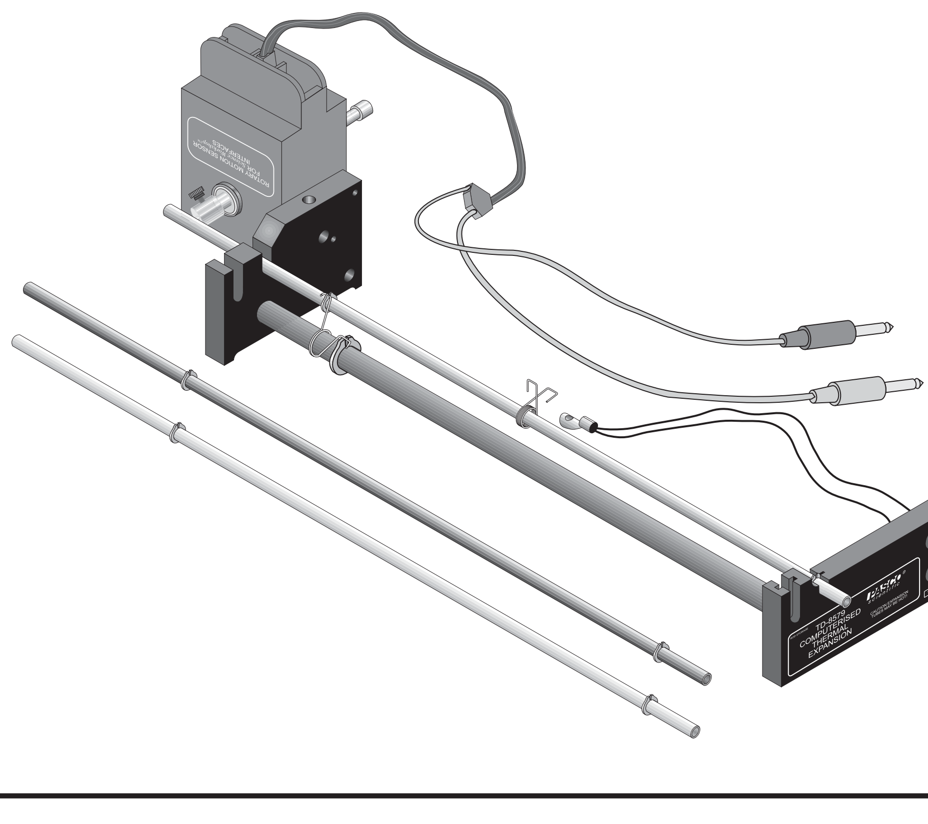
Instruction Manual and Experiment Guide for the PASCO scientific Model TD-8579A

012-07599C

COMPUTER-BASED THERMAL EXPANSION APPARATUS



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Limited Warranty

PASCO scientific warrants the product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace at its option any part of the product which is deemed to be defective in material or workmanship. The warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment after repair will be paid by PASCO scientific.

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Should the product have to be returned to PASCO scientific for any reason, notify PASCO scientific by letter, phone, or fax BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

➤ **NOTE:** NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION FROM PASCO.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

① The packing carton must be strong enough for the item shipped.

② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.

③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument to come in contact with the packing carton.

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web: www.pasco.com

Introduction

Introduction

The PASCO Model TD-8579A Computer-based Thermal Expansion Apparatus provides easy and accurate measurements for the coefficient of linear expansion for brass, copper, and aluminum. The PASCO Model TD-8579A differs from the previous model TD-8578 in that it uses a Rotary Motion Sensor instead of a dial gage for measuring length changes in the rod, a Thermistor Sensor instead of an ohmmeter, and is compatible with a *ScienceWorkshop*® interface for recording sensor measurements in a computer.

The new PASCO CI-6527A Thermistor Sensor can be connected to the apparatus and a *ScienceWorkshop* interface for viewing temperature readings inside DataStudio. With the new thermal expansion model, students no longer have to convert resistance readings to temperature values using a conversion table. DataStudio® provides immediate temperature feedback in either absolute temperature (degrees Kelvin), degrees Celsius (C) or Fahrenheit (F). A setup diskette comes with the apparatus, which includes the pre-defined variables and equations for measuring temperature in degrees Celsius.

