Name _____ Class _____ Date _____

LAB #9: THERMAL EXPANSION OF METALS

OBJECTIVES:

To study how the length of various metal tubes change when their temperature is increased.

EQUIPMENT:

Equipment Needed	Qty	Equipment Needed	Qty
Thermal Expansion Apparatus	1	Steam Generator	1
Thermal Expansion Container	1	Multimeter	1
Meter Stick	1	600mL Beaker	1
Paper Towels			

<mark>**SAFETY REMINDER**</mark> • Follow all safety instructions. • Keep the area clear where you will be working and walking.	**THINK SAFETY** **ACT SAFELY** **BE SAFE!**

INTRODUCTION:

In this lab you will determine experimentally the coefficient of linear expansion for two metal tubes, one copper and one aluminum.

PROCEDURES:

Answer all of the questions on this handout.

PART 1: Determining the Coefficient of Linear Expansion for Copper

With the large plastic beaker, fill your steam generator about three-quarters full of water. Plug it in, turn it on, and adjust the temperature setting to its maximum position. Place the free end of the rubber tube in the large beaker. The equipment that you will be using for the tubes is shown below in Figure #1.

The equation that describes the amount that the length of an object increases with temperature is

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

where "ΔL" is the change in length of the object, "α" is the coefficient of linear expansion, "L_o" is the original length of the object, and "ΔT" is the change in the object's temperature. We will

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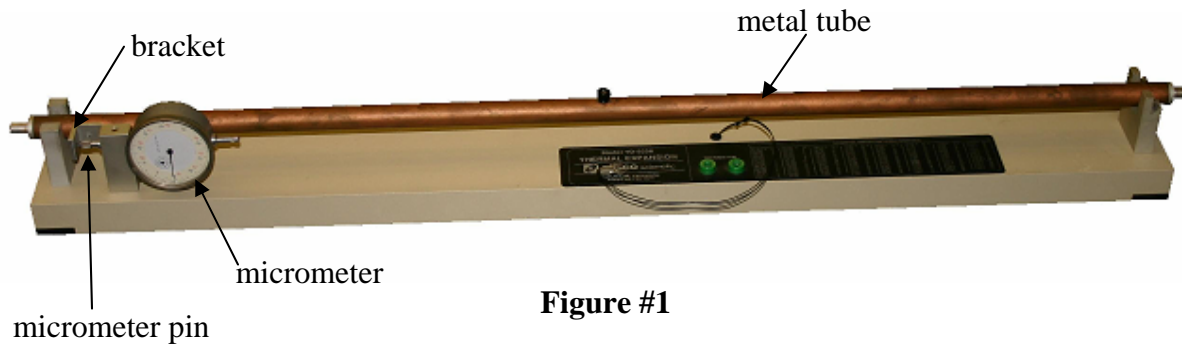be determining the values for "α" for two metals, copper and aluminum.

Figure #1

To measure "ΔL" we will be using a device which holds one end of the tube stationary and then measures the motion of the other end with a micrometer. You will notice that on your apparatus, the tube is held fixed at one end, where the pin through the center is held fixed, and the other end with the bracket is free to move horizontally. The inside edge of the bracket is touched by the micrometer pin, which will accurately measure any motion of the bracket. Remove the tube and notice the direction the micrometer dial gauge moves as the pin is moved in and out of the micrometer. You should notice that the dial moves clockwise when the pin is pushed in the micrometer, and the dial moves counterclockwise when the pin is let out of the micrometer.

1. In what direction will the dial move if the length of the tube increases?

2. As the length of the tube increases, will the dial reading increase or decrease?

Notice that the dial has two needles, a larger needle that indicates numbers on the outer rim of the dial, from 0 – 100, and a smaller needle that is set within the larger circle. One complete rotation of the larger needle will advance the smaller needle one unit. Move the micrometer pin in and out a few times until you understand how the needles move.

