

Technical Report 5-33847
Contract No. NAS8-38609
Delivery Order No. 142

FINAL
TN-39
5-33847
5-33847

Thermal Excitation System for Shearography (TESS)
(5-33847)

Final Technical Report for Period
26 April 1995 through 30 April 1996

July 1996

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Report Document Page

1. Report No. 5-33847		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle Thermal Excitation System for Shearography (TESS)				5. Report Due May 1996	
				6. Performing Organization Code Research Institute, UAH	
7. Author(s) Matthew D. Lansing, Michael W. Bullock				8. Performing Organization Report No. 5-33847	
				10. Work Unit No. Delivery Order #142	
9. Performing Organization Name and Address UAH Research Institute RI E-47 University of Alabama in Huntsville Huntsville, AL 35899				11. Contract or Grant No. NAS8-38609	
				13. Type of report and Period covered Final Report 26 April 1995 through 30 April 1996	
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Marshall Space Flight Center Huntsville, AL 35812				14. Sponsoring Agency Code	
				15. Supplementary Notes	
16. Abstract <p>One of the most convenient and effective methods of stressing a part or structure for shearographic evaluation is thermal excitation. This technique involves heating the part, often convectively with a heat gun, and then monitoring with a shearography device the deformation during cooling. For a composite specimen, unbonds, delaminations, inclusions, or matrix cracking will deform during cooling differently than other more structurally sound regions and thus will appear as anomalies in the deformation field. However, one of the difficulties that cause this inspection to be dependent on the operator experience is the conventional heating process. Fanning the part with a heat gun by hand introduces a wide range of variability from person to person and from one inspection to the next.</p> <p>The goal of this research effort was to conduct research in the methods of thermal excitation for shearography inspection. A computerized heating system was developed for inspection of 0.61m (24 in.) square panels. The Thermal Excitation System for Shearography (TESS) provides radiant heating with continuous digital measurement of the surface temperature profile to ensure repeatability. The TESS device functions as an accessory to any electronic shearography device.</p>					
17. Key Words (Suggested by Author(s)) shearography, inspection, flaw detection, NDE, nondestructive testing, NDT, nondestructive evaluation, experimental mechanics, applied mechanics, solid mechanics, data acquisition			18. Distribution Statement TBA		
19. Security Class. (of this report) Unclassified		20. Security Class. (of this page) Unclassified		21. No. of pages 43	22. Price

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I. INTRODUCTION

One of the most convenient and effective methods of stressing a part or structure for shearographic evaluation is thermal excitation. This technique involves heating the part, often convectively with a heat gun, and then monitoring with a shearography device the deformation during cooling. For a composite specimen, unbonds, delaminations, inclusions, or matrix cracking will deform during cooling differently than other more structurally sound regions and thus will appear as anomalies in the deformation field. However, one of the difficulties that cause this inspection to be dependent on the operator experience is the conventional heating process. Fanning the part with a heat gun by hand introduces a wide range of variability from person to person and from one inspection to the next.

The System Management and Production Laboratory at the University of Alabama in Huntsville (UAH) Research Institute was tasked by the Nondestructive Evaluation (NDE) Branch (EH13) at Marshall Space Flight Center (MSFC) to conduct research in the methods of thermal excitation for shearography inspection. A computerized heating system was developed for inspection of 0.61 m (24 in.) square panels. The Thermal Excitation System for Shearography (TESS) provides radiant heating with continuous digital measurement of the surface temperature profile to ensure repeatability. The TESS device functions as an accessory to any electronic shearography device.

II. PRELIMINARY DESIGN

The original concept for the TESS system was a shrouded heating system with an integral thermocouple array for surface temperature profile monitoring. This idea is illustrated in Figure 1.

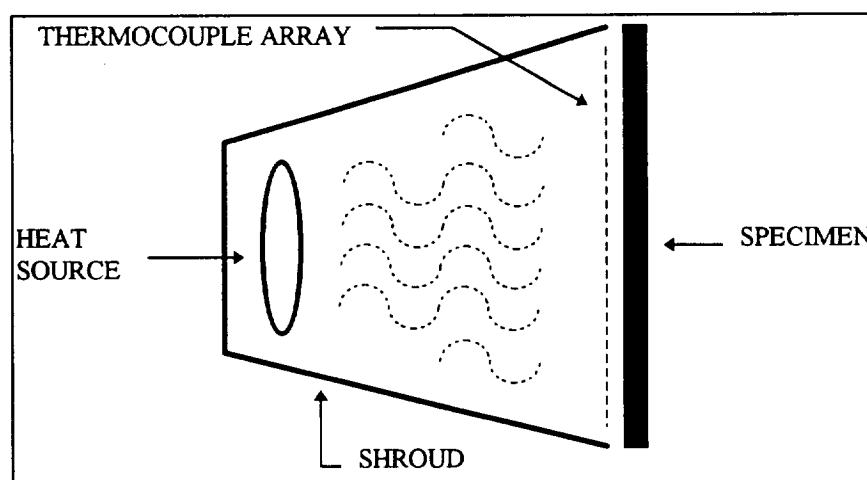


Figure 1. Conceptual Design

III. HEAT SOURCE SELECTION

Heat source types considered for utilization in the TESS apparatus include convective, similar to the conventional heat gun, or radiant. The attributes of both are

shown in Table 1. The convective model is based upon mounting one or more commercially available heat guns in the back of the TESS shroud. The radiant model is based upon mounting one or more commercially available heat lamps in the back of the TESS shroud. Radiant heating was selected as the best method for this application.

Table 1. Heat Source Trade Off

PROPERTY	CONVECTIVE	RADIANT
ease of mounting	requires design and fabrication of bracket	screw mount
noise	loud	silent
heating uniformity	hot spots may require baffles or a very long shroud	hot spots may be lessened by a reflective shroud interior
geometry considerations	allowances must be made for the angled shape of the heat gun handle and outlet	compact and symmetric
load on shroud	air currents on shroud sides and motor rotation may cause vibration and require stiffening	thermal load only

IV. TESS HARDWARE

The TESS materials list is included in Appendix A.1. and a schematic of the device is shown in Figure 2. The shroud is formed from aluminum sheet sheared and broken to the drawing dimensions in Appendix A.2. Pop rivets fasten the shroud components for assembly. A balsa wood frame with 24" internal dimensions is held together with wood glue and wire nails and supports an aluminum screen. The screen serves as a diffuser and has an array of 13 thermocouples interwoven as shown in Figure 3. A thermocouple extension cable connects the thermocouple array to a screw terminal board. During heating the thermocouple voltages on the screw terminal board are measured by a data acquisition board in a personal computer.

V. TESS SOFTWARE

The TESS software controls the heating system data acquisition. This software was written in Microsoft Visual Basic 3.0 Professional and executes in a Microsoft Windows 3.1 or later environment. Temperatures for the 13 thermocouples on the TESS shroud are measured throughout the heating process with user definable frequency and duration. These temperatures are displayed graphically in real time and stored to a comma delimited ASCII text file. Thus, temperature profiles over time may be compared from one experiment to the next to ensure repeatability.

