

Standard Operating Procedure  
Modified ASTM F1717  
**Static Axial Compression Bending for Growing Rod Constructs**  
Last Edited: 6/9/2017

**Equipment:**

- Load Frame: Instron E3000
- Actuator:  $\pm 30\text{mm}$
- Load Cell: 1 kN axial
- PC with Instron Console and Instron WaveMatrix software

**1. Software**

- 1.1. Plug in computer, turn on, and login.
- 1.2. Plug in load cell into port on back of crosshead.
- 1.3. Turn on both power supplies beneath the frame using the black switches above all of the wires in the back. The sides of the switches will be red when they are turned on. The light on the crosshead next to the ElectroPuls logo will be white.
- 1.4. From desktop, open Instron Console. Wait a few minutes for the software to load. Once the software is loaded, the menu bar on the left of the screen will be grey, and a blue 'R' will flash above the ElectroPuls icon.
- 1.5. Click the ElectroPuls icon. If there is a flashing 'R' above the Strain 2 icon, click on it, and then click 'Restore Calibration'.
- 1.6. If a load cell was newly plugged in or switched, a flashing "U" will appear above the Load icon. If so, go through the calibration wizard to set the calibration.

**2. Load Cell Check**

- 2.1. Attach load cell to top or bottom surface of the frame using three 6 mm hex bolts and a number 5 allen wrench.
- 2.2. Live Displays are located in the top menu bar of the Instron Console software. Double click on a display to adjust its properties. Ensure that one of the displays has 'Device' set to 'ElectroPuls', 'Signal Source' set to 'Transducers', 'Channel' set to 'Load', and 'Type' set to 'Track'. The 'Decimal Places' setting can be adjusted by the operator, but at least 2 are recommended for this exercise.
- 2.3. Make sure there are no fixtures attached to the load cell, and no loads are applied.

- 2.4. Click on the 'ElectroPuls' Menu icon on the left menu bar, then click on the 'Load' icon.
- 2.5. Click the 'Calibration' menu on the left, and check to make sure the Calibration Status reads "Calibrated."
- 2.6. As a general rule of thumb, if the load cell has recently been changed, or someone else has run other tests since you have last used it, you should recalibrate the load cell (even if the status reads "Calibrated"). Use the following steps to do so.
  - 2.6.1. Click the 'Calibration Wizard' button.
  - 2.6.2. Keep clicking 'Next' and do not change any of the options. Then click 'Start'
- 2.7. Once the Wizard is finished, it will prompt you to save the Calibration file. These are stored in E:\Shared Documents\Instron\Console\CalWizard. Name using the convention "Load Cell Capacity, followed by serial number" i.e. 1kN107120cal'#'
- 2.8. Offset the ElectroPuls Load by clicking on the 'ElectroPuls' Menu on the left menu bar, then click on the 'Load' icon, and under 'Calibration' click 'Balance'.

### **3. Fixturing**

- 3.1. Attach superior F1717 fixture to the actuator using three 6 mm hex bolts and nuts. Tighten using a number 5 allen wrench.
- 3.2. Position the inferior F1717 fixture to load cell using the custom washers provided and the short 6mm hex bolt. Note the load reading on the top of the computer screen, which should read just the weight of the fixture. Watch the load reading as you tighten the hex bolt using a number 5 allen wrench. Once the load starts to deviate from just the weight of the fixture, you know you have tightened enough.
- 3.3. Make sure the fixtures are parallel using a straight edge. You may have to lower the crosshead in order to do so. For instructions on lowering the crosshead, see steps 4.7-4.8.

### **4. Start Machine and Load Specimen**

- 4.1. Ensure that the control mode is set to 'Position' before continuing.
  - 4.1.1. In the Instron Console software, the control mode icon is highlighted in green at the top of the ElectroPuls menu. To transfer to a different control mode, click on the desired mode's icon, and under 'Shortcuts', click 'Transfer'.
- 4.2. Ensure that the 'Position', 'Load', and 'Digital Position' units are set to SI small (mm, N).

- 4.2.1. For each channel, click on the 'ElectroPuls' menu on the left menu bar, then click on the icon.
  - 4.2.2. Under 'Calibration' change 'Physical Units' to 'mm' or 'N'.
- 4.3. Turn on the load frame by clicking the low-power ( | ) button on the control panel, located on the bottom right of the load frame. The left menu bar on the screen will now flash green, and the crosshead light will also be green.
- 4.4. Move the actuator up to start position. NOTE Actuator Range:  $\pm 30\text{mm}$  from True 0. [(-) Compression; (+) Tension]
  - 4.4.1. Click the 'Open Setpoint Tool' button, which is located on the bottom left of the Instron Console software, and is represented with a blue diagonal arrow pointing at a red dot.
  - 4.4.2. Choose an appropriate 'Ramp Duration' (5 seconds is fine).
  - 4.4.3. Set the 'Mode' to 'Position', and the 'Target' to +25 mm for this test. (Note: This is so that the constructs can utilize the full range of the actuator during bending).
  - 4.4.4. Click Enter.
  - 4.4.5. Click 'Start'.
- 4.5. Fix the inferior UHMWPE test block to the inferior fixture using the  $\text{\O}1/2$ " shoulder bolt- a hammer or mallet may be needed [note: do not fix the superior test block quite yet].
- 4.6. With the inferior fixture in place, tare the 'Load' channel by going to its 'Calibration' menu and clicking 'Balance'. Now the force reading should read '0N' as it is offset to account for the weight of the sample.
- 4.7. Loosen the black handles on either side of the crosshead. Adjust the crosshead height using the black switch with up and down arrows on the left side of the physical control panel, directly below the red emergency stop button (not the buttons on the detachable portion of the panel!). Move the crosshead until you can fix the superior UHMWPE test block into the superior fixture using the  $\text{\O}1/2$ " bolt.
- 4.8. Tighten the black handles.
- 4.9. Using the right detachable portion of the control panel, adjust the 'Position' of the actuator until the load is approximately zero.
  - 4.9.1. Note that the scroll wheel makes more fine adjustments than the up and down arrows.

- 4.10. Tare the 'Digital Position' by going to its 'Calibration' menu and clicking 'Balance'.
- 4.11. Take a photo of the specimen.
- 4.12. Turn the frame onto high-power by clicking the high-power ( || ) button on the control panel, located on the bottom right of the frame. The left menu bar on the screen will now be solid green.

## 5. Set Limits

- 5.1. Double-check and adjust the 'Position', 'Load', and 'Digital Position' limits as necessary for each test.
  - 5.1.1. 'Position' represents the physical position of the actuator in space, and 'Digital Position' (Displacement) represents the relative position of the actuator with respect to an arbitrary zero location, which is specified by the operator.
  - 5.1.2. Tare the Digital Position by clicking on its icon, and under 'Calibration', click 'Balance'.
  - 5.1.3. The up and down arrows next to each icon represent the limits for each control mode. The 'Position' and 'Load' limits should not be changed, but you should change the 'Digital Position' limits based on the length of the test. Click Enter after changing any values. Appropriate limits for static test (ROS1) running from 0 to -50 mm are given below.
 

5.1.4. Upper Position:	28	Lower Position:	28
Upper Load:	800	Lower Load:	-800
Upper Digital Position:	4	Lower Digital Position:	-55
  - 5.1.5. A general rule of thumb when setting limits is to set load limits with a buffer of around  $\pm 20\%$  from the load cell capacity. Displacement limits should be set depending on the expected stiffness of your sample. It helps to know what loads you get at certain displacements when setting these limits.
  - 5.1.6. Make sure that the boxes for 'Limit Enabled' are checked, and the 'Limit Actions' are all set to 'Unload'.

