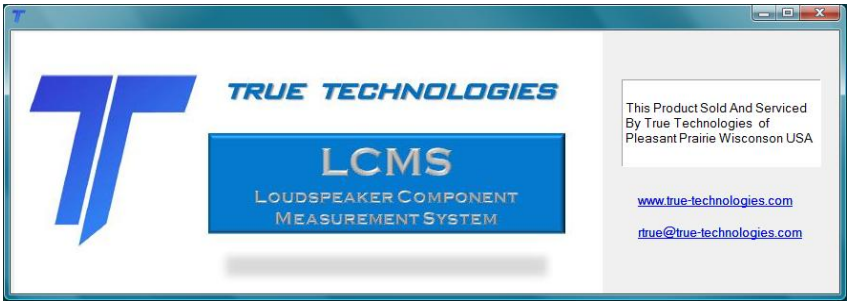
True Technologies LCMS User's Manual



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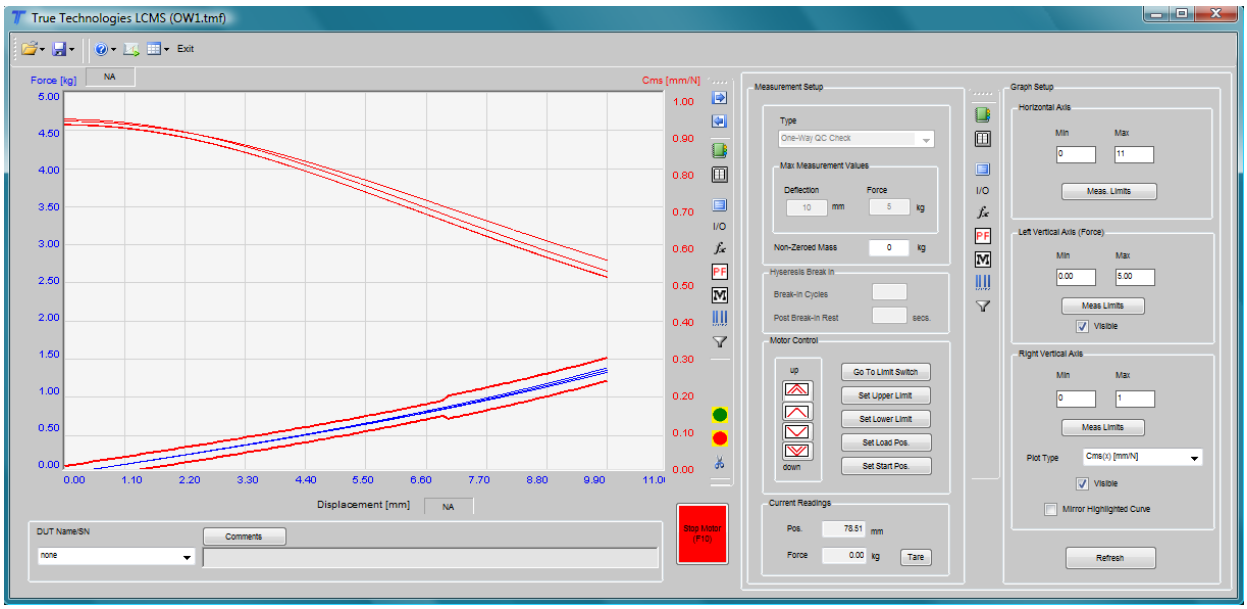
1.0 Introduction

The Loudspeaker Component Measurement System allows users to measure loudspeaker suspension components without having to build up speaker drivers. This type of measurement can be useful for choosing parts for a design or for quality control of production parts.

The graphic below shows the Main Screen that is seen when opening the software. In this example, the force versus deflection characteristic of several spiders is plotted against the left axis in blue lines with a quality control limit window sandwiching the data. The QC limits are referred to in this document as Pass/Fail curves and are saved as Standard files. The compliance curves (cms(x)) is plotted are red curves against the right axis.



See the Appendix for first setup of the LCMS machine.

The following describes the icon functions that drive the use of the software. More detail on many of the functions follows later. Follow the links to get more information.

- Open an existing measurement or standard file or start a new measurement. Multiple measurements can be appended to create new files.
- Save measurements or standard files.
- The user's manual is available here (F1) as well as a list of short cut keys that are useful for controlling the motor and running measurements.
- Opens the calibration window.


Opens the measurement database that can be used to search for existing measurement or standard files. There is also a utility for adding and removing data from the search fields


This icon opens the setup panels shown to the right of the graph. One or two panels can be open at a time. The icons below control what setup panels are shown. The  icon hides the panels.


Setup the main measurement function.


A place to keep your notes. This is a rich text document that can keep almost anything that can be pasted to the windows clipboard.


The graph setup is controlled on this panel.

I/O Controls the I/O setup for the motor and force gage.


Curve processing is done on this panel. The first step to creating Pass/Fail curves begins here.

Pass/Fail curves. Allows viewing and manipulation of the limit curves that are then saved as standard files.

Memory curve control. Measurements can be moved into memory for viewing later or comparing to other measurements.


This controls how the component being measured is labeled. A bar code can be scanned or labels can be typed in. The parts can also be auto numbered.


The filter/format grid controls which curves are visible and what colors they are.


The Go icon starts a measurement (F9 can also be used.)


The Stop icon is used if a measurement needs to be stopped before it has completed (F10). This is basically an emergency button in case something is wrong. The big red Stop Motor box serves the same purpose


This icon deletes unwanted measurements – the highlighted measurement (selected in the DUT Name/SN dropdown) is removed from the group.

2.0 Calibration

Before using the system, it must be calibrated. Click the calibration icon to begin. Follow the instructions given for each step. Make sure the motor slide is free to move the entire stroke from the limit switch at the top to the base plate at the bottom. Calibration requires measuring the location of the force gage at several displacements. The system will first move to the upper home position and then down to a starting location. Measuring the slide location is most easily done by using a height gage that is positioned on the cross bar that supports the motor slide as shown below.

After reaching the starting location, position the height gage and set the reference reading at 0.00mm with the probe touching the force gage adapter plate. When ready, click OK and the gage will move down 50.8mm. Measure the actually displacement and enter the value when prompted. Next, move the gage out of the way and click OK to have the gage move back up to the original reference location. Measure the position – it should be very close to 0.00m. The procedure repeats the down/up measurements one more time before completing. If the distance moved each cycle is not close to 50.8mm, contact True Technologies for assistance.

To complete the calibration, hang calibrated masses from the force gage and verify the reading is accurate over the entire range that the gage will be used. If the gage is not sufficiently accurate, it must be returned to the manufacturer for calibration. This is typically only required if the force gage is driven well beyond its capacity – be careful not to do that!

A calibration spring check gage can also be used to check the machine on a periodic basis. The gage is not included with LCMS, but can be made using a piece of tempered spring steel. A cantilevered piece that is approximately 25 mm wide by 100 mm long and 0.5mm thick works well. A standard file can be created to hold the expected measurement result and the check gage should measure within 1% of the original measurement if nothing on the machine has changed. It is best to set the curve fit order to linear on the fx setup panel for best accuracy. The standard file will force the curve fit order if it is saved with the file.

3.0 Setup Screens

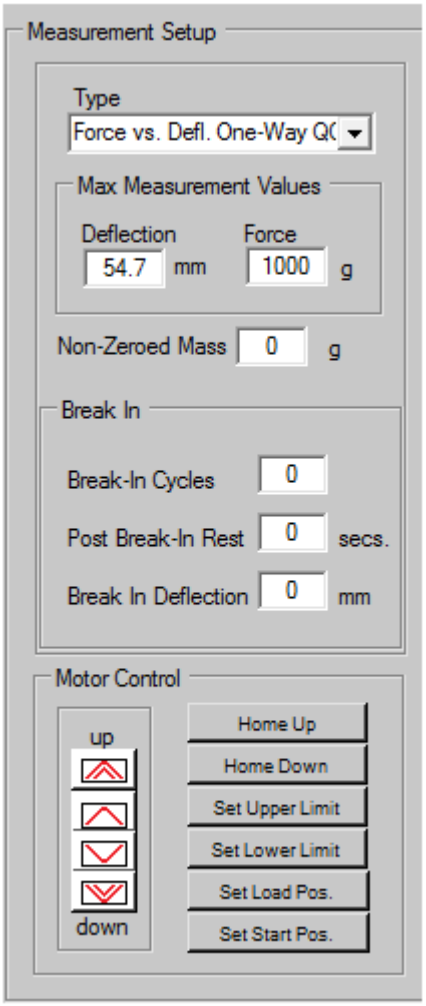
3.1 I/O Settings. Before the LCMS can be used, the **I/O** settings must first be set on the setup panel. Before starting the software, make sure the motor system is connected to a USB port and the force gage is connected to a RS232 serial port. On the **I/O** setup panel the Comm Setting must match the serial port the force gage is plugged in to. To check the connection, click the Read Force Value button. If a value is presented, the connection is OK.

If the motor is properly connected and the drivers properly installed, the Select Motor drop down will present the choice (typically umd01 , Index=0). Select this value and the setup is complete.

Once the I/O settings are complete, they will be save and can be ignored going forward unless the system hardware is changed.

3.2 Measurement Setup. To get ready to make measurements, click the icon to show the Measurement Setup panel shown here.

At the top of the Measurement Setup, first choose the type of the measurement to make. For QC measurements, typically a One-Way QC Check is performed. This is a simple/fast measurement where the force gage is only moved down to touch a plug at the DUT ID and then the force versus deflection characteristic is measured only in the downward direction. More detailed information about the component can be gleaned by selecting the Hysteresis measurement. This is a two-way measurement that requires clamping the force gage probe to the DUT ID so that it can be pushed down and pulled up while measuring the reactionary force in compression and tension respectively. There is also a BL (motor strength) measurement option. See the appendix for more information.



Regardless of the measurement type, the maximum deflection and force must be entered in the boxes. Also, any Non-Zeroed mass must be entered. This is any mass added to the DUT that is not fixed to the force gage and zeroed out. For example, the plug mass in a One-Way measurement should be added here. Note, the units are that of the force gage so a 3.5g plug should be entered as 0.0035kg. The system will not allow maximum force values that exceed the gage capacity (the gage type is communicated by the gage itself and the capacity is automatically known.)

If Hysteresis measurements are being made, the option to pre-exercise the DUT is available by entering the number of Break-In Cycles. A Post Break-In relaxation period can also be entered.

Next, move the motor slide up and down to setup the measurement. The buttons with red arrows provide for fast/slow up/down motion. This can also be accomplished using Ctrl(slow)-Up/Down arrows or Alt(fast)-Up/Down arrows. If it is desired to use the limit switch at the top of the motor slide as the zero reference position, then first click the Go To Limit Switch button to home the motor (this is not necessary.)