For the length measurement, the brass, copper, or aluminum tube is placed on the expansion base. The length of the tube is measured at room temperature, then steam is passed through it. The expansion of the length of the metal rod is measured with 0.006 mm resolution using the Rotary Motion Sensor. Temperatures are measured to within $\pm$0.2 °C using a thermistor attached to the center of the tube. To investigate the expansion of the metals at additional temperatures, hot or cold water can be passed through the metal tubes.

Complete step-by-step instructions and a data sheet for results are provided in this manual.

Temperature Measurement with the Thermistor and Thermistor Sensor

A thermistor's resistance varies reliably with temperature. Typically, as the temperature of a metal rod increases, the resistance decreases proportionally until the temperature equilibrates. Although the relationship between temperature and resistance is not linear, a linear approximation can be accurately used to interpolate between table data points with an accuracy of approximately $\pm$0.2 ^{0}C.

The 10 kΩ thermistor used to measure the rod's temperature is embedded in the thermistor lug. Once thermal equilibrium has been reached, the heat is highly uniform along the length of the rod. The foam insulator is used to inhibit heat loss through the thermistor lug so the lug temperature closely follows the rod's temperature. The insulator does not have any appreciable effect on the local temperature of the rod itself.

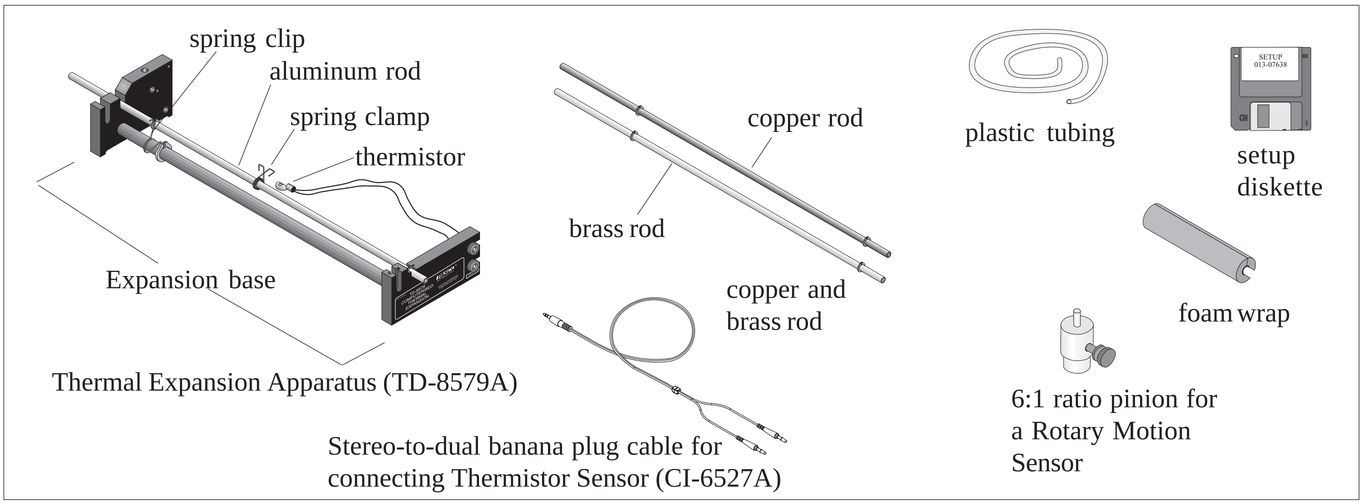
Using the PASCO Thermistor Sensor with a *ScienceWorkshop* interface, the resistance is measured and directly converted to a temperature measurement, which displays in DataStudio.

