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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



# THESIS

H 8143

NUMERICAL FIELD MODEL SIMULATION OF  
FULL-SCALE FIRE TESTS IN A CLOSED  
SPHERICAL/CYLINDRICAL VESSEL  
WITH INTERNAL VENTILATION

by

Richard Reid Houck

September 1988

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**Numerical Field Model Simulation of Full-Scale Fire Tests in a  
Closed Spherical/Cylindrical Vessel With Internal Ventilation**

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## **ABSTRACT**

Shipboard fires have plagued mariners for centuries; they still cause significant damage and casualties each year. Improved fire prevention and control require a sound knowledge of the phenomena of fire. At the same time, a study of fires in enclosed pressure vessels has been undertaken by the Navy using FIRE-1, a large pressure vessel, to conduct full-scale experimental fires. A computer model is being developed to simulate the FIRE-1 tests. This three-dimensional finite difference model uses a cylindrical/spherical coordinate system and includes the effects of turbulence, surface and flame radiation, internal ventilation, global and local pressure corrections, strong buoyancy, and conjugate boundary conditions. Given a heat release rate, the model computes temperature, pressure, density and velocity fields for the entire vessel. This thesis presents the internal ventilation feature of the model and compares the numerical results to a nonventilated case. Additional features such as combustion and gaseous radiation are being incorporated to more accurately model real fires. When validated, this model will become a useful tool for evaluating fire prevention and control procedures and equipment.

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## LIST OF SYMBOLS AND ABBREVIATIONS

A	Area
A	Finite Difference Coefficients
ARU_	Source Term Variable (Eqn. 3.74)
AU_	Source Term Variable (Eqn. 3.73)
C_	Coefficients for Control Volume __ (Eqn. 3.40, 3.64)
C_M	Coefficients for Control Volume __ (Eqn. 3.43)
C_P	Coefficients for Control Volume __ (Eqn. 3.43)
COND_1	Coefficients for Control Volume __ (Eqn. 3.42)
C <sub>pm</sub>	Mean Isobaric Heat Capacity
CURV	Curvature Term (Eqns. 3.25–3.26)
CURVN	Orthogonal Curvature Term (Eqns. 3.30–3.31)
F <sub>Ai-Aj</sub>	View Factor for Radiation Emitted by Surface i and Incident upon Surface j (Eqn. 2.38)
G	Gravitational Acceleration
G	Mass Flux Rate (Eqns. 3.8–3.13)
G	Term Used in Radiation Model (Eqn. 2.35)
g	Curvilinear Base Vector
g <sub>i</sub>	Scaling Term (Eqn. 2.8)
g <sub>ij</sub>	Covariant Metric Tensor (Eqn. 2.16)
g <sup>ij</sup>	Contravariant Metric Tensor (Eqn. 2.17)
H	Mixing Length Parameter (Eqn. 2.31)
h	Scale Factor
h	Convective Heat Transfer Coefficient

J	Total Heat Flux (Eqn. 3.19–3.21)
K	Adjustable Constant (used in Eqn. 2.31)
k	Thermal Conductivity
M	Momentum Flux (Eqn. 3.55)
m	Rate of Change (Eqn. 3.5)
n	Normal Direction Toward the Vessel Center
P	Pressure
Pr	Prandtl Number
Pr <sub>t</sub>	Turbulent Prandtl Number
q	Heat Flux
q <sub>r</sub>	Thermal Radiation Energy
R	Universal Gas Constant
R <sub>_</sub>	Source Term Variable (Eqn. 3.71)
RR <sub>_</sub>	Source Term Variable (Eqn. 3.75)
Ri	Richardson Number (Eqn. 2.30)
r	Distance between Two Surfaces
S <sub>f</sub>	Source Term (Eqn. 2.25)
S <sub>hs</sub>	Heat Source
S <sub>mp</sub>	Mass Source Term
T	Temperature
t	Time
u	Velocity
V	Volume
VIS	Local Viscosity (Eqn. 3.65)
X	Length in X-Direction (In QUICK Scheme)

## GREEK LETTERS

$\beta$	Angles Formed by Radiation Surface Normals
$\chi$	Term Used in Radiation Model (Eqn. 2.37)
$\delta_{ij}$	Kronecker Delta
$\varepsilon$	Emissivity
$\Phi$	Dissipation Function
$\mu$	Dynamic Viscosity
$\theta$	Directions $\theta$ , $r$ , and $\phi$ or $Z$
$\rho$	Fluid Density
$\sigma$	Stress
$\sigma$	Stefan-Boltzmann Constant
$\Psi$	Term Used in Radiation Model (Eqn. 2.36)

## SUBSCRIPTS

B	Control Volume to the Back
b	Back Control Volume Face
E	Control Volume to the East
EQ	Equilibrium
e	East Control Volume Face
eff	Effective
F	Control Volume to the Front
f	Front Control Volume Face
g	Global
N	Control Volume to the North
n	North Control Volume Face
o	Reference

p	Present Cell
R	Reference
S	Control Volume to the South
s	South Control Volume Face
s	Vessel Wall
W	Control Volume to the West
w	West Control Volume Face
,i	derivative with respect to i
,t	derivative with respect to time

### **SUPERSCRIPTS**

n	Future Value
n-1	Present Value
*	Estimated Value
*	Ventilation Values (Eqns. 3.98-3.103)
'	Correction
^	Prior Value



## **I. INTRODUCTION**

### **A. BACKGROUND**

Fires aboard ships pose a great hazard to both personnel and materiel. Millions of dollars are spent annually on repairs of damage due to fires. Personnel casualties caused by fires cannot be measured in dollars and include both fatalities and severe injuries. Most personnel casualties result from toxic gas or smoke inhalation rather than contact with the fire. The prevention and control of shipboard fires is one of the Navy's and Coast Guard's greatest challenges in future ship design. The computer simulation of a shipboard fire presented in this thesis provides a tool which may be used to reduce the damage from shipboard fires.

In order to prevent fires and their associated casualties, it is necessary to better understand the basic phenomena of fire and smoke propagation within enclosed spaces. This requires knowledge of various physical phenomena: combustion, fluid mechanics, and heat and mass transfer. Extensive research using this basic knowledge is needed to predict the behavior of fires. With a better understanding of fires, ship designers and engineers can reduce the probability of ignition and propagation. New systems and procedures for fire control can be developed to reduce the losses should a fire start due to accident, equipment failure, or hostile action.

Shipboard fires have unique complexities not found in other fire scenarios. Access to a fire area is limited and spaces frequently contain electronic equipment, electrical power sources, machinery, combustibles, or toxic materials. Compartments are often closed, permitting pressure to build up in the space. Self-contained or recirculating ventilation systems present unusual fire scenarios. All of these complications must be considered in the study of shipboard fires; the model developed in this thesis has incorporated two of these complexities: pressure build-up and recirculating ventilation.

Shipboard fire research is currently being conducted by many organizations, including the Navy and the Coast Guard. Research includes both experimental work and computer modeling. Experimental work is limited due to its high cost. Scale models of fires do not predict the behavior of full-scale fires because of the complexity of the fire phenomena. It thus becomes necessary to conduct fire research with full-scale testing. At the Naval Research Laboratory in Washington, D. C., the U.S. Navy built FIRE-1, a large pressure vessel designed to simulate fires aboard submarines and surface ships. This unique test facility offers the researcher an opportunity to study a fire with the pressure building up in the vessel. This models a fire in a submarine or in a closed compartment on a surface ship.

