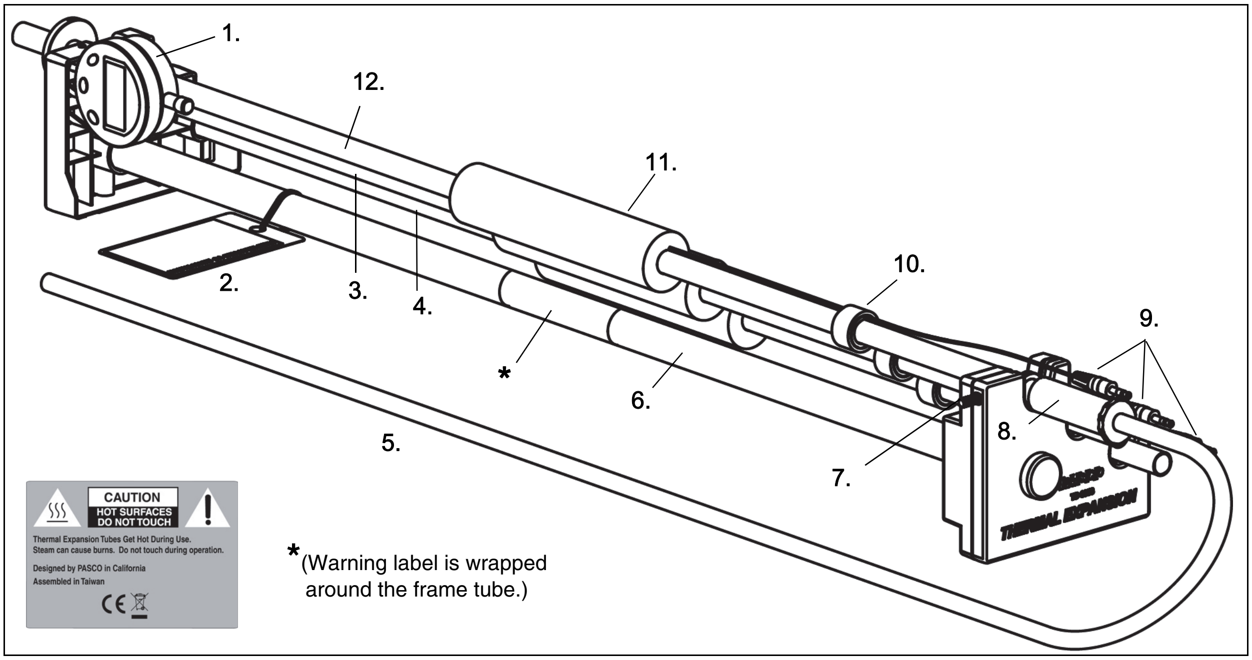
Thermal Expansion Apparatus

TD-8856



*(Warning label is wrapped around the frame tube.)

Included Items

Item	Description	Item	Description
1	Digital Measurement Indicator	7	Thumbscrew
2	Thermistor Conversion Table	8	Tubing Adapter
3	Metal Tube (aluminum, copper, or brass)	9	Thermistor Cable Assembly (3)
4	Metal Tube (aluminum, copper, or brass)	10	Hook and Loop Cable Tie (3)
5	Rubber Tubing, 9.25 mm O.D., 6.35 mm I.D	11	Foam Insulation (3)
6	Frame	12	Metal Tube

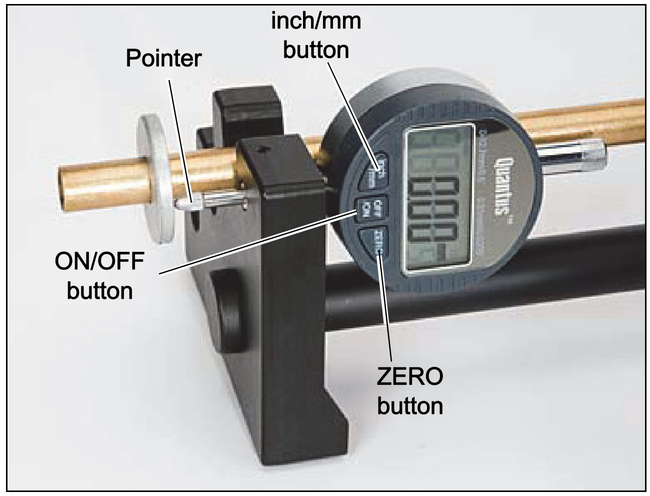
Introduction

The PASCO Thermal Expansion Apparatus provides easy and accurate measurements of the coefficient of linear expansion for brass, copper, and aluminum.