## 6. Procedure

- 6.1. From the desktop, open Instron WaveMatrix.
  - 6.1.1. Note: Since the Method (i.e., test procedure) for static testing was already developed, this document will not go into detail about the procedure. However, you should check the procedure before running it to make sure it has the appropriate test parameters. Click 'Method', open your procedure, and check the action steps and data collection options. Some helpful notes are included below:
    - 6.1.2. The endpoint for the ramp down waveform should be the highest compressive displacement you intend to reach.
    - 6.1.3. The endpoint for the ramp up waveform is -10 mm, so that the user can manually adjust the actuator to a zero load position, without transferring to 'Load' control.
    - 6.1.4. If you are unsure about anything in the Method, contact trained lab personnel.
- 6.2. Click 'Test'.
- 6.3. On the left menu, click 'New Project' and type the specimen name under 'Project Name'. Change the 'Project Folder Location' to the folder titled 'Growing Rod Static'. The complete path is given below. Click 'Next' on the right.

*E:\Documents and Settings\All Users\Documents\Instron\WaveMatrix\Projects\Growing Rod Static*
- 6.4. Select the method 'growing rod static' from the 'Most Recently Used Methods' section. The complete path is given below. Click 'Next' on the right.

*E:\Documents and Settings\All Users\Documents\Instron\WaveMatrix\Methods\growing rod static.im\_gpf*
- 6.5. Start recording on the video camera.
- 6.6. You are ready to run the test as soon as one person stands by an emergency stop button as a precaution.
  - 6.6.1. Click 'Start' on the upper right.
  - 6.6.2. Click 'Ok' on the pop-up window.
- 6.7. Wait for test to finish [note: the programs are set to automatically bring the actuator back to -10 mm 'Digital Position'].
- 6.8. Stop the video recording.

- 6.9. Click 'Finish' in the lower right corner of WaveMatrix.
- 6.10. Set the control mode to 'Position'.
- 6.11. Using the detachable portion of the control panel, manually adjust the actuator 'Position' until the load reads approximately zero on the Live Display.
- 6.12. Unload the specimen by removing the Ø½" bolts.
- 6.13. Set the actuator 'Position' back to 25 mm using the set point tool, as before.
- 6.14. Repeat steps 4.5-4.26 for each sample.
- 6.15. When finished testing, turn off the frame by pressing the ( O ) button on the control panel, exit WaveMatrix, exit Console, and turn off the power supplies beneath the frame.

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- Load Cell: 1 kN axial
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**1. Software**

- 1.1. Plug in computer, turn on, and login.
- 1.2. Plug in load cell into port on back of crosshead.
- 1.3. Turn on both power supplies beneath the frame using the black switches above all of the wires in the back. The sides of the switches will be red when they are turned on. The light on the crosshead next to the ElectroPuls logo will be white.
- 1.4. From desktop, open Instron Console. Wait a few minutes for the software to load. Once the software is loaded, the menu bar on the left of the screen will be grey, and a blue 'R' will flash above the ElectroPuls icon.
- 1.5. Click the ElectroPuls icon. If there is a flashing 'R' above the Static 2 icon, click on it, and then click 'Restore Calibration'.
- 1.6. If a load cell was newly plugged in or switched, a flashing "U" will appear above the Load icon. If so, go through the calibration wizard to set the calibration.

**2. Load Cell Check**

- 2.1. Attach load cell to top or bottom surface of the frame using three 6 mm hex bolts and a number 5 allen wrench.
- 2.2. Live Displays are located in the top menu bar of the Instron Console software. Double click on a display to adjust its properties. Ensure that one of the displays has 'Device' set to 'ElectroPuls', 'Signal Source' set to 'Transducers', 'Channel' set to 'Load', and 'Type' set to 'Track'. The 'Decimal Places' setting can be adjusted by the operator, but at least 2 are recommended for this exercise.
- 2.3. Make sure there are no fixtures attached to the load cell, and no loads are applied.

- 2.4. Click on the 'ElectroPuls' Menu icon on the left menu bar, then click on the 'Load' icon.
- 2.5. Click the 'Calibration' menu on the left, and check to make sure the Calibration Status reads "Calibrated."
- 2.6. As a general rule of thumb, if the load cell has recently been changed, or someone else has run other tests since you have last used it, you should recalibrate the load cell (even if the status reads "Calibrated"). Use the following steps to do so.
  - 2.6.1. Click the 'Calibration Wizard' button.
  - 2.6.2. Keep clicking 'Next' and do not change any of the options. Then click 'Start'
- 2.7. Once the Wizard is finished, it will prompt you to save the Calibration file. These are stored in E:\Shared Documents\Instron\Console\CalWizard. Name using the convention "Load Cell Capacity, followed by serial number" i.e. 1kN107120cal'#'
- 2.8. Offset the ElectroPuls Load by clicking on the 'ElectroPuls' Menu on the left menu bar , then click on the 'Load' icon, and under 'Calibration' click 'Balance'.

### **3. Fixturing**

- 3.1. Attach superior F1717 fixture to the actuator using three 6 mm hex bolts and nuts. Tighten using a number 5 allen wrench.
- 3.2. Position the inferior F1717 fixture to load cell using the custom washers provided and the short 6mm hex bolt. Note the load reading on the top of the computer screen, which should read just the weight of the fixture. Watch the load reading as you tighten the hex bolt using a number 5 allen wrench. Once the load starts to deviate from just the weight of the fixture, you know you have tightened enough.
- 3.3. Make sure the fixtures are parallel using a straight edge. You may have to lower the crosshead in order to do so. For instructions on lowering the crosshead, see steps 4.7-4.8.

### **4. Start Machine and Load Specimen**

- 4.1. In the Instron Console software, the control mode icon is highlighted in green at the top of the ElectroPuls menu. To transfer to a different control mode, click on the desired mode's icon, and under 'Shortcuts', click 'Transfer'. Ensure that 'Position' is highlighted green so that you are in displacement mode.



- 4.2. Ensure that the 'Position', 'Load', and 'Digital Position' units are set to SI small (mm, N). For each channel, click on the 'ElectroPuls' menu on the left menu bar, then click on the icon.
  - 4.2.1. Under 'Calibration' change 'Physical Units' to 'mm' or 'N'.
- 4.3. Turn on the load frame by clicking the low-power ( | ) button on the control panel, located on the bottom right of the load frame. The left menu bar on the screen will now flash green, and the crosshead light will also be green.
- 4.4. Move the actuator up to start position. NOTE Actuator Range:  $\pm 30\text{mm}$  from True 0. [(-) Compression; (+) Tension]
  - 4.4.1. Click the 'Open Setpoint Tool' button, which is located on the bottom left of the Instron Console software, and is represented with a blue diagonal arrow pointing at a red dot.
  - 4.4.2. Choose an appropriate 'Ramp Duration' (5 seconds is fine).
  - 4.4.3. Set the 'Mode' to 'Position', and the 'Target' to +25mm (Note: This is so that the constructs can utilize the full range of the actuator during bending which is 60mm).
  - 4.4.4. Click Enter.
  - 4.4.5. Click 'Start'.
- 4.5. Fix the inferior UHMWPE test block to the inferior fixture using the  $\text{\O}1/2$ " shoulder bolt- a hammer or mallet may be needed [note: do not fix the superior test block quite yet].
- 4.6. With the inferior fixture in place, tare the 'Load' channel by going to its 'Calibration' menu and clicking 'Balance'. Now the force reading should read '0N' as it is offset to account for the weight of the sample.
- 4.7. Loosen the black handles on either side of the crosshead. Adjust the crosshead height using the black switch with up and down arrows on the left side of the physical control panel, directly below the red emergency stop button (not the buttons on the detachable portion of the panel!). Move the crosshead until you can fix the superior UHMWPE test block into the superior fixture using the  $\text{\O}1/2$ " bolt.
- 4.8. Tighten the black handles.
- 4.9. Using the right detachable portion of the control panel, adjust the 'Position' of the actuator until the load is approximately zero.

- 4.9.1. Note that the scroll wheel makes more fine adjustments than the up and down arrows.
- 4.10. Tare the 'Digital Position' by going to its 'Calibration' menu and clicking 'Balance'.
- 4.11. Take a photo of the specimen.
- 4.12. Turn the frame onto high-power by clicking the high-power ( || ) button on the control panel, located on the bottom right of the frame. The left menu bar on the screen will now be solid green.