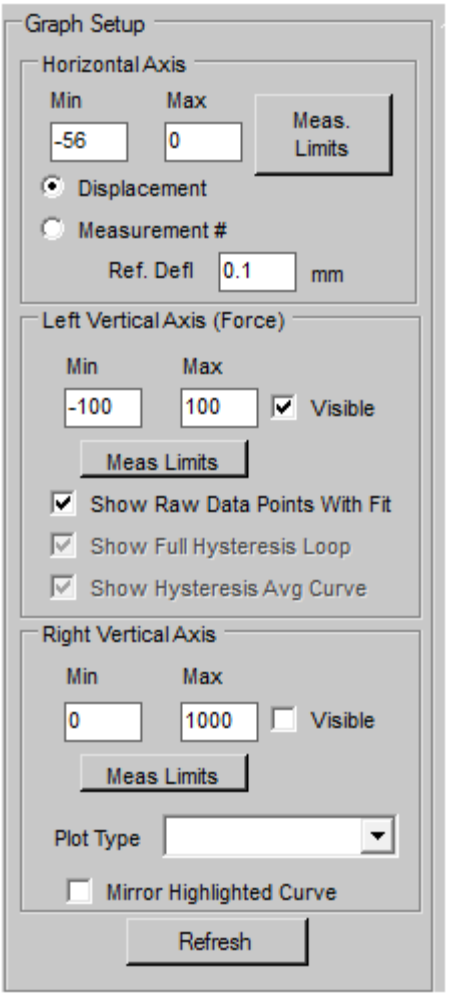
Later versions of LCMS2 also include a lower limit switch. When this is the case, the "Enable Lower Limit Switch" box must be checked on the I/O setup panel.

It is a good idea to set the Upper/Lower travel limits before starting a set of measurements. This will ensure the slide does not move too far if something goes wrong. To do this, move the slide to the desired location and click the relevant Limit button. To reset this limit so the slide can be moved freely past it, click the Set Upper/Lower Limit button and then click cancel to clear the limit. If the limit switches are to be used as the upper/lower travel limits, then the software buttons do not have to be clicked. If both the switches and buttons are used, the buttons will define a smaller range of travel but the switches will stop the motor slide if it reaches these hard limits.

For One-Way QC Measurements, move the slide to a position where it is easy to load/unload parts and click the Set Load Pos. button. The slide will return to this location after each measurement is complete. Finally, after loading the first part, move the slide so the force gage tip is very close to the plug at the DUT ID and click the Set Start Pos. button. The gage will be returned to this position very quickly at start up of each new measurement before the measurement routine begins.

The Current Readings Panel shows the current position of the motor slide and the reading from the force gage. The Tare button can be used to zero out the force gage when needed.

3.3 Graph Settings



The Graph setup Icon presents the panel shown to the right.

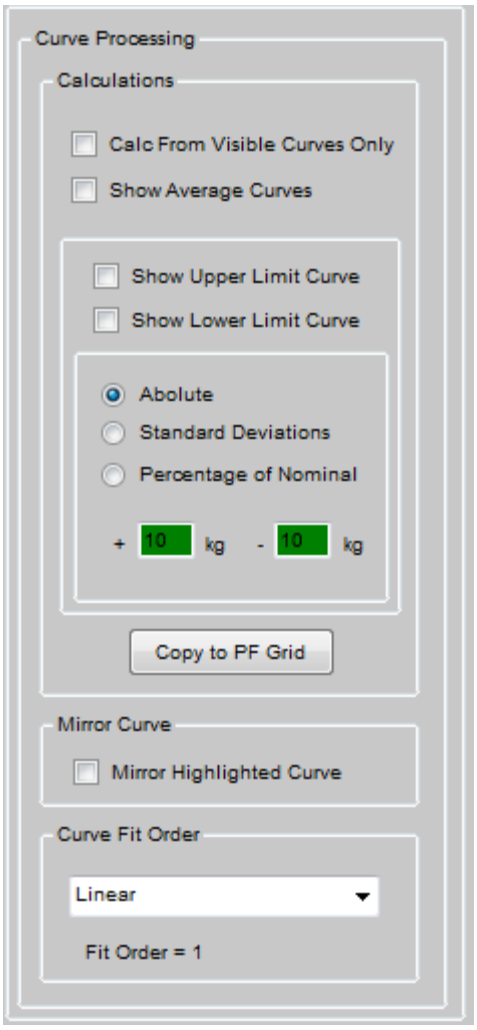
Set the range as desired for each axis. The left axis always shows the force values. The right axis can be set to show either the compliance (cms(x)) or stiffness (kms(x)) curves that are calculated from the slope of polynomials fit to the f vs. d curves. If the Measurement # selection is made for the horizontal axis, the software will plot the force, compliance, or stiffness values for a given displacement for several measurements.

The data associated with either axis can be hidden by unchecking the Visible check box.

In Hysteresis mode, a mirror of the highlighted cms(x)/kms(x) curve can be viewed by checking the box. This allows a quick evaluation of the symmetry of the part. You can also choose to plot the outer loop of the hysteresis measurement or a curve representing the average of the upper and lower legs of the loop.

Finally, the raw data points are shown on the screen with each new measurement. They can be turned off by checking the box.

3.4 Curve Processing. When clicking this icon, the Curve Processing panel shown to the right is presented.



These features allow the user to analyze the statistical nature of a dataset. The processing only applies to the force vs. deflection curves (not cms(x)/kms(x)).

The Calc from Visible Curves Only check box controls whether the average and limit curves are calculated from all curves in the currently loaded dataset or from only those that are currently visible. To exclude a curve from the calculation, hide it on the filter panel .

The Upper/Lower Limit Curves can be calculated based on an absolute offset from the calculated average (the values entered in the boxes are in this case in units of the force gage.) Alternatively, the Standard Deviations option can be selected and the offset curves are then in +x/-y standard deviations where x and y are the values entered in the offset text boxes.

The calculated curves can be used to create Pass/Fail limits for Standard files. When the limits are close to what is desired, click the Copy to PF Grid button. See the next section for more information on how to further manipulate these curves for PF limits.

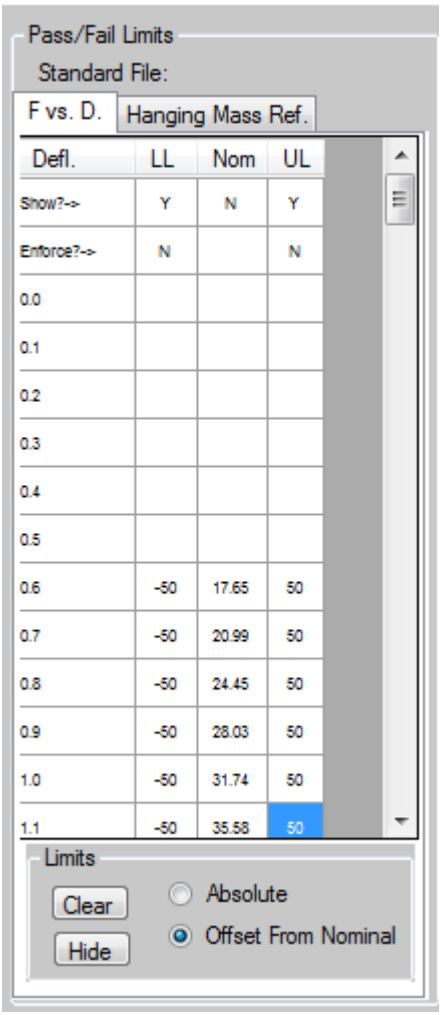
Note, after copying the calculated limits/average curves to the PF grid, it is a good idea to uncheck the Show Limit/Average boxes in order to avoid confusion when viewing the calculated curves and the new PF curves. The calculated lines can later be turned back on to compare the statistics of a current lot of parts to the PF limits setup in a Standard file.

A Mirror of the highlighted (selected in the DUT Name/SN drop down) cms(x)/kms(x) curve will be plotted if the box at the bottom of the panel is checked.

The curve fit polynomial can be forced to a particular order by setting it in the drop down box on this panel. If set to auto, the measurement system will determine the best fit (see section 8 – How It Works.) The order can be changed while the current raw force versus deflection data is still in memory. Once the next measurement is made or after the file is closed, the fit order can no longer be changed. When selecting a curve with the DUT Name/SN dropdown box, the order used will be shown in this box for previous measurements. When a standard is saved, it will hold the

curve fit order (or the auto setting) and the system will be locked to that setting when measurements are made with the standard open.

3.5 PF Pass/Fail Setup. Clicking the PF icon will present the panel shown to the right.



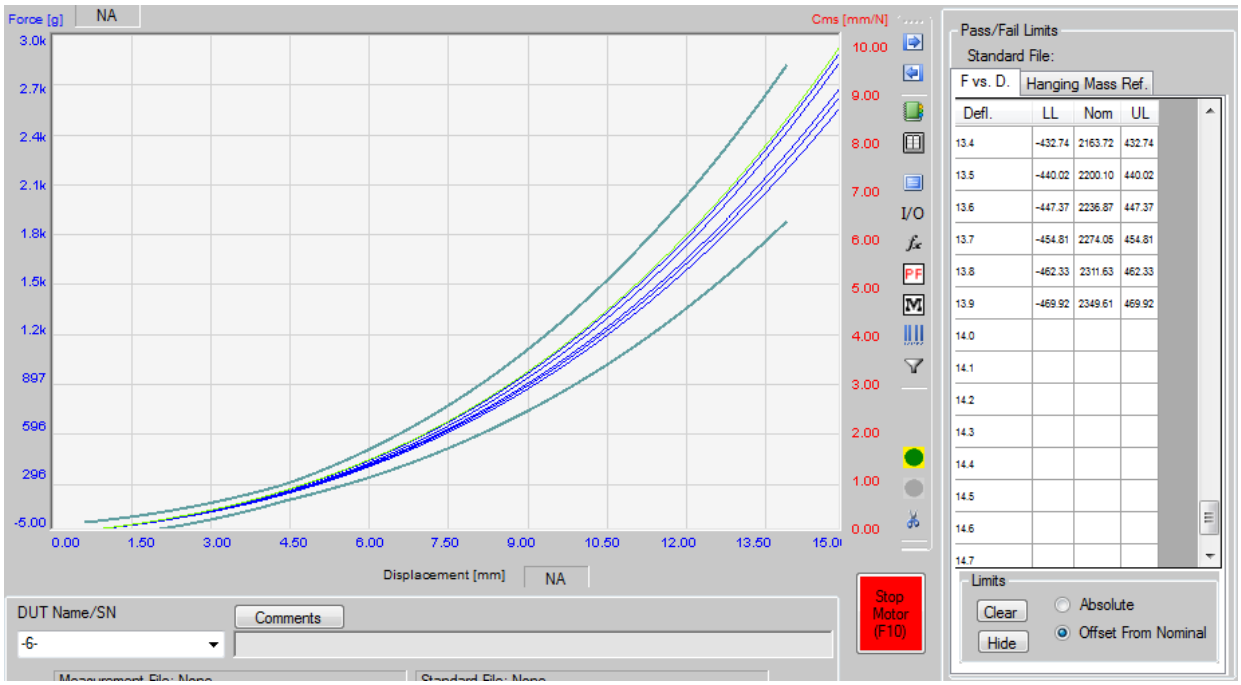
The data in the grid is either loaded from the Copy to PF Grid button on the f_x panel or by loading a Standard file. The Lower/ Upper Limit curves in the columns are labeled LL/UL. The Nominal curve (originally the average curve from the f_x calculation) is the middle column.