Equipment

Equipment Included:

The TD-8579A Computer-based Thermal Expansion Apparatus includes:

- A 40-cm long expansion base with 10 kΩ thermistor
- 3 metal rods — brass, copper (99.5% Cu, 0.5% Te), and aluminum (98.9% Al, 0.7% Mg, 0.4% Si): 6.4 mm outside diameter
- 1 foam insulator to avoid heat loss at the thermistor connection point
- Thermoplastic elastometer tubing with 6.4mm I.D.
- A 3.5 in. experiment setup diskette
- 1 pinion (6:1 ratio of disk radius to pin radius) for the Rotary Motion Sensor, Model CI-6538
- 1 stereo-to-dual banana plug cable for connecting a Thermistor Sensor (CI-5627A)



Additional Equipment Required

In addition to the TD-8579A Thermal Expansion Apparatus, you need the following items to perform the experiment, which is described on pages 5-6 of this manual:

- *ScienceWorkshop* Interface (500, 700 or 750)
- DataStudio®, version 1.5.2 or later
- PASCO Thermistor Sensor, Model No. CI-6527A
- PASCO Rotary Motion Sensor, Model No. CI-6538
- A source of steam or hot water, such as the PASCO Model TD-8556A Steam Generator
- A metric measuring tape or ruler
- A tube clamp to block off one side of the tubing from the Steam Generator
- A container to catch the water as it drains out of the metal rod
- Optional: If additional data points are desired, you will also need a source of hot or cold water.

Apparatus Setup

1. **Attach the Rotary Motion Sensor (RMS) to the large end block on the apparatus.** Use the black thumb screws to attach the RMS to the holes in the larger of the black end blocks (See Figure 1). Place the pinion onto the shaft of the RMS and rotate clockwise to tighten.

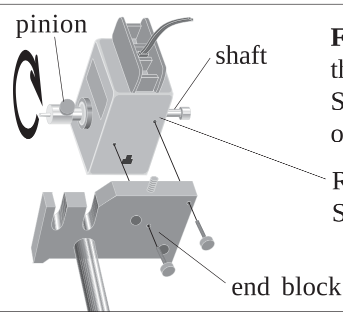


Figure 1: Mounting the Rotary Motion Sensor to the end block of the Apparatus

2. **Align and anchor the copper rod in the expansion base (Figure 2).** The stainless steel ring on the rod fits into the groove on the labeled mounting block, and the metal rod lies over and presses against the pin on the Rotary Motion Sensor. Hook the spring clip (on the support rod) over the top metal rod and to the left side of the grip ring. (Note: This anchors the rod and establishes the zero position).

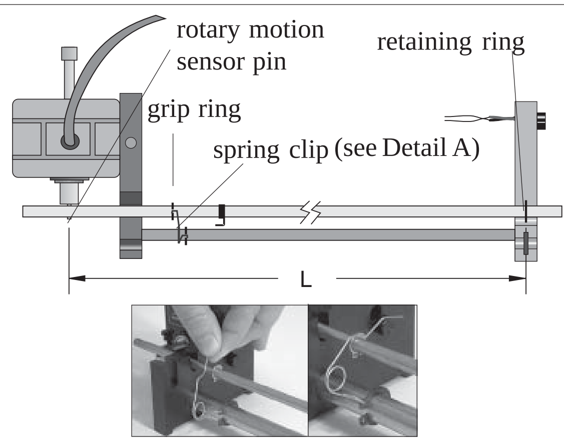


Figure 2: Aligning and anchoring the metal rod in the expansion base.

3. **Attach the Thermistor lug beneath the spring clamp on the metal rod.** With one hand, place the Thermistor lug over the top of the metal rod, such that the concave side fits snugly over the rod (Figure 3). Align the lug with the axis of the rod, so that there is maximum contact between the lug and the rod. With your other hand, press the ends of the spring clamp together. Slide the lug underneath the capture spring to attach the thermistor lug beneath the clamp.

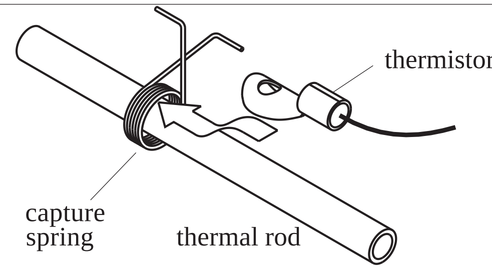


Figure 3: Placing the Thermistor lug (with thermistor) on the metal rod.

