THREE DIMENSIONAL COMPUTER SIMULATION OF AN ISOPERIBOLIC CALORIMETER FOR COLD FUSION EXPERIMENTS

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ABSTRACT

The three dimensional heat conduction computer code HEATING5 was used to simulate the isoperibolic calorimeter being used for cold fusion experiments at Stanford University. The simulation results confirm the measured temperature distribution in the calorimeter. Computer analysis also demonstrates that temperature measurements for this particular calorimeter are independent of the heat source position in the calorimeter. A numerical procedure was developed to derive the transient behavior of the heat generation in the cold fusion cell from the transient temperature measurements. This procedure was exercised using a measured temperature pulse. The transient behavior of the power pulse was in the form of square-wave and its magnitude was slightly higher than the on-line calculation based on a steady-state approach.

INTRODUCTION

This paper describes the numerical simulation of heat generation and heat conduction in an isoperibolic calorimeter used for cold fusion experiments at Stanford University. An analytical procedure is developed for predicting the excess heat source from the temperature measurements. The objective of this work is to confirm the steady state and transient measurements by detailed computer simulation and thus to elucidate the observed phenomena.

ISOPERIBOLIC CALORIMETER

The isoperibolic calorimeter used in the experiment consists of two concentric aluminum cylinders, and an electrolysis cell which is housed in the inner cylinder. The gap between the two cylinder walls is filled with the aluminum oxide (Al_2O_3). Figure 1 illustrates the arrangement of materials and dimensions in the calorimeter.
The design principles of the isoperibolic calorimeter are:

- The temperature distribution is nearly uniform within the aluminum blocks,

- The aluminum oxide is a good insulator and a thick aluminum oxide insulation in the axial direction causes the heat to flow radially,

- The measurement of excess heat generation is based on the temperature difference between the two aluminum blocks,

- The measurement is independent of the location of the heat source.

Further details of the isoperibolic calorimeter are discussed in a separate paper presented in this conference.[1,2]

NUMERICAL SIMULATION

The simulation of heat transfer was performed by using the HEATING5 computer code. HEATING5 is a steady-state and/or transient heat conduction code in three dimensions including the Cartesian, cylindrical, and spherical coordinates. The thermal conductivity, density, and specific heat may be both spatially and temperature dependent. Heat generation rates may be dependent on time, temperature, and position. The boundary conditions may be specified for surface-to-boundary or surface-to-surface, and can be temperatures or any combination of prescribed heat flux, forced convection, natural convection, and radiation. The boundary condition parameters may be time and/or temperature dependent.

HEATING5 uses the finite difference scheme to discretize the heat balance equation in space time domains. The steady state problem may be solved by a direct matrix inversion method for one or two dimensional problems, or the point successive over-relaxation iterative method with a modified Aitken extrapolation process. The transient problem may be solved using the Crank-Nicholson method, the backwards Euler method, or an explicit method which is stable for a time step of any size (Levy's modified explicit method).

In order to estimate the heat source from the measurement, a separate numerical technique has been developed. We approximate the heat source in terms of discrete unit step functions in time,

$u_i(t)$, i=1,...,N:

$$S(t) = \sum_i^N a_i u_i(t)$$

where

a_i = amplitude

$$u_i(t) = \begin{cases} 1 & t_i \leq t < t_{i+1} \\ 0 & \text{otherwise} \end{cases}$$

Let $r_i(t)$ denote a response function representing the temperature difference between two aluminum blocks due to the unit heat source $u_i(t)$. For example, $r_i(t)$ can be determined by running HEATING5 for the given heat source $u_i(t)$.

If T(t) is the measured temperature difference due to the heat source S(t), then the heat source can be approximated by requiring that the integral of squared errors between the measurement and approximation is minimal with respect to variations of a_i, that is

$$\frac{\partial}{\partial a_j}\int \left(T(t) - \sum_i^N a_i r_i(t)\right)^2 dt = 0$$

These equations lead to a system of linear equations for a_i's, which can be solved to determine the unknown heat source.

RESULTS AND DISCUSSION

The isoperibolic calorimeter was modeled in two or three dimensions using HEATING5 for the purpose of the model calibration and heat source analyses of the measurements.

The temperature distribution within the two aluminum blocks at a steady state was computed by using HEATING5 and is shown in Figure 2. This result indicates that the temperature is quite uniform within the aluminum blocks.

Figure 3 compares temperature differences in aluminum blocks computed by using a fixed temperature condition and a forced convection boundary condition on the surface of the colorimeter. In this analysis the transient was initiated by a stepwise increase of heat generation rate from 5 watts to 6 watts at time zero. It is shown in this figure that the temperature difference between two aluminum blocks is relatively insensitive to the type of boundary condition used.

