Concerning an Important Invention

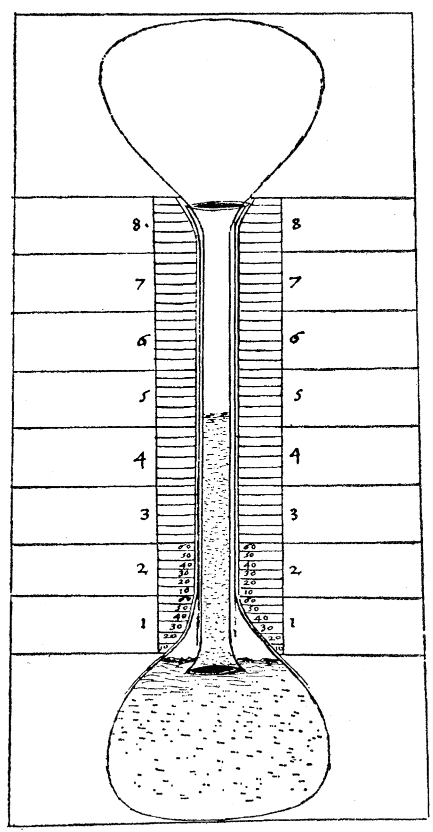
A History of the Thermometer and Its Uses in Meteorology. W. E. Knowles Middleton. Johns Hopkins Press, Baltimore, 1966. 262 pp., illus. $10.

"I cannot hope to have said the last word on the controversy about the 'invention of the thermometer,' or on those that concern the origin of the Fahrenheit and centigrade scales," Middleton says. "All that I have done is to read as many of the documents as possible and then make up my mind." Despite this disclaimer, many people will welcome and accept the verdicts of the foremost modern historian of meteorological instruments. His *Meteorological Instruments* (University of Toronto Press, 1941, 1943, and, with Spilhaus, 1953) has been the authoritative reference, and his recent *The History of the Barometer* (Johns Hopkins Press, 1964) and *A History of the Theories of Rain* (Watts, New York, 1966) have been widely acclaimed. Since his retirement in 1963, after 17 years each as physicist for the Canadian National Research Council and as meteorologist for the Canadian Meteorological Service, Middleton has lived in his native England—except when traveling, on a Leverhulme grant, to track down and translate forgotten books and manuscripts in the libraries, archives, museums, and observatories of western Europe.

His research sheds new light on many old arguments, and some conclusions differ so much from classic accounts, based on incomplete information, that countless textbooks and reference works may need revision. As examples of Middleton's findings, those relating to the "invention of the thermometer" and to the origins of the Fahrenheit and Celsius scales, about 40 pages each of the 240 pages of text, are here summarized.

Thermometry began around 1610, when someone in Italy put a scale on a thermoscope. This device, which had been known for several decades and was called a "weather glass" for the next century and more, demonstrated the expansion of air when heated: the water level sank in the stem of an inverted air-filled bulb inserted in a bowl of water. The earliest description of a "thermometer—a thermoscope with a scale" is in a manuscript by Bartolomeo Telioux, dated Rome, 1611, and now in the Bibliothèque de l'Arsenal in Paris. But Telioux obviously didn't understand it, and hence didn't invent it—nor did Galileo Galilei (1564–1642). Middleton also rejects originality claims for Robert Fludd (1574–1637), a Welsh mystical physician, and Cornelius Drebbel (1572–1633), a Dutch inventor of "perpetual" clocks driven by the expansion and contraction of air.

Unable to identify the inventor of the air thermometer, Middleton settles for "Santorio Santorre, often called Sanctorius" (1561–1636) as the first to use it "as a scientific instrument." He had studied medicine at Padua (under Galileo?) and, after practicing there, in Poland, and elsewhere, became professor of medicine at Padua "on October 6, 1611, the year after Galileo left that famous university for Florence." By 1612 he was expressing in "degrees" the thermoscope water displacement, measured with a compass. "He is famous as the first to apply the quantitative methods of physical science systematically to medicine."



