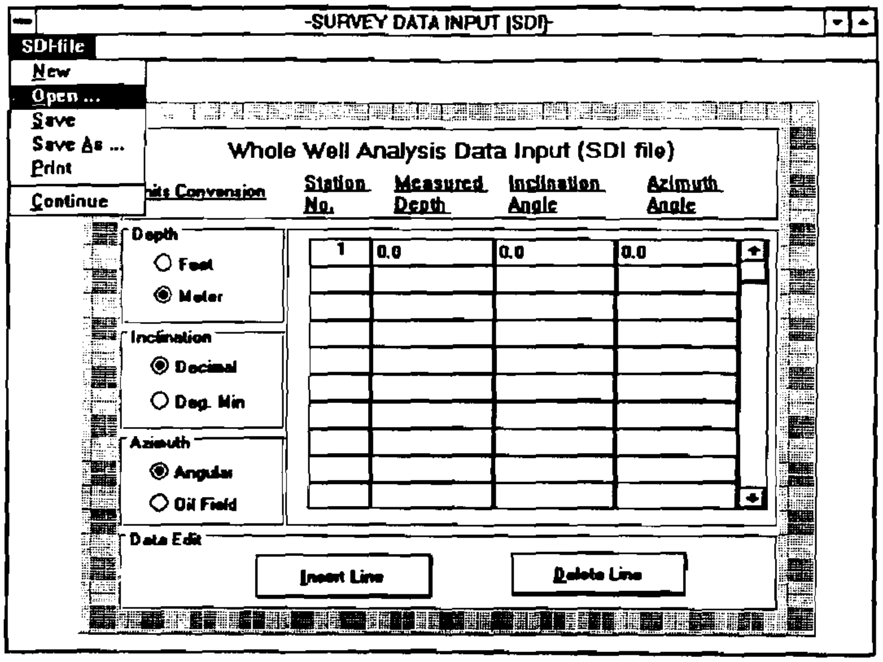

Figure 4-17. Survey Data Input Window

20. Once "open..." is clicked, the following file open dialog box is displayed (Figure 4-18).

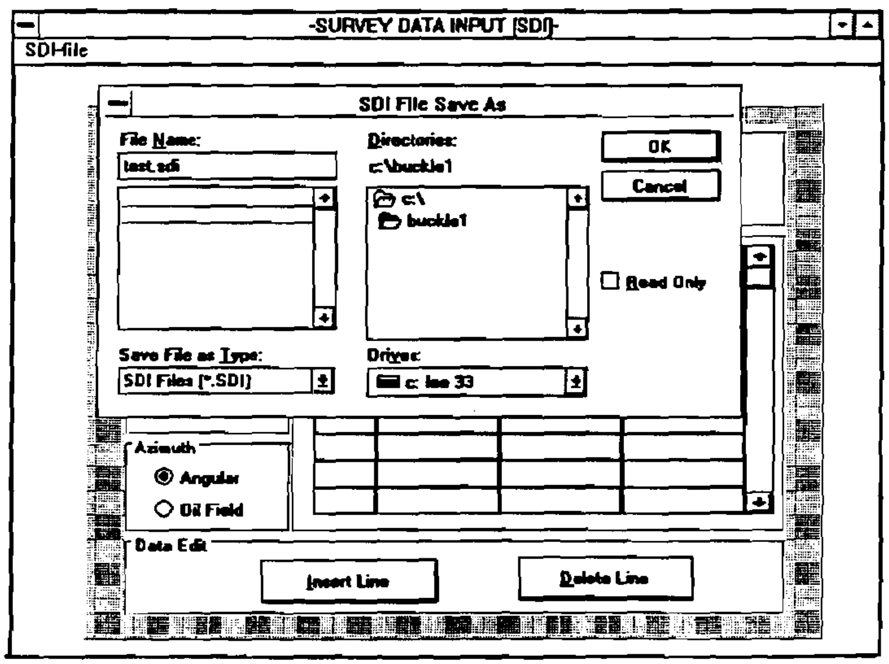

Figure 4-18. SDI File Open Box

21. When the SDI File Open box opens, click on C:\ in the Drive box. This causes the list of *.SDI files stored in drive C:\BUCKLE1\ to appear in the File Name box at the upper left of the window, as shown in Figure 4-18. Now, click on Test.SDI, then click on [OK]. This fills the Survey Data Input window with data, as shown in Figure 4-19.

