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VIEWING THE CONTROVERSY LOSCHMIDT – BOLTZMANN/MAXWELL THROUGH MACROSCOPIC MEASUREMENTS OF THE TEMPERATURE GRADIENTS IN VERTICAL COLUMNS OF WATER

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Abstract

In order to clarify the dispute between Loschmidt and Boltzmann/Maxwell concerning the existence of a temperature gradient in insulated vertical columns of gas, liquid or solid, macroscopic measurements of the temperature distribution in water were performed. A negative temperature gradient, cold at the top and warm at the bottom, is found in insulated tubes, while the outside environment has a reverse gradient. This is explainable by the influence of gravity. These test results strengthen the suggestions of Loschmidt, and contradict the statements of Boltzmann and Maxwell.

Key words: temperature gradient, gravity**,** water, second law, isolated system, energy production, heat bath, Maxwell, Boltzmann, Loschmidt

INTRODUCTION

When the author needed a container with uniform temperatures he found it impossible to create one. Even when the container was carefully isolated from the surroundings, it always ended up with a temperature gradient cold at the top and warm at the bottom, in spite of an opposite gradient in the surroundings. Could gravity be the cause as it was already responsible for creating a pressure gradient within the space?

In checking the literature the author found that late in the 19th century J. Loschmidt believed that a vertical column of gas or a solid in an isolated system would show a temperature gradient under the influence of gravity, being cold at the top and warm at the bottom. L. Boltzmann and J. C. Maxwell disagreed. Their theories and understanding of the Second Law supported an equal temperature over height. This historical discussion between J. Loschmidt, L. Boltzmann and J. C. Maxwell is covered in [1], [2], and [3]. A. Trupp gives a good summary in [4]. See also Section 1 of this paper.

Because neither Loschmidt nor anybody else have proposed a theoretical calculation for estimating the size of this gradient, the author developed a theory as discussed under (2) The results of the calculations are gradients of -.07 K/m for air and -.04 K/m for water. If values of this magnitude would develop in experimental setups, then, together with the improvements of temperature sensors and data collection techniques since the time of Loschmidt, it should now be possible to measure this effect.

The author reported for the first time in [5] and [8] actual measurements of the temperature gradient in gas columns in isolated systems. The value found for air is -.07 K per meter of height; nearly identical to the calculated value (2) and seems to strengthen the position of Loschmidt. They are critically discussed by Sheehan [10].

In trying to reach more stable results, the measurements were extended to vertical columns filled with a liquid. A first report was published in [9]. Water was selected, because of its high density. This way temperature fluctuations of the environment affect the temperature gradient less than when measuring gases. The tests show a gradient of about -.05 K/m, which is close to the calculated value (2).

It is known that temperature gradients in gases and liquids are stable only up to the adiabatic lapse rate [8]. Higher negative values are not possible, because the column of gas or a liquid becomes instable. Lower temperature at the top than at the bottom create higher densities at the top resulting in convection currents which would diminish the temperature gradient to values below the adiabatic lapse rate. In order to make greater values possible, the author tried various convection-suppressing designs. It was found that the use of fine powders, like glass powder, eliminated these convection currents. It had the added advantage that it prevented any heat exchange by radiation within the test setup.

The column used in the reported test had a height of 850 mm. It was chosen as a compromise between a greater height, allowing a greater temperature gradient, which is easier to measure, but having the difficulty to create a good insulation against the temperature fluctuations in the environment, and a smaller height with the opposite advantages and disadvantages.

Great care had to be taken to improve the accuracy of the temperature measurements. Temperature gradients were measured primarily with thermocouples. Often they were used as thermopiles connecting 5 thermocouples in sequence. Critical values were measured twice with switched polarity correcting for any zero offset.

The tests result showed a gradient of about -.05 K/m, close to the calculated -0.04 K/m. This value was generated by two methods. An average value over time was calculated using the so called “future average” eliminating the initial time periods when equilibrium had not been reached yet.. The second method used the values of the measured gradients only at times of constant temperatures in the test column indicating periods of no heat flow. Both methods resulted in very similar values.