## **5. Tuning**

- 5.1. Auto-tune each construct to obtain a stiffness value (do not use a stiffness value that was previously obtained through static testing, because the E3000 does not define stiffness in the same way as ASTM F1717).
  - 5.1.1. Under the 'ElectroPuls' General Menu, click 'Tuning Wizard.'
  - 5.1.2. Click 'Next'. Do not enable "I want to be able to control in Strain."
  - 5.1.3. Click 'Next'. Do not adjust the upper 'Position' value. Use the static load-displacement curves to find the expected displacement at the largest compressive load achieved during the cyclic test. Subtract this displacement value from the upper 'Position' value, and enter it in the lower 'Position' value.
  - 5.1.4. Click 'Start'. The machine will automatically ramp to calculate a stiffness value.
  - 5.1.5. Click 'Ok' once it is done to exit the Wizard.
- 5.2. The load reading might not be zero, even though the construct could appear unloaded. Do not tare the 'Load', or adjust the 'Position' of the actuator! Leave the construct and the actuator as they are after tuning.

## **6. Set Limits**

- 6.1. Double-check and adjust the 'Position', 'Load', and 'Digital Position' limits as necessary for each test.
  - 6.1.1. 'Position' represents the physical position of the actuator in space, and 'Digital Position' (Displacement) represents the relative position of the actuator with respect to an arbitrary zero location, which is specified by the operator.

- 6.1.2. Tare the Digital Position by clicking on its icon, and under 'Calibration', click 'Balance'.
- 6.1.3. The up and down arrows next to each icon represent the limits for each control mode. The 'Position' limits should not be changed, but you should change the 'Load' limits based on test parameters, and the 'Digital Position' limits based on expected displacements for the particular construct. Click Enter after changing any values. Appropriate limits for cyclic test (SSCF1) running from -15 N to -150 N are given below. The expected construct displacements are -3 mm to -35 mm.
 

6.1.4. Upper Position:	28	Lower Position:	28
Upper Load:	20	Lower Load:	-175
Upper Digital Position:	5	Lower Digital Position:	-45
- 6.1.5. A general rule of thumb when setting limits is to set load limits with a buffer of around  $\pm 20\%$  from the load cell capacity. Displacement limits should be set depending on the expected stiffness of your sample. It helps to know what loads you get at certain displacements when setting these limits.
- 6.1.6. Make sure that the boxes for 'Limit Enabled' are checked, and the 'Limit Actions' are all set to 'Unload'.
- 6.2. Transfer the control mode to 'Load'.
  - 6.2.1. Click on the 'Load' icon in the 'ElectroPuls' menu.
  - 6.2.2. Under 'Shortcuts', click 'Transfer'.
  - 6.2.3. Select 'Go To', then type 0N and click Enter.

## 7. Procedure

- 7.1. From the desktop, open Instron WaveMatrix.
  - 7.1.1. Note: Since the Method (i.e., test procedure) for fatigue testing was already developed, this document will not go into detail about the procedure. However, you should check the procedure before running it to make sure it has the appropriate test parameters. Click 'Method', open your procedure, and check the action steps and data collection options. Some helpful notes are included below:
  - 7.1.2. The endpoint for the ramp down waveform should be the mean of the upper and lower 'Load' limits (the baseline of the sine wave).

- 7.1.3. In the sine waveform, the amplitude is the difference between the limits and the mean, or in mathematical terms:  $\frac{1}{2} * |\text{max} - \text{min}|$ .
- 7.1.4. Under the sine waveform data collection box, the 'Monitor Peaks and Trends' tab is used to specify a break detector. The tolerance of the load (called "change") should be set to 20 N, so that if the peaks and valleys of the sine wave deviate by that much from the target values, the test will stop.
- 7.1.5. The 'Event Detector' tab within the sine waveform action box is another way of specifying the 'Position' limits of the test. Set these limits to be more restrictive than the 'ElectroPuls' system limits, so that they will trigger first. That way the machine is less likely to turn off in the event of a break.
- 7.1.6. If you are unsure about anything in the Method, contact trained lab personnel.
- 7.2. Save changes as needed.
- 7.3. Go back to Home page and click 'Test'.  
On the left menu, click 'New Project' and type the specimen name under 'Project Name'. Change the 'Project Folder Location' to the folder titled 'Growing Rod Fatigue'. The complete path is: *E:\Documents and Settings\All Users\Documents\Instron\WaveMatrix\Projects\Growing Rod Fatigue*
- 7.4. Click 'Next' on the right.  
Select the method 'growing rod fatigue' from the 'Most Recently Used Methods' section. The complete path is: *E:\Documents and Settings\All Users\Documents\Instron\WaveMatrix\Methods\growing rod fatigue.im\_gpf*
- 7.5. Click 'Next' on the right.
- 7.6. Start recording on the video camera.
- 7.7. You are ready to run the test as soon as one person stands by an emergency stop button as a precaution.
  - 7.7.1. Click 'Start' on the upper right.
  - 7.7.2. Click 'Ok' on the pop-up window.
  - 7.7.3. Observe the specimen as it ramps down to the target load. As it starts to cycle, the auto-tuning program will slowly adjust the displacements based on the specimen stiffness, in order to reach the minimum and maximum loads. Once the Load Peak/Valley readings on the screen are within 1 N of the maximum and minimum

values for the test, record the number of cycles and steady-state Digital Position readings in your lab notebook.

7.7.4. Stop the video recording.

7.7.5. Wait for test to finish [note: the programs are set to automatically bring the load back to zero after reaching the limits of the procedure so be patient until the MPT stops].

## **8. Finish Test**

- 8.1. Click 'Finish' in the lower right corner of WaveMatrix.
- 8.2. Record all necessary values in your lab notebook (e.g., displacements, cycles, etc).
- 8.3. If there was a break, Specimen Protect may have been triggered, preventing you from perform certain actions in the software or on the Control Panel. To disable it, click the 'ElectroPuls' icon menu, and on the right, you will see a button with a green shield on it. Click that button, and the shield should have a red 'X' on it, meaning it has been disabled.
- 8.4. Set the control mode to 'Position'.
- 8.5. Take a photo of the specimen before unloading it.
- 8.6. Disable the limits by clicking the arrows that were triggered (blinking red arrows) and press "Disarm all limits."
- 8.7. Retrieve raw data from specimen folder (described above).

## **9. Shutting Machine Down**

- 9.1. When finished testing, turn off the frame by pressing the ( O ) button on the control panel, exit WaveMatrix, exit Console, and turn off the power supplies beneath the frame.

Standard Operating Procedure  
Modified ASTM F1717 Test  
**Static Axial Compression Bending for Growing Rod Constructs**  
Last Edited: 7/29/2016

**Equipment:**

- Load Frame: MTS Bionix 858
- Load Cell: 550 lb axial, 250 in-lb torsional (calibration file F\_Torsion-550lbs 10418266.scf which corresponds to the load cell serial #: 10418266)
- PC with MTS software

**1. Sample Preparation**

- 1.1 Check whether the Ø½” shoulder bolts can fit in the UHMWPE test blocks.
- 1.2 Have machine shop drill pilot holes into UHMWPE test blocks. The diameter of the pilot hole should be the minor diameter of the pedicle screw.
- 1.3 Insert the UHMWPE test blocks into a vice, separating them with a pre-cut spacer block and keeping the blocks level.
- 1.4 Label each component with a unique identifier so components can be tracked. Rods and set screws will likely need to be replaced each time while connectors and pedicle screws may be reused.
- 1.5 Insert pedicle screws into UHMWPE test block at an angle normal to the face of the UHMWPE test block — see diagrams in F1717 standard for more detail.
- 1.6 Attach rods and confirm they are straight.
- 1.7 Insert set screw and tighten set screw to a pre-determined torque (60 in-lb) using a torque wrench — see test matrix for specified torques.
- 1.8 Confirm active length by measuring the center-to-center screw distances- see test matrix for active lengths.