Today's supercomputers, with their extremely rapid computational speed and massive storage capability, offer a researcher the option of computer modeling of fires. The systems of partial differential equations which govern the fire phenomena can now be solved

numerically. The first models were simple, but current models are building on the older models, incorporating more phenomena and producing more accurate results. As each new submodel (such as a combustion or gas radiation model) is added, the quality of the numerical solutions improves. The models are being verified by comparison with actual fires, such as those conducted in FIRE-1.

When validated, computer models provide an excellent tool for the fire researcher. In experiments, each test must be repeated many times to verify the procedures, test facility, and data. The cost of these experiments becomes prohibitive. Experimental researchers must determine which test scenarios will produce the most meaningful results and how to design the data collection systems and procedures to monitor the most critical parameters. This is one aspect in which computer fire simulations become invaluable. By developing a code which accurately simulates a fire in FIRE-1, various fire scenarios can be modeled at a reasonable cost. The most interesting scenarios can then be investigated by experiments in FIRE-1.

Computer models may also be used in modeling fires which cannot be tested in full scale due to the size and geometry limitations of FIRE-1. An entire area of a ship might be modeled and the progress of the fire within and between compartments could be investigated. With such simulations, the spread of fire could be analyzed, and new methods can be evaluated to prevent the spread of fire from compartment to compartment. Additionally, the efficacy of fire extinguishing systems can be evaluated by introducing models of these systems into



the fire model. All of these future uses require a validated code and the use of a large computer. While the cost of a computer model test is significantly less than a full-scale test, it still requires extensive computer time. The current code running on an IBM 3033 uses approximately 1.5 CPU hours per second of fire time. A supercomputer and vectorization could reduce this time by one or two orders of magnitude, but the number of model tests needed to fully validate the code still will require significant supercomputer resources.

## **B. COMPUTER MODELING**

There are two basic procedure for modeling fires: field and zone modeling. Zone modeling involves dividing the fire area into control volumes or distinct regions [Ref. 1]. Each region contains a phenomena of particular interest, such as the base of the fire, fire plume, heating of the wall, ventilation inlet or outlet duct, etc. Mass and energy balances are conducted across the boundaries and interconnect all of the control volumes. This procedure provides information for the entire area, but the phenomena occurring within each control volume are not always understood.

Field modeling, also known as differential field equation modeling, divides the compartment into finite volume elements. The conservation equations in differential form are used to calculate the mass, momentum, energy, and smoke concentration at each time interval. The temperature, velocity, pressure, density, and smoke concentration are known in each volume element. Models for additional physical effects, such as turbulence, forced ventilation, and different

geometry (such as equipment or decks) can be included in a field model to better simulate actual fires. Field modeling requires a large, fast computer with significantly more memory than zone modeling. The accuracy of the solution depends upon reducing the size of the control volumes; this increases the number of individual cells, the size of the problem, and the computing expense.

Much fire research has been conducted to provide a solid foundation for this thesis. Work performed at the University of Notre Dame [Refs. 2, 3] included a two-dimensional finite difference field model of aircraft fires. It predicted the movement of hot gases and smoke as well as temperature and smoke concentration levels in the seating area of an aircraft cabin. Additional work by Nicolette, et al. [Ref. 4] included the development of a two-dimensional model of transient cooling by natural convection. This model utilized a fully transient semi-implicit upwind differencing scheme with a global pressure correction. Experimental data showed good agreement with the numerical predictions.

Recent studies [Refs. 5 through 13] have developed numerical solutions for natural convection in three-dimensional rectangular enclosures using field modeling. They successfully solved nonlinear partial differential equations with a finite difference method. Models and studies involving three-dimensional cylindrical coordinate buoyant flows [Refs. 14 through 20] deal primarily with horizontal cylindrical annuli that have walls of different temperatures. Smutek, et al. [Ref. 19] studied convection in a horizontal cylinder with differentially

heated ends at low Rayleigh numbers. Yang, et al. [Ref. 20] conducted a similar numerical study for high Rayleigh numbers.

The difficulty in calculating pressure has been addressed using methods that eliminate pressure from the governing equations. Stream function-vorticity methods [Refs. 14 through 19] have been used to solve natural convection problems in several geometries. The problems inherent in this method include instability at moderate to high Rayleigh numbers, difficulties in handling three-dimensional situations, and the lack of pressure information, which often is a parameter of interest. These problems are addressed by Yang, et al. [Ref. 20], who propose the use of primitive variables with an arbitrary orthogonal coordinate system.

Ozoe, et al. [Ref. 21] used a vorticity vector potential formulation and alternating-direction-implicit finite difference method to compute velocity and temperature fields for three-dimensional natural convection in a spherical annulus.

Baum and Rehm [Refs. 22 through 25] have developed several field models for prediction of fires. Their models use time-dependent inviscid Boussinesq equations to simulate three-dimensional buoyant convection and smoke aerosol coagulation. Field models have also been used to model room fires [Ref. 26] and fires in a general three-dimensional enclosure [Ref. 27].

The numerical method developed by Yang, et al. [Ref. 20] and used in this thesis is based upon the use of primitive variable finite difference discretization in generalized orthogonal coordinates. This

method has the ability to handle complex geometries and the stability inherent in the primitive variable formulation.

### **C. FIRE-1, THE TEST FACILITY**

To better understand the phenomena of fire inside a pressurized compartment, the Navy built an experimental pressure vessel for conducting test fires. This test facility is designated FIRE-1 and is located at the Naval Research Laboratory in Washington, D. C. A brief summary of FIRE-1 is contained here; a more detailed report is provided by Alexander, et al. [Ref. 28]. Figure 1.1 shows the basic layout of FIRE-1. It is a 46.6-foot-long cylindrical vessel with hemispherical ends, capable of pressures up to 89.7 psi at 450 F. The radius of both the cylinder and the end caps is 9.6 feet and the total enclosed volume is 11,639 cubic feet. The vessel is constructed of 3/8 inch ASTM 285 Grade C steel and contains rupture discs at each end to prevent over-pressurization.

Instrumentation monitors various fire parameters, including pressures, temperatures, and smoke concentrations. Pressure transducers and bourdon tube gauges are located at the north and south ends of the vessel. Thermocouples and radiometers are installed as shown in Fig. 1.2. An array of ten thermocouples is located at each end of the tank. Each thermocouple is a chrome alumel wire of 0.2 mm diameter having ceramic insulation enclosed in 1 mm diameter Type 304 stainless steel jackets. Thermocouples are also located on the chamber wall to measure the inside and outside wall temperatures.

