Operator’s Manual: Team #7

Soft Tissue Fatigue Testing Fixture

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IMPORTANT SAFETY INSTRUCTIONS

• Do not eat or drink in the room with the device, as human tissue is used in the lab.
• Do not touch any part of the device when testing is in progress.
• Make sure all nuts and screws are secured tightly prior to testing.
• Use washers with every nut and screw to prevent nuts from loosening.
• Keep all electronics away from the solution tank.
• Keep tank area/Bose platform clear of any components as vibrations can be intense.
• Make sure tank walls are completely inserted in the bottom piece. Also ensure the Velcro straps are tightly connected.
• The tank is not water tight, so a liner must be used with every test. The liner must be inserted properly with enough slack for the lower platform to move without contacting the liner.
• Be careful when filling the tank. Electronic components are stored underneath the tank.
• Use caution when cutting the tissue samples with sharp utensils.
• Avoid spilling the solution on the floor around the device.
• Wear gloves when handling tissue samples. Always wash hands before and after touching the tissue.
PARTS AND ACCESSORIES

- Tank (bottom, short walls, long walls)

- Lower platform
• Lower clamps (large and small pieces)

• Connecting rod

• Top platform
• Upper clamps (large and small pieces)

• Bose Testbench Device

• Liner
• Velcro straps
• Strain Gages: C2A-13-250LW-350 (Vishay Micro-Measurements)

• OMEGA BCM-1 (Bridge Completion Module)

• NI BNC 2120
- NI PXIe-1073 Chassi
- PXI Connector (circled)

- Power Supply: BK Precision DC Power Supply

- Computer with Bose WinTest and NI software
FEATURES

- Tank can be assembled in a coordinated manner so that tissue mounting does not become too laborious or time-consuming.
- Tank can be disassembled after every test; allows for easy setup and removal of tissue.
- Tank can be disassembled after every test; allows for easy setup and removal of tissue.
- The gage length between the upper and lower platform can be adjusted by changing the height of the Bose machine’s platform.
- The stationary fit of both upper and lower platform ensures that the gage length is maintained as accurately as possible for all 12 tissue samples.
- Strain gages are located on the upper clamps right in line with the tissue. Each tissue sample has its own strain gage for individual data collection.
- Upper platform remains stationary; prevents unwanted vibrations from contaminating the data.
- Data can be viewed in real time using the Labview program. Data is also saved to a spreadsheet after testing is completed.
- The LabVIEW program incorporates a VI that inputs voltage values from the completion bridge and converts them into readable strain. This VI can be adjusted to incorporate installation of different types of strain gages or even different types of completion bridges.
- The user is given the control of starting the Bose software and the LabVIEW code in the same computer console.
- Up to 12 tissue specimens can be tested at once.
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1.0 Introduction

1.1 Overview

The Soft Tissue Fatigue Testing Fixture consists of three major units: the Bose Testbench Device, the components that hold the tissue during testing, and the electronic devices and computer software.

The Bose Testbench Device is the machine that actually applies the load to the tissue samples. It consists of a large platform for the testing fixture, two columns to hold up the Bose Device itself, and an arm that can connect to other pieces to apply loads at a desired force, frequency, and duration. The Bose Device can be raised or lowered on the two columns to adjust for height changes in different experimental setups. The Bose Device has its own power supply kept underneath the testing table.

The device that holds the tissue samples during testing is the main mechanical portion of the device. It consists of a tank, an upper and lower platform, and twelve sets of two clamps for holding the tissue samples. Both the upper and lower platforms have two rows of six clamps. They are oriented so they line up to allow for easy and accurate tissue setup. The lower clamps are not identical to the lower clamps. The lower clamps attach to the sides of the bottom platform. They consist of two large pieces of acrylic and one small piece of acrylic. When secured properly, they form the lower clamp. The upper clamps consist of two pieces. A large piece that is connected to the upper platform, and a small piece identical to the small pieces in the lower clamps. The large piece serves two functions: it helps hold the tissue, and serves as the custom load cell. The strain gages are placed on the front of the clamps and detect any strain experienced by the clamp during testing. The lower platform is connected to the Bose device by a connecting rod. At the top of the rod is a circular piece that is held on by screws. A small threaded rod is inserted into this circular piece, which is then screwed into the Bose arm.

