

## Standard Operation Procedure for Tube in Tube Experiments

### Basic Implosion Experiments:

#### Specimen Knowledge and Preparation:

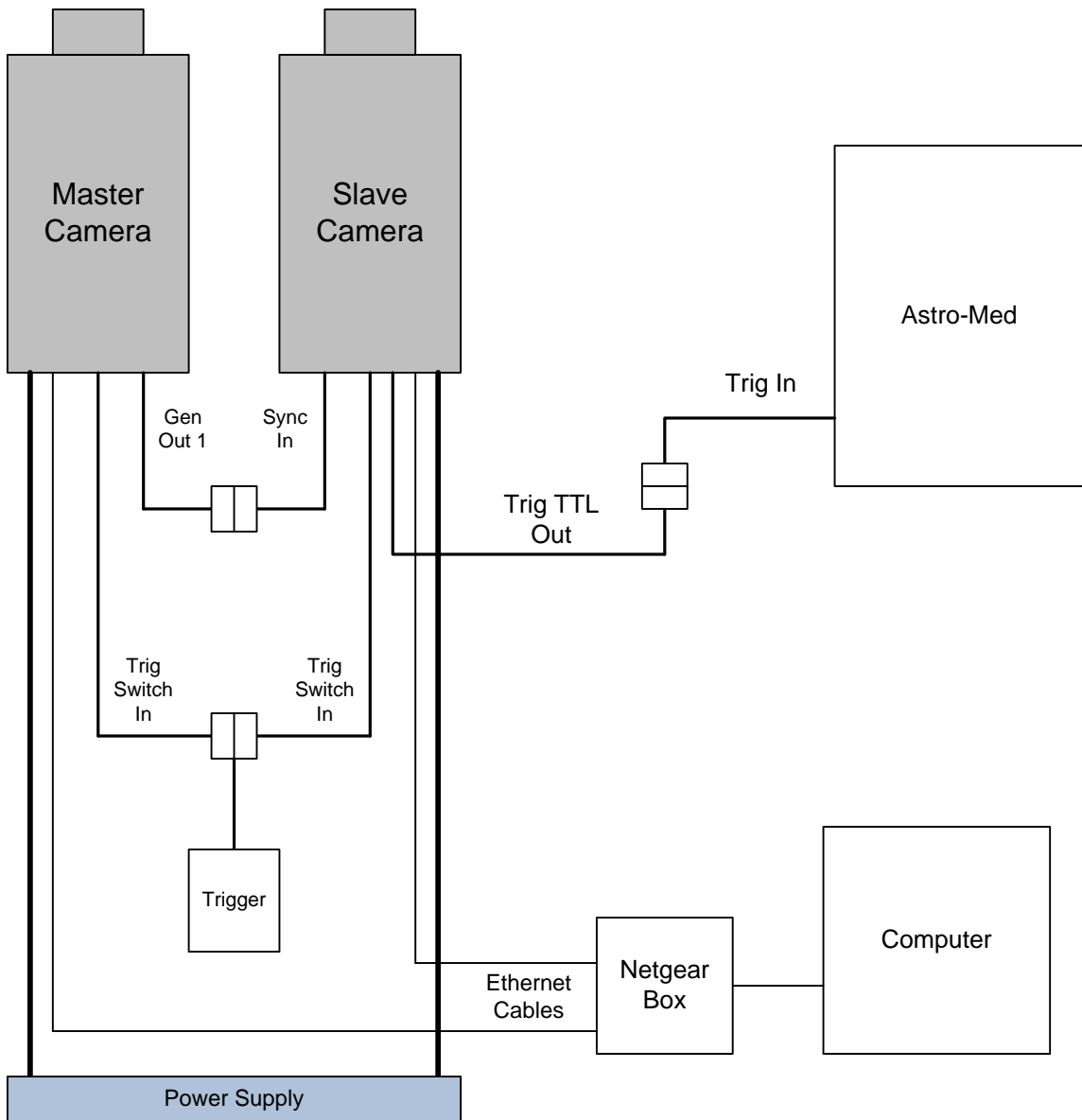
1. For any isotropic material check the Von Mises' paper and calculate the collapse pressure of your specimen based on its geometry. For any composite or anisotropic materials check previous paper on the DPML website for the collapse pressure for that specific geometry and material. For composites a rule of thumb is to use geometries that have already been tested before.
2. When measuring tube specimens use the sample spreadsheet for measuring tubes. The thickness measurements should be taken with a micrometer while, the rest of the measurements can be taken using standard calipers. If the specimen is not a tube, a new standard measuring spreadsheet should be made.
3. Before speckling, identify the thinnest measured mark of the tube and measure the same distance on each side of the mark. Tape those distances (Usually in a tube measured with 12 lines once the thinnest line across the tube is identified, we go three marks on each side of the line and tape on those lines) across the tube. The area marked between the two pieces of tape should cover roughly half the tube or cover a little more than the field of view.
4. Spray the area between the two pieces of tape with white spray paint. Spray multiple light coats to cover any writing or marks under paint. Speckle the area after the white paint has dried. Always put a unique speckle in the very center of your specimen as to easily identify the middle when placing in the specimen in the tube in tube.

