Stress/Strain Apparatus

AP-8214A

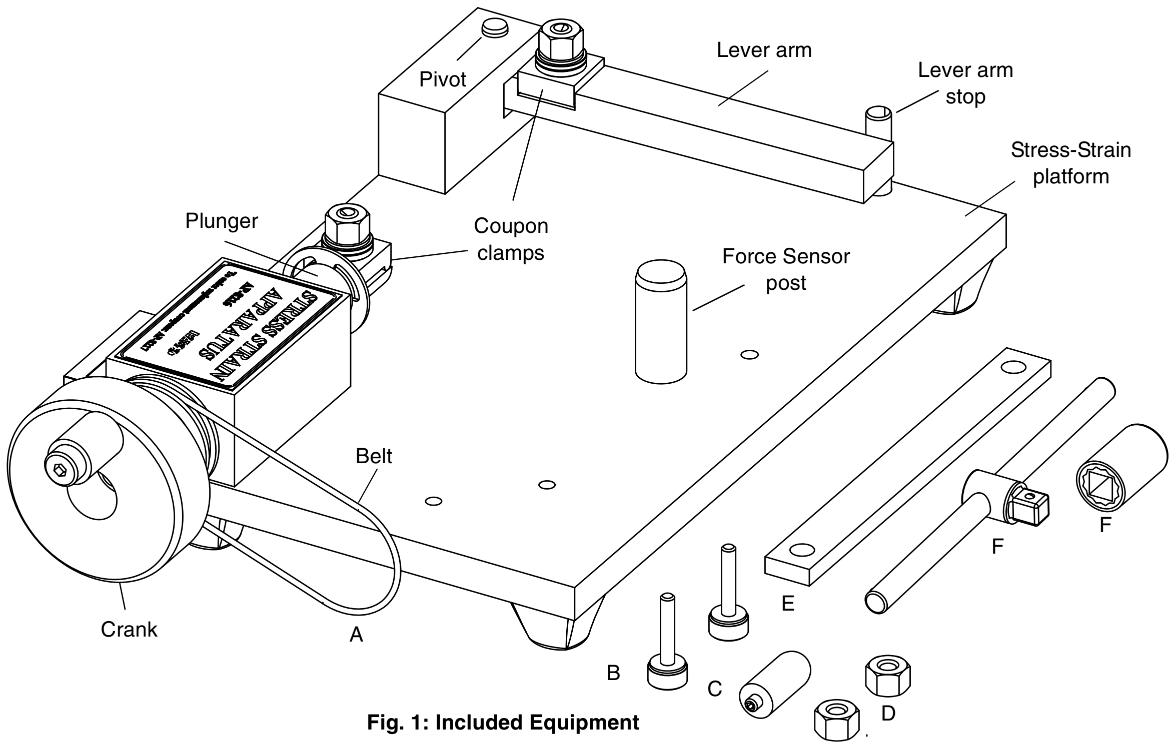


Fig. 1: Included Equipment

Included Equipment

A. **AP-8221 Stress/Strain Apparatus without Coupons**

B. Thumbscrews for Rotary Motion Sensor, 2 pieces

C. Attachment for force sensor

D. Replacement hex nut, 2 pieces

E. Calibration bar

F. Tee handle plus Socket, 3/8 inch

- PASCO Experiment Setup CD-ROM and Storage Box (not shown)

AP-8222 Plastic Test Coupons: 4 color-coded samples, 10 pieces per sample

- high impact polystyrene (HIPS)
- nylon 6 (15% glass fiber reinforced)
- acrylonitrile butadiene styrene (ABS)
- polypropylene (PP)

- The plastic coupons are attached to a rectangular plastic rail called a 'sprue'. Use scissors or a knife to cut the coupon from the sprue.

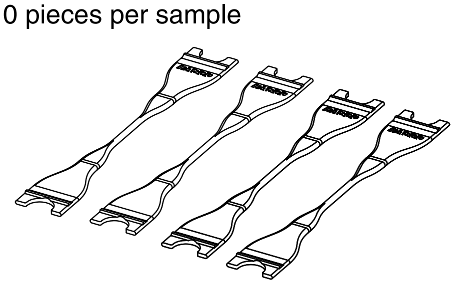


Fig. 2: AP-8222 Plastic Test Coupons

AP-8223 Metal Test Coupons: 5 samples, 10 pieces per sample (sample containers labeled with thickness in inches)

- cold-rolled steel 0.003”
- annealed steel 0.003”
- aluminum 0.003”
- brass (thick) 0.005”
- brass (thin) 0.003”

Fig. 3: AP-8223 Metal Test Coupons

Note: The metal coupons are packaged in plastic containers to prevent bending or creasing of the coupons.

Additional Equipment Required for Use with *ScienceWorkshop* Sensors	**Part Number**
ScienceWorkshop Interface	See PASCO catalog or www.pasco.com
DataStudio[1]	See PASCO catalog or www.pasco.com
Economy Force Sensor	CI-6746
Rotary Motion Sensor	CI-6538

Additional Equipment Required for Use with PASPORT Sensors	**Part Number**
PASPORT Interface[2]	See PASCO catalog or www.pasco.com
DataStudio[1]	See PASCO catalog or www.pasco.com
Force Sensor	PS-2104
Rotary Motion Sensor	PS-2120

[1]DataStudio 1.8 or later recommended. Visit www.pasco.com to download the latest version. DataStudio Lite, the free version, is sufficient for use with the experiment set-up files on the included CD.
[2]The two sensors used on the Apparatus require a single multi-port interface such as the Xplorer GLX (PS-2002) or PowerLink (PS-2001), or two single-port interfaces such as the USB Link (PS-2100) or Xplorer (PS-2000).

