who said that he thought that he had himself invented the three-liquid barometer about 1685 until Hubin told him that it was Hooke's idea. The upper liquid in Amontons' thermometer was clear petroleum oil. But Amontons did much more than this in the study of the air thermometer, and we shall return to him in the next chapter.

The Problem of Temperature and its Measurement

an excerpt from 'A History of the Thermometer'
by W.E. Knowles Middleton

IV

The Search for Rational Scales

1. Introduction. By the year 1700 it was just beginning to be realized that the value of meteorological observations would be vastly greater if the observations made in one place could be compared directly with those made in another. As far as the thermometer was concerned this could have been done in either of two ways. The first was that suggested, as we have seen, by Jurin: to have everyone use thermometers made by the same maker and adjusted in the same way. The second was to establish one or more scales that could be reproduced anywhere by using simple laboratory techniques; one scale, if possible, but if more than one, the readings would still be interconvertible.

Even if Hauksbee's thermometers had been as uniform as Jurin thought they were, the first scheme would have had no future, as Hooke had foreseen in 1664. The world was too large a place; too large even—up to now—for the adoption of any one thermometer scale in all countries and for all purposes. There were bound to be a large number, some better, some worse, and throughout the eighteenth century the history of the thermometer is largely that of the development of these competing scales. For all practical purposes, only three survived into the 19th century, characterized by intervals of 80°, 100°, and 180° between the freezing and the boiling points of water, and popularly associated with the names of Réaumur, Celsius,[1] and Fahrenheit.

There were also a large number of others, many used only by their makers, but several with a certain celebrity in restricted territories, or for one or two decades. By about the middle of the century it was not uncommon for thermometers to be made with more than a dozen scales on a wide board behind the tube. There is one with eighteen scales in the University Museum, Utrecht, dated 1754. None of the scales are centesimal. The man-

[1] Or with the term *centigrade*.

ufacture of such instruments went on for a long time, as witness one at the Museo Copernicano in Rome, dated 1841, and with the following eighteen scales, reading from left to right:

1. Old Florentine	7. Delisle	13. Amontons
2. New Florentine	8. Fahrenheit	14. Newton
3. Hales	9. Réaumur	15. Société Royale
4. Fowler	10. Bellani	16. De la Hire
5. Paris	11. Christin	17. Edinburg
6. H. M. Poleni	12. Michaelly	18. Cruquius.

The reader may expect to meet some, but not all, of these in this book. Some of them are of interest only to the small and gallant band of historical climatologists who will be very familiar with the excellent work by J. H. van Swinden to which I have already referred.[2] My main task in this chapter is to try to unravel the involved and indeed tangled history of the more important scales. I cannot hope to have gotten it completely right; but I think I shall be able to dispel the darkness in a few corners.

2. Rømer and Fahrenheit. The history of the scale known by the name of Fahrenheit has led to a very great deal of controversy, and in no other area of the subject are there so many quicksands. Nevertheless, twentieth-century research has at least disposed of some venerable misconceptions.

Daniel Gabriel Fahrenheit was born in 1686 at Danzig but lived for so much of his life in Holland that the Dutch often consider him as one of themselves.[3] Originally intending to go into business, he became a successful instrumentmaker, and it is undoubtedly because he was a tradesman rather than a "natural philosopher" that he published very little about his methods. Like a number of other eighteenth-century instrumentmakers he was brought into the orbit of the Royal Society, and in the year of his election, 1724, he sent his only papers to the *Philosophical Transactions.*

For the history of the thermometer it is very important that during the first decade of the eighteenth century Fahrenheit was

[2] *Dissertation sur la comparaison des thermomètres* (Amsterdam, 1778).
[3] For biographical details, see: A. Momber, *Schriften naturf. Gesellsch. Danzig*, n.F, Vol. 7, Teil 3 (1890), pp. 108–39; Ernst Cohen and W. A. T. Cohen-De Meester, *Kon. Akad. Wet., Verhand., Afd. Natuurkunde*, erste sectie, Vol. 16, no. 2 (1936), pp. 1–37.

in Denmark for some time,[4] and especially that he visited the famous Danish astronomer Ole Rømer, the discoverer of the finite speed of light.