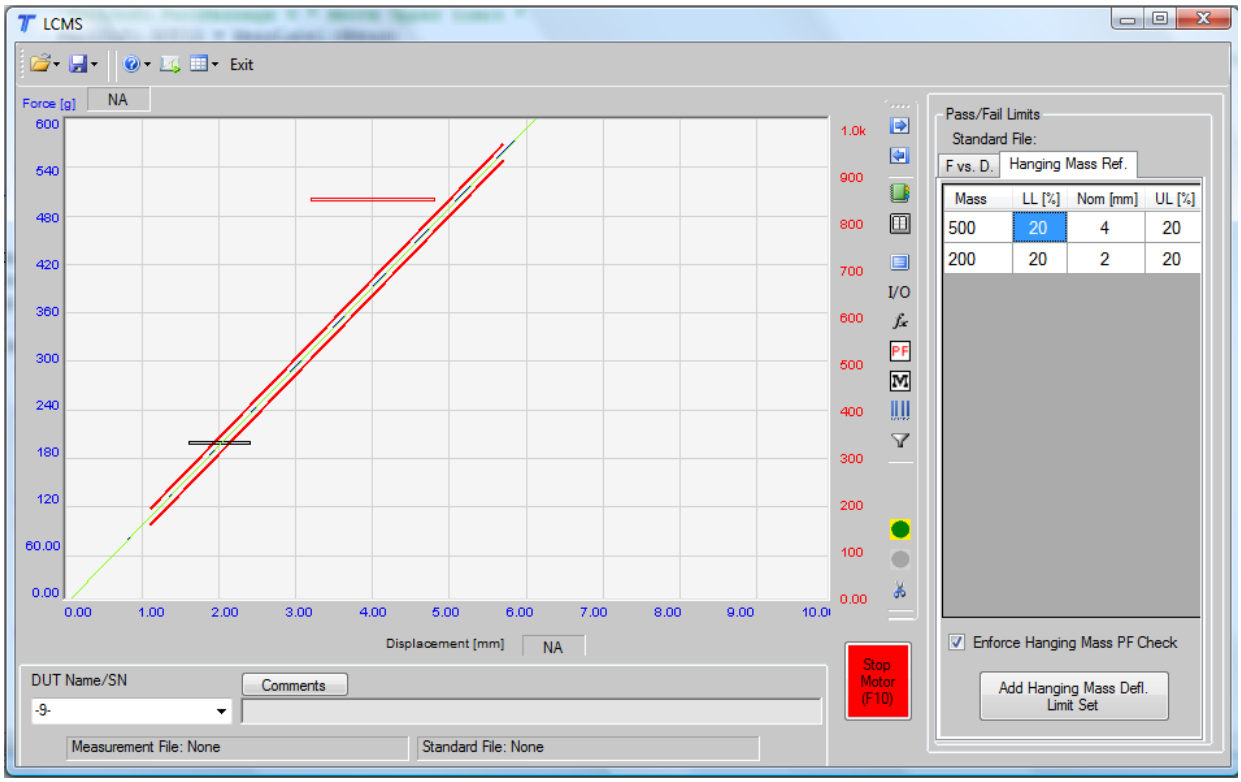
The limit curves can be viewed either in absolute numbers or as offsets from the nominal curve by selecting the relevant option.

Whether a PF curve is visible can be controlled by double clicking the Y/N cell of in the Show Row to toggle the settings. The Hide button sets all the Show values to N and then changes its caption to Show so all curves can easily be toggled to view or not.

For the limit columns, the Y/N can also be toggled in the Enforce Row. If a Limit is enforced, the program will inform the user if a measurement fell below the Lower Limit or rose above the Upper Limit indicating a failed condition. The values of any cell can be edited in the PF grid (hit enter to complete the edit.) Alternatively, select a range of cells in a column by clicking on a starting cell with the left mouse button and holding it down while dragging to an ending cell to highlight the cells to be changed.

Then click the right mouse button over the selected range to be prompted for the new value to fill all highlighted cells with. If the input box value is left blank, the cells will be cleared and the software will not check for pass/fail in this displacement range. In the example shown, the PF Editor was used to clear the PF limits below 0.6mm and open them to +/-50g (original setting in the calculated Stats f_x limits) 4.4mm. The limits were also cleared abouve 14.0mm (shown below.)



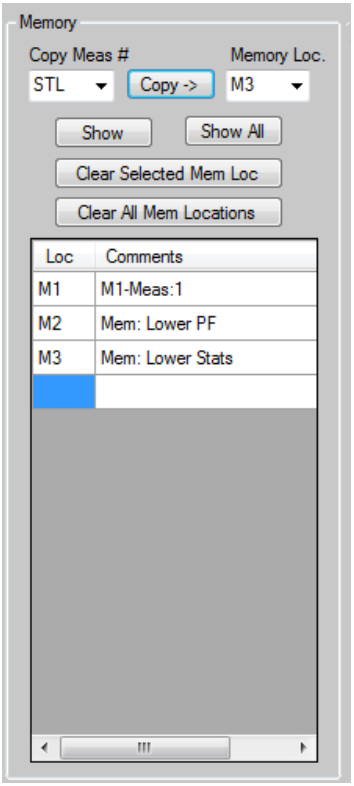


Pass/Fail limits for equivalent hanging mass measurements can also be set by changing to the Hanging Mass Ref. tab on the PF setup screen. Limit sets can be added by clicking the button and adding a mass reference, nominal deflection Value, and lower/upper limit percentages on the deflection value. In the example below the curve must pass through 500 grams at 4mm +/- 20% or between 3.2 and 4.8m. A second limit set was added such that the curve must pass through

200g between 1.6 and 2.4mm. The ranges are shown by the boxes on the graph. By checking the Enforce Hanging Mass PF Check box, the system will report a failure if the conditions are not met. The range indicator will turn red if it failed for that limit set. This Pass/Fail check has been added for legacy purposes for parts that have previously created QC standards based on hanging mass. It should be noted that the hanging mass method and LCMS different significantly in the way the data is collected and the two methods may not agree.

Once the Pass/Fail limits are as desired, they can be save as a Standard file (holds the limits and settings but no measurement data) by clicking the  and selecting Save As Standard. This file can then be opened before measuring future parts of this type to ensure they exhibit the proper force vs. displacement characteristic.

3.6  Memory Locations.



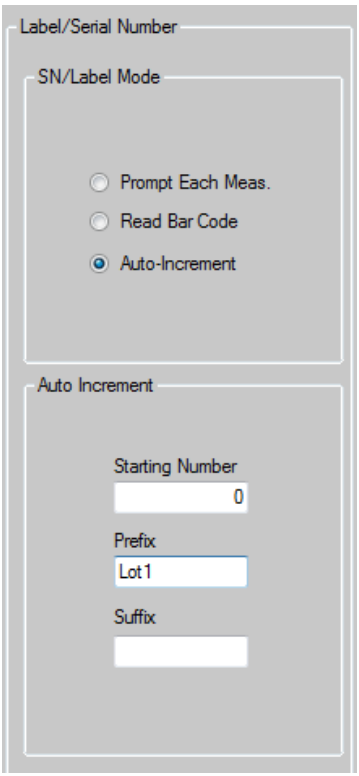
Curves can be copied into memory for later viewing. To copy a curve, select it from the Copy Meas # drop down and select the Memory Location to copy in to. Then click the Copy -> button. Show and Hide individual curves or all curves in memory by clicking the button.

When curves are copied, a comment is created indicating what is each memory location. In the example shown, the first measurement was copied into memory location M1. The Lower PF Limit was copied into M2 and the Lower Stats Limit was copied into M3. Copying lot statistics or PF limits into memory can be useful when comparing different lots of parts.

All memory locations or individual locations can be cleared by clicking the associated button.

Memory curves are also loaded into the DUT Name/SN drop down on the Main Screen so they can be highlighted and distinguished in a set of curves.

3.7 Curve Labels/Serial Numbers.



This panel controls how the program labels each part that is measured. Choose:

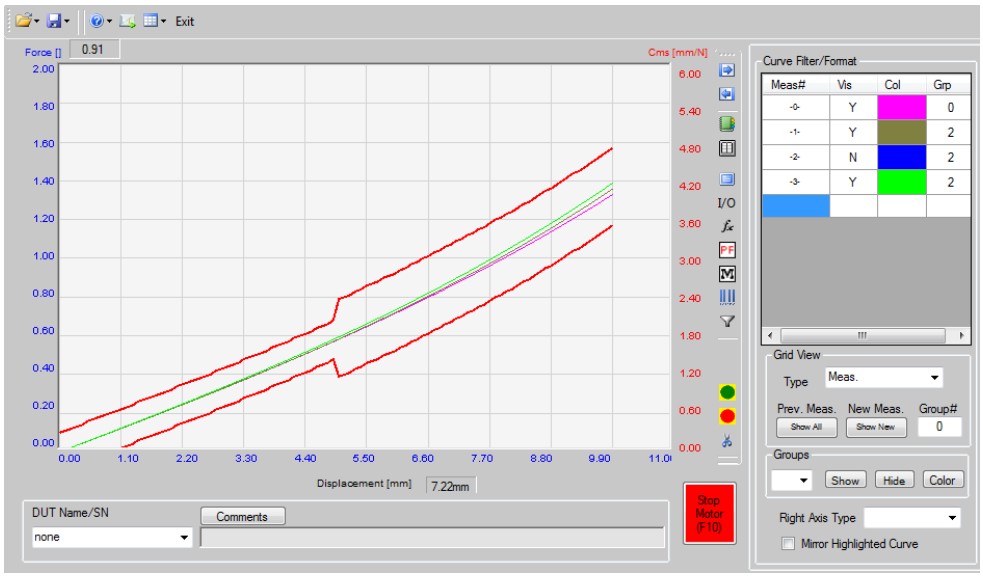
- Prompt Each Measurement. In this mode an input box is presented and a name or serial number of the part can be typed in
- Read Bar Code. An input box is presented before each measurement and a Bar Code Scanner can be used to fill in the label
- Auto – Increment. In this mode, the program will auto number the measured components beginning with the Starting Number entered. If desired, a Prefix and Suffix to the number can be used. With the example shown, the parts will be labeled

  Lot1-0
  Lot1-1
  Lot1-2

  And so on.

3.8 Curve Filters and Formatting.

The Curve Filter Format panel allows for coloring and showing/hiding curves. The example below shows 3 of the 4 measurement curves (labeled -0-, -1-, -2-, and -3-) visible with the colors set differently. To toggle a curve between visible and hidden, double click the Y/N in the Vis cell. Double click the color to be presented with a pallet that a new color can be chosen from.