Recommended Equipment	**Part Number**
Replacement Test Coupons*	AP-8217A
Digital Calipers	SE-8710

**The AP-8217A Replacement Test Coupons include all of the AP-8222 plastic and AP-8223 metal test coupons.*

Introduction

The PASCO AP-8214A Stress/Strain Apparatus illustrates the relationship between stress and strain for various materials. The apparatus stretches a test coupon (and breaks it in some cases) while measuring the amount of stretch and force experienced by the test coupon. Data acquisition software can be used to generate a plot of force versus displacement and also a plot of stress versus strain.

The Stress/Strain Apparatus requires a *ScienceWorkshop* or PASPORT interface, DataStudio software, a Rotary Motion Sensor (RMS), and a Force Sensor. Included with the apparatus are four types of metal test coupons and four types of plastic test coupons. Also included are a tee handle with a socket that fits the hex nuts on the coupon clamps, a bar for calibrating the apparatus, and spare hex nuts for the coupon clamps.

This manual includes instructions for setting up the Stress/Strain Apparatus with *ScienceWorkshop* or PASPORT sensors. It also describes how to do the calibration and the data collection using the DataStudio set-up files that are on the included PASCO Experiment Setup CD-ROM. The CD-ROM has a folder labeled “AP-8214 SETUP” that contains two DataStudio configuration (set-up) files, two DataStudio workbook files, and a sample data file.

Test Coupon Specifications

The data below are intended as a general guide only and do not necessarily represent results that may be obtained. The units for tensile strength and modulus of elasticity are megapascals (MPa or 10^6 N/m^2) and pounds per square inch (psi).

AP-8222 Plastic Test Coupons

Item	**HIPS**	**nylon 6** (+ 15% glass)	**ABS**	**polypropylene**
Color code	orange	black	blue	white
Cross-sectional area	2.482 mm^2	2.482 mm^2	2.482 mm^2	2.482 mm^2
Tensile strength	23 MPa/ 3410 psi	98 MPa/ 14000 psi	47 MPa/ 6800 psi	34 MPa/ 4900 psi
Tensile elongation	40%	2.5%	20%	9%
Modulus of elasticity	2000 MPa/ 280000 psi	2900 MPa/ 420000 psi	2300 MPa/ 380000 psi	1900 MPa/ 239000 psi

AP-8223 Metal Test Coupons

Item	**cold-rolled steel**	**annealed steel**	**aluminum**	**brass (thin)**	**brass (thick)**
Cross-sectional area	0.303 mm^2	0.303 mm^2	0.303 mm^2	0.303 mm^2	0.506 mm^2
Tensile strength	620 MPa/ 90,000 psi	300 MPa/ 44,000 psi	145 MPa/ 21,000 psi	430 MPa/ 44,000 psi	430 MPa/ 44,000 psi
Tensile elongation	none	42-45%	6%	25%	25%
Modulus of elasticity	200,000 MPa/ 29,000,000 psi	200,000 MPa/ 29,000,000 psi	69,000 MPa/ 10,000,000 psi	117,000 MPa/ 17,000,000 psi	117,000 MPa/ 17,000,000 psi

Theory.

A stress-strain tensile test measures the amount of stretching force applied to a sample of material, and the amount of stretch of a material. Stress (σ) is the ratio of force (*F*) per unit of cross-sectional area (*A*). Strain (ε) is the ratio of the change of length (*l*) compared to the original length (*L*). A stress-strain curve is a graphical representation of the load applied and the deformation of the sample. The curve varies from material to material.

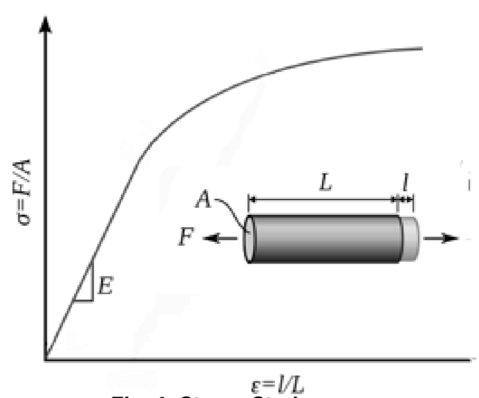


Fig. 4: Stress-Strain curve

Ductile materials like metal have a linear stress-strain relationship up to a point. The slope of the linear part of the stress-strain curve is called “Young’s modulus” or the modulus of elasticity (*E*) and is a property used to characterize materials.

About the Apparatus

The lever arm on the Stress/Strain Apparatus is a Class III lever that transmits the applied force to the Force Sensor. The length of the lever arm from the pivot to the Force Sensor attachment is five times longer than the length of the lever arm from the pivot to the coupon clamp that is part of the lever arm. The force applied to the test coupon is five times more than the force measured by the Force Sensor. Therefore, each DataStudio set-up file uses a calculation that multiplies the measured force by five.