#### Calibration Procedure:

- (a) If moving the cameras, be sure to unplug all of the wires before moving the cameras or lights. Cap the lenses and the cameras after removing the lenses from the cameras.
- (b) Slide the cameras onto the tripod as shown below

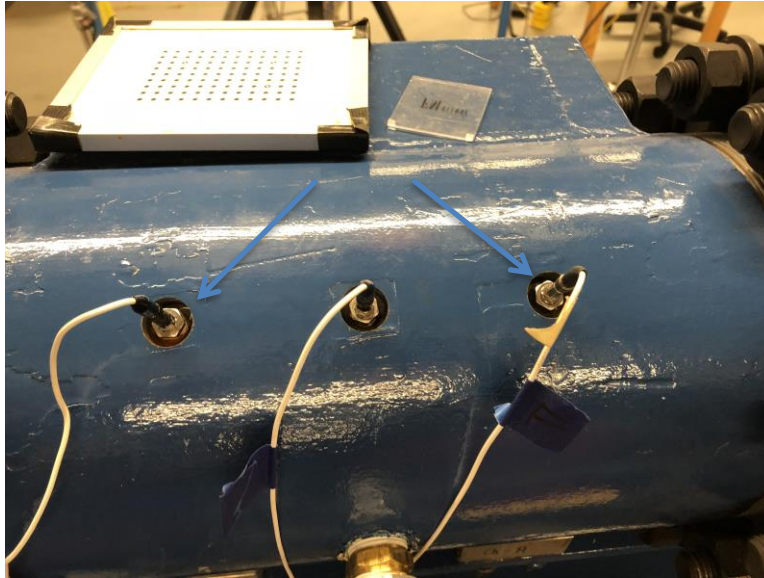


(c) Following the figure below, plug in the wires



(d) Calculate the depth of field for the lenses being used in the experiment. Typically 85 mm lenses are used with a distance of 66-72 inches from the tube in tube midplane to the edge of the tripod fixture. There is an app that is commonly used for calculating this called Digital DoF. The camera in any online depth of field calculator does not matter. Make sure the depth of field is larger than your specimen radius so any outward deformation does not easily lose correlation in the DIC software.

- (e) Remove the following two sensors using a torque wrench.



If there is black tape on the sensor wire then the wire cannot be disconnected from the sensor for easy removal. The torque wrench attachment should have a space for the wire to turn as the sensor is taken out. However if there is no black tape carefully turn and disconnect the sensor wire from the sensor then use the torque wrench to take the sensor out.

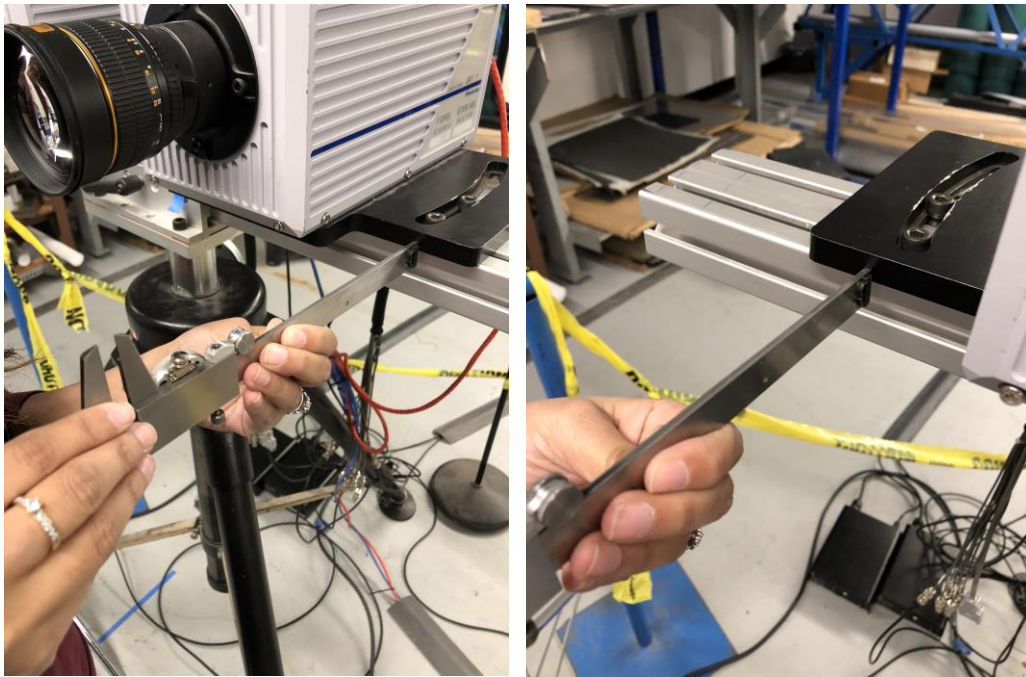
- (f) Take the appropriate calibration (typically we use a 12 dots by 9 dots with 7 mm spacing) grid and tape a rubber band to the back. Insert the extendable rods into the rubber band as shown below. Be sure to write down all the parameters on the back of the grid before filling the tank.



Next insert the extendable rods into the tube in tube and extend until they stay in place. Now take a plastic cord and tape one side on the back on the calibration grid. Run the other end through one of the sensor opening on the tube in tube and then back in through the second sensor opening. Tape the second end of the cord to the back of the calibration grid as shown below.