Put the copper tube on the mount and set the micrometer pin on the tube's bracket. With your hand pull the pin away from the bracket until the larger needle has made exactly one rotation. Notice the distance between the end of the pin and the bracket. This distance will be a standard metric unit and is the answer to the next question.

3. What distance does the micrometer pin move for one complete rotation of the large needle?

These will be the units for distances measured by the micrometer. The small needle will give the "ones" place; the large needle will give the "tenths" and "hundredths" place.

With the meter stick measure the length of the metal tube. The important length is from the center of the fixed pin through the tube, to the inside of the bracket where the micrometer pin rests. Measure this to the closest 0.001m .

4. What is the initial length of the tube?

Attach the thermistor sensor to the center of the tube and lightly tighten the plastic nut. Cover the sensor with the foam sleeve to minimize heat loss. With two wires attach the multimeter to the thermistor plugs and measure the resistance of the thermistor. Your set-up should look like Figure #2. Make sure to use the multimeter setting that will give you the greatest accuracy.
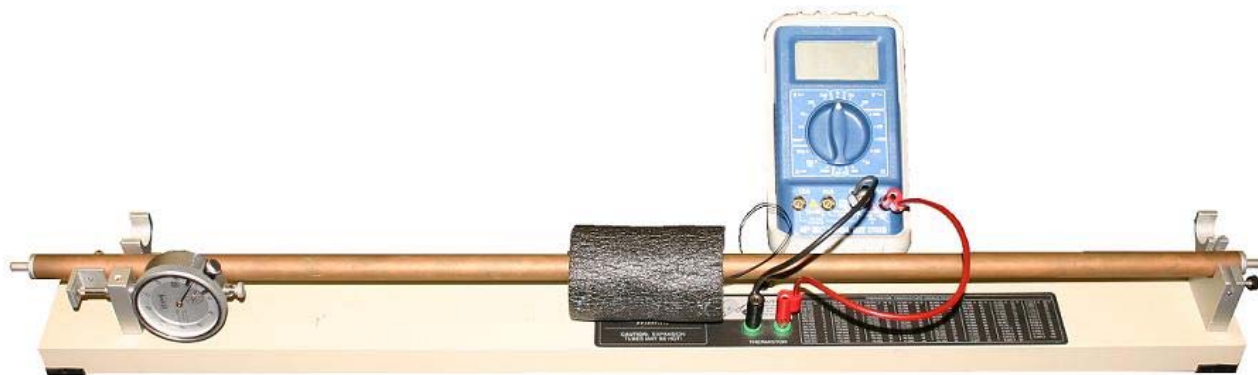

Figure #2

5. What is the resistance of the thermistor?

The resistance of the thermistor varies with its temperature, and so we can use this resistance measurement to determine the tubes temperature. On the front of the apparatus there is a table which lists the corresponding temperature for a number of resistances. Notice that higher resistances correspond to lower temperatures. The resistance the you measured will most likely fall between two of the values on the table. We will use interpolation to determine the correct temperature to the closest $0.1^{o}C$. Enter your measured resistance for "R" in Date Table #1.

From the table on the apparatus, find the resistance just above and just below your measured value. Enter these values as R_1 and R_2 respectively, along with their corresponding temperatures, in Data Table #1.

	Resistances	Temperatures
Higher Resistance / Lower Temp. Values	$R_1 =$	$T_1 =$
Measured / Calculated Values	$R =$	$T =$
Lower Resistance / Higher Temp. Values	$R_2 =$	$T_2 =$

Data Table #1

To use interpolation to find "T", we will assume that resistance and temperature are linearly related between the values of (R_1, T_1) and (R_2, T_2). This is an approximation, but it will give us a result that is good enough. Conceptually speaking, we will assume that the fraction of "$R_2 - R_1$" that "R" is from "R_1" is the same fraction of "$T_2 - T_1$" that "T" is from "T_1". That is,

$$\frac{R - R_1}{R_2 - R_1} = \frac{T - T_1}{T_2 - T_1}.$$

Use this equation to solve for your value of "T" to the closest 0.1°C and put it in Data Table #1.

