

DILATOMETRY

1. PURPOSE OF THE WORK

Determination of the coefficients of linear expansion for different materials (brass, copper, aluminum, steel and Duran glass) and the coefficient of cubic expansion (in volume) for water.

2. THEORETICAL NOTIONS

The quantitative characterization of the thermal expansion of a body at constant pressure is done with the help of the mechanical constant of material α , called the cubic coefficient of thermal expansion:

$$\alpha = \frac{1}{V} \left(\frac{\partial V}{\partial T} \right)_P \quad (1)$$

This coefficient shows how the body volume varies with the temperature for isobaric processes. If only one dimension (e.g., length l) is taken into account, the linear coefficient of expansion is obtained:

$$\alpha_l = \frac{1}{l} \left(\frac{\partial l}{\partial T} \right)_P \quad (2)$$

Due to the fact that the variations in length $\Delta l = l - l_0$ are small compared to the initial length l_0 , we can write:

$$\alpha_l = \frac{1}{l_0} \left(\frac{\Delta l}{\Delta T} \right)_P \quad (3)$$

Similar,

$$\alpha = \frac{1}{V_0} \left(\frac{\Delta V}{\Delta T} \right)_P \quad (4)$$

where V_0 = the initial volume of water before the temperature changes

l_0 = the initial length of the pipe

Linear expansion of different solids and volumetric expansion of liquids are temperature functions. For the metallic materials to be tested, the length variation is a linear temperature function in the selected temperature range. In the case of materials with temperature-dependent coefficients of expansion, the graph is not a straight line, the coefficients of expansion can only be calculated over a temperature range or can be expressed as polynomial functions.

3. EXPERIMENTAL PART

3.1. APPARATUS AND SUBSTANCES

- dilatometer with comparator, immersion thermostat, thermometer, thermostatic bath, rubber hoses, metal pipes, flat bottom flask, graduated tube, 50 mL syringe, 1 mL syringe, distilled water.

3.2. PROCEDURE

In order to investigate the linear expansion, pipes made of brass, copper, aluminum, steel and Duran glass are used through which the water from a thermostatic bath circulates. The length variation is measured at 5 temperatures in the range of 20-70 °C using a dilatometer (fig.1).

The measurement of the water volume variation is performed at 5 different temperatures in the range of 20-70 °C using a flat-bottomed flask with a graduated vertical glass tube (pycnometer) attached, placed in the thermostated bath (fig. 1).

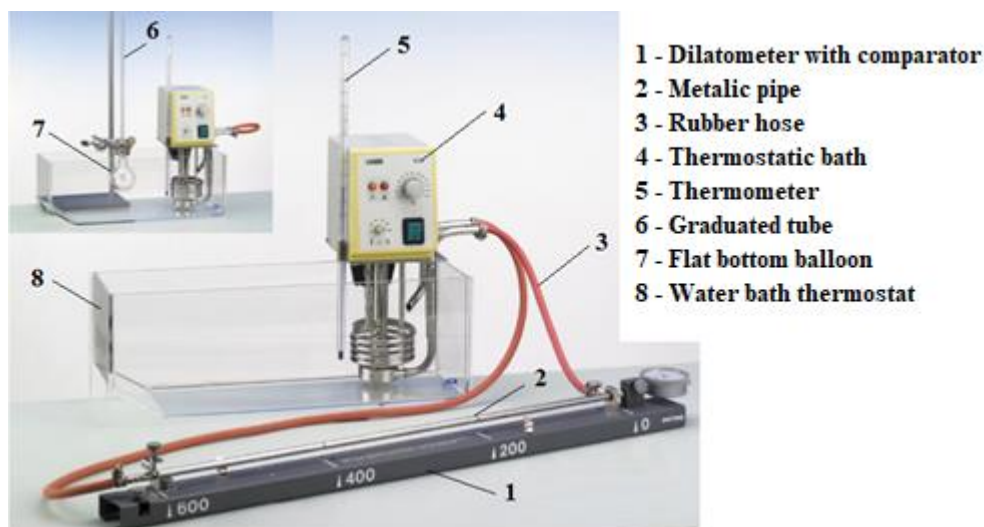


Fig. 1. Experimental installation

I. Measurement of linear expansion

Check with the thermometer mounted in the water bath if the water in the thermostat is cold. If it is not cold, empty the water bath and change the water. Start the thermostat pump without starting the heating yet. Read the temperature on the bath thermometer until it remains constant (~ 3 minutes). If the value is too high (> 25-30 °C), stop the thermostat pump, change the water again and restart the pump waiting for the temperature to stabilize. The water in the bath can be cooled also by opening the cold water flow, starting the pump

