CellScale
biomaterials testing

UniVert

Mechanical Test System

User Manual

version 1.7

Mechanical measurement and analysis of materials

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1. General Information

The UniVert is a precision test instrument designed for the compressive and tensile testing and analysis of materials including metals, polymers, and biological specimens. The system includes a test station and an integrated software interface to run and analyze test results.

Environmental and Electrical Specifications

Electrical Input	100-240VAC, 50-60Hz
Current Rating	1.67 Amp
Environmental Conditions	Maximum Operating Temperature 25ºC 0% - 95% Relative Humidity
Installation Category	Category II
Pollution Degree	Degree 2
Data Connections	1 – USB 2.0 for camera/PC communication 1 – USB 2.0 for controller/PC communication

System Assembly

Some basic assembly and setup is required. An unboxing and setup guide can be found in **Appendix A**. Load cell installation is detailed in **Appendix B** and software installation is described in **Appendix C**. Camera setup is described in **Appendix E**.

Connections to Supply

Connect power supply into properly grounded 100-240VAC power source to ensure safe operation. Ensure that the power cord is easily accessible at all times. The use of an Uninterruptible Power Supply (UPS) is recommended to protect against data loss.

The mains supply voltage fluctuations should not exceed 10% of the nominal supply voltage.

Safety Warnings

This equipment must be used in accordance with the procedures outlined in this manual. Operators of this equipment must be instructed in safe operating procedures to prevent injury and/or damage.

Ensure that the area around the moving actuator is clear before commencing test protocols.

The UniVert presents pinch hazard to extremities. Keep hands clear of moving parts for the duration of the test.

> ***System Alert***
>
> *This equipment must not be disassembled by the user or modified in any way.*

Manual Operating Controls

There is a single power switch on the front of the control unit to turn on the UniVert.

General Maintenance

Clean the system as needed with mild soap and water or alcohol based cleaning solutions.

Approvals and Certification

This product conforms to applicable CE standards.

2. Testing Terminology

The UniVert is designed to apply uniaxial compressive and tensile forces to a variety of materials. This includes metals, plastics, and composites as well as biological materials.

Multiphase Test Cycles

In order to properly characterize and test a specimen, it is often necessary to load it to different degrees and at different rates. There are three main reasons for doing this:

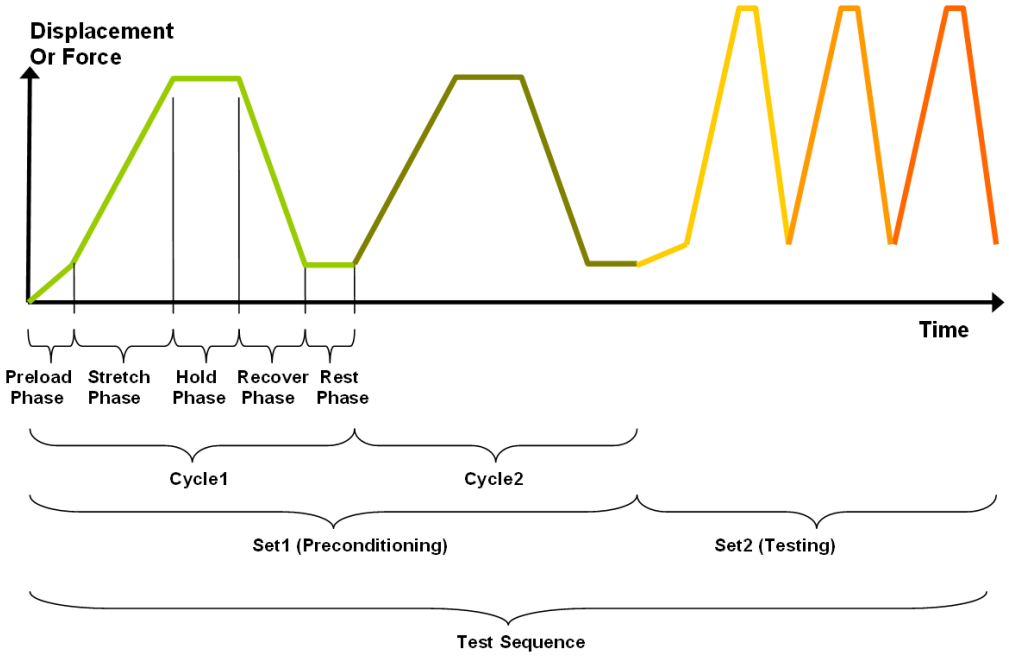
Preconditioningï Especially for biological specimens, the goal of preconditioning is to restore a specimen to its physiological or *in vivo* state. During the process of specimen storage and preparation, a specimen may swell, dry out, have its material fibers realign, or its molecules reorganize. It may take multiple preconditioning cycles for a specimen to be restored to its natural state.

Reproducing Physiological Conditions During Testing - By applying various loads and load rates, natural expansion and contraction of a specimen can be reproduced (for example, the pulse pressure in an organ). In as much as the physiological conditions can be recreated, the specimen can be tested in a more realistic state.

Varying Test Conditions - Variable loads and rates allow you to create a variety of test profiles to best study your specimen.

Phases, Cycles, and Test Sequences

As the following diagram demonstrates, each application and release of load on the specimen is called a ***test cycle***. The same test cycle can be repeated multiple times to achieve a certain goal (preconditioning, physiological conditioning, or testing); this is called a ***test set***. Finally, a ***test sequence*** is made up of multiple test sets.



