The "Scala Graduum Caloris" and Sir Isaac Newton

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An anonymous, six page article appeared in the *Philosophical Transactions* for the months of March and April, 1701. This paper written in Latin was titled "Scala graduum caloris: Calorum descriptiones & signa." Several years later in 1731, this article was republished in the *Abridged Edition* of the *Philosophical Transactions*. Again no author was given, and again it was published in Latin. However, this time the title had been translated as "Scale of the Degrees of Heat." Furthermore, the *General Index* of 1787 to the first seventy volumes of the *Philosophical Transactions* lists both publications of this article, without an author.[3]

The "Scala graduum caloris" is of historical interest for several reasons. First, it contains a scale of the degrees of *calor*. Throughout the "Scala graduum caloris," the author uses the term *calor* interchangeably for the present meanings of "heat" and "temperature;" when this article appeared in 1701, there was not a clear distinction between the terms "heat" and "temperature." For this reason the Latin term *calor* has not been translated.

The scale of the degrees of *calor* is divided into two columns: an arithmetical scale, which could be direct readings from a thermometer, and a geometrical scale, which had some points in common with the arithmetical scale. The arithmetical scale begins with zero for the *calor* of water beginning to freeze and lists and describes about twenty-two degrees of calor. For example, the summer air may be as warm as six on this scale. Twelve is given for the degree of *calor* of the human body. Thirty-three and thirty-four are the degrees of *calor* of boiling water. Forty-eight degrees is the *calor* of melting for a mixture of equal parts of tin and bismuth, while ninety-six is the melting *calor* of lead. One hundred ninety-two is the *calor* of an ordinary coal, kitchen cooking fire. Besides these, other degrees of calor are described in the "Scala graduum caloris."

The second column of the degrees of *calor* is a geometrical progression. The number one in this column is given to the *calor* of the human body, which is twelve in the arithmetical column. Two is the *calor* of melting wax or twenty-four units in the first column. Three is the *calor* of melting for equal portions of tin and bismuth or forty-eight in the first column. Four and five represent the *calors* of melting lead and of a coal, kitchen fire, corresponding to ninety-six and one hundred ninety-two in the first column. Each number in this geometrical scale is twice as great as the preceding one; therefore, the second degree in this column is twice the first, the third twice the second, etc.

The methods by which these scales were determined are also of interest. For the lower degrees of *calor,* a theremometer employing linseed oil for the expanding fluid was utilized. The *calor* of water beginning to freeze was assigned the value of zero on this thermometer, and the *calor* of the human body assigned the value of twelve. Equal divisions were then made between zero and twelve and extended from twelve higher. The melting *calor* of lead was the highest degree of *calor* measurable by this thermometer.

Another method was needed for determining the higher degrees of *calor.* By noting the time taken for the pieces of different metals placed upon a glowing iron bar to harden, and for the bar and metal pieces to cool to the degree of *calor* of the moving air, the degrees of *calor* of the hardening metal pieces could be calculated. The calculations require two postulates: the first assumes that uniformly moving air carries away from a warmer body *calor* in proportion to the total difference in *calor* between it and the flowing air; the second assumes that the excess of the *calor* from the body would be given up in a geometrical progression, while the time of cooling is an arithmetical progression. By placing only small pieces of different metals on the glowing iron bar, the author of this paper essentially determines that the rate of cooling will remain constant—the rate of the bar cooling without metal pieces. Therefore, variations in the rate of cooling of different metals are eliminated. The author concludes by observing that because of agreement between these two methods for determining the degrees of *calor,* the oil thermometer is a valid indicator of degrees of *calor*. The concept used in this second method for determining the degree of *calor* is that of Sir Isaac Newton's "Law of cooling." Moreover, Newton's "law of cooling" is traced directly to this paper, since this law does not appear in Newton's other works.