Now Rømer kept a notebook in which he jotted down all sorts of experiments and calculations. After his death in 1710 this book remained with his widow, who gave it to the University Library in Copenhagen in 1739.[5] It is called simply *Adversaria,* which is Ciceronian Latin for "notebook." But it is not in the state it was in when Rømer died, for his successor, Peter Horrebow, added a large number of remarks in much blacker ink than Rømer had used. This piece of vandalism—as it would be termed nowadays—turns out to be of importance to the history of the thermometer.

The *Adversaria* was published only in 1910,[6] complete with Horrebow's annotations, but without editorial comment except for two pages of introduction. One of the editors, however, let the world know about Rømer's thermometry by way of a summary in *Nature* of part of a book she had written in Danish,[7] and also a fuller article in a German periodical.[8] It is illuminating to examine the *Adversaria* with these papers as a guide. Later Miss Meyer's book, in which she let her enthusiasm for Rømer have full play, appeared in German.[9]

The part of the *Adversaria* dealing with thermometers appears on pages 202 to 213 of the printed edition. It starts with several pages headed "De mensura tubulorum vitreorum pro thermometris" (On measuring glass tubes for thermometers) in which Rømer makes elaborate calculations to show how the degree of uniformity of such tubes may be investigated by measuring the length of a drop of mercury at various places. Finally, he gives instructions for the construction of a standard thermometer, as follows:

> I. By means of a drop of mercury, find out whether the bore of the tube is regular, be it cylindrical or conical, before the bulb is blown. Discard those of irregular shape. Use the cylindrical ones without further examination. With the conical tubes we must proceed as follows:
> II. From the middle of the tube towards the ends take the lengths of the drop of mercury.

[4] Cf. Kirstin Meyer, *Arch. Gesch. Naturw. Techn.*, Vol. 2 (1910), pp. 323–49.
[5] It is now in the Kongelige Bibliotek (Royal Library), ms. E don. var. 16.
[6] *Ole Rømers Adversaria . . . udgivne af det Kgl. Danske Videnskabernes Selskab, ved Thyra Eibe og Kirstine Meyer* (Copenhagen, 1910).
[7] Kirstin Meyer, *Nature*, Vol. 82 (1910), pp. 296–98.
[8] *Arch. Gesch. Naturw. Techn.*, Vol. 2 (1910), pp. 323–49.
[9] Meyer, *Die Entwicklung des Temperaturbegriffs im Laufe der Zeiten* (Brunswick, 1913). (No. 48 in the collection "Die Wissenschaft.")

III. When by this experiment the tube has been divided into two equal parts, these parts are again subdivided, according to their increase or decrease. The whole tube will thus be divided into four equal volumes.
IV. When the thermometer has been made, filled, and sealed, the point of division 7½ is fixed by means of snow or crushed ice, the point 60 by boiling.[10]

In his notes Horrebow dates these experiments of Rømer's. Five thermometers had survived and had been given to Horrebow in 1739. Although he records this gift as "5 vitra pro thermometris,"[11] in April, 1741, he states[12] that he took the thermometers off their bases and put them into snow and then into boiling water, finding after all these years, "precisely the same marks that Rømer himself had scratched on them."[13] He also compared them with a thermometer sent from France, made on Réaumur's principles by the Abbé Nollet.[14]

On April 10, 1741, he asked Rømer's widow when her late husband had made these five thermometers, and she said that it was at a time when Rømer had been confined to the house because of a broken leg. Horrebow at once deduced that it must have been before June, 1703, when he first went to work at Rømer's observatory. This was confirmed by some old servants, perhaps predictably; and on the 17th of April the widow came to see Horrebow and told him that she was now certain that the thermometers had been made in 1702.

It therefore appears that Rømer was the first to make reproducible thermometers using the melting point of ice and the boiling point of water as fixed points, and dividing the scale into equal increments of volume—precisely the method still used, at least in principle, for the construction of liquid-in-glass thermometers. Judging by Horrebow's recalibration after nearly four decades, he seems to have been very successful. But why did he choose such a number as 7½ for the freezing point? The answer that I find most reasonable is that he first chose 60—a number very familiar to an astronomer—for the boiling point and then numbered his scale in such a way that, as he thought, all meteorological temperatures would be represented by positive numbers.