1. The historical dispute between J. Loschmidt, L. Boltzmann and J. C. Maxwell

In trying to formulate and understand the Second Law, Botzmann calculated in 1868 that a column of gas should have the same temperature at the top and at the bottom, but his calculations were limited to ideal gases.

Loschmidt disagreed with some of the conclusions and assumptions. He thought that gravity would create a temperature gradient, cold at the top and warm at the bottom, especially in solids. He felt that this would not contradict the Second Law and had the following vision for the future:

"Thereby the terroristic nimbus of the second law is destroyed, a nimbus which makes that second law appear as the annihilating principle of all life in the universe, and at the same time we are confronted with the comforting perspective that, as far as the conversion of heat into work is concerned, mankind will not solely be dependent on the intervention of coal or of the sun, but will have available an inexhaustible resource of convertible heat at all times" 3) .

Loschmidt never explained, why a temperature gradient would not contradict the Second Law. He believed that only measurements could decide this dispute but, knew that improved sensors and instruments would be needed to measure the small gradients he expected.

Maxwell expected equal temperatures at the top and bottom and in his book "Theory of heat", published in London in 1877, he writes (p. 320):

"... if two vertical columns of different substances stand on the same perfectly conducting horizontal plate, the temperature of the bottom of each column will be the same; and if each column is in thermal equilibrium of itself, the temperatures at all equal heights must be the same. In fact, if the temperatures of the tops of the two columns were different, we might drive an engine with this difference of temperature, and the refuse heat would pass down the colder column, through the conducting plate, and up the warmer column; and this would go on till all the heat was converted into work, contrary to the second law of thermodynamics. But we know that if one of the columns is gaseous, its temperature is uniform. Hence that of the other must be uniform, whatever its material."

2. Theoretical value for temperature gradient $T_{(Gr)}$. .

No published treatise is known to the author for calculating the vertical temperature gradient $T_{(Gr)}$ in solids or liquids under the influence of gravity. But, the value of $T_{(Gr)}$ can be calculated by equating the potential energy of the molecules to the increase of their speed on their downward path. Their speed is related to their temperature. When bouncing off the bottom wall their kinetic energy is zero at the moment of impact. Though the loss of potential energy on their downward movement their energy is totally converted to an increase of their average “temperature”. A heat transfer takes place between water molecules and the upper and the_lower walls of the tube, until the wall temperatures are equal to the "temperature" of the impinging water molecules and equilibrium has been reached.

The potential energy is

$$E_p = -M \times g \times H$$

with M = mass; g = constant of gravity; H = height difference

(negative, because g and H are measured in opposite directions)

We equate this potential energy E_p with the amount of energy available for a temperature increase of this mass

$E_{avail} = M \times c_{Gr} \times T$ with c_{Gr} = effective specific heat; T=Temperature difference

We now can equate E_p wit E_{avail} or

$$E_p = E_{avail} = M \times g \times H = M \times c_{Gr} \times T$$

or

$$T = g \times H / c_{Gr} = T_{Gr}$$

c_{Gr} is not the normal specific heat of the liquid in question, because the acceleration through g affects only the vertical speed component of the molecule. The potential energy is converted only into an increase of their speed in their lateral downward direction while no energy is used or distributed in accordance with the equipartition of energy to the other degrees of freedom like the additional two lateral directions left to right and front to back or towards the rotational energy in molecules with more than one atom. Therefore,

$$c_{Gr}= c / n$$

with c = specific heat; n = number of degrees of freedom

We therefore get

$$T_{Gr}= -g \times H / c_{Gr} = -g \times H / (c/n)$$

With this formula for a height of 1 meter and taking the number of degrees of freedom for water as 18, we obtain