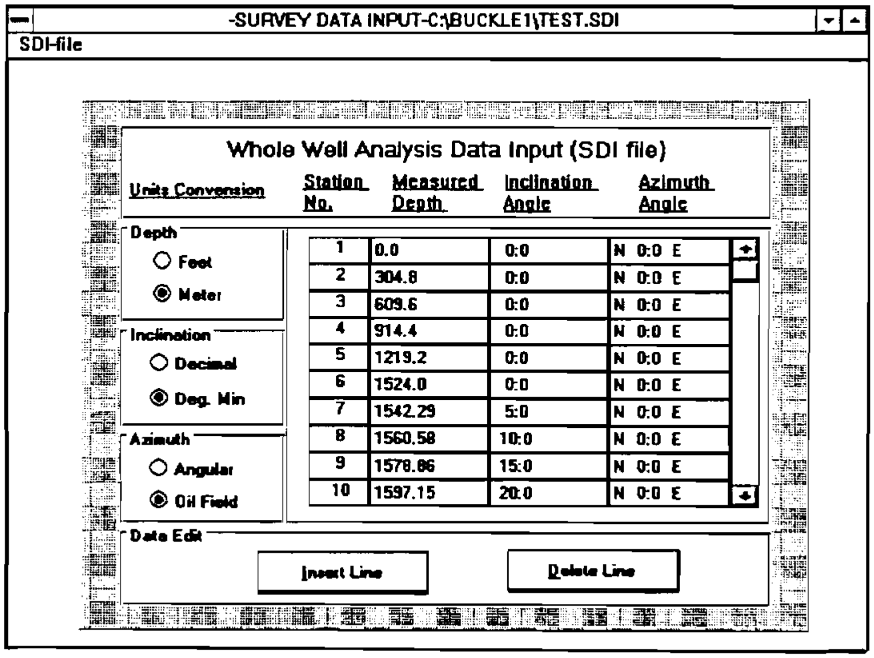

Figure 4-19. Survey Data Input Window — Filled

Notice that there are three sets of options available. These are:

1. Depth — Feet or Meters;
2. Inclination — Decimal degrees or Degrees and Minutes; and
3. Azimuth — Angular or Oil Field Measure.

To change any of these, click on the desired option. If not using a mouse, use the tab key to move from one field to another, and use the arrow keys to move within a field. As the use moves from one value to another, the highlight will move accordingly. Default choices are Feet, Decimal, and Angular, respectively.

Before leaving this Survey Data Input window, set these three options to suit your needs.

22. Now, click on the SDI File in the menu bar at the top of the Survey Data Input window. When the File window opens, as shown in Figure 4-17, click "continue" to go back to Main Window, with the "Survey Data File (SDI)" box now listing C:\BUCKLE\TEST.SDI, as shown in Figure 4-20.

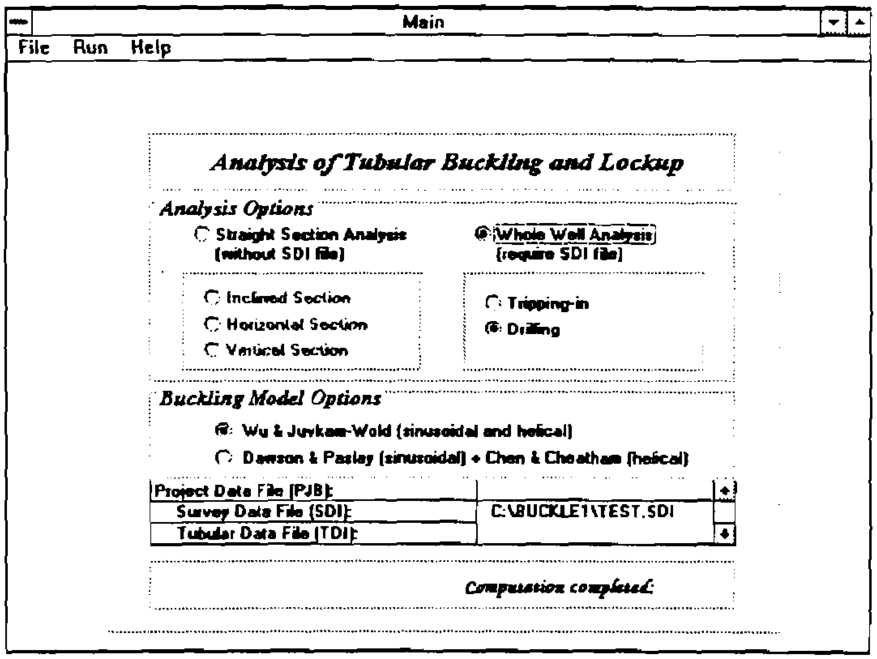

Figure 4-20. Main Window — Filled with SDI File Name

23. Click "TDI-File" under "File" in the menu bar at the top of the Main Window to go to the tubular data input window (Figure 4-21).

