Thermal Excitation System for Shearography (TESS)
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Prepared by
Matthew D. Lansing
Michael W. Bullock

Research Institute
The University of Alabama in Huntsville
Huntsville, Alabama 35899

Prepared for
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812
Attn.: EH13 (Dr. Samuel S. Russell)
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, unbondings, 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 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.
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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](image)

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

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

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).

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.](image)

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.
## A.1. MATERIALS LIST

<table>
<thead>
<tr>
<th>ITEM #</th>
<th>DESCRIPTION</th>
<th>QUANTITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aluminum Sheet, 6061-T6 (4’ x 8’ x 0.025”)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Aluminum Pop Rivets</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Balsa Wood (0.5” x 0.5” x 36”)</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>Wire Nails (17 x 1)</td>
<td>28</td>
</tr>
<tr>
<td>5</td>
<td>Aluminum Window Screen (25” x 25”)</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Data Acquisition Board, 12 bit, 16 single end channels [National Instruments AT-MIO-6]</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Screw Terminal Board [National Instruments SC-207X]</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Steel Enclosure (3 1/16” x 8 1/4” x 6 1/8”) [Radio Shack 270-274]</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Barrier Strip, 8 Position, Dual Row [Radio Shack 274-670]</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>Thermocouples (Type J) 36” x 36 AWG [Omega STC-TT-J-36-36]</td>
<td>13</td>
</tr>
<tr>
<td>11</td>
<td>D-Shell Thermocouple Connector Set (15 pin) [Omega SMTC-15MF]</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>Thermocouple Pins (Iron) [Omega SMTC-IR-P]</td>
<td>15</td>
</tr>
<tr>
<td>13</td>
<td>Thermocouple Sockets (Iron) [Omega SMTC-IR-S]</td>
<td>15</td>
</tr>
<tr>
<td>14</td>
<td>Thermocouple Pins (Constantan) [Omega SMTC-CO-P]</td>
<td>15</td>
</tr>
<tr>
<td>15</td>
<td>Thermocouple Sockets (Constantan) [Omega SMTC-CO-S]</td>
<td>15</td>
</tr>
<tr>
<td>16</td>
<td>Multipair Thermocouple Extension Cable (Type J) 16 twisted pairs, 20 AWG x 12’ [Omega 16-JX-20-PP]</td>
<td>1</td>
</tr>
</tbody>
</table>
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 Picture1
 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
Sub btn_OK.About_Click ()
    Dim User$ As String
    User$ = InputBox(“Please enter user ID”, “Welcome to TESS”, “Lansing”)
    If User$ = “” Then
    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.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.FRZ: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
```
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"
```vbnet
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!
```
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_LoadDialogTitle = "Load TESS Calibration"
  CMD_LoadFilename = ""
  CMD_LoadFilter = "*.txt|*.txt"
  CMD_LoadAction = 1
  If CMD_LoadFilename <> "" Then
    Open CMD_LoadFilename 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 = "*.txt1_.txt"
CMD_Save.Action = 2
Open CMD_Save.FileName For Output As #2
Print #2, "UAE-TESS Calibration"
Print #2, Date$, Time$
Print #2, Users$
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 = &H00COC0C0&
  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
Width = 1455

Begin OptionButton Rdo_TScale
 BackColor = &H00C0C0C0&
  Caption = "F"
  Enabled = 0 'False
  ForeColor = &H00000000&
  Height = 255
  Index = 1
  Left = 7440
  TabIndex = 12
  Top = 7320
  Value = 0
  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"
Height = 375
Left = 7320
TabIndex = 3
Top = 7680
Width = 1455

Begin CommandButton Btn_Pause
BackColor = &H00COCOC0&
Caption = "PAUSE"
Enabled = 0 'False
Height = 375
Left = 3720
TabIndex = 2
Top = 7680
Width = 1455
End

Begin CommandButton Btn_Acquire
BackColor = &H00COCOC0&
Caption = "ACQUIRE"
Height = 375
Left = 1920
TabIndex = 1
Top = 7680
Width = 1455
End

Begin GRAPH Gra_Temp
AsciiFFamily = "O"
AsciiFSize = "100-150-100-100"
AsciiFStyle = "O"
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 = &H00COCOC0&
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 = 14
Left = 8145
TabIndex = 4
Top = 5295
Width = 675
End

Begin Label Lbl_Temp
Alignment = 2 'Center
BorderStyle = 1 'Fixed Single
Height = 255
Index = 13
