CHAM OF NORTH AMERICA, INCORPORATED

ANALYSES OF PHYSICAL-CHEMICAL PROCESSES

GOVERNING SSME INTERNAL FLUID FLOWS;

PROGRESS REPORT FOR MAY-JUNE 1984

by

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TABLE OF CONTENTS

PREFACE

This progress report summarizes the work performed during the report period, and discusses the work to be performed during the next report period. It also indicates current problems (if any), and an estimated percentage completion of the work to be performed in the first year of the contract.

INTRODUCTION

In order to aid the development of current and future (advanced) SSME type engines, it is necessary to improve the understanding of basic issues related with physical-chemical processes of SSME internal flows. Towards this goal, the specific objectives of the subject project are:

1. to supply a state-of-the-art CFD code and graphics package;
2. to demonstrate code usage on SSME-related problems to NASA MSFC personnel;
3. to perform computations and analysis of problems relevant to current and future SSME's; and
4. to participate in development of new physical models of various processes present in SSME components.

The total project duration is three years. This is the first progress report covering the first two months of performance.

WORK PERFORMED DURING MAY-JUNE 1984

During the months of May and June, 1984, the attention was focussed on the first three tasks of the contract. Accomplishments under each of these tasks are described below.

<u>Task 1</u>: Provided PHOENICS and GRAFFIC Computer Codes

Under this task, as planned, the selected general-pourpose flow-analysis code- "PHOENICS" and its associated interactive graphic package GRAFFIC were provided to ED42 NASA MSFC.

<u>Task 2</u>: Interface the Codes with MSFC Facility and Personnel

Under this task, as a first step, both PHOENICS and GRAFFIC code were mounted and made operational at the Perkin-Elmer Computer and graphics facilities of the Atmospheric Science Division of NASA MSFC. A list of all files installed, together with the descriptions of the CSS files and the execution procedures were also provided.

The second activity of this task was to prepare and conduct a six-day training course for NASA MSFC personnel. This course was held at CHAM offices on May 29, 31, June 4, 6, 8 and 12, 1984. Each day lectures were given in the morning and hands-on computer workshops were held in the afternoon. Eleven NASA personnel consisting of 6 from ED42, 4 from ED33, and 1 from EP23 branch attended the course. Each participant was provided with the copies of user's manuals and lecture notes.

Ten lectures were held to cover the following topics:

1. Introduction to PHOENICS
2. Input Data Procedures
3. Example Problem Set Ups
4. Mathematical Basis of Single-Phase Flows; Part I: Equations and Solution Procedure
5. Advanced Input Data Procedures; use of Porosities and Non-Uniform Initial Flow Fields
6. Introduction to GRAFFIC
7. Mathematical Basis of Single-Phase Flows; Part II: Boundary Conditions and Special Source/Sinck Terms
8. Applications of GROUND subroutine for incorporation of new physical models
9. Mathematical Basis of Two-Phase Flows, and
10. General Discussions (Open Forum).

In the computer workshop sessions, no pre-set problems were provided; instead, the participants were encouraged to set up their own problems. Schematics of some of the problems are shown in Figure 1. Salient features and observations of each of these problems are described below.

Problem 1. Driven cavity problem;

Calculations were performed for several Reynolds numbers and different grid distributions. Results were compared with data published in open literature. Figures 2 to 3 present some sample results.

Problem 2. Two-Phase Flow Problems;

Two-dimensional transient calculations were performed to simulate sedimentation of heavier phase and gravity wave problems. Several density ratios and interphase friction factors were employed; no convergence problems were encountered, and results were plausible.

Problem 3. Flow Through a Cylinder with an inner core of porous-medium

Two-and three-dimensional flow calculations were performed for a single-phase turbulent flow (with the $k\sim\epsilon$ model of turbulence) in a cylindrical geometry with porous medium.

Problem 4. Flow Over a Cylinder

A two-dimensional turbulent flow over a circular cylinder was simulated by using the porosity approach. The calculated flow showed expected flow recirculation region.