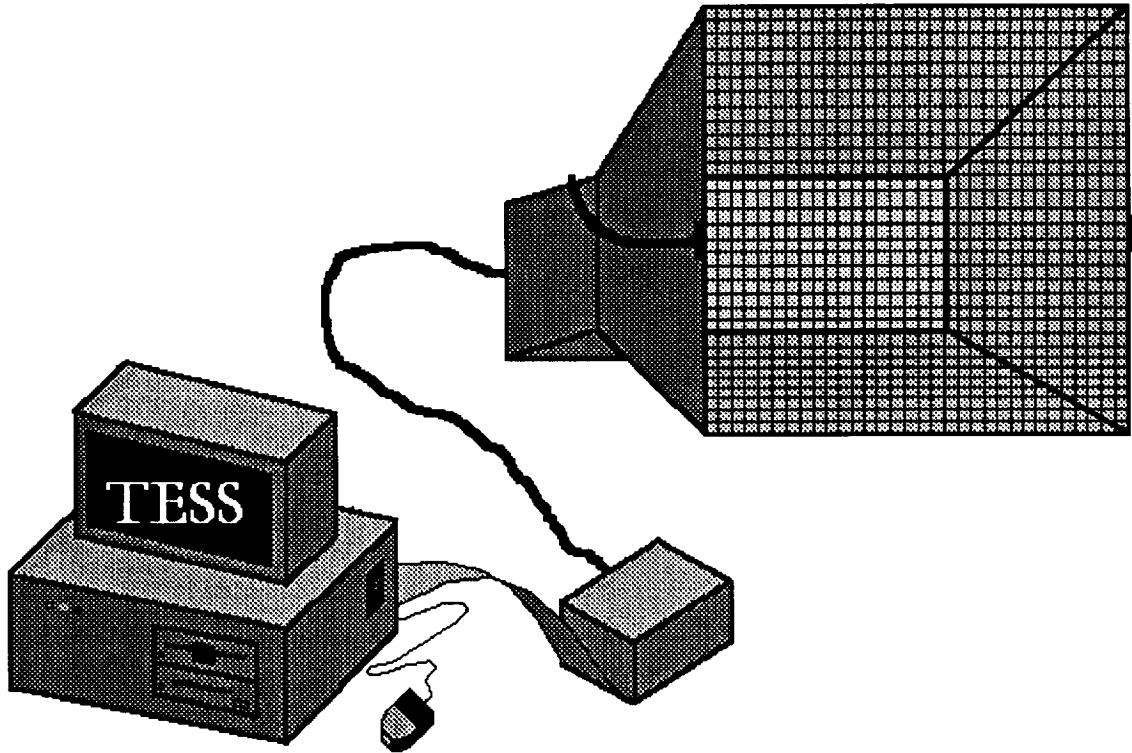


Figure 2. TESS Hardware

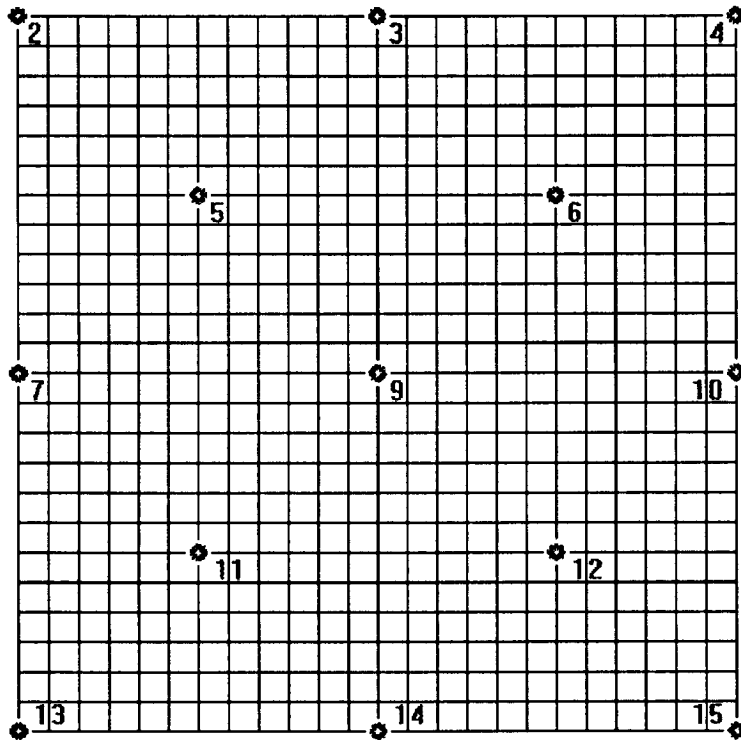


Figure 3. Thermocouple Array Arrangement

VI. PROCEDURES

A. INSTALLATION AND SETUP

1. Install the data acquisition board and drivers as indicated in the manufacturer's manual (National Instruments AT-MIO-6 Hardware Guide)¹.
2. Connect the ribbon cable to the back of the data acquisition board in its expansion slot.
3. Remove the four screws fastening the top on the screw terminal board (STB) enclosure.
4. Connect the ribbon cable to the STB.
5. Replace the top to the STB enclosure and the four screws which hold it in place.
6. Connect the D-shell connectors on the thermocouple extension cable (TEC) to the corresponding connectors on the STB enclosure.
7. Plug in the heat lamp power cords from the back of the TESS shroud to the power strip.
8. Plug the power strip into a standard 120 VAC outlet and make sure the power strip is turned OFF.
9. Insert the TESS software disk and from the Windows File Manager execute the `setup.exe` file.

B. STANDARD OPERATION

1. From the Windows Program Manager select the TESS program group.
2. From the TESS program group double click on the TESS icon.
3. When the About TESS window appears click on the OK button.
4. When the Welcome to TESS window appears enter the appropriate user identification. This can be any combination of alphanumeric characters which may later be used to identify the test operator. The user ID will be included in calibration and data files for future reference. When the user ID has been entered, click on the OK button. Clicking on the CANCEL button will discontinue execution of the TESS program.

¹ It is recommended that computer power be turned off while inserting boards or making any electrical connections in the TESS hardware.

5. When the Load TESS Calibration window appears, select the appropriate calibration file then click on the OK button. An example calibration file named `tess_cal.txt` is provided. If a new calibration is desired, click on the CANCEL button.
6. When the TESS Calibration window appears it will display the calibration data from the previously selected calibration file or remains blank if no file was loaded. Click on the FINISHED button to use this calibration or follow the procedure outlined in section VI.C.3. through VI.C.13 to recalibrate.
7. When the TESS main window appears select the appropriate scale units, Fahrenheit or Celsius degrees, by clicking on either the F or C radio button.
8. Place the specimen to be inspected in the desired position in view of the shearography camera.
9. Start up the shearography apparatus as for any other inspection.
10. Place the TESS shroud in front of the specimen with the diffuser screen frame against the specimen surface to be inspected.
11. On the TESS main window select the desired duration and sampling period to be used during heating the specimen.
12. Turn ON the heat lamp power strip and click on the ACQUIRE button. The TESS software will begin data acquisition. The TESS main window will plot the thermocouple array temperature values in real time. The TESS Profile window will display the temperature distribution over the thermocouple positions as each data series is acquired. This display is color indexed with increasing temperature from blue to yellow, orange, and red. The relative position of each indicator corresponds to the thermocouple arrangement as viewed from the diffuser screen toward the heat lamps.
13. When the selected duration has expired, the TESS software will beep an alarm. Turn OFF the heat lamp power strip.
14. Remove the TESS shroud from the specimen and place it outside the shearography camera field of view.
15. Conduct shearography inspections, acquiring reference images and monitoring deformation as the specimen cools.
16. As prompted by the TESS software Save TESS Log window, enter the file name for the temperature log to be saved, then click on the OK button.
17. If the TESS computer is connected to a printer the temperature profile plot on the TESS main window may be printed by clicking on the PRINT button. The graph will be

sent to the default printer selected in the Windows Print Manager. A color printer is suggested as it may be difficult to interpret which line on the graph corresponds to which channel on a black and white printer.

18. When TESS operation is completed, click on the EXIT button on the TESS main window to terminate program execution.

C. CALIBRATION

1. Click on the CALIBRATE button.
2. As requested, enter the number of calibration points desired. This is the number of different temperatures which will be used for calibration. More calibration points result in higher accuracy for subsequent measurements.
3. When the TESS Calibration window appears enter the number of samples per calibration temperature. The TESS software will acquire this number of measurements at each calibration temperature and average the results. A typical value is 20.
4. The TESS Calibration window features a spreadsheet grid in the center. Each row corresponds to a different calibration temperature. The first column corresponds to the standard or true temperature. The second column will contain the uncalibrated measured value for the corresponding temperature. The third column will contain the calibrated measured value for the corresponding temperature. Select the first column in the first row.
5. Expose the center thermocouple in the TESS thermocouple array to the first standard temperature such as the output from a heat gun.
6. Enter the value for the first standard temperature. A thermometer or hand held thermocouple and readout may be used as a reference. Editing of the standard temperature value input occurs in the text box labeled DATA which is just above the spreadsheet grid and has green numbers on a black background. The spreadsheet grid is updated as the data is entered.
7. Click on the SAMPLE button. As mentioned in VI.C.3. above, the TESS software will automatically acquire the selected number of samples and average the results to determine the uncalibrated measured value. This value will appear in the second column of the first row.
8. Expose the center thermocouple in the TESS thermocouple array to the subsequent standard temperatures and repeat steps VI.C.6. and VI.C.7. until measurements have been acquired for all remaining calibration temperatures. For example allow the center thermocouple to return from the heat gun temperature to room temperature, enter the

standard temperature value indicated by the reference hand held thermocouple readout, and sample the uncalibrated measured value.

9. When all calibration temperature values have been sampled the first two columns of all rows in the calibration spreadsheet grid should contain values. Click on the CALCULATE button. The TESS software will calculate the appropriate calibration coefficients and fill in the third column of the calibration spreadsheet grid with calibrated measured values. The calibration algorithm is essentially a curve fit. The uncalibrated measured values may be plotted against the standard temperature values as discrete values. The calibration curve is a continuous function fit to these points by linear regression. The calibrated measured values correspond to points on the calibration curve at the standard temperature values. The closer these calibrated measured values are to the standard temperature values the closer the calibration curve lies to the discrete points at the measured uncalibrated values and the better the curve fit.

10. Click on the SAVE button.

11. When the Save Calibration window appears enter the file name and click on the OK button.

12. When the TESS Calibration window reappears click on the FINISHED button to return to the TESS main window.

13. The TESS software is now fully calibrated and will not need to be recalibrated unless the software is exited or closed, or if ambient conditions vary considerably. If the TESS application is shut down or restarted the LOAD button on the TESS Calibration window may be used to recall a saved calibration file and avoid recalibration.

VII. EXPERIMENTATION

A. HEAT FLUX MEASUREMENT

The heat flux during thermal stressing with a heat gun for a graphite-epoxy panel was investigated by instrumenting the panel with thermocouples. The convective heat flux into the specimen was measured by comparing the temperature of the heat gun, 399°C (750°F), with the surface temperature of the panel, 104°C (220°F). The convective heat transfer may be expressed as $q/A = h(T_1 - T_0)$ where q/A is the heat flux, h is the convective heat transfer coefficient, T_0 is the heat gun temperature, and T_1 is the panel front surface temperature. The convective heat flux is thus proportional to the temperature difference of 295°C (563°F). The conductive heat flux through the specimen was measured by comparing the temperatures of the panel front, 104°C (220°F), and back, 29°C (84°F). The conductive heat transfer may be approximated as $q/A = k(T_1 - T_2)/t$ where k is the conductive heat transfer coefficient, and T_2 is the panel back surface temperature. The conductive heat flux is thus proportional to the temperature difference of 75°C (167°F).

B. COOLING RATE

The same graphite-epoxy panel was heated again for five minutes with the TESS apparatus. Cooling was then allowed in ambient conditions, 23°C (73°F), as would be done during shearography inspection. A thermocouple on the front of the panel was used to record the surface temperature during the cooling process. The panel temperature dropped from 30°C (86°F) to 23°C (74°F) in 6 minutes, resulting in a cooling rate of 1.2°C (2°F) per minute.

C. DEMONSTRATION

To demonstrate the effectiveness of the TESS apparatus and methods, the system was used for the inspection of a segment from a composite nose cone. This test article was produced in the development of a composite nose cone for the space shuttle external fuel tank. The segment represents a radial wedge of the nose cone including a rectangular cutout with rounded corners. Heat was applied for a duration of 6 minutes, during which the maximum surface temperature was 49°C (120°F). The shearogram shown in Figure 4. was obtained during subsequent cooling with a horizontal image shearing distance of 2.5 cm (1 inch). The white rectangular region is the background showing through the cutout. The uniform dark appearance of the specimen in the shearogram indicates that no anomalies in the deformation pattern were produced by heating. This result demonstrates that the TESS apparatus is not likely to produce false calls during shearography inspection.

