E-NOTE FOR WEEK 3 OF TERM 3 2020 SESSION

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TERM/ WEEK : **THREE / WEEK 3**

SUBJECT: **PHYSICS**

CLASS: **SS 1**

TOPIC: **EFFECTS OF APPLICATION OF HEAT**

EFFECTS OF HEAT

There are series of effects of heat , which are

1 Change in temperature

2 Increase in size or expansion

3 Change of state

4 Change in physical property

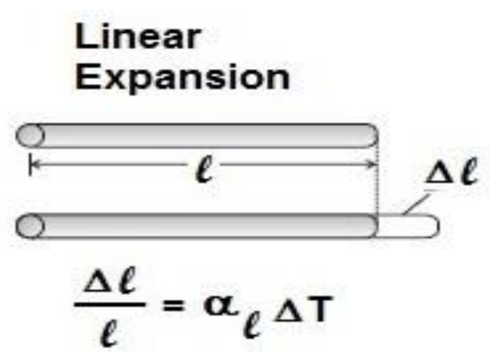
5 Change in chemical property

6 Change in pressure (if it's a gas)

7 thermionic emission .

EXPANSION

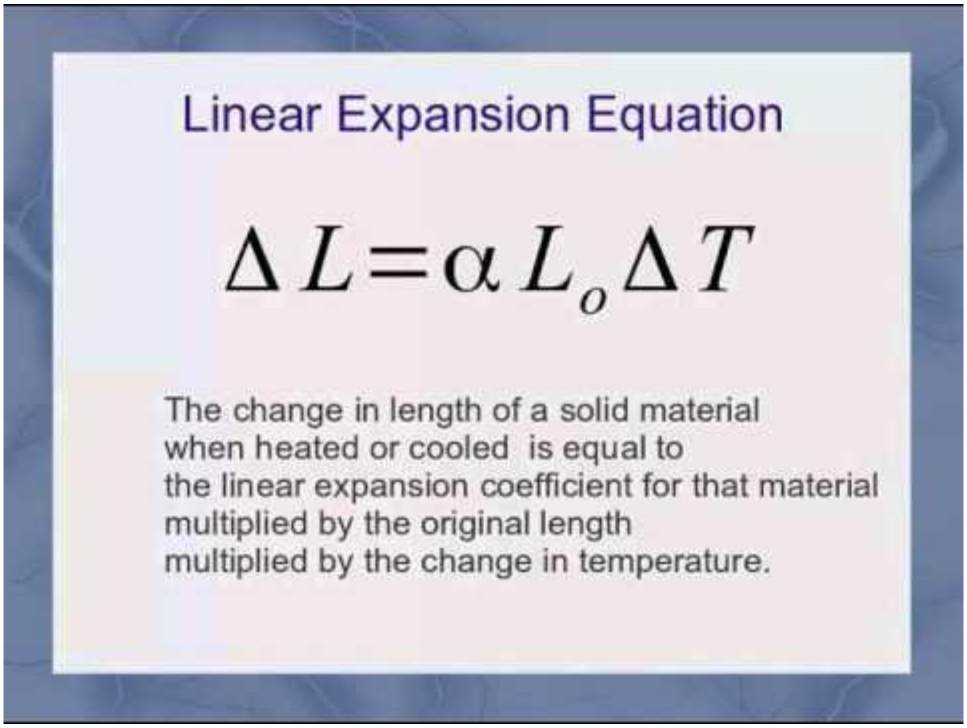
This is an increase in size of an object, when heat is applied to an object it expands.



LINEAR EXPANSIVITY

This can be defined as the change in length per unit length per Kelvin rise in temperature

The coefficient of linear expansivity α differes from one metal to the other. The table below shows the list of metals and ther corresponding coefficient of linear expansivity.



$$\alpha = \frac{\Delta L}{L_{\circ} \Delta T}$$

$\Delta L = Change\ in\ length$

$L_{\circ}$=Original length

$\Delta T = change\ in\ temperature$

QUESTION;

Explain the statement that “ the coefficient of linear expansivity of iron is 0.000012/K

The statement means that, iron will expan 0.000012 of its original length for a degree rise in temperature.

The xperiment below shows the set up to determine the linear expansivity of a metal.

