

MATHEMATICAL MODELING OF MOVING BOUNDARY PROBLEMS IN  
THERMAL ENERGY STORAGE

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PROJECT OUTLINE

Project Title: Mathematical and Physical Modeling for TES Subsystems

Principal Investigator: A. Solomon

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Project Goals: Develop capability for predicting the performance of TES subsystems and components using PCM's based on mathematical and physical models.

Develop mathematical models of the dynamic thermal behavior of TES subsystems using PCM's based on solutions of the moving boundary thermal conduction problem and on heat and mass transfer engineering correlations.

Design, construct, and operate small-scale experiments to provide data for testing and improving the mathematical models.

Project Status: Mathematical model based on conduction in any module geometry has been completed. Physical model in slab geometry has been operated in conduction mode and natural thermal convection mode.

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Funding Source: U.S. Department of Energy  
Division of Energy Storage Systems

Project Title: Mathematical Modeling of Moving Boundary Problems in Thermal Energy Storage\*

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Project Objectives: To develop and apply computer and mathematical models in support of the thermal energy storage program, emphasizing their application to the moving boundary problem in phase change processes for Latent Heat storage.

Technical Progress: 1978-79

a) The Program TES

The computer program TES simulating the behavior of a phase change process in a single PCM body went through its final stages of development and validation. The program, applicable in slab, cylinder and spherical geometries, was applied to a broad family of problems, and its accuracy and validity tested wherever possible. A complete documentation is appearing in the form of a Union Carbide Report, No. CSD-51 [14].

b) Other Computer Codes

A number of additional codes have been prepared for situations not suited for TES, and as means for verifying the TES results. These include a multi-component version of TES, which is to be documented during the present year, and other codes for multidimensional phase change, radiation boundary conditions, and other cases. The methods upon which these codes are based, vary, so as to serve as additional validation tools for each other.

c) Comparison with Experiment

Comparisons of the results of various models with the experimental results of R. Deal have been undertaken [7]. This work has led to questions of the accuracy of inverse problem estimates (e.g. of the heat transfer coefficients and the conductivity) [11], and the development of additional support codes. An example of the use of a support

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code is given in figure 1, where a two dimensional code was used to judge the effect of the plexiglass wall in the experiment.

d) Scoping of Physical Processes

Numerical and analytical models were used for a number of scoping exercises including a PCM wall simulation [5] and a temperature cycling process for a Glaubers salt chub [13].

e) Development of Computable Analytical Models

A number of models extending earlier reported models for melt time of a simple body [3] and melting of a slab [9] were developed. These include a model of a convection surface heat transfer process [4].

f) Computing Considerations

In the course of validating TES and other programs, a number of questions related to their practical use arose. These were studied in [12], [15], and relate to the question of how to know if the results obtained from a phase change simulation scheme are actually correct.

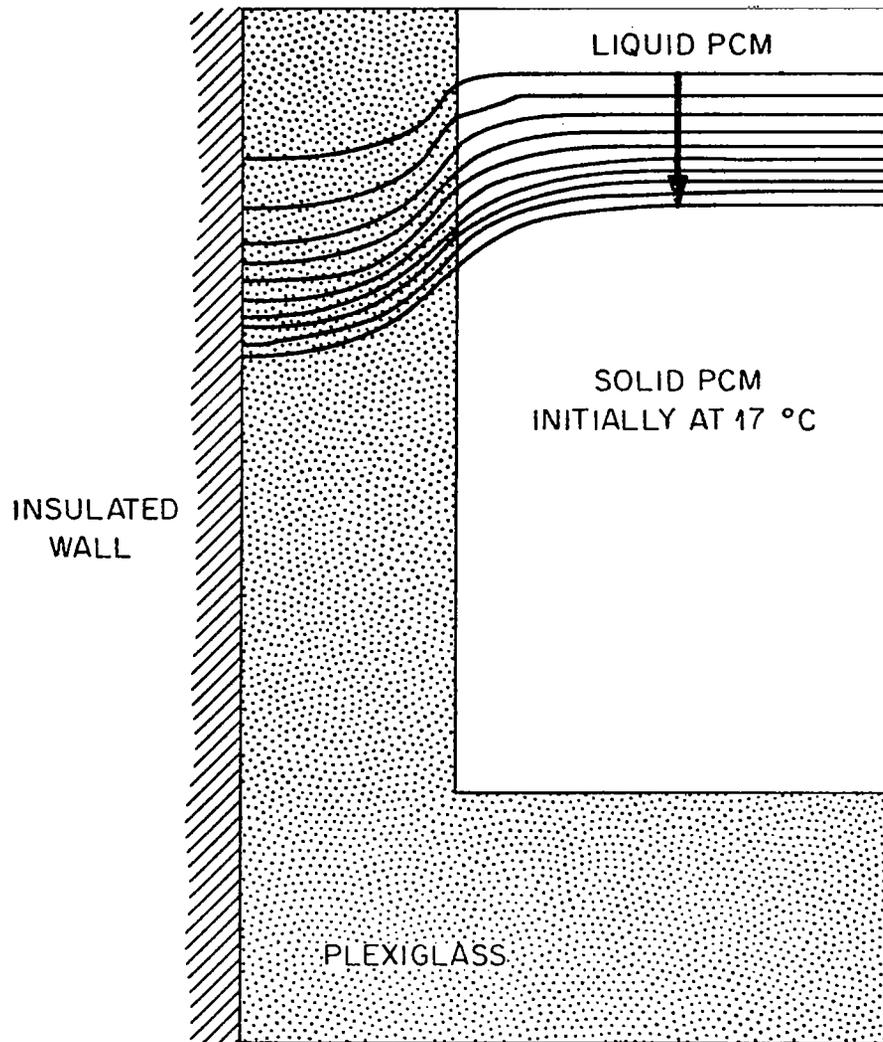
g) Natural Convection Modeling

Experiments were made and rough comparisons carried out with analytical and numerical models for processes which include natural convection of the melt [1]. This work is to continue during the present year.

h) Other Support Activities

Other, more peripheral activities performed during the last year included the preparation of a survey paper on the mathematics of latent heat thermal energy storage processes [6], participation in the preparation of a bibliography of this area [16], and others ([2], [8], [10]).

HEATING PLATE-TEMPERATURE = 60 °C



H  
0.4 cm

28° Isotherms in the N-Octadecane Paraffin Wax PCM and the Plexiglass Wall, at Time Intervals of 1200 sec.

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