

PROCEDURE FOR
**TESTING STEEL COUPONS
WITH MTS C64.206 FRAME
AND 634.25F EXTENSOMETER**

1. PROCEDURE OVERVIEW

This FSEL test standard is used to determine the tensile properties of steel coupons. The testing is based on ASTM A37-17: *Standard Test Methods and Definitions for Mechanical Testing of Steel Products* (Ref. 7.1), ASTM A6-16: *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling* (Ref. 7.2), and Appendices B.7 and B.8 of *Guide to Stability Design Criteria for Metal Structures* (Ref. 7.3). Students are encouraged to review these documents prior to undertaking tensile tests.

This procedure uses the MTS C64.206 test machine (440 kip MTS Test Machine), the MTS 634.25F-24 extensometer designed to work with this machine, and a pre-programmed test procedure. Depending on the gage length set for the extensometer, it may or may not be able to remain on the specimen up to fracture. The extensometer has a maximum stroke of 25 mm (0.98 in.). That stroke represents an ultimate strain of 0.5 for a 50 mm (1.97 in.) gage length but a strain of only 0.125 for a 200 mm (7.87 in.) gage length. If strain measurements to fracture with a long gage length are necessary, consult FSEL technical staff.

Before proceeding, the user should first determine if the 440 kip MTS test machine is the most appropriate machine to use for the tensile test. For the coupon geometry and material being tested, estimate the maximum tension force required to conduct the test. This can be done by multiplying the cross-section area of the coupon with a reasonable upper bound estimate of the tensile strength (F_u) of the material. For example, for ASTM A992 steel (minimum specified $F_u = 65$ ksi), a reasonable upper bound of F_u might be taken as 85 ksi. If the cross-section area of the coupon is approximately 0.5 in.^2 , then an estimate of the maximum tension force needed to test this coupon is $0.5 \text{ in.}^2 \times 85 \text{ ksi} = 43 \text{ kips}$. The estimated maximum force should not exceed the machine capacity, but also should not be less than about 5 percent of the machine capacity, to assure accurate load readings. Thus, if the estimated maximum tension force is less than about 22 kips, it may be advantageous to use a different test machine with a lower capacity, such as the 22 kip MTS frame, or choose a different coupon geometry that provides a greater estimated maximum tension force that is more appropriate for the test machine capacity.

The pre-programmed test procedure in the 440 kip MTS test machine should be adequate for most testing. Should any alteration be needed, consult with FSEL staff beforehand.

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1.1. Student Responsibilities for Testing:

- Read and understand the requirements of this procedure
- Provide samples
- Clean machine after use

1.2. Staff Responsibilities for Testing:

- Read and understand the requirements of this procedure
- Provide students with keys to control cabinet and accessories cabinet
- Assist students with testing as needed

2. EQUIPMENT AND TOOLS

- MTS C64.206 Test Machine
- MTS 634.25F-24F Extensometer
- Grips
- Ladder
- Rubber Bands or Springs
- USB drive
- Shimming Materials for Small Samples

3. MATERIALS

- Steel Samples
- Grease

4. PERSONAL PROTECTIVE EQUIPMENT

- Safety Glasses
- Safety Shoes
- Hearing Protection
- Disposable Rubber Gloves

5. DETAILED PROCEDURE

5.1. Identify and prepare the samples to be tested.

The number samples is to be determined by the research team. Conducting tension tests on multiple samples from the same heat of steel is advantageous to characterize variations in mechanical properties in different parts of the member cross-section (for example, the mechanical properties in the web of a wide flange are often significantly different than in the flanges) and along the length of the member, or at different locations on a plate.

- 5.1.1. Identify and document locations within the member cross section from which samples were taken.

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Section 11.3 of ASTM A6 (Ref. 7.2) specifies locations for where to take coupons from various rolled shapes and for plates, for purposes of routine material verification tests. These are the coupon locations used by steel mills when conducting tensile tests to demonstrate conformance with material standards. While it is useful to be familiar with the standard coupon locations specified in ASTM A6, these locations are not generally adequate for a more thorough characterization of mechanical properties, as needed for research purposes. For example, for a wide flange section, ASTM A6 specifies a single coupon that is cut from a flange. However, as noted in Section 5.1, the mechanical properties in the web can be significantly different in the flanges. Consequently, for research purposes, a more thorough sampling of tension coupons from different parts of the cross-section is desirable. As an example, for a wide flange shape, a possible approach would be to take four coupons from the cross-section, as follows: 1 sample from the top left flange, 1 sample from the bottom right flange, one sample from the middle of the web, and one sample from the web just below the intersection with the flange, i.e. the K-area. The student should work with their faculty advisor to determine a suitable material sampling plan.

- 5.1.2. Select the appropriate coupon geometry for testing.

Three different sample types are commonly used within FSEL:

- *Rectangular section (1.5 in. by material thickness) with 8 in. gage length,*
- *Rectangular section (0.5 in. by material thickness) with 2 in. gage length, and*
- *Round section with ½ in. diameter and 2 in. gage length.*

Detailed requirements for all three of the above geometries are provided in Ref. 7.1. This reference also provides additional options and limitations on the width and thickness of rectangular coupons. In some cases, the thickness of a rectangular coupon can be less than the full thickness of the part being tested, to reduce the maximum tension force required for the coupon test (to stay safely within the test machine capacity). However, a reduction in thickness will require additional machining operations.