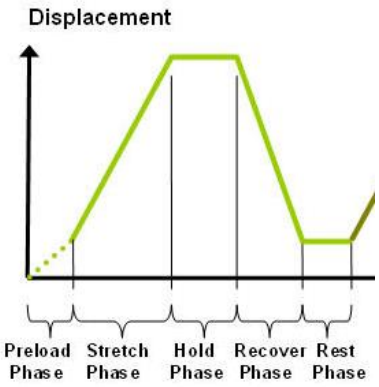
The above example describes the following:

- The entire diagram presents a full *test sequence*.
- Within that sequence, there are two *test sets*: the first set applies preconditioning to the specimen; the second set executes the actual test on the specimen.
- Within the first set (preconditioning), two identical *test cycles* are implemented to bring the sample to a satisfactorily preconditioned state.
- Finally, the second set (testing) is made up of three cycles.

Test Phases: The Smallest Unit of Testing

The test phase is the smallest unit of the test specification. There are five phases within a cycle. Each phase serves a specific purpose:

Preloading- Preloads are applied to bring a test to a well-defined starting point. Because the dimensions of a specimen may change as a result of a loading cycle (stretching of fibers, viscoelastic effects, plastic deformation, or localized material failure at the attachment points), the preload adjustment compensates for any of these changes in specimen geometry.



Stretching - During the stretch phase, a deformation is applied to the specimen. The deformation can be specified either in terms of force applied or displacement achieved.

Holding - The deformation can be held for a given duration. The duration for which it is held is dependent on the nature of the testing.

Recovering - The recovery phase is the time during which the force being applied to the specimen is removed. The duration of the recovery time is configurable and dependent on the nature of the testing.

Resting - Finally, the rest phase is the time between the end of one cycle and the beginning of the next. Some tests may specify a short recover time, while others may specify a longer time. The duration is configurable and dependent on the nature of the testing.

Control Modes

There are two control modes which define the basic approach to a given test: displacement control and force control:

Under **displacement control**, the displacement of the specimen is predefined. The UniVert stretches or compresses the specimen until the predefined displacement is achieved. The force required to achieve the displacement is an output of the test.

Under **force control**, the force applied to the specimen is predefined. The UniVert stretches or compresses the specimen until the predefined force is achieved. The displacement required to achieve the force is an output of the test.

Control Functions

The UniVert makes it possible to test specimens under several control functions:

Under displacement control:

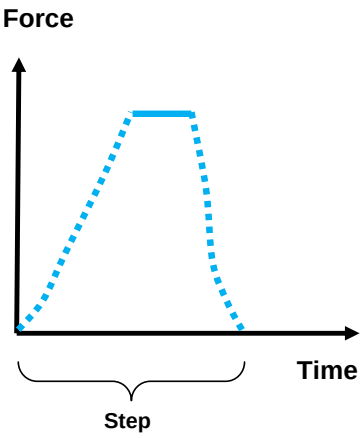
The **true strain function** applies the displacement at a true strain rate, which accounts for the current specimen length while the specimen is being stretched. The UniVert system approximates this with a series of linear segments (default = 10).

The **ramp function** applies the displacement at a constant nominal rate. This is equivalent to engineering strain or constant velocity.

The **sine function** applies the displacement according to a sinusoid with the desired displacement magnitude and duration. The UniVert system approximates this with a series of linear segments.

Under force control:

The **step function** achieves and maintains the desired force as quickly as possible. The amount of time it takes to achieve the desired force depends on the material being tested and the force control settings.



Test Modes

There are three test modes that can be used when performing a test: tension, compression, and 3-point bending.

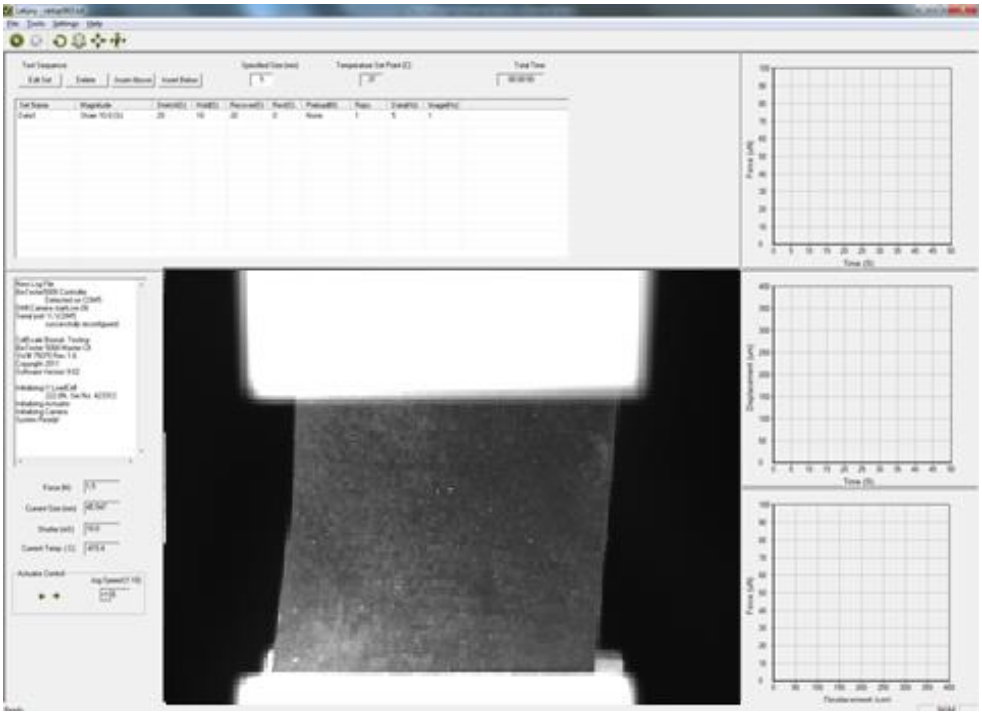
Tensile Test - This test mode is used in combination with provided specimen grips. In this mode, positive displacement is in the direction of increased fixture separation and tension forces are positive.