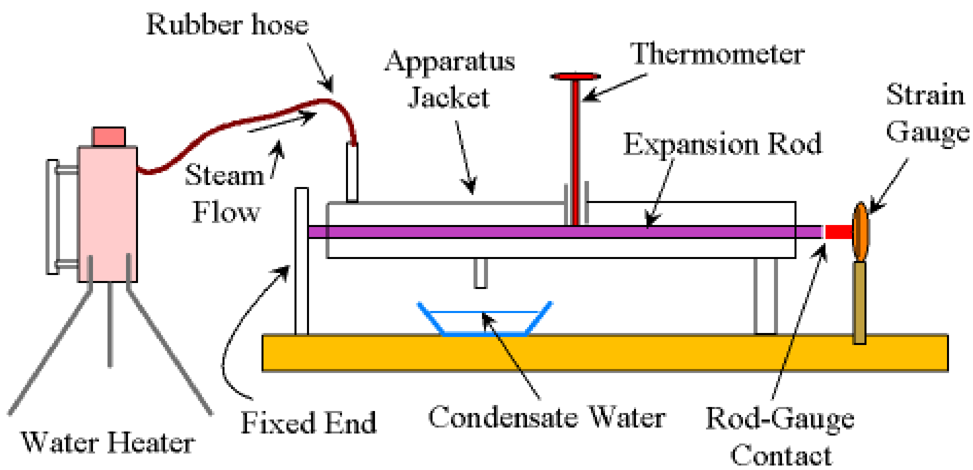


Fig. 1: Linear Expansion Apparatus

The apparatus above can be used to determine the linear expansivity of some metals.

The table below shows the values of the coefficient of linear expansivity of some materials

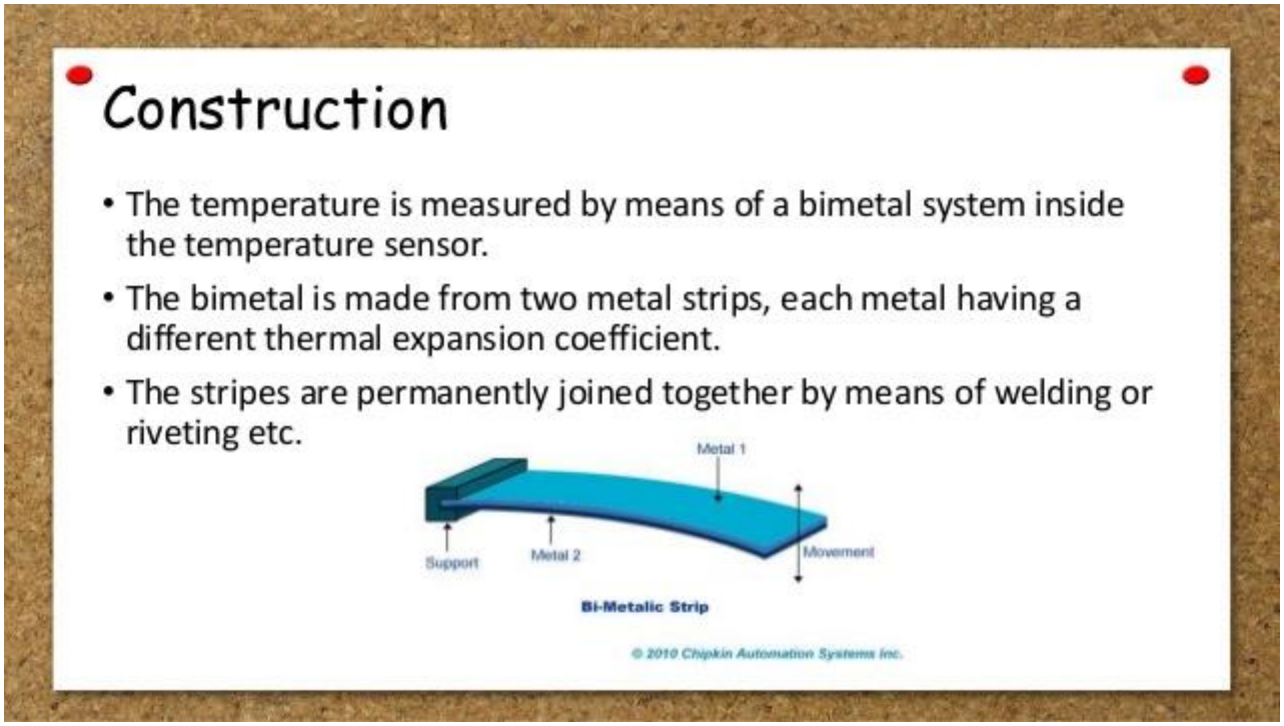
Average Expansion Coefficients for Some Materials Near Room Temperature