The grips for the MTS C64.206 machine are approximately 7 in. long. Ref. 7.1 allows the thicker end section to be increased in length to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

- 5.1.3. Extract the samples from the base material and machine the coupons to obtain the required coupon geometry, within the tolerances specified in Ref. 7.1.

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Contact FSEL technical staff for assistance with preparing steel coupons through cutting, machining, or both.

- 5.1.4. Measure the dimensions of the cross section of the coupon at three locations within the reduced section.

Measure and record the cross-sectional dimensions of tension test specimens as follows:

- *For specimen dimensions ≥ 0.200 in. to the nearest 0.001 in.;*
- *0.100 in. \leq specimen dimension < 0.200 in to the nearest 0.0005 in.;*
- *0.020 in. \leq specimen dimension < 0.100 in to the nearest 0.0001 in.; and*
- *Specimen dimension < 0.020 in. to at least the nearest 1 percent when practicable but in all cases to at least the nearest 0.0001 in.*

- 5.1.5. Calculate the average cross-sectional area of the reduced section of the sample using the measurements taken per Article 5.1.4.

- 5.1.6. Place punch marks to define reference points for measuring the initial and final lengths of the specimen.

A punch mark should be placed at each end of the gage length.

- 5.1.7. Using a set of calipers, measure the distance between the pair of punch marks to determine the initial length.

- 5.2. Obtain the keys to the control cabinet and the cabinet containing the MTS test accessories.

The key to the control cabinet is located in the gray cabinet in the near the test machine. All FSEL staff members have a key to this cabinet.

- 5.3. Prepare the MTS extensometer for testing.

The MTS extensometer and its accessories are contained in two black plastic cases in the gray cabinet near the test machine. The larger case contains the extensometer, a user manual, a plastic bag with drawings, and a small plastic case that contains spare parts, tools, rubber bands, and springs. The smaller case contains three extension bars and a small plastic case with additional parts and tools.

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- 5.3.1. Place the set pin in the extensometer.

The set pin is used to hold the extensometer at a fixed opening distance prior to attaching the extensometer to the specimen. This pin prevents over-extending or over-compressing the instrument during setup. This pin should remain in place whenever the extensometer is being handled but must be removed prior to testing.

- 5.3.2. Add the gage length extender to the extensometer, if needed.

The default gage length of the extensometer is 50 mm (1.97 in.). This gage length can be extended to 200 mm (7.87 in.) by inserting a gage length extender. Note that standard gage lengths are specified in Ref. 7.1 and Article 5.1.2.

A technical drawing showing the installed extender bar is inside the extender case (Reference 7.4). Note that the gage length extenders have a correct and incorrect orientation. Ensure that all parts are installed on the extensometer as shown in the drawing.

- 5.3.3. Install the knife edges appropriate for the specimen being tested.

For round specimens, the straight knife edges should be used. For flat specimens, knife edges with three contact points (two contact points in one knife edge and one contact point in the other knife edge) should be used. Drawings of the knife edges are provided in Figure 1. Note that the flat specimen knife edges are specific to the lower and upper extensometer contact points as shown in the figure.

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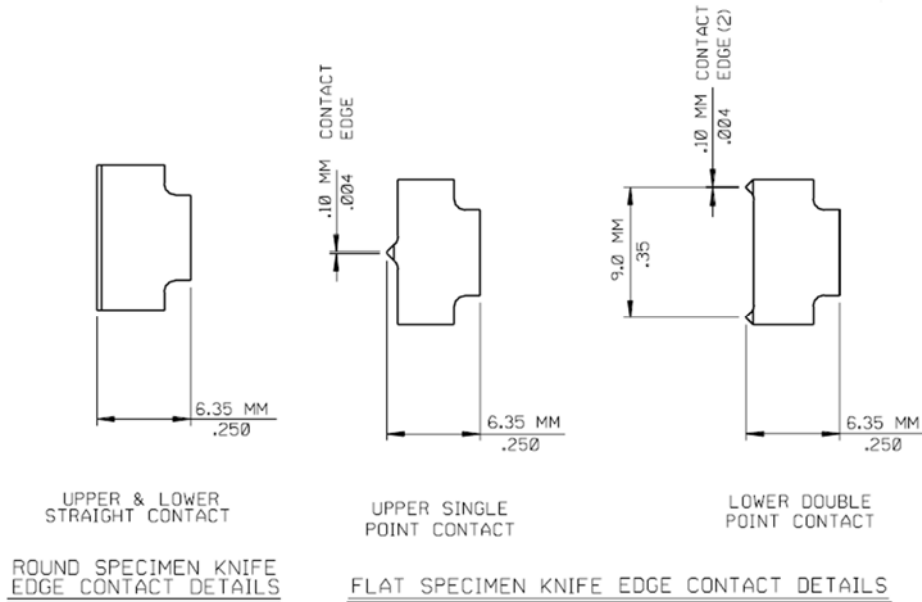


Figure 1 – Knife Edges for round specimens (left) and flat specimens (right) (Ref. 7.6)

5.3.4. Choose a method to attach the extensometer to the specimen being tested.

There are three methods to attach the extensometer to the sample:

Rubber Bands (Preferred Method): Rubber bands of various sizes can be attached to the small wire hooks on the sides of the extensometer as shown on Reference 7.5. Choose rubber bands of the appropriate size to ensure firm contact between the knife edges of the extensometer and the specimen.