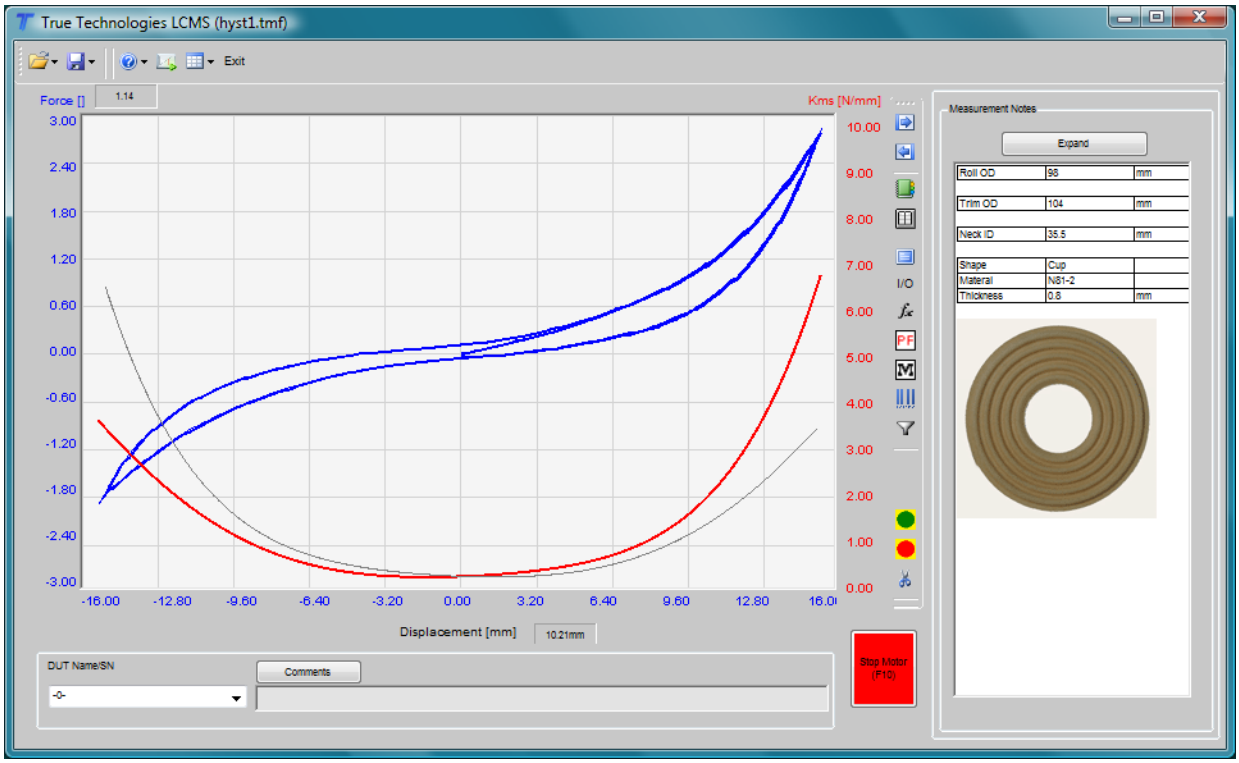
The Grp (Group) column allows sets of parts to be grouped together for so they can be colored the same or shown/hidden as a set. This is useful when comparing multiple sets of parts. The Group # box allows for group numbering as new measurements are made. If during a set of measurements the value is changed, the new measurements will take the new group number. Also, by highlighting a group of parts in the Grp column and then right clicking on the set, the group number can be reassigned.

The Grid View Type drop down determines what set of data the grid operates on. As shown (Meas.) the measurement curves can be recolored, hidden, etc. The other options are stored Memory curves, Stats (f_x) curves), and Pass/Fail Limits.

The Right Axis type sets the calculation to cms(x), kms(x), or none (no value shown in the above example.) When checked, the Mirror Highlighted check box will show a mirrored version of the highlighted cms(x)/kms(x) curve.

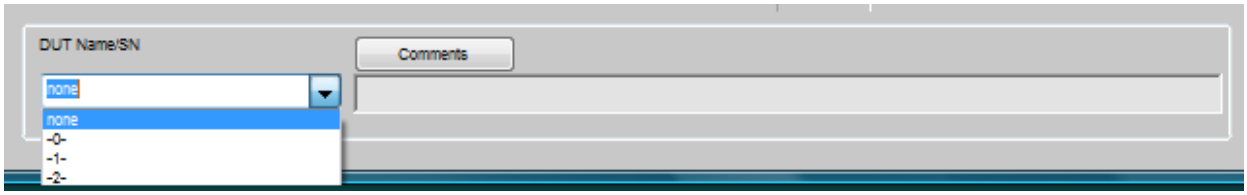
3.9 File Notebook.

The notebook can store anything that can be copied to the Windows notebook as can be seen in the Notes panel on the right side of the graphic below. Spreadsheet grids to hold specs, BOMS, etc. and images can be saved. The expand button shows a larger version of the notes over the graph so all information can be easily viewed.



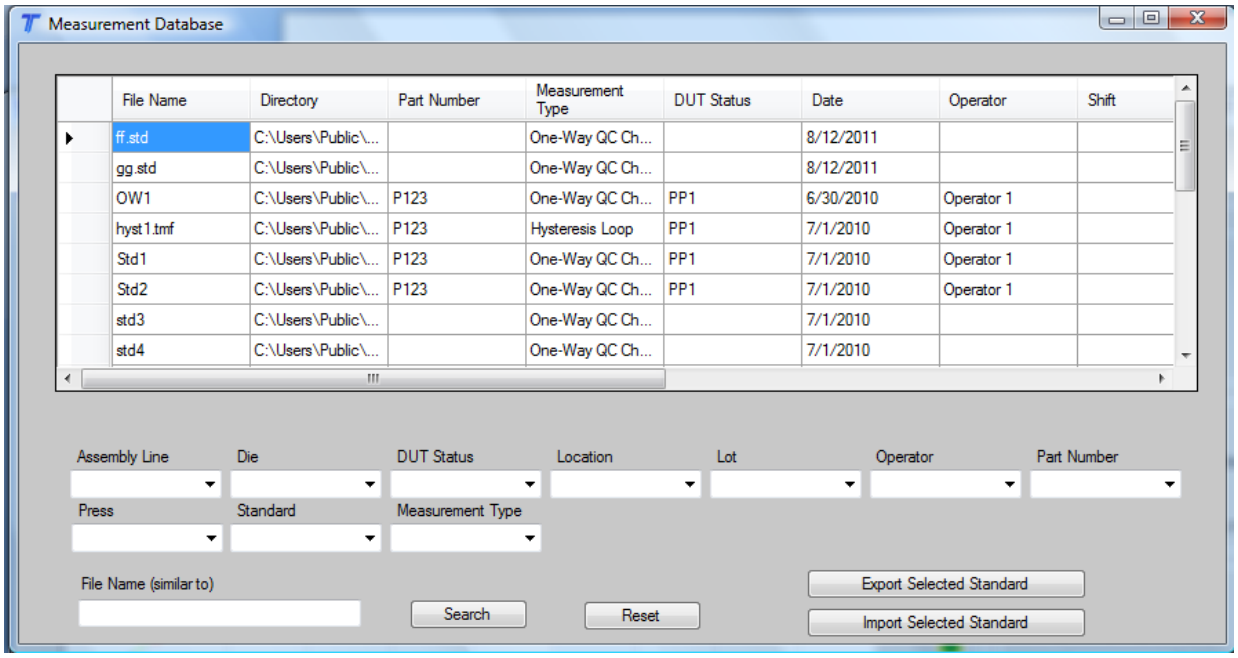
4.0 DUT Names/Serial Numbers and Comments

The DUT Name/SN box shown below keeps a list of the parts that have been measured. When a part is selected from the list, the measurement will be highlighted with a darker/thicker line. The comments box allows the user to enter notes specific to the part number selected (which is automatically set as the last measurement when it is completed.) Clicking the Comments button changes the box to settings that are automatically filled in by the software to keep track of measurement info like max deflection, added mass, etc.

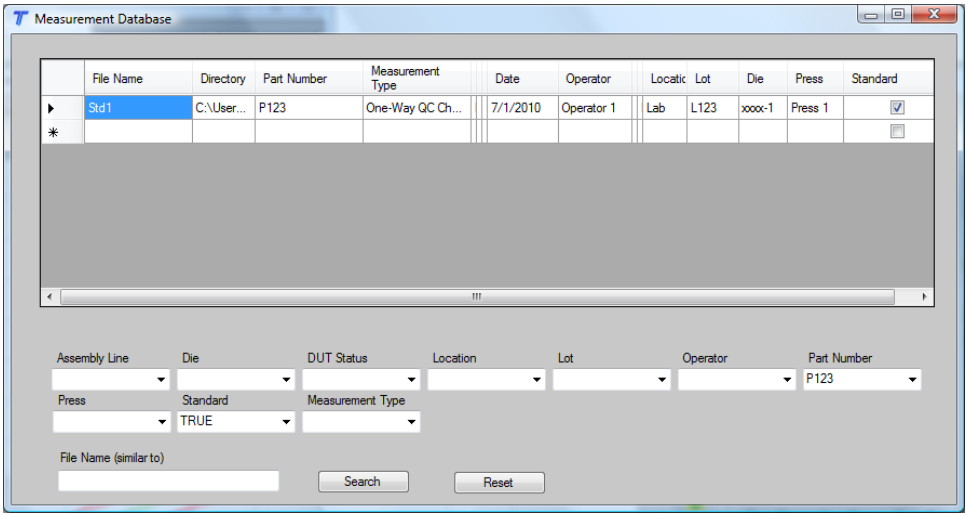


5.0 Measurement Database

The Measurement file database table is shown in the grid below. The boxes below the grid allow the user to quickly search for files associated with given record entries.



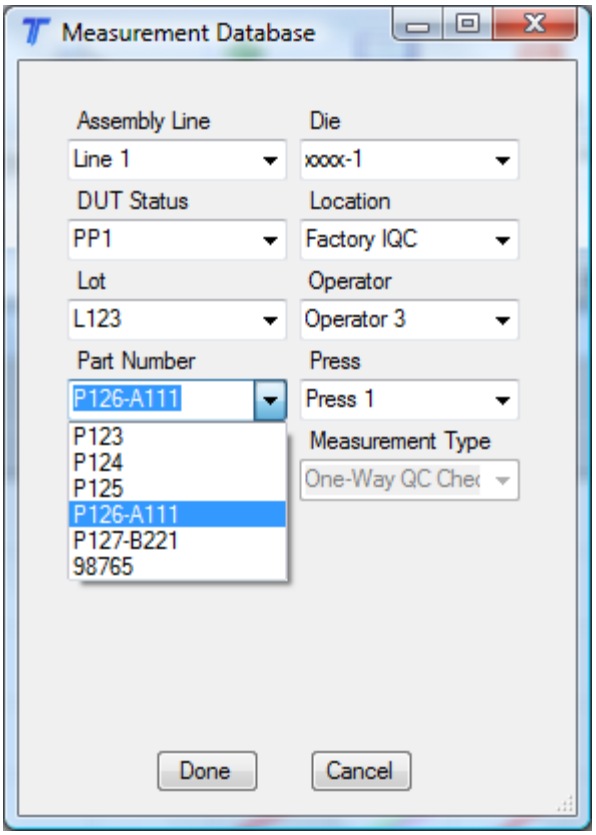
For example, to find a Standard file associated with Part Number P123 set the applicable drop down boxes and click Search to get the results shown here:



Only one record is shown because the LCMS does not allow multiple files with the same Standard name. By double clicking the row in the grid, the standard will automatically open (or any measurement file.)