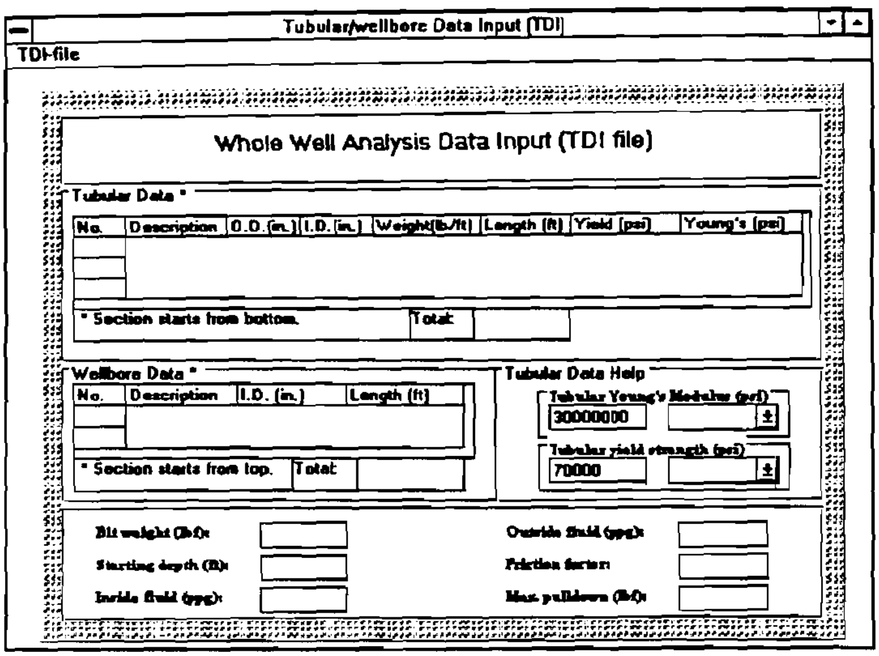

Figure 4-21. Tubular/Wellbore Data Input

24. Once the Tubular Data Input Window appears (Figure 4-21), click "open" under the "TDI-File" in the menu bar at the top of the window to open the file "Open Dialog Box" and input the tubular/wellbore data stored in a data file.

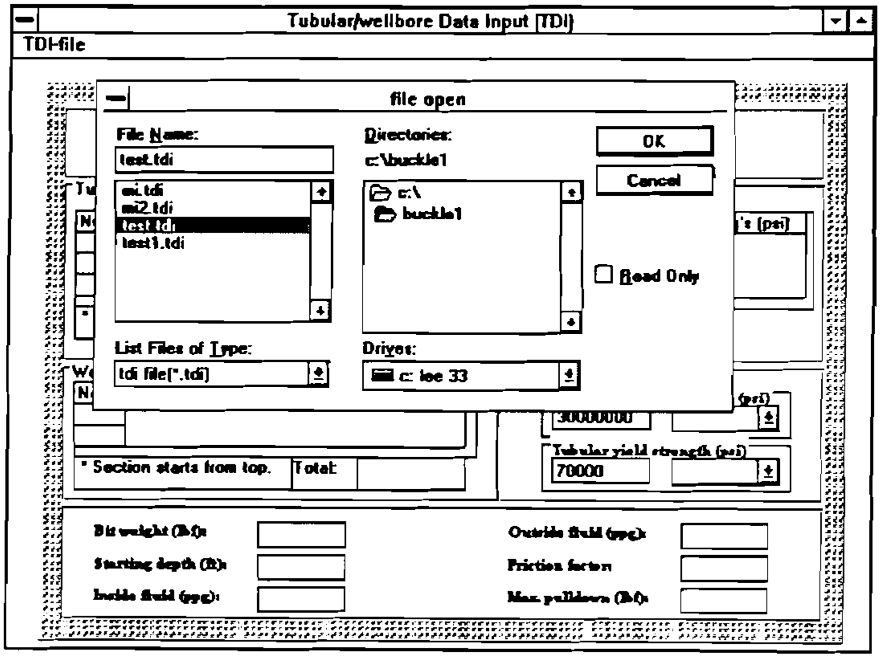

Figure 4-22. TDI File Open Box

25. When the TDI File "open" box opens (Figure 4-22), click C:\ in the Drive box. This causes the list of *.TDI files stored in drive C:\BUCKLE1\ to appear in the File Name box at the upper left of the box. Click on Test.TDI and then click on [OK] and this fills the Tubular Data Input window with data, as shown in Figure 4-23.