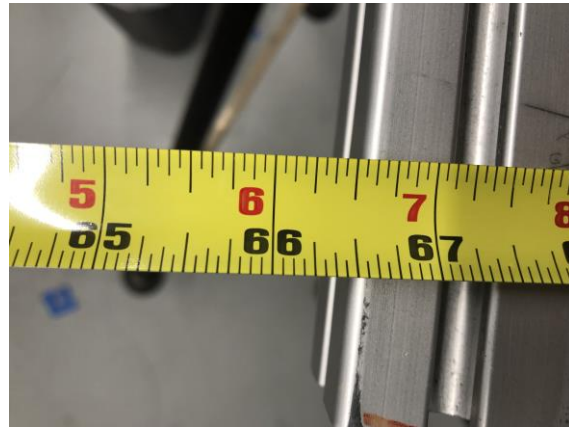
- (g) Next make sure the cameras are parallel with the tripod mounting fixture using calipers as shown below:



First extend the calipers out slightly. Next press the edge of the calipers into one side of the tripod mount and check the distance reading on the caliper. Repeat these steps again on the other side. If a very close reading is seen on both sides then the cameras are roughly parallel to the tripod mount. Finally lock the cameras in place.

- (h) Set the aperture of the lenses to 8. This is what we normally use for standard implosion experiments. However, in some previous work an aperture of 5.6 was used as well.

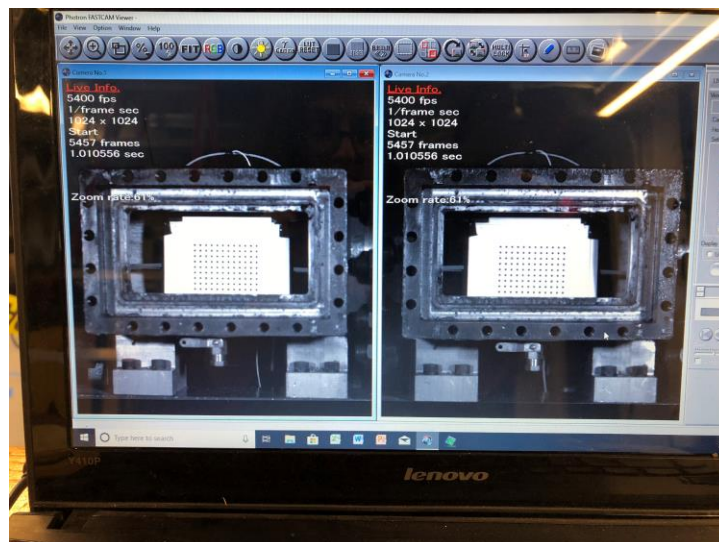
- (i) To check if the tripod mount is parallel to the tube in tube, use a measuring tape measure from the tube in tube to the edge of the tripod mount.



- (j) Next to center the cameras to the window on the tube in tube, very slightly unlock the cameras and move both cameras left to right until the image (seen on the FastCam Viewer) on each camera is the same. Lock one camera to the mount. Tape a protractor to the camera as shown below:

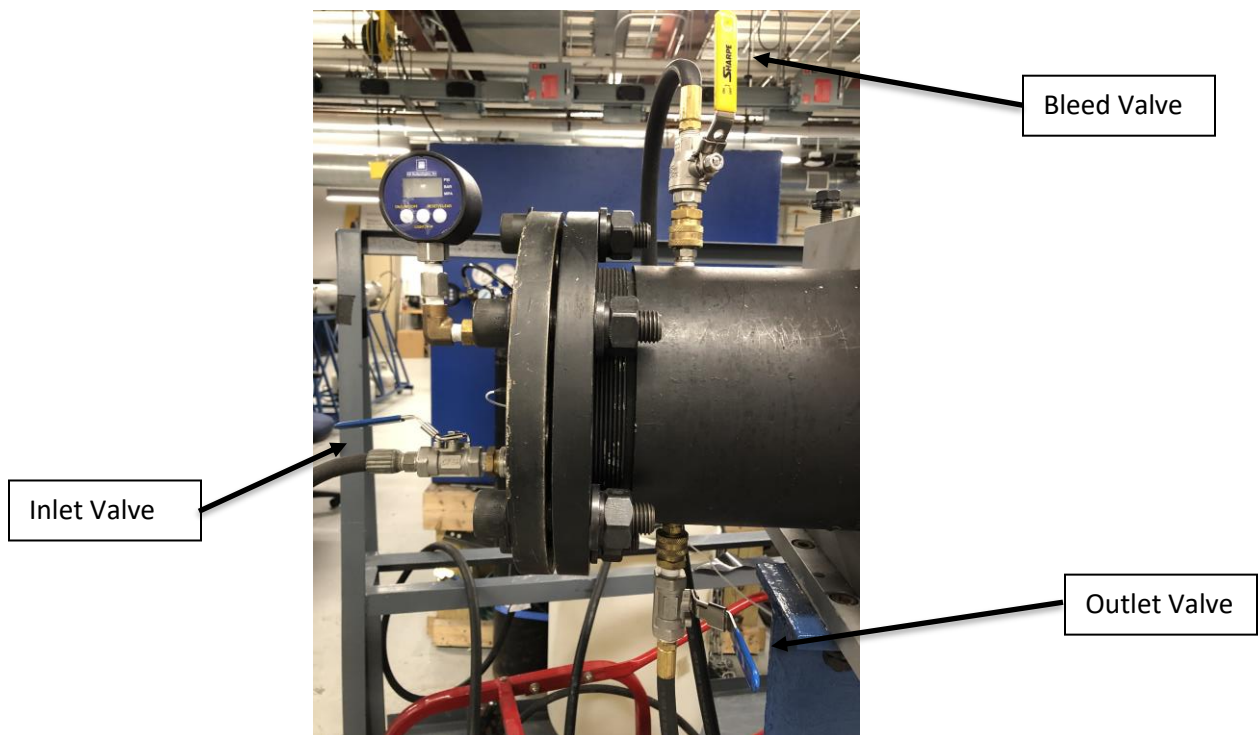


- (k) Move the one camera at a time until the window is centered on the FastCam Viewer software as shown below. Usually with 85 mm lenses with a distance of



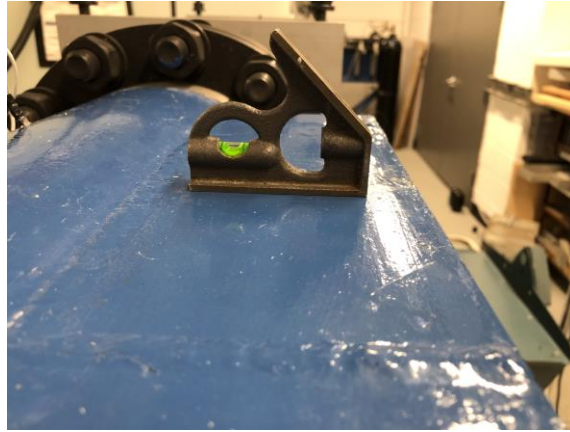
72 inches the angle for each camera should be roughly 5 degrees. So the total angle seen on the protractor should be roughly between 9-11 degrees.

- (l) Carefully clean the window with kimwipes and methanol (and gloves!! You should wear gloves while using any chemical like methanol). Start at the center and be careful to check that there isn't any rust or brown substance on the kimwipe. Pushing around rust or abrasive particles on the window can cause scratches.
- (m) Place the window in the tube in tube. Next place the fixture on the window and begin putting in the bolts in a star pattern. Usually we put in bolt on the top and bottom first to hold the window (do not let go of the fixture) then begin to put in the rest of the bolts.
- (n) To fill the tank open (parallel) the inlet valve and make sure the outlet valve is closed (perpendicular). At this point it does not matter if the bleed valve is open or not.

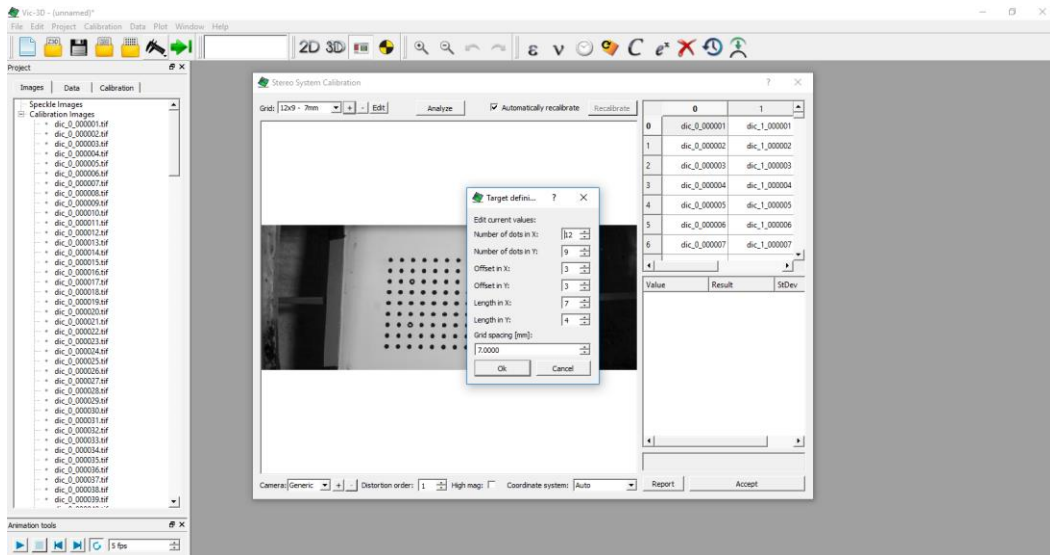


- (o) Begin filling the tank and be sure to not let the tank over fill since the two sensor holes are open due to the calibration grid being in place. As the tank is filling place the lights in front of the cameras so that the lights don't melt the cameras. Move the lights so that the lighting on the specimen is even and no glare is seen by the cameras.
- (p) Once the tank is full, focus the cameras in water using the FastCam Viewer software. The best way to focus is to zoom into the grid and lower the aperture one notch. Now focus the lenses first by going to one extreme and then work your way back to the most focused point.