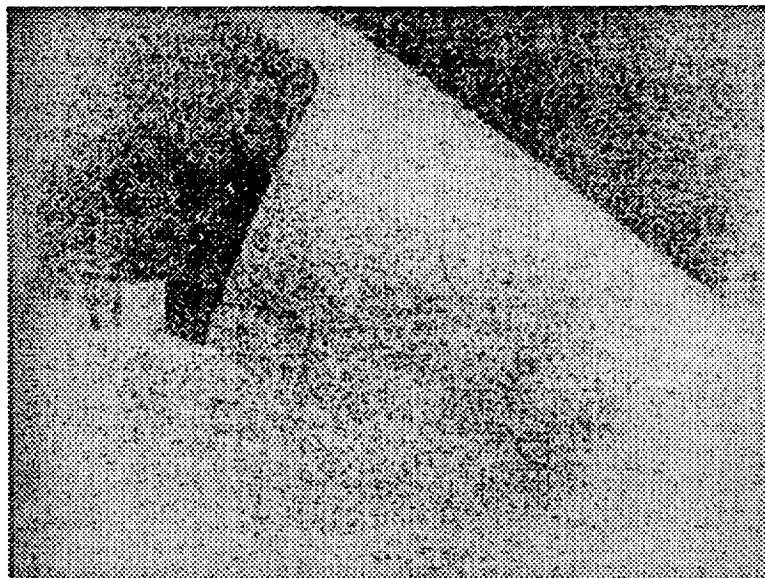


Figure 4. Shearography inspection of a composite nose cone wedge using TESS heating.

VII. SYSTEM INTEGRATION

Integration of the TESS methodology is outlined in the procedures of section VI. The electronic shearography system in use at the MSFC NDE laboratory operates in a DOS environment, and thus is not multi-tasking. If the system was updated from the

current 80386 series processor and provided more memory than the current 4 MB RAM and 30 MB hard drive, then it would be possible to execute the shearography software in a DOS window in a Windows environment. This would allow TESS operation on the shearography system's core PC. Operation would be enhanced by a Windows based software package incorporating both shearography and TESS functions. Currently, TESS operations are conducted on a PC separate from the shearography system. While this stand alone operation is not optimum for mobility and ease of use, it is quite acceptable and does offer the advantage of TESS application with any shearography system or other NDE technology such as thermography.

APPENDIX

A.1. MATERIALS LIST

ITEM #	DESCRIPTION	QUANTITY
1	Aluminum Sheet, 6061-T6 (4' × 8' × 0.025")	1
2	Aluminum Pop Rivets	
3	Balsa Wood (0.5" × 0.5" × 36")	8
4	Wire Nails (17 × 1)	28
5	Aluminum Window Screen (25" × 25")	1
6	Data Acquisition Board, 12 bit, 16 single end channels [<i>National Instruments AT-MIO-6</i>]	1
7	Screw Terminal Board [<i>National Instruments SC-207X</i>]	1
8	Steel Enclosure (3 1/16" × 8 1/4" × 6 1/8") [<i>Radio Shack 270-274</i>]	1
9	Barrier Strip, 8 Position, Dual Row [<i>Radio Shack 274-670</i>]	2
10	Thermocouples (Type J) 36" × 36 AWG [<i>Omega 5TC-TT-J-36-36</i>]	13
11	D-Shell Thermocouple Connector Set (15 pin) [<i>Omega SMTC-15MF</i>]	2
12	Thermocouple Pins (Iron) [<i>Omega SMTC-IR-P</i>]	15
13	Thermocouple Sockets (Iron) [<i>Omega SMTC-IR-S</i>]	15
14	Thermocouple Pins (Constantan) [<i>Omega SMTC-CO-P</i>]	15
15	Thermocouple Sockets (Constantan) [<i>Omega SMTC-CO-S</i>]	15
16	Multipair Thermocouple Extension Cable (Type J) 16 twisted pairs, 20 AWG × 12' [<i>Omega 16-JX-20-PP</i>]	1

A.2. SOURCE CODE

A.2.1. TESS PROJECT FILE

Filename: tess.mak

```

ABT_TESS.FRM
C:\NIDAQWIN\VB_EX\WDAQ_VB.BAS
TESS.BAS
C:\NIDAQWIN\VB_EX\NIDAQCNS.INC
C:\WINDOWS\SYSTEM\GRAPH.VBX
C:\WINDOWS\SYSTEM\GRID.VBX
C:\WINDOWS\SYSTEM\CMDIALOG.VBX
TESSMAIN.FRM
TESS_CAL.FRM
TESS_PRO.FRM
ProjWinSize=189,809,179,566
ProjWinShow=2
IconForm="Frm_Tess"
Title="TESS"
ExeName="TESS.EXE"
Path=".."

```

A.2.2. ABOUT TESS WINDOW

Filename: abt_tess.frm

```

Begin Form Frm_About
  BorderStyle      = 3 'Fixed Double
  Caption          = "About TESS"
  ClientHeight     = 3075
  ClientLeft       = 5220
  ClientTop        = 4305
  ClientWidth      = 4920
  Height           = 3480
  Icon             = ABT_TESS.FRX:0000
  Left             = 5160
  LinkTopic        = "Form2"
  ScaleHeight      = 205
  ScaleMode        = 3 'Pixel
  ScaleWidth       = 328
  Top              = 3960
  Width            = 5040
  Begin PictureBox PictureBox1
    AutoSize       = -1 'True
    BorderStyle    = 0 'None
    Height         = 480
    Left           = 960
    Picture        = ABT_TESS.FRX:0302
    ScaleHeight    = 480
    ScaleWidth     = 480
    TabIndex       = 8
    Top            = 600
    Width          = 480
  End
End

```

```
Begin CommandButton Btn_OK_About
  Caption      = "OK"
  Height       = 375
  Left         = 1920
  TabIndex     = 6
  Top          = 2640
  Width        = 1215
End

Begin Label Label7
  Alignment    = 2 'Center
  Caption      = "Property of"
  Height       = 255
  Left         = 0
  TabIndex     = 7
  Top          = 2040
  Width        = 4935
End

Begin Label Label6
  Alignment    = 2 'Center
  Caption      = "Thermal Excitation System for Shearography"
  FontBold     = -1 'True
  FontItalic   = 0 'False
  FontName     = "MS Sans Serif"
  FontSize     = 9.75
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
  Height       = 255
  Left         = 0
  TabIndex     = 5
  Top          = 1200
  Width        = 4935
End

Begin Label Label5
  Alignment    = 2 'Center
  Caption      = "TESS"
  FontBold     = -1 'True
  FontItalic   = 0 'False
  FontName     = "Arial"
  FontSize     = 24
  FontStrikethru = 0 'False
  FontUnderline = 0 'False
  Height       = 615
  Left         = 0
  TabIndex     = 4
  Top          = 600
  Width        = 4935
End

Begin Label Label4
  Alignment    = 2 'Center
  Caption      = "Research Institute"
  Height       = 255
  Left         = 0
  TabIndex     = 3
  Top          = 360
  Width        = 4935
End
```



```

Begin Label Label3
  Alignment      = 2 'Center
  Caption        = "Version 1.0      10 May 1996"
  Height         = 255
  Left           = 0
  TabIndex       = 2
  Top            = 1560
  Width          = 4935
End

Begin Label Label2
  Alignment      = 2 'Center
  Caption        = "University of Alabama in Huntsville"
  Height         = 255
  Left           = 0
  TabIndex       = 1
  Top            = 120
  Width          = 4935
End

Begin Label Label1
  Alignment      = 2 'Center
  Caption        = "NASA Marshall Space Flight Center"
  Height         = 255
  Left           = 0
  TabIndex       = 0
  Top            = 2280
  Width          = 4935
End
End

Sub Btn_OK_About_Click ()
  User$ = InputBox("Please enter user ID", "Welcome to TESS",
"Lansing")
  If User$ = "" Then
    End
  Else
    Frm_About.Visible = False
    Frm_Calib.Visible = True
    Frm_Calib.CMD_Save.Filename = "TESS_CAL.TXT"
    'Frm_Calib.CMD_Save.Index = 1
    Frm_Calib.CMD_Load.Filename = "C:\TESS\TESS_CAL.TXT"
    'Frm_Calib.CMD_Load.Filetitle = "TESS_CAL.TXT"
    NumCal% = 4
    Frm_Calib.Grd_Calib.ColWidth(0) = 500
    Frm_Calib.Grd_Calib.ColWidth(1) = 1500
    Frm_Calib.Grd_Calib.ColWidth(2) = 1500
    Frm_Calib.Grd_Calib.ColWidth(3) = 1500
    Frm_Calib.Grd_Calib.Rows = NumCal% + 1
    Frm_Calib.Grd_Calib.Row = 0
    Frm_Calib.Grd_Calib.Col = 3
    Frm_Calib.Grd_Calib.Text = "Adjusted"
    Frm_Calib.Grd_Calib.Col = 2
    Frm_Calib.Grd_Calib.Text = "Measured"
    Frm_Calib.Grd_Calib.Col = 1
    Frm_Calib.Grd_Calib.Text = "Standard"
    Frm_Calib.Grd_Calib.Col = 0
    Frm_Calib.Grd_Calib.Text = ""
    For i% = 1 To NumCal%

```

```

        Frm_Calib.Grd_Calib.Row = i%
        Frm_Calib.Grd_Calib.Text = Str$(i%)
    Next i%
    'Grd_Calib.Refresh
    Frm_Calib.SetFocus
    Frm_Calib.Btn_LoadCalib.Value = True
End If
End Sub

Sub Form_Click ()
    Label1.Visible = True
    Label2.Visible = True
    Label3.Visible = True
    Label4.Visible = True
    Label5.Visible = True
    Label6.Visible = True
    Frm_About.Picture = LoadPicture(none)
End Sub

Sub Label5_DblClick ()
    Label1.Visible = False
    Label2.Visible = False
    Label3.Visible = False
    Label4.Visible = False
    Label5.Visible = False
    Label6.Visible = False
    Frm_About.Picture = LoadPicture("c:\do-142\tess\about.bmp")
End Sub

```

A.2.3. TESS CALIBRATION WINDOW

Filename: tess_cal.txt

```

Begin Form Frm_Calib
    BackColor      = &H00C0C0C0&
    BorderStyle    = 3 'Fixed Double
    Caption        = "TESS Calibration"
    ClientHeight   = 4785
    ClientLeft     = 4905
    ClientTop      = 3195
    ClientWidth    = 5535
    Height         = 5190
    Icon           = TESS_CAL.FRX:0000
    Left           = 4845
    LinkTopic      = "Form1"
    MaxButton      = 0 'False
    ScaleHeight    = 4785
    ScaleWidth     = 5535
    Top            = 2850
    Width          = 5655
    Begin CommonDialog CMD_Load
        DefaultExt  = ".txt"
        DialogTitle = "Load TESS Calibration"
        Filename    = "C:\TESS\TESS_CAL.TXT"
        Filter      = "*.TXT"
        Left        = 3960
        Top         = 1920
    End
End