[10] *Adversaria*, ed. cit., p. 210. In view of its importance I give the last sentence in the original Latin:

"IV. confecto impleto et sigillato thermometro per nivem vel glaciem contusam constituatur punctum divisionis 7½ per ebullitionem punctum 60."

[11] *Ibid.*, p. 210.

[12] *Ibid.*, p. 213.

[13] "Praecise eadem signa, quae ipse Roemerus per silicem fecerat."

[14] See below, p. 85.

So he put ⅞ of his entire scale above the freezing point, and ⅛ below "for greater degrees of cold," as Horrebow puts it.[15]

Horrebow asked Rømer's widow whether her husband had later made any changes in his thermometric scale. She did not know; but she gave Horrebow a *vade-mecum* of Rømer's, in which was found a loose leaf, "in which I see that Rømer fixed his point at 8 divisions by means of the snow, and so indeed, as far as we know, the spirit of wine never goes below zero at Copenhagen."[16]

This leaf, part of the front of which is reproduced in Fig. 4.1, contains a graph of daily temperatures from December 26, 1708, to April 6, 1709.[17] The winter of 1708–9 was one of the coldest ever recorded in Europe; but for us the interest in this document lies in the heading, which puts it beyond doubt that by this time Rømer had placed the freezing point at 8°. He had also thought of putting it at zero, as noted in the upper line of figures. Over this Horrebow has written, upside down, "mutaverat ergo Roemerus primum suum propositum."[18] We do not know what the boiling point would have been; logically it might have been 64° if the freezing point were at 8°, or 56°, if at 0°.

Rømer's thermometer would be of much less interest if a young instrumentmaker from Danzig had not visited him in 1708. The name of this young man was Daniel Gabriel Fahrenheit. Before we come to his visit to Rømer, it will be well to say something about his thermometric scale.

Nowadays it is defined rigorously by setting 32° at the temperature of melting ice, and 212° at the temperature of the steam over pure water boiling at normal atmospheric pressure, the intervals presumably being determined according to the volumetric expansion of mercury.[19] This scale closely resembles the last of the three scales used by Fahrenheit, but his scales were defined quite differently. In spite of the fact that in 1724 he gave a description[20] of his fixed points in the most famous of scientific journals, the literature abounds in extraordinary speculations about his scale. As late as 1827 P. N. C. Egen repeated an old story that it was defined by a freezing mixture (0°F.) and the

[15] *Adversaria*, ed. cit., p. 210 (Horrebow's note).

[16] *Ibid.*, p. 211.

[17] The original is preserved in the manuscript of the *Adversaria* at Copenhagen, and is reproduced in the 1910 edition, p. 214.

[18] "Therefore Rømer had changed his first intention." Horrebow has also marked some readings taken in 1740, another very severe winter.

[19] The international scientific community pays almost no attention to the Fahrenheit scale in its deliberations about the measurement and specification of temperature.

[20] Fahrenheit, *Phil. Trans.*, Vol. 33 (1724), pp. 78–84.