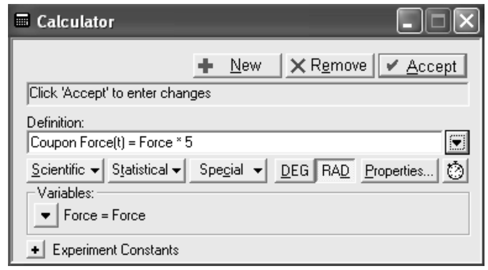


Fig. 5: Force calculation

Equipment Set-up

1. **Attach the Rotary Motion Sensor to the apparatus platform**.

- Remove the rod clamp from the RMS.
- Place the three-step pulley (Item 6) onto the shaft of the RMS with the largest pulley on the outside. The three-step pulley should be on the “clockwise positive” side of the RMS as shown in the figure.
- Place the RMS on the platform as illustrated below. Use the two thumbscrews to fasten the RMS to the platform from beneath.
- Seat the belt (Item 7)on the middle step of the three-step pulley and the groove on the crankshaft.

2. **Attach the Force Sensor to the apparatus platform**.

- Remove the hook from the Force Sensor and replace it with the force sensor attachment (Item 3, included).
- Place the Force Sensor on the apparatus platform by putting the support rod mounting hole onto the Force Sensor post.
- Insert the long thumbscrew supplied with the Force Sensor through the hole on the Force Sensor marked “Cart” and screw it into the threaded hole in the apparatus platform.
- Tighten the setscrew (Item 4) in the support rod mount of the Force Sensor.

3. **Clamp down the apparatus (optional)**. Use a large C-clamp to clamp the Apparatus Platform to the edge of your bench or table. One side of the platform has three feet. In order to avoid bending the platform, position the clamp directly over the center foot.

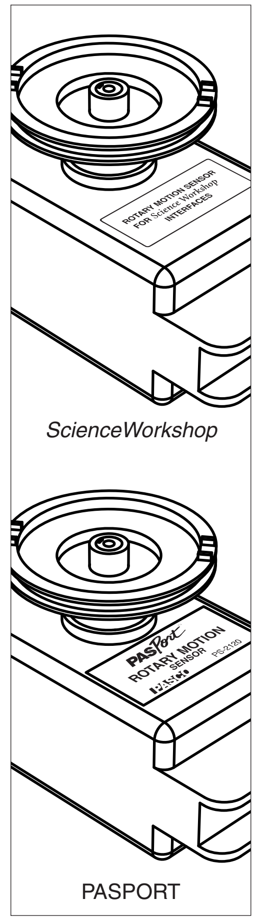
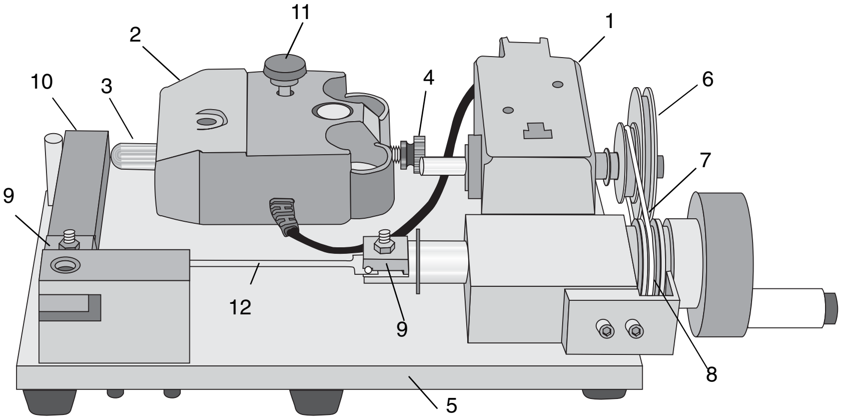


Fig. 6: Three-step pulley on the “clockwise positive” side of RMS

4. **Plug the sensors into the interface**.

- *ScienceWorkshop interface:* Connect the Force Sensor to Channel A. Connect the yellow plug of the RMS to Channel 1 and the black plug to Channel 2.

- *PASPORT interface:* Connect the Force Sensor and the RMS to a multi-port interface or two single-port interfaces.



1. Rotary Motion Sensor (RMS)
2. Force Sensor
3. Force Sensor attachment
4. Force Sensor setscrew
5. Stress Strain platform
6. 3-step pulley
7. belt
8. groove
9. coupon clamps
10. lever arm
11. thumbscrew
12. coupon

Fig. 7: Equipment Set-up

Prepare DataStudio

The included CD-ROM has a folder labeled “AP-8214 SETUP” that contains two DataStudio configuration (set-up) files, two DataStudio workbook files, and a sample data file.

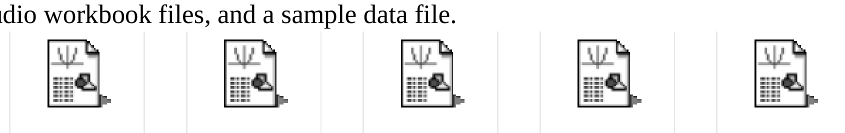


Fig. 8: DataStudio files

Start DataStudio and open the configuration file *Stress Strain SW.ds* (for *ScienceWorkshop*) or *Stress Strain PS.ds* (for PASPORT) located on the included CD-ROM. Each configuration file has Graph displays, Digits displays and several calculations.