Problem 5. Flow In a Diverging Duct

A two-dimensional, turbulent flow in a diverging duct was simulated. As expected, flow separation was predicted near the wall in the downstream section of the duct.

Problem 6. Flow in a Cylinder

A two-dimensional flow with radial-entrance and axial-exit was simulated. Satisfactory flow distributions were predicted.

Problem 7. Natural Convection in a L-shape enclosure with cooled walls.

This problem was set up with specified wall temperatures and inlet and outlet pressures as boundary conditions. Calculated flow rates and flow directions were found to be qualitatively correct.

Problem 8. Flow in a rotating Seal-Cavity

This problem was concerned with an axi-symmetric flow in a cavity with two sides (one axial and one radial) rotating at a prescribed rpm (e.g. 15000 rpm). It was to simulate an experiment. Figure 4 shows sample results.

Task 3: Flow Physics Applications

Subsequent to the training course, several other problems have been set up by

NASA personnel at NASA computer. CHAM has assisted whenever required. In parallel, effort has started to utilize the Body Fitted Coordinate (BFC) system of PHOENICS.

WORK PLANNED FOR JULY-AUGUST, 1984

During the next two months work will continue on Task 3, and will start for Task 4 (Multi-Fluid Model), and Task 5 (SSME Global Flow Model).

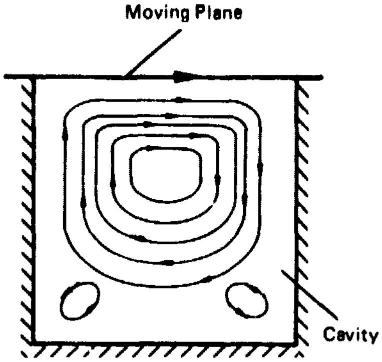
CURRENT PROBLEMS

No problmes are envisaged which may impede performance of this project.

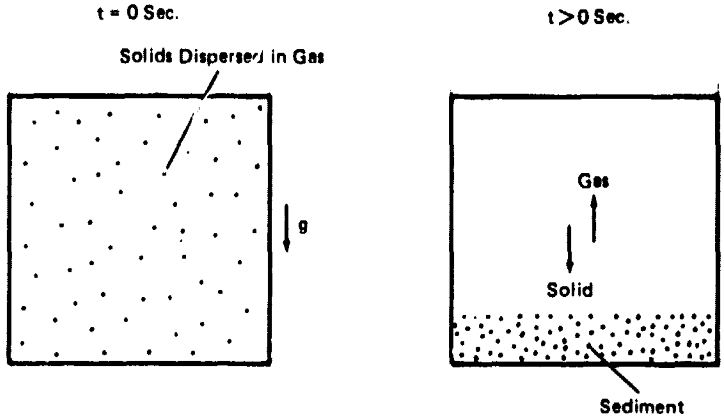
PROGRESS SUMMARY

Estimated percentage completion of the first years effort is 25%. A taskwise progress status is shown in Table 5-1.

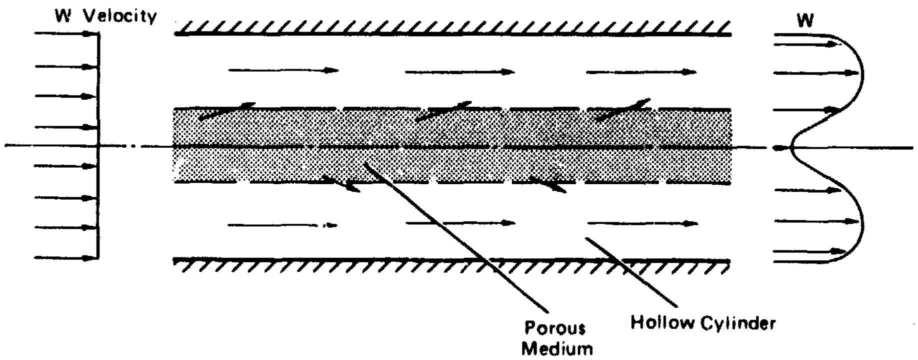
NO.	TASK DESCRIPTION	% COMPLETION OF FIRST YEARS EFFORT, AS ON JUNE 30, 1984
1.	Provide PHOENICS & GRAFFIC codes	100
2.	Interface codes with MSFC Facility & Personnel	85
3.	Flow Physics Applications	15
4.	Multi-Fluid (Phase) Model	0
5.	SSME Global Flow Model	0
6.	Reports	2