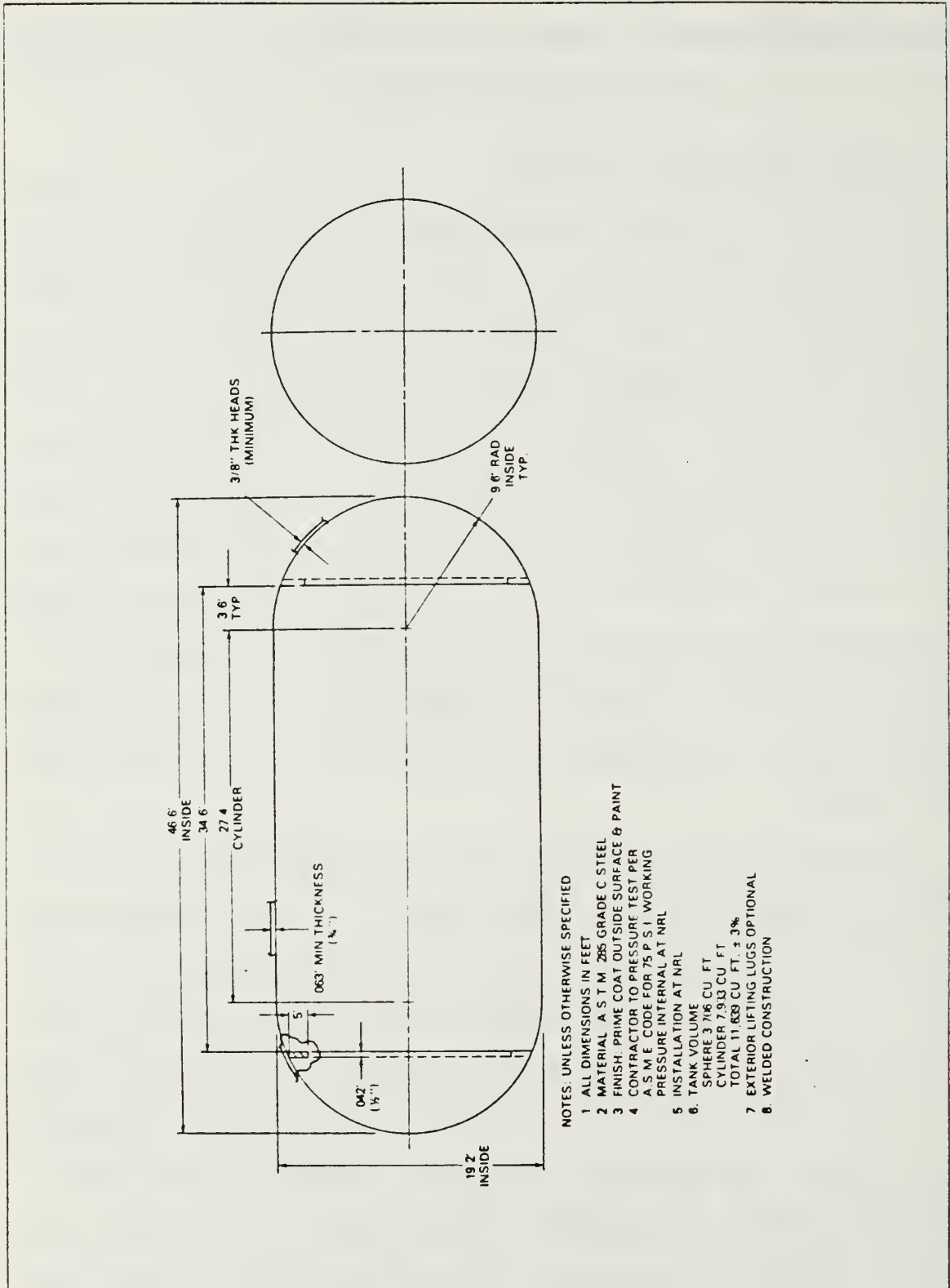


Figure 1-1. Drawing of the FIRE-1 Test Vessel

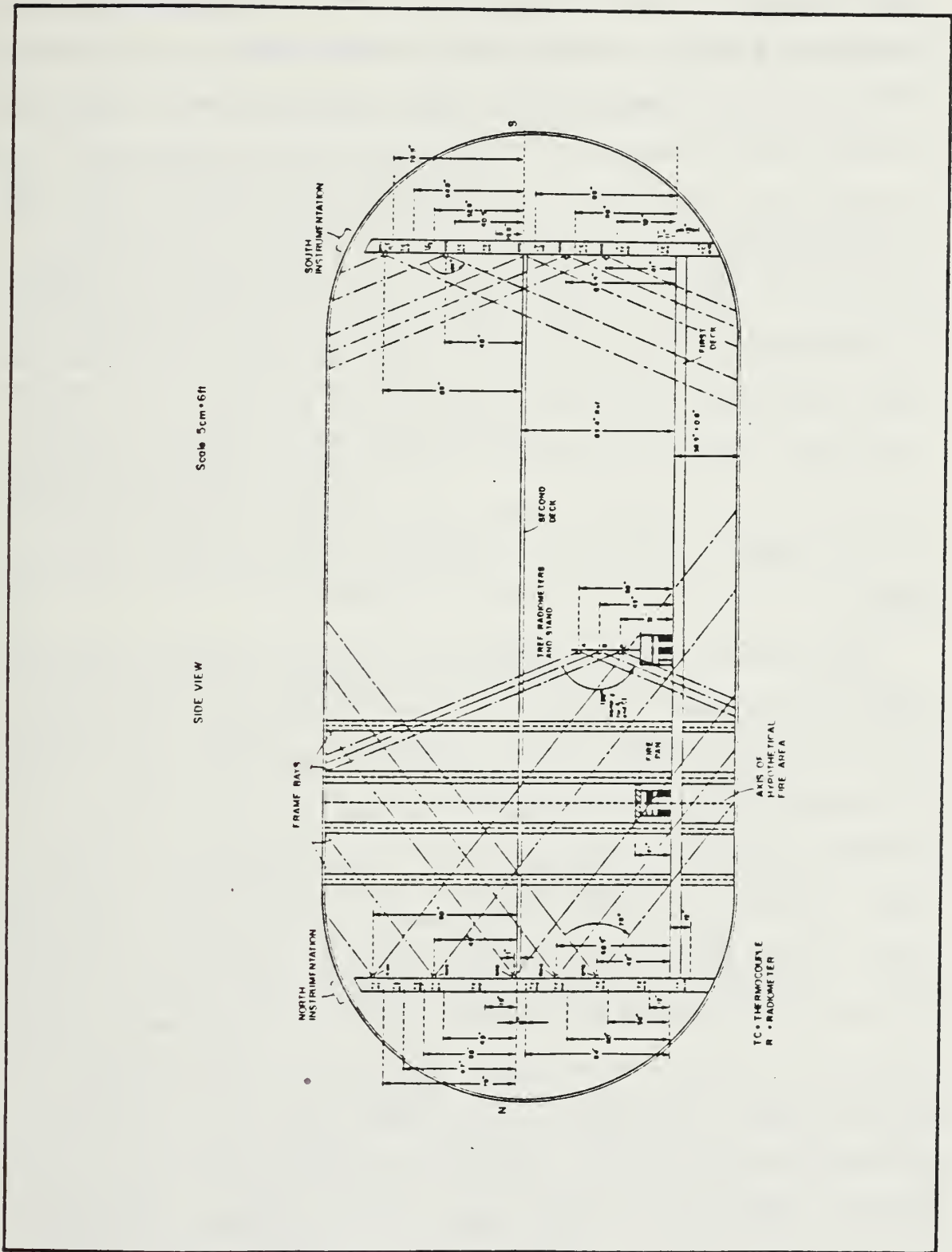


Figure 1-2. Side View of FIRE-1 With Sensor Locations

Additional thermocouples and radiometers are available for temporary installation at various locations as required for different tests. Smoke obscuration can be measured three ways: visual obscuration with video cameras, particle analysis, and obscuration with laser detectors. The fuel burn rate is determined with a round tapered-edge fire pan with various cross-sectional areas, provided with a constant-level fuel supply system. The operation and calibration is described by Alexander, et. al. [Ref 28]. To date, the burn rate data has not been accurate, so further experimentation is necessary to provide fuel burn rate. As discussed later, the lack of accurate burn rate data precludes complete verification of the computer code. In the interim, several methods of deducing burn rate have been developed for use in the computer model.