Quick Attachment Spring: A steel attachment spring is attached to the extensometer connection points. This spring wraps around small diameter (<0.5 in.) sample to form the connection. The spring can be positioned at one of four locations to ensure the proper gripping pressure. Consult with Reference 7.6 to identify the correct spring position.

Coil Springs: Coil springs can be used in place of rubber bands as described above. The spring length should be sized to ensure firm contact between the knife edges of the extensometer and the specimen. Guidance on the proper spring length can be found in Reference 7.7.

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Whichever method is chosen, MTS recommends a contact force between the knife edges and the specimen of approximately 600 g (1.33 lb) per edge.

The extensometer should not be attached to the coupon until after the coupon is installed in the test machine.


- 5.3.5. Make the electrical connection between the extensometer and the MTS test controller.

The free end of the wire coming out of the control console is zip-tied to the southwest column of the test frame. This wire end should be connected to an intermediate wire that will then connect to the wire attached to the extensometer. The intermediate wire should be stored in the locked gray cabinet near the machine.

The extensometer must be connected to the data acquisition system before it is initialized.

- 5.4. Initialize the computer and data acquisition system.


- 5.4.1. Power on the system.

To power on the data acquisition, press the white toggle switch to "I." The green light on the control panel below the switch should illuminate. To power on the pump, press the white button labeled as  on exterior of the control cabinet. The white button should illuminate and the pump should be audible.

Unlock the tray containing the computer keyboard and mouse. The power switch to the computer is behind an additional locked panel behind the keyboard tray. The key to this locked panel is typically left in place and should be visible after opening the keyboard tray.

If the red or yellow lights on the front of the control cabinet illuminate at any point in the test process, contact and FSEL staff member for assistance.

- 5.4.2. Start the MTS TestWare Elite Software.

Double click on the MTS TestWare Elite icon () on the desktop. Log in to the software as "FSEL Student" with the password: daq.

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5.4.3. Load the test protocol.

Click on “Custom Templates” on the left side of the screen. Double-click on “FSEL Steel Coupon Testing Template” to load the test protocol. The version with the latest revision should be used.


5.4.4. Create a folder for your test data.

On the computer desktop, there is a folder titled “TestData”. Create folder for your project within that folder. It is also recommended that you create a subfolder titled as the day of testing in YYYYMMDD format. These folders will help organize files for all projects.

5.4.5. Save the test data.


To avoid overwriting the test protocol at a later stage, it is recommended that you save the test at this stage of the procedure using MTS’ proprietary format. Click on File → Save As → Test... and navigate the folder created in Article 5.4.4. It is recommended that you rename this file to something specific to your project rather than the default file name. Do not overwrite the default test protocol.

5.4.6. Reset interlocks.

Reset the interlocks by clicking the reset button (). Interlocks are safety features that prevent the machine from applying load. If an interlock is tripped, the box to the right of the reset button will be red and there may be additional red indicators in the “Status” portion of the menu bar.

If any red indicators re-appear after clicking the reset button, contact FSEL technical staff for assistance. If the red or yellow lights on the front of the control cabinet illuminate at any point in the test process, contact and FSEL staff member for assistance.

5.4.7. Set the test platen position to the correct initial position.

Click on the  button and enter 0.5 in. to move the test table to 0.5 in. of upward displacement from its resting position. This initial movement will ensure the specimen does not get jammed in the test frame should anything go awry.

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Note that the test platen will move as soon as the "OK" button is clicked. Make sure the machine is free to move before clicking the button.

5.5. Install the test specimen in the test machine.

5.5.1. Select the correct grips for specimen to be tested.

Select the correct grips for specimen based on its cross section type (round or rectangular) and its thickness or diameter. Flat grips should be used for flat specimens and vee grips should be used for round specimens. All grips are marked with the range of specimen size for which they are intended.

5.5.2. If using flat grips, install the alignment aids.

If using flat grips, as opposed to vee grips, alignment aids will be needed to ensure the specimen is placed co-axially with the axis of motion of the test machine. The alignment aids are small, stainless steel "L" shaped pieces that mount to the grips using two screws. With the grips placed on a table, place the specimen in the grips such that it is centered. Loosely place the alignment aids on the grips. With the specimen centered, tighten the screws to fix the alignment aids in the proper position.

Note that while there are four alignment aids, only two are needed. One should be placed on the top grip and one on the lower grip such that they are on opposite sides of the specimen, i.e. top left and bottom right or vice versa.

5.5.3. Grease the back sides of all four grips.



The back sides of the grip plates including all surfaces of the alignment keys should be lightly coated with grease before insertion into machine. Rubber gloves are recommended when handling the grease. If there is still grease present from the last use, this step can be skipped.

5.5.4. Install the grips into the machine.



The grips are keyed to slide into the upper and middle crossheads of the test machine. After the grips are in place, they must be secured by tightening the cap screws on the retaining tabs. A set of metric hex wrenches is in the gray cabinet.