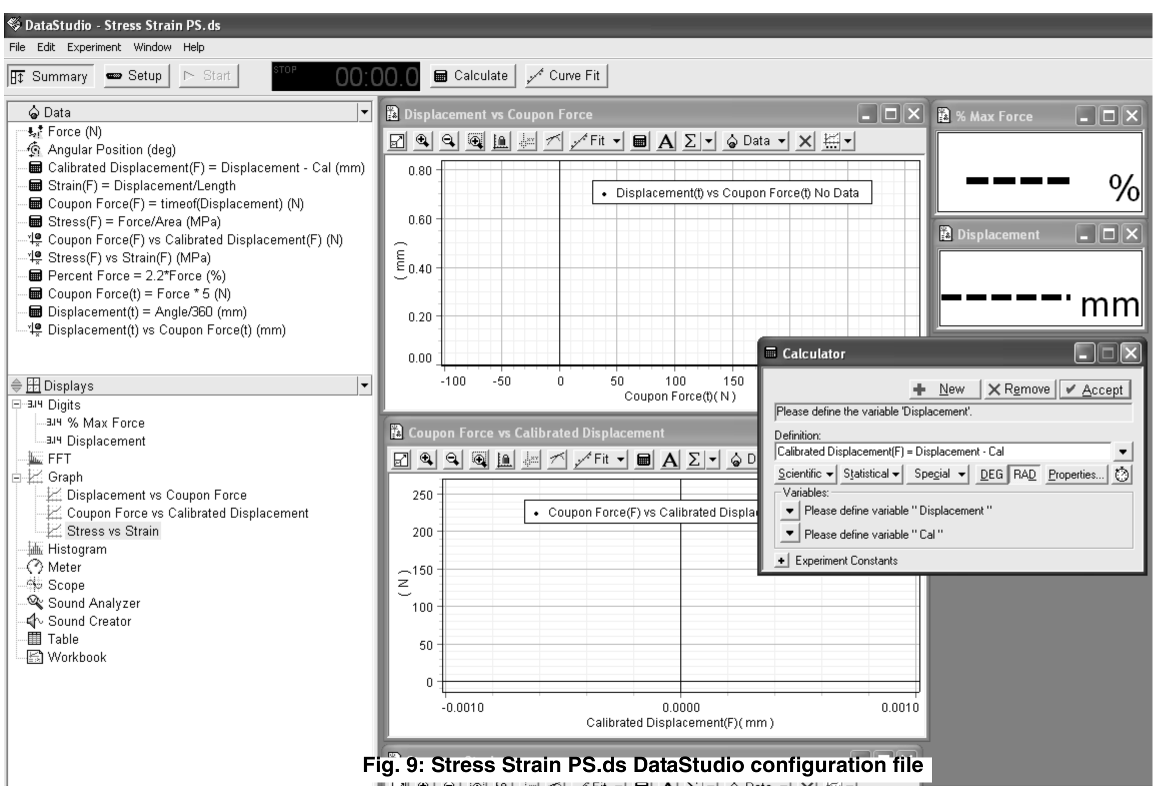


Fig. 9: Stress Strain PS.ds DataStudio configuration file

Apparatus Calibration

As you turn the crank during the experiment, force will be applied to the test coupon causing it to stretch. However, this applied force will also cause the apparatus platform and the Force Sensor to bend slightly. The displacement recorded by the RMS will be the combination of the coupon stretching and the rest of the apparatus bending.

Regardless of how much the coupon stretches, the deformation of the rest of the apparatus is constant for a given force. You can measure this deformation directly by using the calibration bar (which does not stretch significantly) in place of a coupon. In the resulting Displacement versus Force graph, the displacement is due only to bending of the apparatus. Later, you will subtract this calibration plot from a similar plot made with a coupon, in which the displacement results from both bending of the apparatus and stretching of the coupon. The difference will be a plot in which the displacement is due only to stretching of the coupon.

Follow these steps to acquire calibration data:

1. Install the Calibration Bar

- For each coupon clamp, remove the nut, washers, clamp top, and spring from the bolt (Figure 10).
- Turn the crank to adjust the position of the bolts if needed and slip the calibration bar over the bolts. *Do not replace the coupon clamp parts when using the calibration bar.*

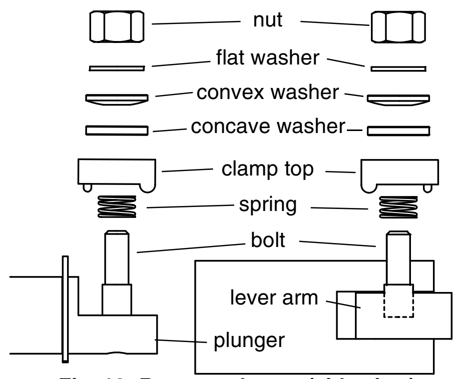


Fig. 10: Remove clamps (side view)

2. Place the lever arm in the starting position. Turn the crank counter-clockwise and pull the lever arm away from the Force Sensor (Figure 11).