4. **Plug the Sensors into the Interface.** Insert the DIN connector of the Thermistor Sensor into an analog channel in the *ScienceWorkshop* interface. Attach the stereo plug of the Thermistor Sensor cable into the 10 kΩ jack on the Thermistor Sensor. Insert the banana plugs for the Rotary Motion Sensor into digital channels 1 and 2 (yellow=channel 1, black=channel 2) on the *ScienceWorkshop* interface.

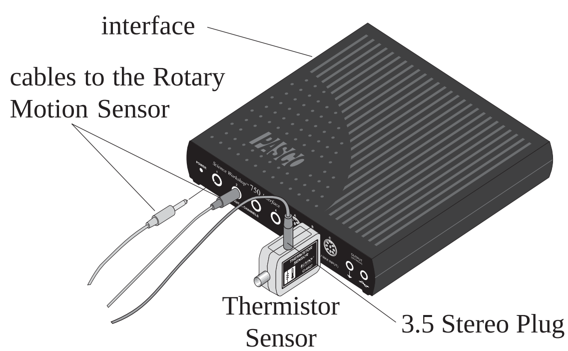


Figure 4: Plugging the Thermistor and Rotary Motion Sensors into the *ScienceWorkshop* Interface

5. **Attach the Rotary Motion Sensor leads to the apparatus.** Insert the red and black banana plugs into the jacks on the endblock (the one with the Thermistor label).

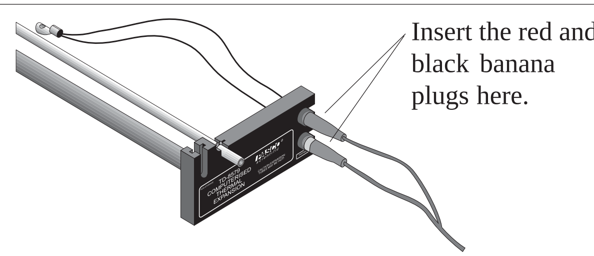


Figure 5: Attaching the banana plugs from the Thermistor Sensor to the end block of the apparatus

Experiment Setup

Calibration

The Thermistor Sensor and Rotary Motion Sensor are both factory-calibrated and do not require additional calibration. However, if you wish to calibrate the Thermistor Sensor, you may do so. For calibration instructions, see the DataStudio (version 1.5.2 or later) online help.

Software Setup

Use the provided Thermal Expansion Setup diskette for setting up your experiment in DataStudio (v. 1.5.2 or later). The Thermal Expansion Setup diskette includes the necessary sensor designation, pre-defined variables, equations, etc., that you will need to run the experiment with the PASCO Thermal Expansion Apparatus (the experiment on pages 5 to 6 of this manual).

Note: You must have DataStudio version 1.5.2 or later to run the setup diskette. PASCO provides a setup diskette for either MacIntosh or Windows operating systems.

1) Insert the Thermal Expansion Setup diskette into your disk drive and open DataStudio. The Experiment Setup window opens and shows the Rotary Motion Sensor icon and Thermistor Sensor icons. If your sensors are connected to the thermal apparatus and *ScienceWorkshop* interface, and you have a heat source running through the metal rod, you are ready to begin collecting data.

The following paragraphs describe the setup information contained in the setup diskette.

Sample Rate: The default sample rate for both the Rotary Motion and Thermistor Sensors is 5 Hertz (Hz). If you want to change the sample rate, click on the sensor icon in the Experiment Setup window. In the Sensor Properties dialog, use the plus and minus buttons to increase or decrease the sample rate.

Measurement units: The setup will give you temperature readings in degrees Celsius. If you also want to view resistance measurements, go to the Experiment Setup window and doubleclick on the Thermistor Sensor icon. In the Sensor Properties dialog, click on the Measurement tab and click to place a check in the Resistance box.

Equation Setup: To view the pre-defined equations for temperature, position, etc., double click on the appropriate Calculator icon in the Data List. The setup diskette includes the following equations:

Delta T = max(x) - min (x) (deg C), where delta T represents the change in temperature, max (x) represents the maximum temperature achieved and min(x) represents the temperature at the initial start time.