Compression Test - This test mode is used in combination with provided compression platens. In this mode, positive displacement is in the direction of decreased fixture separation and compressive forces are positive.

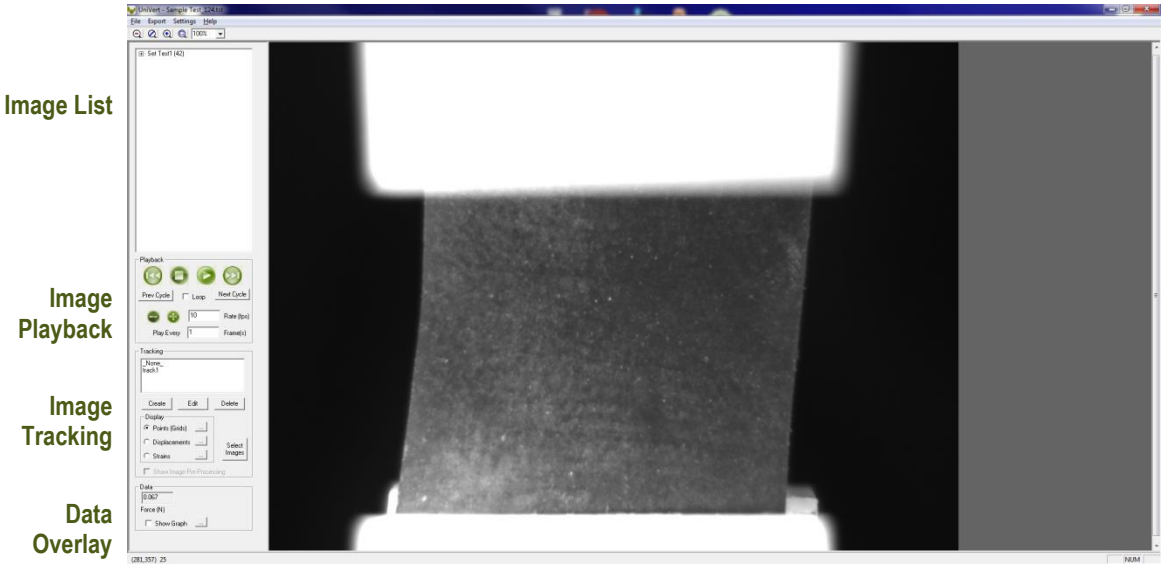
3-point Bend Test - This test mode uses the same displacement and force convention as compression testing but is applied to a 3-point bend setup.

3. Software Overview

The software included with the UniVert device is called UniVert. It is divided into two modules, a data collection module and a review and analysis module. The data collection module is used to set test parameters, enable specimen loading and testing, and monitor test progress. The screen layout for this module is shown below:



The review and analysis module is used to playback accelerated or decelerated test images, perform image analysis and tracking, and output movie files for presentation purposes. The screen layout for this module is shown below:



Output Files and Data Structures

For each test, the UniVert creates and saves three file types. The following table describes the three file types for a project named ñSample1ò. Output from this test would be found in a ñSample1òoutput directory (a sub directory of the user specified data directory).

File Type	Description
.tst file	The Sample1.tst file that contains the exact protocol and settings used for the test.
.csv file	The Sample1Data.csv file that contains comma separated numerical data such as time, force and displacement values.
.jpg files	Captured images such as Sample1.000010.3.jpg, which would correspond to an image captured at 10.3 seconds from the start of the test.

Each test folder will also contain 2 subfolders. The ñLogsò subfolder contains a text file of the content of the text dialogue portion of the main screen. It is useful as reference to troubleshoot problems with your system, should they occur.

The ñTrackingò subfolder is initially empty. If tracking is done on any of the images in the test folder using the ñAnalyze and Reviewò software module, there will be data files that contain the tracking information stored in this directory.

While using the ñAnalyze and Reviewòsoftware module, you may create additional data files such as text files (*.csv) containing tracking results, images with force data or tracking results overlaid (*.wmf), or movie files (*.avi). These additional files can be stored in the test directory or elsewhere on your computerõs hard drive without interfering with the software application (once created, they cannot be opened by the UniVert application).

When working with the data, you should be aware of a few details regarding the data output:

1. The output specimen size is based on the spacing between the grips or platens and does not account for the specimen material outside of the test region.
2. The software cannot calculate stress since the thickness of the specimen is not known. To calculate stress, you will have to manually measure the thickness of the material before or after the test is performed.
3. Strains can be calculated using the output displacement values (which are based on the grip or platen motions). The specimen may actually be subjected to less strain than the calculated values due to attachment site effects. The image tracking module is useful for determining the actual strain values and variations within the specimen.

4. Setting Up & Starting a Test

Overview

Setting up and running a new test is a simple process made up of both mandatory and optional steps. The following list presents all of the steps, while the rest of this chapter describes each of the steps in detail.