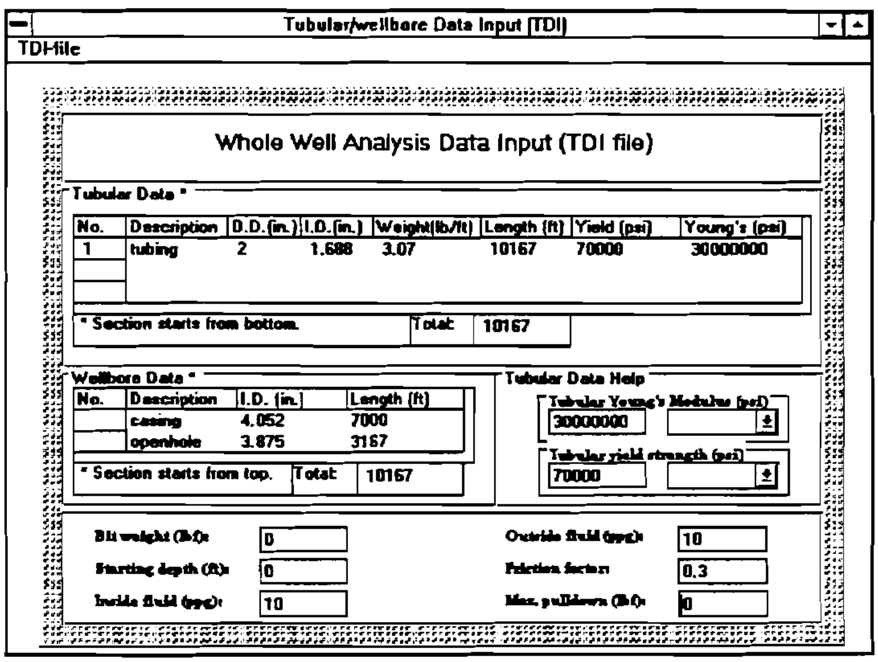

Figure 4-23. Tubular/Wellbore Data Input — Filled

26. Click "Continue" under "TDI-File" in the menu bar at the top of the window to go back to the Main Window. With the "Tubular Data File (TDI)" box listing C:\BUCKLE1\TEST.TDI, as shown in Figure 4-24.

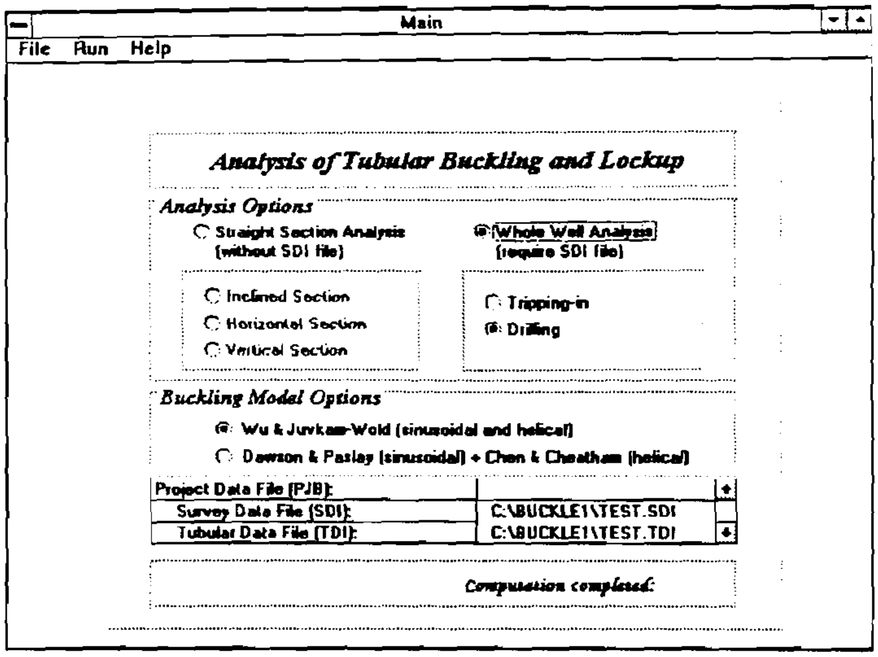

Figure 4-24. Main Window — Filled with SDI and TDI File Names

27. Click "Start" under "Run" from the pull-down menu bar of the Main Window to start computing. An indicator will display the percent of computation completed as a function of time. When the indicator reaches 100%, the Main Window disappears and the result output window displays (Figure 4-25) with the graphs and one table being displayed on Tile mode.