To make a measurement, the brass, copper, or aluminum tube is placed on the top position of the apparatus frame. The length of the tube is measured at room temperature, and then steam is passed through it. The expansion of the metal is measured with 0.01 millimeter resolution using the built-in digital measurement indicator. Temperature is measured to within 0.5°C using a 10,000 ohm (10 kilo-ohm) thermistor that is attached to the center of each metal tube and covered with foam insulation. The output from the thermistor can be read using a digital ohmmeter or a PASCO temperature sensor that accepts the thermistor's stereo phone plug (such as PS-2125 PASPORT Temperature Sensor). If you wish to investigate the expansion of the metals at additional temperatures, hot or cold water can be passed through the tubes.

This manual contains descriptions of the included equipment, complete instructions for the experiment, and additional information.

Equipment



The Thermal Expansion Apparatus has a 74 cm long base with a built-in digital measurement indicator. The digital indicator has three control buttons: ON/OFF, ZERO, and inch/mm, When one of the metal tubes is mounted in the frame, the end of the digital indicators pointer rests against the circular disk attached to the tube. The digital indicator end of the frame is slightly lower than the other end in order to allow liquid to drain out of the metal tube.

The three metal tubes are approximately 83.18 cm (32.75 in) in length, with a 1.27 cm (0.50 in) outside diameter. The material for each of the tubes is as follows:

- Aluminum: drawn aluminum tube, 6061-T6
- Brass: drawn brass tube, C270
- Copper: hard drawn copper tube, C122

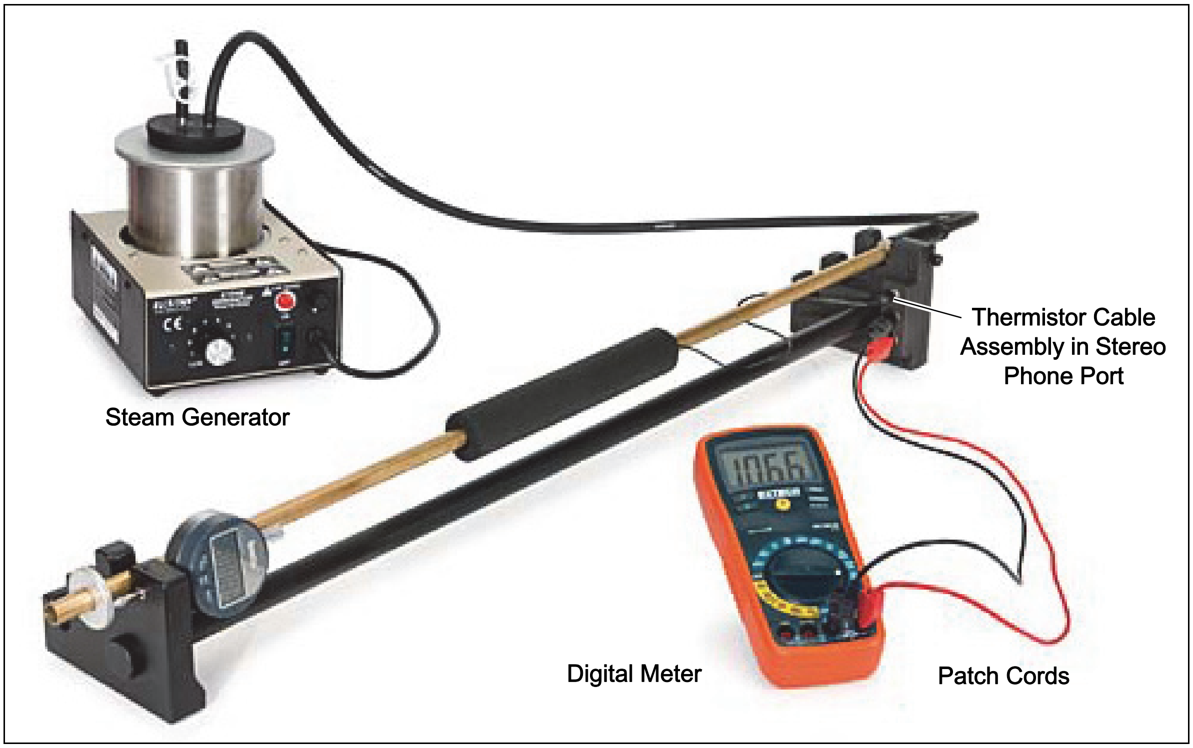
Each tube has a 10 kΩ thermistor attached at its midpoint. A thermal paste is spread between the thermistor and the surface of the tube. The foam insulation on each tube helps to avoid heat loss at the thermistor connection point. The thermistor cable assembly connects directly to a port on the “high” end of the frame. A digital ohmmeter connects to the banana jacks just below the port.