Step 1: Start a New Test

Step 2: Reset the Actuator

Step 3: Specify Test Type

Step 4: Move the Actuator to a Specified Size

Step 5: Zero the Load Cell (occasional)

Step 6: Modify the Test Parameters (optional)

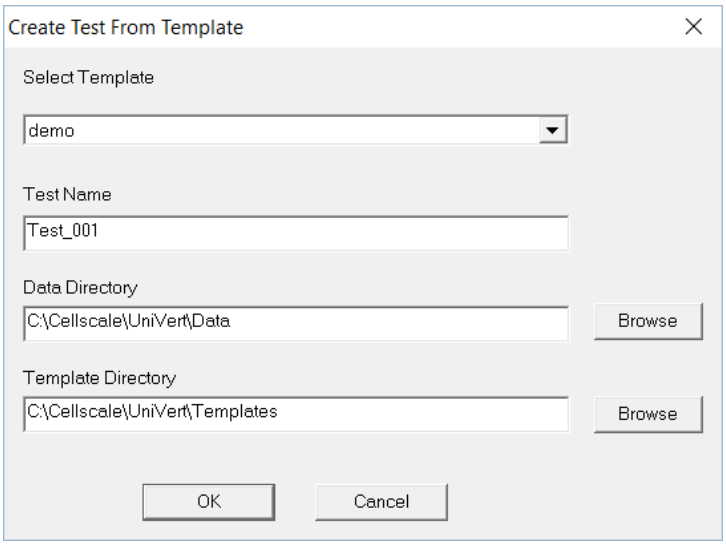
Step 7: Mount the Specimen

Step 8: Execute the Test

Step 9: Terminate the Test Prematurely (optional)

Step 1: Start a New Test

Launch the UniVert software and then select *Collect New* from the File menu.



In the *Create Test From Template* dialog, perform the following steps:

1. Select a template that matches the type of test you wish to perform. See the *UniVert Tip* on how to select and use a template. You can modify the template parameters in Step 4, below.
2. Name your test. The dialog will have a default test name. You can use the default or rename the test. Each time you start a new test, the default name will continue to increment the number at the end of the name.

3. If desired, you can change the location of the output data. The location of your output data and images is determined by specifying a *Test Name* and *Data Directory*. The template and data directories are user specific (computer login name). Each system user can store their files to a different default location. The system uses the last location selected as the default.

> ***UniVert Tip: Selecting and Using Templates***
>
> *How to select a template: Designing an appropriate test sequence is an art that depends on both the type of material being tested and the specific material properties you are interested in measuring. When first testing a new material, you should expect to have to experiment with the settings until the test yields meaningful data.*
>
> *The system comes loaded with example templates to help you get started. Selecting a template does not lock you into a specific test sequence or protocol – rather a template defines a test sequence and settings, all of which can be changed before a test is run. Once you have developed a test sequence and settings that are appropriate for the material you are testing, you should save these settings using "Save As Template" from the File menu. You can then select your template the next time you initiate a test.*

Step 2: Reset the Actuator

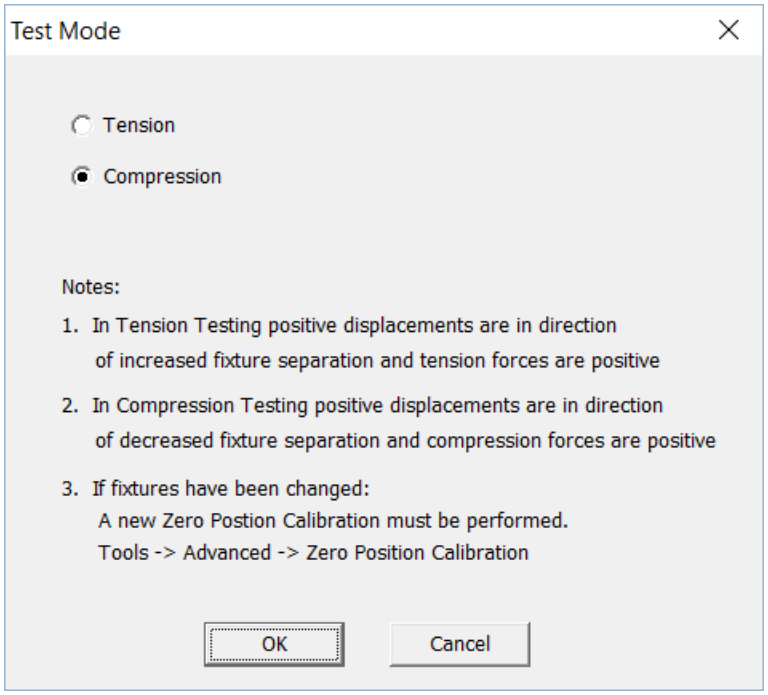
We suggest performing a reset at the start of a new test session. This command sends the actuator to its fully retracted position and resets the displacement value. If you have stopped the previous test in mid cycle, then you should also reset the actuator. By resetting the actuator, you are ensuring that the physical measurements taken by the UniVert are accurate.

To reset the actuator, select *Reset Actuator* from the Tools menu, or press on the toolbar.

> ***System Alert***
>
> *You should **NOT** reset the actuator if the specimen is already loaded in tension. Doing so will damage your specimen and/or the load cell.*

Step 3: Specify Test Type

Access *Test Mode* in the *Settings* menu to select the appropriate test mode and install the platens, grips, or 3-point bend attachments (see **Appendix D** for this procedure).



Step 4: Move the Actuator to a Specified Size

After the actuator has been reset, it will remain in the fully retracted position and must be moved to a specified (reference or starting) position.

To move the actuator to the specified position, select *Move Actuator to Specified Size* from the Tools menu, or press on the toolbar. This size may be entered in the ñSpecified Sizeò dialogue.