**2. Software**

- 2.1 Plug in axial and torsional cables into load cell.
- 2.2 From desktop, open Station Manager.
- 2.3 *Single* click the Axial\_Torsional.cfg program within the Config folder. Under parameter sets, click on ASTM F1717 Axial. Click Open and several windows may pop up.
- 2.4 Find the main screen for Station Manager, and check the box next to Exclusive Control under Station Controls.

- 2.5 Since the MPT (i.e., test procedure) was already programmed, this document will not go into detail about the procedures. However, ensure that the correct procedure is set (e.g., Axial Static) is selected. If not, open the correct procedure.
- 2.6 Under Station Setup, confirm that correct load cell calibration file is uploaded under the Sensor tab in Axial Force.
- 2.7 Under Station Limits, check whether any red boxes appear in the station limits. If so, determine what is causing the program stop interlock before proceeding by reading the text box at the bottom of the Station Manager window (once you understand the reasons behind the interlock, hit Reset next to Program 1 if it is safe to do so). If no station limits were tripped, hit Reset next to Interlock 1.
- 2.8 Turn on the servo-hydraulic system by finding the rows labeled HPU T7-J25 and HSM Axial towards the bottom right side of the Station Manager window.
  - 2.8.1 Click the button with 2 white stripes along the HPU T7-J25 row and wait for the yellow to stop blinking.
  - 2.8.2 Click the button with the 3 white stripes along the HPU T7-J25 row [note: actuator may jump slightly when powering up but use any emergency stop buttons if more than a small jump occurs].
  - 2.8.3 Click the button with 2 white stripes along the HSM Axial row followed by the button with 3 white stripes.
- 2.9 Allow the hydraulics to warm up for 10 minutes, especially if performing a fatigue test.

### **3. Load Cell Check (if needed)**

- 3.1 Attach load cell to mounting plate on the table of the load frame and tighten with allen wrench.
- 3.2 Pull up the Meters and Auto Offset windows.
- 3.3 Offset the Axial Force using Auto Offset.
- 3.4 Using 5kg, 10kg, and 20kg standardized weights, place weights on top of load cell in increments.
- 3.5 Determine if Axial Force readings are accurate and calculate the percent difference.
- 3.6 If readings are >2% different, the load cell is not fit for testing and must be calibrated.
- 3.7 Torsional Torques can also be evaluated using a torque wrench, if needed.

#### 4. Fixturing

- 4.1 Insert adaptor thread into actuator that accepts  $\text{Ø}\frac{1}{2}$ " threaded bolt.
- 4.2 Attach anti-torsional fixture to actuator via the  $\text{Ø}\frac{1}{2}$ " threaded bolt and tighten by hand or allen wrench.
- 4.3 Set torque wrench to 100Nm and tighten  $\text{Ø}\frac{1}{2}$ " threaded bolt to 100Nm.
- 4.4 Attach interface plate to anti-torsional fixture and tighten using an allen wrench.
- 4.5 Attach superior F1717 fixture to the interface plate and tighten using an allen wrench.
- 4.6 Attach inferior F1717 fixture to load cell and tighten using an allen wrench while monitoring axial force and torsional torque readings on the Meter [note: the limits will trip if over torqued].
- 4.7 Determine if actuator is at its true zero axial position by removing the axial displacement offset (Station Controls → Auto Offset → Clear Offset) and manually commanding the axial displacement to zero (Station Controls → Manual Command).
- 4.8 Move cross head down as needed, making sure to lock the cross head securely via the table controls as well as the manual bolts. If you do not know *how* to move and lock the cross head, do not attempt it yourself. Instead, find a trained lab member to show you.

#### 5. Sample Mounting

- 5.1 Fix the inferior UHMWPE test block to the inferior fixture using the  $\text{Ø}\frac{1}{2}$ " shoulder bolt- a gentle tap with a hammer or mallet may be needed [note: do not fix the superior test block quite yet].
- 5.2 Check the Meter readings and Auto Offset to determine that only the weight of the inferior fixture and specimen are contributing to the forces/torques.
- 5.3 Tare the axial force under Auto Offset.
- 5.4 Under Station Controls, click on Manual Command and enable it by checking the box. Incrementally change the Axial *Displacement* and Torsional *Angle* until you can fix the superior UHMWPE test block into the superior fixture. Fix the superior UHMWPE test block to superior fixture using the  $\text{Ø}\frac{1}{2}$ " shoulder bolt- a gentle tap with a hammer or mallet may be needed.



- 5.5 After the test blocks are mounted and secure, use Manual Command to adjust the Axial *Displacement* and Torsional *Angle* to remove any Axial Force or Torsional Torque on the sample.

## **6. Load Cell Limits**

- 6.1 Check again to see if station limits were tripped or program interlocked. Reset as needed.
- 6.2 The limits of the load cell will need to be set to “Program Stop and Ramp” action.
- 6.3 Click the Station Setup icon on the top row in the Station Manager window and drop down the Channels on the left hand side of the Station Setup window. Note: these limits are only applicable to the identified load cell. If a different load cell is used, you must set the limits accordingly. If any limits are changed, you must hit enter for them to be saved.
- 6.3.1 Find the Limits tab for Torsional Torque, and confirm that the upper and lower limits are highlighted green, set to +10 N-m and -10 N-m respectively, and Program Stop and Ramp is set as the action.
- 6.3.2 Find the Limits tab for Torsional Angle, and confirm that the upper and lower limits are highlighted green, set to +30° and -30° respectively, and Program Stop and Ramp is set as the action.
- 6.3.3 Find the Limits tab for Axial Force, and confirm that the upper and lower limits are highlighted green, set to +1000 N and -1000 N respectively, and Program Stop and Ramp is set as the action.
- 6.3.4 Find the Limits tab for Axial Displacement, and confirm that the upper and lower limits are highlighted green, set to +50 mm and -50 mm respectively, and Program Stop and Ramp is set as the action.
- 6.3.5 Exit window.

## 7. Procedure

- 7.1 Under Manual Command, manually command the Torsional *Angle* until the torque reads zero [note: do not Auto Offset the Torsional Torque]. Alternatively, the Torsional Angle can be incrementally changed until the Torsional Torque is zero based on the reading on the Meter.
- 7.2 Under Manual Command, manually command the Axial *Displacement* until the Axial Force reads zero [note: do not Auto Offset the Axial Force].
- 7.3 Take a photo of the specimen and position the camera for a video recording (do not start recording just yet).
- 7.4 Open the MPT Procedure Editor (icon is under the MPT section on the Station Manager window) and check limits of the procedure based on the testing protocol [note: this refers to the limits you wish to test the sample to and differs from the limits of the load cell. This should already be programmed but always a good idea to double check].
  - 7.4.1 For static testing, the primary limit you need to concern yourself with is the end of the downward displacement-controlled ramp. For the constructs tested during the summer of 2016, -30 mm was chosen for the Mid-Construct specimens, and -40 mm for the Adjacent to Tandem and Anchor Foundation specimens.
- 7.5 In the MPT Procedure Editor window, double click the Data acquisition icon and click on the Destination tab where you must change the file name. Copy this file name and paste it within the Destination tab under the Test Info command icon. Save the procedure.
- 7.6 Auto Offset both the Axial *Displacement* and Torsional *Angle*.
- 7.7 Go to the Specimen Editor icon found under the MPT section of the Station Manager window.
  - 7.7.1 Set the directory path to the ASTM F1717 Growing Rod folder.
  - 7.7.2 Click New on left side of window, type in the specimen name (top left hand corner), and hit enter. For example, the specimen name can be “MCL0S1” for Mid-Construct, zero rod-lengthenings, static 1.
  - 7.7.3 Exit window.
  - 7.7.4 Pull down your sample name under Specimen on the Station Manager window.