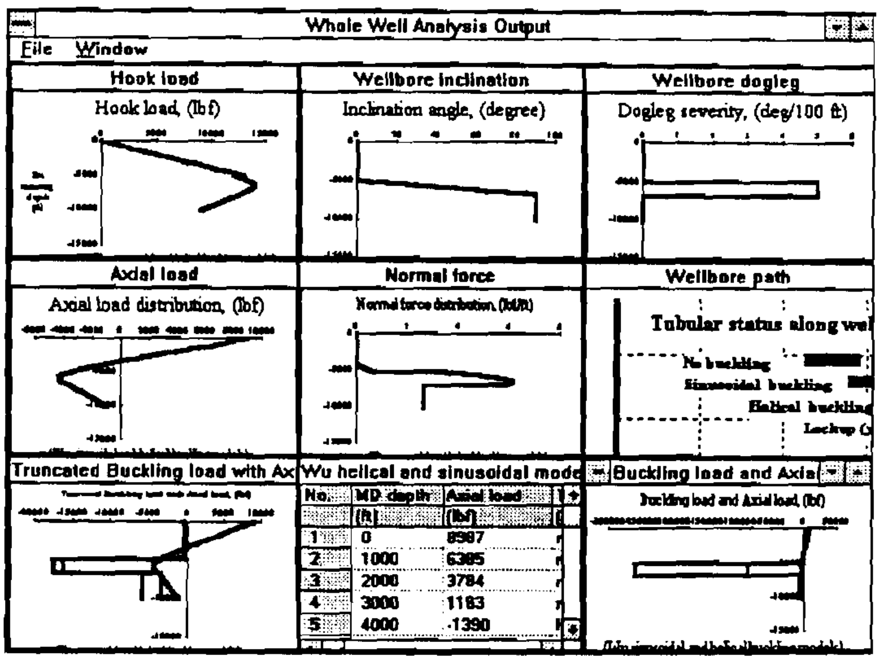

Figure 4-25. Whole Well Analysis Output

28. Click the right-top corner of each graph or table to pull up the graph or table to full-screen as shown in Figure 4-26. Again the table shows the numerical values of the active graph.

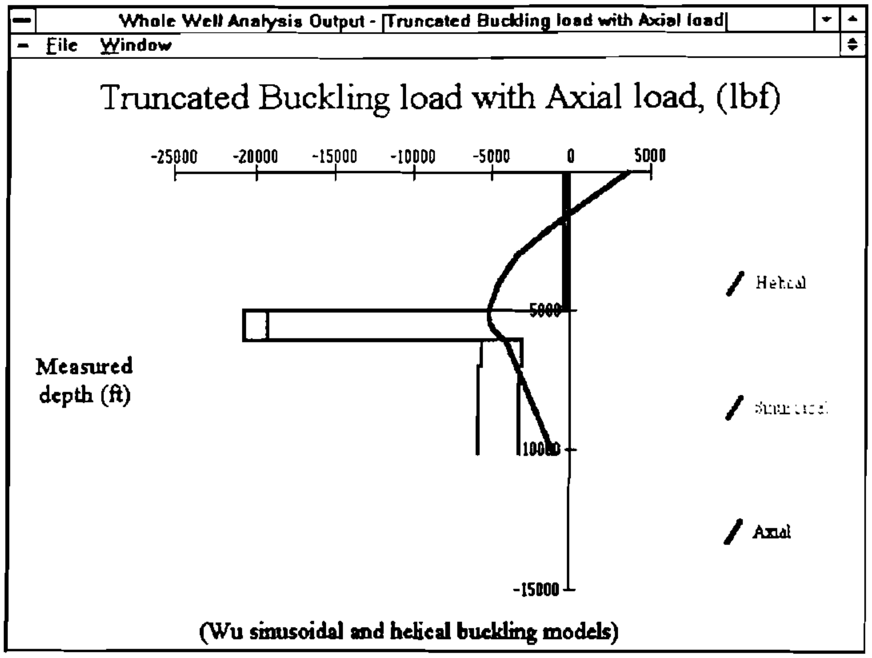

Figure 4-26. Full-Screen Graph

29. Click "Tubular Buckling Animation" under the "window" in the menu bar of the whole well analysis output window (Figure 4-27) to display the "Tubular Buckling Animation" screen displays (Figure 4-28).