The electronic devices and components are what detect the strain in the load cells and send it to the computer for analysis. Each strain gage requires its own power supply and bridge in order to function properly. The NI BNC 2120 receives the signals from the strain gages and sends them to the computer. The computer runs both the Bose software and the Labview program. The Bose software is used to operate the Bose device, while the Labview program is
used to collect and analyze the data. The data from each individual strain gage can be viewed graphically as it is collected, and is also stored in a spreadsheet.

In order for this device to be operational, a great deal of care must be put into setting it up. Along with following a precise procedure (which is described in the next section), several important guidelines must be adhered to.

- The Bose Device must be adjusted to the proper height. This ensures that the proper amount of force is applied to the tissue specimens, and that the testing fixture can be assembled properly.
- The majority of the setup time will be spent assembling the testing fixture. The twelve upper and lower clamps must be put together and secured to their respective platforms with the proper orientation (with the small piece of the clamp facing the wall of the tank, not the interior).
- Anytime a screw and nut are used to hold two pieces together, a washer and spacer must be placed between the acrylic and the nut, as well as between the acrylic and the head of the screw. This will prevent the vibrations experienced during testing from loosening the screws and damaging the device.

The small circular piece at the top of the connecting rod must be attached with the proper orientation. A mark is etched into the space between to the of the four screw holes on this piece. That side must be facing the thicker of the two walls of the tank. If this is not done, the lower platform will be twisted by 90 degrees, making testing impossible.

1.2 Assembly Instructions

The following instructions pertain mainly to the mechanical assembly of the fixture. Instruction on the usage of the Bose WinTest software and the NI LabView program are included later in this manual.

1. Assemble clamps on lower platform using the assorted tools (figure 1.2.1)
2. Attach lower platform to connecting rod (fig. 1.2.2).

![Figure 1.2.2](image)

3. Attach clamps with strain gages to upper platform. Screw in tightly. Secure lead wires with tape if necessary. Ensure correct bridge completion configuration (fig. 1.2.3).

![Figure 1.2.3](image)
4. Adjust height of Bose Device (figs. 1.2.4-5).

Figure 1.2.4

Figure 1.2.5
5. Secure bottom of tank. Screws holes are highlighted (fig. 1.2.6)

![Figure 1.2.6](image)

6. Place connecting rod and bottom platform through hole in upper platform.
7. Secure connecting rod and lower platform into Bose Device, with the connecting rod still going through upper platform (fig. 1.2.7).

![Figure 1.2.7](image)
8. Insert two long walls into bottom of tank.

9. Place liner into tank, leaving enough room for the connecting rod to move unhindered.
10. Screw top platform into long walls (fig. 1.2.9).
11. Prepare tissue specimens, leaving them in solution until they can be clamped.
12. Attach tissue specimens to clamps.
13. Slide in two short walls (fig. 1.2.10).

![Figure 1.2.10](image)

14. Secure walls of tank using Velcro strap (fig. 1.2.11).

![Figure 1.2.11](image)
15. Fill tank with solution carefully through the center hole (fig. 1.2.12) in the upper platform. Avoid solution contact with strain gage(s).

16. Turn on Bose Device (circled), power supply, and NI instruments. Turn on computer console.

17. Prepare experiment using Bose software (frequency, cycles, and displacement). Detailed instructions are located in the “WinTest” section below. Turn on bridge supply voltage. Make sure DAQ hardware is on and connected properly.
18. Open Labview program.

19. Run Labview program after setting appropriate controls. Detailed instructions are located in the “LabVIEW” section below

20. Run Bose software
21. Check that data is being picked up, Bose Device is running properly, and for any leaks in tank
22. Check device periodically while running.