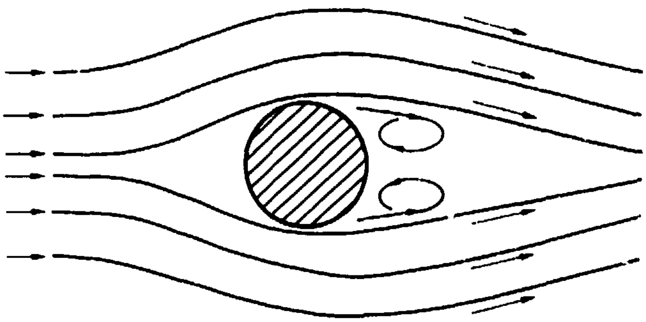
1. DRIVEN CAVITY PROBLEM



2. SEDIMENTATION PROBLEM

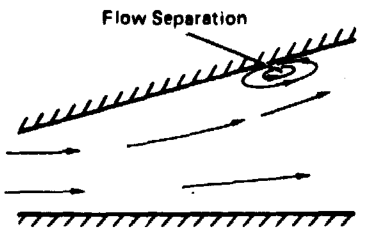


3. FLOW IN HOLLOW CYLINDER WITH A POROUS-MEDIUM CORE

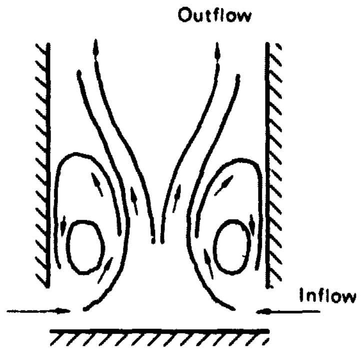


4. FLOW OVER A CYLINDER

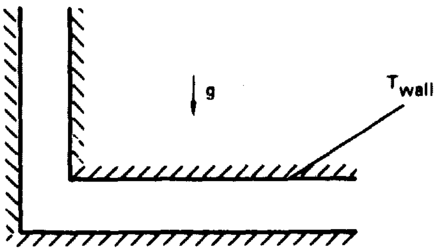
Figure 1(a). Schematics of Problems Simulated by NASA MSFC Personnel During PHOENICS Course



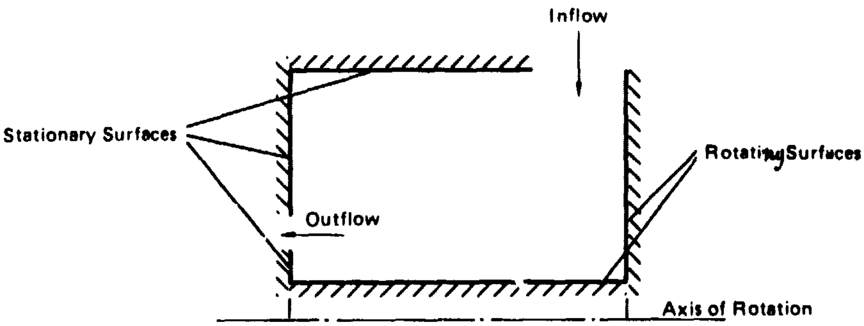
5. FLOW THRU A DIVERGING DUCT



6. FLOW IN A CYLINDER WITH RADIAL-BOTTOM-ENTRY AND AXIAL-TOP-EXIT



7. NATURAL CONVECTION IN A L-SHAPED ENCLOSURE



8. FLOW IN A ROTATING SEAL-CAVITY

Figure 1(b). Schematics of Problems Simulated by NASA MSFC Personnel During PHOENICS Course

