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# CHARLES CLÉOPHAS PERSON

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Key words: adiabatic calorimeter, fusion, heat of dilution, heat of solution, latent heat, neural currents, physiology, specific heat, thermometry, vaporization, vision.

**RESUMEN.** Charles Cléophas Person (1801-1884), médico francés convertido en estudioso de la termodinámica, que investigó en particular propiedades como los calores latentes de fusión, vaporización, y dilución, el calor específico de compuestos puros y soluciones salinas, termometría, fisiología neural, etc. Entre sus logros particulares se encuentra un procedimiento para mejorar la lectura de termómetros, un galvanómetro para detectar corrientes instantáneas débiles y un calorímetro adiabático.

**ABSTRACT.** Charles Cléophas Person (1801-1884), French physician, transformed into researcher of thermodynamic properties such as latent heats of fusion, vaporization, and dilution, the specific heat of pure compounds and saline solutions, thermometry, neural physiology, etc. Among his achievements we can mention a procedure for improving the lecture of thermometers, a galvanometer for detecting weak instantaneous currents, and an adiabatic calorimeter.

## LIFE AND CAREER<sup>1,2</sup>

Charles Cléophas Person was born on Mussy-sur-Seine (Aube) on May 1, 1801, and died in Paris in 1804. After completing his basic education at the Collège de Charlemagne he served as intern for seven years in the Parisian hospitals and then enrolled in the Faculté de Médecine de Paris and in 1831 received his degree of *docteur en médecine* after successfully defending a thesis about a theory of galvanism.<sup>3</sup> Simultaneously he studied at the Faculté des Sciences de Paris where he earned successively the degrees of *licencié ès sciences mathématiques*, *licencié ès sciences physiques*, and, finally, the degree of *docteur ès sciences physiques* after successfully defending two theses, one on the measurement of temperature and the laws of cooling, and the other about the chemical system and chemical formulas.<sup>4,5</sup> Immediately thereafter he won by competition a position of *agrégé de physique* at the Faculté de Médecine de Paris with a thesis about the changes induced by atmospheric air on inorganic substances and organized bodies, a position which allowed him to pursue an academic and research career.<sup>6</sup> Thus he became professor of physics at the Collège de Nancy (1832), professor of physics at the Collège de Metz (1833), and professor of physics at the Collège Royal de Rouen. In 1843 he won by competition the chair of medical physics at the Faculté de Médecine de Paris, with a thesis about the general laws of molecular action and analysis and discussion of their action on physiological and pathological phenomena.<sup>7</sup> He also served as professor of physics at the Faculté des Sciences at Besançon (1851-1856); during this same period he replaced Henry Sainte-Claire Deville (1818-1881) as dean of the faculty. Person retired in 1856 and was appointed honorary professor. In 1836 he was elected member of the Académie de Stanislas (Nancy) and in 1851 chevalier of the Légion d'Honneur.

## SCIENTIFIC CONTRIBUTION

Person wrote over 35 papers, booklets and books<sup>8,9</sup> in the areas of physiology, physics, medicine, thermodynamics, thermometry, astronomical phenomena, etc. As customary for all candidates to the Académie, he published a booklet describing his researches and achievements.<sup>2</sup> In addition to the subjects discussed below Person presented a new theory for the phenomenon of vision;<sup>10</sup> measured the temperature at the bottom (183 m) of an artesian well in Rouen;<sup>11</sup> explained the mode of operation of the Chinese magic mirror;<sup>12</sup> determined the rain regime at Besançon;<sup>13,14</sup> described the physics of the siphon;<sup>15</sup> reported on the use of Bohnenberger's apparatus for solving certain astronomical problems,<sup>16,17</sup> determined the mechanical equivalent of heat,<sup>18</sup> etc.