First known drawing of a thermometer, which appears in Bartolomeo Telioux's manuscript. Although Telioux was evidently not the inventor, the date of 1611 on the manuscript establishes a latest-possible date for the invention. [From *A History of the Thermometer and Its Uses in Meteorology*]

By 1644, the variation of atmospheric pressure became known (a barometer was developed in 1643), and the unsealed air thermometer was recognized as responding to pressure as well as temperature. Hence "the sealed liquid-in-glass thermometer was invented by . . . the Grand Duke of Tuscany, Ferdinand II" (1610–1670). His first models (by 1641) contained several glass balls of differing densities which sank, one by one, as the spirits of wine expanded: "the temperature of the spirit can be estimated from the number that have sunk." His second models (by 1654), prototypes of today's, used the expansion rather than the density of the spirit to measure temperature. Most of the models were graduated from 0° at about −19°C to 50° at 55°C, with the ice point at about 13½ °C.

"By about 1660 the spirit-in-glass thermometer had been brought to a technically satisfactory state. . . . The mercury-in-glass thermometer had been tried and temporarily abandoned. . . . The history of thermometry for the succeeding century and more is largely a record of attempts to make thermometers universally comparable."

Most of the scientists of the late 17th and early 18th centuries were involved: Robert Hooke (1635–1703), Christopher Wren (1632–1723), Robert Boyle (1627–1691), Isaac Newton (1642–1727), Edmond Halley (1656–1742), Christiaan Huygens (1629–1695), Edme Mariotte (1620–1684), and others less famous. They sought better ways of making thermometer tubes, better liquids (Newton tried linseed oil), and better reference points, which ranged from the temperature of melting butter to that in deep caves. They used widely differing scales; Middleton mentions two thermometers, made in 1754 and 1831, with cards bearing 18 scales each. The two scales that survived to the present seem both to have originated in Scandinavia.

"The famous Danish astronomer, Ole Rømer (1644–1710), the discoverer of the finite speed of light," by about

1702 "had settled on a thermometer scale having 60° as the boiling point of water and 7½° as the melting point of ice," so that one-eighth of the scale extended to subfreezing temperatures. On a visit in 1708, Daniel Gabriel Fahrenheit (1686–1736) "saw Rømer calibrating . . . meteorological thermometers [spirit] at a temperature of 22½° on his scale by comparison with one of his own thermometers in a vessel of warm water. . . . Later in 1708 Rømer changed his scale so that the melting point of ice became 8°."

Fahrenheit used this scale, multiplied by 4, for spirit thermometers in 1714 and for mercury thermometers in 1717. Apparently the young visitor thought Rømer's warm-water calibration represented body heat, which he used, first as 90°, later as 96°, for his upper point, keeping $4 \times 8 = 32°$ for the melting point of ice. "He did not use the boiling point of water as a fixed point, but stated it as 212°"; soon after his death it generally replaced body heat as the upper fixed point.

In England around 1700, many thermometers were scaled according to latitude, with small numbers for equatorial heat, large ones for polar cold: 0° = Extream Hott, 90° = Extream Cold. In 1723, James Jurin (1684–1750), secretary of the Royal Society, asked for pressure and temperature observations from throughout the world and recommended spirit thermometers made by Francis Hauksbee (1687–1763) bearing such a scale. At Uppsala, Sweden, regular observations were made with a Hauksbee thermometer from 1726 to 1750.

Another thermometer with 0° at the boiling point was sent to Uppsala in December 1737 by Joseph Nicolas Delisle (1688–1768), a French astronomer who directed Peter the Great's observatory from 1725 to 1750. In 1724 in Paris, he and his brother had calibrated spirit thermometers at "0° in boiling water and 100° in the Observatory cellars," which, being 28 meters deep, were around 12° C. In St. Petersburg, having no cellar, he used only one fixed point, 0° for boiling, on his mercury thermometers, calibrating them according to the contraction of mercury. In Moscow in 1738, his associate, Josias Weitbrecht (1702–1747), found that ice melted at 149.5° Delisle, and recalibrated the scale to make it 150°, having found that mercury contracted by 150/10,000 when cooled from the boiling point to the ice point.