- 7.8 Under Manual Command, make sure you are in Axial *Displacement* and Torsional *Angle* modes [note: this will ensure you are in displacement control when unloading your specimen from the machine after testing is completed].
- 7.9 Disable Manual Command by unchecking the box within the manual command window.
- 7.10 Check again if any interlocks or limits were tripped. Reset as needed.
- 7.11 Pull up the Scope, and make an XY plot of the Axial Force vs. Axial Displacement. This will provide a real-time plot that you can monitor throughout the test.
- 7.12 You are ready to run the test as soon as one person stands by an emergency stop button as a precaution.
  - 7.12.1 PUT ON SAFETY GLASSES
  - 7.12.2 Press play on the main screen.
  - 7.12.3 You will be prompted to insert the Operator, Specimen Name, and Date. Fill in this information. BE SURE TO START THE VIDEO RECORDING BEFORE PRESSING “OK.”
  - 7.12.4 Observe the specimen as it ramps down to the target displacement. Be prepared to stop the test if the rods fracture or the machine acts unexpectedly.
  - 7.12.5 Wait for test to finish, and then stop the video.
- 7.13 Click the unlock icon under MPT section of the Station Manager window once the test is finished.
- 7.14 Manually command the Axial Displacement until the Axial Force is near zero so that you can unload the specimen.
- 7.15 Unload the specimen by removing the Ø1/2” shoulder bolts.
- 7.16 Repeat steps 5.1 to 7.15 for each sample.
- 7.17 When all testing is complete, manually command the actuator back to its zero Axial Displacement position.
- 7.18 Raise the crosshead to allow the actuator room to relax. There should be at least a foot in between the bottom of the actuator fixtures and the top of the load cell fixtures.
- 7.19 Turn off the servo-hydraulic system by finding the rows labeled HPU T7-J25 and HSM Axial towards the bottom right side of the Station Manager window.
  - 7.19.1 Click the button with 2 white stripes along the HSM Axial row followed by the button with 1 white stripe.

- 7.19.2 Click the button with 2 white stripes along the HPU T7-J25 row followed by the button with 1 white stripe.
- 7.20 Close Station Manager Software by X-ing out of the main window.

## **8. Data Retrieval and Analysis**

- 8.1 On the desktop, open the Specimens folder.
- 8.2 Find ASTM F1717 Growing Rod folder and specimen file.
- 8.3 Right click the .dat file and open with Excel or notepad.
- 8.4 Save Excel sheet to a thumb drive.

Standard Operating Procedures  
Modified ASTM F1717 Test  
**Dynamic Axial Compression Bending for Growing Rod Constructs**  
Last Edited: 7/27/2016

**Equipment:**

- Load Frame: MTS Bionix 858
- Load Cell: 550 lb axial, 250 in-lb torsional (calibration file F\_Torsion-550lbs 10418266.scf which corresponds to the load cell serial #: 10418266)
- PC with MTS software

**1. Sample Preparation**

- 1.1 Check whether the Ø½” shoulder bolts can fit in the UHMWPE test blocks.
- 1.2 Have machine shop drill pilot holes into UHMWPE test blocks. The diameter of the pilot hole should be the minor diameter of the pedicle screw.
- 1.3 Insert the UHMWPE test blocks into a vice, separating them with a pre-cut spacer block and keeping the blocks level.
- 1.4 Label each component with a unique identifier so components can be tracked. Rods and set screws will likely need to be replaced each time while connectors and pedicle screws may be reused.
- 1.5 Insert pedicle screws into UHMWPE test block at an angle normal to the face of the UHMWPE test block — see diagrams in F1717 standard for more detail.
- 1.6 Attach rods and confirm they are straight.
- 1.7 Insert set screw and tighten set screw to a pre-determined torque (60 in-lb) using a torque wrench — see test matrix for specified torques.
- 1.8 Confirm active length by measuring the center-to-center screw distances- see test matrix for active lengths.

**2. Software**

- 2.1 Plug in axial and torsional cables into load cell.
- 2.2 From desktop, open Station Manager.
- 2.3 *Single* click the Axial\_Torsional.cfg program within the Config folder. Under parameter sets, click on AB Growing Rods (7/16). Click Open and several windows may pop up.
- 2.4 Find the main screen for Station Manager, and check the box next to Exclusive Control under Station Controls.

- 2.5 Turn on power backup source by following instructions on the generator (large black box in the corner of the lab). If you do not know how to turn this on, you are not properly trained and need to contact a trained staff member.
- 2.6 Since the MPT (i.e., test procedure) was already programmed, this document will not go into detail about the procedures. However, ensure that the correct procedure is set (e.g., Axial Fatigue) is selected. If not, open the correct procedure.
- 2.7 Under Station Setup, confirm that correct load cell calibration file is uploaded under the Sensor tab in Axial Force.
- 2.8 Under Station Limits, check whether any red boxes appear in the station limits. If so, determine what is causing the program stop interlock before proceeding by reading the text box at the bottom of the Station Manager window (once you understand the reasons behind the interlock, hit Reset next to Program 1 if it is safe to do so). If no station limits were tripped, hit Reset next to Interlock 1.
- 2.9 Turn on the servo-hydraulic system by finding the rows labeled HPU T7-J25 and HSM Axial towards the bottom right side of the Station Manager window.
  - 2.9.1 Click the button with 2 white stripes along the HPU T7-J25 row and wait for the yellow to stop blinking.
  - 2.9.2 Click the button with the 3 white stripes along the HPU T7-J25 row [note: actuator may jump slightly when powering up but use any emergency stop buttons if more than a small jump occurs].
  - 2.9.3 Click the button with 2 white stripes along the HSM Axial row followed by the button with 3 white stripes.
- 2.10 Allow the hydraulics to warm up for 10 minutes, especially if performing a fatigue test.

### **3. Load Cell Check (if needed)**

- 3.1 Attach load cell to mounting plate on the table of the load frame and tighten with allen wrench.
- 3.2 Pull up the Meters and Auto Offset windows.
- 3.3 Offset the Axial Force using Auto Offset.
- 3.4 Using 5kg, 10kg, and 20kg standardized weights, place weights on top of load cell in increments.

- 3.5 Determine if Axial Force readings are accurate and calculate the percent difference.
- 3.6 If readings are >2% different, the load cell is not fit for testing and must be calibrated.
- 3.7 Torsional Torques can also be evaluated using a torque wrench, if needed.

#### **4. Fixturing**

- 4.1 Insert adaptor thread into actuator that accepts Ø½” threaded bolt.
- 4.2 Attach anti-torsional fixture to actuator via the Ø½” threaded bolt and tighten by hand or allen wrench.
- 4.3 Set torque wrench to 100Nm and tighten Ø½” threaded bolt to 100Nm.
- 4.4 Attach interface plate to anti-torsional fixture and tighten using an allen wrench.
- 4.5 Attach superior F1717 fixture to the interface plate and tighten using an allen wrench.
- 4.6 Attach inferior F1717 fixture to load cell and tighten using an allen wrench while monitoring axial force and torsional torque readings on the Meter [note: the limits will trip if over torqued].
- 4.7 Determine if actuator is at its true zero axial position by removing the axial displacement offset (Station Controls → Auto Offset → Clear Offset) and manually commanding the axial displacement to zero (Station Controls → Manual Command).
- 4.8 Move cross head down as needed, making sure to lock the cross head securely via the table controls as well as the manual bolts. If you do not know *how* to move and lock the cross head, do not attempt it yourself. Instead, find a trained lab member to show you.

#### **5. Sample Mounting**

- 5.1 Fix the inferior UHMWPE test block to the inferior fixture using the Ø½” shoulder bolt- a gentle tap with a hammer or mallet may be needed [note: do not fix the superior test block quite yet].
- 5.2 Check the Meter readings and Auto Offset to determine that only the weight of the inferior fixture and specimen are contributing to the forces/torques.
- 5.3 Tare the axial force under Auto Offset.
- 5.4 Under Station Controls, click on Manual Command and enable it by checking the box. Incrementally change the Axial *Displacement* and Torsional *Angle* until you can fix the superior UHMWPE test block into the superior fixture. Fix the superior UHMWPE test

block to superior fixture using the Ø1/2" shoulder bolt- a gentle tap with a hammer or mallet may be needed.