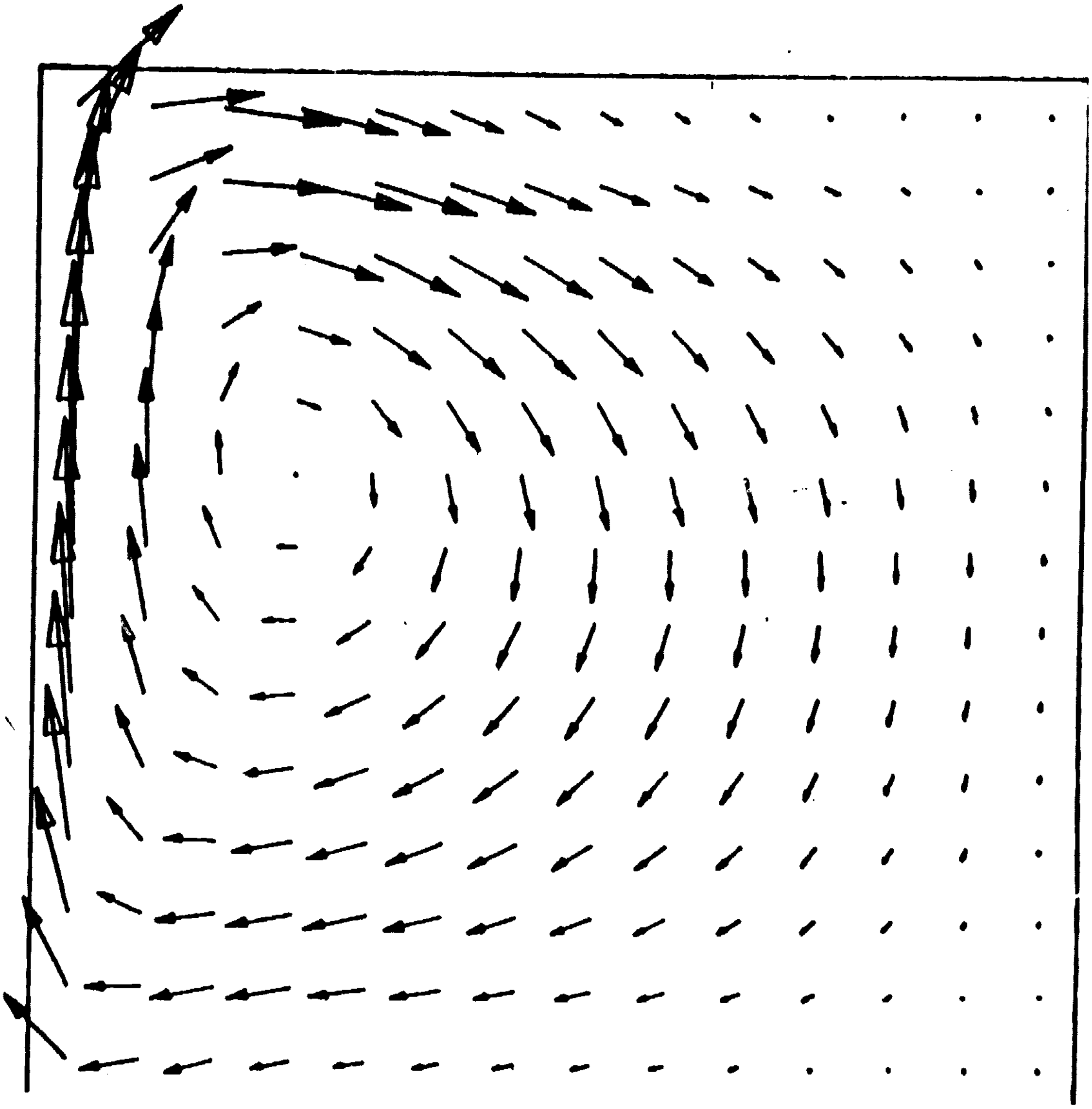


Figure 2. Velocity Field in Cavity.