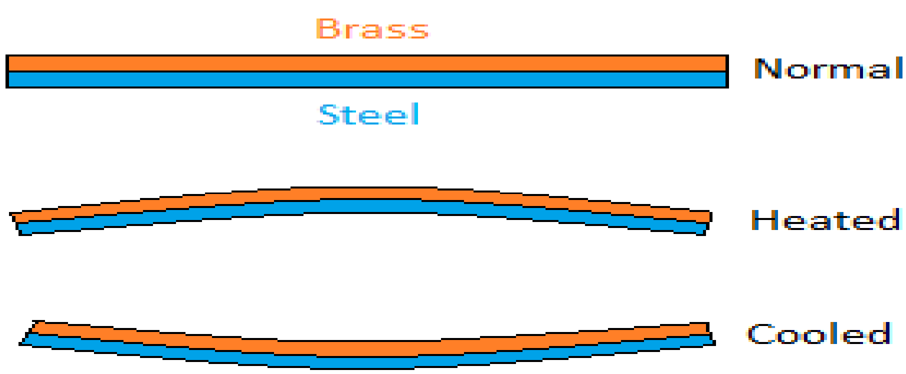
Material (Solids)	Average Linear Expansion Coefficient $(\alpha)(°C)^{-1}$	Material (Liquids and Gases)	Average Volume Expansion Coefficient $(\beta)(°C)^{-1}$
Aluminum	24×10^{-6}	Acetone	1.5×10^{-4}
Brass and bronze	19×10^{-6}	Alcohol, ethyl	1.12×10^{-4}
Concrete	12×10^{-6}	Benzene	1.24×10^{-4}
Copper	17×10^{-6}	Gasoline	9.6×10^{-4}
Glass (ordinary)	9×10^{-6}	Glycerin	4.85×10^{-4}
Glass (Pyrex)	3.2×10^{-6}	Mercury	1.82×10^{-4}
Invar (Ni–Fe alloy)	0.9×10^{-6}	Turpentine	9.0×10^{-4}
Lead	29×10^{-6}	Air[a] at 0°C	3.67×10^{-3}
Steel	11×10^{-6}	Helium[a]	3.665×10^{-3}

[a]Gases do not have a specific value for the volume expansion coefficient because the amount of expansion depends on the type of process through which the gas is taken. The values given here assume the gas undergoes an expansion at constant pressure.