Left = 8160
TabIndex = 5
Top = 4860
Width = 675
End

Begin Label Lbl_Temp
Alignment = 2 'Center
BorderStyle = 1 'Fixed Single
Height = 255
Index = 12
Left = 8160
TabIndex = 22
Top = 4425
Width = 675
End

Begin Label Lbl_Temp
Alignment = 2 'Center
BorderStyle = 1 'Fixed Single
Height = 255
Index = 11
Left = 8160
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 = 8145
  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
End
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 = &H00COC0C0&
  Caption = "STATUS"
  Height = 195
  Left = 60
  TabIndex = 15
  Top = 8100
  Width = 750
End

Begin Label Label5
  BackColor = &H00COC0C0&
  Caption = "minutes"
  Height = 255
  Left = 6360
  TabIndex = 11
  Top = 7020
  Width = 735
End

Begin Label Label4
  BackColor = &H00COC0C0&
  Caption = "sec/pt"
  Height = 255
  Left = 2820
  TabIndex = 10
  Top = 7020
  Width = 735
End

Begin Label Label3
  BackColor = &H00COC0C0&
  Caption = "SAMPLE PERIOD"
  Height = 255
  Left = 60
  TabIndex = 8
  Top = 7020
  Width = 1815
End

Begin Label Label2
  BackColor = &H00COC0C0&
  Caption = "SAMPLE DURATION"
  Height = 255
  Left = 3660
  TabIndex = 6
  Top = 7020
  Width = 1875
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$(i%)'DEAD 8
Next i%
Gra_Temp.AutoInc = False
Gra_Temp.DrawMode = 3
NumPts% = 1 + Int(Scr_Dur.Value * 60 / Scr_Freq.Value)
Gra_Temp.NumPoints = NumPts%
'Cleargraph data
For i% = 2 To 15
  If i% <> 8 Then 'DEAD 8
    'Chann%(i%) = i%
    Gra_Temp.ThisSet = i% - 1
    For j% = 1 To NumPts%
      Gra_Temp.ThisPoint = j%
      Gra_Temp.GraphData = 0
    Next j%
  End If
Next i%
Gra_Temp.TickEvery = Int(NumPts% / 10)
Gra_Temp.LabelEvery = Int(NumPts% / 10)
If Rdo_TScale(0) = True Then
  Gra_Temp.YAxisMax = 100
  Gra_Temp.LeftTitle = "C"
  TScale$ = "C"
Else
  Gra_Temp.YAxisMax = 200
  Gra_Temp.LeftTitle = "F"
  TScale$ = "F"
End If
'Initialize output log
Open LogFileName$ For Output As #i
Print #i, "UAH-TESS Data Log"
Print #i, DateS, TimeS, TScale$
Print #i, Users
Print #i, "Time";
For i% = 2 To 15
  If i% <> 8 Then Print #i, "," ; i% ; 'DEAD 8
Next i%
Print #i, 
'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% = 2 To 15 'Step Through Channels
               If k% <> 8 Then 'DEAD 8
                  VoltSum#(k%) = VoltSum#(k%) + v#
                  Next j%
            Voltsum#(k%) = Voltsum#(k%) / CDbl(NumAve$)
            Next k%
         Temp#(k%) + 32 End If
         Next k%
         Gra_Temp.ThisPoint = i%
         For k% = 2 To 15
            If k% <> 8 Then 'DEAD 8
               Gra_Temp.ThisSet = k% - 1
               Gra_Temp.GraphData = Temp#(k%)
               CurVal% = Int(Temp#(k%) + .5)
               Lbl_Temp(k%).Caption = Str$(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 #I, ....
         Gra_Temp.DrawMode = 3
         OldTime# = NewTime#
         If i% = 1 Then FirstTime# = OldTime#
         Print #I, ((NewTime# - FirstTime#)); ",";
         For k% = 2 To 15
            If k% <> 8 Then Print #I, 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 #I

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_SaveDialogTitle = "Save TESS Data Log"
Frm_Calib.CMD_SaveFilename = LogFileName$
Frm_Calib.CMD_SaveFilter = "*.csv|*.csv"
Frm_Calib.CMD_SaveDefaultExt = "csv"
Frm_Calib.CMD_SaveAction = 2  'cancel crashes
'MsgBox "LOG:" + LogFileName$ + " FORM:" +
Frm_Calib.CMD_SaveFilename, 0, "FileName Difference?"
If ((Len(Frm_Calib.CMD_SaveFilename) > 0) And
(Frm_Calib.CMD_SaveFilename <> LogFileName$)) Then
FileCopy LogFileName$, Frm_Calib.CMD_SaveFilename
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$))
    Frm_Calib.Grd_Calib.ColWidth(0) = 500
    Frm_Calib.Grd_Calib.ColWidth(1) = 1500
    Frm_Calib.Grd_Calib.ColWidth(2) = 1500
    Frm_Calib.Grd_Calib.ColWidth(3) = 1500
    Frm_Calib.Grd_Calib.Rows = NumCal% + 1
    Frm_Calib.Grd_Calib.Row = 0
    Frm_Calib.Grd_Calib.Col = 3
    Frm_Calib.Grd_Calib.Text = "Adjusted"
Frm_Calib.Grd_Calib.Col = 2
Frm_Calib.Grd_Calib.Text = "Measured"
Frm_Calib.Grd_Calib.Col = 1
Frm_Calib.Grd_Calib.Text = "Standard"
Frm_Calib.Grd_Calib.Col = 0
Frm_Calib.Grd_Calib.Text = ""
For i% = 1 To NumCal%
    Frm_Calib.Grd_Calib.Row = i%
    Frm_Calib.Grd_Calib.Text = Str$(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(DevNum8)
    If (er% <> 0) And (er% <> -74) Then
        DAQmessage er%
    End If
End Sub

SubBtn_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 ()
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
End

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 = 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 = 12
  Left = 1080
  TabIndex = 3
  Top = 2040
  Width = 375
End
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:
Lamp Housing

44.0
PART NAME:
Left Flight

NOTE: 2 pcs.
PART NAME:
Top//Bottom

NOTE: 2 pcs.