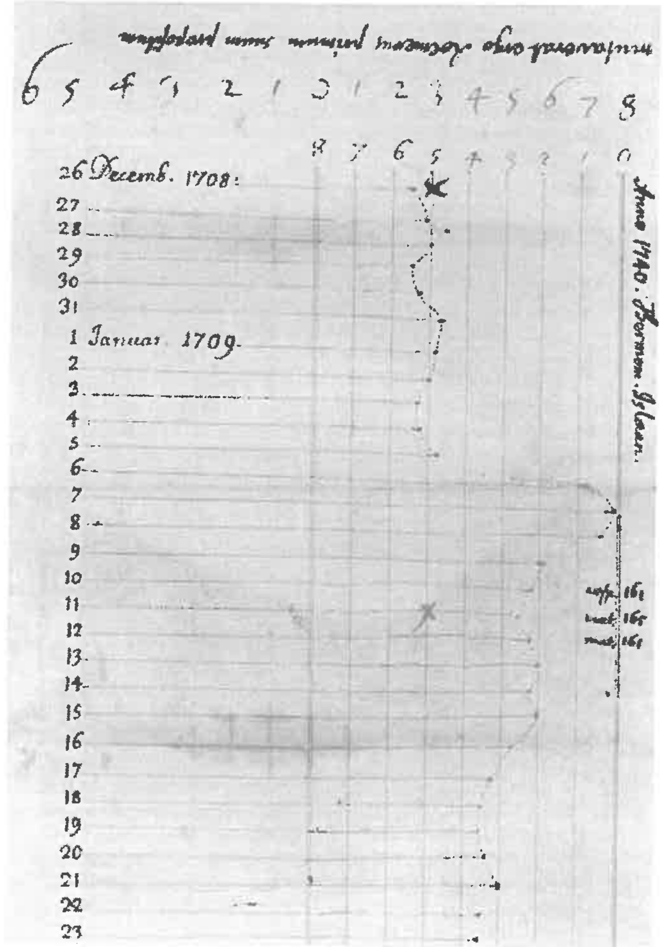

Fig. 4.1 Rømer's temperature curve, 1708–9.
(Courtesy of the Royal Library, Copenhagen.)

boiling point of mercury (600°F.)![21] I do not propose to go into detail about all these speculations, which would fill many pages.

Miss Meyer, finding evidence that Fahrenheit was in Denmark between 1702 and 1710,[22] strongly suspected that he may have learned from Rømer about thermometer-making. This could only be a speculation until Professor Ernst Cohen found among Herman Boerhaave's correspondence at Leningrad a letter from Fahrenheit to Boerhaave, dated April 17, 1729, apparently written in reply to a request for information, and stating clearly that Rømer had indeed given him his first ideas about it.[23] Professor Cohen writes with truth, "How much less printer's ink would have been used, if [this] letter had been known."[24] It is only fair to remark that a good deal has been used since; but first (using still more) I must record what Fahrenheit wrote.

> Now concerning the way in which I came to begin improving thermometers,[25] I am glad to inform you that I obtained the first incitement to it in the year 1708 through conversation with the excellent Rømer in Copenhagen. For once, when I went to see him on a fine morning, I found that he had stood several thermometers in water and ice, and later he dipped these in warm water, which was at blood-heat (*welches blutwarm war*). And after he had marked these two limits on all the thermometers, half the distance found between them was added below the point in the vessel with ice, and the whole distance was divided into 22½ parts, beginning with 0 at the bottom, then 7½ for the point in the vessel with ice and 22½ degrees for that at blood-heat. I also used this graduation until the year 1717, but with the difference that I divided each degree into 4 smaller ones. And in this manner were also divided the two thermometers, about which Professor Wolf[26] wrote a report in the *Acta Lipsiana* for August 1714. As this graduation is inconvenient and awkward because of the fractions, I decided to alter the scale, and to use 96 instead of 22½ or 90; this I have always used since then. And I found, although this is only by chance, that it agrees approximately, though not exactly, with the graduation of the thermometer than hangs in the Paris Observatory. After I had thus laid the foundations for the improvement of thermometers at Mr. Rømer's, I began to read some books about barometers and thermometers, and as I heard that in the French Memoirs of the *Académie des Sciences* a great deal had

[21] Egen, *Ann. der Phys.*, Vol. 11 (1827), p. 293.
[22] Meyer, *Arch. Gesch. Naturw. Techn.*, Vol. 2 (1910), p. 344.
[23] This was first published in its original Dutch in an article about Fahrenheit: Ernst Cohen and W. A. T. Cohen-De Meester, *Chem. Weekblad*, Vol. 33 (1936), pp. 374–93; and later in German in *Verh. K. Akad. Wetensch, te Amsterdam, afd. Natuurkunde* (1e sectie), Vol. 16, no. 2 (1936), pp. 1–37. I have used the German version, which is stated to be "möglichst wort-und stilgetreu" (*ibid.*, p. 9, note).
[24] *Ibid.*, p. 9.
[25] Note that he says "thermometers," not "my thermometers."
[26] [Christian Wolff], *Acta Eruditorum* (1714), pp. 380–81. The article is not signed.

been reported about these things, I began, with a good grammar and a dictionary, to study the French language, of which in a short time, thanks to my Latin, I got so good a command, that I was able to read and translate the writings of the Society [the *Académie*]. In this way a great light dawned upon me, to which the papers of Maraldi, De la Hire, and Amontons contributed much, especially the last, because he has taken very great pains to give the thermometer a firm foundation. Of the Englishmen who have written about the thermometer I have read only Boyle's writings, as far as they are translated into Latin. Those of the [Royal] Society I never began to read before the year 1724, when I was elected a Fellow. Since then I have come so far with it that I can read their writings too, and understand most of them. These are, in brief, the means by which I was put in the way of these improvements, with which I hope, Sir, you will be satisfied. . . .[27]