Three features permit modification of the tests to more accurately model the submarine or ship compartment being tested. First, there are two removable decks, one installed in the mid plane of the vessel and the other slightly over three feet above the bottom. Grated or solid deck plates can be installed to test various shipboard configurations. The decks have been incorporated in the computer model but have not yet been tested and verified. Second, a nitrogen pressurization system extinguishes the fire and can be used to evaluate its performance in an actual fire situation. Ten seconds after energizing the nitrogen system, the pressure in the vessel rises to two atmospheres and extinguishes the fire by reducing the partial pressure of oxygen to less than 10.5 percent. Third, there are two ventilation fans which

can be installed to simulate the effects of internal ventilation. The ventilation system has been included in the computer model and is the subject of verification in Chapter 4 of this thesis.

#### **D. FEATURES OF THE PROGRAM**

The computer model was developed as a low-cost alternative to predict the spread of fire and smoke in enclosed spaces on naval vessels. Together with the FIRE-1 test facility, which can be used for validation of the computer code, it can be used to evaluate the effectiveness of damage control systems and new ship designs in the prevention and control of fires.

The computer model is a joint effort of the University of Notre Dame and the Naval Postgraduate School. The original work by Nies [Ref. 29] involved a model of a rectangular volume similar to FIRE-1. The model was a three-dimensional, finite difference model employing primitive variables. It included a global pressure correction, surface radiation, turbulence, and simple conduction at the walls. The unreliability of the burn rate data from FIRE-1 experiments caused a problem in validation of the computer model. To overcome this problem, a scheme for developing the burn rate based on the experimental pressure was developed; the procedure is describe by Nies [Ref. 29:pp. 61-63].

Raycraft [Ref. 30] developed a more sophisticated model which uses a spherical/cylindrical coordinate system to more accurately model FIRE-1. It also includes a more detailed formulation of surface radiation, global pressure correction, turbulence, and conduction. The



problem with burn rate data persisted, and three trials were run to attempt to better simulate the burn rate. The conclusions were:

1. The pressure tracking case, Trial 1, provided a numerically generated heat release curve from other available sources. The pressure was forced to follow the experimental curve, causing large oscillations in the heat release and temperature data.
2. Trial 2 used a third-order polynomial fit of the experimental data provided by NRL. The pressure and temperature did not oscillate greatly, but the values obtained were very high. This indicated that experimental burn rate data was also too high. It was known at the onset that the heat release rate data could be off by some unknown scaling factor.
3. Of the three test cases examined, Trial 3 was a better representation of the fire in FIRE-1. This case combined the heat release rate levels obtained from Trial 1 with the third-order polynomial fit variation from Trial 2. The results were a realistic burn rate curve to use as input into the computer code. [Ref. 30]

The present code includes internal forced ventilation into the model. The effects of two fans blowing into the end caps of the vessel is investigated in this thesis using the burn rate curve discussed above in Conclusion 3. The results are compared with existing data of the fire model without ventilation.

## **E. THESIS OUTLINE**

This thesis describes the numerical model, its derivation, and application. In Chapter 2, the governing equations, initial and boundary conditions, and the various submodels employed are discussed. Chapter 3 presents the derivation of the finite difference equations. The use of the control volume method in the spherical/cylindrical geometry is explained. The conservation equations are presented and integrated, finite difference equations are developed, and the pressure

correction procedures are described. Chapter 4 presents the experimental data for the internal ventilation model and compares it with the nonventilated case. The conclusions and recommendations for future work are presented in Chapter 5. The appendix contains the code for the model.

## II. NUMERICAL MODEL

### A. GOVERNING EQUATIONS

#### 1. Introduction

The governing differential equations used in the computer model are described in this section. They are initially presented for a Cartesian system and then transformed into a generalized curvilinear coordinate system using standard tensor notation. Several assumptions are made in the development of the governing equations. The fire is modeled as an unsteady volumetric heat source that is a third order polynomial in time, which resulted from previous work [Ref. 30]. The effects of combustion have not yet been incorporated into the code. Density varies in accordance with the perfect gas law.

Nies [Ref. 29] developed a computer code to model a fire in FIRE-1 using Cartesian coordinates as an initial approximation. Raycraft [Ref. 30] describes the code for the current spherical/cylindrical geometry which is summarized below.

#### 2. General Equations

The governing equations include: conservation of mass (continuity), conservation of momentum, conservation of energy, and the equations of state. These are presented below in Cartesian coordinates and in standard tensor notations. The continuity equation is:

$$\rho_{,t} + (\rho u_i)_{,i} = 0 \quad (2.1)$$

The momentum equation is given as:

$$(\rho u_i)_{,i} + (\rho u_i u_j)_{,j} = -P_{,i} - \rho G_i + (\sigma_{ij})_{,j} \quad (2.2)$$

and the energy equation is:

$$(\rho C_{pm} T)_{,i} + (\rho u_i C_{pm} T)_{,i} = (k T_{,j})_{,j} + \mu \Phi + P u_{i,i} \quad (2.3)$$

The stress tensor is given as:

$$\sigma_{ij} = \mu_{eff} \left( u_{i,j} + u_{j,i} - \frac{2}{3} \delta_{ij} u_{k,k} \right) \quad (2.4)$$

with  $\delta_{ij}$  being the Kronecker delta, which equals the value of 1 when  $i = j$  and equals the value of 0 when  $i \neq j$ . The dissipation function is:

$$\Phi = 2(u_{i,j}^2) \delta_{ij} + [u_{i,j}(1 - \delta_{i,j})]^2 - \frac{2}{3}(u_{i,i})^2 \quad (2.5)$$

The equations of state are given as:

$$P = \rho RT \quad (2.6)$$

$$h = C_{pm}(T - T_R) \quad (2.7)$$

Since the computer model of FIRE-1 is in a combination of spherical and cylindrical coordinates, these equations must be transformed into a general curvilinear coordinate system  $(\theta^1, \theta^2, \theta^3)$ . Yang, et. al. [Ref. 20] outlines this process, using the rules established by Eringen [Ref.

