

Evolution of the Thermometer.

Carrie Wagner.

Class of '01.

Outline.

1. What the ancients thought about heat.
2. Why they needed instruments to measure it.
3. The First Thermometer.
 1. When made
 2. By Whom
 3. Its Efficiency.
4. The Growth of the Thermometer.
5. Our Modern Thermometer.
 1. How Made.
 2. Standard Instruments.
 3. Kinds
 4. Uses.
6. How Extreme Temperatures are measured.

From the earliest dawn of science, till the eighteenth century two theories of heat were prevalent. By one known as the caloric theory, heat was supposed to be a subtle elastic fluid, which passed through and filled the spaces between the molecules of matter. The other, which comes from the ancient Greeks and has in it the germ of the modern theory, supposed heat to be due to a rapid vibration of the molecules of a body, and therefore attributed heat to motion. Smelin defined heat as that substance whose entrance into our bodies causes the sensation of warmth and when it leaves the body, a sensation of cold.

For many centuries the ancients had no means of measuring heat, they knew something of its effects, as that heat expands, and cold contracts. It was not until about the middle of the sixteenth century that the thermometer was invented, but it is not certainly known when or by whom it was first brought into use. The Dutch authorities ascribe it to Cornelius Drebbel, the Italians to Sanctorius. Galileo is the first who invented a thermometer of which we have any positive proof. The first improvement of Galileo's thermometer was made by Jean Rey, a Frenchman, who simply inverted Galileo's instrument, filling the bulb

with water and the stem with air. As Rey's thermometer was not sealed there was constant danger from evaporation.

The early thermometers were very imperfect instruments, they consisted of a glass bulb, having a ball blown on one extremity, the other end being left open. A portion of air was expelled from the ball by heat, the open end was then plunged into a cup containing a liquid, when the bulb cooled, the liquid would rise in the tube, and the variations of its height indicate the increase or diminution of the temperature of the bulb. The instrument had no scale and was therefore merely an indicator of changes of temperature; it was defective even in this respect, inasmuch as it is affected not merely by heat and cold, but by the varying pressure of the atmosphere on the liquid column. The Florentine Academicians first excluded the influence of atmospheric pressure by using a spirit instead of an air thermometer, and hermetically sealed the tube. This idea of sealing the tube was a quarter of a century after Rey's invention. The next improvement was the adoption of a fixed point in the scale, before this Galileo had an arbitrary scale to his thermometer.

Boyle proposed the melting oil of aniseeds,

which he preferred to thawing ice, since it could be readily obtained any time of the year. Halley proposed the uniform temperature of a deep pit, which he probably considered would be the mean temperature of the earth; but he also suggested the point at which spirits boil, as well as the boiling point of water. Newton was the first who is known to have seen the advantage of having two fixed points in a scale, and in order that the instrument might be applicable to a wider range of temperature he used linseed oil as the thermometric fluid, but this was found not to serve the purpose on account of its slow motion and its adhesion to the sides of the tube. Röemer proposed mercury which is now generally used.

The readings recorded by the first thermometers were thought to be of no value as they could not be compared with our present thermometric scales, but in 1829 a number of these thermometers were found and their graduations compared with Réaumur's so that they can now be interpreted.

One of the first researches was to determine whether the melting of ice always took place at the same temperature. Newton in 1701 proposed the melting of ice and the boiling of water as the standard temperatures.

It was during the seventeenth century that the thermometer now in use was invented. Fahrenheit about 1714 constructed the first uniformly graduated thermometer. These were much used in England, and are still the most common. The temperature of melting ice is marked 32° and that of boiling water 212° . The knowledge of the fluctuations of the boiling point of water, owing to atmospheric pressure is due to Fahrenheit, 1724. It is thought by some that the selection of Fahrenheit's zero, probably arose from the erroneous idea that the ordinary freezing mixtures of ice and salt give the lowest attainable temperature.

The Centigrade scale was introduced by Celsius of Upsala. In it the freezing-point is marked 0° and the boiling point 100° . The simplicity of this way of dividing the space between the points of reference has caused it to be generally adopted.

The scale of Reaumur in which the freezing point is marked 0° and boiling point 80° is still used for certain medical and domestic purposes.