### Electrical current in nerves

The contractile property of muscles had interested scientists for many years. In 1823 Jean Louis Prévost (1790-1850) and Jean-Baptiste André Dumas (1800-1884) published an extensive memoir about the phenomena that accompanied the contraction of muscular fibers.<sup>19</sup> They concluded that in a state of rest muscular fibers were parallel

and rectilinear but under contraction they flexed in a zigzag manner, presenting regular undulations. This change occurred without change in volume. The vertexes of these curves were always situated in those parts where the nervous and muscular fibers intersected each other at right angles. Muscles could be considered to be a true galvanometer, with mobile branches, able to show electromotive effects similar to the action of a cold metal on a hot one, of an alkali on an acid, and able to identify very weak quantities of electricity. The muscle contracted every time it was transversed by an electrical current. Electricity was developed whenever the muscle was compressed, heated, or plunged into a concentrated acid. Prévost and Dumas believed that two currents were present in the nerve, one ascending and the other descending, which originated in the frontal and posterior parts of the spinal marrow.<sup>19</sup>

At the meeting of the 25th October of 1831 of the Académie des Sciences, Person read a memoir about animal electricity and a new galvanometer he had developed for measuring instant and very weak currents, which could not be detected by Johann Salomo Christoph Schweigger's (1779-1857) electromagnetic multiplier.<sup>3,20-22</sup> Person's galvanometer consisted basically of a wire wrapped as a cylinder and having a small iron needle in its axis. A steel needle hanging freely from a thread indicated the pole changes when a weak current flowed through the wire of the circuit, which magnetized the small iron needle in the opposite direction. He opened the spinal canal of different animals (cats, dogs, rabbits, eels, and frogs) and connected the poles of his galvanometer to the anterior and posterior parts of the spinal marrow, which were the source of very different functions, without obtaining any indication of the existence of electrical currents through this substance. These experiments were repeated at different parts, after the root of the nerves had been cut, and also at the cerebellum and the medulla. The experiences were repeated after he had injected strychnine in the abdomen of the animals in order to provoke muscular contraction at will. The results were always negative, no matter how sensitive the instruments were.<sup>3,20,21</sup>

Person summarized his results as follows: (1) the existence of electrical currents in the nerves, during life, was an hypothesis disproved by experiment; (2) the action of electrical currents on the nerves should be momentarily assimilated to that of mechanical and chemical stimulus; (3) the contraction that occurred in a frog when a weak current flowed through the nerve in a muscle was not enough to prove the existence of electrical currents in animal organs, because the same effect was obtained with cauterization or any other procedure used for exciting the nerve; (4) it was not necessary that an electrical current travel throughout a nerve in order to produce muscular contractions because the same effect took place, however small the extent of nerve traversed by the current that flowed between the two poles of the galvanometer; (5) the nerves were not better conductors than the wet muscles of other animal parts; (6) the shock produced by electrical fish was really caused by electricity; (7) the new galvanoscope explained the experiments of Humboldt and Gay-Lussac, why, for instance, we received a shock from carrying a torpedo in the naked hand, when none was felt if it was carried on a metallic plate; and why Davy did not perceive any deviation in Schweigger's galvanometer, though he received shocks across this instrument which were felt even up to the shoulder, and (8) the neurilemma (Schwann's sheath) was incapable of isolating the most feeble current that can be observed in galvanic experiments; so that a current running through a nerve, instead of following its ramifications, passed through the muscles whenever they presented a shorter passage (least resistance).<sup>3,20,21</sup>

In an additional note to the Académie Person tried again to prove that the hypothesis of electrical currents in nerves did not agree with experience; he seconded this opinion on the fact that metals were better conductors than nerves, a fact which he originally believed was well known. Finding, however, that this was disputed, he conducted the following experiment: He prepared a frog in the usual way for Volta's experiment, by isolating the lumbar plexus and a part of the sciatic nerves, and leaving them attached to the vertebral column. He then placed a plate of zinc on the thigh and noticed that electricity was produced by the action of the moist flesh on the metal, causing the metal to become *resinously* electrified, while the muscles became *vitreously* electrified. Connecting the other thigh with the zinc by means of a less oxidizable metal (e.g. copper) the resulting circuit caused a current from below to above and from above to below, which necessarily flowed through the nerves. When the nerves were contacted with the platinum wire of the galvanometer, the needle showed a deviation according with the course of the current. This result proved that the current flowed now through the metals proving that they were better conductors than nerves. It should also be observed, that the metallic wire afforded a passage for the electricity five or six thousand times longer.<sup>3,20,21</sup> (Footnote 1)

[1] Accordingly to the prevailing theory, there were two kinds of electricity, one produced by glass (vitreous) and the other by resin (resinous). The actual terms are positive and negative electrical charges.