5.5.5. Insert and grip the specimen in the upper crosshead.

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Press the  button on the control panel at the right side of the test frame. The green light on the button should illuminate. Hold the specimen between the upper grips such that the lower end of the enlarged gripping section of the specimen is approximately flush with the lower edge of the grips and centered within the grips. Turn the upper knob to the grip position () while making sure hands and fingers are clear of the grips. Note that the grips will slide downward to grip the specimen.

- 5.5.6. Raise or lower the middle crosshead to the correct position to grip the lower end of the specimen.

Press the  or  button to raise or lower the middle crosshead. The crosshead should be raised until the upper end of the enlarged gripping section of the specimen is approximately 3-4 in. above the upper edge of the lower grips. Note that the lower grips, which are located in the middle crosshead, will move upward to engage the specimen and the final position of the middle crosshead will be checked later in this procedure.

If the middle crosshead is raised or lowered too much, it will trigger limit switches that will create interlocks, which stop the test machine.

- 5.5.7. Tare the force.

Near the lower left corner of the screen, the current force measured on the system is displayed. Right-click on the value and chose "Zero signal" to define the zero force point prior to gripping the lower end of the specimen. The number will drift slightly, but should remain near 0 kips.

- 5.5.8. Install the extensometer on the specimen.

- 5.5.8.1. Using the method identified in Article 5.3.4 attach the extensometer to the specimen.

After connecting the extensometer, ensure it is tightly attached to the specimen.

- 5.5.8.2. Zero the extensometer reading.

Right click on the extensometer reading and select "Zero signal."

- 5.5.8.3. Remove the restraining pin from the extensometer.


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To remove the restraining pin, rotate it slightly while pulling. Check the extensometer reading after removing the pin. If the reading varies more than about ± 0.05 in. from zero, reinsert the pin and go back to Article 5.5.8.2.

5.5.8.4. Re-zero the extensometer.

This step will establish the final zero value for upcoming elongation measurements.

5.5.9. Grip the specimen in the lower crosshead


The specimen should be suspended by the upper grips and the lower crosshead should be raised per Article 5.5.6. Make sure hands and fingers are clear of the grips. Turn the lower knob to the grip position (). Note that these grips will move upward to grip the specimen.

5.5.10. Inspect position of lower grips.

The upper end of the enlarged gripping section of the specimen should be at approximately the same elevation as the upper edge of the lower grips. If this is not the case, ungrasp the lower end and raise or lower the middle crosshead as needed.

After engaging the lower grips, the test machine will likely indicate a moderate compressive load (-0.5 to -1.5 kip). This load is real and represents the load induced by raising the lower grips. Do not zero this load. The extensometer should also indicate slight shortening of the specimen; do not zero this extension.

5.5.11. Remove control from the handset and restore control to the control console.

Press the  button on the handset to restore control to the control console. The green light on the button should turn off.

5.6. Load the specimen.

Test procedures for tensile coupons are described in ASTM A370 (Ref. 7.1). Some of these procedures, particularly concerning specimen loading rate and interpretation of test results, are intended for routine material verification tests used by steel mills, but are often not appropriate for material characterization for research purposes. Suggested procedures for tension testing and interpretation of test results appropriate for research purposes are provided in SSRC Technical Memoranda 7 and 8 (Ref 7.3).

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One of the key issues to consider in tensile coupon tests is the rate of loading. Rate of loading can be controlled by controlling the strain rate or by controlling crosshead speed. Controlling strain rate provides the best definition of loading rate. However, controlling strain rate requires running the test machine based on extensometer control. This approach is difficult and can lead to safety concerns if the extensometer slips or is otherwise disturbed. Consequently, tensile coupon tests at FSEL are normally run using crosshead rate control.

Loading of the specimen is controlled by the test protocol program. The program will initially load the specimen at a crosshead movement rate of 0.02 in./min. After the specimen reaches a an elongation of 0.2 in. (based on the extensometer reading) the loading rate increases to 0.125 in./min. The loading rate will remain at that value until failure of the specimen. The dynamic yield stress and dynamic tensile strength are a function of loading rate on the coupon. The crosshead rates noted above have been chosen somewhat arbitrarily, but are intended to provide a reasonably low rate of loading for determining the dynamic yield stress. After the yield stress is established, the loading rate is increased to avoid an excessively long time to complete the tension coupon test. However, there are a number of factors to consider when choosing the coupon loading rate, to allow proper interpretation of the test results. SSRC Technical Memorandum 7 (Ref. 7.3) discusses some of the issues to consider when choosing a coupon loading rate. The student should consult with their faculty advisor to discuss tension coupon loading rates.

- 5.6.1. Define the static pause points for the specimen by editing the appropriate points in the procedure.

To determine the static yield stress, the load should be paused at three points on the yield plateau of the coupon. Typically, those points are at strains (based on the extensometer measurement) of 0.004, 0.008, and 0.012. Based on the gage length, those strain points must be converted to elongations and input into the test procedure.

Table 1 – Elongation Values for Various Strains and Extensometer Lengths

Gage Length (mm)	50	100	150	200
Gage Length (in.)	1.97	3.94	5.91	7.87
Extensometer Elongation (in.) at $\epsilon = 0.004$	0.008	0.016	0.024	0.031
Extensometer Elongation (in.) at $\epsilon = 0.008$	0.016	0.031	0.047	0.063
Extensometer Elongation (in.) at $\epsilon = 0.012$	0.024	0.047	0.071	0.094

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5.6.2. Make sure that all personnel and materials are free of the test machine and will not be affected by machine movements.