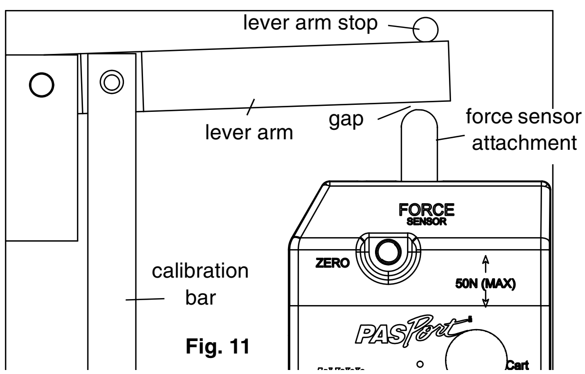


Fig. 11

3. Collect Displacement versus Force Data.

- Press the Tare or Zero button on the Force Sensor.
- Click the Start button.
- Turn the crank clockwise. Starting just before the lever arm comes into contact with the Force Sensor attachment, turn the crank very slowly. DataStudio will start recording when the force applied to the coupon reaches 2.5 N, or 1% of maximum (as shown in the "% Max Force" digits display).
- Continue to turn the crank until the force reaches 100% of maximum. At this point, DataStudio will stop recording automatically.

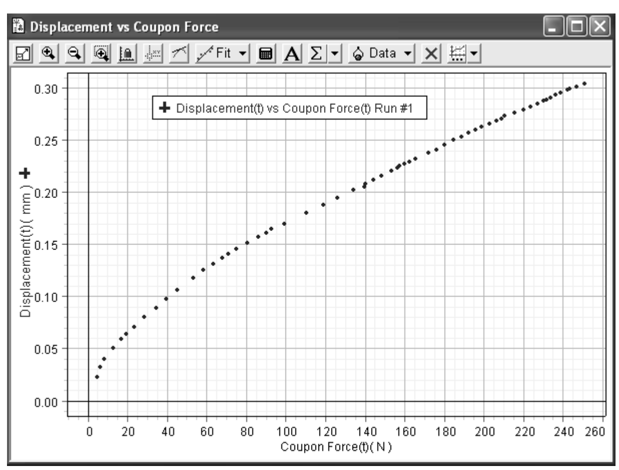


Fig. 12: Displacement(t) vs Coupling Force(t) calibration data

- Change the name of the data run (Run #1) containing the calibration data to “Cal”.*

> * To rename a data run, click the run name (e.g. “Run #1”) where it appears in the Data List. Wait about 1 second then click it again. Enter the new name. A dialog box will appear. Select Yes. (If a window titled “Data Properties” appears, you didn't wait long enough after the first click; close that window and try again.)

DataStudio Set-up

1. **Prepare the calculation for “Calibrated Displacement(F)”**. In the Calculator window, select the “Calibrated Displacement(F)” calculation and define the variables.

- Drag “Displacement(t) vs Coupon Force(t) (mm)” to “Please define variable ‘Displacement’.” (Figure 13)

- Drag “Cal” to “Please define variable ‘Cal’” in the Calculator window. (DataStudio will display a warning box stating that a “single run is selected”. Click the Yes button in that box.)