## Latent heats

### Heat of vaporization

In a first paper on the subject Person wrote that it was well known that water poured over a very hot surface accumulated as round drops, which evaporated very slowly, even when the surface was incandescent.<sup>23</sup> There was no agreement on the arrangement of the liquid; according to Count Rumford (Benjamin Thomson, 1753-1814.), Martin-Heinrich Klaproth (1743-1817), and Auguste Laurent (1807-1853), the liquid touched the surface at a point, as did a drop on water on carbon black or a mercury drop on a glass surface. Common opinion was that the liquid was separated from the surface but no one had provided experimental evidence that this was true. Person designed a piece of equipment that allowed seeing the light between the surface and the liquid. The pertinent space was a fraction of a millimeter and increased or decreased according to the temperature of the base.<sup>23</sup>

Person was interested in knowing the force that supported the liquid. He did not believe, as some scientists, that it was the repulsive force of heat because molecular forces acted only at extremely small distances. Another opinion was that it was the force of the vapor (vapor pressure); this opinion was backed by the fact that the phenomenon took place with volatile liquids at very low temperatures. Nevertheless, in other cases another force was present: the phenomenon took place with water at 84 °C over a surface having a temperature below 100 °C. In this situation the vapor pressure was unable to support the liquid, hence a mixture of air and vapor supported the latter. Experiments carried on under vacuum confirmed this obvious explanation. The facts that the liquid was isolated from the surface and its disposition in drops were simply a consequence of the internal attraction in the liquid.<sup>23</sup>

The temperature of the liquid changed with that of the surface as shown by the fact that a small piece of alloy melting at 95 °C released into the water drop, melted or not depending if the surface was heated more or less. Experiments conducted by Person with very small thermometers showed that temperatures of 84 °C and more than 100 °C were the lower and upper limit for the phenomenon. According to Person, the relation between the time of evaporation  $\tau$ , the temperature of the water  $\theta$ , and that of the surface just covered with liquid ( $t$ ) was

$$\tau = t + [0.0225 (\theta + 75)]^4 \quad (1)$$

For very small amounts of water its temperature was related to the time of evaporation by

$$\theta = 469.6 \sqrt[6]{\frac{R}{\tau}} - 75 \quad (2)$$

where  $R$  is the radius on the drop in centimeters and  $\tau$  the temperature of evaporation in seconds. When the water was at a temperature above 100 °C it was possible to assume that if the surface was very hot then the liquid exerted a vapor pressure of 1 atmosphere.<sup>23</sup>

Rumford explained the slowness of evaporation assuming that a large part of the incident heat was reflected but Macedonio Melloni (1798-1854) showed that the reflected heat was less than 4% of the incident one. Claude Pouillet (1790-1868) had assumed that part of the incident heat crossed the liquid without heating it but Melloni showed that a drop of water of 2 mm diameter transmitted less than 6% of the heat radiated by an incandescent metal; for more voluminous drops the transmission was essentially nil. In other words, an explanation based on transmission was insufficient.<sup>23</sup>

According to Person it was quite easy to determine the amount of heat that the liquid received in a closed crucible maintained at a constant temperature. Since the liquid did not touch the walls, it was possible to describe the phenomenon using the laws of Dulong-Petit for heat radiation. The amount of heat received was identical to the one released by a surface identical to that of the liquid, independently of the dimensions of the crucible. Assuming a spherical drop all this heat was employed in vaporizing the liquid. A simple integration gave

$$\tau = \frac{6kr}{c} \quad (4)$$

where  $\tau$  was the time of vaporization in seconds,  $k$  the heat of vaporization per gram of liquid [Person reported the values 543, 208, and 91 units for water, alcohol, and ether, as measured by César Despretz (1791-1863)],  $r$  the radius of the drop in mm, and  $c$  the heat released by 1 cm<sup>2</sup>/min under the given conditions. According to Person, the experiences of Dulong and Petit, using a silvery thermometer containing 1,500 g of mercury indicated that

$$c = 0.1785 a^t (a^\theta - 1) \quad (5)$$

where  $t$  is the temperature of the liquid,  $(t + \theta)$  that of the surroundings, and  $a = 1.0077$ .