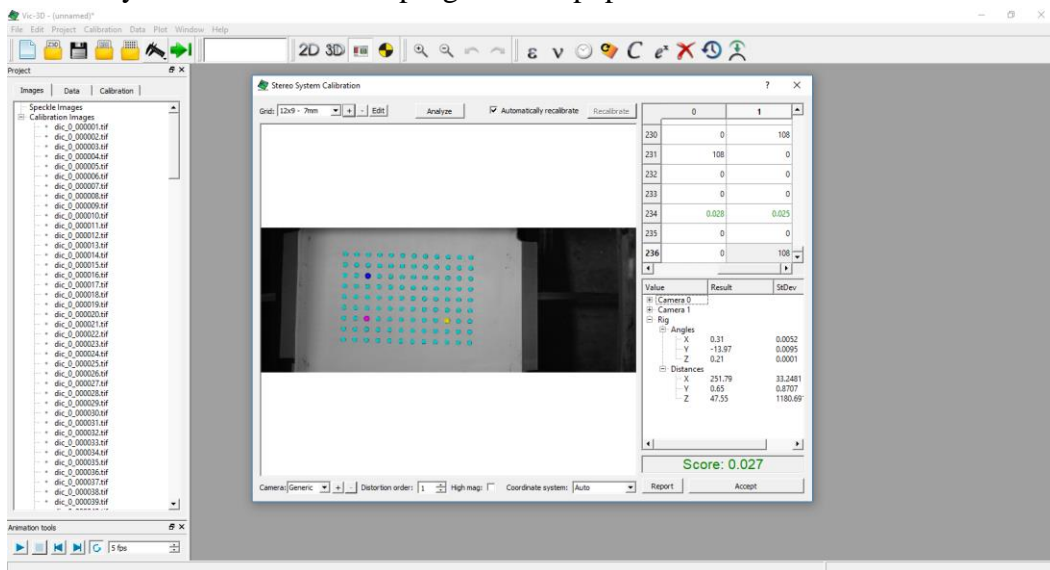
- (q) Place a level on the tube in tube above the window. Make sure the window is level before taking any images as shown below.



- (r) On the FastCam Viewer software right click on the camera 1 window. In the drop down menu that appears click camera options. A small window will pop up, on the thumbnails on the left click O/I. Set Trig TTL In to Trig Neg and Sync In to On Camera Pos. Now click Apply at the bottom of the pop up window. Next left click on the camera 2 window. The same small window will pop up, on the thumbnails on the left click O/I. Set Trig TTL In to Trig Neg. Now click Apply at the bottom of the pop up window.
- (s) To shade the cameras, place the lens caps on the camera lenses. Now on the FastCam Viewer software click shading on the menu on the right. Any time parameters are in the FastCam Viewer software you must shade again.
- (t) Lastly set the trigger mode on the on the menu on the right on the FastCam Viewer software. Select Random and set the number of frames from 50 to 1.
- (u) Now you are ready to start taking your calibration images. Two people are needed to calibrate any setup in the lab. One person sits at the laptop and clicks the trigger to take picture while the other person slowly moves the grid around covering all degrees of freedom. For a standard implosion experiment we generally take around 300 pictures. You need atleast 30 good images to get a calibration score in the VIC 3D software.
- (v) Save the images in the appreciate folder. Be sure that the file name for the camera one images are dic\_0\_ or refdic\_0\_ and the camera 2 images are dic\_1\_ or refdic\_1\_.
- (w) Open the VIC 3D software on the laptop (You must have the DIC Key inserted in the laptop before opening the software). Under common tasks click Calibration Images. Next import all images from the folder of calibration images. Next click the black calipers on the top left corner.
- (x) A pop up window should appear on the window, click the drop down menu for grid size and choose the appropriate grid size (12x19 -7mm). now click edit and make sure all the parameters match the ones on the back of the grid used. Hit OK if the parameters match.

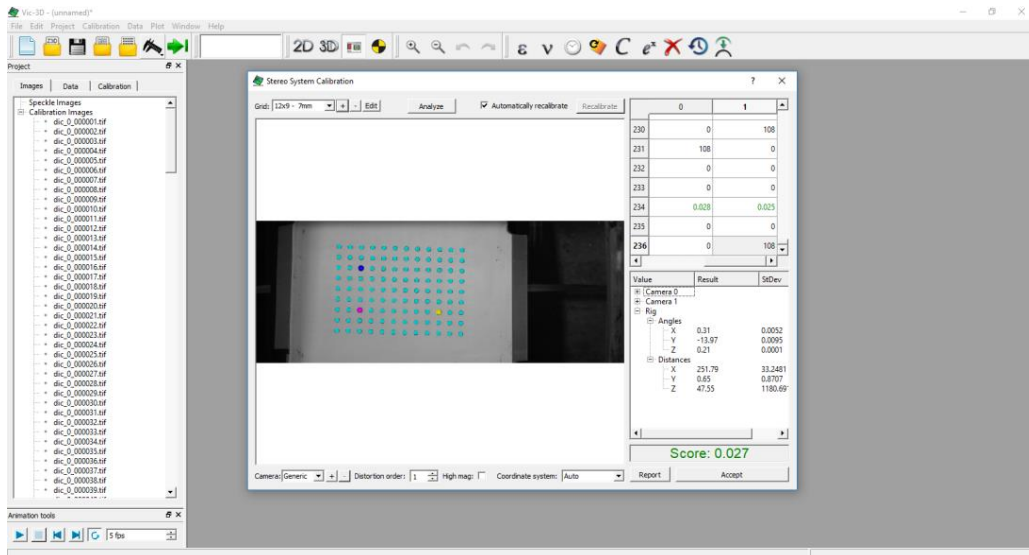


- (y) Next hit analyze and pull the DIC Key out of the laptop. Once the analyzing process is done a score should appear on the bottom right of the pop up window. The score should be below 0.05 however, for the best results with this setup we aim for as low of a score as possible. You can scroll through the images and delete any bad scores on the top right of the pop window.