Step 5: Zero the Load Cell (occasionally)

While it is not necessary to zero the load cell with every test sequence, we suggest zeroing the load cell at the start of a new test session. With repeated use, the zero point of the load cell can drift. By zeroing the load cell, you are ensuring that the force measurements are accurate.

To zero the load cell, select *Zero Load Cell* from the Tools menu or press on the toolbar.

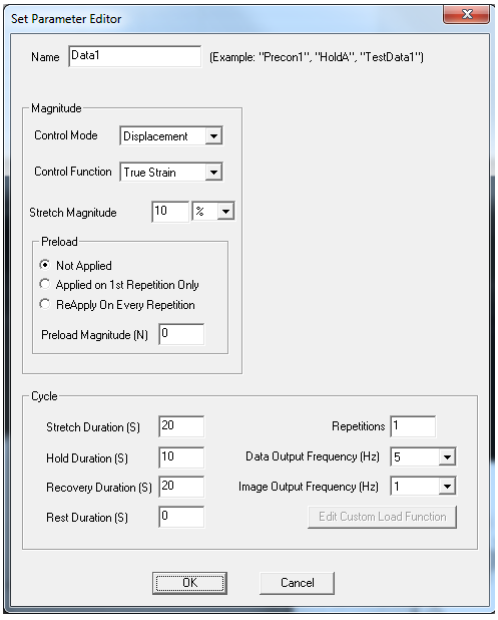
> ***System Alert***
>
> *You should zero the load cell after attaching a platen or grip but before mounting a sample. If a specimen is already loaded when the load cell is zeroed, the force reading will include an offset load.*

Step 6: Modify Testing Parameters (optional)

You can select and modify the parameters in the test sets by clicking on a row in the Test Sequence table and then pressing the *Edit Set* button (or by double clicking on the desired row). When you do so, the *Set Parameter Editor* dialog will appear.

Note that displacements are specified in either % strain, or mm. Force loads are specified in N, and durations are specified in seconds.

The following table describes each of the parameters.



Test Parameter	Description
Control Mode	Tests are typically performed under displacement control, however, you can select the following control modes to achieve specific testing objectives: • For creep testing, use force control with a long hold duration. • For stress relaxation testing, use displacement control with a long hold duration.
Control Function	True Strain or Ramp is typically selected for tests performed in displacement control mode. For tests performed in force control mode, Step controls are selected.
Stretch Magnitude (Load Magnitude when in Force Control mode)	Selecting a stretch magnitude is dependent on the material you are testing. A sound approach is to begin with a small magnitude and iteratively move up to larger magnitudes. If you are using Displacement control mode, you can specify the displacement in either mm or as a percentage. For example, the displacement on a 5mm specimen can be expressed as either 0.5mm or 10%. If you are using Force control mode, you can only specify the force in N. Watch the test results carefully to determine which magnitude setting best achieves your test goals.
Preload	Preload is typically reapplied on every repetition during a preconditioning set as well as on the first repetition of a testing set. Specimen size is adjusted after a preload adjustment. Strain calculations are based on the specimen size after the last preload adjustment. If you are working with a material for which preload values have been suggested, you can set the value accordingly. Otherwise, zero is a good initial choice.
Preload Magnitude	As with stretch magnitude, the preload magnitude settings depend on the material you are testing. While Preload can be set at zero, typically you would set the preload magnitude somewhere between zero and 10% of the peak load you expect to achieve.
Stretch Duration	For evenly spaced images, it is recommended to choose a number that is an integer multiple of the Image Output Frequency.
Hold Duration	Hold Duration is typically set to 0, however it is useful for creep or relaxation testing.
Recovery Duration	Recovery Duration is typically set to the same value as the Stretch Duration.
Rest Duration	Rest duration is typically set to 0, however a non-zero value may be used to mimic *in vivo* conditions or for specialized testing.
Repetitions	Apply enough repetitions until the force deformation curves from one repetition to the next start to overlie each other.
Data Output Frequency	Typically set to the same frequency as the image output frequency.
Image Output Frequency	Typically set to 1Hz for cycles > 5 seconds and 15 Hz for cycles < 5 seconds.

UniVert Tip: Idle Current

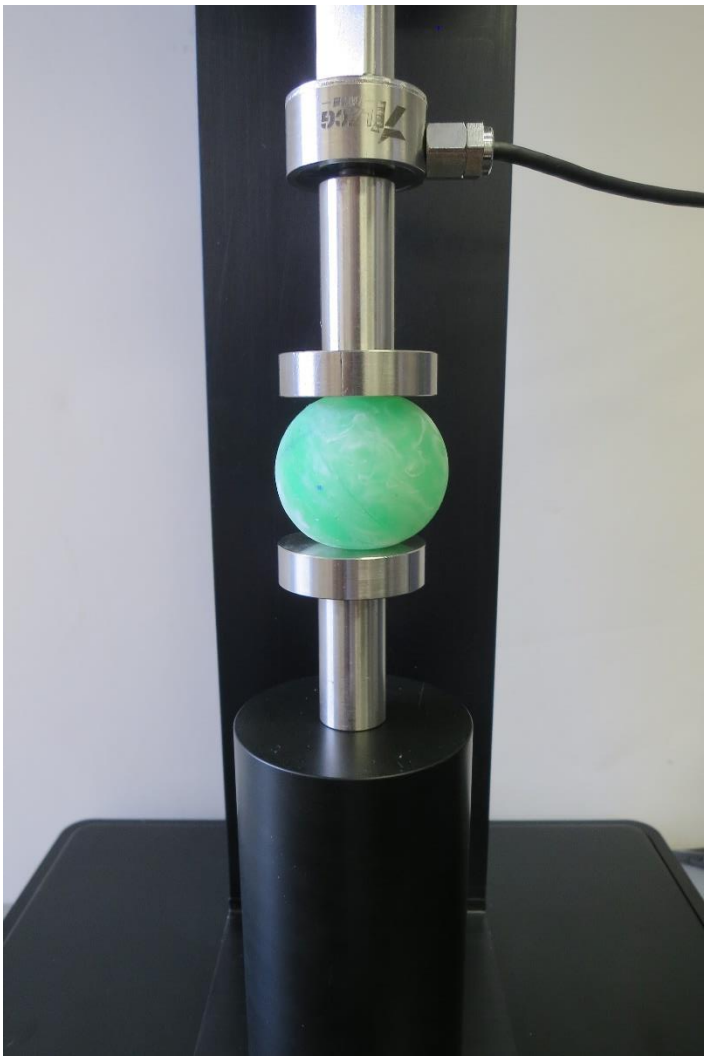
Idle current (holding current) can be applied to the motors. The motors have a holding force in the de-energized state of approximately 100N. If forces in excess of 100N are expected it is recommended that idle current is used to prevent position loss during velocity and direction changes when the motors are de-energized for a very short time. When idle current is activated the motors will produce **more noise**, even when the actuator is at rest. This setting may be accessed by selecting *Hardware* from the Settings menu.