without heating, and wait for temperature of water in the bath to drop below 30 °C. After the temperature has stabilized, the comparator is set (by rotating the dial) to zero. Note the initial temperature in the results table and start heating the thermostat by setting the temperature to ~75 °C. The thermometer in the water bath is also monitored and when it indicates temperatures of 30 °C, 40 °C, 50 °C, 60 °C and 70 °C read and note as accurately as possible the value displayed by the comparator corresponding to each temperature.

Turn off the heating and thermostat pump and carefully drain the (**hot!**) water from the thermostat, replacing it with a cold one. Lift the platform on which the pipe is mounted and open the hoses, making sure that they are held in the air at a higher height than the water in the bath. Attach the second pipe along its entire length to the platform and reconnect the rubber hoses. Check that the comparator rod is in firm contact with the pipe and securely fastened. Keep the hoses as far away from the platform as possible so as not to overheat it. The measurements are resumed, following the above procedure for each of the other materials. After completing the measurements, the pump and the thermostat are switched off.

II. Measurement of the volume variation of a liquid (volume expansion)

The first step is to calibrate the pycnometer. For this purpose, measure the mass of the empty pycnometer and then fill the pycnometer with water. First fill the flask with a flat bottom, and a syringe is used to bring the water level into the graduated tube to the "100" graduation. Then heat the pycnometer with water, in a thermostated bath at 80 °C, to remove the dissolved gas. After this, it is thermally balanced at 25 °C and all the gas bubbles are removed (**CAUTION! Hitting the graduated tube can lead to its rupture**). Read the water level in the graduated tube, carefully dry its outer surface and weigh the pycnometer again. Use the syringe to inject 1 mL of water into the graduated tube and balance the temperature of the new volume to the same value of 25 °C. Read the level again and weigh the pycnometer. Repeat the procedure for different filling levels. Based on these values and the density of water at 25 °C (0.9970 g / cm³), the volume corresponding to a graduation can be calculated. This value should be around 0.01 mL.

After calibration, measure the volume of water at 5 different temperatures between 25 °C and 70 °C.

4. EXPERIMENTAL DATA PROCESSING

4.1. The measured data are entered in a table of the following form for each material, noting the value of the initial temperature:

	(Initial temperature), °C	30 °C	40 °C	50 °C	60 °C	70 °C
Δl Brass, mm	0					
Δl Copper, mm	0					
Δl Aluminum, mm	0					
Δl Steel, mm	0					
Δl Duran glass, mm	0					

One unit on the comparator is equal to 0.01 mm.

4.2. To determine the coefficients of linear expansion and the coefficient of cubic expansion, graphical representations of the variation of the pipe length (Δl) and, respectively, of the water volume as a function of temperature (T) are made;

4.3. The coefficients of linear expansion for each material are calculated analytically based on equation (4) and graphically, dividing the slope of the linearization line of the graphical representation $\Delta l = f(T)$ to the initial length of the pipe ($l_0 = 600$ mm). The results will be completed in the following table:

MATERIAL	$\alpha_l \cdot 10^5 \text{ K}^{-1}$, (literature data)	α_l (experimental results)
Brass	1,8	
Copper	1,5	
Aluminum	2,3	
Steel	1,2	
Duran glass	0,4	

4.4. The cubic coefficients of expansion are calculated based on equation (3), on different temperature ranges.

Data from the literature

FLUID	$\alpha_v \cdot 10^3, \text{ K}^{-1}$ (at 20 °C)
Water	0,2
Glycerin	0,5
Olive oil	0,72
Ethyl acetate	1,37

5. QUESTIONS

5.1. Estimate the length of the pipes made of the 5 materials at 80 °C based on the data from the literature regarding the coefficients of linear expansion.