5.6.3. Click the start button to execute the test protocol.

Click the  button to begin the test.

5.6.4. Input the correct values for the extensometer gage length and the cross sectional area calculated per Article 5.1.5. You may also enter a specimen name for your records.

The extensometer gage length should be 1.969 in. or 7.874 in. based on the extensometer initial length. The cross sectional area will be used for on-screen calculations of stress during the test. This value will not affect the recorded data.

Note that the test will begin immediately after these values are entered. Make sure all personnel are at a safe distance from the test machine and everything is ready for testing.

5.6.5. Observe the real-time stress vs. elongation curve on the screen to ensure that the test is proceeding normally.

If the displayed data do not appear correct, stop the test by pressing one of the red stop buttons or by clicking stop in the control software. You can change the axes of the plot by right-clicking on the screen.

5.6.6. When the extensometer nears its measurement limit prior to fracture of the specimen, remove it and reinsert the locking pin.

The test protocol will pause the test and hold the load when the extensometer reaches an extension of 0.8 in. Carefully remove the extensometer from the specimen and replace the locking pin. Place the extensometer in a safe place for the remainder of the test.

For specimens that are known to be especially brittle, it may be necessary to pause the test for extensometer removal prior to the preset 0.8 in. limit.


If extension data beyond the preset 0.8 in. limit are desired, when the testing pauses, the extensometer can be removed from the specimen, reset to its initial gage length, and returned to the specimen per Article 5.5.8. This process allows for an additional 1 in. of stroke, which can be used to measure a greater range of extensions and develop

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a more complete stress-strain response. If this repositioning process is used, the user must manually pause the test after the peak stress has been observed but before fracture of the specimen to remove the extensometer.

Note that handling the extensometer will introduce aberrant data to the test record and to the data displayed on the screen. These aberrant data are normal and can be removed from the finished data file after completion of the test.

- 5.6.7. Click start to resume the test protocol.

After clicking the  button, the test will resume and load the specimen to fracture. After fracture, the machine will freeze all movement.

- 5.6.8. After the sample has fractured, ensure that the machine has stopped all movement.

The break detection feature of the software should pause the machine immediately upon failure. If this is not the case, stop the test machine by pressing one of the red stop buttons or by clicking stop in the control software.

- 5.7. Export test data.

- 5.7.1. Export the test data to a text file.

After the test is complete, the software will change views to show a load vs. deflection plot of the test. On the left side of the screen, each test run will be listed. Right click on the run to be exported and choose "Export Raw Data."

- 5.7.2. Complete the information on the pop-up window to complete the export.

For the "Folder Path" select the folder that was created in Article 5.4.4. For the "Folder Save" option, it is recommended to create a new folder. Add all necessary signals to the "Signal List" by clicking the "+" button at the right of the window.



- 5.7.3. Confirm export has completed.

After performing the export in Article 5.7.2, navigate to and open the file to confirm the data have been written to the disk.


- 5.8. Remove the failed specimen from the grips.

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- 5.8.1. While holding onto the upper portion of the failed specimen, release the top grips.

Press the unlock button () on the control panel at the right side of the test frame. The green light on the button should illuminate. Turn the upper knob to .

- 5.8.2. While holding onto the lower portion of the failed specimen, release the bottom grips.

Turn the lower knob to .


- 5.8.3. Return machine control to the control unit.



Press the  button on the handset to restore control to the control console. The green light should turn off.

- 5.8.4. Clean the area surrounding the lower grips.

A significant amount of mill scale will have fallen onto the lower grips from the specimen during testing. Clean the top surfaces of the lower grips and the middle crosshead to keep the scale from collecting in or on the jaw mechanism.

- 5.8.5. Return the test machine to the original displacement position.

To return to the original displacement position click the  button after making sure that the machine is free to lower to the original position with any obstruction.

Note that this action will return the test machine to the position at which the last test was started. If multiple tests are being run back-to-back, it may be necessary to lower the test platen further than the  button will allow. If this happens, right click on the displayed displacement and select "Remove Zero." Click and hold the blue down arrow () until the position indicates approximately 0.5 in.

- 5.9. Determine the final length of the specimen.

- 5.9.1. Place the pieces of the failed specimen on a work surface and align the fracture surfaces.

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- 5.9.2. While holding the portions together, measure the distance between the pair of punch marks to determine the final length of the specimen.

These measurements are similar to those performed per Article 5.1.7 and will be the used for calculating the elongation of the specimen. It may be necessary for a second person to hold the specimen while making these measurements.

- 5.10. To perform additional test(s), return to Article 5.5 and repeat this procedure as needed.

- 5.11. If no more tests are to be performed, shut down the test machine.

- 5.11.1. Return the test platen to its lowest position.


Click and hold the down arrow button () while monitoring the “Actuator” displayed value. The value should begin decreasing shortly after clicking and holding the button. Continue holding this button until the reading reaches its minimum value and no longer changes.

- 5.11.2. Save the test.

It is recommended that the all test data be saved in MTS’ proprietary format as a back-up to the text files saved in Article 5.7.1 of this procedure. Save the test to the same location and file name as used in Article 5.4.5.

- 5.11.3. Exit the MTS TestWare software.

- 5.11.4. Turn off the pump.