The reader will have noticed a serious discrepancy between the process described in this letter and that given unequivocally by Rømer in the *Adversaria*. Nothing was said by Rømer about blood heat; his upper fixed point, numbered 60°, was the temperature of boiling water.[28] This discrepancy has supported some doubts about the extent to which Fahrenheit was indebted to Rømer.[29] It is certainly unlikely that Fahrenheit would have misremembered this important occasion to such an extent, even after twenty-one years, for he had been dealing with thermometers during the whole of the interval. I see no irrefragable solution to the problem unless further documents are discovered, but I shall set forth what I believe to be a reasonable guess at what had happened between 1702 and 1708.

In the first place, a thermometer graduated up to the boiling point of water is not a very handy instrument for meteorological use. Too much of the scale is superfluous. It may well be that Rømer had noticed that the temperature of the air never went above about 20° on his scale, and that he had calibrated some thermometers of shorter range by comparison with his earlier instruments, making the top of their scale 22½°, three-eighths of the way from his zero to his boiling point. Plainly, there was no means of holding a vessel of water at blood heat, or anything near it, without the aid of a thermometer; so one of the thermometers that Rømer "dipped" into the warmer of the two vessels must have been calibrated. Of course, if we assume the scale of the thermometer to be linear, this vessel was a long way from blood heat, as has been pointed out (e.g., by Dorsey); but

[27] E. Cohen *et al.*, *Verh. K. Akad. Wetensch.*, Vol. 16 (1936), pp. 9–10.

[28] One might quibble by suggesting that water is not mentioned.

[29] Cf. N. Ernest Dorsey, *J. Washington Acad. Sci.*, Vol. 36 (1946), pp. 361–72.

it must be remembered that Rømer's thermometers were spirit thermometers, of which the scale is far from linear, as Deluc found,[30] so that it might well have been fairly close to the temperature of the human body. It would be very natural for Rømer to refer to it as "blood-heat." I am aware that this is all very speculative, but at least there seems to be no escape from the conclusion that Rømer had a calibrated thermometer in the vessel, if Fahrenheit's account is correct.

Another point of interest is that at some time between Fahrenheit's visit and the end of the year, Rømer changed his scale so that the freezing point became 8 degrees instead of 7½. We may imagine that the younger man said something about the inconvenience of fractions; but Fahrenheit does not seem to have known that his mentor had made the change, and kept the less convenient scale for some time. Rømer died in September, 1710.

Even after the publication of the famous letter, Fahrenheit's dependence on Rømer was the subject of argument, I. Bernard Cohen taking the extreme view that the Fahrenheit thermometer "should, in all fairness, be called the Rømer thermometer,"[31] and N. Ernest Dorsey the opposite view that Fahrenheit learned almost nothing from Rømer.[32] I think that my readers will agree at this point that the latter view is too extreme, and in what follows it will also appear that what we now know as the Fahrenheit thermometer differs greatly from Rømer's. I am aware of the opinions expressed in 1937 by J. Newton Friend,[33] who could not believe that Rømer "could be so inartistic as to choose arbitrarily the curious figure of 7½ for his lower fundamental fixed point."[34] But we have seen[35] that this is just what he said he did, and I hope I have shown that this figure was not entirely arbitrary, being merely one-eighth of 60. Dr. Friend believes that Rømer based his scale on a freezing mixture, although he nowhere said so.[36]

We learn from a letter to Boerhaave dated March 3, 1729, that Fahrenheit was at Berlin in 1713, where he "investigated the exact dilatation of mercury in a thermometer made of Potsdam

[30] See p. 124 below. With a linear scale, 22½° of Rømer's would correspond to about 28.3°C.; but this probably comes to about 33.5° on the basis of Deluc's corrections, and if Rømer's spirit of wine was rather dilute it might have been higher.

[31] *Isis*, Vol. 31 (1940), p. 362.

[32] *J. Washington Acad. Sci.*, Vol. 36 (1946), p. 370.

[33] *Nature*, Vol. 139 (1937), pp. 395–98 and 586.