31]. The generalized orthogonal coordinates are transformed as follows:

$$X_i \rightarrow \theta^i \quad (2.8)$$

with a scale factor,  $h_i$ , for curvilinear coordinates given as:

$$h_i = \sqrt{\vec{g}_i \cdot \vec{g}_i} = \sqrt{\left(\frac{\partial X_j}{\partial \theta^i}\right) \cdot \left(\frac{\partial X_j}{\partial \theta^i}\right)} \quad (2.9)$$

The scale factor is a component, therefore the summation rule does not apply to the subscript of  $h_i$ . Reference 31 gives the scale factors in cylindrical coordinates as:

$$h_1 = r = \theta^2 \quad (2.10)$$

$$h_2 = 1 \quad (2.11)$$

$$h_3 = 1 \quad (2.12)$$

In spherical coordinates, the scale factors are:

$$h_1 = r \sin \theta = \theta^2 \sin \theta^3 \quad (2.13)$$

$$h_2 = 1 \quad (2.14)$$

$$h_3 = r = \theta^2 \quad (2.15)$$

The covariant and contravariant metric tensors of orthogonal coordinates are given as:

$$g_{ij} = \vec{g}_i \cdot \vec{g}_j = \delta_{ij} h_i h_j \quad (2.16)$$

$$g^{ij} = \frac{\delta_{ij}}{h_i h_j} \quad (2.17)$$

The vector tangent to the  $u_i$  curve at P is given as:

$$u_i = \frac{g_{ij} u^{(j)}}{h_j} \quad (2.18)$$

and the velocity vector is given as:

$$u^i = \frac{u^{(i)}}{h_i} \quad (2.19)$$

In generalized orthogonal coordinates [Ref. 20], the continuity equation is:

$$\rho_t + \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^i} \left( \sqrt{g} \rho \frac{u^i}{h_i} \right) = 0 \quad (2.20)$$

and the energy equation becomes:

$$\begin{aligned} (\rho C_{pm} T)_t + \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^i} \left( \sqrt{g} \rho C_{pm} u^i \frac{T}{h_i} \right) \\ = \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^i} \left( \sqrt{g} \frac{k_{eff} T_{,i}}{h_i^2} \right) + S_f \end{aligned} \quad (2.21)$$

with the momentum equation given as:

$$\begin{aligned}
 (\rho u^i)_{,i} + \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^i} \left( \sqrt{g} \frac{u^i u^j}{h_j} \right) &= \frac{-P_{,i}}{h_i} + \rho G^i + \\
 + \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^j} \left( \frac{\sqrt{g} \sigma_i^j}{h_j} \right) - \frac{1}{h_i h_j} \frac{\partial h_i}{\partial \theta^j} (\rho u^i u^j - \sigma_i^j) &+ \quad (2.22) \\
 + \frac{1}{h_i h_j} \frac{\partial h_j}{\partial \theta^i} (\rho u^j u^i - \sigma_j^i) &
 \end{aligned}$$

The stress tensor is:

$$\sigma_i^j = \mu_{\text{eff}} \left[ \begin{aligned} &\frac{h_j}{h_i} \frac{\partial}{\partial \theta^i} \left( \frac{u^j}{h_j} \right) + \frac{h_i}{h_j} \frac{\partial}{\partial \theta^j} \left( \frac{u^i}{h_i} \right) + \\ &+ \frac{\delta_{ij}}{h_i h_j} \frac{\partial q_{ii}}{\partial \theta^m} \left( \sqrt{g} \frac{u^m}{h_m} \right) \end{aligned} \right] \quad (2.23)$$

and the dissipation function is:

$$\begin{aligned}
 \Phi = 2 \left[ \left( \frac{u^i}{h_i} \right)_{,j} \right] \delta_{ij} + \left[ \left( \frac{u^i}{h_i} \right)_{,j} (1 - \delta_{ij}) \right]^2 - \\
 - \frac{2}{3} \left[ \left( \frac{u^i}{h_i} \right)_{,i} \right]^2 \quad (2.24)
 \end{aligned}$$

The only difference between these equations and the cartesian coordinate equations is the additional terms in the momentum equation for Coriolis and centrifugal forces. In the energy equation, several terms have been lumped together in the source term:

$$S_f = \mu \Phi + P \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^i} \left( \sqrt{g} \frac{u^i}{h_i} \right) + S_{hs} \quad (2.25)$$

The heat source term,  $S_{hs}$ , is nonzero only in the fire, since gas radiation effects have yet to be incorporated into the computer model. Furthermore, since the present study deals with turbulent flow, the conductivity,  $k_{eff}$ , and dynamic viscosity,  $\mu_{eff}$ , are the effective quantities which include both the laminar and turbulent contributions.

## **B. INITIAL AND BOUNDARY CONDITIONS**

In order to solve the governing equations, both initial and boundary conditions must be applied to the model.

### **1. Initial Conditions**

The initial conditions of the model are the same as the conditions immediately prior to the ignition of the fire in FIRE-1. The air within the vessel is assumed to be totally at rest, so the entire velocity field is set equal to zero. The forced ventilation does not begin until the fire starts, so that the velocity field due to the forced ventilation builds as the fire starts to burn. The temperature of the field is uniform and equal to the ambient temperature, which corresponds to a nondimensional temperature of 1.0. Pressure and density distributions are due to the static equilibrium distribution inside the tank.

### **2. Boundary Conditions**

The pressure vessel forms a solid wall around the entire area, so all velocities on the wall are zero; this satisfies the no-slip condition. Since there is no mass flux through the wall, all velocities



normal to the wall are set equal to zero. Temperatures on the inside of the wall are equal to the temperature of the fluid immediately adjacent to the wall eliminating temperature discontinuities. The following equations describe these boundary conditions.

$$u^i = 0 \quad (2.26)$$

$$T_{\text{surf}} = T_{\text{fluid}} \quad (2.27)$$

Continuity of heat flux must be met at the walls.

$$q_r - k_f \frac{\partial T}{\partial n} = -k_s \frac{\partial T_s}{\partial n} \quad (2.28)$$

with  $n$  representing the normal direction towards the center of the vessel and  $q_r$  representing the thermal radiation energy. There is heat conduction through the walls and heat convection from the exterior walls to the environment at the ambient temperature.

Due to the cylindrical and spherical geometry, there is a singularity at a radius of zero which requires special treatment. Several different methods of correcting this problem are discussed by Yang, et al. [Ref. 20:pp. 167-168]. The method chosen for this model involves applying continuity to two consecutive radial control volumes placed in the vicinity of radius equal to zero. Of all the methods investigated, this was found to give the best representation of the flow and temperature flow fields.

The boundary conditions for the control volumes adjacent to the ventilation control volumes are discussed in Chapter 3.