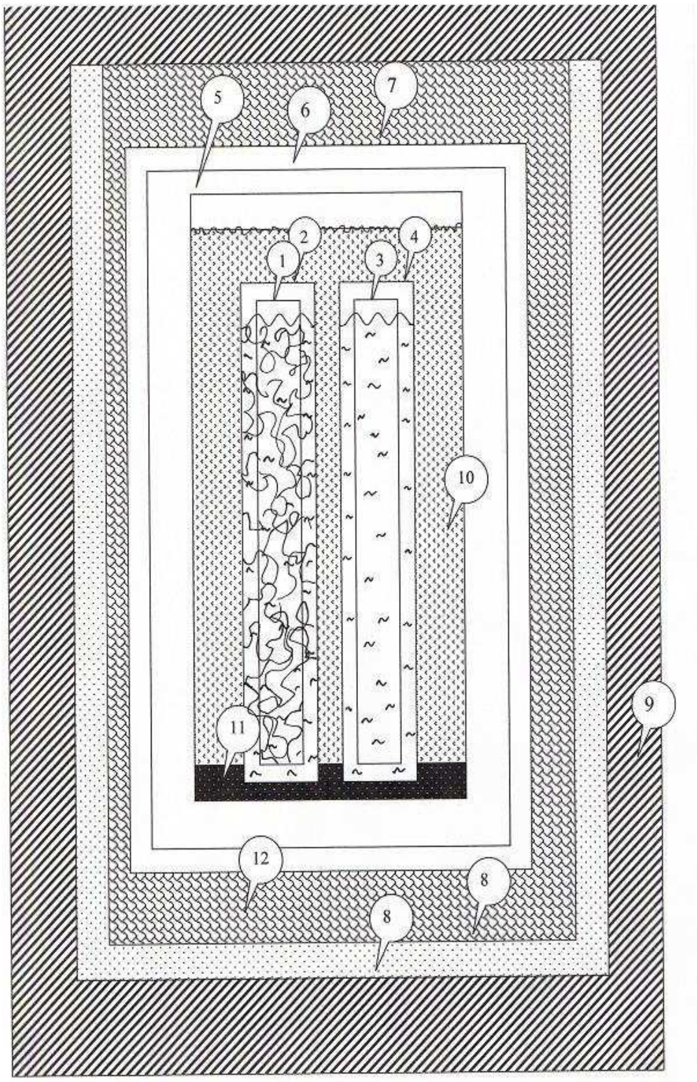
$$T_{(Gr)} = -.04 \text{ K/m}$$

3. Demonstrating a temperature gradient in a vertical column filled with water.

The following test, called here B372 was carried out in Burgberg, Germany on water as liquid. It was selected due to its high density. This way temperature fluctuation of the environment affects the temperature gradient less than when measuring gases. Calculations, described in section 2, show that water, having a higher specific heat than air and a greater number of degrees of freedom -- 18 compared to only 5 for air -- should give a temperature difference of about -.04 K/m. Such a gradient should be measurable within a setup similar to the one used for gases as described in [5] and [8].

31. Test setup

Fig. 1:



1: Glass tube 1, filled with
water and glass powder
L= 850 mm, D= 40 mm

2: PVC tube 1,
L= 910 mm, D= 50 mm .

3: Glass tube 2, filled only
With water
L= 850 mm, D= 40 mm

4: PVC tube 2,
L= 910 mm, D= 50 mm.

5: PVC tube 125 mm,
L= 1000 mm, D= 125 mm

6: Aluminium tube 150 mm,
L= 1100 mm, D= 150 mm

7: Aluminium tube 220 mm,
L= 1200 mm, D= 220 mm

8: Double wall housing
L= 1500 mm, D= 500 mm

9: Glass fiber insulation 100 mm

10: Glass foam, balls 1 mm

11: Brass shavings

12: PET fibers

Test B 372, as shown in Fig 1, measures the vertical temperature gradient in two identical glass tubes of 40 mm diameter and 850 mm length. Each glass tube is individually surrounded by a PVC tube of diameter 50 mm and length 910 mm. Tube 1 **(1)** and its surrounding PVC tube **(2)** are filled with water and fine glass powder, while tube 2 **(3)** and its PVC tube **(4)** only with clear water.