[34] *Ibid.*, p. 586.

[35] P. 68 above.

[36] The notes by Horrebow that are discussed in another connection below (p. 94) seem to make Dr. Friend's position much less tenable.

glass, which almost agrees with one made of Bohemian glass."[37] At the beginning of 1617 he had settled in Amsterdam and had begun to make mercury thermometers.[38]

Meanwhile, he had received an enthusiastic advertisement from Christian Wolff of Halle in the article mentioned in his letter. But he had not remembered correctly, for it is clear from Wolff's detailed description of the thermometers that they had the 24-degree scale. They also had cylindrical bulbs, a shape that Fahrenheit early adopted as standard, and were filled with blue spirit. Although the bulbs were of slightly different sizes, the two thermometers shared the same scale, and Wolff notes that they read the same to within 1/16 of a degree, which may surprise us as much as it surprised Wolff, who notes that Fahrenheit had his own reasons for concealing the means by which he made his instruments agree with one another.

Like the barometermakers of the time, the thermometermakers felt that words as well as figures were useful on their scales. Wolff's pair of thermometers had them, as follows:

0°–Frigus vehementissimus
4°–Frigus ingens
8°–Aer frigidus
12°–Temperatus
16°–Calidus
20°–Calor ingens
24°–Aestus intolerabilis

These may be compared with John Patrick's notations given on page 61 above. If the degrees are multiplied by four they will correspond fairly closely to the present Fahrenheit scale, and the descriptions then seem very appropriate, with some reservations about "calidus."

In 1724, the year of his election to the Royal Society, Fahrenheit contributed five papers in Latin to the *Philosophical Transactions*—his entire published work. One of these was about his hydrometer, another,[39] which interests us somewhat more, is on the boiling points of various liquids, in which he ascribes his use of mercury as a thermometric liquid to learning of Amontons' demonstration[40] that the readings of the mercury barometer should be corrected for its temperature. He gives the boiling point of water as 212° on his scale; but it is only in a later

[37] Quoted by Cohen *et al.*, *Verh. K. Akad. Wetensch.*, Vol. 16 (1936), p. 10.
[38] *Ibid.*, p. 11.
[39] Fahrenheit, *Phil. Trans.*, Vol. 33 (1724), pp. 1–3.
[40] Amontons, *Mém. Acad. r. Sci. Paris* (1704), pp. 164–72.

paper,[41] in which he describes his accidental discovery of the supercooling of water—he slipped on the stairs while carrying a flask of supercooled water, and found that it suddenly became full of flakes of ice—that we get a description of his thermometers and the way they were calibrated. They were of two kinds, those filled with mercury and those filled with spirit of wine. They were of whatever length was suitable; he is careful to state that the length does not matter, because they are graduated between fixed points. Those intended only for meteorological observations were graduated from 0° to 96°. He tells us how the fixed points (*termini fixi*) are found:

> The division of their scales is based on three fixed points, which can be produced accurately as follows: The first is placed at the lowest part or beginning of the scale, and is attained with a mixture of ice, water, and sal-ammoniac or sea-salt; if the thermometer is placed in this mixture, its fluid descends to a point that is marked zero. This experiment succeeds better in winter than in summer. The second fixed point is obtained if water and ice are mixed together without the above-mentioned salts. If the thermometer is placed in this mixture its fluid takes up the thirty-second degree, which I call the point of the beginning of congelation, for in winter stagnant waters are already covered with a very thin layer of ice when the liquid in the thermometer reaches this degree. The third fixed point is found at the ninety-sixth degree; and the spirit[42] expands to this degree when the thermometer is held in the mouth, or under the armpit, of a living man in good health, for long enough to acquire perfectly the heat of the body. . . . The scale of thermometers for determining the heat of boiling liquids also begins at zero, and contains 600 degrees; for the mercury that fills the thermometer begins to boil at about that point.[43]

This passage contains the only authentic information about Fahrenheit's scale available for two centuries. I believe that much of the confusion has resulted from believing that he meant exactly what he said, and discounting the natural tendency of an instrumentmaker to wish to conceal his processes, or at least to obfuscate his readers. The mere fact that either of two salts was to be used in his freezing mixture, and the note that "the experiment succeeds better in winter than in summer," should have warned his readers that such a zero would not be even approximately a fixed point. Dr. N. H. de V. Heathcote has stated his belief that the temperature of melting ice and blood temperature were the real fixed points,[44] and I am sure that this is so. Yet as early as 1732 we find Pieter van Musschenbroek mentioning the