When saving a measurement or standard file, the user is presented with this screen:

The values that are stored into the database fields for the new record are chosen from the drop down boxes on the form. The measurement Type and Standard (TRUE/FALSE) is set automatically depending on the settings.

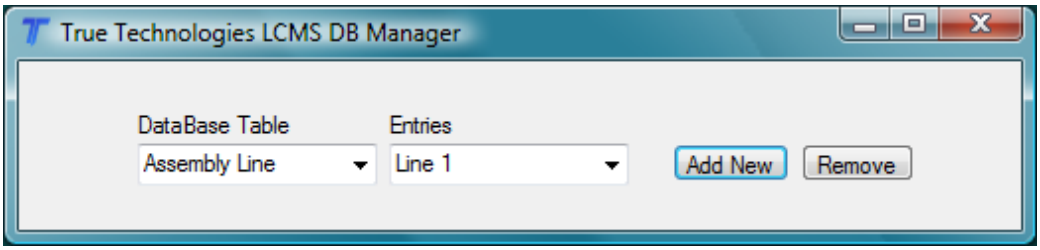


By forcing the user to choose from drop down choices instead of typing in values, the search function is very effective since typos or arbitrary entries are not allowed.

The underlying database is simply a Microsoft Access file (LCMS_DB.mdb). To control the values to be stored (and that are later searchable), a table must be created in the database (use the same format as other provided tables) and the name of the table entered into the Table Names table with the Include? field set to TRUE.

For the example shown to the right, the Table Names table in the LCMS_DB database has entries [Assembly Line], [Die], [DUT Status], [Location], [Lot], [Operator], [Part Number], [Press], [Standard], and [Measurement Type] and there is an associated table for each.

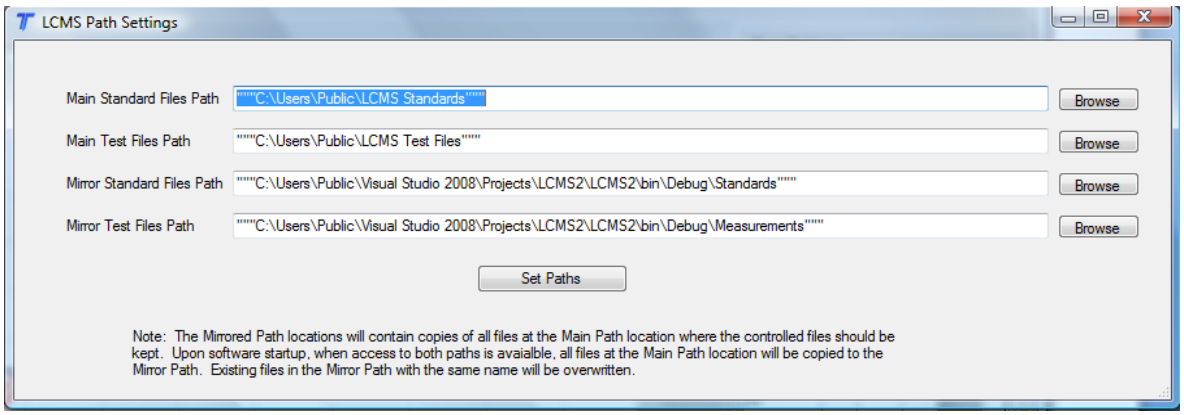
In the Part Number Table, there are records P123, P124, P125, P126-A111, P127-B221 and 98765. New records can be added or removed from any table (provided the Include? Filed =TRUE in the Table Names table) by using the Database Manager utility (selected under the icon) shown below.



Simply choose the Database Table to add/remove entries to/from and click the appropriate button. An input box prompts the user for new entries.

6.0 Setting Paths for Standard and Measurement Files

LCMS will default to the paths as set in the screen shown below for saving/retrieving measurement and standards files. The main paths are the default locations. These are typically network directories where the data is stored so it can be backed up and retrieved by locations other than the measurement computer (the software can be run in demo mode if the equipment is not hooked up – this mode allows for viewing and processing data.) Standard files at this location should be treated as the controlled copies.

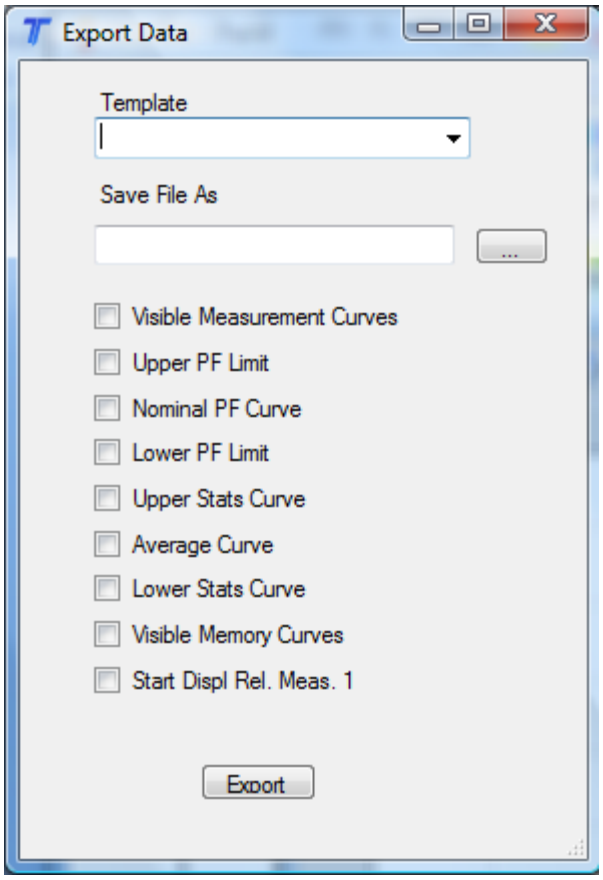


The mirror path is typically a local path. It can be used for files not intended to be available to other users. It is also used to keep a copy of the files in the main directory in case they are not accessible for any reason – e.g., the network is not available. Every time the software is started, all files in the main directory are copied to the mirror directory. Any duplicate file already in the mirror directory will be over written.

To set the paths for each type of directory, use the browser buttons to define the locations and then click the Set Paths button.

7.0 Exporting Data

The measurement data, calculated curves, and PF limits can be exported to an Excel spreadsheet. Under the folder Icon, select the Export to Excel option. This will bring up this form.



Previously created templates can used for export into. The data will always be exported into the same location in Sheet1. Other sheets in the template can be used for charts, reports, etc. that uses the exported data. Templates must be saved in the \Excel Templates directory to be available for selection from the drop down box.

If no template is desired, leave the drop down box empty and a new file will be created with the name and in the directory as set by the file manager that is presented with the … button.

Check the boxes of the data to be exported. Note, curves to be exported must be visible on the graph. Use the curve formatting setup panel to ensure the desired curves will indeed be exported. The last check box will result in the starting displacement measurement relative to the first part in the group to be exported to the file. This allows a comparison of offsets that might be the result of part shape variations. Note, the relative displacement information is only available if the measurement was recently made and the data is still in memory. The data will be lost if saved in a file and the software is exited or a new measurement is made.

8.0 How It Works

The data collection for LCMS is straight forward. The system collects simultaneously slide table position and force gage readings to generate the curves shown. A polynomial curve fit is employed and the derivative is evaluated versus displacement and converted for force/displacement units to yield the stiffness kms(x) curves. The reciprocal of the stiffness is the compliance curve cms(x). The order of the polynomial is set by evaluating the mean squared error and searching for an adequate minimum without adding too many terms that result in

unnatural wiggles in the curve. For shorter measurement distances, (under 2mm) the machine will run slower. This is to ensure there are enough data points to adequately constrain the curve fit.

For Qne-Way QC measurements and Hysteresis measurements, the raw force versus deflection data collection begins sometime after the first non-zero force reading is made. The actual value depends on motor timing and the stiffness of the part. Since the part dimensions, even when measuring the same parts, will change at least a little, it is not practical to determine the actual zero displacement location for each part measured. The measurement begins by temporarily assigning the location of the first non-zero force reading as zero deflection. After all the data is collected, the software finds the best fit straight line through the near zero data points up to a point where the data begins to deviate from the straight line. The initial straight line fit is used to determine what real zero deflection (resulting obviously in zero force) is and the data is shifted accordingly.

For the One-Way QC measurements the data near the origin is mirrored about the origin (i.e, more points are added with negative deflection and force values) before the final curve fitting is done. In other words, the DUT is assumed to be completely symmetric in both directions of stretch near the origin. This forces a better representation of the slope through zero deflection. Without this, the curve fit can slightly bend off of the true underlying trend near the zero deflection limit and strange results can be noted in the evaluated derivative.

For Hysteresis curves, first the upper (going from full negative to positive displacement) and lower (going from full positive to negative displacement) legs of the loop are fit with polynomials and the two sets of coefficients are averaged together. This yields a fit of the average curve and the derivative is evaluated to produce the kms(x) or cms(x) curves.

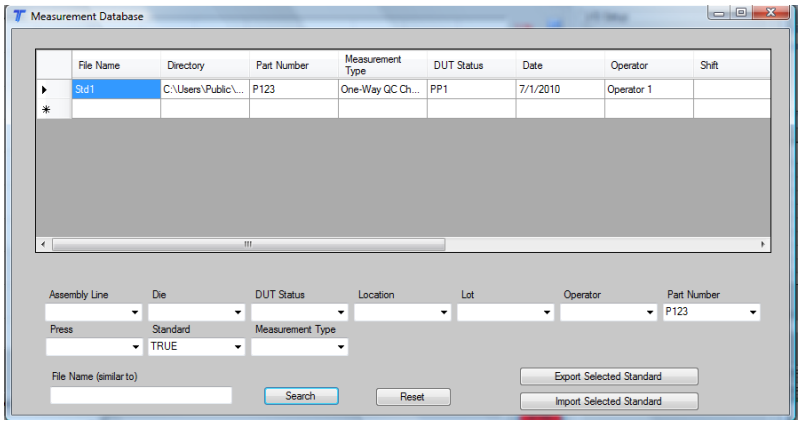
For BL vs. Deflection measurements, the absolute position of the coil relative to the motor is determined through user entered dimensional information. This is described in detail in the appendix.

9.0 Appendices

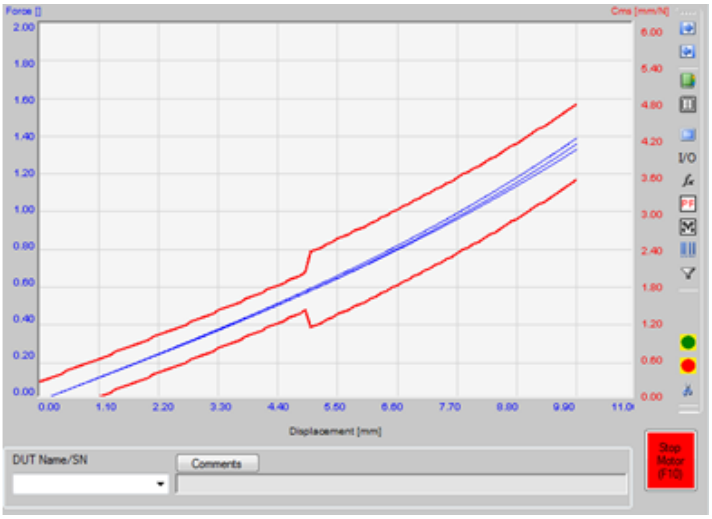
9.1. Quick Start – One Way QC Measurements Using A Standard

- The steps below describe the typical procedure followed when making one-way QC measurements on incoming parts. The user should read the manual and be familiar with the system operation and software setup panels before doing measurements.