These are arranged in a PVC tube of diameter 125 mm and 1000 mm length **(5).** The remaining space is filled with small balls of glass foam of 1mm diameter **(10)**. The bottom part is filled with small brass shavings **(11)** in order to try to equalize the bottom temperatures of the two 50 mm PVC tubes.

The assembly is inside a 150 mm diameter and 1100 mm length aluminum tube of wall thickness 5 mm **(6)**. This in turn is placed into another aluminum tube of 220 mm diameter, 1200 mm length and a wall thickness of 5 mm **(7)**. Each of these is closed at the top with round aluminum plates of the same thickness.

The aluminum tubes containing the test assembly are standing in the center of a double walled aluminum housing of height 1500 mm and an inner diameter of 500 mm with 50 mm between the two walls **(8).** This space is filled with water **(8a).** The whole assembly is insulated on the outside with 100 mm of glass wool **(9).** The space between the larger aluminum tube and the inner aluminum housing, i.e. between **(7)** and **(8),** is filled with fine PET fibers **(12).**

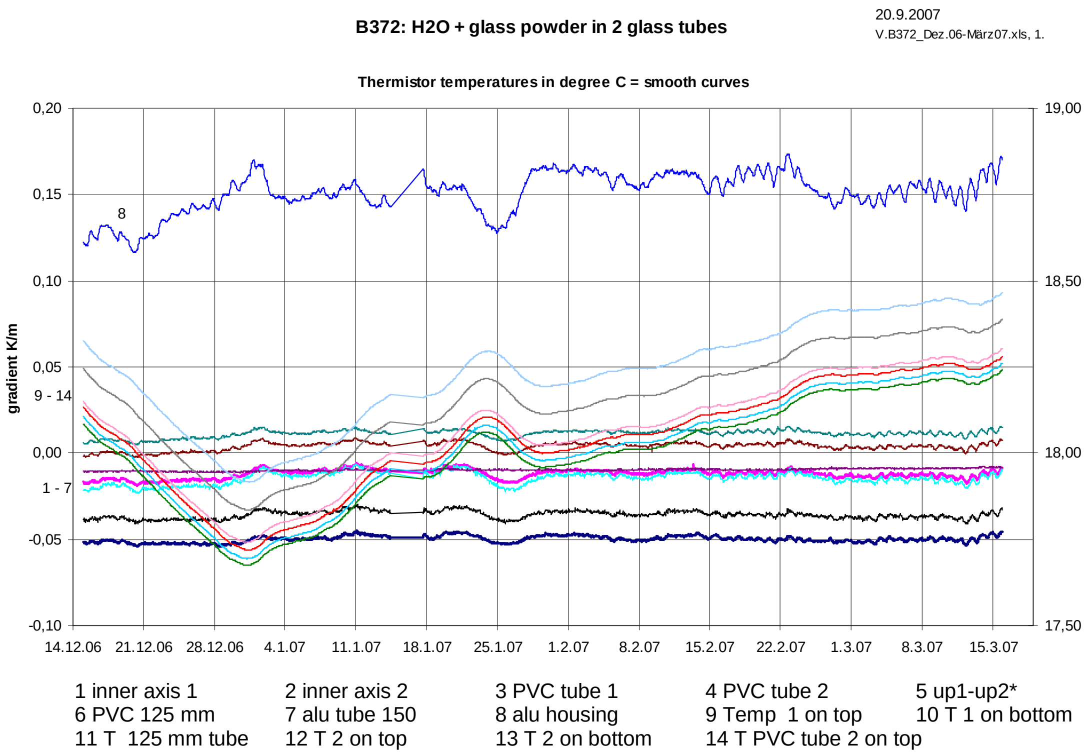
The temperatures inside the test setup are measured by thermocouples and by thermistors. These are mounted at the tops and at the bottoms of the inner axes of the two glass tubes. Additional sensors are mounted on the outside of these glass tubes and on the outside of the two PVC tubes. The temperatures of the double wall aluminum housing are measured 3 cm below the top and above the bottom.