```

```
Begin CommonDialog CMD_Save
  DefaultExt = ".txt"
  DialogTitle = "Save TESS Calibration"
  Filename = "C:\TESS\TESS_CAL.TXT"
  Filter = "*.txt"
  InitDir = "c:\tess"
  Left = 3240
  Top = 1920
End
Begin CommandButton Btn_LoadCalib
  Caption = "Load"
  Height = 375
  Left = 3360
  TabIndex = 13
  Top = 3720
  Width = 975
End
Begin CommandButton Btn_SaveCalib
  Caption = "Save"
  Height = 375
  Left = 2280
  TabIndex = 12
  Top = 3720
  Width = 975
End
Begin HScrollBar Scr_SampleSize
  Height = 255
  Left = 1920
  Max = 100
  Min = 1
  TabIndex = 8
  Top = 3360
  Value = 20
  Width = 1575
End
Begin CommandButton Btn_Calib
  Caption = "Calculate"
  Height = 375
  Left = 1200
  TabIndex = 5
  Top = 3720
  Width = 975
End
Begin CommandButton Btn_Sample
  Caption = "Sample"
  Height = 375
  Left = 120
  TabIndex = 4
  Top = 3720
  Width = 975
End
Begin Grid Grd_Calib
  Cols = 4
  Height = 2775
  Left = 120
  Rows = 10
  TabIndex = 0
  Top = 480
  Width = 5295
End
```

```
Begin TextBox Txt_Calib
  BackColor      = &H00000000&
  ForeColor      = &H0000FF00&
  Height         = 285
  Left           = 840
  TabIndex       = 3
  Top            = 120
  Width          = 975
End
Begin CommandButton Btn_Fill
  Caption        = "Fill"
  Height         = 255
  Left           = 3840
  TabIndex       = 2
  Top            = 3360
  Visible        = 0 'False
  Width          = 1575
End
Begin CommandButton Btn_Exit
  Caption        = "Finished"
  Height         = 375
  Left           = 4440
  TabIndex       = 1
  Top            = 3720
  Width          = 975
End
Begin Label Lbl_Status
  Alignment      = 2 'Center
  BackColor      = &H00FF0000&
  BorderStyle    = 1 'Fixed Single
  Caption        = "READY."
  ForeColor      = &H00FFFFFF&
  Height         = 495
  Left           = 840
  TabIndex       = 15
  Top            = 4200
  Width          = 4575
End
Begin Label Label4
  BackColor      = &H00C0C0C0&
  Caption        = "Status"
  Height         = 255
  Left           = 120
  TabIndex       = 14
  Top            = 4200
  Width          = 615
End
Begin Label Label2
  BackColor      = &H00C0C0C0&
  Caption        = "DATA:"
  Height         = 255
  Left           = 120
  TabIndex       = 11
  Top            = 120
  Width          = 615
End
Begin Label Label3
  Alignment      = 2 'Center
  BackColor      = &H00C0C0C0&
  Caption        = "Least Squares Error"
```

```

        Height          = 255
        Left            = 2760
        TabIndex       = 10
        Top            = 120
        Width          = 1695
    End
    Begin Label Lbl_LSE
        Alignment       = 2 'Center
        BackColor       = &H00000000&
        ForeColor       = &H000000FF&
        Height          = 255
        Left            = 4560
        TabIndex       = 9
        Top            = 120
        Width          = 855
    End
    Begin Label Lbl_SampleSize
        Alignment       = 2 'Center
        BorderStyle     = 1 'Fixed Single
        Caption         = "20"
        Height          = 255
        Left            = 1320
        TabIndex       = 7
        Top            = 3360
        Width          = 495
    End
    Begin Label Label1
        BackColor       = &H00C0C0C0&
        Caption         = "Sample Size"
        Height          = 255
        Left            = 120
        TabIndex       = 6
        Top            = 3360
        Width          = 1095
    End
End
End

Dim z!(3)

Sub Btn_Calib_Click ()
    Lbl_Status.Caption = "Calculating Calibration Coefficients..."
    SumX! = 0!
    SumY! = 0!
    SumX2! = 0!
    SumXY! = 0!
    For i% = 1 To NumCal%
        Grd_Calib.Row = i%
        Grd_Calib.Col = 2
        x! = Val(Grd_Calib.Text)
        Grd_Calib.Col = 1
        y! = Val(Grd_Calib.Text)
        SumX! = SumX! + x!
        SumY! = SumY! + y!
        SumXY! = SumXY! + (x! * y!)
        SumX2! = SumX2! + (x! * x!)
    Next i%
    mXY! = (NumCal% * SumXY!) - (SumX! * SumY!)
    mXY! = mXY! / ((NumCal% * SumX2!) - (SumX! * SumX!))
    bXY! = (SumY! - (mXY! * SumX!)) / NumCal%
    ff! = 0!
End Sub

```

```

For i% = 1 To NumCal%
    Grd_Calib.Row = i%
    Grd_Calib.Col = 2
    x! = Val(Grd_Calib.Text)
    Grd_Calib.Col = 1
    y! = Val(Grd_Calib.Text)
    Grd_Calib.Col = 3
    y0! = bXY! + (mXY! * x!)
    Grd_Calib.Text = y0!
    ff! = ff! + ((y! - y0!) ^ 2)
Next i%
Lbl_LSE.Caption = Left$(Str$(Sqr(ff!)), 6)
Lbl_Status.Caption = "Calibration Coefficients Calculated.  READY."
MsgBox "m =" + Str$(mXY!) + ", b =" + Str$(bXY!)
End Sub

Sub Btn_Exit_Click ()
'Mess$ = "End Calibration and Return to TESS?"
'Query% = MsgBox(Mess$, 4, "Confirm Completed Calibration")
'If Query% = 6 Then
    Frm_Calib.Visible = False
    Frm_Tess.Visible = True
    Frm_Tess.SetFocus
'End If
End Sub

Sub Btn_Fill_Click ()
For i% = 1 To 2
    Grd_Calib.Col = i%
    For j% = 1 To NumCal%
        Grd_Calib.Row = j%
        Grd_Calib.Text = Str$(Int(100 * Rnd))
    Next j%
Next i%
End Sub

Sub Btn_LoadCalib_Click ()
Lbl_Status.Caption = "Loading Calibration Log..."
CMD_Load.DialogTitle = "Load TESS Calibration"
CMD_Load.FileName = ""
CMD_Load.Filter = "*.txt|*.txt"
CMD_Load.Action = 1
If CMD_Load.FileName <> "" Then
    Open CMD_Load.FileName For Input As #2
    Input #2, Dummy$
'MsgBox Dummy$, 0, "Header"
    Input #2, CalibDate$
'MsgBox CalibDate$, 0, "CalibDate"
    Input #2, OldUser$
'MsgBox OldUser$, 0, "OldUser"
    Input #2, Dummy$
    Input #2, bXY!, mXY!
'MsgBox Str$(bXY!) + " +" + Str$(mXY!) + " * X", 0, "Least Squares"
    Input #2, Dummy$
    Input #2, NumCal%, SSize%, TScale$
    If TScale$ = "F" Then
        Frm_Tess.Rdo_TScale(1).Value = True
    Else
        Frm_Tess.Rdo_TScale(0).Value = True
    End If
End If

```

```

'MsgBox Str$(NumCal%), 0, "NumCal"
'MsgBox Str$(SSize%), 0, "SampleSize"
Scr_SampleSize.Value = SSize%
Grd_Calib.Rows = NumCal% + 1
Input #2, Dummy$
Input #2, Dummy$
For i% = 1 To NumCal%
    Grd_Calib.Row = i%
    Input #2, z!(1), z!(2), z!(3)
    For j% = 1 To 3
        Grd_Calib.Col = j%
        Grd_Calib.Text = Str$(z!(j%))
    Next j%
Next i%
Input #2, Dummy$
Input #2, Dummy$
Lbl_LSE.Caption = Dummy$
Close #2
Lbl_Status.Caption = "Calibration Log (" + CalibDate$ + ", " +
CalibTime$ + ") Loaded.  READY."
Else
    Lbl_Status.Caption = "Calibration Log NOT Loaded.  READY."
End If
End Sub

Sub Btn_Sample_Click ()
'Read Channel #9
VSTemp# = 0#
For j% = 1 To Scr_SampleSize.Value
    er% = AI_VRead(DevNum%, 9, gain%, vv#)
    If er% <> 0 Then
        DAQmess er%
    End If
    VSTemp# = VSTemp# + vv#
Next j%
VTemp# = VSTemp# / Cdbl(Scr_SampleSize.Value)
TTemp# = Tcon#(VTemp#)
If Frm_Tess.Rdo_TScale(1).Value = True Then TTemp# = 1.8 * TTemp# +
32
Grd_Calib.Col = 2
Grd_Calib.Text = Str$(Int(.5 + TTemp#))
End Sub

Sub Btn_SaveCalib_Click ()
Lbl_Status.Caption = "Saving Calibration Log..."
CMD_Save.DialogTitle = "Save TESS Calibration"
CMD_Save.FileName = "tess_cal.txt"
CMD_Save.Filter = "*.txt|*.txt"
CMD_Save.Action = 2
Open CMD_Save.FileName For Output As #2
Print #2, "UAH-TESS Calibration"
Print #2, Date$, Time$
Print #2, User$
Print #2, ""
Print #2, bXY!, mXY!
Print #2, ""
TScale$ = "C"
If Frm_Tess.Rdo_TScale(1).Value = True Then TScale$ = "F"
Print #2, NumCal%, Scr_SampleSize.Value, TScale$
Print #2, ""

```

```

Print #2, "Standard", "Measured", "Adjusted"
For i% = 1 To NumCal%
  Grd_Calib.Row = i%
  For j% = 1 To 3
    Grd_Calib.Col = j%
    z!(j%) = Val(Grd_Calib.Text)
  Next j%
  Print #2, z!(1), z!(2), z!(3)
Next i%
Print #2, ""
Print #2, Lbl_LSE.Caption
Close #2
Lbl_Status.Caption = "Calibration Log Saved.  READY."
End Sub

Sub Grd_Calib_DblClick ()
  Txt_Calib.SetFocus
End Sub

Sub Grd_Calib_SelChange ()
  Txt_Calib.Text = Grd_Calib.Text
End Sub

Sub Scr_SampleSize_Change ()
  Lbl_SampleSize.Caption = Str$(Scr_SampleSize.Value)
End Sub

Sub Txt_Calib_Change ()
  Grd_Calib.Text = Txt_Calib.Text
End Sub