- Load the standard. Click the database icon and search for the standard to be measured against. Set the Standard search field to TRUE and select the part number to be measured from the drop down box and click Search. If the standard is found, double click the row and the showing the file and the software will open it.

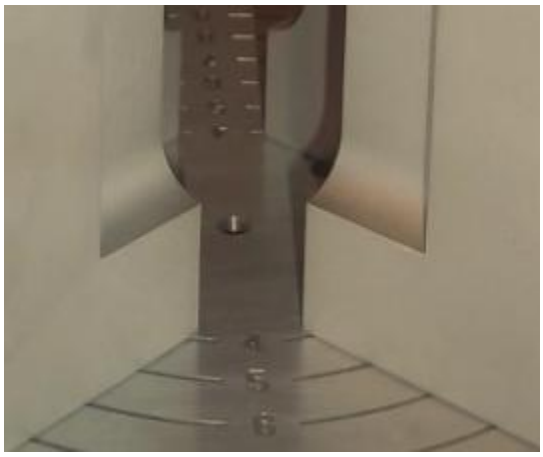


- When the standard is opened, the software will automatically be setup with the appropriate settings including the max deflection and max force measurement limits. The pass/fail window will also be evident as shown in the example below (after 3 measurements made.)



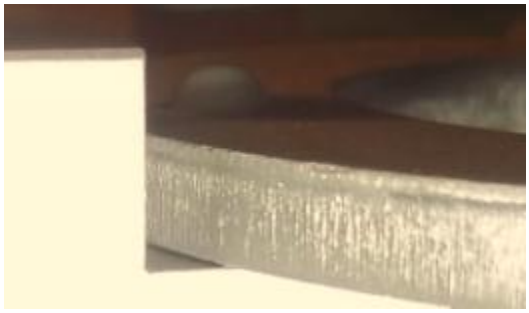
- Next, locate the clamp ring set identified for the part number to be measured. It is very important to use the correct clamp ring set. See Appendix E for creating properly fitting clamp rings.

Place the clamp rests so the front edge is just forward of the nominal OD of the clamp ring. Shown here, the rests are setup up for a 4” OD clamp ring set.



Tighten the black thumb screw in each clamp rest so they firmly fixed to the table.

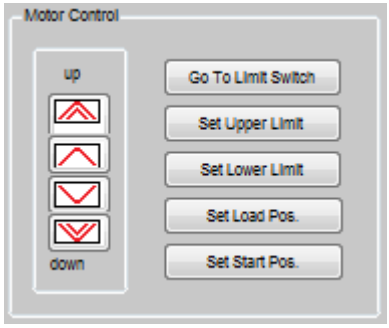
Place the lower clamp ring so that the plunger in each clamp rest protrudes through the clamp ring holes. The plungers hold the top clamp ring up off the part to be measured while it is being positioned.



Next place the part to be measured in the clamp ring and place the top ring over it. Position the part properly and then close the clamps 2 at a time by closing the clamps opposite each other at the same time.

Insert the ID plug specified for the part to be measured and ensure it is seated properly.

The part is now ready to be measured. Using the Motor Control buttons on the main measurement panel first set the probe Load Position. Use the positioning buttons to move the probe so that it is high enough above the clamp rest that the next parts can be loaded easily and then click the Set Load Pos button. Next, move the probe down close to the ID plug, within 1 or 2 mm and then click the Set Start Pos button.



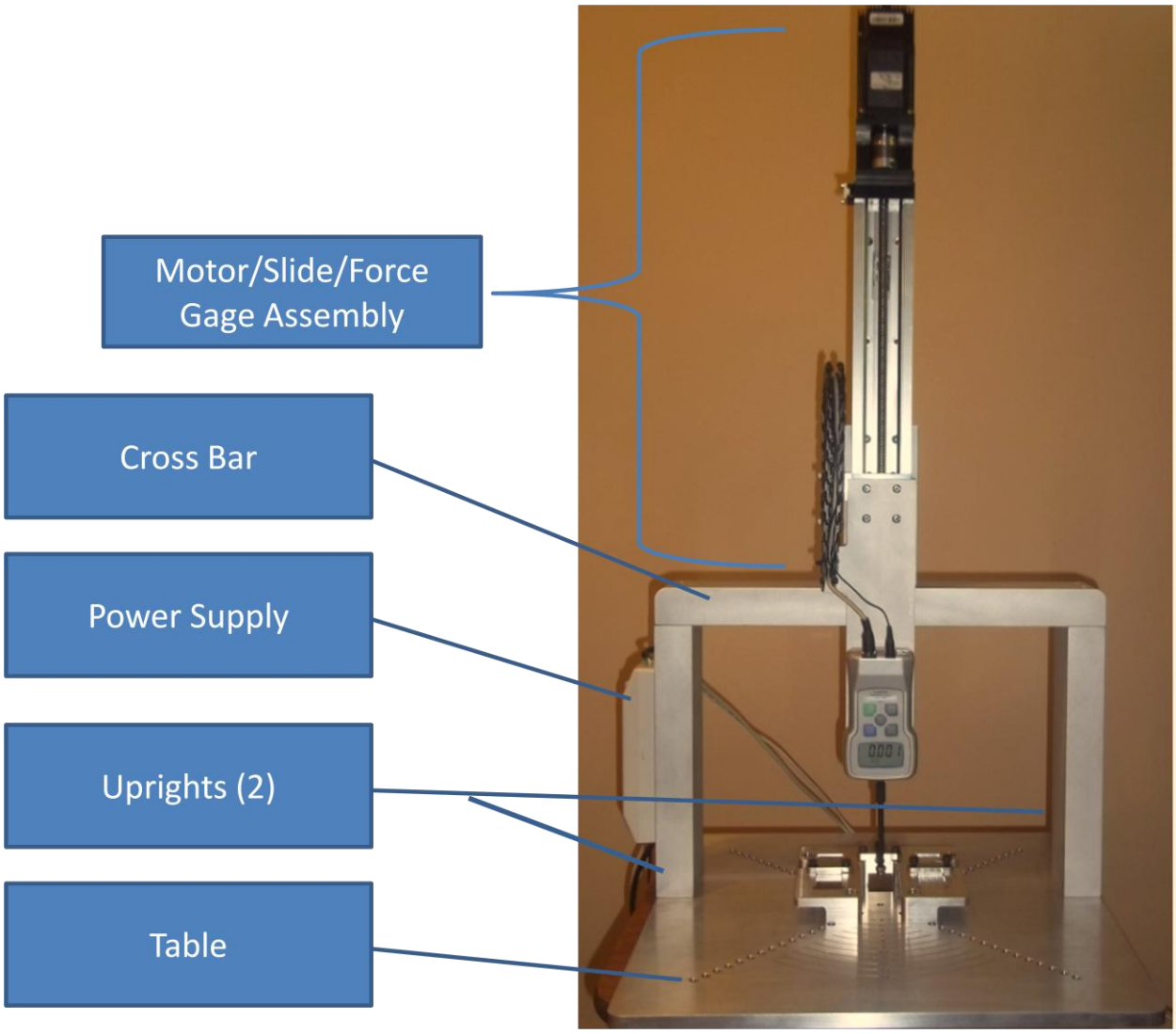
To start the measurement, click the Green Go icon. The probe will move from the Load Position to the Start Position quickly. The system will search for the starting location and begin collecting the measured force vs. deflection data.

If ever there is a problem with the probe moving too far, click the large red Stop Motor emergency stop button to end the measurement. Pushing F10 serves the same function

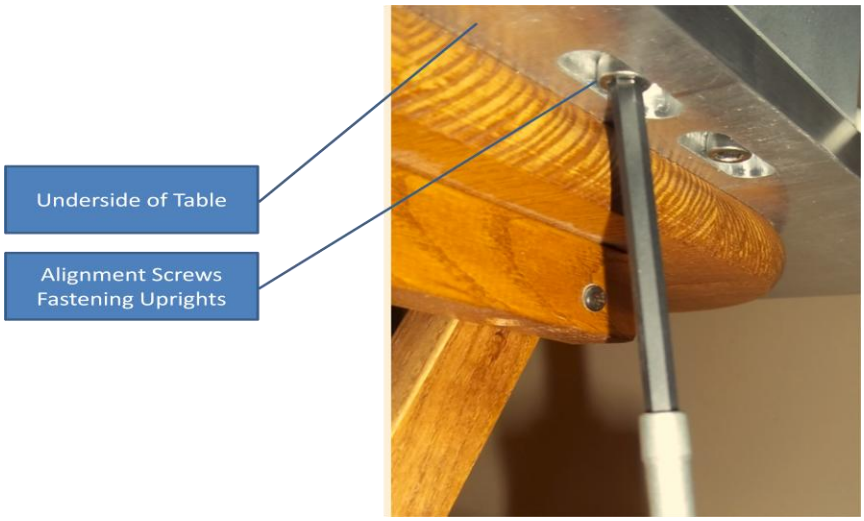
If a measurement needs to be repeated, first delete in by clicking on the scissors icon and then re-measure. The data can be saved to a file and the database by clicking on the save icon and Save As Measurement.

9.2. Setting up LCMS for the first time

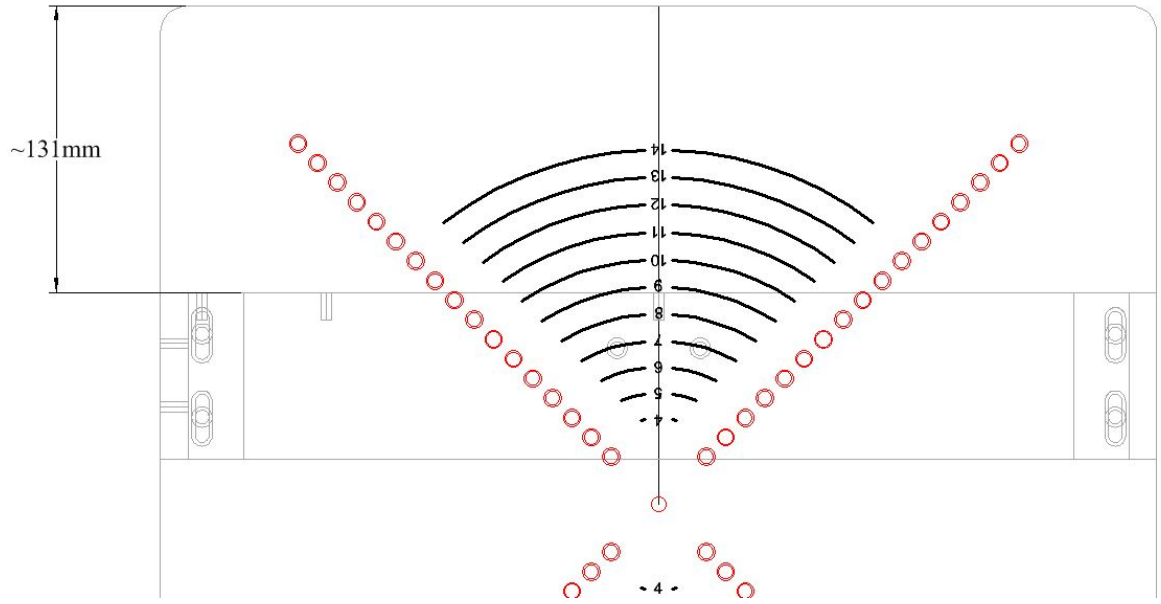
Refer to the diagrams below when setting up the LCMS for the first time.