- 5.5 After the test blocks are mounted and secure, use Manual Command to adjust the Axial *Displacement* and Torsional *Angle* to remove any Axial Force or Torsional Torque on the sample.

## 6. Tuning

- 6.1 If you are running a fatigue test, you must tune the machine based on the stiffness of each sample. Tuning should only be performed by trained personnel!

6.1.1 Under Station Setup, click on the Tuning icon and go to the Axial Displacement and Axial Force channels to confirm the proper settings.

6.1.2 For the constructs tested during the summer of 2016, the following tuning parameters should be used in conjunction with a Peak/Valley Compensator, which is preset in the procedure:

Axial Displacement:

P-gain: 7.0

I-gain: 0.4

D-gain: 0.0

Axial Force:

P-gain: 200

I-gain: 0.2

D-gain: 0.001

6.1.3 Under the Axial Force channel, confirm the Dither settings are at 0.00 V amplitude and 528 Hz frequency.

6.1.4 If the above values are not appropriate for a given construct, proceed with the Tuning instructions provided below (with trained personnel).

- 6.2 Click the Station Setup icon on the top row in the Station Manager window and drop down the Channels on the left hand side of the Station Setup window. The limits will not engage if they are on "Program Stop" or "Program Stop and Ramp," because you are using the Function Generator instead of running a program while tuning. Instead, make sure they are set to "Interlock." Note: these limits are only applicable to the identified load cell. If a different load cell is used, you must set the limits accordingly. If any limits are changed, you must hit enter for them to be saved.



- 6.2.1 Find the Limits tab for torsional torque, and confirm that the upper and lower limits are highlighted green, set to +5 N-m and -5 N-m respectively, and Interlock is set as the action.
- 6.2.2 Find the Limits tab for torsional ADT (displacement), and confirm that the upper and lower limits are highlighted green, set to +10° and -10° respectively, and Interlock is set as the action.
- 6.2.3 Find the Limits tab for axial force, and confirm that the upper and lower limits are highlighted green, set to +500 N and -500 N respectively, and Interlock is set as the action.
- 6.2.4 Find the Limits tab for axial displacement, and confirm that the upper and lower limits are highlighted green, set to +10 mm and -45 mm respectively, and Interlock is set as the action.
- 6.2.5 Exit window
- 6.3 On the drop down menu at the top of the station manager row, select Tuning and enter the password. Only trained personnel will have the password.
- 6.4 Under Station Setup window, click the Tuning icon on the left column and click on the channel (e.g., Axial Force) that you plan to tune. Check the P and I Gains and determine how they match up compared to the previously recorded values. Always start with low gains and work up if you are not familiar with these values.
- 6.5 Open the Scope. Make a time plot with Axial Force and Axial Command. Click the Same Scale icon. You will need to adjust your trace time depending on the test frequency.
- 6.6 On the Station Manager window, click on the Function Generator icon. Enter the channel you wish to tune (e.g., Axial Force).
- 6.7 Enter the target force and amplitude. The target force is the median of the sine wave, and the amplitude is the difference between the target force and the maximum and minimum forces you plan to use during testing. For example, if your protocol requires you to test to -150 N and -15 N, then the target will be -82.5 N with amplitude of 67.5 N.
- 6.8 Set a low frequency (e.g., 1 Hz or less).
- 6.9 PUT ON SAFETY GLASSES.
- 6.10 Auto Offset the Axial Displacement if you are near the limit.

- 6.11 Press Play. Determine how Axial Force and Axial Command align in the plot on the Scope. Incrementally adjust P and I Gains as needed. Make sure to slightly undershoot the values since PVC Compensator will take care of the rest.
- 6.12 Incrementally increase frequency to match desired protocol in testing (e.g., 4 Hz).
- 6.13 Incrementally adjust P and I Gains as needed. I Gain is typically ~10% of P Gain.
- 6.14 Record gain values and save for later use (see sample table). Samples will need to be retuned when changing any part of the specimen that will affect its stiffness (e.g., device material, lengthenings).
- 6.15 Turn on PVC Compensator to ensure the upper and lower load magnitudes are reached. Adjust gain values as needed and record values.
- 6.16 Press Stop. Exit tuning by going back into MPT mode.

**Sample Tuning Table for Growing Rods**

Device Material	Lengthening #	Channel/Target/Amplitude	Frequency	P Gain	I Gain	D Gain (rarely used)	F Gain (rarely used)
Titanium	0	Axial/-165 N/135 N	5Hz	900	10	0.01	0
Titanium	3	Axial/-165 N/135 N	1 Hz	500	50	0	0
Titanium	3	Axial/-165 N/135 N	2 Hz	600	60	0	0
Titanium	0	Torsion/0 Nm /2 Nm	2Hz	2.5	0.01	0	0

## 7. Load Cell Limits

- 7.1 Check again to see if station limits were tripped or program interlocked. Reset as needed.
- 7.2 The limits of the load cell will need to be readjusted after tuning and set to “Program Stop and Ramp” action.
- 7.3 Click the Station Setup icon on the top row in the Station Manager window and drop down the Channels on the left hand side of the Station Setup window. Note: these limits are only applicable to the identified load cell. If a different load cell is used, you must set the limits accordingly. If any limits are changed, you must hit enter for them to be saved.
  - 7.3.1 Find the Limits tab for Torsional Torque, and confirm that the upper and lower limits are highlighted green, set to +5 N-m and -5 N-m respectively, and Program Stop and Ramp is set as the action.

- 7.3.2 Find the Limits tab for Torsional Angle, and confirm that the upper and lower limits are highlighted green, set to  $+10^{\circ}$  and  $-10^{\circ}$  respectively, and Program Stop and Ramp is set as the action.
- 7.3.3 Find the Limits tab for Axial Force, and confirm that the upper and lower limits are highlighted green, set to +1200 N and -1200 N respectively, and Program Stop and Ramp is set as the action.
- 7.3.4 Find the Limits tab for Axial Displacement, and confirm that the upper and lower limits are highlighted green, set to +10 mm and -45 mm respectively, and Program Stop and Ramp is set as the action.
- 7.3.5 Exit window.

## 8. Procedure

- 8.1 Under Manual Command, manually command the Torsional *Angle* until the torque reads zero [note: do not Auto Offset the Torsional Torque]. Alternatively, the Torsional Angle can be incrementally changed until the Torsional Torque is zero based on the reading on the Meter.
- 8.2 Under Manual Command, manually command the Axial *Displacement* until the Axial Force reads zero [note: do not Auto Offset the Axial Force].
- 8.3 Take a photo of the specimen and position the camera for a video recording (do not start recording just yet).
- 8.4 Open the MPT Procedure Editor (icon is under the MPT section on the Station Manager window) and check limits of the procedure based on the testing protocol [note: this refers to the limits you wish to test the sample to and differs from the limits of the load cell. This should already be programmed but always a good idea to double check].
- 8.5 In the MPT Procedure Editor window, double click the Data acquisition icon and click on the Destination tab where you must change the file name. Copy this file name and paste it within the Destination tab under the Test Info command icon. Save the procedure.
- 8.6 Auto Offset both the Axial *Displacement* and Torsional *Angle*.
- 8.7 Go to the Specimen Editor icon found under the MPT section of the Station Manager window.
  - 8.7.1 Set the directory path to the ASTM F1717 Growing Rod folder.