The apparatus includes a piece of Norprene® (neoprene) rubber tubing approximately 1 m (39”) long with a tubing adapter at one end. The tubing adapter fits snugly over the end of the metal tube. The other end of the tubing can be connected to a steam generator (such as the PASCO TD-8556).

Additional Equipment Required

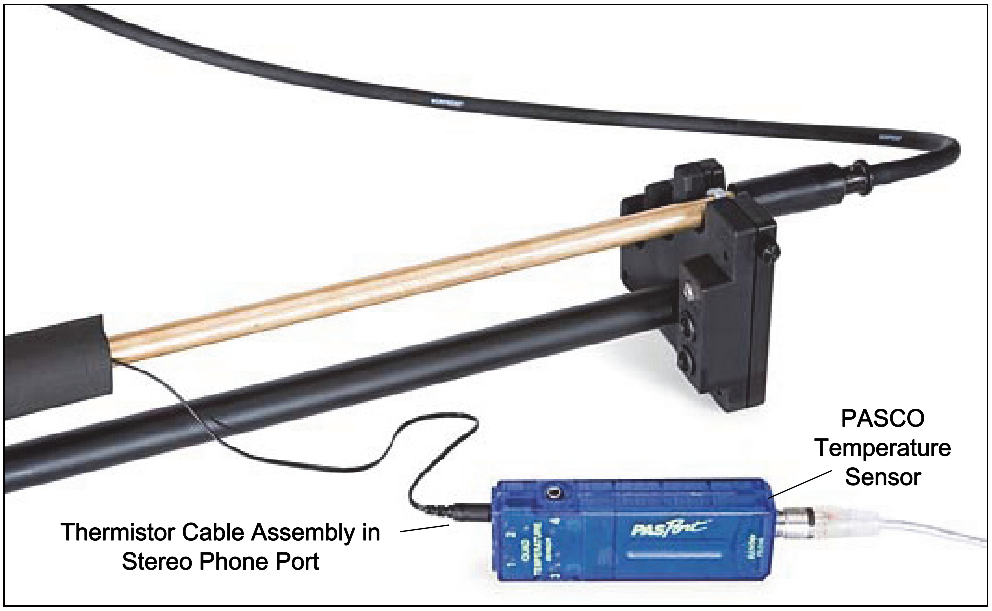
The following items are needed to perform the experiment:

- A source of steam or hot water, such as the PASCO TD-8556 Steam Generator.
- A digital ohmmeter (or multimeter that reads resistance). NOTE: Depending on what is included with the meter, you may also need banana plug patch cords for connecting the apparatus to the meter. See the PASCO web site at www.pasco.com for more information about meters and banana plug patch cords.
- A container to catch any water as it drains out of a tube.



Using a PASCO Sensor with the Apparatus

The thermistor cable assembly can also connect directly to the stereo port found on several PASCO temperature sensors and MultiMeasure ™ sensors. Examples are the PS-2125 PASPORT Temperature Sensor and the PS-2168 PASPORT General Science Sensor.



Using a PASCO sensor with the apparatus requires an interface and software.

An interface for the PASCO Temperature or MultiMeasure Sensor

PASCO offers several interfaces that support temperature sensors and MultiMeasure sensors. Examples include: PS-3200 Wireless AirLink, PS-2011 SPARKlink Air, UI-5001 550 Universal Interface, and the UI-5000 850 Universal Interface. See the PASCO web site at www.pasco.com for more information.

PASCO Capstone Software or SPARKvue

PASCO Capstone Software is best for Windows or Mac in Physics and Engineering laboratories. The site license allows students to use it at home.

Use SPARKvue if you are on a mobile platform: iOS, Android, or Chrome.

Notes on Temperature Measurement

A thermistor’s resistance varies reliable with temperature. The resistance can be measured with an ohm-meter and converted to a temperature measurement using the conversion table provided on the tag attached to the apparatus and also found at the end of this manual. 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 ±0.2°C.