Unpack the LCMS machine and assemble the Motor slide/force gage assembly to the Cross Bar using the 2" ¼-20 screws provided. Also use 2" ¼-20 screws to attach the cross beam to the left and right uprights. Make sure the power supply is on the correct side with the Cross Bar wire clamps (not seen above) are on the same side as the power supply.

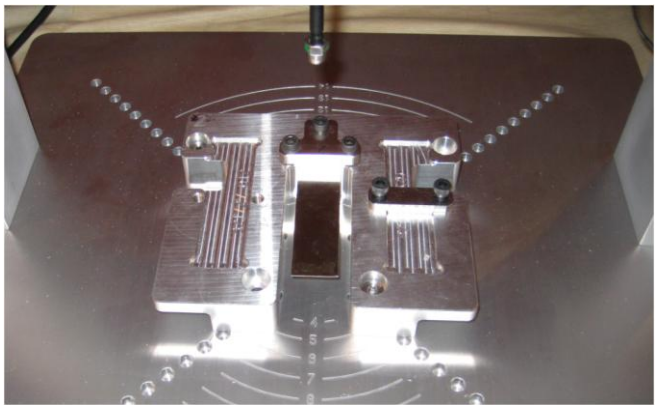


Do not fully tighten the screws yet. Next assemble the cross beams to the table by inserting the 1 ½" ¼-20 screws up through the underside of the table and into the bottom of the uprights. Attach the force gage extension probe and lower the gage so the end of the probe is just above the base center hole. Visually check to confirm the probe is lined up laterally with the center hole. Next, use a calipers to set the distance from the back side of each upright to the back edge of the table top to 131mm as shown as a preliminary setting.



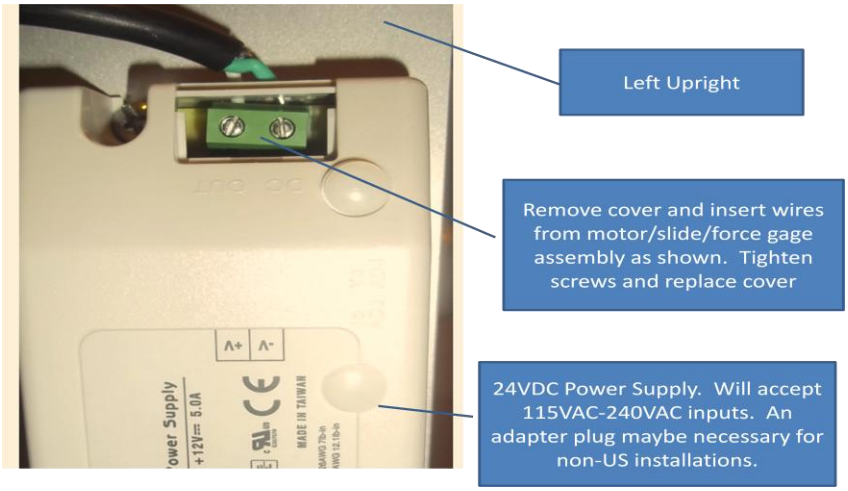
Next, use a spring calibration gage that precisely screws to the table threaded top clamping holes to measure the force vs. deflection characteristic of the gage in the “Force vs. Defl. One-Way QC” mode with the spring tip toward the front of the machine. Next, turn the gage 180 degrees and remeasure the check gage. The curves from the front and back orientations should match very closely, usually within 0.5%, if the force gage is properly centered from front to back. If the curves do not match, slide the uprights forward or backward to change the relative stiffness of the spring as necessary. Make sure both uprights are an equal distance to the back edge of the table top.

First, measure the force vs. deflection curve with the check gage facing forward as shown to the left. Then, rotate the gage 180 degrees and remeasure. The curves should match very closely if the force gage probe is centered on the table top.



The gage can also be oriented and measured as it is facing left and then as it is facing right. These additional curves should match each other as well as the front and back oriented curves. All curves should match within 1% of the group average.

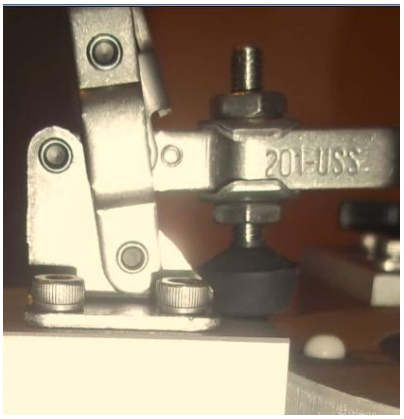
The motor power supply is fixed to the left upright. Remove the DC Out cover and insert the green wire into the V- euro connector opening and the white wire into the V+ opening. Tighten the screws and replace the cover. Route all of the wires through the cable clamps on the back side of the cross bar. Plug in the force gage power supply and the cord to the motor power supply power.



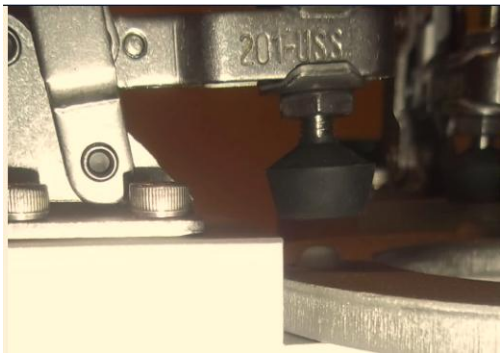
Both supplies will work with 115VAC-240VAC line voltages, though adapters may be needed for non-US installations.

Finally, plug the force gage RS232 plug (may need an extension cable and/or a USB adapter) and the stepper motor USB cable into the computer. Allow the force gage battery to charge for several hours before the first use.

The clamp rest clamps should be setup so they provide adequate clamping force on the clamp rings. If they do not provide enough force, the measurement may not be accurate. First loosen the nuts holding the clamp cushions and slide the cushion over the top surface of the clamp rest as shown. Adjust the nuts so the cushion rests on the clamp rest.



Now slide the cushion away from the clamp such that it is centered over the plunger in the clamp ring rest surface. Tighten the nuts so the cushion remains at the correct height and over the plunger.



Next, install the software by downloading the install package from http://www.true-technologies.com/uploads/LCMS_Install.zipp . Start the software. You will be given a code that must be emailed to rtrue@true-technologies.com. A return email with an activation code will be sent. Restart the software and enter the code to activate the license. Next, install the latest update from the Help\Update LCMS menu option – follow the instructions.

Make sure the force gage settings are correct. For Shimpo FGV force gauges, first power on the gage, if the LCD reads upside down, power of the gage and power back on while holding the Unit button. Release the Unit button after the gauge is powered on.

To check the function settings, turn the power off, hold down the Zero button and power the gage on. Release the Zero button after power is on. This will put the gage in the functions menu. To cycle through functions F01-F06, push the Peak button. To change the value for a particular function, push the Units button to change the values for each function. When the settings are correct, push the Zero button to save and return to the measurement mode.

The FGV force gage settings should be as follows:

- F01 – Polarity = Positive (no – sign in front of the digits.)
- F02 – Display Update Time = 3 times/second (doesn't matter)
- F03 – Auto Power Off = oFF
- F04 – RS-232 Baud Rate = 19200
- F05 – Response time = 3 msec
- F06 – Output Type = ouEr (doesn't matter)

Push the Zero button to save and exit the function menu to go into measurement mode. Make sure the Peak indicator is not present on the LCD – if it is, toggle to off by pushing the Peak button. Check the polarity by pulling on the force gage probe – the readings should be negative.

Next, go to the I/O tab of the software. Choose the serial port that the force gage is connected to. Click the Read Force Value button to verify the communication with the gage is OK. If a lower homing switch is installed on the machine, the "Enable Lower Limit Switch" box should be checked. The lower limit switch can be adjusted up and down to set the maximum downward travel distance.

9.3. Troubleshooting

If the LCMS appears to not be functioning properly, look for the symptom below and follow the instruction.

- Calibration fixture does not measure within the Standard limits.
    - Make sure the springs are properly clamped according to the instructions provided with the fixture. Reset the springs and measure again
    - Check the force gage to make sure the units are correct
    - Check the force gage to ensure the readings are correct by hanging masses over the entire range of the gage
    - Check the force gage alignment using the centering plug as described in the setup appendix
    - Run the calibration routine. Make sure the motor moves 0.5" for each calibration step (within 0.2% or 0.001")

- Force gage communication error upon startup
    - Make sure the force gage is turned on
    - Make sure the settings are as described in the setup connection
    - Make sure the I/O serial port is set properly on the I/O tab
    - Restart the software after making any changes

- Motor reading error upon software startup
    - Unplug the 24VDC power supply. Wait 10 seconds and plug back in. Wait 10 seconds and restart the software
    - Exit the software, unplug and plug the USB cable and wait 10 seconds. Restart the software.
    - Make sure the 24VDC power supply is plugged in and the voltage value is correct at the motor input connector
    - Make sure a device shows up on the I/O tab and is selected. Restart the software after making changes
    -
- If you have concerns about the machine when parts don't measure within Standard Limits
    - Check the steps for the Calibration Fixture trouble shooting
    - Make sure the proper clamp ring and ID plug are being used
    - Make sure the parts are measured in same the state as they were when the Standard was created. For example, should the parts be virgin (not previously measured), or pre-exercised with a given regimen?
    - Make sure the ambient conditions are the same, i.e., temperature and %RH
    - Make sure the clamp rest cushions are in good condition and properly setup (see the setup section.) Too little clamping force may reduce the force versus deflection curve slope.

