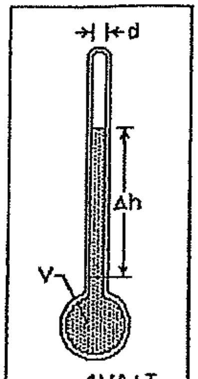
From http://mysite.du.edu/~jcalvert/phys/mercury.htm

The Thermometer



$$\Delta h = \frac{4V\beta\Delta T}{\pi d^2}$$

Thermometer

In 1714, Gabriel Fahrenheit (1686-1736) invented the mercury-in-glass thermometer, shown at the left. This instrument depends on the volume thermal expansion of mercury, or actually the expansion of the mercury relative to glass. If they both expanded at the same rate, the length of the mercury column would not change. Mercury not only expands much more rapidly than glass, but its expansion is fairly uniform, so it is a good thermometric substance. The sensitivity of the thermometer depends on the ratio of the reservoir volume to the square of the inside diameter of the stem. The formula is shown, where β is the coefficient of relative thermal expansion.

Thermometer design is a relatively simple matter. We measure the thermal expansion of a volume V of liquid by its expansion into a capillary of cross-sectional area A. Since the coefficient of cubical expansion is $\beta = (1/V)(dV/dT)$, and $dV = Adx$, where x is the length of liquid in the capillary, the sensitivity of the thermometer, $dx/dT = \beta(V/A)$. For β, we use the difference of the cubical expansion coefficients of the liquid and glass. Thermometers are not affected by vapor pressure above the capillary column, as a barometer would be. It is only necessary that the liquid be clearly distinguishable from the volume above the liquid. The glass capillary magnifies the column, and can be shaped to increase the magnification.

Mercury has $\beta = 0.181 \times 10^{-3}$ per °C, while ordinary soda-lime glass has $\beta = 0.0276 \times 10^{-3}$ per °C. The β of most liquids is on the order of 10^{-3}, while that of most solids is about 10^{-5}, so the solid expansion is only about 1% of that of the liquid. For mercury, the difference is $\beta' = 0.153 \times 10^{-3}$ per °C. Suppose our thermometer has $V = 250$ mm^3, with a capillary bore of 0.2 mm. The sensitivity will be $dx/dT = 1.22$ mm/°C, so a scale reading from -10°C to 110°C will be 158 mm long. This is actually fairly typical of small mercury thermometers. Mercury melts at -38.87°C, and boils at 356.7°C, so it is useful over a wide range. A mercury column is also very easily seen.

Objections, which I regard as specious, have been made to mercury thermometers because of the danger of mercury spillage. A popular alternative fluid is an alcohol. Ethyl alcohol boils at 78.4°C (173°F), so it would be all right for room thermometers, and has been widely used for that purpose for many years. The alcohol is colored red (usually) so it can be seen easily. Amyl alcohol (1-pentanol) melts at -78.9°C and boils at 138.1°C, so it can be used to replace mercury in laboratory thermometers that must read to 110°C. Its coefficient of cubical expansion is 0.902×10^{-3} per °C, so $\beta' = 0.874 \times 10^{-3}$. If we want the same sensitivity as before, 1.22 mm/°C, then if V is to be the same, $A = 0.179$ mm^2, or the capillary bore should be 0.7 mm. This larger column is more easily seen, which is an advantage.

When Fahrenheit made his thermometer, the significance of fixed points such as the freezing and boiling points of water was not appreciated, and Fahrenheit calibrated his thermometer rather arbitrarily, trying to encompass the full range of temperatures met with in practice. The coldest temperature he could get, that of a freezing mixture, he called 0°. Body temperature, which he knew to be constant, he called 24°, and noted that water froze at 8° on his scale. These were "old" degrees, which were multiplied by 4 to get a finer scale. Now the ice point became 32°, and body temperature 96°. When the boiling point of water was taken as a new fixed point, it fell at 212°. Meanwhile, it seemed body temperature was a little hotter (depending on how you measure it) and became 98°, and finally 98.6°. The idea of having a really accurate thermometer was a surprising one, and it took a while for it to sink in. It might seem that he could have aimed at an even 100° for body temperature, but this was not the case.

Fahrenheit, a German, was made a fellow of the Royal Society and his thermometer became the English thermometer. Réaumur, a Frenchman, devised a scale that became the German thermometer. Anders Celsius (1701-1744), a Swede, created a scale based on the freezing and boiling points of water which became the French thermometer. On the Réaumur scale, ice melts at 0° and water boils at 80°. A Réaumur degree was represented by an expansion of 1/10000 of his fluid, alcohol with 1/5 its volume of water added, at 0°R. 20°C, a comfortable room temperature, is 16°R and 68°F. Mercury solves most of the problems of a thermometric substance quite neatly, since it neither freezes nor boils in extremes of weather.

Any thermometer based on the expansion of a substance is essentially arbitrary, except one based on an ideal gas, for which $p = nkT$. (n is the number density of molecules, and k is Boltzmann's constant.) This gives us the *absolute temperature* T, now measured in kelvin, K. Experiments are difficult, but thermometer scales have be calibrated absolutely by this and other means. 0°C corresponds to 273.15K. The absolute temperature based on the Fahrenheit scale is in rankine, R. 32°F corresponds to 491.67R, or 0°F to 459.67R. All thermometer scales are equally good, none is superior to any other, and the concept of "metric" is meaningless, since all are divided decimally.

Any skilled glassblower was once able to make a thermometer from a length of capillary tube. The bulb is blown, then filled with water which is heated to make steam. The tube is put in some mercury, the correct amount of which is pushed into the vacuum (or sucked in by the vacuum, as some would say) when the steam condenses. Then the mercury is heated and vapor expelled until the tube is clean, and the tube is finally fused closed.

Frigorific Mixtures.

Materials.	Parts.	The thermometer falls
Hydrochlorate of ammonia	5	From 50° to 10°.
Nitrate of potassa	5	
Water	16	
Hydrochlorate of ammonia	5	From 50° to 4°.
Water	16	
Nitrate of ammonia	1	From 50° to 4°.
Water	1	
Sulphate of soda	3	From 50° to 3°.
Dilute nitric acid	2	
Sulphate of soda	8	From 50° to 0°.
Hydrochloric acid	5	
Snow	1	From 32° to 0°.
Common salt	1	
Snow	1	From 30° to —13°.
Caustic potash, crystallized	1	
Snow	1	From 20° to —60°.
Sulphuric acid, dilute	1	
Snow	2	From —4° to —57°.
Chloride of calcium	3	
Sulphuric acid, dilute	10	From —67° to —90°.
Snow	8	