The following set of instructions pertains to disassembling the fixture once the given number of cycles has been completed and the data has been collected.

CAUTION: Always use gloves and other proper attire such as lab coats or face masks as needed.
1. Stop the LabView program.
2. Once prompted, choose the save location of Excel file that contains the data. It is advised that a sizable USB flash drive to be used as storage.
3. Turn off the power supply for the strain gage(s).
4. Remove screws holding upper platform.
5. Cut tissue specimens, and dispose them accordingly in specialized containers located in the laboratory.
6. Raise upper platform and use paper towels to dry the surrounding area if solution splashes out.
7. Remove screws holding base of tank on the table top
8. Carefully pick up entire tank and drain in appropriate waste disposal container. Remove and dispose liner.
9. Remove any stray tissue particles and lightly dry clamps and platforms with paper towels as needed.

The software component that accompanies the Bose TestBench is named “WinTest”. The following section details instructions on the initial set-up, tuning the system and setting the loading cycles.

Setting up the WinTest: Computer console should be turned on.

1. Turn on Bose machine and input channel box below the table.
2. Open the latest installed version of WinTest on the Desktop (fig. 1.2.14).

![Image](figure1.2.14)

3. Select “5lb load cell-Fatigue Test” to test 1 specimen or “50 lb load cell- Fatigue Test” for multiple specimen.

![Image](figure1.2.15)

4. After attaching the tissue samples accordingly (see “Assembly Instructions” above), tare the load
   a. Right click on “Load” channel box on right → Properties → Auto.
5. Configure WinTest to run on displacement control (fig. 1.2.17).  
   a. Select “Feedback” on upper panel → choose “disp”
6. Turn on machine through WinTest  
   a. Click “Local” on upper panel → High, make sure to wait a few seconds to observe the “On” switch lighting green.

![Figure 1.2.18](image1)

7. Using position tool to pull the tissue samples taut  
   a. Ensure load is approximately zero.  
   b. Select “Position” on upper panel.  
   c. Move dial left/right to stretch tissue.

![Figure 1.2.19](image2)
Tuning System: The system needs to be re-tuned every time new test is initiated.

1. Change feedback to direct command: Feedback → DirCmd.
2. Click on TunnelQ Waveform on the top panel.
   a. Feedback → Displacement
   b. Cyclic Parameters-->
   c. Select “TunnelQ Run” on bottom right corner.
   d. After tuning is complete, throw out sample and set up a new test.

Setting Up Loading Cycles

1. Select “TunnelQ Waveform”
   a. Change following parameters
      i. Cyclic Parameters
      1. Level 1: current displacement value.
      2. Level 2: desired second displacement value (must be within range).
   ii. Frequency: any number up to 50 Hz.

b. Start/Done Parameters
   i. Done Level: same as Level 1.

2. Click “OK”.
3. Run → Start.

By step 3 above, the LabVIEW program needs to be opened. The subvi’s within the program must be double-checked for proper functionality. The DAQ assistant and the filter subvi should appropriately configured (see the “Technical Description” subsection that addresses the LabVIEW program).

Starting the LabVIEW program.

1. Open the LabVIEW file titled “Gage1DataInputprog.vi” before starting the Bose machine to run.
2. Make sure to set the correct parameters (gage factor, Vex etc.) in the “User Controls” box (fig. 1.2.22).
3. Click the “play” button to start collecting and displaying data (1.2.23).

4. Check each tab (1.2.24) to ensure the data is being displayed properly.
5. After the cycles are completed in the fixture stop the program as soon as possible to prevent unnecessary data from being collected.

6. This will trigger a prompt by the program to select the save location of the data file. It is optimal to save the data to an external drive or USB, especially if the console computer has a hard drive that is filling up.
2.0 Maintenance

2.1 Mechanical

It is important to maintain the device and check it for damage or wear before each use. Because each trial can take up to several weeks, it is especially undesirable if a trial is halted prematurely due to a problem that could have been avoided by carefully maintaining the device. A thorough inspection on the tightness of all the screw fittings and wall insertions needs to be undertaken whenever a fatigue test is to be conducted. Below are some considerations that need to be understood in order to ensure mechanical stability of the device under testing conditions.