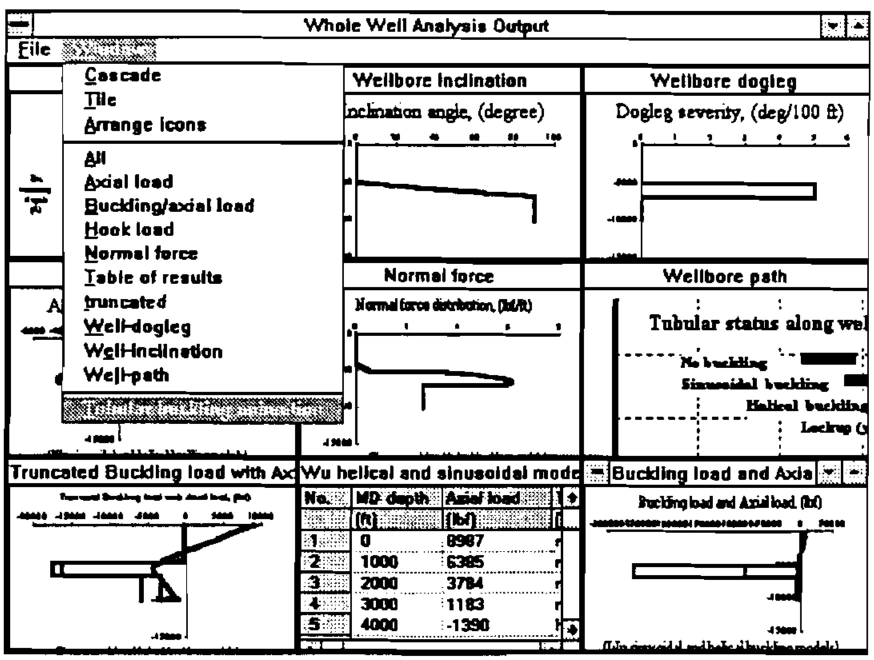

Figure 4-27. Whole Well Analysis Output

30. Click the "+" or "-" buttons (Figure 4-28) to increase or decrease bit weight. The buckling development can be seen by the color change on the right graph and shape change on the left graph.

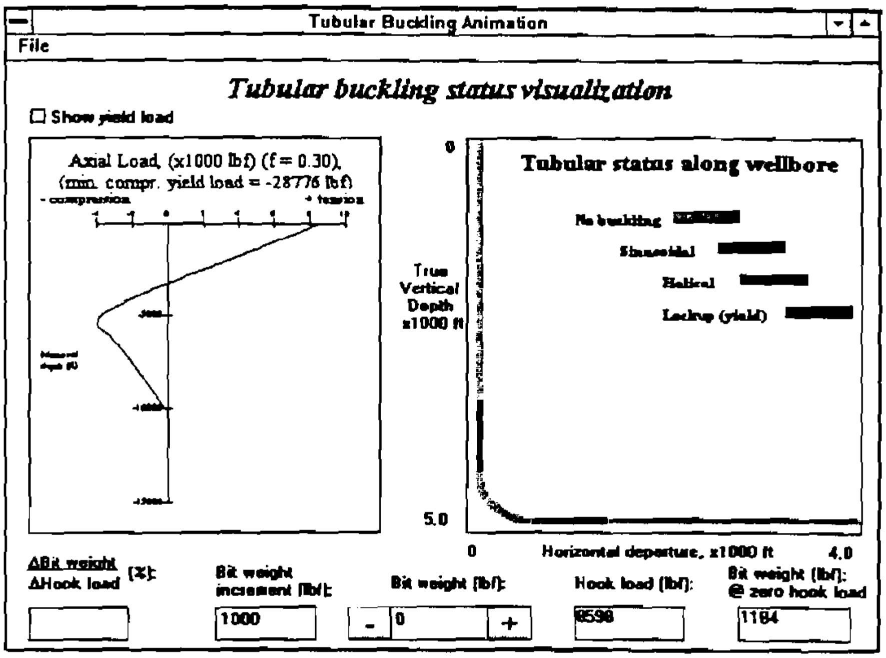

Figure 4-28. Tubular Buckling Animation Window

31. To leave the Tubular Buckling Animation window, click on File in the menu bar. When the File window opens, click on "Back to Main." This will return the user to the Main Window.

32. The opened data file's names can be saved into a project file, so that the user can open the data files by opening the project file, allowing the computer to read the data automatically. Click "Save as..." under "File" in the menu bar at the top of the Main Window (Figure 4-29) to open the "Save" dialog box.