Figure 4 compares the measured temperature difference against the simulation of the measurement using HEATING5. Measured heat sources were used in modeling this calibration experiment. The agreement between the measurement and simulation is shown to be quite good confirming the adequacy of the HEATING5 and modeling input parameters.

Next the transient data obtained from the isoperibolic calorimeter was analyzed to determine the heat source using the source discretization method discussed above. Figure 5 shows the heat generation obtained by an on-line calculation neglecting the time delay effect of heat conduction from the source to the instruments. The total heat generation (areas under the curves) are conserved in both curves. However, the time of heat generation and the magnitude of peak are different in the two cases due to the time lag and heat dissipation during the heat conduction through materials.

Finally, Figure 6 compares the temperature difference between measurement and HEATING5. In HEATING5 calculation, the predicted heat generation rate shown in Figure 5 was used as the heat source. A good agreement between the measurement and simulation is observed, which confirms the accuracy of the procedure for estimating heat source from the measurement.

CONCLUSION

The three dimensional heat conduction computer code HEATING5 was used to simulate the isoperibolic calorimeter being used for cold fusion experiments at Stanford University. The simulation results confirm the accuracy of the temperature measurements in the calorimeter. The Computer analysis also demonstrates that temperature measurements for this particular calorimeter are independent of heat source position in the calorimeter. The working principles of this type of calorimeter are verified by the computer simulation.

REFERENCES

1. Martha Schreiber, Turgut M. Gür, George Lucier, Joseph Ferrante, Jason Chao, and Robert Huggins, "Recent Measurements of Excess Energy Production in Electrochemical Cells Containing Heavy Water and Palladium," this volume.

2. Turgut M. Gür, Martha Schreiber, George Lucier, Joseph Ferrante, Jason Chao, and Robert Huggins, "Experimental Considerations in Electrochemical Isoperibolic Calorimety," this volume.