Velcro: It is important to check that the Velcro straps are still in good condition and can maintain a strong grip. If they are unable to maintain a strong grip then they may need to be replaced. Velcro tapes of almost any length can be purchased at any home improvement store.

Screw holes: It is important to take care when inserting screws into the acrylic. If screws are fitted improperly, then the threading in the acrylic can be damaged. If the threading is damaged then it must be repaired by filling in the hole and tapping it again.

Maintain labels: It is important to maintain the labels on the various components of the tank. These labels are key in identifying the correct parts and orientations of parts when assembling the tank. Trying to put a wall into the wrong slot or backwards can result in damaging the tank and/or compromising water tightness.

Usage of screw accessories: If certain screws are too long to be secured tightly, washers, bolts and nuts are highly recommended to compensate for excess screw length.

Liner holes: It is important to check the liner for holes between each use. The liner is important because it prevents the tank from leaking. Holes can develop if the liner is caught on something or is poorly handled between uses.

Replacements: If certain clamps are worn or chipped beyond repair, it is important to purchase new acrylic and machine strong replacements. Usage of acrylic cement or glue cannot ensure clamp stability by itself.

Cleaning: It is important to periodically clean solution contacting parts. Any sign of corrosion on metallic screws, bolts or washers might indicate the need for replacements. Any stray pieces of tissue must be thoroughly extracted and disposed of properly.
2.2 Electrical

It is important to maintain the electrical components properly because misuse may result in collection of poor data, lack of signal generation, or safety concerns. The following points highlight important areas of concern in electrical maintenance.

Strain gage coating: It is important to make sure that the strain gages are fully coated by an epoxy coating. This not only protects the user from electrical shock but also makes them watertight. For both these reasons, it is important to check that the strain gages are fully coated before use.

Wire entanglement: The device can have up to 12 wires coming in and out of the tank. If they are orderly then it will be easier to troubleshoot, modify, or even just operate the device. If more strain gages are installed, it is important to drill holes on the top platform to allow for convenient wire access.

Wire coating: If the wire coatings develop any tears or nicks then these flaws will need to be repaired. If they are not repaired then they could lead to a short circuit in across the wires. This could not only ruin test results, it could also damage the device and may harm the user.

Plug into a surge protector: This device has some very sensitive and expensive components. For this reason, it is always a good idea to use a surge protector to ensure that they are protected from power surges and lightning strikes.

Bridge completion modules: The Omega BCM-1 model features several precision resistors. Their functionality must be periodically tested to ensure a sound strain gage Wheatstone bridge completion. The use of a multimeter can be helpful in diagnosing basic problems, but an oscilloscope must be used to read output voltages to observe any problems in the overall gage-bridge circuit.

2.3 Strain Gage Considerations

Strain gages wear out over multiple sessions of testing, especially if each test features more than $10^6$ cycles. The figure below is an example chart from Vishay Micro-Measurements. There is a trade-off between how much micro-strain the gages can sustain and how accurate they remain over long periods of testing.

![Figure 2.3.1](image)
It is recommended that the strain gages should be purchased and periodically replaced. The following link provides step-by-step instructions on installing a gage with M-Bond 200 adhesive which was purchased along the strain gages. Vishay Micro-Measurements: http://www.vishaypg.com/docs/11127/11127_b1.pdf

![Image of Ideal SG Placement](image)

The ideal placement is illustrated above in figure (2.3.2). The gage should be applied longitudinally with the lead wire coming away from the tissue attachment points. The gage should be placed halfway up the thinned section to avoid complications with stress concentrations.

3.0 Technical Descriptions

3.1 Acrylic Component

The fatigue testing fixture is made up of multiple sections that work together. These different parts include the tank, upper platform, lower platform and connecting rod, upper clamps, and lower clamps. All of these parts are constructed from acrylic. This ensures that there will be no interaction between the solution in the tank and the fixture itself. A detailed overview of each of these parts will be given here.