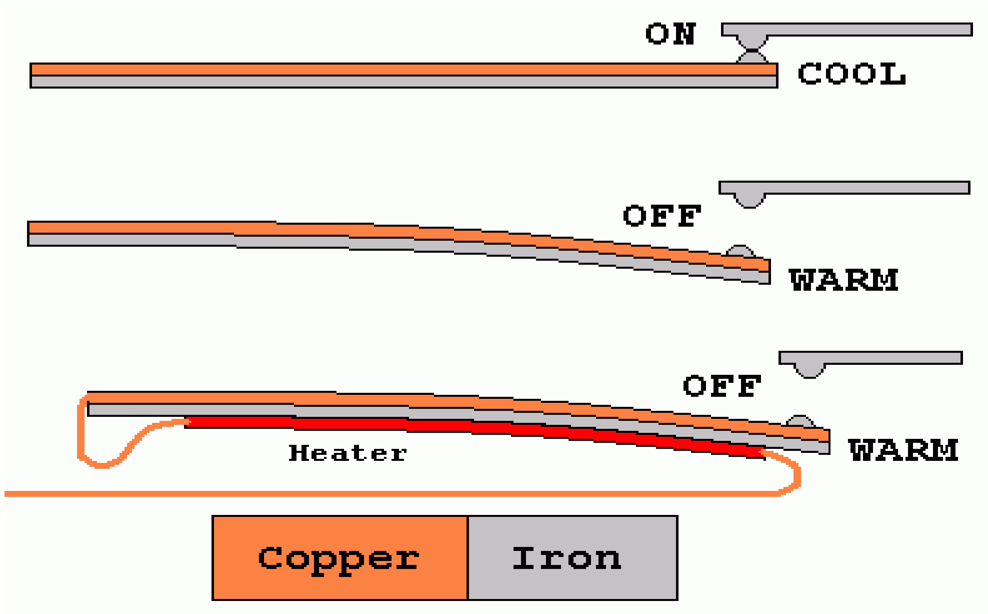
BIMETALIC STRIP

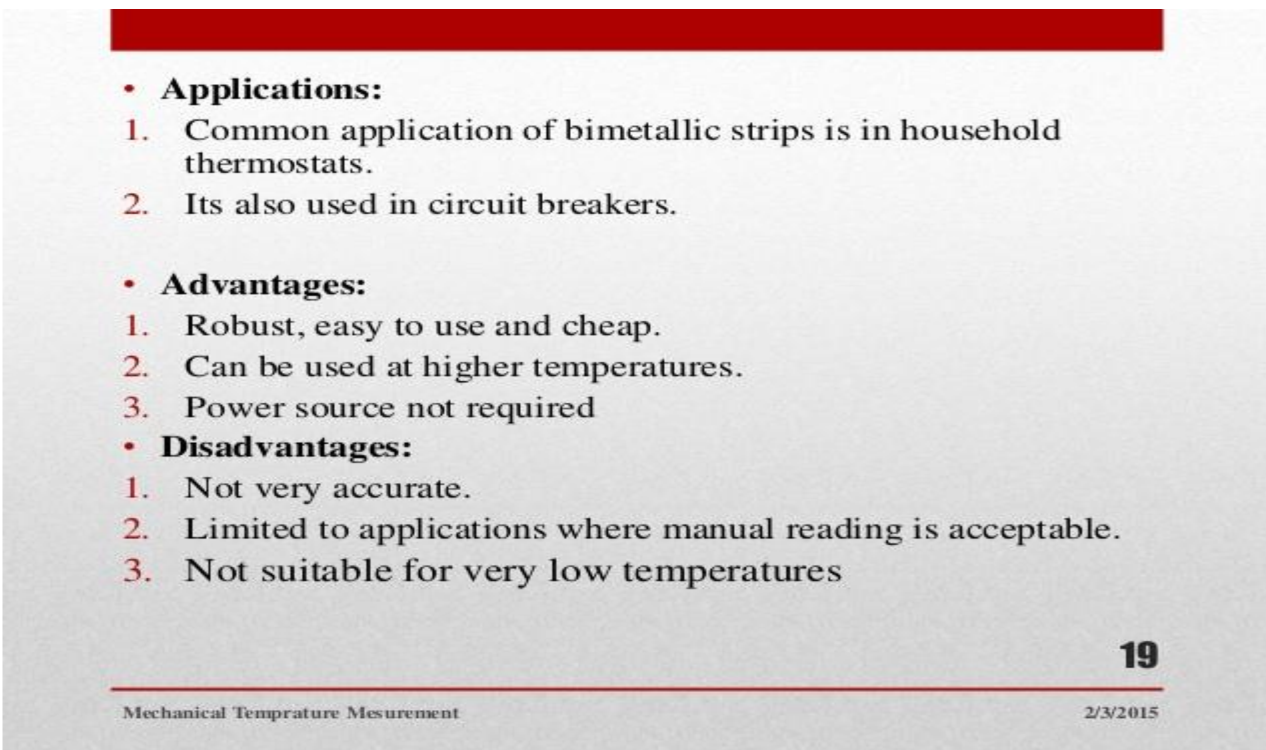
It consists of two metal e.g braa and steel of different coefficient of linear expansivity that are riveted together. When these metals are heated, they will expand differently for the same temperature rise and the metal will bend as shown in the diagram below.