```

A.2.4. TESS MAIN WINDOW

Filename: tessmain.frm

```

Begin Form Frm_Tess
  BackColor      = &H00C0C0C0&
  Caption        = "Thermal Excitation System for Shearography
(TESS)"
  ClientHeight   = 8415
  ClientLeft     = 3105
  ClientTop      = 1425
  ClientWidth    = 8895
  Height         = 8820
  Icon           = TESSMAIN.FRX:0000
  Left           = 3045
  LinkTopic      = "Form1"
  ScaleHeight    = 8415
  ScaleWidth     = 8895
  Top            = 1080
  Width          = 9015
  Begin CommandButton Btn_Calib
    BackColor     = &H00C0C0C0&
    Caption       = "CALIBRATE"
    Height        = 375
    Left         = 120
    TabIndex     = 13
    Top          = 7680
  End

```



```

        Width          = 1455
    End
    Begin OptionButton Rdo_TScale
        BackColor      = &H00C0C0C0&
        Caption        = "F"
        Enabled        = 0 'False
        ForeColor      = &H00000000&
        Height         = 255
        Index          = 1
        Left           = 7440
        TabIndex       = 12
        Top            = 7320
        Width          = 495
    End
    Begin OptionButton Rdo_TScale
        BackColor      = &H00C0C0C0&
        Caption        = "C"
        ForeColor      = &H00000000&
        Height         = 255
        Index          = 0
        Left           = 8160
        TabIndex       = 20
        Top            = 7320
        Value          = -1 'True
        Width          = 495
    End
    Begin CommandButton Btn_GraPrint
        BackColor      = &H00C0C0C0&
        Caption        = "PRINT GRAPH"
        Height         = 375
        Left           = 5520
        TabIndex       = 19
        Top            = 7680
        Width          = 1455
    End
    Begin HScrollBar Scr_Freq
        Height         = 255
        LargeChange    = 5
        Left           = 60
        Max            = 60
        Min            = 1
        TabIndex       = 9
        Top            = 7320
        Value          = 1
        Width          = 3495
    End
    Begin HScrollBar Scr_Dur
        Height         = 255
        LargeChange    = 5
        Left           = 3660
        Max            = 30
        Min            = 1
        TabIndex       = 7
        Top            = 7320
        Value          = 1
        Width          = 3495
    End
    Begin CommandButton Btn_Exit
        BackColor      = &H00C0C0C0&
        Caption        = "EXIT"
    End

```

```

    Height      = 375
    Left        = 7320
    TabIndex    = 3
    Top         = 7680
    Width       = 1455
End
Begin CommandButton Btn_Pause
    BackColor   = &H00C0C0C0&
    Caption     = "PAUSE"
    Enabled     = 0 'False
    Height      = 375
    Left        = 3720
    TabIndex    = 2
    Top         = 7680
    Width       = 1455
End
Begin CommandButton Btn_Acquire
    BackColor   = &H00C0C0C0&
    Caption     = "ACQUIRE"
    Height      = 375
    Left        = 1920
    TabIndex    = 1
    Top         = 7680
    Width       = 1455
End
Begin GRAPH Gra_Temp
    AsciiFamily = "0"
    AsciiFSize  = "100~150~100~100"
    AsciiFStyle = "0"
    BottomTitle = "pts"
    DrawMode    = 3 'Blit
    GraphStyle  = 4
    GraphType   = 6 'Line
    GridStyle   = 3 'Horizontal and Vertical
    Height      = 6855
    LabelEvery  = 10
    Left        = 60
    LeftTitle   = "T"
    NumPoints   = 100
    PrintStyle  = 3 'Color with Border
    RandomData  = 0 'Off
    TabIndex    = 0
    ThickLines  = 0 'Off
    TickEvery   = 10
    Top         = 60
    Width       = 8055
    YAxisMax    = 50
    YAxisStyle  = 2 'User-defined
    YAxisTicks  = 10
End
Begin Label Labell
    Alignment   = 2 'Center
    BackColor   = &H00C0C0C0&
    Caption     = "SCALE UNITS"
    Height      = 255
    Left        = 7320
    TabIndex    = 34
    Top         = 7080
    Width       = 1455
End

```

```
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle   = 1 'Fixed Single
  Height        = 255
  Index         = 15
  Left          = 8160
  TabIndex      = 33
  Top           = 6165
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle   = 1 'Fixed Single
  Height        = 255
  Index         = 14
  Left          = 8145
  TabIndex      = 14
  Top           = 5730
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle   = 1 'Fixed Single
  Height        = 255
  Index         = 13
  Left          = 8160
  TabIndex      = 4
  Top           = 5295
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle   = 1 'Fixed Single
  Height        = 255
  Index         = 12
  Left          = 8160
  TabIndex      = 5
  Top           = 4860
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle   = 1 'Fixed Single
  Height        = 255
  Index         = 11
  Left          = 8160
  TabIndex      = 22
  Top           = 4425
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle   = 1 'Fixed Single
  Height        = 255
  Index         = 10
  Left          = 8145
  TabIndex      = 32
  Top           = 4005
  Width         = 675
End
```

```

Begin Label Lbl_Temp
  Alignment      = 2  'Center
  BorderStyle   = 1  'Fixed Single
  Height        = 255
  Index         = 9
  Left          = 8160
  TabIndex      = 31
  Top           = 3555
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2  'Center
  BorderStyle   = 1  'Fixed Single
  Height        = 255
  Index         = 8
  Left          = 8160
  TabIndex      = 30
  Top           = 3105
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2  'Center
  BorderStyle   = 1  'Fixed Single
  Height        = 255
  Index         = 7
  Left          = 8160
  TabIndex      = 29
  Top           = 2700
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2  'Center
  BorderStyle   = 1  'Fixed Single
  Height        = 255
  Index         = 6
  Left          = 8160
  TabIndex      = 28
  Top           = 2250
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2  'Center
  BorderStyle   = 1  'Fixed Single
  Height        = 255
  Index         = 5
  Left          = 8160
  TabIndex      = 27
  Top           = 1800
  Width         = 675
End
Begin Label Lbl_Temp
  Alignment      = 2  'Center
  BorderStyle   = 1  'Fixed Single
  Height        = 255
  Index         = 4
  Left          = 8145
  TabIndex      = 26
  Top           = 1350
  Width         = 675
End

```

```
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle    = 1 'Fixed Single
  Height         = 255
  Index          = 3
  Left           = 8160
  TabIndex       = 25
  Top            = 900
  Width          = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle    = 1 'Fixed Single
  Height         = 255
  Index          = 2
  Left           = 8160
  TabIndex       = 24
  Top            = 480
  Width          = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle    = 1 'Fixed Single
  Height         = 255
  Index          = 1
  Left           = 8220
  TabIndex       = 23
  Top            = 240
  Visible        = 0 'False
  Width          = 675
End
Begin Label Lbl_Temp
  Alignment      = 2 'Center
  BorderStyle    = 1 'Fixed Single
  Height         = 255
  Index          = 0
  Left           = 8160
  TabIndex       = 21
  Top            = 120
  Visible        = 0 'False
  Width          = 675
End
Begin Label Lbl_Freq
  Alignment      = 2 'Center
  BorderStyle    = 1 'Fixed Single
  Caption        = "1"
  Height         = 255
  Left           = 1980
  TabIndex       = 18
  Top            = 7020
  Width          = 735
End
Begin Label Lbl_Dur
  Alignment      = 2 'Center
  BorderStyle    = 1 'Fixed Single
  Caption        = "1"
  Height         = 255
  Left           = 5580
  TabIndex       = 17
  Top            = 7020
```

```
        Width          = 735
End
Begin Label Lbl_Status
    Alignment          = 2 'Center
    BackColor          = &H00FF0000&
    BorderStyle        = 1 'Fixed Single
    Caption            = "READY."
    ForeColor          = &H00FFFFFF&
    Height             = 255
    Left               = 900
    TabIndex           = 16
    Top                = 8100
    Width              = 7935
End
Begin Label Label8
    BackColor          = &H00C0C0C0&
    Caption            = "STATUS"
    Height             = 195
    Left               = 60
    TabIndex           = 15
    Top                = 8100
    Width              = 750
End
Begin Label Label5
    BackColor          = &H00C0C0C0&
    Caption            = "minutes"
    Height             = 255
    Left               = 6360
    TabIndex           = 11
    Top                = 7020
    Width              = 735
End
Begin Label Label4
    BackColor          = &H00C0C0C0&
    Caption            = "sec/pt"
    Height             = 255
    Left               = 2820
    TabIndex           = 10
    Top                = 7020
    Width              = 735
End
Begin Label Label3
    BackColor          = &H00C0C0C0&
    Caption            = "SAMPLE PERIOD"
    Height             = 255
    Left               = 60
    TabIndex           = 8
    Top                = 7020
    Width              = 1815
End
Begin Label Label2
    BackColor          = &H00C0C0C0&
    Caption            = "SAMPLE DURATION"
    Height             = 255
    Left               = 3660
    TabIndex           = 6
    Top                = 7020
    Width              = 1875
End
End
```

```

Dim z!(3)

Sub Btn_Acquire_Click ()
  'Initialize Controls
  Btn_Pause.Enabled = True
  Frm_Profile.Visible = True
  Frm_Tess.SetFocus
  'LastChann% = NumChann% - 1
  Lbl_Status.Caption = "Initializing..."
  Lbl_Status.Refresh
  Btn_Acquire.Enabled = False
  Btn_GraPrint.Enabled = False
  Rdo_TScale(0).Enabled = False
  Rdo_TScale(1).Enabled = False
  Scr_Dur.Enabled = False
  Scr_Freq.Enabled = False
  Gra_Temp.GraphTitle = ""
  Gra_Temp.NumSets = 14
  Gra_Temp.AutoInc = 1      'True
  For i% = 2 To 15
    Gra_Temp.LegendText = Str$(i%)  'DEAD 8
  Next i%
  Gra_Temp.AutoInc = False
  Gra_Temp.DrawMode = 3
  NumPts% = 1 + Int(Scr_Dur.Value * 60 / Scr_Freq.Value)
  Gra_Temp.NumPoints = NumPts%
  'Clear Graph Data
  For i% = 2 To 15
    If i% <> 8 Then  'DEAD 8
      'Chann%(i%) = i%
      Gra_Temp.ThisSet = i% - 1
      For j% = 1 To NumPts%
        Gra_Temp.ThisPoint = j%
        Gra_Temp.GraphData = 0
      Next j%
    End If
  Next i%
  Gra_Temp.TickEvery = Int(NumPts% / 10)
  Gra_Temp.LabelEvery = Int(NumPts% / 10)
  If Rdo_TScale(0) = True Then
    Gra_Temp.YAxisMax = 100
    Gra_Temp.LeftTitle = "C"
    TScale$ = "C"
  Else
    Gra_Temp.YAxisMax = 200
    Gra_Temp.LeftTitle = "F"
    TScale$ = "F"
  End If
  'Initialize Output Log
  Open LogFileName$ For Output As #1
  Print #1, "UAH-TESS Data Log"
  Print #1, Date$, Time$, TScale$
  Print #1, User$
  Print #1, ""
  Print #1, "Time";
  For i% = 2 To 15
    If i% <> 8 Then Print #1, ", "; i%;  'DEAD 8
  Next i%
  Print #1, ""
  'Begin DAQ Loop