Tank:

The tank of the fatigue testing fixture serves two purposes: it holds the solution around the tissue and supports the upper platform. It includes four walls and a base platform. The tank was designed to be assembled and taken apart with each experiment. This makes setting up the tissue specimens much easier without having walls in the way of the clamps. In order to make sure the tank is water tight without applying glue, a liner is used. The walls are held together by
grooves in the base, the upper platform, and a Velcro strap around the outside. All of these together with the liner create a tight seal between the walls.

The base is constructed of ½ inch acrylic. Four holes have been drilled near each corner so it can be screwed into the base of the Bose Testbench device. The image clearly shows the grooves that the walls are set into. This helps keep the walls steady during testing. The grooves
are cut ¼ inch into the base. The long side walls are thicker than the short end walls, so the grooves along the long sides are thicker.

The long walls are made from ⅜ inch acrylic. This provided the necessary thickness to drill holes into the top edge for securing the upper platform. It also allowed a notch to be cut at
each end for the short walls to slide into. All of the walls have been marked with tape to clearly show what side of the base they fit into, and the proper orientation of the upper platform.

The short walls are made from ¼ inch acrylic. This matched the thickness of the notches in the long walls. Once the long walls are in place in the base, the short walls can simply slide into their grooves between the adjacent long walls.
The Velcro strap is actually two straps secured together. The strap is placed around the top of the tank and secured as tightly as possible.

Upper Platform:
The upper platform is where the upper clamps are attached. It is secured to the top of the tank walls, which helps keep the tank together during testing. The platform was constructed from 3/8 inch acrylic. In order to accommodate the connecting rod, a section was removed from the center of the platform. This allows the connecting rod to pass through the upper platform without coming into contact with any other parts.

Figure 3.1.8: Liner and Upper platform attachment

Two holes were drilled on each of the long sides of the upper platform. This allows screws to pass through the upper platform and tighten into the long walls of the tank. Two rows of six holes were drilled around the center of the platform where the connecting rod passes through. These holes are where the upper clamps are held.

Upper Clamp:
The upper clamp doubles as a means of holding the tissue during testing, and as a way of detecting the stress applied to the tissue. The upper clamps were designed so that they would deform during testing when the Bose device applied a load to the bottom platform. This load would stretch the tissue, which would then apply a force on the upper clamps. This force is what deforms the clamp, which has a sensitive strain gage attached to it. An Abaqus simulation was used to help determine the design of the upper clamps.

The amount that the upper clamp deforms is directly related to the material it is made out of, the cross-sectional area, and the applied load. This is illustrated by the following equations. 

\[ \sigma = E \varepsilon \] (eqn. 1)
\[ \sigma = \frac{P}{A}, \text{(eqn. 2)} \]
\[ \therefore \frac{P}{A} = E\varepsilon, \text{(eqn. 3)} \]

where \( P = \) pressure, \( A = \) cross-sectional area, \( E = \) Young’s Modulus, \( \sigma = \) stress, and \( \varepsilon = \) strain.

According to the final equation, the only ways to increase the load without changing the material or applied force is to reduce the cross-sectional area. This was the method used for the upper clamps. The area where the strain gages were placed was made much thinner than the rest of the clamp. The strain gage section was cut to approximately 0.2” x 0.5” x 0.5”. The thin section was made significantly longer than the strain gage itself. This was done to ensure homogeneous strain. Homogeneous strain means that the strain in all locations around the strain gage is the same; one side isn’t being altered more than the other. The Abaqus simulation shows stress concentrations at the corners of the thin section. The final clamp design was then created in SolidWorks.