- (z) The final check that you have a good calibration is to check the Y in the angles and see if it a max of 5 degrees off the actual reading on the protractor. The reason that we will never see the exact angle as on the protractor is because the light has to travel through the 1 inch acrylic window and water to the specimen and back to the cameras so the light will be slightly refracted. Thus the software will think the cameras are at a larger angle than they are. Check the X under Distances as well since that should be roughly equal to the distance between the center of one lens to the center of the second lens.



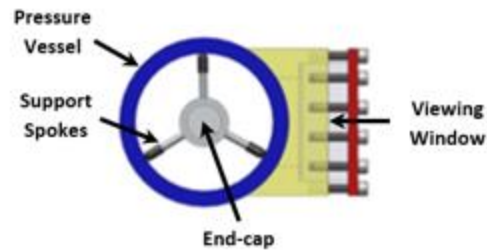


If you have a good calibration click accept at the bottom right of the pop up window. Save the calibration by click File on the top left on the software. Click Save As and save the z3d file in the same file as the images.

- \* If you do not have a good score or the VIC 3D software doesn't pick up enough images, try taking the images again. If the new images still do not work then make sure the cameras are parallel to the tube in tube and that the cameras are centered and that one camera isn't turned more degrees than the other. Lastly if all else fails drain the tank by opening (parallel) the outlet valve and closing (perpendicular) the inlet valve and try the calibration first in air so without the window then in glass by the putting the window back. If these two calibrations work then move on to water again. If the glass calibration doesn't work then try cleaning the window again. If the air calibration does not work then you made a fundamental mistake somewhere in the setup so ask another more experienced student for help.

### Experimental Procedure:

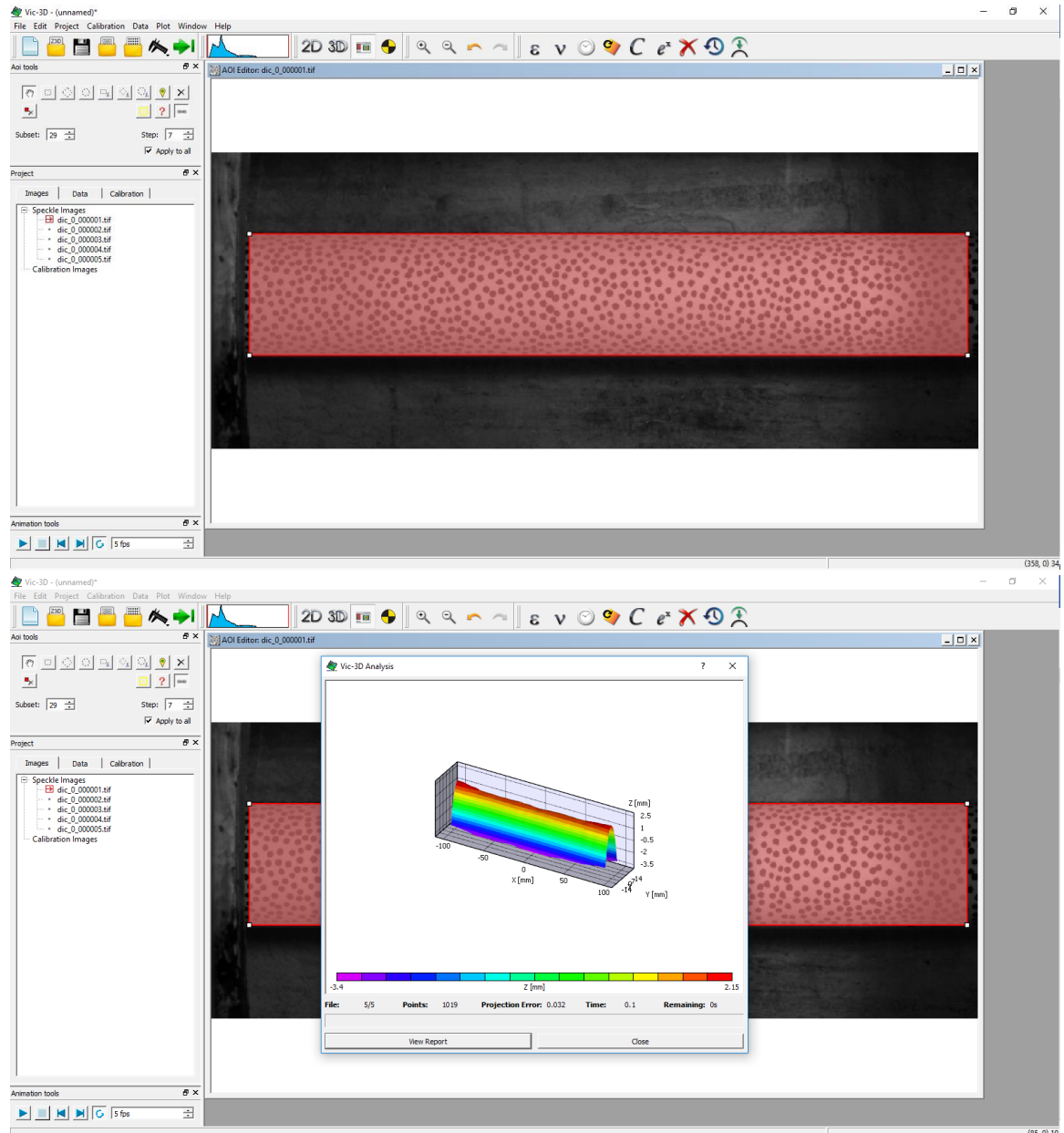
- (a) Take the window fixture and window out once the tank has drained. Take the calibration grid, extendable rods, and plastic cord out.
- (b) To place the sensors back, first clean the threads. Next wrap the threaded part of the sensor with thin Teflon tape. Using the torque wrench screw the sensors back into the opening (Do not exceed 40 inch pounds). Once the sensor is flush with the inside of the tube in tube do not turn the sensors any more. If the sensor is not flush by 40 inch pounds then you need to go back and clean the sensor opening thread again.
- (c) First take off the side of the tube in tube tank. Undo the bolts and gently place the side on the fork lift.
- (d) For tube specimens place the end caps in your specimen and screw on the spokes. The best way to make sure they spokes will slide into the tube in tube through the side to measure from the center of the end cap to the end of the spoke to make sure they are all slightly under 3.5 inches since the tube in tube diameter is 7 inches.