The thermistor used to measure the tube temperature is embedded in that thermistor lug that is fastened to the tube. Once thermal equilibrium has been reached, the heat is highly uniform along the length of the tube. The foam insulation is used to inhibit heat loss th rough the thermistor lug so the lug temperature closely follows the tube temperature. The insulator does not have an appreciable effect on the local temperature of the tube itself.

WARNING! HIGH TEMPERATURE

The metal tube gets hot during the experiment. Steam can cause burns. Do not touch the metal tube during operation.

Accepted Values for the Coefficient of Thermal Expansion, α_L

Material	α_L(x 10^{-6}/°C)	Composition (%)
Aluminum (6061-T6)	23.6	Al (95.8 - 98.6), Mg (0.80 - 1.2), Fe (<0.70), Si (0.40 - 0.80)
Brass (C270)	20.3	Brass (63 - 68.5), Zn (31.3 - 37), Pb (0.1), Fe (0.07)
Copper (C122)	17.0	Cu (99.9), P (0.02 nominal)

Replacement Parts

Contact PASCO Technical Support regarding possible replacement parts.

Technical Support

For assistance with any PASCO product, contact PASCO at:

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

Phone: 916-462-8384 (worldwide)
800-772-8700 (U.S.)

Web: www.pasco.com

Email: support@pasco.com

Limited Warranty

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

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

Required Equipment

Thermal Expansion Apparatus	Steam Generator
Container (to catch water)	Meter Stick or Measuring Tape

Introduction

Most materials expand somewhat 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.

For 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 so that the degree of expansion depends not only on the magnitude of the temperature change, but on the absolute temperature as well.

In this experiment, you will measure α for aluminum, brass, and copper. These metals are isotropic so that a need only be measured along one dimension. Also, within the limits of this experiment, a does not vary with temperature.

Procedure

1. Measure L, the length of the aluminum tube at room temperature. Measure from the inner edge of the larger circular disk on one end to the inner edge of the smaller circular disk at the other end (see Figure 1). Record your results in Table 1.

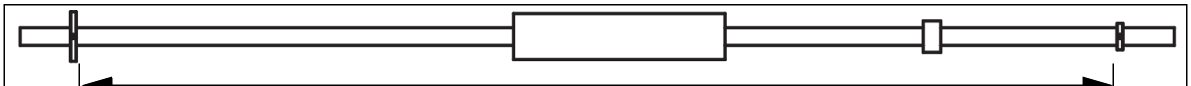


Figure 1

2. Mount the aluminum tube in the apparatus frame as shown in Figure 2. The smaller circular disk on the tube fits into a slot on the “high” end frame. The larger circular disk on the tube presses against the tip of the spring arm of the dial indicator.

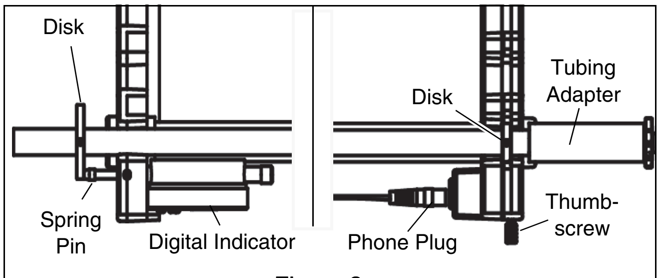


Figure 2

3. Turn the metal tuabe so that the thermistor lug under the foam insulation is on top. Connect the phone plug on the end of the thermistor cable into the phone port on the “high” end frame, or into the phone jack on a compatible PASDCO sensor.

4. Tighten the thumbscrew in the “high” end frame against the tube until it can no longer be moved. .

5. Make sure that the foam insulator is centered over the thermistor lug.

6. If you are used an ohmmeter (or multimeter), plug the leads of your ohmmeter into the banana plug connectors on the “high” end frame just under the phone plug port.

7. Measure and record R_{rm}, the resistance of the thermistor at room temperature. Record this value in the table.

8. Attach the tubing adapter of the rubber tubing to the end of the aluminum tube. (Attach it to the end farthest from the digital indicator.) Connect the other end of the tubing to the steam generator.

9. Place a container under the other end of the tube to catch the draining water that condenses in the tube.

10. Press the ON/OFF button on the digital indicator to turn it on. Press the ZERO button to set the initial digital reading to zero. As the tube expands, the spring pin of the digital indicator will stay in contact with the larger circular disk on the tube.