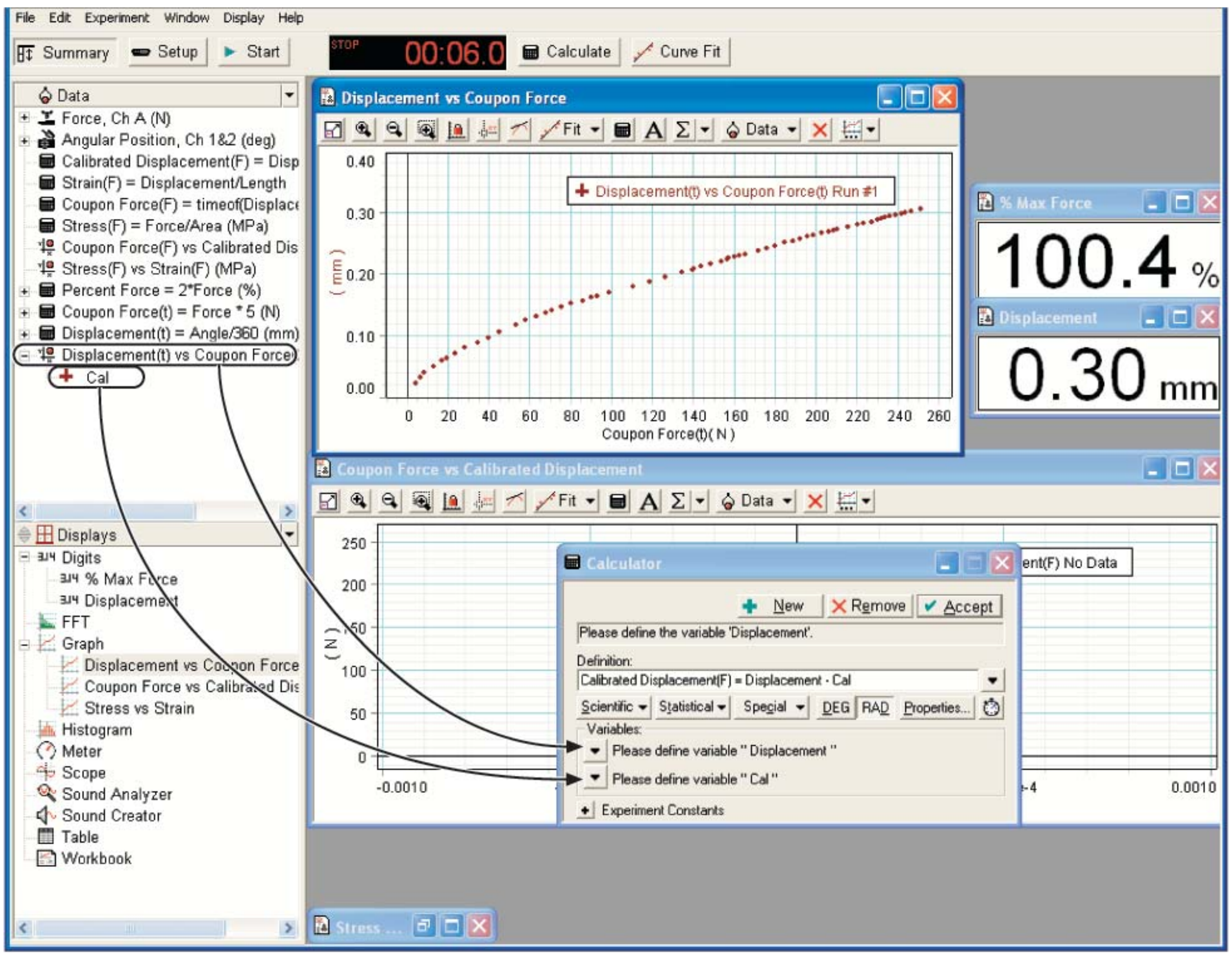
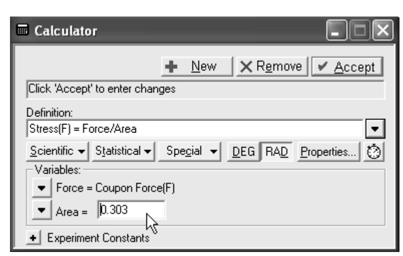
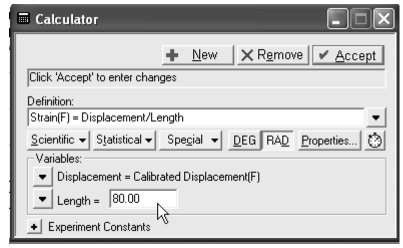


Fig. 13: Define Variables in Calculator

2. **Prepare the calculation for “Stress(F)”**. In the Calculator window, select the defined function “Stress(F) = Force/Area”. In the Variables section, enter the cross-sectional Area of the coupon *in square millimeters*. See the **Test Coupons Specification**s section for the cross-sectional Area. (The cross-section Area in this example is 0.303.)



3. **Prepare the calculation for "Strain(F)"**. First, measure the length of the narrow part of the test coupon. (The nominal length is 80 mm for the metal coupons and 18 mm for the plastic coupons.) In the Calculator window, select the defined function "Strain(F) = Displacement/Length". In the Variables section, enter the Length of the narrow part of the coupon *in millimeters*.



4. **Close the Calculator window**.

You now have a the characteristic baseline curve for your particular apparatus. You can save the file and use it as the starting point for future experiments instead of repeating the calibration.

Data collection

1. **Mount a coupon**.

- Remove the calibration bar from the bolts. Replace the spring, clamp top, concave washer, convex washer, flat washer, and hex nut onto the bolts (Figure 11).
- Place one end of a coupon under one of the clamp tops.
- NOTE: The plastic test coupons have ridges on their top sides. Place the end of the plastic test coupon under the clamp top with the ridge on top.

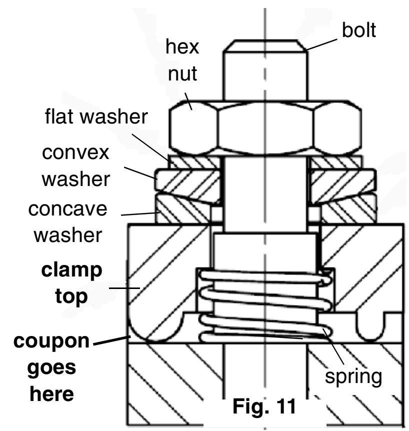


Fig. 11

- Adjust the crank so that the opposite end of the coupon can slip easily under the other clamp (Figure 12).
- Tighten both nuts with the tee handle with socket. With no force applied to the coupon, as little twist as possible should be visible in the coupon. *The clamps should hold the coupon tightly enough that it will not slip when force is applied. However, over-tightening the nuts will damage the bolts. If in doubt, err on the side of under-tightening*.