9.4. Notes on system Gage R&R performance and Inter-Machine Correlation

The LCMS should yield a very good gage R&R performance, typically with < 10% R&R at displacements where the force measurements are higher than 10x the resolution of the force gage. However, to achieve these results care must be taken to ensure the following:

- Make sure the parts are not changing (i.e. breaking in without proper recovery) from one measurement to the next. It is recommended that the parts be studied thoroughly so the break-in/recovery characteristic is well understood before doing the gage R&R study. Past studies have been most successful when the parts were broken in with 10 pre-cycles using a max deflection of 80% of their maximum excursion. A 24 hour recovery period

after break in was used. For the R&R measurements, no pre-cycling is done and the parts are tested with the max deflection set at 50% of the maximum excursion. The parts should be allowed to rest at least 5 minutes between measurements in the R&R study

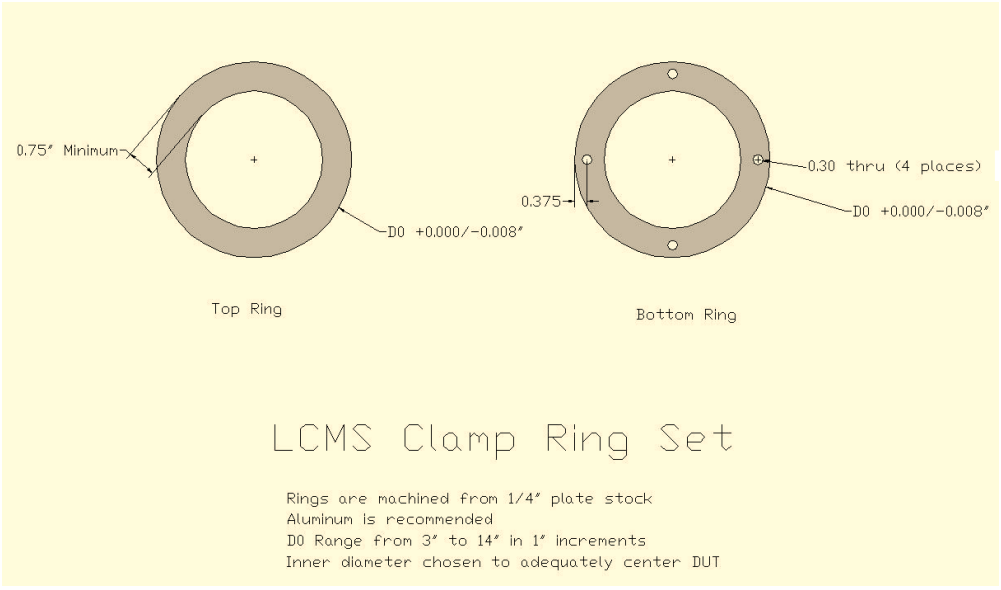
- Make sure the parts are acclimated to the test conditions for at least 24 hours and that the ambient conditions, i.e., temperature and relative humidity, are maintained within a few percent for the duration of the study
- Make sure the guidelines in the appendix for clamp rings are followed

The LCMS should also yield very good inter-machine agreement, typically within 1% or within the force gage resolution over low force reading displacement regions. When using cantilevered spring steel pieces for comparison measurements, it is very important that the probe contact the steel at a precise distance from the clamped end of the steel, within 0.2mm. It is also important that the steel be clamped firmly with equal force across the clamping line. The fixture must also be precisely positioned and firmly screwed to the LCMS table. It is also important that the force gage probe tip being used be the same. Different tips can produce different results.

9.5. Manufacturing clamp rings for use with LCMS

To get repeatable/reproducible measurements using LCMS, the clamp rings should be manufactured with the following recommendations

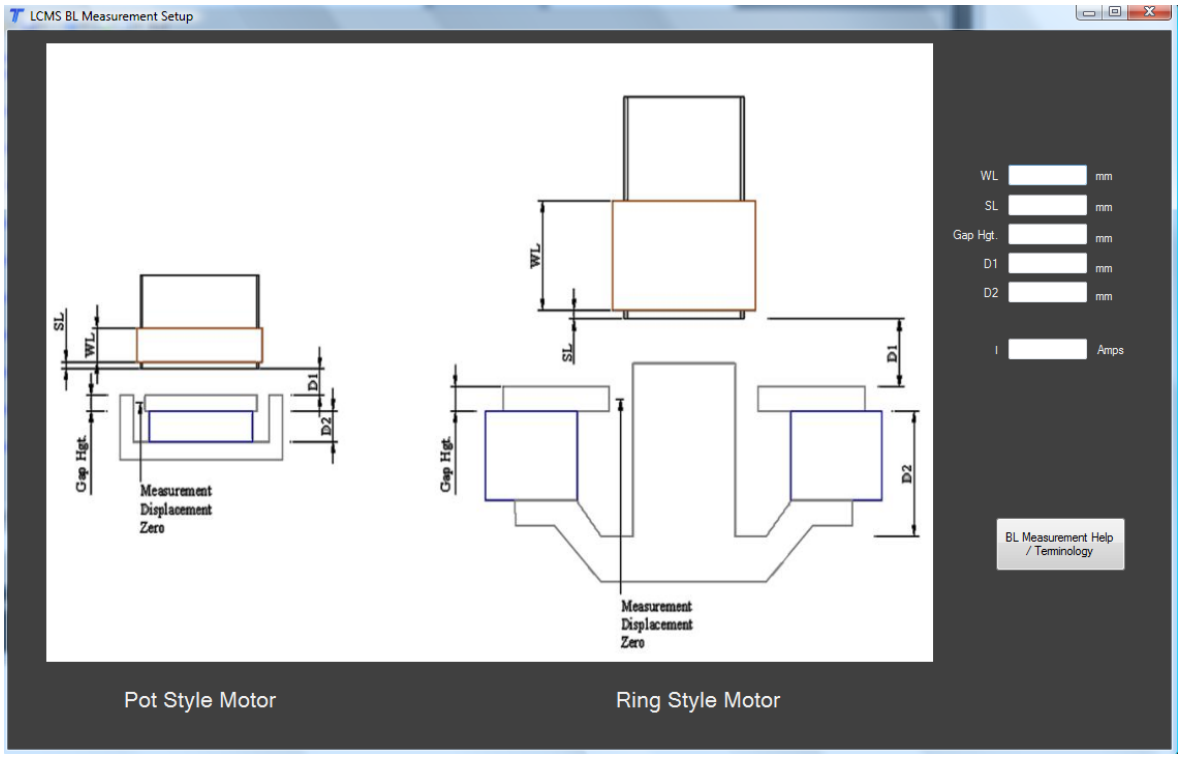
- The clamp rings should be machined from flat plate, typically aluminum, according to the drawing below (all dimensions in inches)
- Measurement repeatability will improve with better centering of the part under the force gage tip.



9.6. Notes on Measuring Motor Strength (BL Product)

The LCMS can also measure loudspeaker motor/coil combinations as BL (motor strength) vs. coil position. To make this measurement, select BL vs. Defl. Measurement from the Type drop down box on the Measurement Setup panel.

A setup window will pop up where dimensional information about the motor/coil to be measured must be entered.

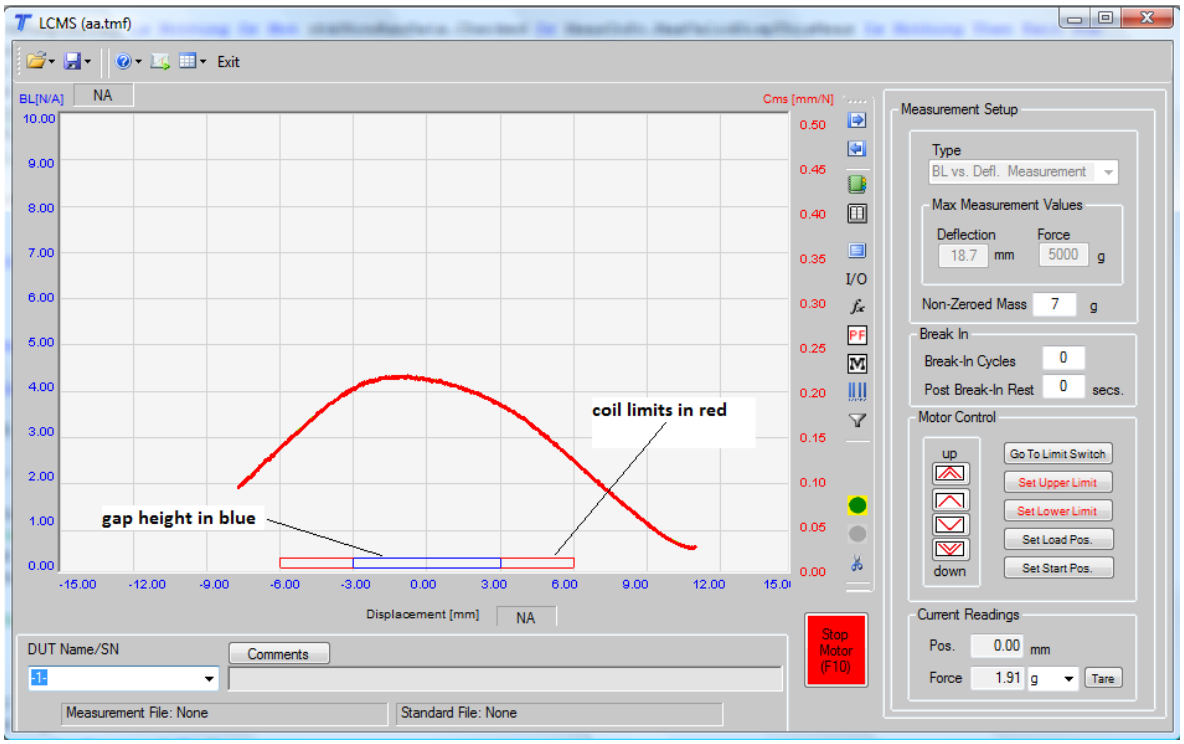


A constant current source must be provided and the current value entered into the textbox. The system will measure the force generated by the motor at many displacement locations as the coil is moved down into the motor. The dimensional information must be set accurately to ensure the coil does not collide with the hard motor back plate. If this happens, the overload force reading will cause the measurement to halt, thus protecting the force gage and LCMS system. However, damage to the coil or erroneous readings can result.

The displacement axis shows the coil position with zero being the location where the coil winding is centered on the top plate (in the middle of the gap.) Positive displacement indicates the center

of the winding is closer to the outside of the motor (above it.) Hence, the readings will start positive and get smaller and go into negative values as the coil lowers into the motor.

The vertical axis reads BL in Newtons/Ampere (N/A) as calculated by BL=F/I where F is the force gage reading converted to Newtons (kg*gravity) and I is the entered constant current value.



It is important to use a constant current source for this measurement. Simply applying a constant voltage will result in erroneous measurement if the coil begins to get warm during the measurement and the resistance of the coil goes up (current goes down.) A current value should be used that generates large enough force values to give well resolved measurements, but not so large that the coil is damaged from too much heat.

9.7. Replacement Parts

LCMS was designed to last for years without service. The component parts were chosen based on the manufacturer/vendor's reputation for quality. However, in the event a replacement of any part is needed, the vendors and part numbers are below.

Component	Part Number	Manufacturer	Info
Stepper Motor	DMX-UMD-23	Arcus Technologies	http://arcus-technology.com/products/12.html
Force Gage	FGV-10XY	Shimpo	http://www.testequipmentdepot.com/shimpo/digital-force-gauges/dart-fgv10xy.htm
Toggle Clamps	5126A41	McMaster Carr	http://www.mcmaster.com
Power Supply	PLC-60-12	Mean Well	http://www.meanwell.com/search/plc-60/plc-60-spec.pdf
Linear Slide Table	6734K62	McMaster Carr	http://www.mcmaster.com