After additional algebra Person deduced the final formula:<sup>23</sup>

$$\tau = \frac{kr}{0.0297 a^t (a^\theta - 1) + 0.084 \theta^{0.92}} \quad (6)$$

In following paper Person used a modified form of equation (6) to calculate the heat of vaporization of bromine, iodine, mercury, sulfur trioxide, sulfuric acid, carbon disulfide, and methanol.<sup>24</sup> The experimental procedure was very

simple: a small silver or platinum crucible was suspended by three wires over an ordinary oil lamp. The heat generated was enough for cause the heavy and less volatile liquids to be suspended by their own vapors. A drop of known weight was added to the crucible, and the duration of the process, and the temperature measured. The corresponding heat of vaporization ( $k$ ) was calculated using following the expression:

$$k = 0.02687\tau \left( \frac{1+\delta}{D} \right)^{\frac{3}{5}} \left( \frac{c+c'}{p^{\frac{1}{3}}} \right) \quad (7)$$

where  $D$  is the specific weight of the liquid,  $\delta$  the dilation up to the boiling temperature,  $p$  the weight of the sample,  $\tau$  the duration in seconds,  $c = ma'(a^\theta - 1)$ ,  $t$  the boiling temperature,  $t + \theta$  the temperature of the crucible,  $a = 1.0077$ ,  $m = 0.1$  in a flat capsule and  $0.2$  in a deep one, and  $c' = 0.48\theta^{0.92}$ .<sup>24</sup> In an additional note Person showed that equation (8) was very appropriate for calculating the latent heat of fusion of alloys.<sup>25</sup>

In a following paper Person reported the fusion temperature, the latent heat of fusion and the specific heat (at different temperature ranges) of tin, bismuth, lead, zinc, phosphorus, sulfur, d'Arcet alloy (31.25 % lead, 18.75 % tin, and 50 % bismuth), a lead-bismuth-tin alloy, sodium nitrate, sodium phosphate, calcium chloride, and yellow beeswax. He mentioned that he had measured the specific heats using the apparatus and high precision air thermometers provided by Victor Regnault (1810-1878).<sup>26</sup> The experimental procedures were discussed in detail in other publications.<sup>27-29</sup> The first one (1847a) is particularly interesting because it describes the construction and operation of an *adiabatic calorimeter*.

In a more extensive paper Person remarked that the latent heat of fusion did not vary in inverse ratio with the atomic masses as he had assumed previously. This time he found that these properties were better related by the equation

$$l = (t + 160)\delta \quad (8)$$

where  $t$  was the temperature of fusion,  $l$  the latent heat, and  $\delta$  the difference in specific heats of the solid and the liquid states. According to this equation the latent heat of could be easily calculated by multiplying the difference in specific heats in the solid and liquid states by the number of degrees from 160 degrees below the zero up to the fusion temperature of the compound. Person illustrated the accuracy of his relation by comparing the calculated against the experimental value of the latent heat of water, calcium chloride, sodium phosphate, phosphorus, sulfur, sodium nitrate, and potassium nitrate, nevertheless it failed completely when applied to the metals because of the small difference of specific heat in their solid and liquid states, which made the value of  $\delta$  almost zero. This led him to modify equation (8) as follows; Let  $c$  and  $C$  be the specific heat of a solid and liquid state ( $160 + t$ ), where  $c$  represents the heat (enthalpy) existing from 160 °C to  $t$  degrees in unit of weight in a solid state. Addition of the heat of fusion ( $l$ ) will represent the heat (enthalpy) contained in the liquid within the same limits. A heat balance gives:<sup>30</sup>

$$(t + 160)c + l = (160 + t)C \quad (9)$$

$$l = (160 + t)(C - c) \quad (10)$$

that is, the heat taken from a liquid state can be calculated as if the mass had remained liquid, without changing in state.