Position = x*radius (mm), where position is the linear position of the rod, x is the angular position in radians, of the Rotary Motion Sensor, and the rotary pin radius is 1.327 mm.

Delta X = max(x) - min(x), where max(x) represents the longest position attained and min(x) represents the initial position of the rod. The initial position is always zero.

Note: The position is calculated from the rotational change of the Rotary Motion Sensor pin. As the rod expands, it pushes against the pin and causes the pin to rotate. From the radius of the pin and the amount of angular rotation relative to the pin's zero position, the Rotary Motion Sensor determines the linear change in length (L) for the rod.

Experiment: Measuring the Coefficient of Linear Expansion for Copper, Brass, and Aluminum

Introduction

Most materials expand when heated through a temperature range that does not produce a change in phase. The added heat increases the average amplitude of vibration of the atoms in the material, which increases the average separation between the atoms.

Suppose an object of length L undergoes a temperature change of magnitude ΔT. If ΔT is reasonably small, the change in length, ΔL, is generally proportional to L and ΔT. Stated mathematically:

$$\Delta L = \alpha L \, \Delta T;$$

where α is called the coefficient of linear expansion for the material.

Materials that are not isotropic, such as an asymmetric crystal for example, α can have a different value depending on the axis along which the expansion is measured. The coefficient (α) can also vary somewhat with temperature. Therefore, the degree of expansion depends not only on the magnitude of the temperature change, but also on the absolute temperature.

In this experiment, you will measure α for copper, aluminum, and brass. These metals are isotropic, so it is necessary to measure α along only one dimension. Also, within the limits of this experiment, α does not vary with temperature.

Procedure

1. With a measuring tape or metric ruler, measure L, the length of the aluminum rod, at room temperature. Measure from the center of the stainless steel ring (in the groove of the small end block), to the center of the rotary pin at the other end (see Figure 1). Record your results in Table 1 in the Data and Calculations section.

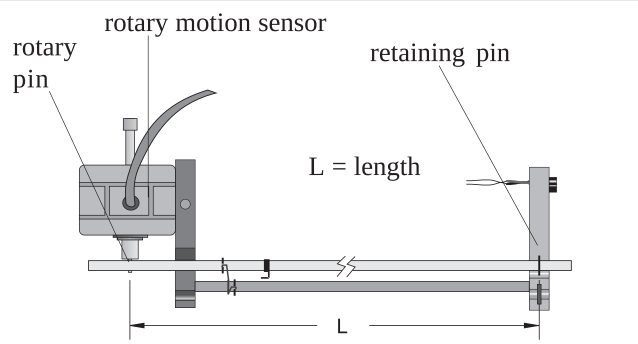


Figure 1: Measuring Tube Length

2. Insulate the rod and thermistor with a slitted, tubular foam wrap. Slide the foam wrap from underneath the rod until the foam covers the circumference of the rod. The spring clamp should jut out from the top of the foam slit (See Figure 2).

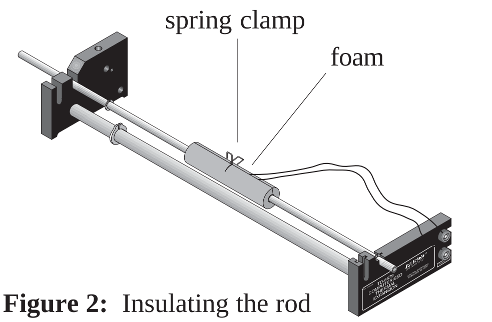


Figure 2: Insulating the rod

Experiment (Continued)

3. Cut and place the plastic tubing over both ports on top of the lid covering the Steam Generator (See Figure 3). [Note: Cut the tubing enough to allow it to reach the rod on the apparatus, but keep the tubing as short as possible, to prevent kinks and maximize rapid heat transfer.] Plug one end off with a plastic tube clamp. Connect the plastic tubing on the other port to one end of the metal rod (the labeled end block, away from the Rotary Motion Sensor).