### C. PHYSICAL MODELS

#### 1. Turbulence Model

An algebraic model is used to predict the average values of the dependent variables. More complicated models could be used, but the increase in computing time does not warrant their use. Nee and Liu [Ref. 32] developed a model that obtains the effective viscosity,  $\mu_{\text{eff}}$ , in recirculating buoyant flows with large variations in turbulence levels. The equation, after being transformed to the generalized orthogonal coordinate system, is:

$$\frac{\mu_{\text{eff}}}{\mu_o} = 1 + \frac{\left(\frac{1}{H}\right)^2 \sqrt{\left(\frac{1}{h_j} \frac{\partial u^i}{\partial \theta^j}\right)^2 (1 - \delta_i^j)}}{2 + \frac{\text{Ri}}{\text{Pr}_t}} \quad (2.29)$$

where  $\text{Pr}_t$  is the turbulent Prandtl Number and the Richardson Number,  $\text{Ri}$ , is given as:

$$\text{Ri} = \frac{H}{u_i^2} \frac{\left(\frac{\partial T}{\partial n}\right) \vec{n} \cdot \vec{g}}{\left[\left(\frac{\partial u^1}{\partial n}\right) \vec{n} \cdot \vec{g}\right]^2 + \left[\left(\frac{\partial u^2}{\partial n}\right) \vec{n} \cdot \vec{g}\right]^2 + \left[\left(\frac{\partial u^3}{\partial n}\right) \vec{n} \cdot \vec{g}\right]^2} \quad (2.30)$$

with  $\vec{n}$  a unit vector in the direction opposite to gravity and  $1/H$  the nondimensional mixing length parameter:

$$\frac{1}{H} = K \left\{ \frac{\sqrt{u^i u^i}}{\sqrt{\sum_{i,j} \left( \frac{1}{h_j} \frac{\partial u^i}{\partial \theta^j} \right)^2}} + \frac{\sqrt{\sum_{i,j} \left( \frac{1}{h_j} \frac{\partial u^i}{\partial \theta^j} \right)^2}}{\sqrt{\sum_{i,j} \left( \frac{1}{h_i h_j} \frac{\partial^2 u^i}{\partial \theta^i \partial \theta^j} \right)^2}} \right\} \quad (2.31)$$

where K is an adjustable constant. The effective conductivity is defined by the following equation:

$$k_{\text{eff}} = \frac{1}{Pr} + \frac{1}{Pr_t} \frac{\mu_{\text{eff}}}{\mu_o} \quad (2.32)$$

## 2. Conduction Model

As the fire progresses, the heat energy transferred to the environment becomes increasingly important. This requires a model for the heat conduction through the vessel walls. The energy transfer is treated as unsteady, one-dimensional heat conduction through the wall and convection with a constant heat transfer coefficient at the wall exterior. The energy equation in this case is:

$$(\rho_s C_{ps} T)_t = \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^i} \left( \sqrt{g} k_s T_{,j} g^{ij} \right) + S \quad (2.33)$$

with  $\rho_s C_{ps}$  being the heat capacitance of the wall and  $k_s$  being the conductivity of the wall.

## 3. Radiation Model

The radiation model is described in detail by Raycraft [Ref. 30:pp. 22–44] but is summarized below. The radiation model used is based on three assumptions. First, the model only considers surface

radiation; this means that the gas and smoke inside the tank is considered to be transparent. Second, all surfaces are modeled as grey surfaces, with radiation diffusely distributed. Third, the tank walls and the flame of the fire are treated as surfaces. The radiation model is based on the net radiosity model discussed by Sparrow and Cess [Ref. 33]. The net rate of heat loss per unit area is given as:

$$\frac{Q_i}{A_i} = \sum_{j=1}^N G_{ij} \sigma T_j^4 \quad (2.34)$$

with the following definitions:

$$G_{ij} = \frac{\epsilon_i}{1 - \epsilon_i} (\delta_{ij} - \Psi_{ij}) \quad (2.35)$$

$$\Psi_{ij} = \chi_{ij}^{-1} \quad (2.36)$$

$$\chi_{ij} = \frac{\delta_{ij} - (1 - \epsilon_i) F_{Ai-Aj}}{\epsilon_i} \quad (2.37)$$

$F_{Ai-Aj}$  is the view factor for the radiation emitted by the surface  $i$  and incident upon surface  $j$ . Generally, it is given as

$$F_{Ai-Aj} = \frac{1}{A_i} \int_{A_i} \int_{A_j} \frac{\cos \beta_i \cos \beta_j dA_i dA_j}{\pi r^2} \quad (2.38)$$

The view factor calculations are given in detail by Raycraft [Ref. 30:pp. 29 through 44].

#### **4. Internal Ventilation Model**

The internal ventilation model allows the user to set up forced internal ventilation in the field. This would normally represent outlets of the ship's ventilation system, but could also model ventilation due to damage (i.e., ruptured air lines or ventilation ducts) or damage control smoke removal equipment. The internal ventilation model defines a velocity in one or more control volumes.

### **III. FINITE DIFFERENCE EQUATIONS AND CALCULATIONS**

#### **A. INTRODUCTION**

The numerical solution for the computer model has space and time as the independent variables, and velocity (in three directions), pressure, temperature, and density as the dependent variables. With six unknown dependent variables, six equations are needed to obtain a solution. The conservation of mass equation (Eqn. 2.20), conservation of energy equation (Eqn. 2.21), conservation of momentum equations (Eqn. 2.22), and the equation of state (Eqn. 2.6) are used. These equations are discretized in a method similar to that described by Doria [Ref. 34], based on the general discretization concept presented by Patankar [Ref. 35]. Doria divided the domain into separate control volumes and wrote conservation equations for each cell in an integral form. These integral equations became a set of finite difference equations which could be solved to provide a solution.

In the flow field, each cell is treated as a unit, with one value of each property reigning throughout the cell. The center of the cell determines the value of temperature, pressure and density. The velocity grids are staggered one-half cell away from the center. Patankar [Ref. 35:pp. 115-120] describes two problems which arise when the velocity cells are coincident with the basic cells. First, the velocity at the staggered cell center is calculated as a function of the pressure differential between the two adjacent nonstaggered cells. If

the cells were not staggered, the velocity would be calculated based on the pressures of adjacent cells, which are twice as far away as in the staggered cell case. Second, staggered cells preclude unrealistic oscillating solutions.

Employment of primitive variables presents a problem with the coupling of the pressure term in different equations. Others have used the stream function to eliminate this coupling [Refs. 14–19] but in the present case, with the desire to determine the pressure, this method is inappropriate for the reasons cited in Chapter 1. In the computer code, an iterative procedure is used to estimate pressure. To ensure that the results are physically realistic, a numerical method must not violate the conservation properties. Patankar [Ref. 35:pp.120–126] and Doria [Ref. 34:pp.26–32] describe the method of satisfying conservation by correcting the estimated pressure to ensure that mass is conserved at every cell. In addition to the local pressure correction, a global pressure correction is included to account for the total energy change in the system, as described by Nicolette, et al. [Ref. 4].

In the finite difference method, differential elements are replaced by finite quantities in the integral form of the equations. Many methodologies have been developed for dealing with the differencing techniques and each has inherent features and problems. The QUICK methodology (Quadratic Upstream Interpolation for Convective Kinematics) developed by Leonard [Ref. 36] is used here for the convective terms. QUICK uses locally two-dimensional quadratic interpolation functions for estimating control volume face values and gradients of

transported variables. It is third-order accurate and permits practical grid sizes. Yang [Ref. 13] employed QUICK in the coupled momentum, energy, and pressure equation solutions for three-dimensional flow in tilted rectangular enclosures.

## B. CONTROL VOLUME

When defining the problem to be solved numerically, the flow field is divided up into finite elements, or cells that together make up the entire field. At the center of each cell is a grid point that is defined as the governing point of the cell. In discussing the grid points, the following nomenclature is used. The grid of interest is called P (I, J, K), with adjacent grids being defined as: East (I+1, J, K), West (I-1, J, K), North (I, J+1, K), South (I, J-1, K), Front (I, J, K+1), and Back (I, J, K-1). The boundaries of the cell with grid point P are designated by lower case letters, or e, w, n, s, f, and b. Figures 3.1 and 3.2 shows typical cells in cylindrical and spherical coordinate systems.

