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The Love Meter

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This toy is also referred to as temper meter, hand boiler or even baromètre d'amour. But neither temper nor temperature can be determined.

When you hold the bottom part of the glass vessel shown in Fig. 1 in the palm of your hand, the typically colored liquid rises in the central tube bubbling into the upper part. The warmer the hand, the faster the liquid rises. If, the upper part is then exposed to higher temperature than the bottom part, the liquid flows back again.

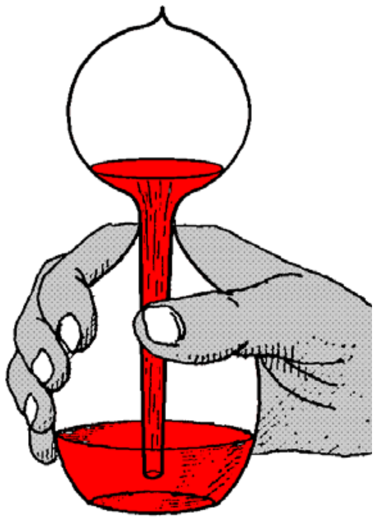

Fig. 1: Structure of a simple love meter

Naturally, this is attracting particularly children to find out, who has warmer hands. Then there is a risk of broken glass. Today, for safety reasons, the toy is in Germany in this form no longer widely available. In the past, it contained diethyl ether, Freon or methyl chloride, nowadays mostly less critical methanol. There are all sorts of variations of this toy, with spiral or heart-shaped central tubes and even quite erotic designs. If you are lucky, you will find one today in magic or joke shop.

The toy features interesting aspects of physics and prompted German physics educationalist Richard Kluge to study the toy in detail [1]. The glass vessel consists of two parts. A narrow tube protrudes from the upper part almost to the bottom of the lower part where it is immersed in the liquid. The liquid inside is characterized by a high temperature dependence of its vapor pressure (see information box). It is only in equilibrium with its own vapor. There is no air inside. If the liquid in the bottom part is warmed up by the palm of your hand or by some other heat source, some of the liquid evaporates and increases the pressure. The only way to escape is for the liquid to rise upwards through the tube. As the liquid in the upper, cooler part is also in equilibrium with its vapor, there is no excess pressure, rather steam will condense. Liquid can only rise as long there is significantly large temperature differential between upper and lower part. As shown in the table in the information box, for commonly used liquids a temperature differential of 1 K is already sufficient. Therefore, at normal room temperature (approximately 20 °C) even 'cold' hands (about 25 °C) cause the liquid to rise. This device is not a thermometer in the usual sense, since it allows only rough qualitative statements about the temperature, at best.

From the preceding it may be concluded that the liquid can also be pulled up by cooling the upper part of the vessel. This causes condensation in the upper part and the resulting negative pressure causes the rising of the liquid or the greater pressure in the bottom part causes the rise.

After keeping the entire vessel for some time in the fridge, covering the bottom with a warm hand literally causes the liquid to shoot up. After warming up the entire vessel evenly to about hand temperature, e.g. in the sun, even touching will not cause any rise.

If both lower and upper part have the same temperature, the liquid flows to the bottom part due to gravity. In fact, normally the entire system is under negative pressure, because the boiling point of the liquids used today is higher than typical room temperature or the temperature of the extremities.

The behavior of the liquid can not be substantiated sufficiently with the volume expansion of gases with increasing temperature. In the presence of air inside the vessel, upon heating the liquid in the bottom part would rise initially due to the higher pressure in the tube. Since the pressure in the upper part of the vessel increases, there would be a rise only until there is pressure equilibrium. Whether some liquid would actually enter the upper part of the vessel would depend on the inner diameter of the tube, the volume of air in the lower and upper part and, of course, on the temperature differential. If there is only the liquid and its own steam, the inner diameter of the tube or the steam volumes do not matter, because steam condenses or liquid evaporates to reach pressure equilibrium. Saturated steam below the boiling temperature is just not behaving like a gas or ideal gas.