Person used equation (10) to reach the (wrong) conclusion the absolute zero was located 160 °C below zero.<sup>30</sup>

In an additional note Person showed that equation (8) was very appropriate for calculating the latent heat of fusion of alloys.<sup>31</sup>

Person also measured the freezing temperature of mercury and its latent heat of fusion.<sup>32,33</sup> He wrote that for freezing large amounts of material he had used thin-walled metallic vases, enclosed one in the other and separated by air spaces that served as an excellent insulation. As a freezing medium he employed a mixture of calcium chloride and snow; 400 g of the salt and 300 g of snow were enough for freezing about 700 g of mercury in about 40 to 50 minutes, if the air was dry and at about 0 °C. This mixture allowed him to reach temperatures down to -48.5 °C, measured with an alcohol thermometer. The latent heat of freezing was calculating using the equation

$$l = \frac{(PC + \nu)(T - T') + a}{m} - \left( C + \frac{\mu}{m} \right) (t - t') \quad (11)$$

where  $\nu$  was the equivalent in water of the vase that constituted the calorimeter,  $P$  the weight of liquid employed,  $C$  its specific heat,  $m$  the weight of mercury,  $t$  and  $t'$  its initial and final temperatures, and  $\mu$  and  $c$ , the thermal equivalent of the vase it contained it and its specific heat,  $T$  and  $T'$  the initial and final temperatures, and  $a$  the heat lost during the experience.<sup>32</sup>

The result of three experiments gave the values 2.77, 2.86, and 2.83 units/g for the latent heat of fusion of mercury.<sup>32</sup>

In an extension of the above publication Person justified his use of calcium chloride as the freezing medium, gave a very detail description of the adiabatic calorimeter and its operation, and of the derivation of equation (11).<sup>33</sup>

### Heat of fusion

According to Person, during the melting of a metal the molecules forming the ensemble were separated and a considerable amount of work was done by thermal energy. It was expected that with different metals the same amount of heat would produce the same amount of work, which would be identical to the heat of fusion. Person used this assumption to derive a formula for calculating the heat of fusion.<sup>34</sup>

Techniques were available for measuring the heat of fusion, but how could the work produced be measured? Parson believed that the work required to separate the molecules had to be connected by a simple relation to the work required to separate them by a certain amount. The available information indicated that there was a remarkable proportionality between the latent heat of fusion and the coefficient of elasticity (defined as the weight required to double the length of a stem of 1 mm<sup>2</sup> section, assuming that the elongation is proportional to the traction). For example, the force required to extend zinc was double that for elongating tin; similarly, the amount of heat required for melting zinc was double that for melting tin. For a given elongation, the amount of force required by lead was 20% that required for zinc; their heats of fusion were in the same proportion. A similar relation existed between bismuth and crystallized zinc. Hence, calling  $q$  and  $q'$  the coefficients of elasticity of the two metals, and  $l$  and  $l'$  their corresponding heats of fusion we could write, at least approximately,  $q:q' = l:l'$ . Obviously, the same elongation would occur in unequal weights of the two metals. In practice, the heat of fusion should be proportional to a function of the coefficient of elasticity representing the amount of work necessary to overcome the cohesion of the molecules present in a *unit of weight*. Person showed that calculation of the amount of work required for annihilating the cohesion between the molecules contained in a cube of unit weight led to the relation<sup>34</sup>

$$\frac{q}{q'} \left[ \frac{1 + \frac{1}{\sqrt{p}}}{1 + \frac{1}{\sqrt{p'}}} \right] = \frac{l}{l'} \quad (12)$$

where  $p$  and  $p'$  were the specific gravities of the metals. According to this equation the ratio of the latent heats was equal to that of the coefficients of elasticity, multiplied by a function of the specific gravities. The available information indicated that for zinc and lead the ratio  $q/q' = 4.80$  so that  $l/l' = 5.28$ , close enough to the actual value 5.03. For tin and lead  $q/q' = 2.20$  and  $l/l' = 2.42$  against 2.65, for d'Arcet's alloy, the calculated value of  $l/l'$  was 3.92 against 3.68. Calculation of the latent heat of fusion for cadmium and silver yielded the values 13.66 and 20.38, against the experimental ones, 13.52 and 21.07, respectively.<sup>34</sup>

In a publication about the latent heat of fusion of ice Person remarked that experimental evidence on the fusion of solids indicated that the process was not sudden; it was always preceded by a softening of the solid during which a certain amount of heat became latent. For certain substances like beeswax, the softening began quite far from the fusion point and the heat absorbed during this stage could be larger than the heat of fusion proper. This phenomenon could lead to a sensible error in the calculation of the heat of fusion and explained the difference in the values for the heat of fusion of ice reported in the literature. For ice, the softening began at about 1 or 2 degrees below the point of fusion. The true measure of the heat of fusion should then be calculated with the equation

$$A = c(\tau - t) + C'(t - \tau) \quad (13)$$

where  $A$  is the heat absorbed by a unit weight of the substance between the temperatures  $t$  and  $t'$  located far from the point of fusion  $\tau$ .<sup>25</sup>