- 8.7.2 Click New on left side of window, type in the specimen name (top left hand corner), and hit enter. For example, the specimen name can be “MCL0F1” for Mid-Construct, zero rod-lengthenings, fatigue 1.
- 8.7.3 Exit window.
- 8.7.4 Pull down your sample name under Specimen on the Station Manager window.
- 8.8 Under Manual Command, make sure you are in Axial *Displacement* and Torsional *Angle* modes [note: this will ensure you are in displacement control when unloading your specimen from the machine after testing is completed].
- 8.9 Disable Manual Command by unchecking the box within the manual command window.
- 8.10 Check again if any interlocks or limits were tripped. Reset as needed.
- 8.11 Pull up the Scope, and make a Time plot of the Axial Force and Axial Command, which may have already been set up during Tuning. This will provide a real-time plot that you can monitor throughout the test.
- 8.12 You are ready to run the test as soon as one person stands by an emergency stop button as a precaution.
  - 8.12.1 Press play on the main screen.
  - 8.12.2 You will be prompted to insert the Operator, Specimen Name, and Date. Fill in this information. BE SURE TO START THE VIDEO RECORDING BEFORE PRESSING “OK.”
  - 8.12.3 Observe the specimen as it ramps down to the target load. As it starts to cycle, the PVC will slowly adjust to match the Axial Force and Axial Command plots on the scope. Once the Axial Force Peak/Valley readings on the Meter are within 1 N of the maximum and minimum values for the test, record the number of cycles and steady-state Axial Displacement Peak/Valley readings in your lab notebook.
  - 8.12.4 Stop the video recording.
  - 8.12.5 Wait for test to finish [note: the programs are set to automatically bring the load/torque back to zero after reaching the limits of the procedure so be patient until the MPT stops].
- 8.13 Click the unlock icon under MPT section of the Station Manager window once the test is finished.
- 8.14 Take a photo of the specimen before unloading it.

- 8.15 Unload the specimen by removing the  $\varnothing\frac{1}{2}$ " shoulder bolts.
- 8.16 Manually command the actuator back to its zero Axial Displacement position.
- 8.17 Repeat steps for each sample.

## **9. Data Retrieval and Analysis**

- 9.1 On the desktop, open the Specimens folder.
- 9.2 Find ASTM F1717 Growing Rod folder and specimen file.
- 9.3 Right click the .dat file and open with Excel or notepad.
- 9.4 Save Excel sheet to a thumb drive.

Standard Operating Procedure  
Modified ASTM F1717 Test  
**Dynamic Axial Compression Bending for Growing Rod Constructs**  
Last Edited: 6/9/2017

**Equipment:**

- Load Frame: MTS Uniaxial
- Actuator Range:  $\pm 120$ mm
- Load Cell: 550 lb axial
- PC with MTS software

**1. Sample Preparation**

- 1.1 Check whether the  $\varnothing 1/2$ " shoulder bolts can fit in the UHMWPE test blocks.
- 1.2 Have machine shop drill pilot holes into UHMWPE test blocks. The diameter of the pilot hole should be the minor diameter of the pedicle screw.
- 1.3 Insert the UHMWPE test blocks into a vice, separating them with a pre-cut spacer block and keeping the blocks level.
- 1.4 Label each component with a unique identifier so components can be tracked. Rods and set screws will likely need to be replaced each time while connectors and pedicle screws may be reused.
- 1.5 Insert pedicle screws into UHMWPE test block at an angle normal to the face of the UHMWPE test block — see diagrams in F1717 standard for more detail.
- 1.6 Attach rods and confirm they are straight.
- 1.7 Insert set screw and tighten set screw to a pre-determined torque (60 in-lb) using a torque wrench — see test matrix for specified torques.
- 1.8 Confirm active length by measuring the center-to-center screw distances- see test matrix for active lengths.

**2. Software**

- 2.1 Plug in axial cable into load cell.
- 2.2 From desktop, open Station Manager.
- 2.3 Double click the ASTM F1717 project folder.
- 2.4 *Single* click the ftse.cfg program within the Config folder. Under parameter sets, click on 1 kN – growing rods. Click Open and several windows may pop up.

- 2.5 Find the main screen for Station Manager, and check the box next to Exclusive Control under Station Controls.
- 2.6 If power backup source isn't turned on, turn it on by following instructions on the generator (large black box in the corner of the lab). If you do not know how to turn this on, you are not properly trained and need to contact a trained staff member.
- 2.7 Since the MPT (i.e., test procedure) was already programmed, this document will not go into detail about the procedures. However, ensure that the correct procedure is set (e.g., Fatigue) is selected. If not, open the correct procedure.
- 2.8 Double Check your procedure to ensure that nothing has been changed.
- 2.9 Under Station Setup, confirm that correct load cell calibration file is uploaded under the Sensor tab in Load
- 2.10 Under Station Limits, check whether any red boxes appear in the station limits. If so, determine what is causing the program stop interlock before proceeding by reading the text box at the bottom of the Station Manager window (once you understand the reasons behind the interlock, hit Reset next to Program 1 if it is safe to do so). If no station limits were tripped, hit Reset next to Interlock 2.
- 2.11 Turn on the servo-hydraulic system by finding the rows labeled HPU T7-J25 and HSM Axial towards the bottom right side of the Station Manager window.
  - 2.11.1 Click the button with 2 white stripes along the HPU T7-J25 row and wait for the yellow to stop blinking.
  - 2.11.2 Click the button with the 3 white stripes along the HPU T7-J25 row [note: actuator may jump slightly when powering up but use any emergency stop buttons if more than a small jump occurs].
  - 2.11.3 Click the button with 2 white stripes along the HSM Axial row followed by the button with 3 white stripes.
- 2.12 Allow the hydraulics to warm up for 10 minutes, especially if performing a fatigue test.

### 3. Load Cell Check (if needed)

- 3.1 Attach load cell to mounting plate on the table of the load frame and tighten with allen wrench.
- 3.2 Pull up the Meters and Auto Offset windows.
- 3.3 Offset the Load using Auto Offset.
- 3.4 Using 5kg, 10kg, and 20kg standardized weights, place weights on top of load cell in increments.
- 3.5 Determine if Load readings are accurate and calculate the percent difference.
- 3.6 If readings are >2% different, the load cell is not fit for testing and must be calibrated.

### 4. Fixturing

- 4.1 Insert adaptor thread into actuator that accepts Ø½” threaded bolt.
- 4.2 Attach anti-torsional fixture to actuator via the Ø½” threaded bolt and tighten by hand or allen wrench.
- 4.3 Set torque wrench to 100Nm and tighten Ø½” threaded bolt to 100Nm.
- 4.4 Attach interface plate to anti-torsional fixture and tighten using an allen wrench.
- 4.5 Attach superior F1717 fixture to the interface plate and tighten using an allen wrench.
- 4.6 Attach inferior F1717 fixture to load cell and tighten using an allen wrench while monitoring Load readings on the Meter [note: the limits will trip if over torqued].
- 4.7 Determine if actuator is at its true zero axial position by removing the Stroke offset (Station Controls → Auto Offset → Clear Offset) and manually commanding the Stroke to zero (Station Controls → Manual Command).
- 4.8 Move cross head down as needed, making sure to lock the cross head securely via the table controls as well as the manual bolts. If you do not know *how* to move and lock the cross head, do not attempt it yourself. Instead, find a trained lab member to show you.

### 5. Sample Mounting

- 5.1 Fix the inferior UHMWPE test block to the inferior fixture using the Ø½” shoulder bolt- a gentle tap with a hammer or mallet may be needed [note: do not fix the superior test block quite yet].



- 5.2 Check the Meter readings and Auto Offset to determine that only the weight of the inferior fixture and specimen are contributing to the Load.
- 5.3 Tare the Load under Auto Offset.
- 5.4 Under Station Controls, click on Manual Command and enable it by checking the box. Incrementally change the Stroke until you can fix the superior UHMWPE test block into the superior fixture. Fix the superior UHMWPE test block to superior fixture using the Ø½” shoulder bolt- a gentle tap with a hammer or mallet may be needed.
- 5.5 After the test blocks are mounted and secure, use Manual Command to adjust the Stroke to remove any Load on the sample.