[41] Fahrenheit, *Phil. Trans.*, Vol. 33 (1724), pp. 78–84.
[42] *Spiritus.* For the moment he had forgotten about mercury.
[43] *Phil. Trans.*, Vol. 33 (1724), pp. 78–79.
[44] Heathcote, *Ambix*, Vol. 6 (1958), pp. 155–56.

two lower fixed points but saying nothing of the third, although he was using a thermometer made by Fahrenheit himself.[45] The authority of Musschenbroek was considerable and long-lasting, and we find his words almost repeated in an anonymous book on meteorological instruments ascribed to Michael Adelbulner, which went through three editions between 1768 and 1789.[46]

It is quite certain that Fahrenheit did not use the boiling point of water as a fixed point, and indeed he described[47] a "new barometer" based on his discovery[48] that the boiling point varies with the pressure. This instrument, the first hypsometric thermometer, is almost sufficiently described by reference to Fig. 4.2, in which it will be seen that he graduated the upper part *DE* of the scale directly in terms of barometer readings in inches of mercury, so that the atmospheric pressure could be determined merely by putting the instrument in boiling water.

It is, therefore, probable that his determination of the boiling point of water as 212° was made before he recognized its variability; at least it was reported a few months earlier. These figures of 212°, and boiling points of other liquids up to oil of vitriol at 545°, were certainly obtained with a thermometer having its scale extrapolated upward from 96°, a tricky business, depending critically on the uniformity of the tube at least, and of course begging all sorts of questions about the uniformity of the expansion of the thermometric liquid. Normal blood heat is 98.6° on the present-day Fahrenheit scale—instead of 96°—so that his 212° was probably fortuitous. Musschenbroek's instrument read 214° in boiling water. So did one used by Poleni,[49] though it is possible that he was merely copying Musschenbroek. But by about 1740 it seems to have become common practice to consider 212°F. both as the boiling point and as a fixed point, to the exclusion of blood heat.

The great chemist Herman Boerhaave was a faithful customer of Fahrenheit's and praised him highly. He once ordered two thermometers, one filled with mercury, the other with "the lightest alcohol." Careful examination showed that they did not quite agree in their readings. He told Fahrenheit, who acknowledged the defect but could not at first understand the reason. After thinking about it, Fahrenheit suggested that it was because they were made of glass from different places.[50] He missed the explanation of the main part of the difference, which is that alcohol and mercury do not expand proportionally.

Fahrenheit died in 1736, and the manufacture of his thermometers was continued by Hendrik Prins, as we are told in a

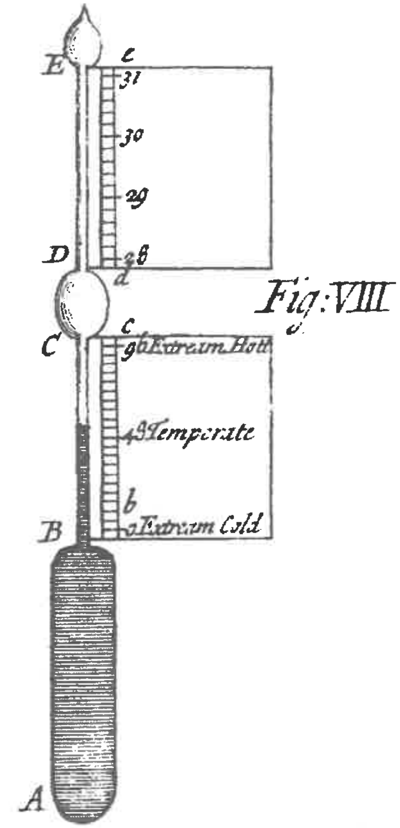

Fig. 4.2 Fahrenheit's "new barometer" or boiling-point thermometer.

[45] Musschenbroek, *Phil. Trans.*, Vol. 37 (1732), p. 358.