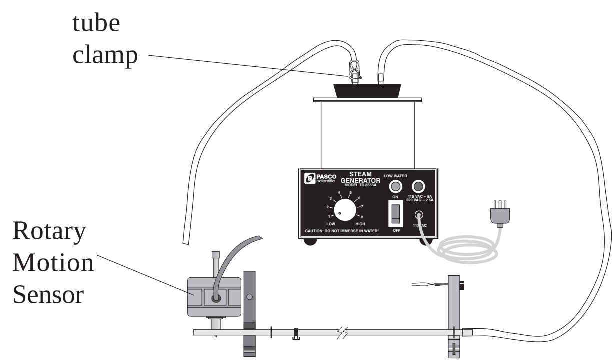


Figure 3: Connecting the tubing from the Steam Generator to the Thermal Expansion Apparatus

4. In DataStudio, load the provided setup diskette. (For more information on software setup, see page 4).

5. Fill the Steam Generator half to three-quarters full with water. Plug the Steam Generator into a three-receptacle outlet. [Do not use another outlet. Please refer to the Steam Generator instruction sheet (012-04696) for appropriate safety precautions and settings.]

6. Turn on the Steam Generator and wait for it to warm up. When you first hear a gurgle sound, (but before the steam travels through the clear tubing), click the START button to begin recording the temperature. Steam will begin flowing through the rod shortly thereafter. As steam begins to flow, watch the temperature rise in the DataStudio Graph display as the rod heats.

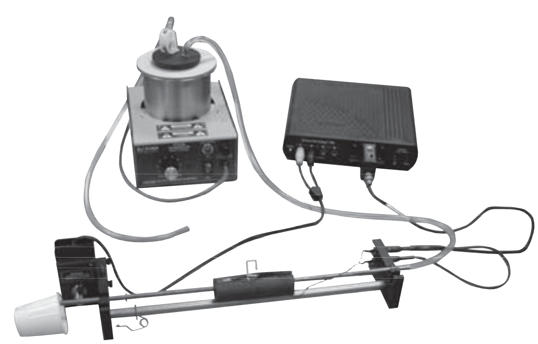


Figure 4: Experiment Setup

CAUTION: THE STEAM GENERATOR AND METAL ROD WILL BE HOT. TO AVOID BURNS, DO NOT TOUCH!

Note: Have a styrofoam cup or other basin available to capture the steam running off the rod (the end closest to the Rotary Motion Sensor.

When the temperature reading stabilizes, record the temperature change (ΔT) in Table 1. Also record the expansion of the rod's length (ΔL), as indicated by the position displacement (x in mm). [Note: If you want to increase the precision of your measurements, click on the Calculator button. In the Calculator dialog, click on Properties. Under Precision, enter the number to indicate the number of decimal places to display.]

7. In DataStudio, save your activity file for the aluminum rod. Repeat the experiment for the copper and brass rods.

Data and Calculations

1. In DataStudio, from the Digits display, record the maximum length change (delta ΔL) and the temperature change (ΔT) for each rod. Record your results in Table 1.
2. Using the equation $\Delta L = \alpha L \ \Delta T$, calculate α for copper, brass, and aluminum. Record your results in Table 2.

TABLE 1: Data and Calculations

Material	L (mm)	ΔL (mm)	ΔT (°C)
Copper			
Brass			
Aluminum			

TABLE 2: Coefficient of Thermal Expansion

Material	α coefficient ($x10^{-6}$/∞C)	α (experimental)	Percent difference (%)
Copper	17		
Brass	19		
Aluminum	23		

Questions

1. Look at the accepted values for the linear expansion coefficient for copper, brass, and aluminum (Table 2). Compare these values with your experimental values. What is the percentage difference in each case? Is your experimental error consistently high or low?

2. On the basis of your answers in question 1, speculate on the possible sources of error in your experiment. How might you improve the accuracy of the experiment?

Sample Data

The following are examples of data obtained using DataStudio™, a *ScienceWorkshop*® 750 Interface and the TD-8556A Steam Generator. The data will vary according to experimental conditions, setup modifications, temperature of the heat source, type of experiment, temperature units (degrees K, F, or C), etc.

Within Datastudio, you can use the cursor to adjust the axes to fit your data inside the Graph display. Other displays, such as the Digits or Table display, may be simultaneously or later opened to view actual data values. You can use the Smart Tool to display the coordinates for the values at room temperature and at the final temperature at equilibrum.