There is a very close relationship between this toy and the famous drinking duck. The inside of the duck is virtually identical. Here, a moistened coating in the upper part causes an evaporative cooling effect. With an appropriate arrangement and mounting in which the duck can move, the tilting is achieved.

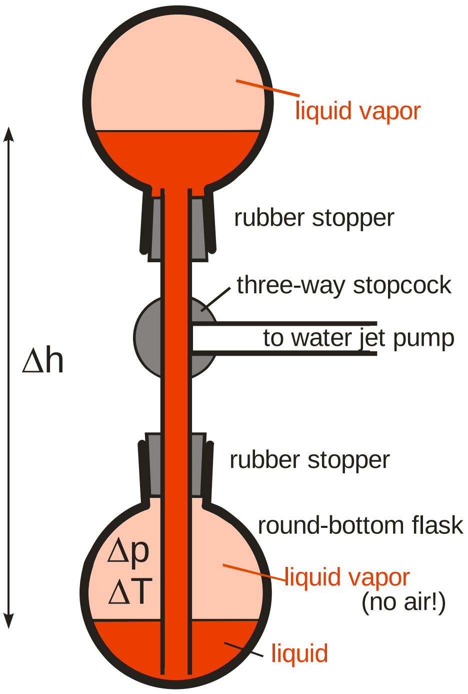

Fig. 2: A self built love meter from round-bottomed flasks and three-way stopcock

With a few components from a chemistry laboratory you can build your own love meter. Two small flasks are connected airtight with a three-way stopcock. In one of the flasks, a tube must reach almost all the way to the bottom. Fill one of the flasks about half way with alcohol (ethanol) and evacuate of the entire system using a water jet pump, followed by closing of the three-way stopcock appropriately and you already have your own love meter. You can also try slightly different liquids.

The vapor pressure

Within small temperature intervals, the vapor pressure p of many liquids can be described quite well with the following formula:

$$\log p = -\frac{A}{T} + B \quad \textit{respectively} \quad p = 10^{-\frac{A}{T}+B}$$

p = vapor pressure in Pa; T = temperature in K; A, B characteristic constants.

Water requires a more complicated formula. However, the vapor pressure of water as function of temperature may be found directly in tables in many textbooks.

From the formula, dp/dT can be calculated. With a suitable arrangement, such as in the love meter, a pressure increase Δp may cause a rise of the liquid of Δh = Δp/ρ·g (ρ = density, g = gravitational constant). Hence, the maximum height per temperature difference may be calculated. Results for two temperatures (room temperature T = 20 °C and extremity temperature T = 30 °C) are shown in the table. A strong temperature dependence is evident.

Liquid	**A** [K]	**B**	T = 20 °C ρ [g/cm^3]	T = 20 °C **Δh/ΔT** [cm/K]	T = 30 °C **Δh/ΔT** [cm/K]	Boiling point [ºC]
Diethyl ether (C_2H_6O)	1657	10.492	0.71	43.0	61.8	34.5
Methyl chloride (CH_2Cl_2)	1698	10.497	1.33	17.2	25.0	40.2
Methanol (CH_4O)	2077	11.206	0.79	9.2	14.8	68.7
Ethanol (C_2H_6O)	2257	11.461	0.79	4.4	7.4	78.3
Water (H_2O)			1.00	1.5	2.5	100.0

The values in the table are taken from: Landolt-Börnstein: Zahlenwerte und Funktionen, II.Band, 2.Teil, 6. Aufl. 1960 and converted to SI units.

According to the table, diethyl ether would be best suited, but it is too dangerous because it is an explosion hazard and a narcotic. Methyl chloride has been previously used, but is now considered harmful. Methanol is now the liquid of choice for this toy. Ethanol (alcohol) is only half as good as methanol, water is even worse.

Reference:

[1] Kluge, R.: Spielzeuge als Zugang zur Physik (toys as an access to physics), Verlag M. Diesterweg, Frankfurt am Main 1973

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