## 6. Tuning

- 6.1 If you are running a fatigue test, you must tune the machine based on the stiffness of each sample. Tuning should only be performed by trained personnel!
  - 6.1.1 Under Station Setup, click on the Tuning icon and go to the Stroke and Load channels to confirm the proper settings.
  - 6.1.2 For the constructs tested during the summer of 2016, the following tuning parameters should be used in conjunction with a Peak/Valley Compensator, which is preset in the procedure:

Stroke:	Load:
P-gain: 7.0	P-gain: 200
I-gain: 0.4	I-gain: 0.2
D-gain: 0.0	D-gain: 0.001
  - 6.1.3 Under the Load channel, confirm the Dither settings are at 0.00 V amplitude and 528 Hz frequency.
  - 6.1.4 If the above values are not appropriate for a given construct, proceed with the Tuning instructions provided below (with trained personnel).
- 6.2 Click the Station Setup icon on the top row in the Station Manager window and drop down the Channels on the left hand side of the Station Setup window. The limits will not engage if they are on “Program Stop” or “Program Stop and Ramp,” because you are using the Function Generator instead of running a program while tuning. Instead, make sure they are set to “Interlock.” Note: these limits are only applicable to the identified

load cell. If a different load cell is used, you must set the limits accordingly. If any limits are changed, you must hit enter for them to be saved.

- 6.2.1 Find the Limits tab for Load, and confirm that the upper and lower limits are highlighted green, set to +5 kN and -5 kN respectively, and Interlock is set as the action.
- 6.2.2 Find the Limits tab for Stroke, and confirm that the upper and lower limits are highlighted green, set to +10 mm and -45 mm respectively, and Interlock is set as the action.
- 6.2.3 Exit window
- 6.3 On the drop down menu at the top of the station manager row, select Tuning and enter the password. Only trained personnel will have the password.
- 6.4 Under Station Setup window, click the Tuning icon on the left column and click on the channel (e.g., Load) that you plan to tune. Check the P and I Gains and determine how they match up compared to the previously recorded values. Always start with low gains and work up if you are not familiar with these values.
- 6.5 Open the Scope. Make a time plot with Load and Command. Click the Same Scale icon. You will need to adjust your trace time depending on the test frequency.
- 6.6 On the Station Manager window, click on the Function Generator icon. Enter the channel you wish to tune (e.g., Load).
- 6.7 Enter the target load and amplitude. The target load is the median of the sine wave, and the amplitude is the difference between the target load and the maximum and minimum loads you plan to use during testing. For example, if your protocol requires you to test to -150 N and -15 N, then the target will be -82.5 N with amplitude of 67.5 N.
- 6.8 Set a low frequency (e.g., 1 Hz or less).
- 6.9 PUT ON SAFETY GLASSES.
- 6.10 Auto Offset the Stroke if you are near the limit.
- 6.11 Press Play. Determine how Load and Command align in the plot on the Scope. Incrementally adjust P and I Gains as needed. Make sure to slightly undershoot the values since PVC Compensator will take care of the rest.
- 6.12 Incrementally increase frequency to match desired protocol in testing (e.g., 4 Hz).
- 6.13 Incrementally adjust P and I Gains as needed. I Gain is typically ~10% of P Gain.

- 6.14 Record gain values and save for later use (see sample table). Samples will need to be retuned when changing any part of the specimen that will affect its stiffness (e.g., device material, lengthenings).
- 6.15 Turn on PVC Compensator to ensure the upper and lower load magnitudes are reached. Adjust gain values as needed and record values.
- 6.16 Press Stop. Exit tuning by going back into MPT mode.

**Sample Tuning Table for Growing Rods**

Device Material	Lengthening #	Channel/Target/Amplitude	Frequency	P Gain	I Gain	D Gain (rarely used)	F Gain (rarely used)
Titanium	0	Axial/-165 N/135 N	5Hz	900	10	0.01	0
Titanium	3	Axial/-165 N/135 N	1 Hz	500	50	0	0
Titanium	3	Axial/-165 N/135 N	2 Hz	600	60	0	0
Titanium	0	Torsion/0 Nm /2 Nm	2Hz	2.5	0.01	0	0

## 7. Load Cell Limits

- 7.1 Check again to see if station limits were tripped or program interlocked. Reset as needed.
- 7.2 The limits of the load cell will need to be readjusted after tuning and set to “Program Stop and Ramp” action.
- 7.3 Click the Station Setup icon on the top row in the Station Manager window and drop down the Channels on the left hand side of the Station Setup window. Note: these limits are only applicable to the identified load cell. If a different load cell is used, you must set the limits accordingly. If any limits are changed, you must hit enter for them to be saved.
  - 7.3.1 Find the Limits tab for Load, and confirm that the upper and lower limits are highlighted green, set to +5 kN and -5 kN respectively, and Program Stop and Ramp is set as the action.
  - 7.3.2 Find the Limits tab for Stroke, and confirm that the upper and lower limits are highlighted green, set to +10 mm and -45 mm respectively, and Program Stop and Ramp is set as the action.
  - 7.3.3 Exit window.

## 8. Procedure

- 8.1 Under Manual Command, manually command the *Stroke* until the Load reads zero [note: do not Auto Offset the Load].
- 8.2 Take a photo of the specimen and position the camera for a video recording (do not start recording just yet).
- 8.3 Open the MPT Procedure Editor (icon is under the MPT section on the Station Manager window) and check limits of the procedure based on the testing protocol [note: this refers to the limits you wish to test the sample to and differs from the limits of the load cell. This should already be programmed but always a good idea to double check].
- 8.4 In the MPT Procedure Editor window, double click the Data acquisition icon and click on the Destination tab where you must change the file name. Copy this file name and paste it within the Destination tab under the Test Info command icon. Save the procedure.
- 8.5 Auto Offset both the *Stroke*.
- 8.6 Go to the Specimen Editor icon found under the MPT section of the Station Manager window.
  - 8.6.1 Set the directory path to the ASTM F1717 Growing Rod folder.
  - 8.6.2 Click New on left side of window, type in name of specimen (top left hand corner), and hit enter. For example, the specimen name can be “MCL0F1” for Mid-Construct, zero rod-lengthenings, fatigue 1.
  - 8.6.3 Exit window.
  - 8.6.4 Pull down your sample name under Specimen on the Station Manager window.
- 8.7 Under Manual Command, make sure you are in *Stroke* mode [note: this will ensure you are in displacement control when unloading your specimen from the machine after testing is completed].
- 8.8 Disable Manual Command by unchecking the box within the manual command window.
- 8.9 Check again if any interlocks or limits were tripped. Reset as needed.
- 8.10 Pull up the Scope, and make a Time plot of the Load and Load Command, which may have already been set up during Tuning. This will provide a real-time plot that you can monitor throughout the test.
- 8.11 You are ready to run the test as soon as one person stands by an emergency stop button as a precaution.

- 8.11.1 Press play on the main screen.
- 8.11.2 You will be prompted to insert the Operator, Specimen Name, and Date. Fill in this information. BE SURE TO START THE VIDEO RECORDING BEFORE PRESSING “OK.”
- 8.11.3 Observe the specimen as it ramps down to the target load. As it starts to cycle, the PVC will slowly adjust to match the Load and Load Command plots on the scope. Once the Load Peak/Valley readings on the Meter are within 1 N of the maximum and minimum values for the test, record the number of cycles and steady-state Stroke Peak/Valley readings in your lab notebook.
- 8.11.4 Stop the video recording.
- 8.11.5 Wait for test to finish [note: the programs are set to automatically bring the load/torque back to zero after reaching the limits of the procedure so be patient until the MPT stops].
- 8.12 Click the unlock icon under MPT section of the Station Manager window once the test is finished.
- 8.13 Take a photo of the specimen before unloading it.
- 8.14 Unload the specimen by removing the Ø½” shoulder bolts.
- 8.15 Manually command the actuator back to its zero Stroke position.
- 8.16 Repeat steps for each sample.

## **9. Data Retrieval and Analysis**

- 9.1 On the desktop, open the Specimens folder.
- 9.2 Find ASTM F1717 Growing Rod folder and specimen file.
- 9.3 Right click the .dat file and open with Excel or notepad.
- 9.4 Save Excel sheet to a thumb drive.