FIGURE 1

A Conduction Calorimeter

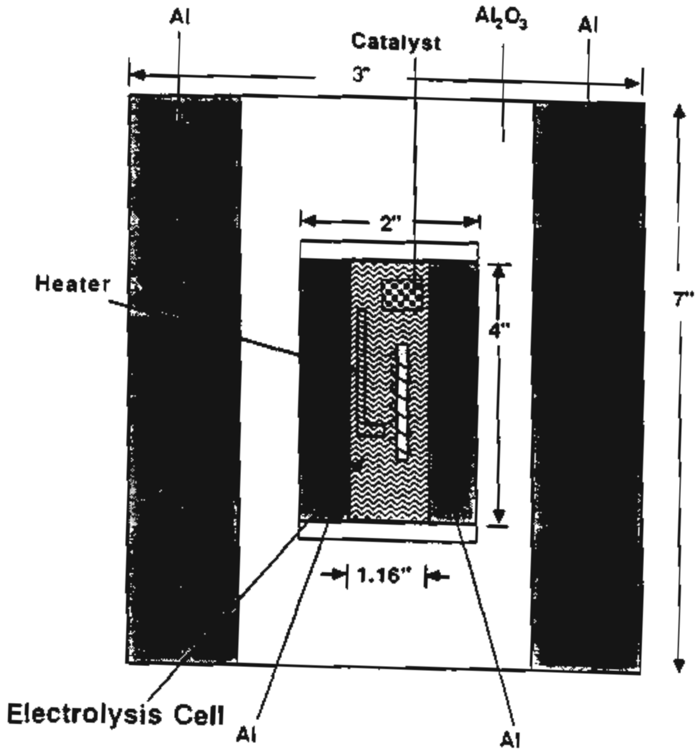

FIGURE 2

TEMPERATURE DISTRUTION

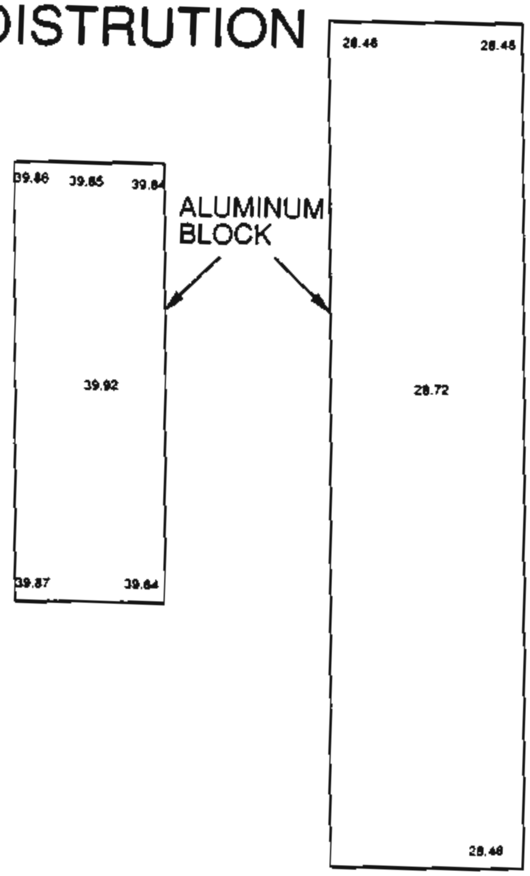