Place the wood block under the end of the set-up that is farthest from the micrometer. Place the small plastic beaker under the other end of the metal tube. This will catch the condensed water that drips out of the metal tube.

6. What is the micrometer reading to the nearest 0.01mm?

If the water in the steam generator is boiling, be very careful of the steam coming from the end of the rubber tube. Connect the hose from the generator to the raised end of the tube. Now be careful of the escaping steam from the other end of the tube. Your set-up should now look like Figure #3.
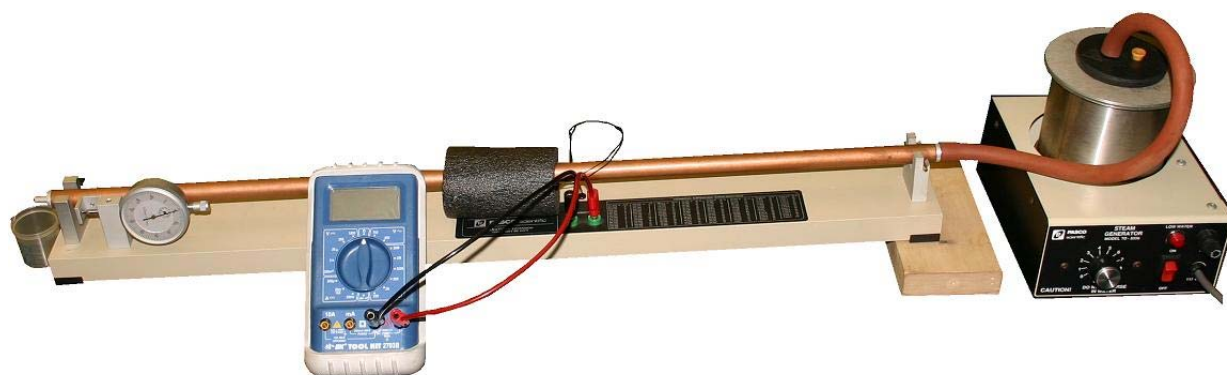

Figure #3

Watch the micrometer and the multimeter. As the tube heats up, it will expand, changing the reading on the micrometer. Also, as the thermistor heats up along with the tube, its resistance will change, and so the multimeter reading will drop. Wait until the micrometer reading has stopped changing and the multimeter reading has stabilized. The multimeter might continue to fluctuate, but the changes should be small.

7. What is the final micrometer reading?

8. What is the final multimeter reading?

Using your final multimeter reading, interpolate to determine the final temperature of the tube to $0.1^{\circ}C$.

9. What is the final temperature of the tube?

10. What is ΔL for the tube?

11. What is ΔT for the tube?

Using the linear expansion equation,

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

determine the linear expansion coefficient for copper.

12. What is your experimental value for α_{copper}? (Include your units.)

13. What is the accepted value for α_{copper}?

14. What is the percent error of your value?

PART 2: Determining the Coefficient of Linear Expansion for Aluminum

You will now perform the same experiment with the aluminum tube. Be very careful with the copper tube now that it is hot. Wait until it is cool enough to handle and then replace it with the aluminum tube, but do not attach the steam generator, yet. Proceed with the instructions as you did for the copper tube.

15. What is the initial length of the aluminum tube?

16. What is the initial resistance of the thermistor?

17. What is the initial temperature of the tube to the nearest 0.1°C?

18. What is the initial micrometer reading to the nearest 0.01mm?

19. After heating, what is the final micrometer reading?

20. What is the final resistance of the thermistor?

21. What is the final temperature of the tube?

22. What is your experimental value for $\alpha_{aluminum}$?

23. What is the accepted value for $\alpha_{aluminum}$?

24. What is the percent error of your value?

25. List two factors that could have contributed to your percent errors.

   a)

   b)

Clean-Up

Turn off your steam generator, unplug it, and remove the rubber stopper from the top. Leave the generator, with the water in it, on your bench to cool. Return all of the other equipment to the arrangement in which you found it.