As previously discussed, velocities are defined in a staggered grid system. To illustrate this, Figure 3.3 shows a two-dimensional cell; Figure 3.4 shows the location of the staggered velocities around the grid. The velocity,  $u_1^1$ , for the basic cell is located on the west face;  $u_j^2$  is on the south face; and  $u_k^3$  (not shown) is on the back face. In all cases, the staggered cell system is offset one-half cell from the primary cell system.



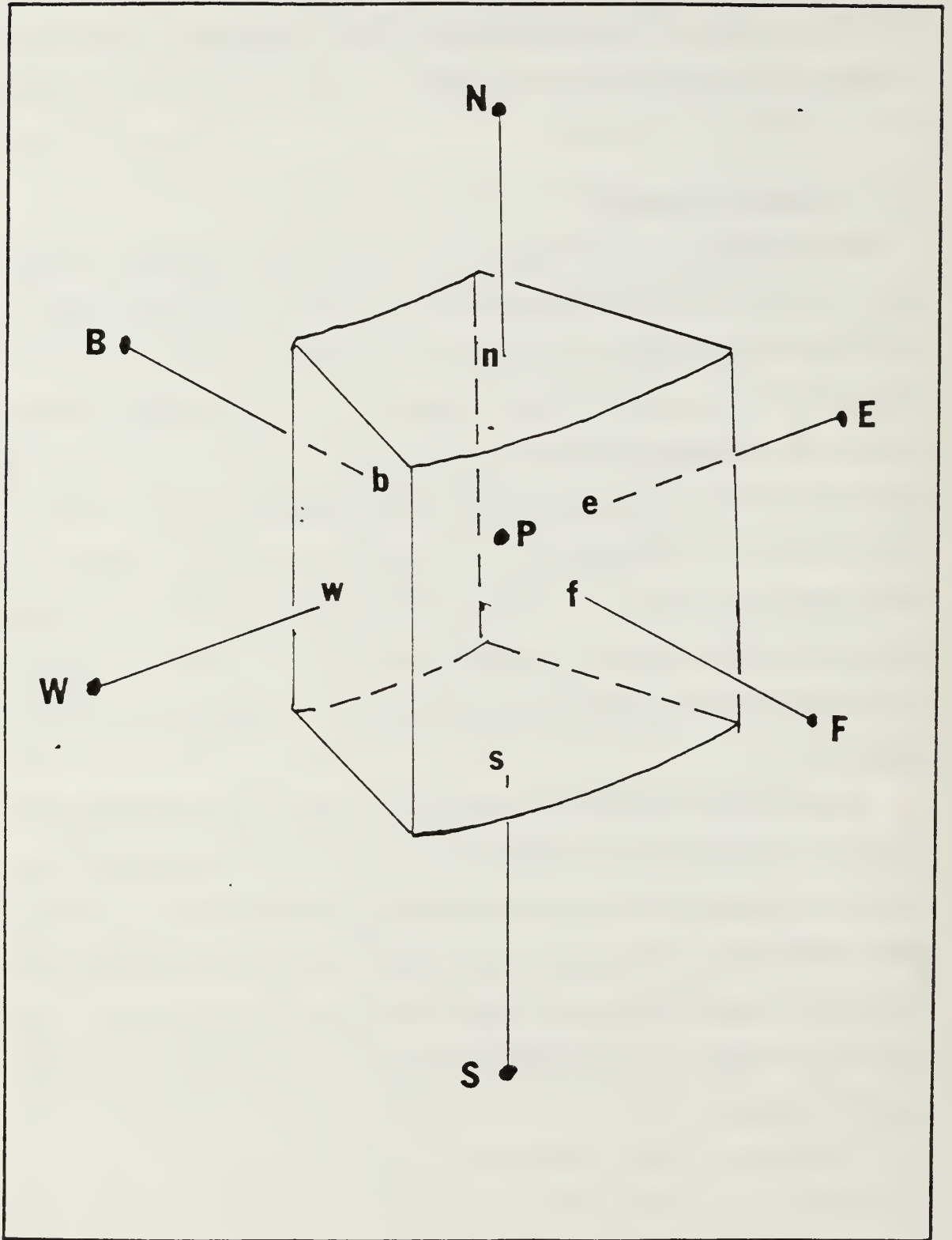


Figure 3-1. Basic Cylindrical Cell

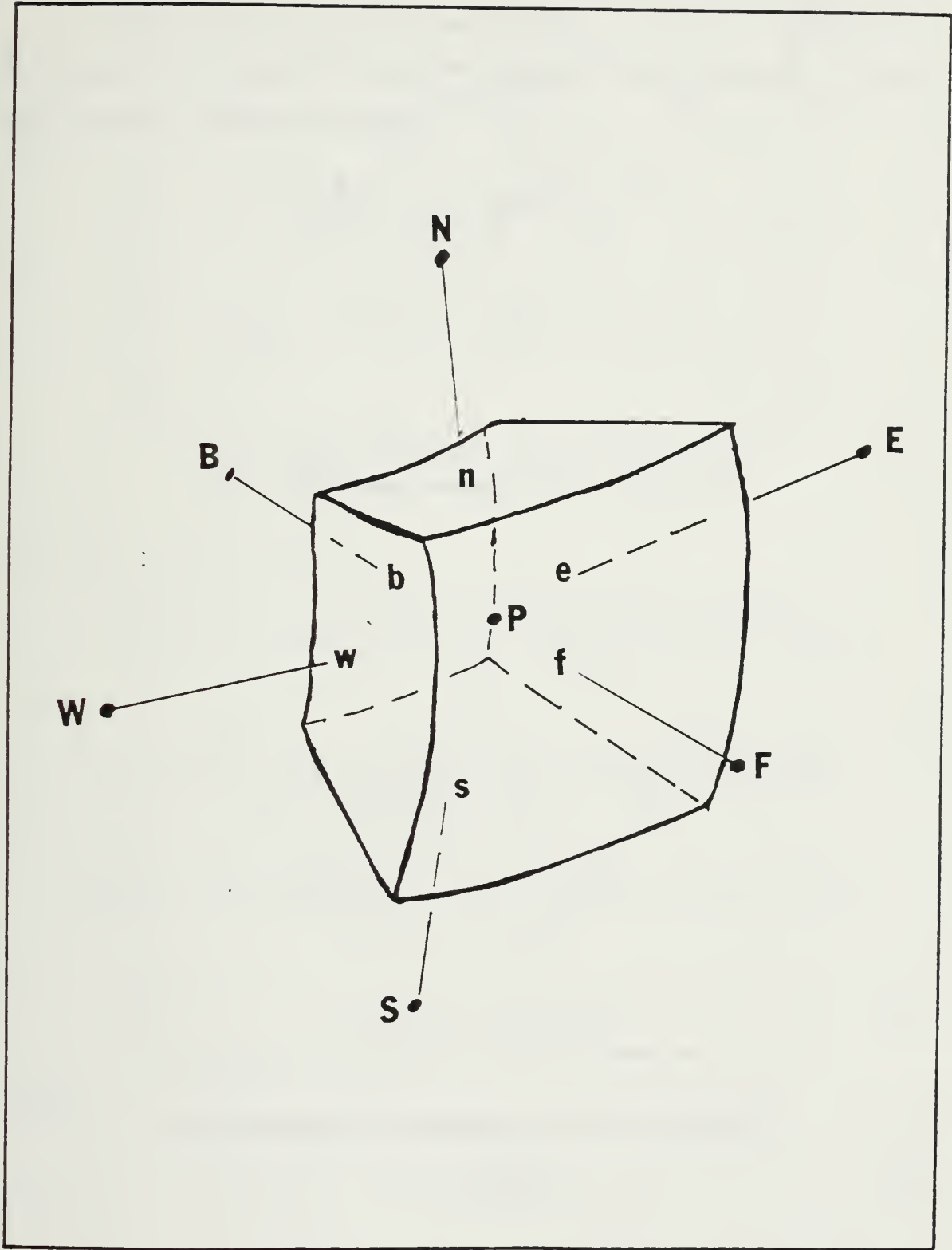


Figure 3-2. Basic Spherical Cell

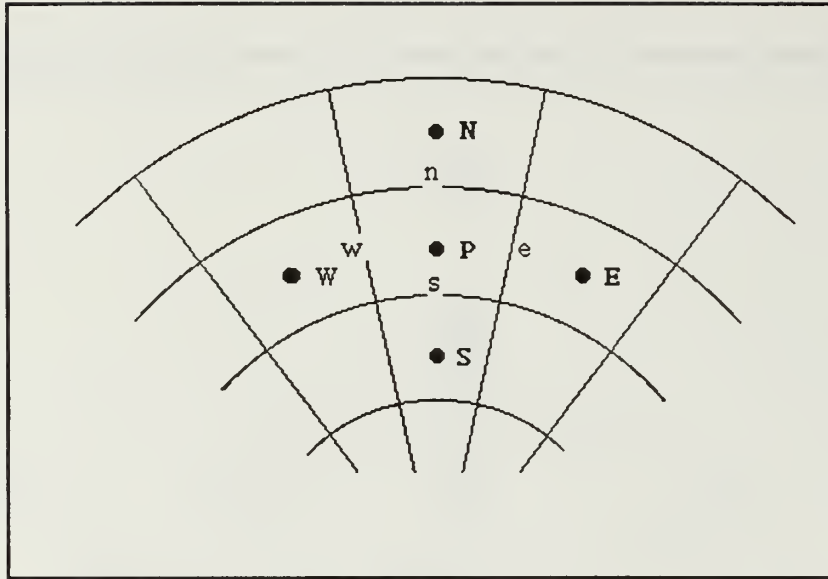


Figure 3-3. **Two-Dimensional Basic Cell**

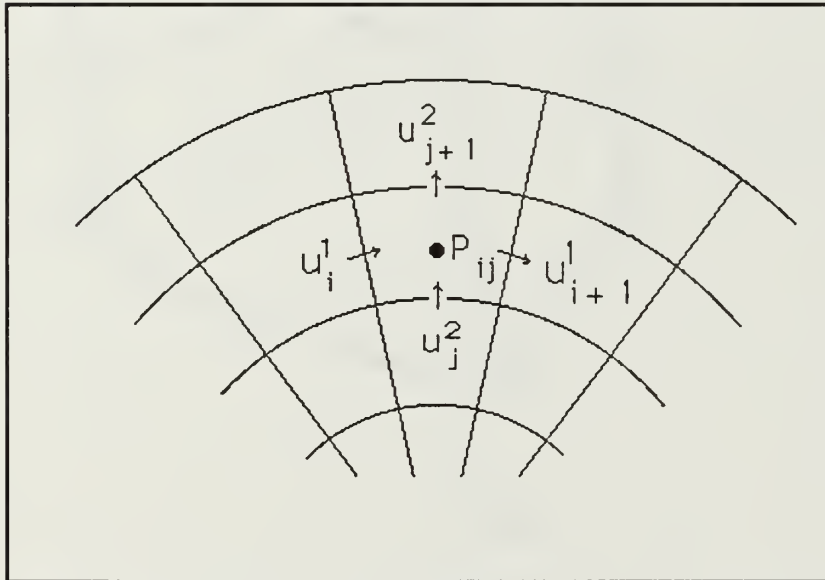


Figure 3-4. **Two-Dimensional Staggered Cell**

### C. INTEGRATION OF CONSERVATION EQUATIONS

To discretize the conservation equations, it is first necessary to put them into an integral form by integrating over the volume of a cell. The continuity equation becomes:

$$\int \frac{\partial \rho}{\partial t} h_1 h_2 h_3 d\theta^1 d\theta^2 d\theta^3 + \int \left[ \frac{\partial}{\partial \theta^1} (\rho u^1 h_2 h_3) + \frac{\partial}{\partial \theta^2} (\rho u^2 h_3 h_1) + \frac{\partial}{\partial \theta^3} (\rho u^3 h_1 h_2) \right] d\theta^1 d\theta^2 d\theta^3 = 0 \quad (3.1)$$

