STUDY OF TEMPERATURE DEPENDENCE OF LINEAR EXPANSION COEFFICIENT OF SOLID BODIES

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Abstract: Measurement of temperature dependence of coefficients of linear expansion of brass, steel and glass. Determination of coefficients of linear expansion of brass, steel and glass.

Key words: Brass, steel, glass, expansion coefficient, thermodynamic balance, circulation thermostat.

Theoretical part. The length of a solid body λ depends linearly on the temperature t:

$$l = l_0(1 + \alpha \Delta t) \quad (1.1)$$

where l_0 is the length at room temperature, t is the temperature in °C.

The coefficient of linear expansion of solids, α, is determined by their material. In this work, a circulation thermostat is used to heat water, and heated water flows through pipes made of different materials [7]. The rotary scale is used to measure the change in length $\Delta l = l - l_0$ as a function of temperature t using a device consisting of 0.01 millimeter scale divisions [16-17].

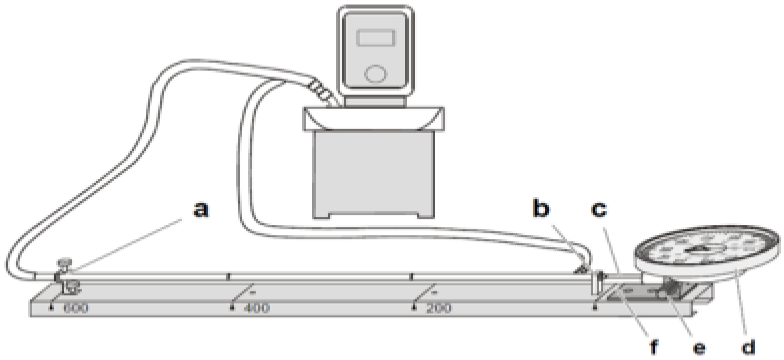


Figure 1. Schematic view of the experimental device for measuring the linear expansion of pipes as a function of temperature together with the expansion apparatus.

Test procedure:

- Turn the body of the dial indicator to set the zero.
- Measure the initial temperature, i.e. room temperature t0.
- Connect the circulation thermostat and set its temperature to 5 °C higher than t0.
- Wait until thermodynamic equilibrium is established.
- Measure the temperature t.
- Record the reading of the dial indicator.
- Increase the temperature to 100 °C in steps of about 5 °C.
- Allow the brass tube to cool to room temperature.

- Replace the brass tube with a steel tube and set the fixed support of the expander (a) to the 600 mark and slide the open end of the steel tube into the fixed support smoothly.
- Perform similar experiments with a glass tube. In this case, raise the temperature t in steps of about 10 °C.

Experimental device.

Figure 1 shows the experimental device schematically.

- Unscrew the dial indicator (381 36) (e) in the holder (for details, use extension hardware instruction 381 341) and install the dial indicator (361 15) (d) in its place [7-8].
- Set the fixed support of the expander and the brass tube (a) to the 600 mark, and insert the open end of the brass tube into the fixed support and slide it smoothly.
- Slide the tube connecting the closed end of the brass tube into the guide (b) evenly so that the short tube (f) faces down [9-10].
- Tighten the screw to fasten the brass pipe to the fixed support (the screw must enter the groove in the pipe). (the screw must fit into the groove in the tube).
- Install the expansion part (c) (see the corresponding sheet of the dial indicator 361 instruction)
- Prepare and connect the circulation thermostat. (For fuller protocol details, refer to the appropriate page of instruction 666 768.)
- Fill the circulation thermostat bath with distilled water [13-15].
- Connect the instrument to the circulation thermostat using silicone tubing, i.e. connect the open end of the brass tube and the short tube (f) to the short tube of the thermostat pump
- Use the thermometer (382) to measure the temperature T of the water bath.

Technical safety.

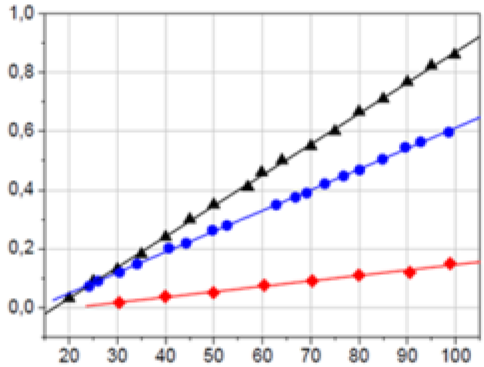
- Check the silicone joints before each operation of the appliance to prevent uncontrolled escape of hot water and thus injury and damage to the surroundings [11-12].
- Follow the instructions for using the circulation thermostat.
- When working with a glass tube, follow the instructions given in the description of the apparatus.