![Figure 3.1.11: Updated CAD profile of upper clamp](image)

Lower Platform and Connecting Rod:
The Lower platform and connecting rod are the only moving parts of the fatigue tester. The connecting rod is a solid acrylic cylinder approximately one inch in diameter. The lower platform is the same platform used in the old device, but with several modifications.
The connecting rod is held to the lower platform by two screws. A small piece from the Bose machine is attached to the top end of the connecting rod by four small screws. This piece is then screwed into the Bose machine by a threaded metal cylinder (screw with the head removed). The bottom platform had two sections removed to help reduce the force the solution would apply during testing. This force could skew the data collected by the strain gages, so it is important to make is as small as possible. The lower clamps are attached to the lower platform by threaded holes in the side of the platform.
Lower Clamps:

The lower clamps are constructed entirely from pieces reused from the old testing fixture. Each clamp consists of two large pieces and one small piece, along with the necessary screws, washers, and spacers.
Much of the assembly of the lower clamps can be done prior to setting up an experiment. This helps reduce the setup time of an experiment. The quicker an experiment can be setup, the less time the tissue will have to dry out. This will improve the data gathered by using tissue specimens in ideal condition.

### 3.2 Strain Gage and Bridge

The strain gages used in this project were purchased from Vishay Micro-measurements. The gage designation is C2A-13-250LW-350 with a resistance of 350 +/- 0.6%. The C2A featured encapsulated lead wires that were pre-soldered.
The following table contains important specifications for this model.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
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<tbody>
<tr>
<td>Gage Length</td>
<td>0.250 in</td>
</tr>
<tr>
<td>Overall Length</td>
<td>0.363 in</td>
</tr>
<tr>
<td>Grid Width</td>
<td>0.100 in</td>
</tr>
<tr>
<td>Grid Area</td>
<td>0.0250 sq. in</td>
</tr>
<tr>
<td>Overall Width</td>
<td>0.100 in</td>
</tr>
<tr>
<td>Matrix Length</td>
<td>0.440 in</td>
</tr>
<tr>
<td>Matrix Width</td>
<td>0.170 in</td>
</tr>
<tr>
<td>C2A Strain Range</td>
<td>+/- 3%</td>
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<tr>
<td>Temperature Range</td>
<td>-50C to + 80C</td>
</tr>
<tr>
<td>Gage Factor</td>
<td>2.130 +/-0.5%</td>
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Table 1: Grid Specifications
The excitation optimal excitation voltage depends on the material type of bending bar upon which the strain gage is installed and the desired level of precision.

<table>
<thead>
<tr>
<th>Accuracy Requirements</th>
<th>EXCELLENT Heavy Aluminum or Copper Specimen</th>
<th>GOOD Thick Steel</th>
<th>FAIR Thin Stainless Steel or Titanium</th>
<th>POOR Filled Plastic such as Fiberglass-Epoxy</th>
<th>VERY POOR Unfilled Plastic such as Acrylic or Polystyrene</th>
</tr>
</thead>
<tbody>
<tr>
<td>STATIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>2–5 [0.1-7.6]</td>
<td>1–2 [1.6-3.1]</td>
<td>0.5–1 [0.76-1.6]</td>
<td>0.1–0.2 [0.16-0.31]</td>
<td>0.01–0.002 [0.016-0.031]</td>
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<tr>
<td>Moderate</td>
<td>2–10 [7.6-16]</td>
<td>2–5 [3.1-7.8]</td>
<td>0.5–1 [1.6-3.1]</td>
<td>0.02–0.02 [0.031-0.078]</td>
<td>0.01–0.002 [0.031-0.078]</td>
</tr>
<tr>
<td>Low</td>
<td>10–20 [16–31]</td>
<td>5–10 [7.8–16]</td>
<td>2–5 [3.1–7.8]</td>
<td>0.5–1 [0.78–1.6]</td>
<td>0.02–0.1 [0.078–0.16]</td>
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<td>DYNAMIC</td>
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<td></td>
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</tr>
<tr>
<td>High</td>
<td>5–10 [7.8–16]</td>
<td>5–10 [7.8–16]</td>
<td>0.5–1 [3.1–7.8]</td>
<td>0.02–0.1 [0.078–0.16]</td>
<td>0.01–0.002 [0.016–0.078]</td>
</tr>
<tr>
<td>Moderate</td>
<td>10–20 [16–31]</td>
<td>10–20 [16–31]</td>
<td>2–5 [1.6–3.1]</td>
<td>0.05–0.2 [0.078–0.31]</td>
<td>0.01–0.002 [0.016–0.078]</td>
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<td>Low</td>
<td>20–50 [31–78]</td>
<td>10–20 [16–31]</td>
<td>5–10 [7.8–16]</td>
<td>0.5–1 [3.1–7.8]</td>
<td>0.02–0.5 [0.31–0.78]</td>
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</tbody>
</table>