However, neither the scale nor the methods for determining *calor* would be of especial interest, if it were not for this connection between it and Sir Isaac Newton regarding his "Law of cooling." The "Scala graduum caloris" was published in Newton's collected works in 1744 and in 1782, although a reason for its inclusion was not offered. By 1751 George Martine in his *Essays and Observations on Thermometers* informs his reader of Newton's authorship of this paper but does not present a reason for doing so.[3] However, Sir David Brewster in his *Memoirs of Sir Isaac Newton* of 1855 offers his version of the circumstances of publication of this article:

> The only chemical paper of importance published by Sir Isaac, was read at the Royal Society on the 28th of May 1701, and printed in the Philosophical Transactions without his name, under the title *Scala graduum Caloris.*[3]

The following information was obtained from the *Journal Book* of the Royal Society entered for 28 May 1701:

> There was read a paper concerning the degrees of heat, measured by the melting of sevl [several] bodies etc. The Author was ordered the thanks of the Society and it was desired it should be printed as being likely to be very usefull.[4]

Thus, the records of the Royal Society fail to substantiate Brewster's claim for Newton's authorship. Similarly, in 1703 Guillaume Amontons critically reviewed the "Scala graduum caloris" in the *Memoires* of the Royale Academie of Paris. Amontons failed to note its author also. The following listings of Newton's works fail to note a manuscript version of this paper: the *Catalogue* of the Babson Collection of Newton's works, George J. Gray's *A Bibliography of the Works of Sir Isaac Newton,* and the sale *Catalogue of the Portsmouth Collection of the Newton Papers.* And it also is not *listed among the Classified Papers in the Archives of the Royal Society* under Newton's name. No one seemed to be aware that Newton wrote this paper. One might even suspect that Newton did not write it, if it were not for the circumstantial evidence that follows:

Passages in two of Newton's works, the *Principia* and the "Queries" in the *Opticks*, indicate Newton's interest in heat phenomena to be similar to those held by the author of "Scala graduum caloris." In the *Principia* Newton gives in several passages ratios between different degrees of *calor*. Sometimes Newton's ratios agree with those calculated from the "Scala graduum caloris;" other times they do not. An example of agreement is that seven times the *calor* of the summer sun is the degree of *calor* of boiling water. Another similarity illustrated in the *Principia* is Newton's interest in theories of cooling. This "Law of cooling" is different from that normally ascribed to him in the "Scala graduum caloris." This other cooling law supposes that as globes of various sizes cool; the time taken to cool is proportional to their diameters. In both the *Principia* and the "Queries" in the *Opticks*, Newton mentions glowing iron bars. In the "Queries" he further mentions that bits of metals were placed on glowing iron bars, as did the author of the "Scala graduum caloris." Generally, in both the *Opticks* and in the *Principia,* Newton indicates interests in many more different problems involving heat phenomena, than does the author of the "Scala graduum caloris."[5]

The most conclusive evidence supporting Newton's authorship of the "Scala graduum caloris" is given by David Gregory, who prepared the third edition of the *Principia*. In "Memoranda of May 1694," Gregory says that Newton claimed a glowing iron bar had the same degree of *calor* as the kitchen fire which warmed it. This statement is similar to one in the "Scala graduum caloris." Gregory continued that Newton determined the *calor* using two methods: the time taken for a body to cool, and an oil filled thermometer. Later Gregory added a note to these "Memoranda" stating that the oil in Newton's thermometer was either linseed or olive and that Newton determined the melting *calor* of the following substances: lead, tin, silver, bismuth, resin, and wax.[7] Moreover, not only did Newton utilize similar methods to do similar things, as did the author of the "Scala graduum caloris," but Newton was doing them or had done them eight years before the "Scala graduum caloris" was published. The concluding evidence from Gregory appeared in h's "Memoranda" for 1705:

> [25 Feb. 1705/6] The Table of the Degrees of heat in the Philos. Transact. for March & Aprile 1701 is Sir Isaac Newtons, as he told me 25 Feb. 1705/6, and he talks of reprinting it in Addenda at the end of the Latin Translation of his Opticks.[8]

SELECTED NOTES AND REFERENCES

[1]"Scala graduum caloris: Calorum descriptiones & signa," *Philosophical Transactions*, XXII (1701), 824-829. "A Scale of the Degrees of Heat," *The Philosophical Transactions (From the Year 1700 to the Year 1720) Abridg'd under General Heads*, IV (In two parts, 2d. ed.; London: 1731), pt. II. 1-4. *Paul Henry Maty, A General Index to the Philosophical Transactions, From the First to the End of the Seventieth Volume* (London: Printed for Lockyer Davis and Peter Elmsly, 1787), 424. The "Scala graduum caloris" has been translated in the following works into English: William Francis Magie, *A Source Book in Physics* (New York: McGraw-Hill Book Co., 1935), 125-128; and Isaac Newton, *Isaac Newton's Papers & Letters on Natural Philosophy and Related Documents*, I. Bernard Cohen (ed.), assisted by Robert E. Schofield (Cambridge: Harvard University Press, 1958), 259-268.