Step 7: Mounting a Specimen

Platen Mounted Specimens

1. Select an appropriate riser to accommodate the size of the specimen (see **Appendix D**).
2. Place the specimen on the bottom platen.
3. Jog the top platen to the correct position using the jog arrows in Actuator Control

Alternately, the *Move Actuator to Specified Size* command may be used.



> ***UniVert Tip: Compression Specimen Mounting***
>
> Make sure to center the specimen on the platen as much as possible to ensure accuracy in the force reading. Ideally, specimens will have two parallel flat sides and will make full contact with both platens. Although this is not always possible, flat testing surfaces will improve force distribution.

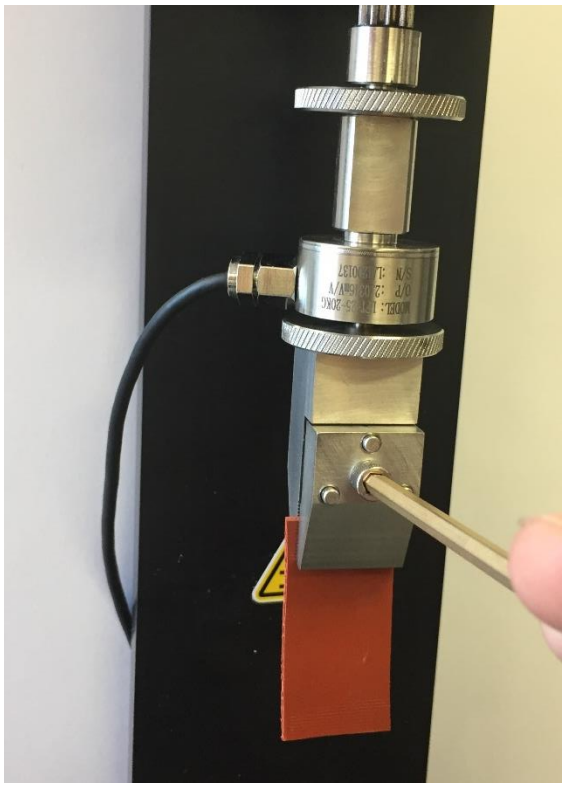
Grip Mounted Specimens:

Low Force Grips

1. Select an appropriate riser to accommodate the size of the specimen (See **Appendix D**).
2. Select a grip with appropriate clamping force for the specimen being tested (see **Appendix E** for more details).
3. Jog the actuator using Actuator Control or select *Move to Specified Size* until the grips are sufficiently far apart and attach the specimen to the top grip.
4. Using Actuator Control, lower the top grip (with specimen attached).
5. Open the bottom grip and lower the specimen between the grip surfaces. Release the bottom grip.

High Force Grips

1. Select an appropriate riser to accommodate the size of the specimen (See **Appendix D**).
2. Select a grip with appropriate clamping force for the specimen being tested (see **Appendix E** for more details).
3. Jog the actuator using Actuator Control or select Move to Specified Size until the grips are sufficiently far apart and attach the specimen to the top grip using the 9/64 hex key provided.



4. Using Actuator Control, lower the top grip (with specimen attached).
5. Open the bottom grip and lower the specimen between the grip surfaces. Grip the specimen by tightening the grip using the 9/64 hex key again.

3-point Bend Specimens

1. Use the 80mm riser to ensure the sample is in the range of the actuator (see **Appendix D**)
2. Choose an appropriate sized 3-Point Bend dowel for the type of test you wish to perform.
3. Install the 3-Point Bending test setup (See **Appendix D**)
4. Move the sliders into desired position and lock in place by tightening the M3 fastener to the rail.
5. Place the specimen on top of both lower dowels and begin testing.

Step 8: Execute the Test

Select *Execute* from the File menu, or press the button on the toolbar.

Step 9: Terminate the Test Prematurely (optional)

You can stop a test at any time by clicking on the toolbar, or by selecting *Stop* from the File menu. This is preferred over powering down the equipment, as it allows the software to store the current actuator position.

At the end of the completed test (both normally or prematurely terminated) the actuators will maintain their current position.