11. Turn on the steam generator. As steam begins to flow, watch the digital display and the resistance reading on the ohmmeter (or computing device). When the thermistor resistance stabilizes, record the resistance (R_{hot}) in Table 1. Also record the expansion of the tube length (ΔL) as indicated by the display on the digital indicator.

- Repeat the experiment for the other two metal tubes.

Data and Calculations

Table 1: Results

	Data				Calculations		
Tube	L (mm)	R_{rm} (Ω)	ΔL (mm)	R_{hot} (Ω)	T_{rm} (°C	T_{hot} (°C)	ΔT (°C)
Aluminum							
Brass							
Copper							

1. Use the Conversion Table at the end of this manual, or the one attached to the frame tube of the apparatus, to convert your thermistor resistance measurements, R_{rm} and R_{hot}, into temperature measurements, T_{rm} and T_{hot}. Record your results in the table.

2. Calculate $\Delta T = T_{hot} - T_{rm}$. Record the result in the table.

3. Using the equation $\Delta L = \alpha L \Delta T$, calculate α for aluminum, brass, and copper.

- Aluminum = __________
- Brass = ___________
- Copper = ______________

Questions

1. Look up the accepted values for the linear expansion coefficient for aluminum, brass, and copper. 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?

3. From your result, can you calculate the coefficients of **volume** expansion for aluminum, brass, and copper? (i.e. $\Delta V = \alpha_{vol} V \Delta T$)

Thermistor Conversion Table

Temperature Versus Resistance

THERMISTOR: TEMPERATURE VERSUS RESISTANCE

55,142 Ω	-10 °C	26,645 Ω	4 °C	13,676 Ω	18 °C	7,405 Ω	32 °C
52,235	-9	25,357	5	13,068	19	7,100	33
49,499	-8	24,138	6	12,491	20	6,810	34
46,924	-7	22,984	7	11,941	21	6,534	35
44,500	-6	21,892	8	11,418	22	6,271	36
42,215	-5	20,858	9	10,921	23	6,019	37
40,057	-4	19,880	10	10,450	24	5,778	38
38,025	-3	18,953	11	10,000	25	5,549	39
36,107	-2	18,074	12	9,572	26	5,329	40
34,298	-1	17,242	13	9,166	27	5,120	41
32,590	0	16,452	14	8,778	28	4,920	42
30,974	1	15,704	15	8,409	29	4,729	43
29,448	2	14,992	16	8,058	30	4,546	44
28,007	3	14,317	17	7,724	31	4,371	45

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THERMISTOR: TEMPERATURE VERSUS RESISTANCE

4,204 Ω	46 °C	2,489 Ω	60 °C	1,531 Ω	74 °C	975 Ω	88 °C
4,045	47	2,401	61	1,480	75	945	89
3,892	48	2,317	62	1,432	76	917	90
3,745	49	2,236	63	1,386	77	889	91
3,601	50	2,158	64	1,341	78	862	92
3,471	51	2,084	65	1,298	79	837	93
3,342	52	2,012	66	1,256	80	812	94
3,219	53	1,942	67	1,216	81	788	95
3,101	54	1,877	68	1,178	82	765	96
2,988	55	1,814	69	1,141	83	742	97
2,880	56	1,753	70	1,105	84	721	98
2,776	57	1,694	71	1,071	85	700	99
2,677	58	1,637	72	1,038	86	680	100
2,580	59	1,583	73	1,006	87		

Teacher's Notes

Notes on Procedure

If you allow too much time to elapse before making your length measurements, the digital indicator spring pin will absorb heat, which will decrease the measurement. The thermistor takes longer to reach equilibrium than the tube, though, so you must allow a little time for your temperature measurement to stabilize.

To get the best results despite these problems, record the maximum change in length shown on the digital indicator display, and the minimum resistance recorded by the ohmmeter (or computing device).

Notes on Questions

1. The answers about how well the experimental values compare to the accepted values will vary. Sample data show percent difference of 2% or less. Answers about the difference in values being consistently high or low will vary.

2. Answers about possible sources of error and improvement of the accuracy of the experiment will vary.

3. From your result, can you calculate the coefficients of **volume** expansion for aluminum, brass, and copper? (i.e. $\Delta V = \alpha_{vol} V \Delta T$).

   One possible answer is $\alpha_{vol} = (\alpha_{linear})^3$