To power of the pump, press the black button labeled as  on exterior of the control cabinet. The white button should no longer be illuminated and the pump should no longer be audible.

- 5.11.5. Turn off the data acquisition system.

To power off the data acquisition, press the white toggle switch to “O.” The green light on the control panel below the switch should turn off.

- 5.11.6. Copy the saved data onto an external USB drive.

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5.11.7. Shut down the computer.

5.12. Return the various test fixtures to the storage cabinet and clean the machine.

5.12.1. Remove the grips and return them to the storage cabinet.

The back sides of the grip plates should be cleaned of any excess grease and the remaining surfaces should be cleaned of any mill scale or other debris before returning them to the cabinet.

5.12.2. Clean the middle cross head.

With the grips removed, additional areas that require cleaning will be accessible. These areas need to be thoroughly cleaned of debris to ensure the gripping mechanism is not compromised.

5.12.3. Remove the gage length extender from the extensometer and return the extensometer and extender to their respective cases.

The extensometer should be returned to the configuration shown in Reference 7.6 for storage in its case. The gage length extenders should also be returned to the proper case for storage. Ensure that all small parts are also returned to the correct cases when the testing is complete.

5.12.4. Return all parts to the gray cabinet and lock the cabinet.

5.13. Lock the keyboard tray and return the key to an FSEL staff member.

5.14. Report the test results.

Typical values reported for a tensile coupon test may include the upper yield point, the dynamic yield stress, the static yield stress, the initial strain hardening modulus, the dynamic tensile strength, the strain at the onset of hardening, the strain at the development of the tensile strength (onset of necking), the elongation at fracture, and the gage length over which elongation was calculated.

Per ASTM E6 (Ref 7.8), the upper yield point is “the first stress maximum (stress at first zero slope) associated with discontinuous yielding at or near the onset of plastic deformation.” The dynamic yield stress is the average stress on the plateau region of the stress-strain curve, measured while the crossheads are in motion. The dynamic yield stress is a function of strain

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rate. Consequently, the reported dynamic yield stress should be reported along with the crosshead speed used during this part of the test.

The static yield stress is the stress measured while the crossheads are stopped along the yield plateau, and held stationary for approximately 3 minutes. If the stress-strain curve does not exhibit a yield plateau, the static yield stress is taken as the stress at zero strain rate corresponding to a total strain of 0.005 or to 0.2% offset, depending on the product specification (see SSRC Technical Memorandum B7 (Ref. 7.3))

To determine the static yield stress, loading was paused three times within the plastic range for 3 minutes. During the pause, the stress relaxes to a stable value. The static yield stress is the average of the minimum stresses recorded during those pauses.

The dynamic tensile strength is the greatest stress on the stress strain curve. The value of the dynamic tensile stress is a function of strain rate. Consequently, the reported dynamic tensile stress should be reported along with the crosshead speed used during this part of the test

Elongation at fracture is calculated as:

$$\% \text{ Elongation} = \frac{L_{\text{final}} - L_{\text{initial}}}{L_{\text{initial}}} \times 100\%$$

Where: % Elongation = percent elongation of specimen at fracture

L_{final} = final gage length as measured in Article 5.9

L_{initial} = initial gage length as measured in Article 5.1.7

The elongation at fracture (strain at fracture) can also be determined directly from the stress-strain curve, if the extensometer remained on the coupon through fracture.

A value of modulus of elasticity, i.e., the slope of the initial linear portion of the stress-strain curve cannot normally be accurately determined using "one-sided" extensometers available at FSEL. A one-sided extensometer only measures strain on one-face of the coupon. If there is any bending of the coupon, the measured strain will be a combination of the axial strain and bending strain. There is often a small amount of bending of the coupon during initial loading. This bending may occur because the coupon is not initially perfectly straight or has not been accurately aligned within the test machine. Even a small amount of bending can lead to inaccurate readings of axial strain in the initial part of the stress-strain curve, when a one-sided extensometer (such as those available in FSEL) is used. For an accurate measurement of the modulus of elasticity, an "averaging extensometer" should be used. An averaging extensometer

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measures strain on opposite faces of the coupon, and then averages these values. This type of measurement cancels out bending strains, leaving an accurate measurement of axial strain. The errors introduced by using a one-sided extensometer are general only significant when attempting to measure modulus of elasticity. The error in strain readings introduced in the inelastic portion of the stress-strain are generally minor.

For structural steel coupons, there is generally no need to measure the modulus of elasticity, as this value is quite constant over a wide range of steel grades and products. Thus, using a handbook value of $E \approx 29,400$ ksi (Ref. 7.9) normally provides sufficient accuracy. Note that $E = 29,000$ ksi is commonly used for design purposes.

If it is desired to measure the modulus of elasticity, one approach is to attach strain gages on opposite sides of the coupon, and then use the average measured strain in the initial linear range to estimate the value.

Example:

Figure 2 and Figure 3 show the results of a tension test for a coupon cut from the flange of a W10x19 section made of ASTM A992 steel. Figure 2 shows the entire stress-strain curve, and Figure 3 shows the initial portion of the stress-strain curve up to 5 percent strain. Also shown on these figures are various values that will be reported as test results. Note that in addition to reporting these values, it is useful to include the actual stress-strain curve in a research report or test report where possible. Including the actual stress-strain relationship helps clarify how values of stress and strain were determined, and allows re-interpretation of the data, if needed. Following the figures is a list of test results for this coupon test.