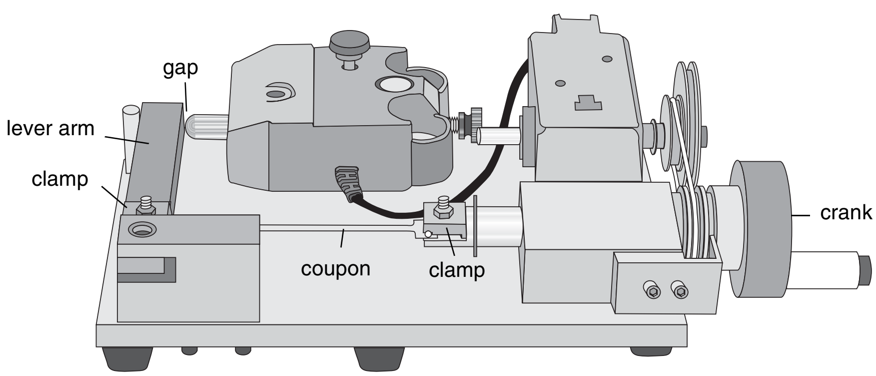


Fig. 12: Coupon Installed

2. **Place the lever arm in the starting position**. Turn the crank counter-clockwise and pull the lever arm away from the Force Sensor so that there is a small gap between the end of the Force Sensor Attachment and the lever arm..

3. **Collect Data**.

- Press the Tare or Zero button on the Force Sensor.
- Click the Start button in DataStudio.

- Turn the crank clockwise. Starting just before the lever arm comes into contact with the Force sensor, turn the crank very slowly.*

- When you have finished collecting data, click Stop. (If you reach the maximum force, DataStudio will stop automatically.) If the coupon breaks, it should break in the middle. If the coupon breaks near the end, it was probably twisted slightly when you mounted it, resulting in a point of higher stress where it broke.

* When you observe on the Stress versus Strain plot that the material has been stretched beyond the elastic region, you can begin to turn the crank faster.

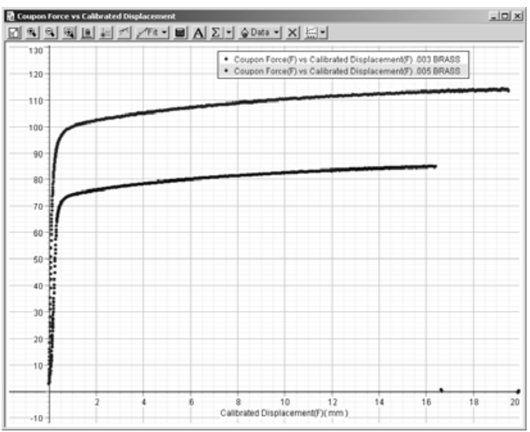
4. **Rename the data run to identify the coupon**. Use the same method you used to rename the calibration data.

Data Analysis

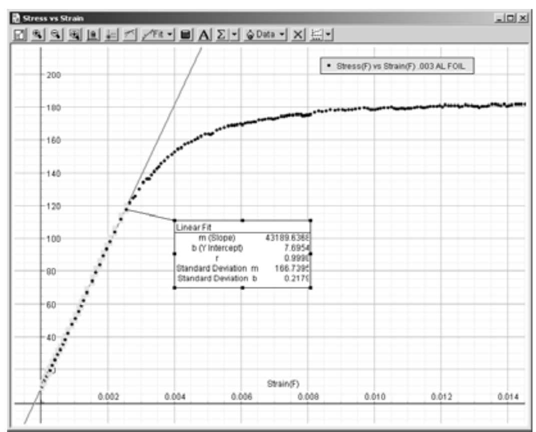
On the Stress versus Strain graph, you can identify features such as the elastic region, the plastic region, the yield point, and the break point.

To calculate Young's modulus, drag the mouse to select a data region covering the linear, lower left-hand part of the graph. (You may find that the very first part of the plot is not linear. This nonlinearity is likely due to the straightening of bends and twists in the coupon as force is first applied. Do not include this region in your selection.) Click the Fit button to apply a linear curve fit to the selected data. The slope of the line is Young's modulus in units of MPa (or MN/m^2 or N/mm^2).

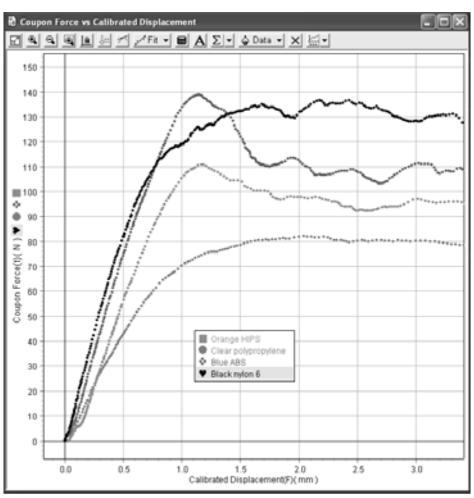
Sample Data



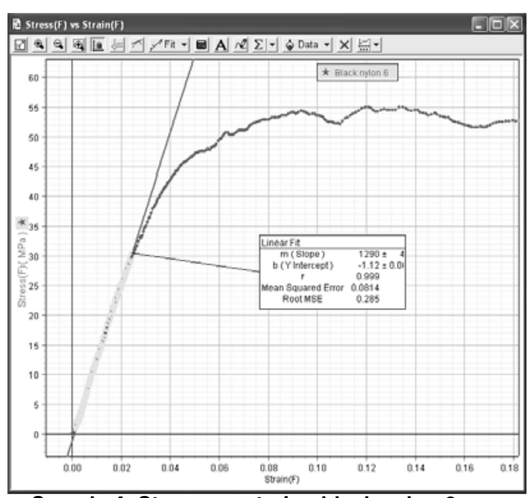
Sample 1: Force vs. displacement - brass 0.003 and brass 0.005