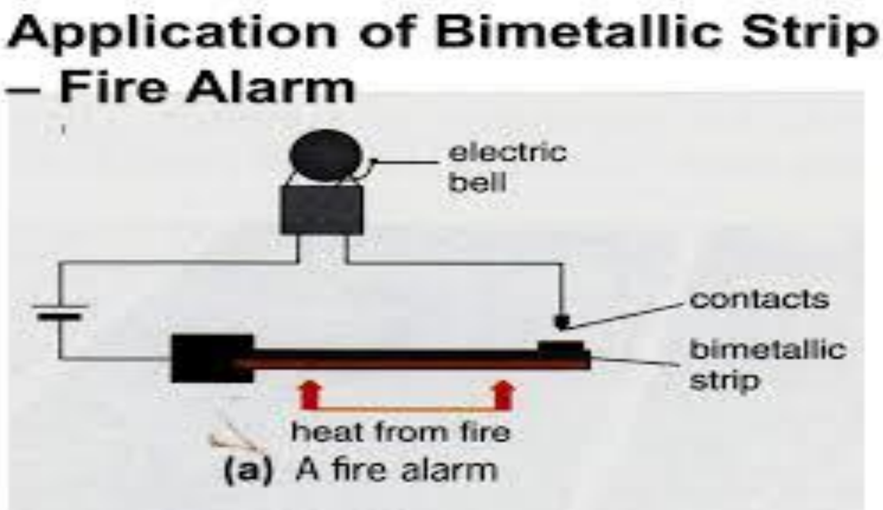


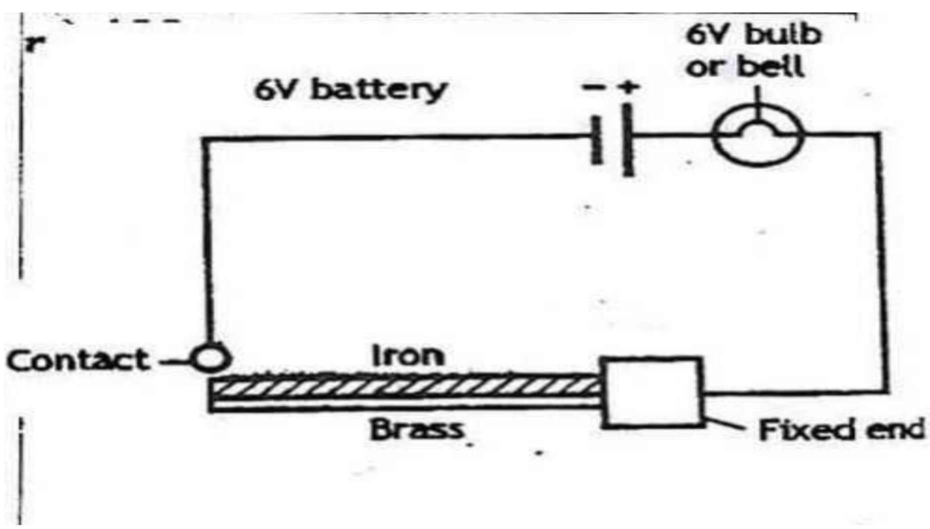


This arrangement is used in thermostart









CALCULATIONS:

1 Steel bar each of length 3m, at 29^0C are to be used for constructing a rail line, if the linear expansivity of steel is $1.0 \times 10^{-5}/k$. Calculate the safety gap that must be left between successive bars if the highest temperature expected is 41^0C.

SOLUTION 1

The safety gap to be left is found by calculating the change in length.

From $\alpha = \Delta l / l_1(\theta_2 - \theta_1)$

Change in length, Δl = $\alpha l_1(\theta_2-\theta_1)$

Given: linear expansivity, α = $1.0 \times 10^{-5}/K$

Original length, l_1 = 3m

Initial temperature, θ_1 = 29^0C

Final temperature, θ_2 = 41^0C

Δl = $1.0 \times 3(41-29)$

= 0.00003(12)

= 0.00036m or 3.6×10^{-4}m

2 A metal rod of length 50cm is heated from 40^0C to 80^0C. If the linear expansivity of the material is **α**, calculate the increase in length of the rod (in metres) in terms of **α**.