32. Description of the test results.

The test setup B372 was installed in May 2006. All sensors were connected to DMM Multimeter Keithley model 2700 and the data fed into a computer. Measurement results are reported from December 2006 through March 2007, a time period long after the setup, so that it can be expected that equilibrium conditions had been reached.

B372: H2O in two glass tubes, one with and one without glass powder

Fig. 2:



B372: H2O + glass powder in 2 glass tubes

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Thermistor temperatures in degree C = smooth curves

* up1-up2 stands for the temperature difference between the tops of glass tubes 1 and 2

Fig. 2 shows all measured values from December 14 through March 15. The noisy curves are values of the temperature gradients, measured by thermocouples as temperature differences. Each point of the curve represents a 10 value average (of a ten times repeated reading of the same object) measured every hour, using the scale on the left side of the graph. The smooth lines represent the thermistor measurements, each value measured hourly in centigrade, using the scale on the right side.

Environmental influences

Ideally, the measurements would take place in an isolated system not allowing the exchange of matter or energy across the boundaries. While the exchange of any matter can be eliminated, the exchange of energy cannot be avoided even with an optimal insulation. Because the temperature on the outside will always fluctuate to some degree, some energy will always pass through the boundaries and influence the measurements.

The temperatures, measured by the thermistors at various locations within the test setup, give an indication of the amount of energy entering or leaving the system. From initial values around 18.25 C the temperatures all declined to about 17.75 C during the first 17 days (winter) and rose to a peak around 18.5 C during the following 50 days (spring).

This gives a maximum change of only 0.75 C in a 13 week period that is caused by the temperature fluctuations of the environment.

Even an air-conditioned room can have such fluctuations. These experiments were carried out in a basement without air-conditioning, but with a thermostat-controlled heating system during the winter. The smooth parallel temperature curves (see curves 9 through 14 in Figure 2) indicate that the heat transfer took place uniformly in all parts of the test setup, not significantly disturbing the temperature differences that we tried to measure.

Vertical temperature gradients

The most important result is shown in curve 1 of Figure 2 (lowest blue curve), the temperature gradient of the inner axis of glass tube 1, filled with water and glass powder. It is quite stable around a value of about -.05 K/meter; the minus sign indicating a lower temperature at the top than at the bottom.

Going from the inner axis radially outwards, curve 3 -- for PVC tube 1, enclosing glass tube 1 (black curve, second from below) -- shows a slightly less pronounced gradient of about -.036 K/m, but still colder at the top than at the bottom.

The glass tube filled only with water (Tube 2, curve 2, the lowest red curve) with its value of about -.01 K/m, has a less negative gradient than tube 1. This is plausible, because tube 2 contains only water and has no convection-hindering glass powder like tube 1 does.

The observations on curve 4, belonging to PVC tube 2 is comparable to that of PVC tube 1.

Next further out is the PVC tube of diameter 125 mm, enclosing both PVC tubes 1 and 2, followed by the150 mm aluminum tube. Both show positive gradient values close to zero (red curve and blue curve near zero), which means that the top is warmer than the bottom.

Also very important is the gradient on the inner wall of the aluminum housing, curve 8 (uppermost blue curve) with a value of +.15 K/m. It is always positive, warm at the top and cold at the bottom. Only under these conditions does the gradient at the inner axis of tube 1 or 2 -- cold at the top and warm at the bottom -- becomes meaningful.