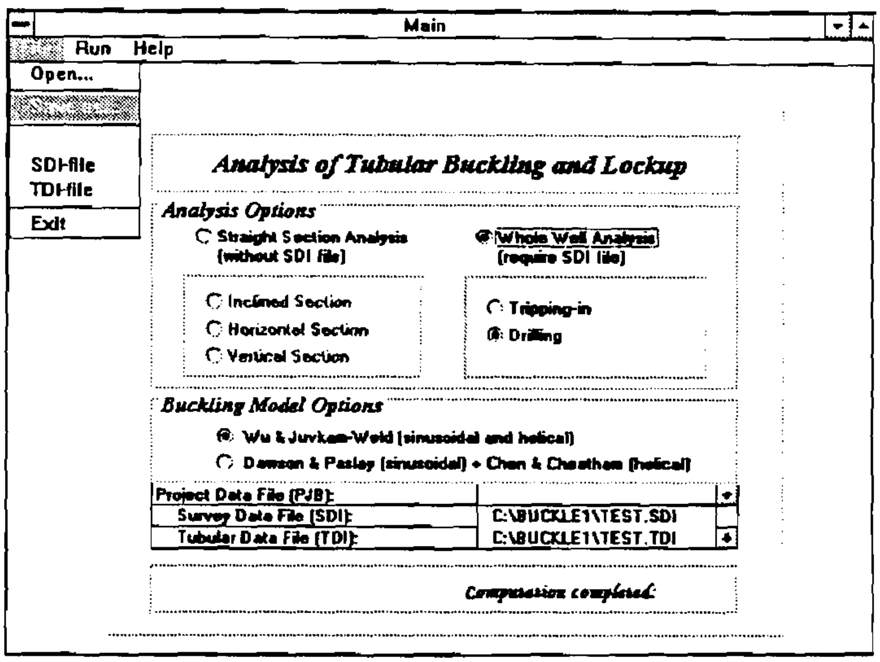

Figure 4-29. Project File Saving

33. After saving the project file, its name is shown in the Main Window (Figure 4-30).

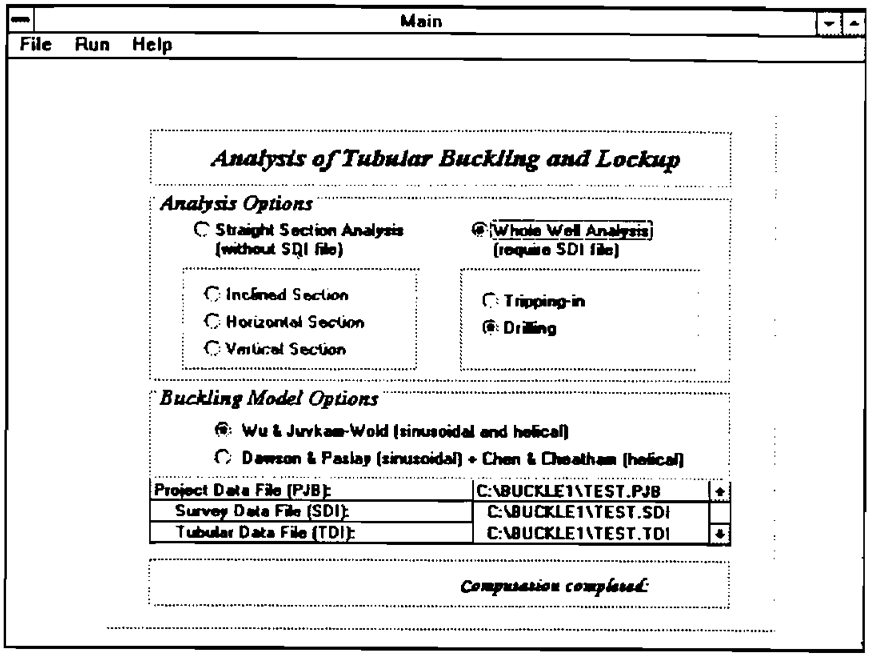

Figure 4-30. Main Window — Filled with PJB Name

34. To open a pre-saved project file, click "Open..." under "File" in the menu bar at the top of the Main Window (Figure 4-29). Choose the project file name (.PJB), the computer automatically reads the data stored in *.XDI, *.SDI, and *.TDI files. The data file's names are also shown in the Main Window as shown in Figure 4-30.

35. The Help option at the right end of the menu bar in the Main Window opens the Help window. Two options available in this window are Assistance and About.. . Clicking on Assistance will open the window shown in Figure 4-29, which gives phone and fax numbers and individuals to contact for assistance with the program. Clicking on About... in the help window opens a window with information about the program and a listing of the equipment used to run the program (Figure 4-31).