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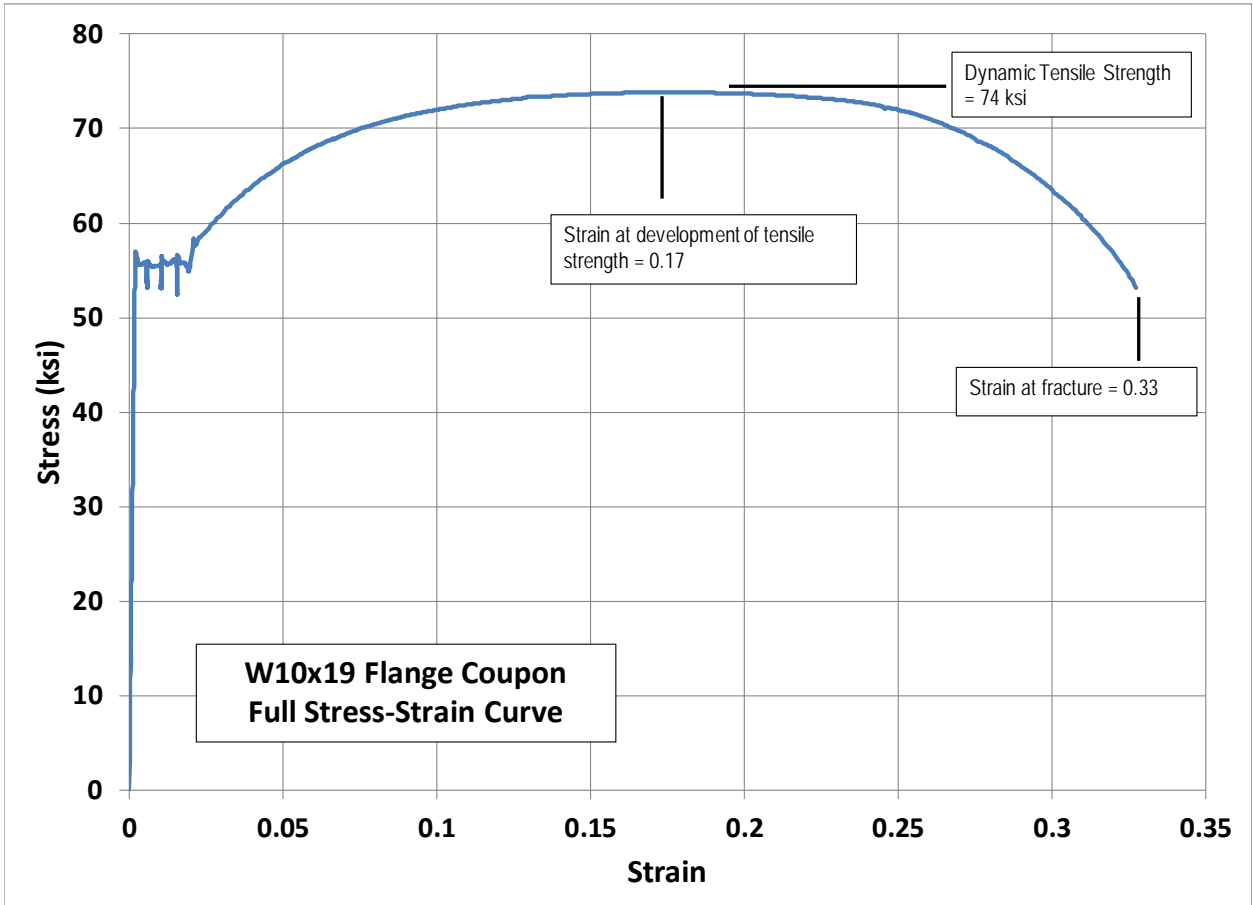