Note: The displays shown are in DataStudio version 1.5.2. DataStudio displays are subject to future modifications with continuous upgrades. The displays shown may not appear identical to those of later versions.

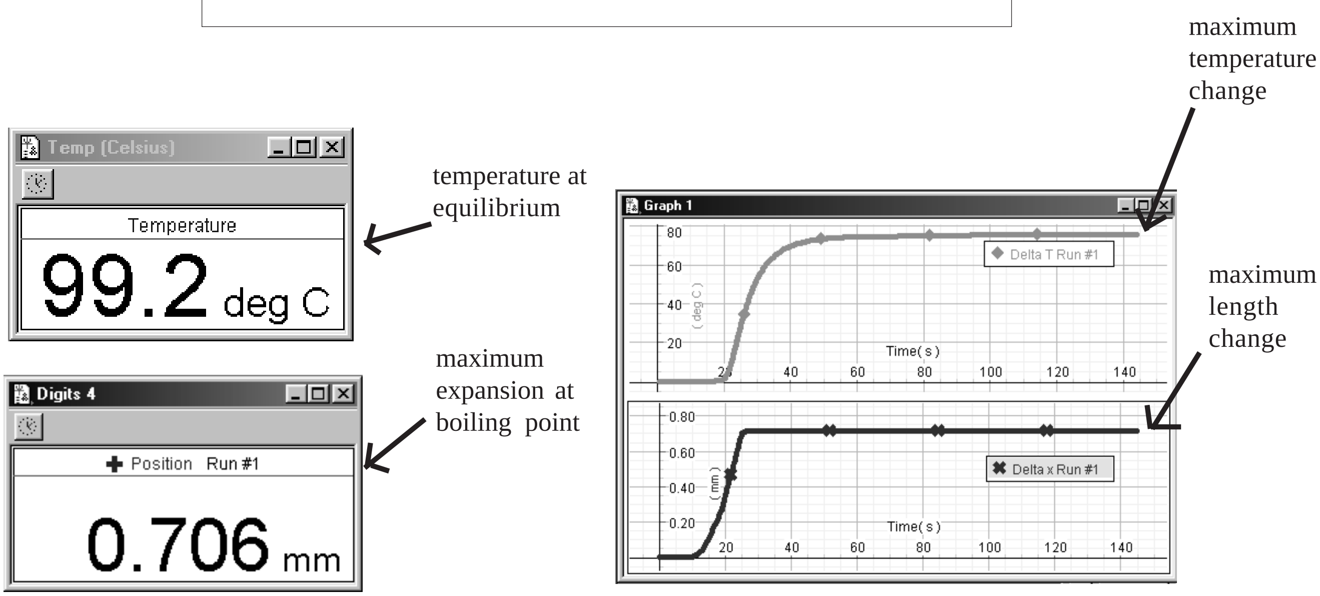


Figure 7: Data obtained during thermal expansion with the aluminum tube

Resistance to Temperature Conversion Chart (10KΩ Thermistor)

16460 Ω	14 °C	12,490 Ω	20 °C	9,574 Ω	26 °C	7,404 Ω	32 °C
15710 Ω	15 °C	11,940 Ω	21 °C	9,166 Ω	27 °C	7,098 Ω	33 °C
15000 Ω	16 °C	11,420 Ω	22 °C	8,778 Ω	28 °C	6,808 Ω	34 °C
14320 Ω	17 °C	10,920 Ω	23 °C	8,408 Ω	29 °C	6,532 Ω	35 °C
13680 Ω	18 °C	10,450 Ω	24 °C	8,058 Ω	30 °C	6,268 Ω	36 °C
13070 Ω	19 °C	10,000 Ω	25 °C	7,722 Ω	31 °C	6,016 Ω	37 °C

Table 3: Resistance to Temperature Conversion Chart (10 kΩ Thermistor)

Troubleshooting

Problem: *During the experiment, temperature measurements do not appear in an open DataStudio display.*

Solution(s): a) Ensure that all connections between the Thermistor lug and rod, and Thermistor Sensor and *ScienceWorkshop* interface are tight. (See Apparatus Setup on page 3 for instructions). b) In DataStudio, double click on the Thermistor icon. Click on the Measurement tab. Verify that there is a check in the box next to the Temperature option. If not, click to place a check inside this box. Click OK to save the changes.