Figure 3. Pressure Field in Cavity

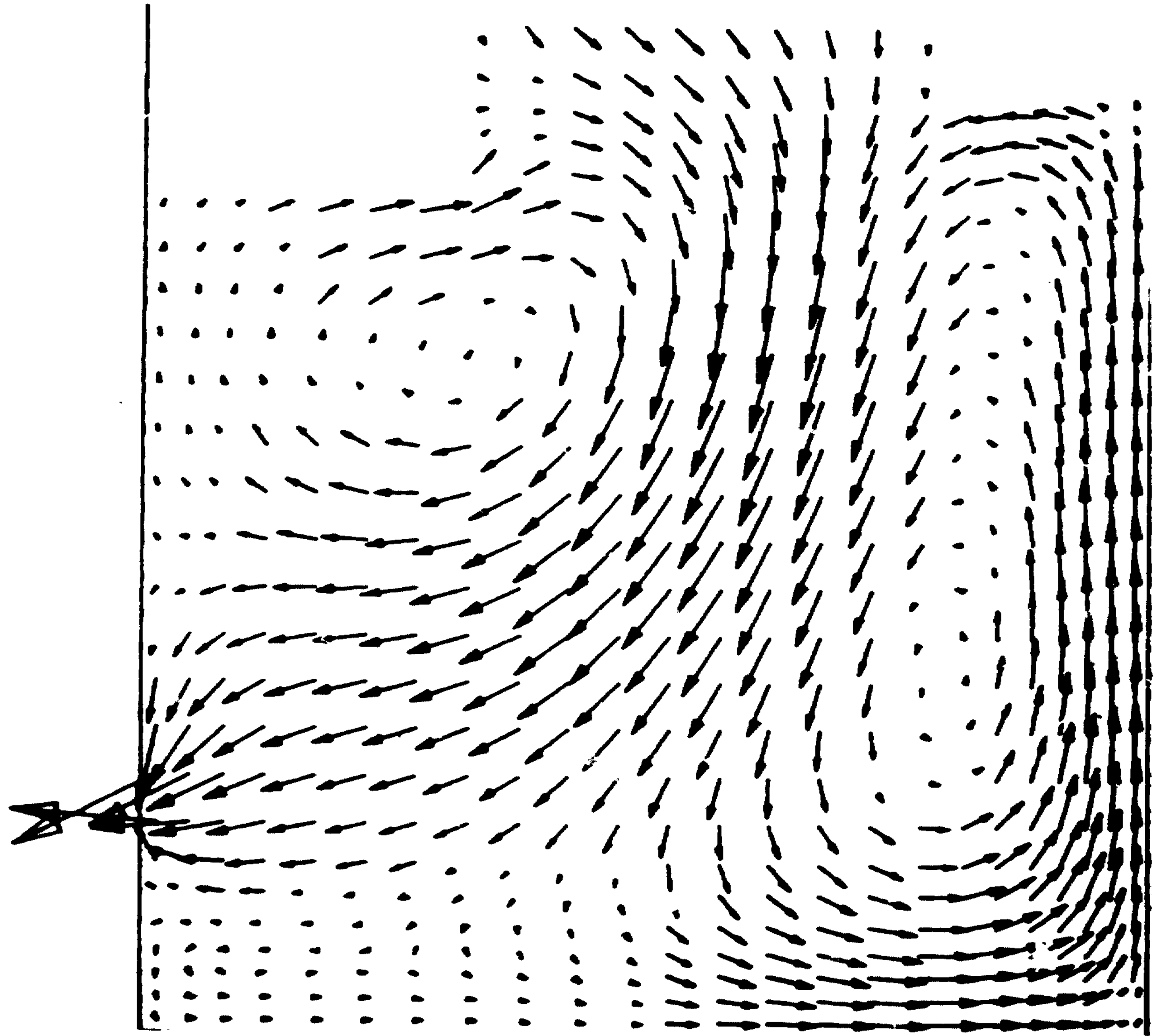


Figure 4. Velocity Field in Rotating Seal-Cavity
RPM = 15000, mas flow rate = 6.4 lbs/s