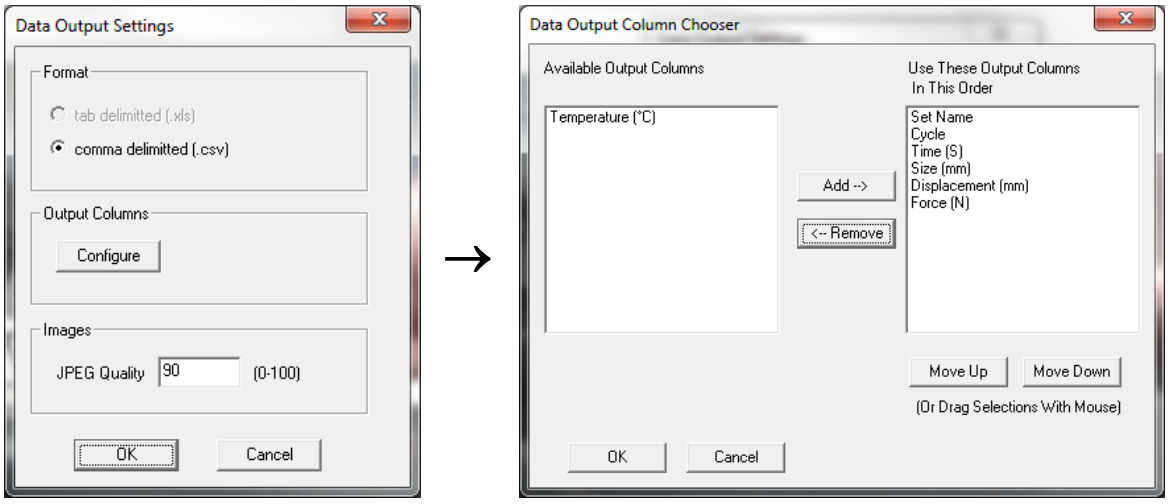
> ***UniVert Tip: Specimen Thickness***
>
> *Measuring the specimen thickness before and/or after a test is performed will allow stress calculations to be made from your output data.*

> ***System Alert: Load Cell Handling***
>
> *It is important to handle load cells carefully. Here are some things to consider while handling a load cell:*
>
> - *The load cells are designed to handle overloads of up to 120% full scale value. Overloading a load cell past this rating may cause permanent damage to the load cell*
> - *Avoid applying excessive torque and transverse forces to the load cells. Over tightening grips or platens onto the active end of the load cell may damage it.*
> - *Accidently crashing the platens or grips together will produce more force than most load cells can handle. Be careful and reduce actuator speed when jogging grips or platens close together.*
> - *Generally avoid dropping, tapping, and exerting unnecessary force to increase the life the load cell.*

5. Additional Settings

Configuring Output Data Files

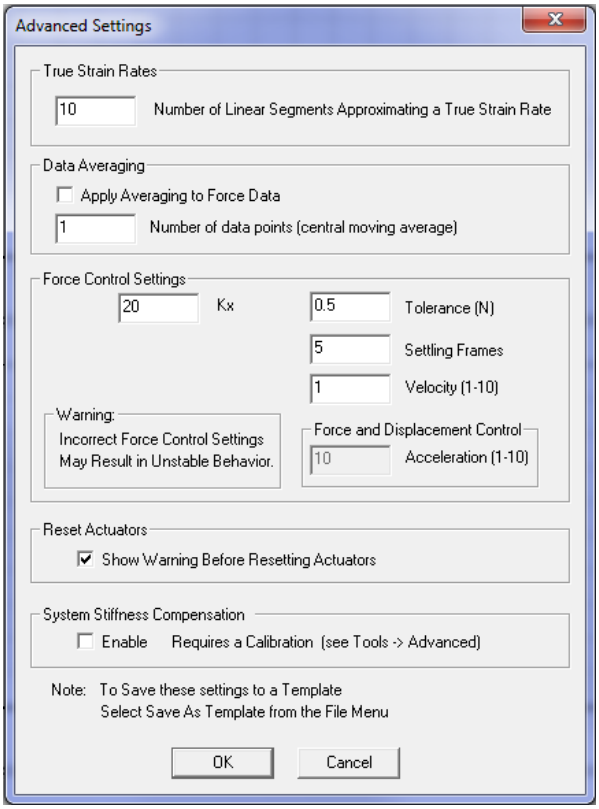
From the Settings menu, select *Data Output* to display the dialogue shown on the left. Click the *Configure* button to select which of the following columns to output.



Output Column	Description
Set Name	User defined name of each set
Cycle	Cycle and Phase information
Time (S)	Time in seconds
Size (mm)	Specimen Gage Length
Force (N)	Load Cell reading
Displacement (mm)	Reports the change in size relative to the initial size
Compensation (mm)	Reports overall compensation due to system stiffness (see Section 8). Off by default.

Advanced System Settings Dialogue

Advanced settings are available by selecting *Advanced* from the *Settings* menu. All of these settings are specific to the test template selected.



True Strain Rate

Unlike nominal or engineering strain rate, a plot of velocity versus time for a true strain rate test would be non-linear. The degree of non-linearity increases with increasing strain. The UniVert approximates this non-linear curve with a series of linear segments. Typically, 10 line segments is a sufficiently close approximation. More segments can be used, but you should bear in mind that the actuator velocity can only be updated every 250ms.

Data Averaging

The load cells are sampled at 100Hz with hardware using a central moving average of 8 samples. Further data averaging can be applied to smooth noisy data.

Force Control Settings

Force Control Settings affect the rate and stability at which forces are achieved in force controlled procedures. These settings apply to preloads as well as Force Control Modes.