Problem: *The temperature (or resistance if displaying) measurements do not appear accurate.*

Solution(s): a) Ensure that all connections between the Thermistor lug and rod, and Thermistor Sensor and *ScienceWorkshop* interface are tight. In the setup file the Thermistor Sensor is lugged into Channel B of the interface. (See Apparatus Setup on page 3 for instructions). b) Make sure that you have used the appropriate temperature equation for the units desired. The setup diskette includes the equation for temperature in degrees Celsius (C). To perform measurements in degrees Kelvin or Fahrenheit, define your own equation using the Calculator in DataStudio. c) If you have a couple of resistors available, you can calibrate and/or check the resistance measurement accuracy of the Thermistor Sensor using a voltmeter or multimeter. See the DataStudio online help for calibration instructions. d) If steps a), b), and c) fail to correct the problem, you may have a faulty Thermistor Sensor. Call PASCO's Technical Support Department (see page 11 of this manual) to order a replacement sensor. Only Thermistor Sensor model CI-6527A measures a 10 kΩ thermistor. Model CI-6527 only measures 100 kΩ thermistors.

Problem: *I want to view resistance measurements, but they do not appear in the Graph display.*

Solution(s): The setup diskette does not include the settings for showing resistance measurements. This is to help eliminate student confusion about resistance and shift the focus to temperature and thermal expansion. However, if you want your students to see resistance data during the experiment, do the following: a) In DataStudio setup window, double click on the Thermistor icon. Click on the Measurement tab. Verify that the box next to the Resistance option is checked. If not, click to place a check inside this box. Click OK to save your changes. Then perform another experiment run.

Problem: *In DataStudio, position (length) measurements do not display or appear inaccurate.*

Solution(s): a) Check to ensure that you have properly inserted the cables for the Rotary Motion Sensor into the *ScienceWorkshop* interface. If you have reversed your banana plug connections, you may observe negative readings. Also check that you have correctly aligned the rod in the expansion base of the Thermal Expansion Apparatus. (See page 3 for instructions). b) Check the software settings for the Rotary Motion Sensor in DataStudio. If you did not use the setup diskette provided for this experiment, go to the Experiment Setup window and double click on the Rotary Motion Sensor icon. In the General tab, set the sample rate to 5 Hz or try another sample rate. Click on the Measurement tab. Verify that Angular Position (Rad) is checked. Click on the Rotary Motion Sensor tab. Verify that the divisions per rotation is 1440. c) If steps a and b fail to yield accurate measurements, you may have a faulty Rotary Motion Sensor. Call PASCO's Technical Support department (see page 11 of this manual) for a replacement sensor.

Additional or Replacement Parts

You can order any of the following parts from PASCO scientific. See the Technical Support section of this manual (page 11) for telephone and address information.

Description	Part No.
Aluminum tube	648-07139
Banana plug connectors	517-010
Brass tube	648-07140
Copper tube	648-07141
Expansion base	003-07600
Experiment setup diskette	013-07599
Foam wrap, 6" length	716-041
Rotary Motion Sensor	CI-6538
Spring clamp	632-07090
Steam Generator	TD-8556A
Support tube	648-07086
Thermal Expansion Apparatus	TD-8579A
Thermistor, 10 kΩ	150-040
Thermistor Sensor	CI-6527A
Thermoplastic elastomer tubing with 6.4 I.D.	640-018

Technical Support

Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

To Reach PASCO

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

Fax: (916) 786-3292

E-mail: techsupp@pasco.com

Web: www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

➤ If your problem is with the PASCO apparatus, note:

- Title and model number (usually listed on the label);
- Approximate age of apparatus;
- A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
- If possible, have the apparatus within reach when calling to facilitate description of individual parts.

➤ If your problem relates to the instruction manual, note:

- Part number and revision (listed by month and year on the front cover);
- Have the manual at hand to discuss your questions.