Most thermometers are made on the same general plan; an important object to be secured in thermometry is that all thermometers shall be strictly comparable. The modern liquid thermometers are drawn not bored and it is necessary that the tubes be most carefully calibrated; first, roughly, in

ored to reject all that are not nearly uniform in bore throughout; then more carefully, to discover and tabulate the process. It consists in introducing a little column of mercury an inch or two in length in each successive position. There are instruments made for this purpose. The length of the thread of mercury at any part of the tube is made by means of a horizontal cathetometer, the tube being placed horizontally. A split lens arrangement by which both the scale and thread may be viewed at the same time, and the reading of the end of the thread made without altering the focus of the microscope. This is done by placing a half lens before the object glass of the microscope, which had the effect of bringing the focus of half the field nearer the object glass. Hence by properly adjusting the distance of the half lens, the scale may be seen through the half lens at the same time as the thread of mercury is viewed through the uncovered part of the object glass. The narrower the bore at the place occupied by mercury, the longer will be the column.

The size of the bulb, which in standard instruments is usually cylindrical, is then to be estimated by three quantities: first, by the section of the tube, second, by the expansibility of the liquid used; and third, by the desired length of one degree of scale.

After the bulb is blown, it is gently heated in a spirit-lamp to expel a little air, and the open end of the tube is plunged into the liquid to be used. As the bulb cools some of the liquid is forced into the stem by atmospheric pressure, and on erecting the instrument part of it passes into the bulb. This portion of the liquid is now made to boil freely so that its vapor expels the air, and the end of the tube is again suddenly immersed in the liquid. When the whole has cooled both bulb and stem are filled with the liquid and the excess is again expelled by warming the bulb. The liquid is once more boiled so as to expel the air from the stem, and the end of the tube is hermetically sealed.

The freezing point is determined by immersing the bulb and part of the stem of the instrument in pounded ice from which water is dripping away; here it remains for some time, or until the upper surface of the mercury, which is just visible above the ice, takes a definite position. This is carefully marked on the glass tube as the zero-point.

To ascertain the boiling-point the instrument is immersed, as carefully as possible, in steam freely escaping from water, that is, boiling under a pressure of one atmosphere. Steam is used because it is found that the boiling point of water is not con-

stant.

In whatever position the thermometer has had its fixed points determined, the readings should be taken in that position, the reason being, that for the same temperature the same instrument will give a higher reading in a horizontal than a vertical position, since in the latter position the hydrostatic pressure on the column of mercury is greater and consequently decrease the volume.

After the freezing and boiling points have been ascertained and marked, the interval between them may be divided into any desired number of equal parts. Each of these parts is called a degree and hence we speak of a temperature being so many degrees above or below freezing point. In the best modern thermometers the scale is marked on the glass stem of the instrument itself, but in most of the ordinary thermometers the gradations are made on a piece of wood, ivory, or porcelain, to which the thermometer is attached, these methods being cheaper. The graduation on the glass of the stem itself is superior though it is more difficult to read the divisions. Lens front tubes are used for thermometers of fine bores, the stem being a magnifying glass, for the purpose of enlarging the bore.

Standard thermometers are those of most accurate make. Spherical bulbs are best adapted to resist the varying pressure of the atmosphere, while cylindrical bulbs expose larger surfaces of mercury, and are therefore preferred for more delicate instruments.

Various plans have been suggested in order to obtain thermometers of extreme sensitiveness for delicate experiments. Some have been made with very thin bulbs, to contain a very small quantity of mercury; but in these the indicating column is generally so fine that it can only be read by the aid of a powerful lens. Instruments have been made with spiral or coiled tubular bulbs; but the thickness of glass required to keep these in shape spoils the effect desired namely, instantaneous action.

Meteorological instruments have been successfully made which combine sensitiveness and quickness of action, and which present a good visible column.

The sensitiveness of thermometers, the power of revealing minute variations of temperature, is increased by narrowing the tube or by enlarging the bulb. A large bulb is however inconvenient; because it is difficult of insertion into small openings, a fault which may be remedied by giving the bulb a cylindrical form; because it

may alter materially the temperature of the object whose temperature is to be ascertained; because it slowly equalises its temperature with that of the object. A narrow tube is inconvenient because a narrow thread of mercury is hard to read, but this may be remedied by using a tube of flat elliptical section and enamelling the back of it.