```

```

Gra_Temp.DrawMode = 3
Gra_Temp.Refresh
StartTime$ = Time$
OldTime# = Timer
FirstTime# = OldTime#
NewTime# = 0#
For i% = 1 To NumPts%
    Lbl_Status.Caption = "Acquiring (" + Str$(i%) + "/" +
Str$(NumPts%) + ")..."
    If PauseFlag% = True Then
        i% = i% - 1
    Else
        min% = 100
        max% = -100
        While (NewTime# < (Cdbl(Int(OldTime#) + Scr_Freq.Value)))
            NewTime# = Timer                'Wait Loop
        Wend
        For k% = 2 To 15                    'Step Through Channels
            If k% <> 8 Then                  'DEAD 8
                VoltSum#(k%) = 0#
                For j% = 1 To NumAve%      'Average Several
                    er% = AI_VRead(DevNum%, k%, gain%, v#) 'DAQ
                    If er% <> 0 Then
                        DAQmess er%
                    End If
                    VoltSum#(k%) = VoltSum#(k%) + v#
                Next j%
                Volts#(k%) = VoltSum#(k%) / Cdbl(NumAve%)
                Temp#(k%) = bXY! + mXY! * Tcon#(Volts#(k%))
                If Rdo_TScale(1).Value = True Then Temp#(k%) = 1.8 *
Temp#(k%) + 32
            End If
        Next k%
        Gra_Temp.ThisPoint = i%
        For k% = 2 To 15
            If k% <> 8 Then 'DEAD 8
                Gra_Temp.ThisSet = k% - 1
                Gra_Temp.GraphData = Temp#(k%)
                CurVal% = Int(Temp#(k%) + .5)
                Lbl_Temp(k%).Caption = Str$(CurVal%)
                Frm_Profile.Lbl_Profile(k% - 2).Caption =
Str$(CurVal%)
                If CurVal% > max% Then max% = CurVal%
                If CurVal% < min% Then min% = CurVal%
            End If
        Next k%
        Print #1, ""
        Gra_Temp.DrawMode = 3
        OldTime# = NewTime#
        If i% = 1 Then FirstTime# = OldTime#
        Print #1, ((NewTime# - FirstTime#)); ", ";
        For k% = 2 To 15
            If k% <> 8 Then Print #1, Temp#(k%); ", "; 'DEAD 8
        Next k%
        Print ""
        delta% = max% - min%
        For ii% = 0 To 13
            Select Case (Int(3 *
(Val(Frm_Profile.Lbl_Profile(ii%).Caption) - min%) / delta% + .5))

```



```

                                Case 0
                                Frm_Profile.Lbl_Profile(ii%).BackColor = RGB(0,
0, 255)
                                Case 1
                                Frm_Profile.Lbl_Profile(ii%).BackColor =
RGB(255, 255, 0)
                                Case 2
                                Frm_Profile.Lbl_Profile(ii%).BackColor =
RGB(255, 128, 0)
                                Case 3
                                Frm_Profile.Lbl_Profile(ii%).BackColor =
RGB(255, 0, 0)
                                Case 4
                                Frm_Profile.Lbl_Profile(ii%).BackColor =
RGB(255, 255, 255)
                                End Select
                                Next ii%
                                Frm_Tess.Refresh
                                Frm_Profile.Refresh
                                End If
                                DoEvents
                                Next i%
                                'End DAQ Loop
                                Close #1
                                Gra_Temp.GraphTitle = Date$ + " " + StartTime$ + " to " + Time$
                                Gra_Temp.DrawMode = 3
                                Lbl_Status.Caption = "Data Acquisition Complete. READY."
                                Rdo_TScale(0).Enabled = True
                                Rdo_TScale(1).Enabled = True
                                Btn_Acquire.Enabled = True
                                Btn_GraPrint.Enabled = True
                                Scr_Dur.Enabled = True
                                Scr_Freq.Enabled = True
                                Beep
                                Frm_Calib.CMD_Save.DialogTitle = "Save TESS Data Log"
                                Frm_Calib.CMD_Save.FileName = LogFileName$
                                Frm_Calib.CMD_Save.Filter = "*.csv|*.csv"
                                Frm_Calib.CMD_Save.DefaultExt = "csv"
                                Frm_Calib.CMD_Save.Action = 2 'cancel crashes
                                'MsgBox "LOG:" + LogFileName$ + " FORM:" +
Frm_Calib.CMD_Save.FileName, 0, "FileName Difference?"
                                If ((Len(Frm_Calib.CMD_Save.FileName) > 0) And
(Frm_Calib.CMD_Save.FileName <> LogFileName$)) Then
                                    FileCopy LogFileName$, Frm_Calib.CMD_Save.FileName
                                End If
                                End Sub

Sub Btn_Calib_Click ()
    Dummy$ = InputBox$("Enter the number of calibration points to be
used, or select cancel.", "Confirm TESS Calibration", "3")
    If Dummy$ <> "" Then
        NumCal% = Int(Val(Dummy$))
        Frm_Calib.Grd_Calib.ColWidth(0) = 500
        Frm_Calib.Grd_Calib.ColWidth(1) = 1500
        Frm_Calib.Grd_Calib.ColWidth(2) = 1500
        Frm_Calib.Grd_Calib.ColWidth(3) = 1500
        Frm_Calib.Grd_Calib.Rows = NumCal% + 1
        Frm_Calib.Grd_Calib.Row = 0
        Frm_Calib.Grd_Calib.Col = 3
        Frm_Calib.Grd_Calib.Text = "Adjusted"
    End If
End Sub

```

```

    Frm_Calib.Grd_Calib.Col = 2
    Frm_Calib.Grd_Calib.Text = "Measured"
    Frm_Calib.Grd_Calib.Col = 1
    Frm_Calib.Grd_Calib.Text = "Standard"
    Frm_Calib.Grd_Calib.Col = 0
    Frm_Calib.Grd_Calib.Text = ""
    For i% = 1 To NumCal%
        Frm_Calib.Grd_Calib.Row = i%
        Frm_Calib.Grd_Calib.Text = Str$(i%)
    Next i%
    'Grd_Calib.Refresh
    Frm_Calib.Visible = True
    Frm_Calib.SetFocus
End If
End Sub

Sub Btn_Exit_Click ()
    Close
    er% = DAQ_Clear(DevNum%)
    If (er% <> 0) And (er% <> -74) Then
        DAQmess er%
    End If
    End
End Sub

Sub Btn_GraPrint_Click ()
    Gra_Temp.DrawMode = 5
    Gra_Temp.DrawMode = 3
End Sub

Sub Btn_Pause_Click ()
    If PauseFlag% = False Then
        Btn_Pause.Caption = "RESUME"
        PauseFlag% = True
    ElseIf PauseFlag% = True Then
        Btn_Pause.Caption = "PAUSE"
        PauseFlag% = False
    End If
End Sub

Sub Form_Load ()
    PauseFlag% = False
    'bXY! = 0!
    'mXY! = 1!
    'For i% = 27 To -118 Step -1
    '    DAQmess i%
    'Next i%
    Lbl_Temp(8).Visible = False
End Sub

Sub Gra_Temp_DblClick ()
    Gra_Temp.Refresh
End Sub

Sub Scr_Dur_Change ()
    Lbl_Dur.Caption = Str$(Scr_Dur.Value)
    Gra_Temp.NumPoints = Int(Scr_Dur.Value * Scr_Freq.Value)
End Sub

Sub Scr_Freq_Change ()