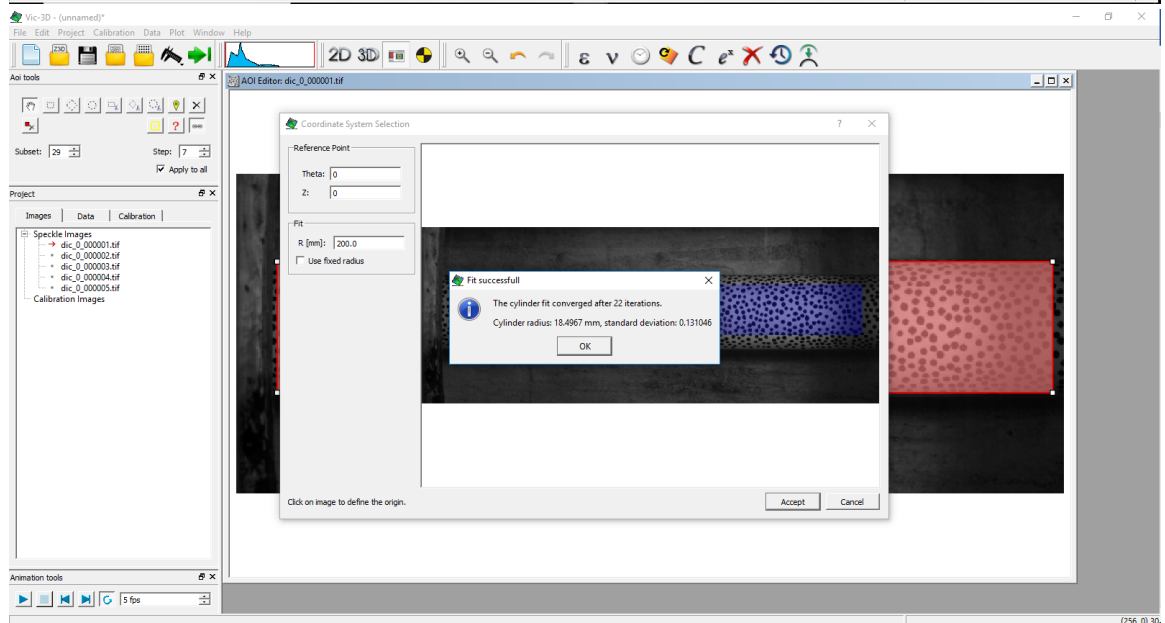
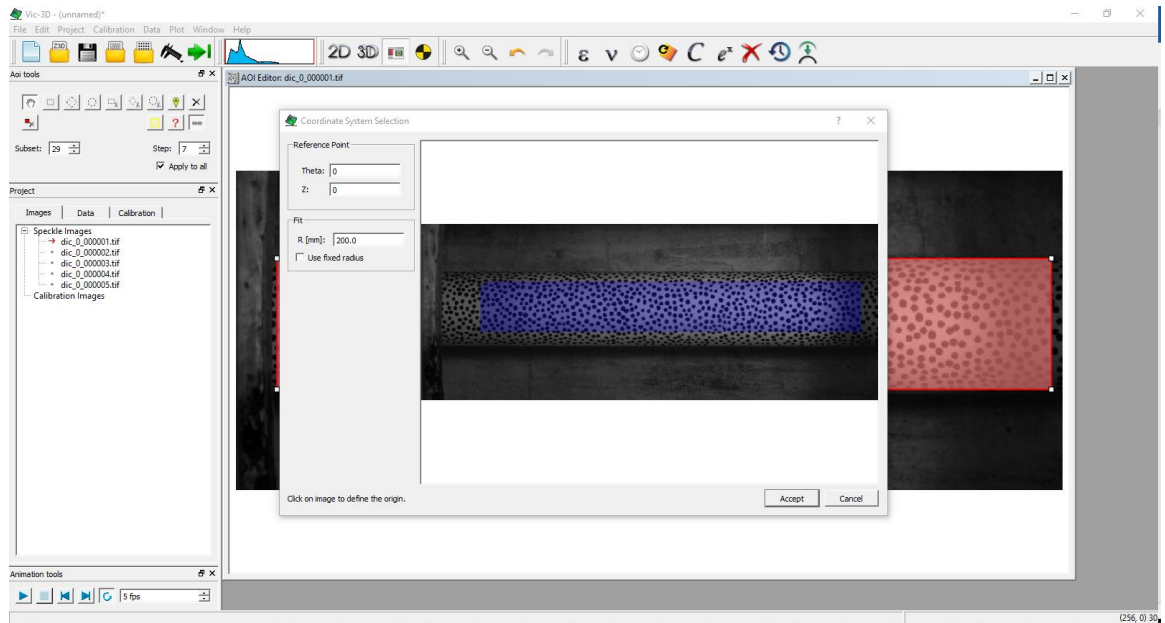
- (e) Center the specimen and turn the spokes until the specimen will not move. Make sure the specimen is level so the one end of the tube is not higher than the other.
- (f) Place the side of the tube in tube back and put the bolts back in place. Put the window in as well and screw in the window fixture.
- (g) Using the fork lift, (make sure there is metal plate between the fork lift and the tube in tube before lifting) lift the tube in tube slowly as far as it will go.
- (h) Before turning on the pump, make sure the inlet valve and the bleed valve are open (parallel) while the outlet valve is closed. Turn the pump on to fill the tank.
- (i) Once the tank is full, slowly let the fork lift drop so that it is not supporting the tube in tube anymore.
- (j) Check to see that the tube in tube has not rotated by repeating step (r) from calibration. If the tank has rotated then use the wrench and hex key to make the window level.
- (k) Now on the FastCam Viewer software set the trigger mode to end trigger.
- (l) Make sure the AstroMed is on and the capture software is open. Go up to Capture and click Capture Settings in the drop down menu. Depending on the type of experiment we set the percent pre trigger. For a standard implosion experiment we set it to 75 percent. Make sure the sampling rate is 2 million. Click OK to go back to all the channels.
- (m) Now click Setup then click Amplifier Channel Settings in the drop down menu. Select channels 1-7, and click on span and set the Span and Center based on the pressure that will be seen in the experiment. For a standard implosion experiment we set the Span to 2.5 and the center to -0.25. Click OK when done.
- (n) Now go back to the FastCam software, click record twice until it says endless record.
- (o) Next on the AstroMed click the image with a graph and a green arrow below pointing to a grey box. A small window should pop up and say recording pretrigger data.
- (p) Test the trigger by hitting the trigger. If the AstroMed triggered without you pressing the trigger, check the wiring on the cameras. One of the wires could be loose.
- (q) If the test trigger worked, repeat step (n) and (o).
- (r) Take reference (roughly 5 images) images of your specimen and save them the same way you saved the calibration images. Open the VIC 3D software and click Calibration in the top left corner. Click From Project File in the drop down menu.