Figure 2 – Stress-Strain Curve for W10x19 (A992) Flange Coupon

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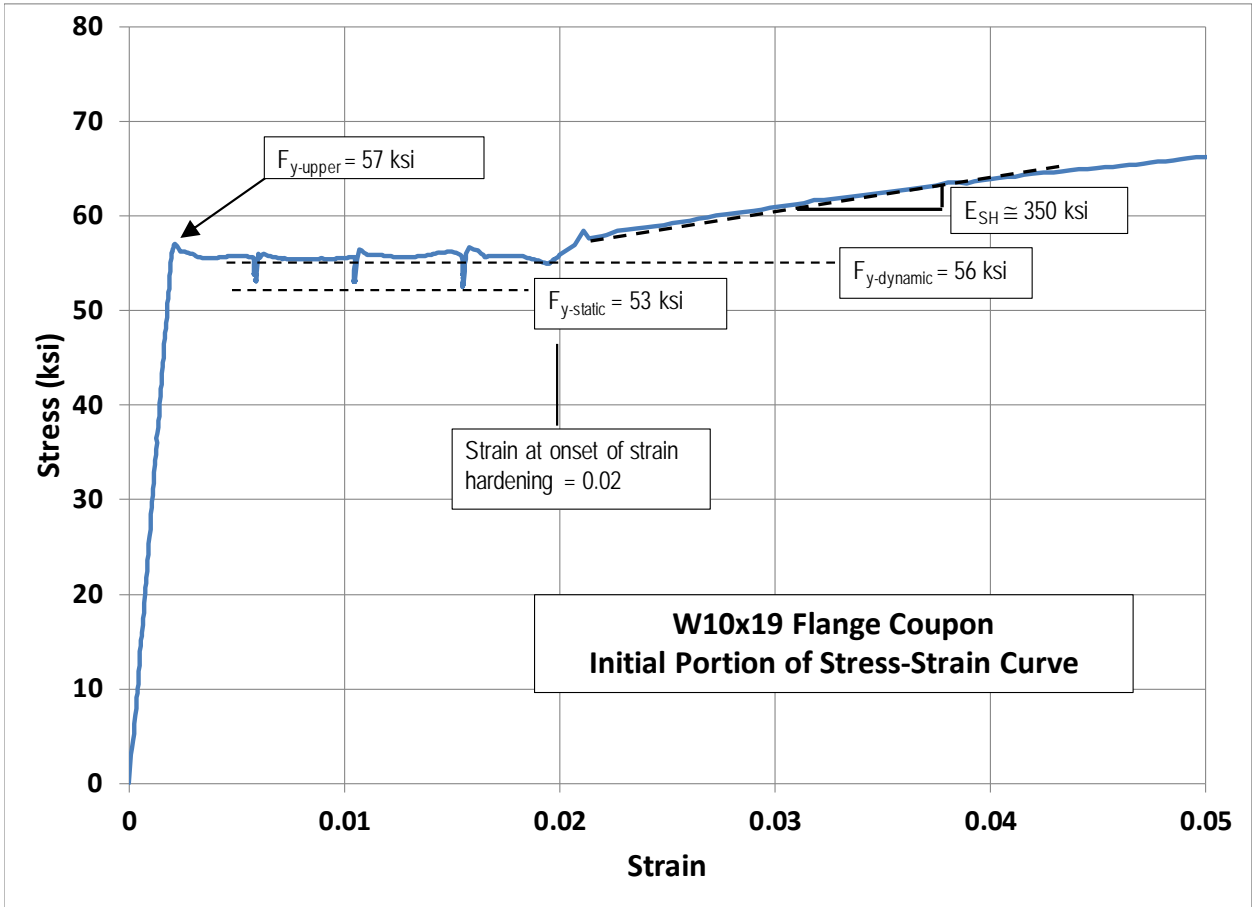


Figure 3 – Initial Portion of Stress-Strain Curve for W10x19 (A992) Flange Coupon

Coupon Test Report:

Coupon taken from flange of W10x19 section of ASTM A992 steel (include sketch showing coupon location in cross-section, if possible).

Coupon dimensions per ASTM A370-15 – rectangular plate type coupon with 2-inch gage length.

Crosshead rates: A loading rate of 0.02 inches per minute (cross-head speed) was used for the measurement of the upper yield point, the dynamic yield stress, the strain at onset of hardening, and the strain hardening modulus. After determination of strain at onset of hardening, the loading rate was increased to 0.125 inches per minute (cross-head speed) for

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the measurement of the dynamic tensile strength. This loading rate was maintained until failure of the coupon.

Test Results:

<i>Upper yield point:</i>	<i>57 ksi</i>
<i>Dynamic yield stress:</i>	<i>56 ksi</i>
<i>Static yield stress:</i>	<i>53 ksi</i>
<i>Strain at onset of hardening:</i>	<i>0.02</i>
<i>Initial strain hardening modulus:</i>	<i>350 ksi</i>
<i>Dynamic tensile strength:</i>	<i>74 ksi</i>
<i>Strain at development of tensile strength:</i>	<i>0.17</i>
<i>Elongation (strain at fracture):</i>	<i>33 percent (based on 2 in. gage length)</i>

6. SUPPORTING DOCUMENTS

None.

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7. REFERENCED DOCUMENTS

It is the responsibility of project personnel to ensure that the most recent versions of the referenced FSEL documents are utilized during procedure implementation.

- 7.1. ASTM A370-17: *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*. West Conshohocken: ASTM International, 2015.
- 7.2. ASTM A6-16: *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*. West Conshohocken: ASTM International, 2016.
- 7.3. *Guide to Stability Design Criteria for Metal Structures*, Sixth Edition, Edited by Ronald D. Ziemian, 2010, John Wiley & Sons, Inc.
- 7.4. MTS Technical Drawing 700-000-290 – “GL Extend 634.15-4X Long Post Install” Rev A.
- 7.5. MTS Technical Drawing 495732-01 – “Extensometer, Sm. Elastic Band Attachment Sys.” Rev A.
- 7.6. MTS Technical Drawing 700-001-693 – “Extensometer Model 643.25-2X Installation” Rev A.
- 7.7. MTS Technical Drawing 446065-01 – “Extensometer Spring & Elastic Band Attachment” Rev B.
- 7.8. ASTM E6-15: *Standard Terminology Relating to Methods of Mechanical Testing*. West Conshohocken: ASTM International, 2015.
- 7.9. Galambos, T.V. and Ravindra, M.K., “Properties of Steel for Use in LRFD,” *Journal of the Structural Division*, ASCE, Vol. 104, No. ST9, Sept 1978.

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8. RECORD OF REVISIONS

Revision	Date	Affected Pages	Description
0	2016-06-05	All	Initial Issue