Temperatures within the test setup

As already discussed in the section “Environmental influences” the smooth curves (9-14 in Figure 2) represent temperatures measured by the thermistors. In comparing the measurements at different locations, one has to consider that the precision of a thermistor amounts to only +/- .1 C. But the measurements are very constant over time, as indicated by the smoothness of the curves, whereby the temperature change over time is measured to a much greater precision than the absolute values.

This fact becomes very important, when one looks at long time periods, during which the upper and the lower temperatures in a tube do not change. During these times one can decide, whether a temperature gradient T_{Gr} exists under equilibrium conditions.

33. Determination of the temperature Gradient T_{Gr} as a long term average.

While in Figure 2 the curves 1-7 are very close together, Figure 3 provides a better resolved picture in the form of long term averages.

Fig. 3:

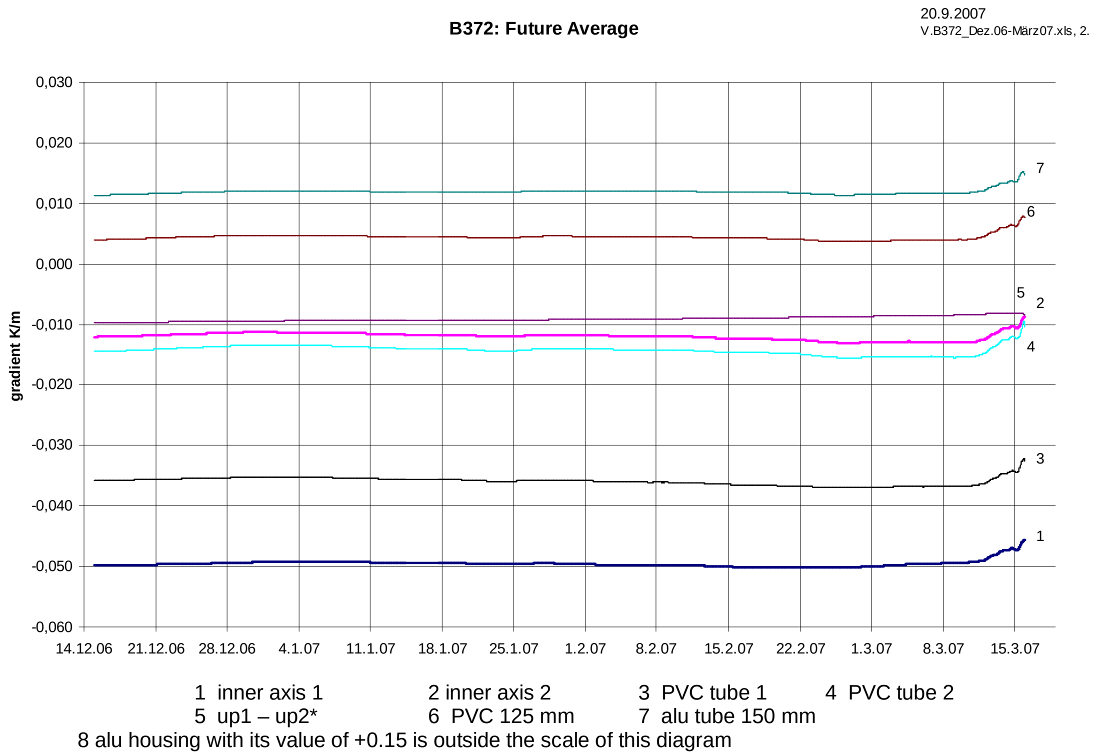


Fig. 3 “**B372: Future Average**” shows average values of all gradients over time. Each point on a curve represents the average value calculated for this gradient from that time through the last point of the curve to the right. For example, the values shown on December 14 are, therefore, the averages for the time from December 14 through March 15, while the last points on the right represent the values on March 15. Thus we can ignore the right end of the curves, where too few measurements are included in every point and the values are unreliable. For the inner axis of tube 1 we get a steady average gradient of -.05 K/m.