```

```

    Lbl_Freq.Caption = Str$(Scr_Freq.Value)
End Sub

```

A.2.5. TESS PROFILE WINDOW

Filename: tess_pro.frm

```

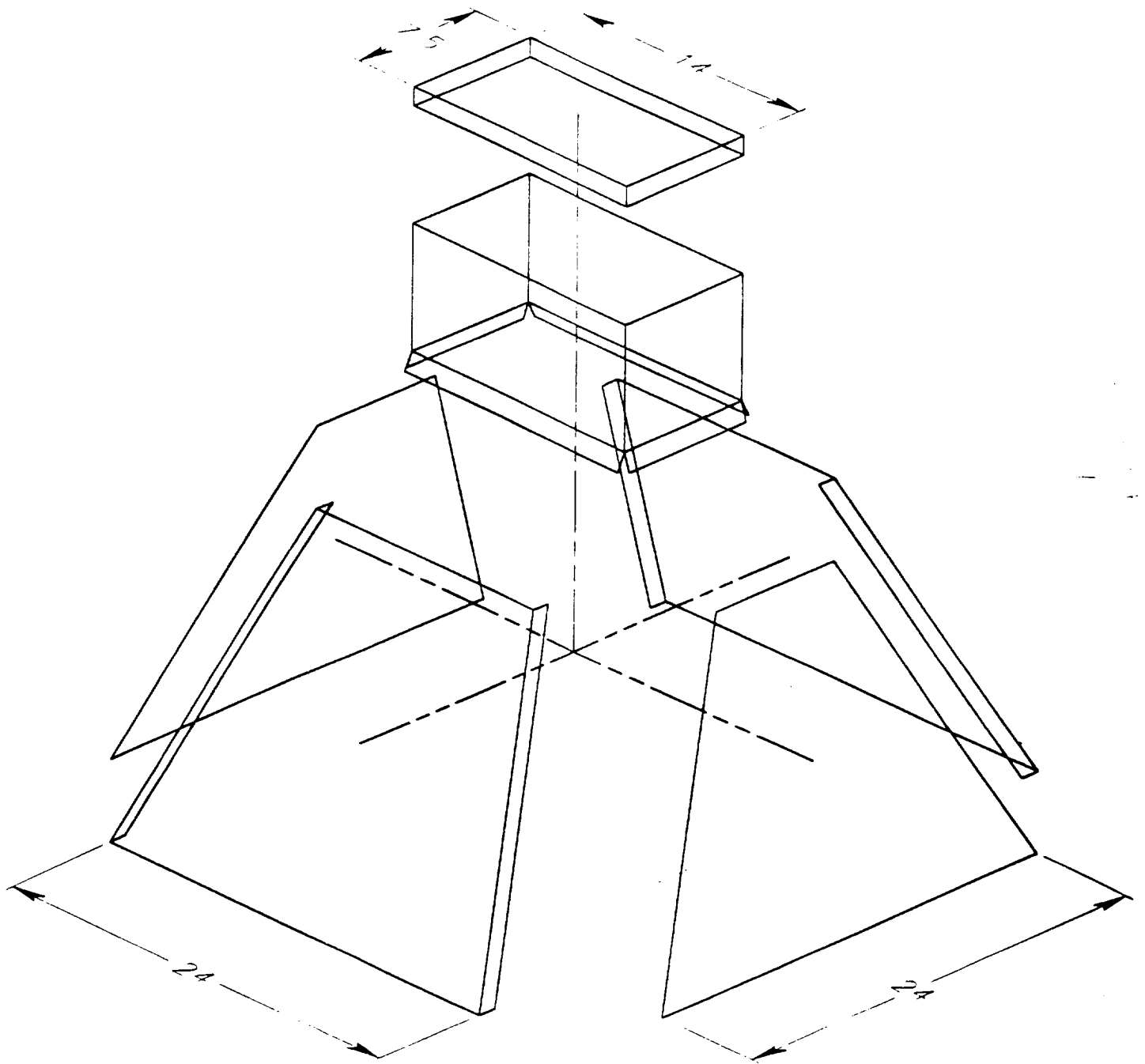
Begin Form Frm_Profile
  BackColor      = &H00C0C0C0&
  BorderStyle    = 3 'Fixed Double
  Caption        = "TESS Profile"
  ClientHeight   = 2535
  ClientLeft     = 12135
  ClientTop      = 1425
  ClientWidth    = 2535
  Height         = 2940
  Left           = 12075
  LinkTopic      = "Form1"
  ScaleHeight    = 2535
  ScaleWidth     = 2535
  Top            = 1080
  Width          = 2655
  Begin Label Lbl_Profile
    BackColor      = &H00000000&
    BorderStyle    = 1 'Fixed Single
    ForeColor      = &H00000000&
    Height         = 375
    Index          = 13
    Left           = 2040
    TabIndex       = 1
    Top            = 2040
    Width          = 375
  End
  Begin Label Lbl_Profile
    BackColor      = &H00000000&
    BorderStyle    = 1 'Fixed Single
    ForeColor      = &H00000000&
    Height         = 375
    Index          = 1
    Left           = 1080
    TabIndex       = 2
    Top            = 120
    Width          = 375
  End
  Begin Label Lbl_Profile
    BackColor      = &H00000000&
    BorderStyle    = 1 'Fixed Single
    ForeColor      = &H00000000&
    Height         = 375
    Index          = 12
    Left           = 1080
    TabIndex       = 3
    Top            = 2040
    Width          = 375
  End
  Begin Label Lbl_Profile
    BackColor      = &H00000000&
    BorderStyle    = 1 'Fixed Single

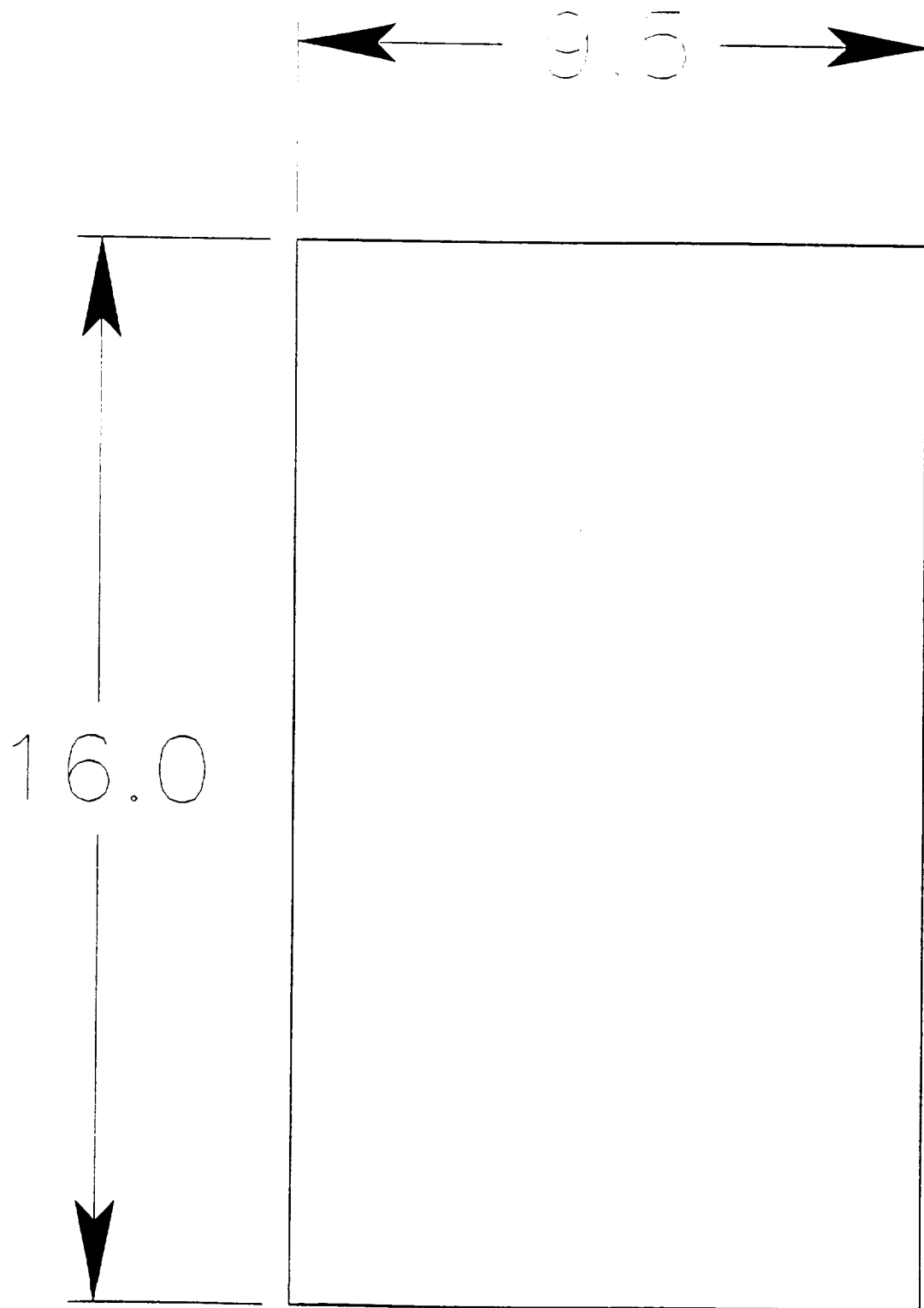
```

```
    ForeColor      =    &H00000000&
    Height         =    375
    Index          =    11
    Left           =    120
    TabIndex       =    4
    Top            =    2040
    Width          =    375
End
Begin Label Lbl_Profile
    BackColor      =    &H00000000&
    BorderStyle    =    1 'Fixed Single
    ForeColor      =    &H00000000&
    Height         =    375
    Index          =    10
    Left           =    1560
    TabIndex       =    13
    Top            =    1560
    Width          =    375
End
Begin Label Lbl_Profile
    BackColor      =    &H00000000&
    BorderStyle    =    1 'Fixed Single
    ForeColor      =    &H00000000&
    Height         =    375
    Index          =    9
    Left           =    600
    TabIndex       =    12
    Top            =    1560
    Width          =    375
End
Begin Label Lbl_Profile
    BackColor      =    &H00000000&
    BorderStyle    =    1 'Fixed Single
    ForeColor      =    &H00000000&
    Height         =    375
    Index          =    8
    Left           =    2040
    TabIndex       =    11
    Top            =    1080
    Width          =    375
End
Begin Label Lbl_Profile
    BackColor      =    &H00000000&
    BorderStyle    =    1 'Fixed Single
    ForeColor      =    &H00000000&
    Height         =    375
    Index          =    7
    Left           =    1080
    TabIndex       =    10
    Top            =    1080
    Width          =    375
End
Begin Label Lbl_Profile
    BackColor      =    &H00000000&
    BorderStyle    =    1 'Fixed Single
    ForeColor      =    &H00000000&
    Height         =    375
    Index          =    6
    Left           =    600
    TabIndex       =    9
```