[2]George Martine, *Essays and Observations on the Construction and Graduation of Thermometers* (Edinburgh: Printed for Alexander Donaldson, 1780), 53-54, 18, 67, 116, 123, 188, *et passim*. Cf. George Martine, *Dissertations sur la chaleur, avec des observations nouvelles sur la construction et la comparaison des thermometres* (Paris: Chez Jean-Thomas Herissant, 1751). Isaac Newton, *Isacci Newtoni, Equitis Aurati, Opuscula Mathematica, philosophica et philogica*, Joh. Castillioneus (ed.) (Genevae: Marcum-Michaelem Bousquet & Socios, 1744), II, 419-423. Isaac Newton, *Isaaci Newtoni Opera Quae Exstant Omnia*. Samuel Horsley (ed.) (Londini: Joannes Nichols, 1782), IV, 403-407.

[3]Sir David Brewster, *Memoirs of the Life and Writings of Sir Isaac Newton* (2 Vols.; Edinburgh: Thomas Constable and Co., 1855), I, 362. Many biographers of Newton use only Brewster's information concerning the "Scala graduum caloris."

[4]Letter from R. W. Smith, London, England, August 28, 1962. Dr. Smith transcribed this passage from the *Journal Book* of the Royal Society during a research trip to London.

[5]Guillaume Amontons, "Remarques sur la table des degrez de chaleur, extraite des Transactions Philosophiques du mois d'Avril 1701; lue par M. Geofroy en l'Assemblee du Mardy 24 Juillet 1703," *Memoires*, 200-212, in

Histoire de l'Academie Royale des Sciences, (1703). *A Descriptive Catalogue of the Grace K. Babson Collection of the Works of Sir Isaac Newton and the Material Relating to him in the Babson Institute Library, Babson Park, Mass.,* introduction by Robert Babson Webber, (New York: Herbert Reichner, 1950). Gerald Vernon Wallop 9th earl of Portsmouth, *Catalogue of the Newton Papers Sold by Order of the Viscount Lymington, Great-Neice of Sir Isaac Newton. Which Will Be Sold by Auction by Messrs. Sotheby and Co.* July 13th, 1936, and following Day (London: by H. Davy, 1936). George J. Gray, *A Bibliography of the Works of Sir Isaac Newton: Together with a List of Books Illustrating his Works* (2d. ed.; Cambridge: Bowes and Bowes, 1907). See n. 4, above.

[6]Isaac Newton, *Philosophiae Naturalis Principia Mathematica* (Londini: Jussu Societatis Regiae ac typis Josephi Streater, 1687), 415-416, 498-499, 237, 236, *et passim.* Isaac Newton, *Opticks or a Treatise of the Reflections, Refractions, Inflections & Colours of Light* (Based on the fourth edition; London: Dover Publications, 1952), 339, 340, 341-3, 345, 348-9, 374-6, 396, 399, *et passim.*

[7]Isaac Newton, *The Correspondence of Isaac Newton,* H. W. Turnbull (ed.),(Cambridge: At the University Press, 1961), III, 313, 318, 322 n. 15.

[8]David Gregory, *David Gregory, Isaac Newton and their Circle: Extracts from David Gregory's Memoranda 1677-1708,* W. G. Hiscock (ed.), (Oxford: Printed for the Editor, 1937), 32-33. In a note Hiscock observes that the "Scala graduum caloris" was not published with the *Opticks.* I. B. Cohen also reports this quotation in Gregory's *Memoranda;* see I. Bernard Cohen, *Franklin and Newton: an Inquiry into Speculative Newtonian Experimental Science and Franklin's Work in Electricity as an Example There of* (Philadelphia: The American Philosophical Society, 1956), 68.