The result of six experiments indicated that at 0 °C the heat of fusion of ice was 80 units/g and its specific heat 0.48 units/g.degree.<sup>25</sup>

### Specific heat and heat of solution of salts

In 1850 Person reported to the Académie des Sciences the results of his experiments about the specific heat ( $C$ ) and heats of solution ( $q$ ) in water of a variety of inorganic salts (potassium nitrate, sodium nitrate, the double nitrate of sodium and potassium, sodium chloride, and hydrates of calcium chloride and of sodium phosphate) at different concentrations and temperatures, using the adiabatic calorimeter he had developed.<sup>34,35</sup> A following publication described in detail the experimental procedure and the equation used for calculating these properties:

$$C = \frac{(mc + v)(t - t') + a}{M((T' - T))} - \frac{\mu}{M} \quad (13)$$

$$q = \frac{1}{n} [(P + n)c + \mu](\theta - \theta') \quad (14)$$

$$q = \frac{1}{n} [P + \mu + (p + n)c + \pi](\theta - \theta') \quad (15)$$

where  $M$  is the weight of the liquid and  $n$  that of the salt, and the other symbols have the meaning reported above. Equation (15) was used for very concentrated solutions. The specific heat of the water (1.0016) was considered to be constant between 0 and 40 °C.

The experimental results led Person to conclude as follows; (1) The specific heat of saline solutions was always less than that of its components; that is to say, less heat was always required to heat a solution than to heat separately the water and the salt, which composed it. The difference could be very small for certain concentrations, but it never changed sign. This simple relation was valid only when the salt was considered in the liquid state; there was no regularity when it was supposed that the salt maintained in the solution the specific heat proper to the solid state; (2) the reduction of the specific heat was not related to the affinity. For example, it should not be expected to be greater with calcium chloride, which had so strong an affinity for water, than with any other salt which had a much less affinity for that liquid; (3) the diminution of specific heat was not related to the diminution of volume which took place simultaneously; (4) measurement of the heat of solution required previous knowledge of the specific heat of the solution; and (5) the heat of solution varied with the relative proportion of the two components, indicating the presence of a *latent heat of dilution*.<sup>35,36</sup>

### Thermometry

All the work done by Person on calorimetry needed careful and accurate measurement of the temperature. Hence, he paid particular care to the type of thermometer he was using and their calibration.<sup>37,38</sup> In a first paper on the subject Person remarked that in most thermometers having two fixed points, the distance between two degrees was hardly more than 4 to 5 mm, which meant that the uncertainty of the measured temperature was at least 0.01 degree.<sup>37</sup> The problem became more serious if the thermometers were marked for temperatures different from 0 and 100°. Person believed that this problem could be partially solved by using only one fixed point, particularly around the temperature being measured. Instruments having no fixed points were appropriate only for measuring differences in temperature. Person proposed a very simple solution for overcoming this limitation with thermometers having two fixed points: Addition of an intermediate reservoir that accommodated the expansion of the mercury for the temperatures not needed. In this situation, for example, in thermometers used for measuring atmospheric temperatures, the last 70 °C were replaced by a small reservoir located below the mark 100 °C. In this situation the average mark between two consecutive degrees became about 17 mm, allowing a satisfactory reading of 1/100 of a degree. In this paper Person gave a detailed description of the best way to construct this type of thermometer.<sup>37</sup>

In a second paper, Person discussed the thermometry problems caused by the displacement of the zero of a thermometer, a phenomenon caused by the changes of the glass dimensions with time, particularly when the same instrument was first used to measure temperatures below 0 °C and then higher ones. In this situation the level of the mercury did not return to its original position.<sup>38</sup> César-Mansuète Despretz (1791-1863) had discussed this problem in detail and proven that the zero of a thermometer was an ever oscillating phenomenon; if the thermometer was withdrawn from the cold or hot source, the zero moved very slowly towards the zero determined before the change, and for this reason the zero of a thermometer used to measure atmospheric temperature ascended in winter and descended in summer.<sup>39</sup> This anomaly required that the thermometers be calibrated very often.

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