SOLUTION 2

Given : Original length, l_1 = 50cm = 0.5m

Initial temperature, θ_1 = 40^0C

Final temperature, θ_2 = 80^0C

Linear expansivity, α = α

From $\alpha = \Delta l / l_1(\theta_1-\theta_2)$

Increase in length, $\Delta l = \alpha \times l_1(\theta_2-\theta_1)$ = $\alpha \times 0.5(80-40)$

= $\alpha \times 0.5 \times 40$

= 20α

AREA EXPANSIVITY (β)

This can be defined as change in area per unit area per Kevin rise in temperature. Area expansivity is a two dimensional expansivity which is represented by β. The mathematical analysis is as shown below.

Area expansivity

$$\beta = \frac{A_2 - A_1}{A_1\,(\theta_2 - \theta_1)}$$

This can be rearranged to calculate change in area

$$(A_2 - A_1) = \beta A_1\,(\theta_2 - \theta_1) = \beta A_1\theta$$

Or calculate final lenght A_2

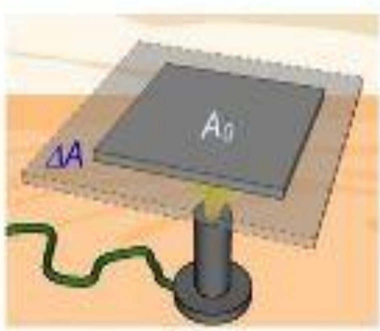
$$A_2 = \beta A_1\theta - A_1 = A_1\,(1 + \beta\theta)$$

Area expansion

- This expansion involving the expansion of a surface area of an object.
- Consider a plate with initial area, A_0 at temperature T_0 is heated to a new uniform temperature, T and expands by ΔA, as shown in figure below.
- From this experiment, we get

$$\Delta A \propto A_0 \quad \text{and} \quad \Delta A \propto \Delta T$$

$$\boxed{\Delta A = \beta A_0 \Delta T}$$



ΔA : change in area $= A - A_0$

ΔT : change in temperature $= T - T_0$

β : coefficient of area expansion

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Area Thermal Expansion Coefficient Formula

$$\alpha_A = \frac{1}{A}\,\frac{\Delta A}{\Delta T}$$

$\alpha_A -$ area thermal expansion coefficient

$A -$ area of the object in m^2

$\Delta A -$ change in area in m^2

$\Delta T -$ change in temperature in kelvin

VOLUME/ CUBICAL EXPANSIVITY

This can be defined as change in volume per unit volume per Kevin rise in temperature.It is a three dimensional expansivity and it is represented by ɣ.

Volume expansion

Consider a metal cube with side length, l_0 is heated and expands uniformly. From the experiment, we get

$$\Delta V \propto V_0 \quad \text{and} \quad \Delta V \propto \Delta T$$

$$\Delta V = \gamma V_0 \Delta T$$

ΔV : change in volume $= V - V_0$

ΔT : change in temperature $= T - T_0$

γ : coefficient of volume expansion

$$\gamma = \frac{\Delta V}{V_0 \Delta T}$$

Unit of γ is $°C^{-1}$ or K^{-1}.

The **coefficient of volume expansion,** γ is defined as ***the change in volume of a solid per unit volume per unit rise in temperature.***

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RELATIONSHIP BETWEEN ALPHA α, BETA β AND GAMMA ɣ

$\beta = 2\alpha$

$\gamma = 3\alpha$

$\beta = 2/3\ \gamma$

$\gamma = 3/2\ \beta$

WORKED EXAMPLE

1 A solid metal cube of side 10cm, is heated from 10^0C to 60^0C. If the linear expansivity of the metal is $1.2 \times 10^{-5}/K$, calculate the increase in its volume.

SOLUTION

Original length, l_1 = 10cm

Therefore, original volume = $l_1 \times l_1 \times l_1$

= $10 \times 10 \times 10$

= $1000cm^3$

Initial temperature, $\theta_1 = 10^0C$

Final temperature, $\theta_2 = 60^0C$

$\alpha = 1.2 \times 10^{-5}/K$

Cubic expansivity, $\gamma = 3\alpha$

$= 3(1.2 \times 10^{-5})$

$= 3.6 \times 10^{-5}/K$

$\gamma = \Delta V/V_1(\theta_2-\theta_1)$

$\Delta V = \gamma \times V_1(\theta_2-\theta_1)$

$= 3.6 \times 10^{-5} \times 1000 \times (60-10)$

$= 3.6 \times 10^{-2} \times 50$

$= 1.8cm^3$

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