Sample 2: Stress vs. strain - aluminum 0.003 Units of slope are MPa



Sample 3: Force vs. displacement - plastic coupons



Sample 4: Stress vs. strain - black nylon 6 Units of slope are MPa

Notes on the DataStudio Set-up File

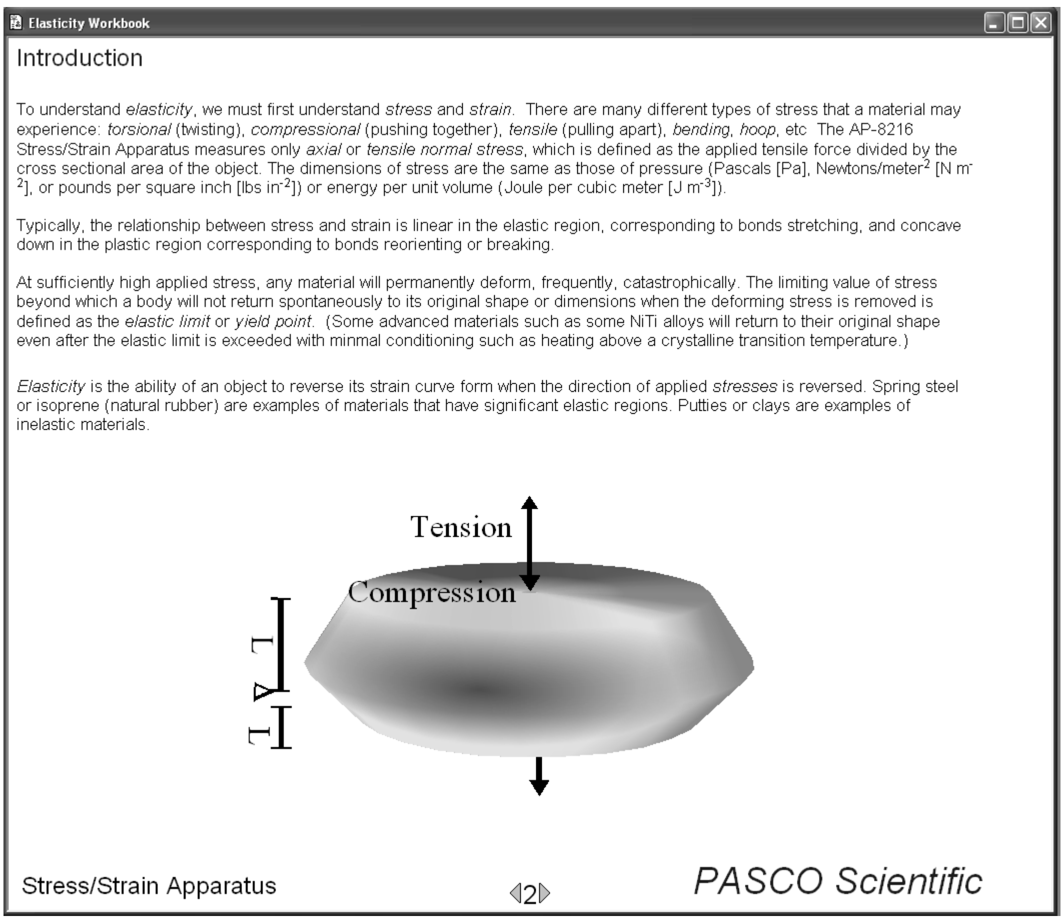
- For comparison of different materials, you can collect additional data runs with other coupons. Note that the Stress calculation applies only to coupons of the thickness that you entered in the Calculator window. It is easiest to compare coupons of the same thickness. However, to simultaneously display stress versus strain plots for coupons of different thicknesses, you must create a separate Stress calculation for each thickness. Copy the existing Stress calculation exactly (including the calculation properties), but give it a unique name (indicating the thickness for which it is designed) and enter the applicable cross-section area for the Area constant.

- When you create a new Stress calculation, note that there are two different calculations for Coupon Force- "Coupon Force(F)" and "Coupon Force(t)". Always use the "Coupon Force(F)" calculation. The "(F)" identifies data as a function of Force, and "(t)" identifies data as a function of time. DataStudio records data as a function of time, but this experiment requires data to be recast as a function of Force. Whenever you create a new calculation or graph, be certain to use only data that is a function of Force.

- When you add a new Stress calculation to the graph, it will initially appear with time on the horizontal axis. Click the word "time" and select Strain instead.

Optional DataStudio Files

- The AP-8214 SETUP CD includes two DataStudio Workshop files; one for use with a *ScienceWorkshop* interface and sensors, and the other for PASPORT.



- Start DataStudio, open one of the Workbook files, and follow the instructions presented in the Workbook.

Technical Support

For assistance with any PASCO product, contact PASCO at

:

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S)

Fax: (916) 786-3292

Web: www.pasco.com

Email: techsupp@pasco.com

For more information about the Stress-Strain Apparatus and the latest version of this instruction manual, visit the PASCO web site at www.pasco.com and enter AP-8214A in the Search window.

Limited Warranty
For a description of the product warranty, see the PASCO catalog.