FIGURE 3

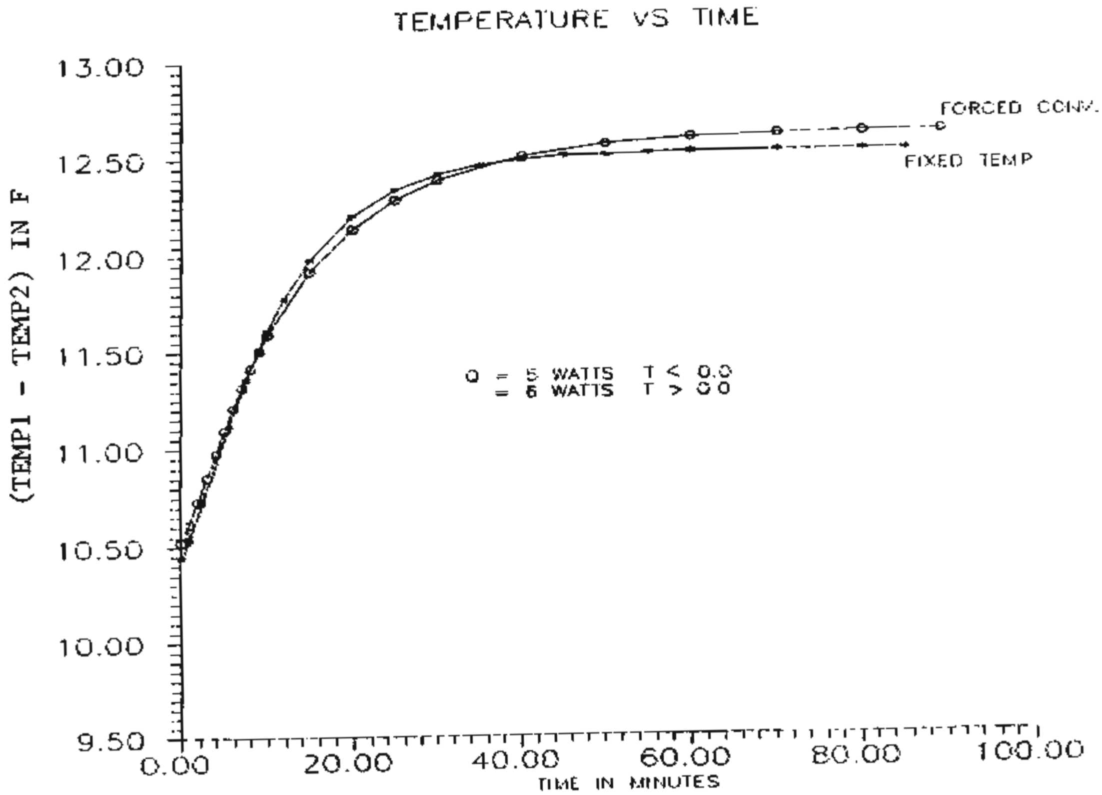

FIGURE 4

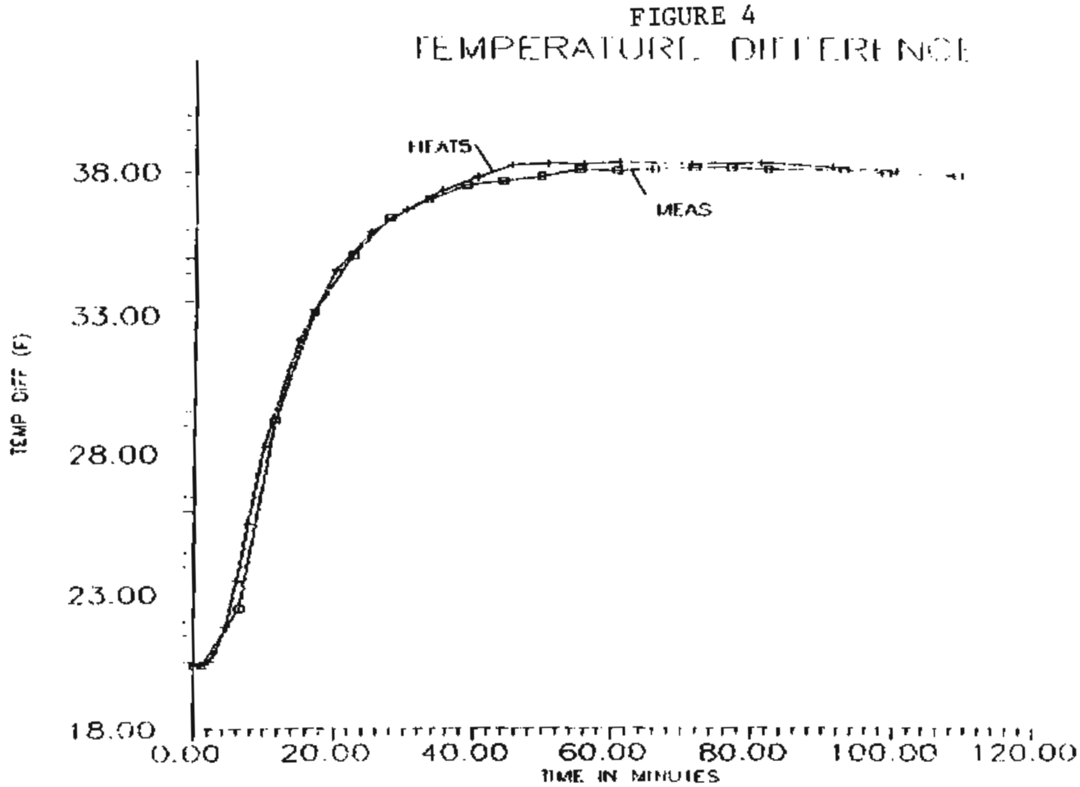

FIGURE 5

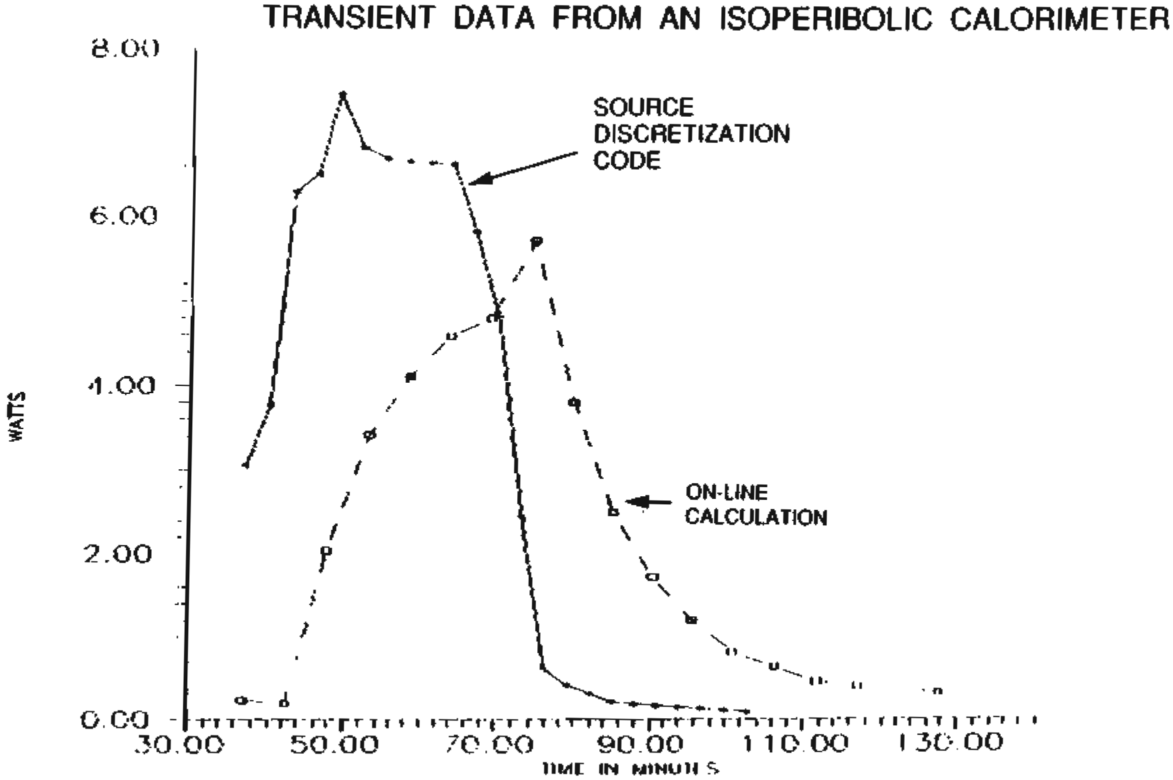

FIGURE 6