Open the z3d calibration file you saved. Now import your reference images as speckle images.

- (s) Select the speckled region of your specimen. Click the green arrow on the top left corner. Select the appropriate subset size by roughly checking that each grid box contains about 9 dots. A window will pop up, in the window click Run. Let the analysis run and click close when it is done.



- (t) Now click Data, click Coordinate Tools, and then Compute Cylindrical Transformation in the drop down menu. A window should pop up, hit Accept on the bottom right.



- (u) The computed radius should be close to the actual radius of the specimen.
- (v) Close the bleed valve on the tube in tube. Turn the pressure sensor on as well. Lastly turn on the pump and begin recording the pressure readings. Previous we use a phone on selfie mode to record the pressure as we pressurize.
- (w) One person should not be at the pump valve to pressurize while the other person has their hands on the trigger and reading the pressure out loud.



Pump Valve  
used to  
pressurize  
the tank

- (x) Slowly pressurize the tank. Once you hear a large crack hit the trigger quickly. You might hear small crackling while pressurizing however when your specimen implodes it will be large loud crack. Quickly turn the pump off and close the inlet valve. To depressurize slowly open the bleed valve until the pressure sensor reads 0 psi.
- (y) Go to the FastCam Viewer software and make sure you got the implosion in the recording. Chop the implosion event to about 1000 images at most. Play back the chopped segment to make sure you didn't accidentally chop the implosion. Save the images to a folder.
- (z) Now insert a flash drive into the AstroMed, click File on the top left corner. Select Archive File and Entire File in the drop down menu. A window will pop up, click the folder with a magnifying glass in the bottom left corner. In the pop up window find the flash drive and the folder designated for the pressure data and save the data.

### **Data Analysis:**

Since there are various types of data analysis for implosion experiments, please reference the VIC-3D manual and Dr.Shukla's Experimental Solid Mechanics book for DIC analysis. For pressure analysis import your saved pressure data into the AstroView software. Select the region with your data and save it as an excel file. Next import the data into Matlab and write a code to filter and normalize the pressure data or use a previously written code.