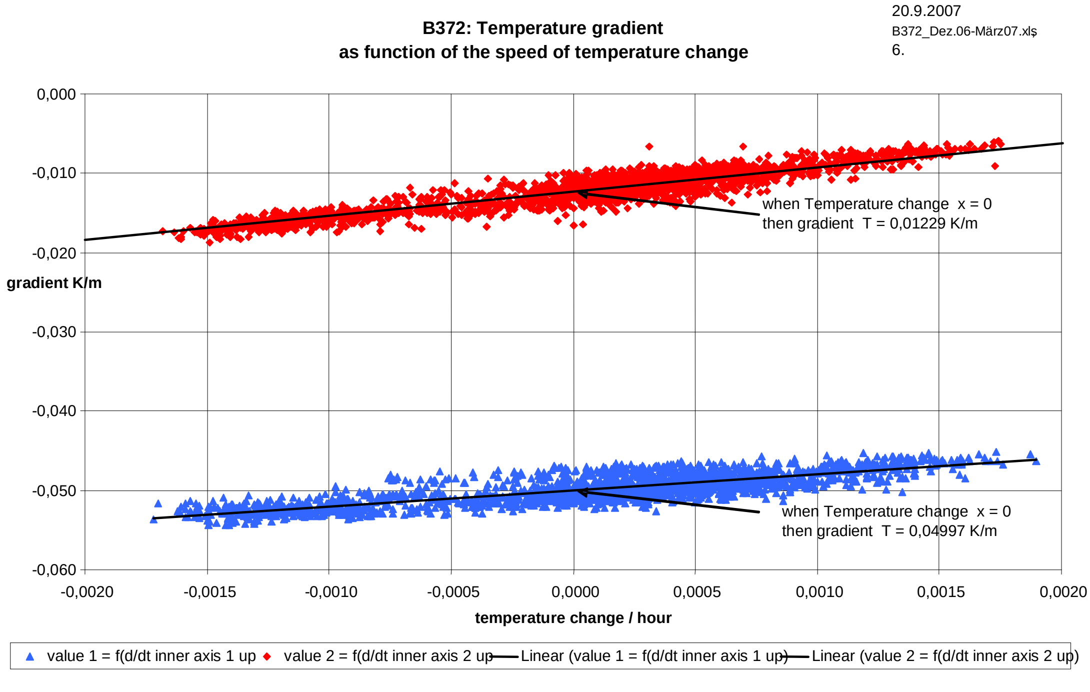
34. Determination of T_{Gr} at equilibrium.

The measured values of T_{Gr} fluctuate over time, because even the best insulation can not prevent small temperature changes in the test setup. If heat, entering or leaving the test specimens by conduction through the insulation, would be identical at the top and at the bottom of the test column, then they would not affect the value of $T_{(Gr)}$. But, because the temperature fluctuations in the environment are different at different heights of the test setup and the various insulation materials are never totally identical over height, the temperature changes and their timing may be different at the top from that of the bottom. Therefore, $T_{(Gr)}$ fluctuates over time around the correct average value. In order to obtain this correct value, one has to measure over longer time periods.

$T_{(Gr)}$ can be found very efficiently, when all measured temperature gradient values are plotted as a function of the rate of the temperature change (Figure 4). We measured these rates both at the top and at the bottom of the tubes, and found very similar results. The parallel nature of the actual temperature changes at different points in the system were already observed in Figure 2. In Figure 4 the x-axis stands for the rate of temperature changes measured only at the top of the tubes in question. The correct value of $T_{(Gr)}$ can be obtained, whenever the rate of temperature change is zero. At these times no heat is flowing in or out of the system and we have equilibrium conditions, no temperature change over time.

Trend lines are calculated as least squares regression lines for the scattered values. The trend line for the blue triangles for inner tube 1 (water with glass powder) crosses the vertical zero line -- where the rate of temperature change is 0 -- at -0.05 K/m. The red markers give a $T_{(Gr)}$ value of -0.12 K/m for inner tube 2 (only water). Both of these values agree well with the long term average values, seen on curves 1 and 3 in Figure 3.