Figure 3.2.3: Heat Sink conditions; image credit: Vishay Micro-Measurements.

The table above by Micro-Measurements indicates that acrylic materials tend have poor heat-sink conditions. For high accuracy requirements in a dynamic mode, the highlighted power...
densities are required. Figure (3.2.4), also provided by Micro-Measurements, is a chart that shows optimal bridge excitation voltage based on power densities requirements and grid area.

The recommendation for the 350 Ohm gages is 0.5-1.5 Volts for the collection of reasonably accurate data. The excitation voltage is provided by a voltage supplier directly to the bridge, so that all the necessary wire connections occur in one component. The bridge completion modules (BCM-1) were purchased from Omega. They featured mounting holes to which lead wires from strain gage could be attached. Excitation voltages coming from the power supply and output voltages leading to the DAQ hardware could be attached to different mounting holes in close proximity. The figures (3.2.5-6) below provide a schematic on how lead wires were connected.

The 350 Ohm gages are meant to be attached a 2-Wire quarter-bridge configuration. The resulting equation (eqn. 4) is as follows.

\[
\frac{V_{\text{sig}}}{V_{\text{ex}}} = -\frac{GF \cdot \varepsilon}{4} \left( 1 + \frac{1}{GF+2} \right) \quad \text{(eqn. 4)}
\]

The equation could be implemented in the final LabVIEW program to convert the voltage readings (Vsig) from the completion modules into strain (\( \varepsilon \)) readings.
3.3 NI LabView

The figure above represents the functional unit block diagram of the LabVIEW program. Data comes in through the DAQ VI on the left and is run through a series of calculations (highlighted by the red oval) that determine the raw strain using equation (1). Then the data is filtered using a Filter subVI, which is set a low-pass Butterworth high order level, and displayed as a dynamic indicator and a waveform chart. The math nodes that convert strain into stress and estimated load are highlighted in the green oval. Outside of the loop, the data can be set to write automatically to a text file. There are various user controls such as the gage factor, excitation voltage and Young’s modulus can be changed, depending on the type of gage used.
Figure (3.3.2) is a screenshot of the DAQ VI. In this module the DAQ VI can be tested before it is built. It also allows variables such as the buffer size and sampling frequency to be modified. Any error in sampling frequency, hardware recognition or connectivity can be detected in this window before the program is started.

Above is figure (3.3.3) containing the screenshot of the Filter VI. Here the filter type, order, cutoff frequencies can be selected. For the purposes of using the fatigue testing fixture at loading frequencies of 0.5-30 Hz, a low pass (Butterworth order 5) configuration at a high cut-off frequency of about 40 Hz is used.
Figure (3.3.4) depicts the front panel of the program while a low frequency cycle is performed on one specimen. Above the graph are different tabs where the desired type of data can be selected. Raw voltage, raw strain, filtered strain, stress, and estimated load are displayed as waveform charts.

Figure 3.3.5: Save option.