[46] *Kurze Beschreibung der Barometer und Thermometer, auch anderer zur Meteorologie gehöriger Instrumente* (Nuremberg, 1768; 2nd ed., Frankfurt and Leipzig, 1776; 3rd ed., revised by J. C. Heppe, Nuremberg, 1789). I have seen the 2nd edition; the passage is on p. 86.

[47] Fahrenheit, "Barometri novi descriptio," *Phil. Trans.*, Vol. 33 (1724), pp. 179–80.

[48] Johannis Poleni ("Dissertatio de barometris & thermometris" in *Miscellanea* [Venice, 1709], p. 13) says that Bernardus states that the temperature of boiling water depends on the pressure, but that he, Poleni, does not believe this. I have not traced the reference to Bernardus.

[49] J. Poleni, *Comm. Acad. Petrop.*, Vol. 8 (1736), p. 448.

[50] Boerhaave, *Elementa chemiae* (Leiden, 1732), p. 141.

manuscript note, probably by Delisle.[51] And on July 12, 1743, Anders Celsius wrote from Uppsala to Antoine and Jean Grill of Amsterdam, acknowledging the receipt of a "Prince thermometer."[52] Prins and Fahrenheit seem to have been considered equally able by Pieter van Musschenbroek.[53]

Two thermometers signed by Fahrenheit survive in the Rijksmuseum voor de Geschiedenis der Natuurwissenschaften at Leiden.[54] One (inventory no. Th 1) is a mercury thermometer with a brass scale, signed on the back. It is graduated from 0° to 600°, and has a bulb about 15 mm. in diameter and 50 mm. long. The other (no. Th 1a) is signed "D. G. Fahrenheit 1727." Although it is graduated from −8° to +600° (marked in Dutch as being the boiling point of mercury), it is filled with a dark-colored liquid, but there is a strong probability that the glass parts of the instrument are not original.

There is also a spirit thermometer (inventory no. 477) at the University Museum, Utrecht, signed "D^L^. G^L^. Fahrenheit." This has scales from −104° to +400°F., and −61° to +170°R, which must mean that it is one of his later productions for details of Réaumur's experiments can scarcely have reached Amsterdam much before 1733. I think that its authenticity is somewhat doubtful.

Before leaving Fahrenheit and Rømer I had better give a brief summary of the tentative conclusions at which I have arrived:

1) By about 1702 Ole Rømer had settled on a thermometer scale having 60° at the boiling point of water and 7½° at the melting point of ice. He had a fairly well-developed method of investigating the bores of tubes, and had made several thermometers.

2) In 1708 Fahrenheit saw Rømer calibrating thermometers. By this time Rømer had realized the convenience of calibrating meteorological thermometers at a temperature of 22½° on his scale by comparison with one of his own thermometers in a vessel of warm water. Fahrenheit referred to this as blood heat.

3) Later in 1708 Rømer changed his scale so that the melting point of ice became 8° and made observations with such a thermometer during the cold winter of 1708–9.

4) The spirit thermometers that Fahrenheit made for Christian Wolff about 1714 were calibrated according to this scale.

5) In 1713 Fahrenheit began experimenting with mercury thermometers and in 1717 began to make them commercially. At about this time he divided his degrees into quarters.

6) Fahrenheit's final scale was really based on two "fixed" points: the melting point of ice (32°), and the heat of the healthy human body (96°). He did not use the boiling point of water as a fixed point, but stated it as 212°.

7) Soon after his death the boiling point replaced blood heat as the upper fixed point.

It would seem that the Fahrenheit scale quickly came into use in the Low Countries and in England. In France it remained unused and practically unknown even to the *savants,* and a French thermometer with a Fahrenheit scale is a rarity,[55] though toward the end of the eighteenth century a few were made with both Réaumur and Fahrenheit scales.[56]

[51] Observatoire de Paris, ms. A.7.4, item 28, fol. J. "Mr Prins fait et vend à Amsterdam des thermometres de mercure entierement conforme à la division de Mr Fahrenheit."

[52] Upsala, University Library, ms. A533, item 164. I have to thank Dr. G. H. Liljequist for translating this letter.

[53] Musschenbroek, *Beginselen der Natuurkunde* (Leiden, 1736), p. 599.

[54] See also C. A. Crommelin, *Descriptive Catalogue of the Physical Instruments of the 18th Century,* Rijksmuseum, Communication no. 81 (Leiden, 1951), p. 34.