Kx (Default = 100, integer values) is a proportional gain tuning parameter. It controls the sensitivity or the amount of corrective action that is applied to the difference between the current and target force values. At low gain values the system may be safe and stable but may be sluggish in response to changing conditions. If the proportional gain is increased the system becomes more responsive and loads are achieved more quickly. If Kx is set too high, an unstable oscillating system may result and forces may never be achieved. The optimal value for these settings depends on the properties of the material being testing. For stiff materials, values may range between 10 and 50. For soft materials, values may range between 50 and 500.

Tolerance (N) (Default = 0.1) controls how close to the specified force the actual load values need to be. For example, a specified force of 10N with a Tolerance of 0.1 N will be considered achieved when the loads are between 9.9 and 10.1 N. Keep in mind the accuracy of the load cell being used when choosing the value for this parameter. The load cells typically fluctuate by about 0.1% of their full scale during the course of a test. For a 10N load cell this is about 0.01N but for a 200N load cell, this is about 0.2N. This value should usually be 0.2-0.5% of full scale to ensure stable operation.

Settling Frames (Default = 5) controls how many successive load samples (sampled at 100 Hz) need to be within the Tolerance criteria for the force to be considered achieved. For example, a specified force of 10N with a Tolerance of 0.1 N and Settling Frames = 5 will be considered achieved when the loads are between 9.9 and 10.1 N for 5 successive data samples at 100Hz.

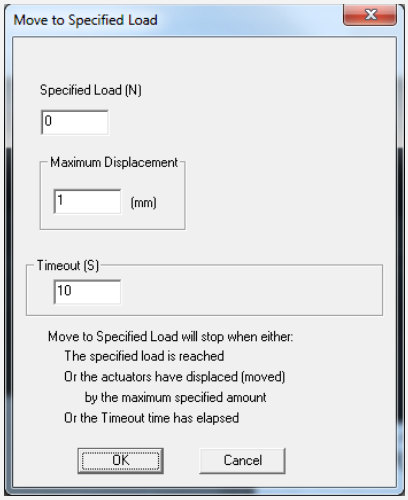
Velocity (1-10 integer values) matches actuator jog speed. Typically for stiffer materials, this value should be between 6 and 8 and for soft materials, this value should be between 8 and 10.

Acceleration (1-10 integer values). Typically this should be set to the default value of 10 (maximum acceleration). Changes made to the acceleration will affect tests under both force and displacement control. Reducing this value may help smooth force controlled tests under low loads or displacement controlled tests at high speeds. Tests run with lower accelerations will have softer transitions at direction or speed changes but may take longer than specified to achieve testing cycles.

UniVert Tip: Testing Force Control Settings

It is important to have appropriate Force Control Settings that match the materials you are testing.

To safely test Force Control Settings: press *on the tool bar, or from the Tools menu select Move Actuators to Specified Load. The dialogue shown on the right will appear. The UniVert will attempt to achieve the specified load (force) but will stop when the specified load is reached, the actuator has displaced by the maximum specified amount, or the timeout time has elapsed.*



If the actuator oscillates around the specified loads but never achieves them try reducing Kx and/or decreasing the velocity.

If the actuator reaches the specified load too slowly, try increasing Kx and/or increasing the velocity.

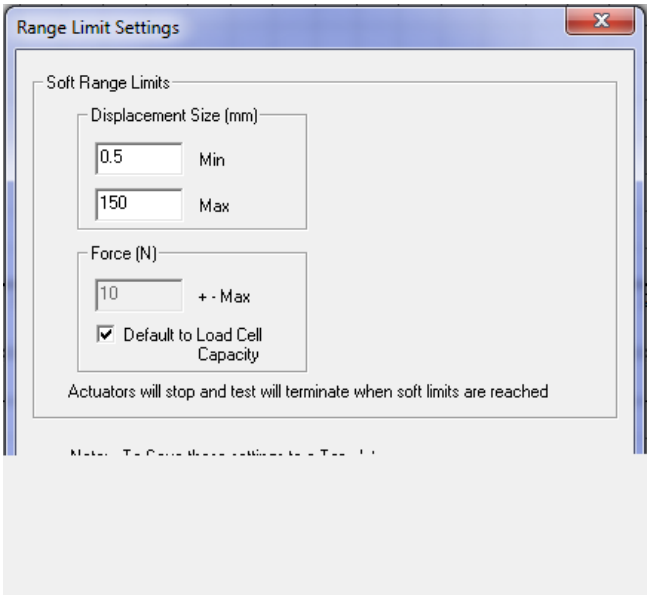
Reset Actuators

Resetting the actuators with a sample attached may damage the specimen, BioRakes, and/or load cells. To avoid resetting the actuators with a sample attached, a warning dialogue will appear after ñReset Actuatorsò is selected, prompting the user to proceed. This feature can be disabled by de-selecting ñShow Warning Before Resetting Actuatorsò

Range Limits

Range limits can be accessed by selecting *Range Limits* from the Settings menu.

Soft Limits



To avoid collisions or sample destruction, it is useful to assign reasonable travel limits to the actuators. This is especially important during force control or preloading, where if specified loads cannot be reached, the actuators will keep moving until they reach the soft limits.

Min and Max Displacement, in mm, set the minimum and maximum positions to which the grips or platens are allowed to move. These settings require adjustment especially when the riser is changed.

Max Force, in N, sets the maximum value of force at which a test will be automatically stopped. The default value is set to the capacity of the load cells. Setting this value may be useful to prevent sample destruction or overloading of the load cells.