The reservoir is made of glass, so thin that it can not be blown; it can only be formed by means of a spirit lamp, yet its shape gives it such rigidity that its indications are not affected by altering its position or by standing it on its bulb. The reservoir of the most delicate of these instruments contains about nine inches of excessively thin glass, the outer diameter of which is not more than the twentieth of an inch, and, owing to the large surface that is exposed to the air the indications are practically instantaneous. This form of thermometer was constructed expressly to meet the requirements of scientific balloon ascents, to enable the observer to take thermometric readings at precise elevations.

Strange as it may seem the standard instrument today may not be accurate tomorrow. It is more than probable that the freezing point will become displaced. This curious phenomenon has

never been satisfactorily explained. Some give as the cause that either the prolonged effect of the atmosphere upon the thin glass of the bulbs, or the gradual restoration of the equilibrium of the particles of the glass after having been greatly disturbed by the operation of boiling the mercury, cause a change in the volume of the bulb. Standard thermometers sometimes read from a few tenths to a degree higher in the course of some years. Some makers lay the tubes away for about six-months before fixing the freezing-point. Instruments however carefully made should from time to time be plunged into finely pounded ice, in order to maintain the accuracy of the freezing-point.

The first use of thermometers was to ascertain the temperature of the human body, but today they are used for many different purposes. The following are a few of the most common uses.

For Technical purposes they are made in a variety of forms, the scale is often dispersed with in these instruments, a movable pointer being fixed at the point at which the mercury is to be kept. Air or steam thermometers are rapidly superseding mercury instruments for all temperatures above the boiling point of water.

The earliest observations of the temperature

of water beneath the surface were made by raising samples of water in a valved box and noting the temperature on board ship. Later, thermometers for taking deep-sea temperatures were filled with alcohol and had a bulb more than an inch in diameter, which was imbedded in a mass of wax and enclosed in a stout wooden case. It assumed the temperature of the water slowly and retained it for a long time and with very satisfactory results. The effect of the pressure of great depths however made these records unreliable. A modification of this thermometer was made having an outer bulb partially filled with mercury.

The intensity of solar radiation is measured by the pyrheliometer, which usually consists of a body heated by the sun's rays and a thermometer to measure the rise of temperature.

In clinical thermometers the range is above 25° . Olive-shaped bulbs have been used, but a cylindrical form is most common.

Thermometers used to measure the heat of the earth, have long stems, which can be read above ground.

Instruments designed for the measurement of high temperatures are called pyrometers. It is very difficult to estimate accurately high temper-

atures. One difficulty consists in getting material that will not fuse when exposed to high temperatures.

The ultimate practical standard of reference in pyrometry is the air thermometer, furnished with a porcelain bulb. The method of measuring temperature by the change of volume or pressure of a gas has been chosen. Glass bulbs cannot be used for high temperatures on account of the fusion of glass. Deville and Troost found that gases at high temperatures passed through platinum bulbs and hence could not be used. The porcelain bulb is filled with dry air and placed in the furnace and when the temperature of the furnace is attained the stem is ripped off under mercury, so that the mercury rises into the bulb. The bulb is then lowered until the mercury stands at the same level within and without. Next the stem is closed with wax, and the apparatus removed and weighed. The mercury it contains is also weighed. It is afterwards filled and again weighed. By this means the fraction of the gas which escapes by expansion while in the furnace is determined, and consequently the whole expansion under constant pressure is known, and the temperature of the

furnace determined.

The pressure of the remaining air instead of its volume may be determined when it has cooled. For this purpose the bulb is provided with a long fine neck and a tap, which may be connected with a manometer. This tap is left open while the bulb is in the furnace, and is closed when the final temperature is reached. The bulb is then allowed to cool, and the residual pressure determined.

To compute the accuracy of this instrument, it is necessary to know the coefficient of expansion of porcelain, and any uncertainty in the value of this coefficient will limit the accuracy of its indications. All uncertainty from this cause disappears in a vapour-pressure thermometer, in which it is pressure alone that is to be measured, and not the volume or the pressure under any volume.