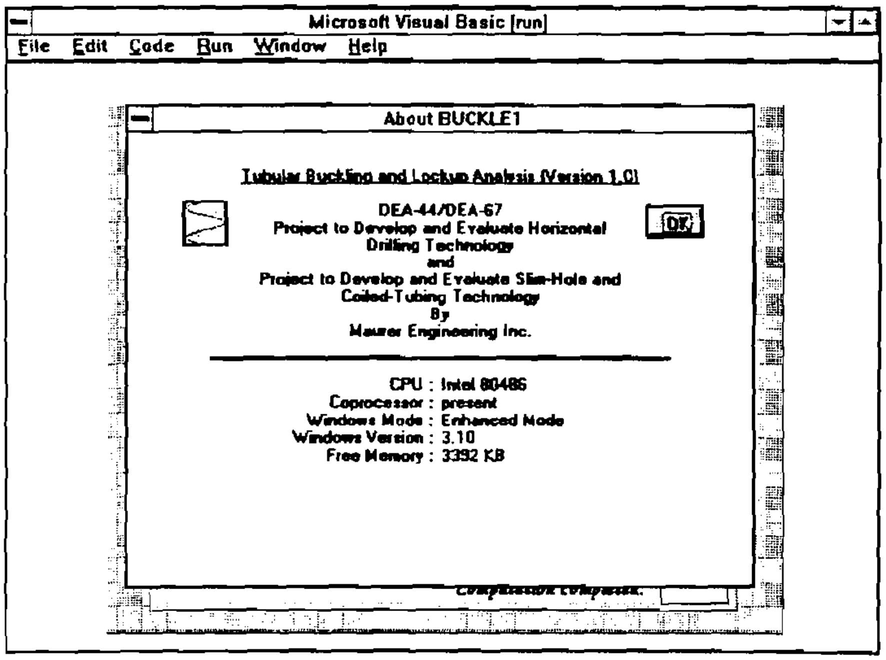

Figure 4-31. About Window

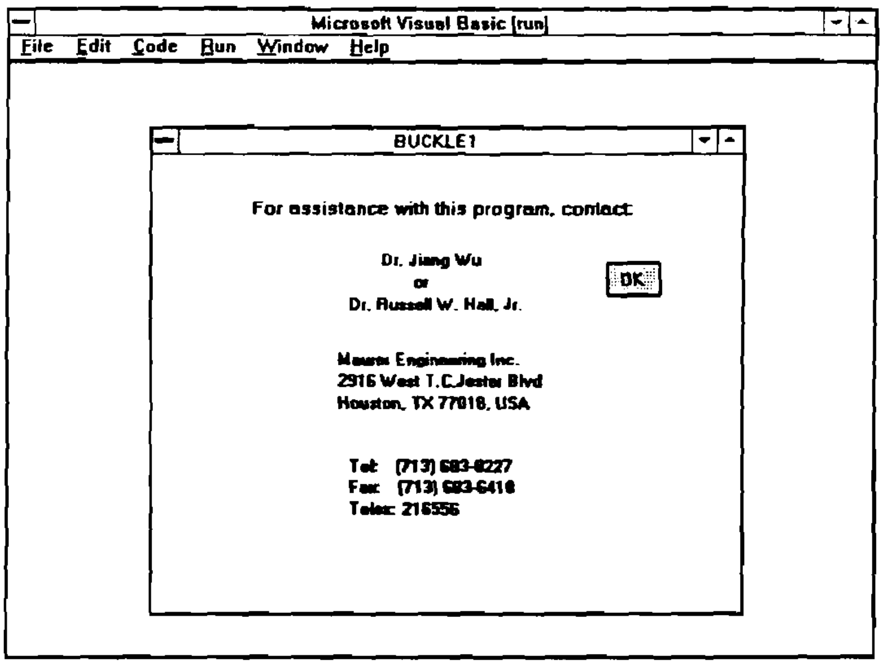

Figure 4-32. Help Window

36. To exit the program, click File in the menu bar of the Main Window. When the File window opens, click EXIT.

5. References

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Wu, Jiang and Juvkam-Wold, H.C., 1993A: "Preventing Helical Buckling of Pipes in Extended Reach and Horizonal Wells," paper (93-PET-7) presented at the 1993 ETCE Drilling Technology Symposium, Houston, Texas, January 31—February 4.

Wu, J. and Juvkam-Wold, H.C., 1993B: "Frictional Drag Analysis for Helically Buckled Pipes in Extended Reach and Horizontal Wells," paper (93-PET-8) presented at the 1993 ETCE Drilling Technology Symposium, Houston, Texas, January 31—February 4.

6. BUG Report or Enhancement Suggestion Form

Name: ______________________ Company: ______________________
Address: ______________________ City: ______________ State: ________
Phone No.: ______________________ Fax No.: ______________ Date: ________
☐ Bug\Problem Report ☐ Enhancement Suggestion

Program Name and Version Number: ______________________________
____

Bug\Problem Description or Enhancement Suggestion: ______________________________
____
____
____
____

Regarding the Bug Report, please answer the following questions:

Computer System Brand: ______________

Chip: ☐ 286 ☐ 386 ☐ 486 ☐ Pentium
Type: ☐ Desktop ☐ Laptop ☐ Notebook ☐ Other
RAM: ______MB Speed: ______ MHz
Math-Coprocessor Present: ☐ Yes ☐ No ☐ Unknown

Printer Type: ______________________ (for printing error only)
Plotter: ______________________ (for plotting error only)
Within Network System: ☐ Yes ☐ No Type: ______________
Video Type: ☐ EGA ☐ VGA ☐ SVGA ☐ Mono ☐ LCD
Video Card Ram: ______________ (video problem only)

Operating System

MS-DOS Version No.: __________ MS-Windows Version No.: __________(for Windowsapplications)
OS2 ______________ MS-Windows NT Version No.: __________
Other ______________

BUG Detecting Data

☐ Will be mailed on diskette ☐ Will be faxed ☐ Attached ☐ None

Other Comments: ______________________________
____
____
____

Please send or fax to:

Lee Chu
MAURER ENGINEERING INC.
2916 West T.C. Jester
Houston, TX 77018-7098
Ph.: 713/683-8227 • Fax: 713/683-6418