Anders Celsius (1701–1744), professor of astronomy at Uppsala since 1730, apparently disliked both Hauksbee's and Delisle's scales. By the end of 1741 he had marked a new scale on Delisle's mercury thermometer, keeping 0° for boiling but putting 100° for the ice point, at 151.8° Delisle. The same year, Celsius induced his Uppsala colleagues to offer a chair to Carl von Linné, or Linneaus (1707–1778), who had just become uncomfortable at Stockholm. Linné liked thermometers with 0° at the ice point—he had ordered one in 1737—and inverted Celsius' scale after his friend died in 1744. By 1745 he had ordered "a centigrade thermometer with the zero at the ice point" for use in his greenhouses, and similar thermometers were used, from 1747 onward, by Märten Strömer (1707–1770), who succeeded Celsius at the observatory.

Beginning in 1730, René-Antoine Ferchault de Réaumur (1683–1757) tried to bring order out of thermometric chaos by determining the volumetric increase in alcohol from the ice point to the boiling point of water. He assigned to this expansion "80 parts in 1000, mainly because 80 is 'a number convenient to divide into parts' "; Rømer had similarly liked 60. After a few decades 80° was set at the boiling point, although Réaumur had always used only the ice point and his expansion factor for alcohol.

"In 1736, it appears, the Académie Royale des Sciences had sent to the Lyon observatory, and also to several other parts of the kingdom, Réaumur thermometers." Jean Pierre Christin (1683–1755), of the Lyon Académie, tried to make mercury thermometers according to Réaumur's volumetric procedure, and by May of 1743 had deduced that mercury expanded by 6700/6600 when heated from the ice point to the boiling point. His instrument-maker, Pierre Casati, began producing 0–100° mercury thermometers, which were used in southern France despite the opposition of Réaumur and his Paris colleagues.

Middleton does not point out the equivalence of the expansion coefficients of Christin and Delisle-Weitbrecht: 1/66 = 15/1000. He concludes that identification of the "inventor" of the centigrade temperature scale, since 1948 officially designated as the Celsius scale, depends on definitions of invention and of scale. Celsius had 100 degrees between the boiling point (0°) and the ice point (100°) in 1741. Linné reversed the scale by 1745. By May 1743, Christin had a mercury thermometer with 0° at the ice point as the only fixed value, although the boiling point was approximately 100°.

Much, much more detail is given by Middleton about these matters, about arguments on the invariance of the ice and boiling points, about the slow development of the concept of temperature, about absolute temperature and gas thermometers, about self-registering thermometers (the conventional minimum thermometer with "dumbbell" floating index dates from 1780, the maximum with a constriction from 1852), about thermographs and metallic and electric thermometers, and about the exposure and protection of meteorological thermometers and their ventilation. The handsomely printed volume contains 82 figures, almost all reproductions of original engravings.

But the accounts are often bewildering, with few attempts at integration. The parallelism between simultaneous developments is not stressed, and in many places the chronology is hard to establish: the picture is blurred by too much detail. Lack of cross-referencing makes necessary frequent recourse to the excellent and comprehensive index —which contains life-span dates not given in the text. A tabular chronology of the salient developments would be welcome. Those who would rely on Middleton in revising or framing their capsules of thermometric history must read and re-read this book carefully. I hope that the summaries offered here, of the early development of the thermometer and of its present scales, represent fairly Middleton's mind.

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Curious Beliefs

The Midwife and the Witch. THOMAS ROGERS FORBES. Yale University Press, New Haven, Conn., 1966. 210 pp., illus. $6.50.

The study of superstitions, magic, and the use of mystical symbols is a fascinating and revealing way to view the culture and heritage of a people. Forbes, a professor of anatomy at Yale University School of Medicine, defines superstition as "an unreasoning and unquestioning belief in some aspect of the natural or supernatural" (p. vii)