Fig.4:



B372: Temperature gradient
as function of the speed of temperature change

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6.

when Temperature change x = 0
then gradient T = 0,01229 K/m

when Temperature change x = 0
then gradient T = 0,04997 K/m

4. Precision of measurements

Thermistors have a precision of only about +/- .1 K, not sufficient to measure gradients of .01 K/m without making difficult additional calibrations. In the above measurements thermistors are used not for reliably measuring gradients, but in order to establish the changes of temperatures at different locations. The precision of measuring these temperature changes is better than .001 K/hour.

Type E thermocouples are used to measure the temperature gradients as the difference of the voltages between two thermocouple points. Connecting these in series, one obtains thermopiles. The values reported here are more than 10 times the precision of individual thermocouple measurements.

Actually, the precision of the absolute value of $T_{(Gr)}$ (20 or 30% higher or lower) is not as important as deciding, whether the direction of the temperature gradient is positive or negative. But this direction can be decided upon to a very great precision, because the zero offset of the instrument can be determined measuring each value twice, the second time with switched polarity.

5. Consequences of the measured temperature gradients for the Second Law

The brown curve 5 in Fig. 2 shows the temperature differences between the top of tube 1 and tube 2 with an absolute average value of about .01 K. This temperature difference could be used to create work by supplying electric power through a thermocouple, which is actually, continuously taking place during the tests described here. The amount of energy so produced is, of course, extremely small. It does not affect the equilibrium condition of the experiment, because this small amount of energy taken out of the system is easily replenished from the heat bath of the environment. The observation is that heat flows under the influence of gravity from a cold reservoir to one with a higher temperature.

The Second Law of Thermodynamics, as stated by Clausius in 1854 (11) says:
"No process is possible for which the sole effect is that heat flows from a reservoir at a given temperature to a reservoir at a higher temperature."
It is assumed that the process takes place within an isolated system with no exchange of matter and energy across its bounders. It also implies, like any other presently used statement of the Second Law, that the isolated system might be exposed to a force field, like gravity, and in spite of this, the assertion remains valid.

Contrary to the statement by Clausius, the reported results show that *in an isolated system under the influence of a force field like gravity heat can flow from a reservoir at a given temperature to a reservoir at a higher temperature.*
This leads to the need of a new general statement of the Second Law:
In isolated systems – with no exchange of matter and energy across their boundaries AND WITH NO EXPOSURE TO FORCE FIELDS - initial differences of

temperature, densities, and concentrations in assemblies of molecules will disappear over time, resulting in an increase of entropy.

Conversely:
In isolated systems - with no exchange of matter and energy across its borders - FORCE FIELDS LIKE GRAVITY can generate in macroscopic assemblies of molecules temperature, density, and concentration gradients. The temperature differences may be used to generate work, resulting in a decrease of entropy.

SUMMARY

Measurements of the temperature gradient in insulated vertical tubes, filled just with water or with water and small glass beads, show a negative temperature gradient, cold at the top and warm at the bottom.

These gradients appear in spite of positive temperature gradients in the environment. They are not explainable by today's accepted laws of heat transport in liquids, gases and solids, because positive temperature gradients in the environment would allow only positive gradients within the test setup.

The temperature differences created in vertical, isolated columns of water under the influence of gravity allow the production of work using only the effect of gravity. Therefore; basic statements of the Second Law of Thermodynamics would have to be restated to reflect the effects of force fields like gravity.

Epilogue

The author would like to motivate experimental scientists to duplicate these experiments on the same, or preferably on a larger scale. At the same time, theoretical scientists are also challenged to develop a theory explaining these findings.

If this will allow mankind to use, as Loschmidt foresaw,

"*……. an inexhaustible resource of convertible heat at all times….*" 3) …only future will tell.

Roderich Graeff

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