Figure (3.3.5) is an image of the save option that appears at the termination of an experiment. Users are given an option of where they would like to save their data as well as a chance to title it. Data is saved in a text file and can easily be imported into Microsoft Excel 2010.
Figure 3.3.6: User controls

The user controls depicted in this figure (3.3.6) contain various inputs to change parameters such as the gage factor, the excitation voltage, the clamp length, the clamp width, and the Young’s Modulus of the acrylic. It also displays the key area and the filtered strain. Underneath is the large stop button, which should be pressed as soon as the cycles are finished.
# 4.0 Troubleshooting

<table>
<thead>
<tr>
<th>Problem</th>
<th>Potential Causes</th>
<th>Solutions</th>
</tr>
</thead>
</table>
| Bose machine won’t run at certain frequencies or displacements. | 1. Frequency or displacement is outside of allowable range.  
2. Component of Bose machine is damaged.  
3. Error with Bose software. | 1. Check that frequency and displacement values were input properly and are within allowable range.  
2. Component will need to be replaced.  
3. Contact Bose company about troubleshooting issue. |
| Walls won’t fit into base. | 1. Walls are not being put into proper slots.  
2. Walls are not being inserted in proper order.  
3. Edges of walls have been chipped or worn out.  
4. Slots in base of tank have been chipped or worn out. | 1. Check that colored tape on walls matches colored tape on each side of the tank base.  
2. Long walls must be inserted first. Small walls should be inserted carefully at the same time.  
3. Walls will need to be rebuilt.  
4. Base of tank will need to be rebuilt. |
| Tissue samples aren’t evenly loaded. | 1. Tissue samples not clamped properly.  
2. Upper or lower platform is not level.  
3. Clamps were not assembled properly. | 1. Upper clamp should be tightened on tissue first. Hold tissue slightly taught with tweezers while lower clamp is tightened.  
2. Check that all screws securing upper platform are completely tightened with proper washers and spacers. Check that connecting rod is properly and completely tightened into Bose machine.  
3. Check that all clamp pieces are aligned properly, and that all screws have proper washers and spacers. |
<table>
<thead>
<tr>
<th>Problem</th>
<th>Potential Causes</th>
<th>Solutions</th>
</tr>
</thead>
</table>
| Bottom platform too low or too high. | 1. Bose machine not set at proper height on columns.  
2. Connecting rod not fully inserted into Bose machine.  
3. Displacement not properly set in Bose software. | 1. Readjust the placement of the Bose machine on the two support columns. Tissue specimens should NOT be clamped while adjusting height on the columns.  
2. Check that the connecting rod is as tight as reasonably possible in the Bose machine.  
3. Adjust displacement setting in Bose software. |
| Damaged Clamp.                | 1. Clamp has worn out from regular use.  
2. Clamp was damaged during installation or removal. | 1. Clamp must be rebuilt.                                                   |
| Leak in liner.                | 1. Liner has a tear.  
2. Liner not installed properly. | 1. Liner must be replaced.  
2. Check that liner is above all four walls and held tight by Velcro strap. |
| Screws no longer fit into holes. | 1. Wrong sized screw being used.  
2. Threading has worn out | 1. Check that proper sized screw is being used.  
2. Part can either be rebuilt, or a new, slightly larger hole can be tapped in place of worn out screw hole. |
| Damaged Strain gages.         | 1. Wires broke during setup or disassembly of experiment.  
2. Strain gage worn out from regular use. | 1. Damaged or worn strain gages must be replaced. |
<table>
<thead>
<tr>
<th>Strain gages won’t detect any strain.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Strain gages not wired properly to bridge circuit.</td>
</tr>
<tr>
<td>2. Strain gage is damaged.</td>
</tr>
<tr>
<td>3. Strain in clamp is too small.</td>
</tr>
<tr>
<td>1. Check that wiring was done properly according to setup guide.</td>
</tr>
<tr>
<td>2. See previous problem</td>
</tr>
<tr>
<td>3. Either a larger load must be applied, or a thinner clamp must be built and used.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LabVIEW error: DAQ assistant malfunctioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Sampling rate too small.</td>
</tr>
<tr>
<td>2. Improper connection.</td>
</tr>
<tr>
<td>3. Device is not being recognized by the computer.</td>
</tr>
<tr>
<td>1. Change the sampling rate in the DAQ assistant properties section.</td>
</tr>
<tr>
<td>2. Ensure tight connection of all wires.</td>
</tr>
<tr>
<td>3. Try restarting the computer with DAQ hardware turned on.</td>
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