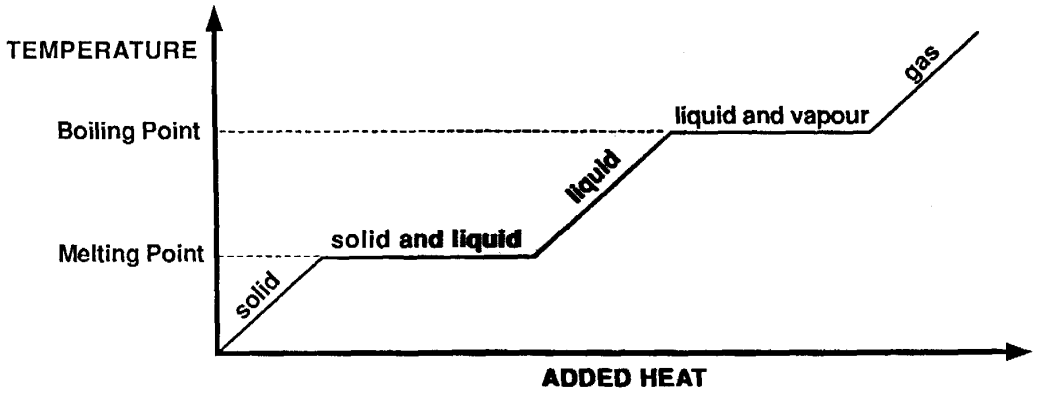
Specific and Latent Heat Calculations

As heat is added to a substance an increase in temperature followed by a change in state may be observed.



A Heating Curve

When water is used to take heat from a fire, normally both a change of temperature and a change of state occur.
HEAT ABSORBED = MASS (kg) x SPECIFIC HEAT x TEMPERATURE CHANGE
To calculate the heat absorbed during a change of state use:
HEAT ABSORBED = MASS (kg) x LATENT HEAT
For example: Water leaves a hose at 20°C and is converted by the heat from the fire into steam at 300°C. What amount of heat is removed from the fire by 1 tonne (1000 kg) of water?
Specific heat of water = 4.2 kJ/kg°C
Latent heat of vaporisation of water = 2260 kJ/kg
Specific heat of steam = 2.0 kJ/kg°C
This calculation must be done in 3 steps;

1. Heat to raise temperature of water from 20°C to 100°C
   = 1000 x 4.2 x 80
   = 336,000 kJ
2. Heat to change water at 100°C to steam at 100°C
   = 1000 x 2260
   = 2,260,000 kJ
3. Heat to raise temperature of steam at 100°C to 300°C
   = 1000 x 2.0 x 200
   = 400,000

Total heat = 2,996,000 kJ (or 2996 MJ)

That is: each tonne of water sprayed onto the fire removes about 3000 MJ of heat.

Expansion Calculations

Change in length is usually the change of most importance when solids expand on heating. This can be calculated by using the linear coefficient of expansion for the material.

Material	Coefficient of linear expansion (per K or °C)
aluminium	0.000023
copper	0.000017
steel	0.000012

concrete	0.000008
invar	0.0000001

CHANGE IN LENGTH = ORIGINAL LENGTH x COEFFICIENT OF LINEAR EXPANSION x TEMP CHANGE

Example

An aluminium girder 10m long is heated in a fire to 450^{o}C from an original temperature of 15^{o}C.
What is it's final length?

Change in length = 10 m x 0.000023 x 435
= 0.100 m
Final length = 10.100m

Area of a Solid

If the change in **area** of a solid is of importance, then use **two times** the coefficient of linear expansion, for the material.

CHANGE IN AREA = ORIGINAL AREA x 2 x COEFFICIENT OF LINEAR EXPANSION x TEMP CHANGE

Example

A sheet of glass has an area of 6000 cm^{o} C at 10 C. If the temperature rises to 200 C. what will be its new area?

Change in area = 6000^{2}cm x 2 x 0.000008 x 190
= 18.2 cm^{2}
New area = 6018.2 cm^{2}

Volume of a Solid

If the change in **volume** of a **solid** is important, then use **three times** the coefficient of linear expansion.

Example

A steel storage tank has a volume of 20^{3}m at 20^{o}C. As a result of a fire the tank is raised to 300^{o}C. What is the new volume of the tank?

Change in volume = 20 m^{3} x 3 x 0.000012 x 280
= 0.20 m^{3}
new volume = 20.20 m^{3}

Expansion of Liquid

To calculate the expansion of a **liquid,** then the **co efficient of cubical (volume) expansion** for the liquid needs to be known.

For example: ethanol 0.0011 /^{o}C
Oil 0.0009 /^{o}C

Example

If the steel storage tank in the example above were filled with oil, what would be the increase in the volume of the oil in that fire?

Change in volume of oil = 20 m^3 x 0.0009 x 280

= 5.04 m^3

That is: the oil would expand more than the steel drum and the oil would overflow. (Change in volume of the drum is only 0.20m^3)

Summary

1. For change in temperature use:

Heat absorbed = mass x specific heat x temperature change.

2. For change in state use:

Heat absorbed = mass x latent heat.

3. If both change of temperature and change of state occur then work these out separately and add together
4. For linear expansion of solids:

Change in length = original length x coefficient of linear expansion x change in temperature

5. For area expansion of solids:

Change in area = original area x 2 x coefficient of linear expansion x change in temperature.

6. For volume expansion of solids:

Change in volume = original volume x 3 x coefficient of linear expansion x change in temp.

7. For volume expansion of liquids:

Change in volume = original volume x coefficient of cubical expansion x change in temperature.