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# Experiment 10 – Coefficient of Linear Thermal Expansion

## Objective

To measure the coefficient of linear thermal expansion for several metals.

## Equipment

- Linear Expansion apparatus.
- Metal rods.
- Rubber stoppers.
- Boiler.
- Hot plate.
- Rubber hoses.
- 2 beakers (to collect condensation).
- Hot pads.
- Meter stick with caliper jaws.
- -20°C–110°C *or* -20°C–150°C thermometer.
- Power supply.
- Light bulb.

## Theory

We've seen in lecture that increasing the temperature of a gas increases the average kinetic energy of the gas molecules. This means that the gas molecules are moving at a higher average speed. The molecules in a solid, while not free to move about at random, respond to changes in temperature in a similar fashion. As the temperature increases, the molecules in a solid vibrate more vigorously about their average positions. As the amplitude of this vibration increases, the molecules effectively fill a larger volume of space: the solid expands. In this experiment we will study the change in length of several rods of different metals as they change in temperature.

Experimentally, it is observed that the change in length of an object is proportional to its original length and to the change in temperature:

$$\Delta L = \alpha L_0 \Delta T. \tag{1}$$

The proportionality constant $\alpha$ is called the coefficient of linear thermal expansion. The "normal" length of the object, $L_0$, is typically its length at 0°C. However, for most solids, we may use the length at room temperature with very little difference in the results.

## Procedure

1. Fill the boiler $\frac{1}{3}$ to $\frac{1}{2}$ full of water, attach a hose to the steam outlet, screw on the lid, and start heating it on the hot plate.

2. Attach the power supply to the inputs on the thermal expansion apparatus.

3. Measure the length of one of the metal rods with the meter stick and caliper. (Tip: Since the length of the rod is the difference between the readings of the calipers at each end, you may wish to position one of the two caliper jaws at a convenient value, like 10.00 cm.) Record your measurement in the table on page 3.

4. Insert the rod into the heating jacket at attach it to the linear expansion apparatus. Make sure that the fixed end of the rods in contact with the stop: insert a folded up piece of paper to raise the rod if necessary. Tighten the vertical screw to hold the steam jacket in place. *Carefully* insert the thermometer. A small bottle of glycerin is available to lubricate the glass if necessary. Adjust the vernier end of the linear expansion apparatus until there is electrical contact at both ends of the rod. Turn on the power supply and slowly increase the voltage until the bulb lights. *Do not exceed 10 volts!*

5. Back the vernier away from the rod. Move the vernier towards the rod slowly, and stop as soon as the light bulb lights. Record the vernier reading. (Each full turn of the verier equals 1 millimeter. Since the scale on the verier is divided into 100 parts, you can read it to the nearest $\frac{1}{200}$ mm, that is, to the nearest 0.005 mm.) Repeat this 3 times (for total of 4 readings), and compute the average.

6. Record the initial temperature reading from the thermometer.

7. Back the vernier away from the rod 3 full turns. (Carefully keep track of this or use the horizontal scale below the vernier disk. Each turn advances the edge of the disk by one marking on that scale.) Connect the boiler to the steam jacket and wait until equilibrium is reached. Record the final temperature of the rod.

8. Move the vernier towards the rod, and stop as soon as the bulb lights. Record the vernier reading. Repeat 3 times (for a total of 4 readings) and compute the average value. The difference between the hot and cold vernier readings gives the change in length of the rod in millimeters.

9. Remove the steam connection from the jacket. Disassemble when cool enough to handle. Further cool the jacket and rod to room temperature under cold running water. Note that rubber has a low thermal conductivity: you will have to allow sufficient time for the stoppers (including the one around the thermometer) to cool off throroughly.

10. Repeat steps **3**–**9** for the next sample. Between samples is a good time to refresh the water level in the boiler, if necessary.

11. Using Eq. (1) and the data you have collected, compute your measured of the coefficient of linear thermal expansion $\alpha$. Compare to the accepted value by computing the percentage difference $[(measured - accepted)/accepted]$. Use a separate piece of paper, if necessary.

**TABLE 1: Data for Coefficient of Linear Expansion**

| | Copper | Brass | Aluminum | Steel |
|---|---|---|---|---|
| Unheated Length of Rod ($L_0$) | | | | |
| Avg. Cold Vernier Reading (from Table 2) | | | | |
| Avg. Hot Vernier Reading (from Table 3) | | | | |
| Change in Length ($\Delta L$) | | | | |
| Initial Temperature | | | | |
| Final Temperature | | | | |
| Change in Temperature ($\Delta T$) | | | | |
| Measured Value of $\alpha$ | | | | |
| Accepted Value of $\alpha$ | $17 \times 10^{-6}/°C$ | $19 \times 10^{-6}/°C$ | $23 \times 10^{-6}/°C$ | $11 \times 10^{-6}/°C$ |
| % difference | | | | |

**TABLE 2: Cold Vernier Readings**

| | Copper | Brass | Aluminum | Steel |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| avg. | | | | |

**TABLE 3: Hot Vernier Readings**

| | Copper | Brass | Aluminum | Steel |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| avg. | | | | |