Measured length change values Δl as a function of temperature t

Table 1

Brass		**Steel**		**Glass**	
t °C	Δl, Mm	*t* °C	Δl, Mm	*t* °C	Δl, mm
20.0	0.03	24.1	0.07	30.4	0.02
25.0	0.09	26.0	0.09	39.9	0.04
30.0	0.13	30.5	0.12	49.9	0.05
35.0	0.18	34.1	0.15	60.3	0.08
40.0	0.24	40.7	0.20	70.3	0.09

45.0	0.30	44.3	0.22	79.9	0.11
50.0	0.35	49.7	0.26	90.5	0.12
57.0	0.41	52.7	0.28	98.9	0.15
59.8	0.46	62.8	0.35	-	-
64.0	0.50	66.8	0.38	-	-
70.0	0.55	69.1	0.39	-	-
75.0	0.60	72.9	0.42	-	-
80.0	0.67	76.8	0.45	-	-
85.0	0.71	80.1	0.47	-	-
90.0	0.77	84.9	0.51	-	-
95.0	0.82	89.6	0.55	-	-
99.8	0.86	92.8	0.56	-	-
-	-	98.6	0.60		



2 - picture. Length change Δl as a function of temperature 0: brass (▲), steel (•), glass (♦). Solid lines (II) correspond to the approximation according to Eq.

Various measurements are given in Table 1. To determine the coefficient of linear expansion α as a function of temperature t, a graph is constructed based on the measurement of the change in length Δl (see Figure 2). By subtracting the initial length λ_0 determined at room temperature from both sides of equation (1), the following can be obtained for the length change Δl:

$$l - l_0 = l_0 \alpha t$$

$\Delta l = kt$ (2)

Here $k = l_0 \cdot \alpha$

(2) gives a linear approximation of the measured results α (Fig. 2).

The results are presented in Table 2.

The linear expansion coefficients determined from Fig. 2 plotted by equation (2) are a.

Table 2.

Material	Δl, *Mm*	Experience, α, K^{-1}	Results in the literature, α, K^{-1}
Brass	600	17.8-10^{-6}	18-10^{-6}

Steel	600	$11.7\text{-}10^{-6}$	$11\text{-}10^{-6}$
Glass	600	$3.1\text{-}10^{-6}$	$3\text{-}10^{-6}$

Additional Information

Additionally, linear thermal expansion can be measured as a function of the full pipe length l0.

Linear expansion from heat to temperature difference

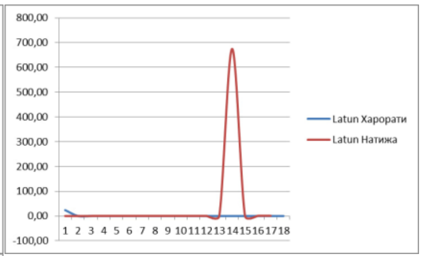
$$\Delta t = t_1 - t_0$$

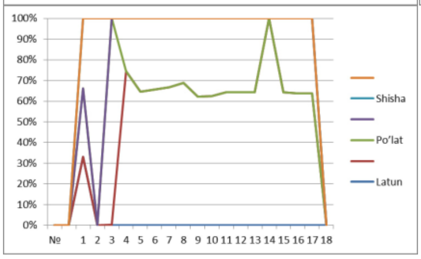
experimental procedure for determining dependence P2.1.1.2. given in the instruction.

Using a steam generator P2.1.1.2 instead of a circulation thermostat allows you to determine the length change Δl.

Table 3

Brass		**Steel**		**Glass**	
t °C	Δl, Mm	*t* °C	Δl, Mm	*t* °C	Δl, mm
23.8	0	24.1	0,001	24,4	0,001
25.0	0,012	26.0	0,006	30.4	
30.0	0,067	30.5	0,015	39.9	
35.0	0,12	34.1	0,041	49.9	
40.0	0,16	40.7	0,088	60.3	
45.0	0,21	44.3	0,11	70.3	
50.0	0,29	49.7	0,145	79.9	
57.0	0,365	52.7	0,165	90.5	
59.8	0,39	62.8	0,238	98.9	
64.0	0,44	66.8	0,265	-	-
70.0	0,505	69.1	0,282	-	-
75.0	0,565	72.9	0,315	-	-
80.0	0,62	76.8	0,346	-	-
85.0	0675	80.1	0,384	-	-
90.0	0,73	84.9	0,405	-	-
95.0	0,783	89.6	0,447	-	-
99.8	0,842	92.8	0,48	-	-
-		98.6			





Conclusion: Thus, the coefficient of linear expansion, for example, of brass pipes of different lengths (200 mm, 400 mm, 600 mm), can be determined by measuring the initial t0 and final t temperatures set in the circulation thermostat, as shown in Figure 2 in the instruction P2.1.1.2

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