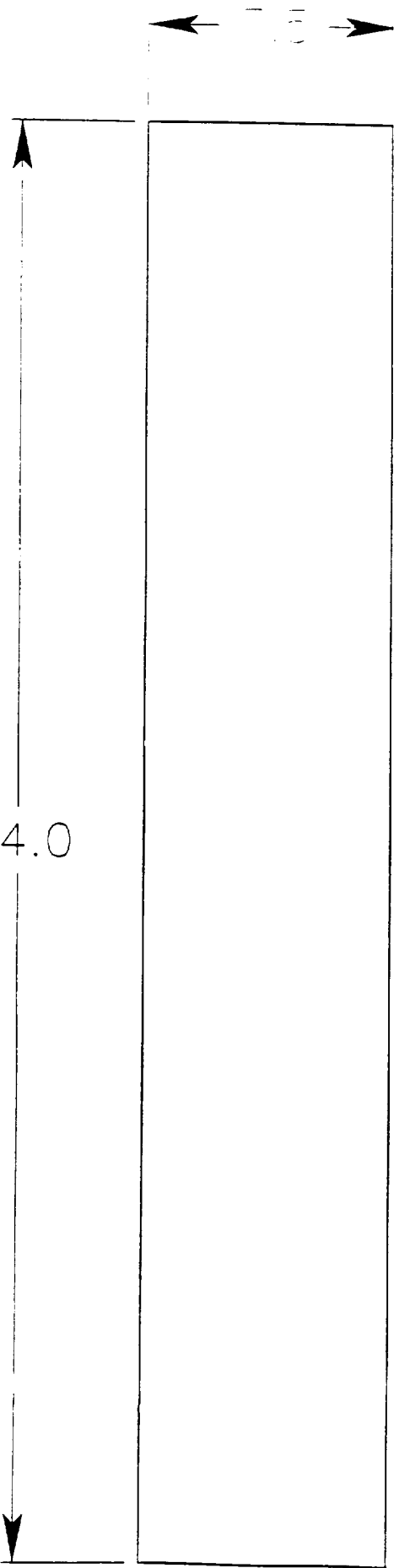
```
Top          = 1080
Visible      = 0  'False
Width       = 375
End
Begin Label Lbl_Profile
  BackColor  = &H00000000&
  BorderStyle = 1  'Fixed Single
  ForeColor  = &H00000000&
  Height     = 375
  Index      = 5
  Left       = 120
  TabIndex   = 8
  Top        = 1080
  Width      = 375
End
Begin Label Lbl_Profile
  BackColor  = &H00000000&
  BorderStyle = 1  'Fixed Single
  ForeColor  = &H00000000&
  Height     = 375
  Index      = 4
  Left       = 1560
  TabIndex   = 7
  Top        = 600
  Width      = 375
End
Begin Label Lbl_Profile
  BackColor  = &H00000000&
  BorderStyle = 1  'Fixed Single
  ForeColor  = &H00000000&
  Height     = 375
  Index      = 3
  Left       = 600
  TabIndex   = 6
  Top        = 600
  Width      = 375
End
Begin Label Lbl_Profile
  BackColor  = &H00000000&
  BorderStyle = 1  'Fixed Single
  ForeColor  = &H00000000&
  Height     = 375
  Index      = 2
  Left       = 2040
  TabIndex   = 5
  Top        = 120
  Width      = 375
End
Begin Label Lbl_Profile
  BackColor  = &H00000000&
  BorderStyle = 1  'Fixed Single
  ForeColor  = &H00000000&
  Height     = 375
  Index      = 0
  Left       = 120
  TabIndex   = 0
  Top        = 120
  Width      = 375
End
End
```

A.3. MECHANICAL DRAWINGS





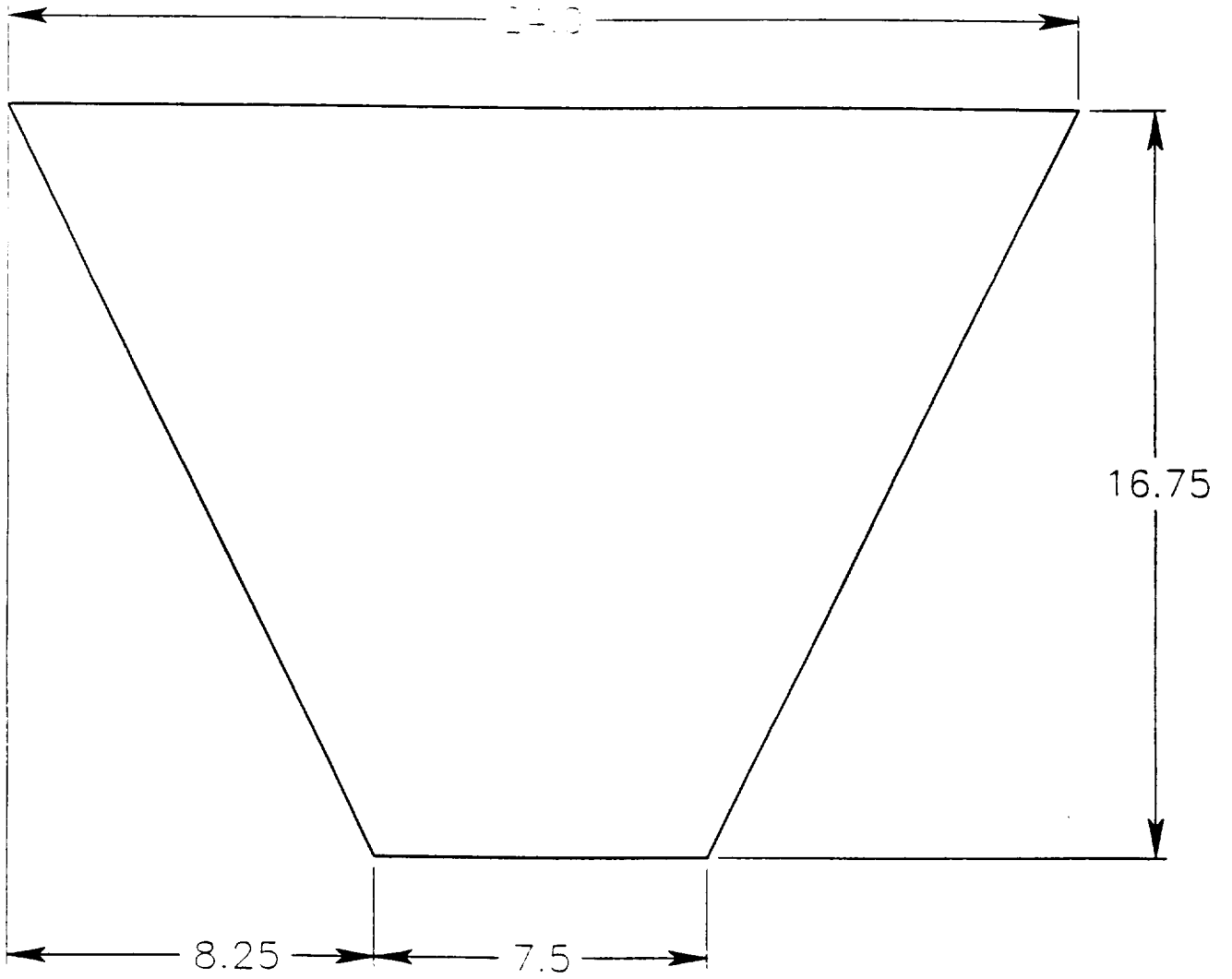
PART NAME:
Housing Back



44.0

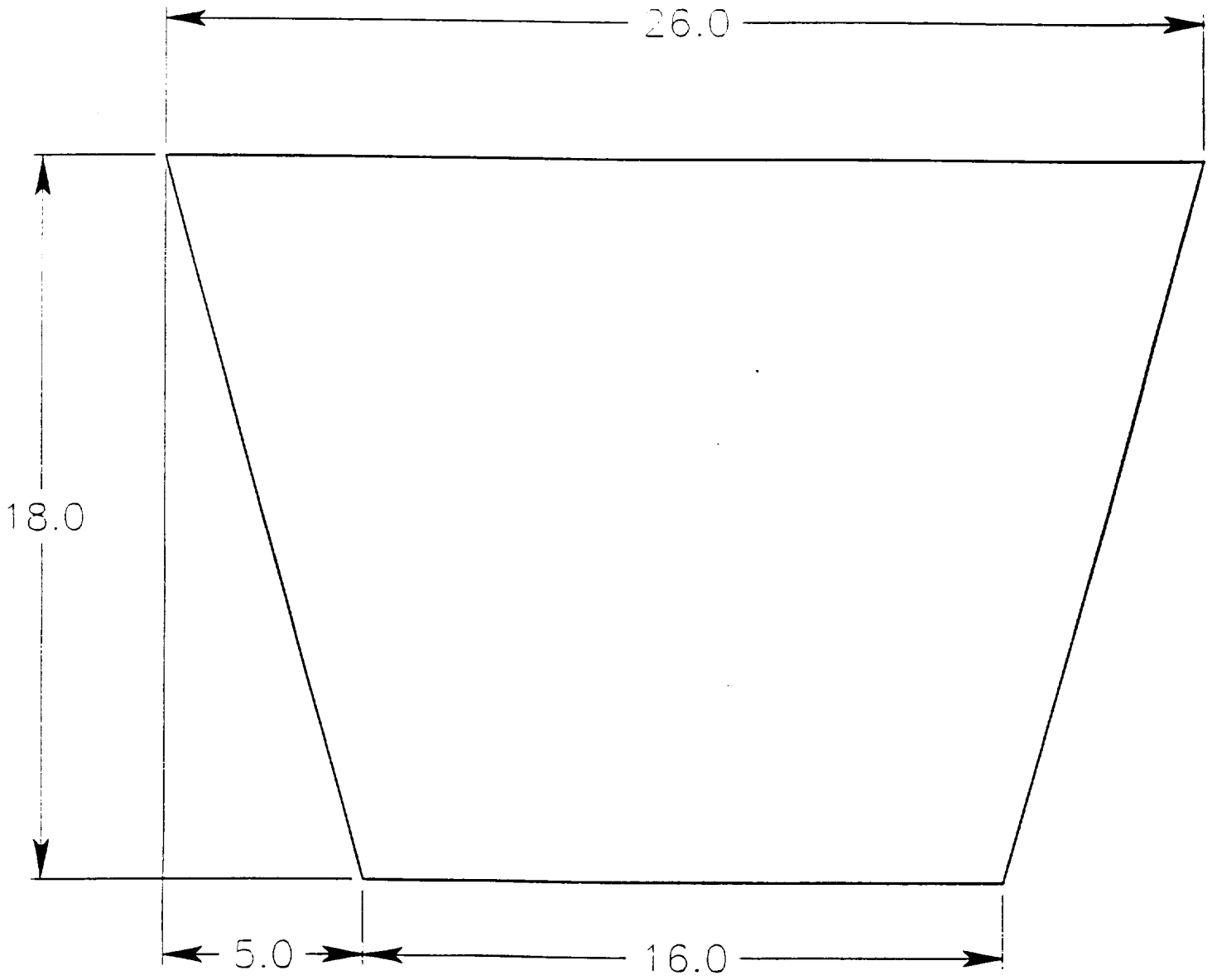
A technical drawing of a lamp housing, represented as a vertical rectangle. To the left of the rectangle is a vertical dimension line with arrows at both ends, indicating a height of 44.0. Above the rectangle is a horizontal dimension line with arrows at both ends, indicating a width. To the right of the rectangle, the text 'PART NAME: Lamp Housing' is written in a simple, sans-serif font.

PART NAME:
Lamp Housing



PART NAME:
Left Right

NOTE: 2 pcs.



PART NAME:
Top/Bottom

NOTE: 2 pcs.