and the energy equation is:

$$\int \frac{\partial (\rho C_{pm} T)}{\partial t} h_1 h_2 h_3 d\theta^1 d\theta^2 d\theta^3 + \int \left[ \frac{\partial}{\partial \theta^1} (\rho C_{pm} u^1 T h_2 h_3) + \frac{\partial}{\partial \theta^2} (\rho C_{pm} u^2 T h_1 h_3) + \frac{\partial}{\partial \theta^3} (\rho C_{pm} u^3 T h_1 h_2) \right] d\theta^1 d\theta^2 d\theta^3 - \int \left[ \frac{\partial}{\partial \theta^1} (q^1 h_2 h_3) + \frac{\partial}{\partial \theta^2} (q^2 h_1 h_3) + \frac{\partial}{\partial \theta^3} (q^3 h_1 h_2) \right] d\theta^1 d\theta^2 d\theta^3 + \int S h_1 h_2 h_3 d\theta^1 d\theta^2 d\theta^3 \quad (3.2)$$

with:

$$q^1 = - \frac{k}{h_1} \frac{\partial T}{\partial \theta^1} \quad (3.3)$$

The momentum equations are:

$$\begin{aligned}
& \int \frac{\partial}{\partial t} (\rho u^i) h_1 h_2 h_3 d\theta^1 d\theta^2 d\theta^3 + \int \frac{\partial}{\partial \theta^j} \left[ \left( \frac{h_1 h_2 h_3}{h_j} \right) \rho u^i u^j \right] d\theta^1 d\theta^2 d\theta^3 \\
& = \int - \frac{\partial}{\partial \theta^i} \left( P \frac{h_1 h_2 h_3}{h_i} \right) d\theta^1 d\theta^2 d\theta^3 + \int \rho G_i h_1 h_2 h_3 d\theta^1 d\theta^2 d\theta^3 \\
& \quad + \int \frac{\partial}{\partial \theta^j} \left( \sigma^{ij} \frac{h_1 h_2 h_3}{h_i h_j} \right) d\theta^1 d\theta^2 d\theta^3 \\
& \quad - \int \frac{h_1 h_2 h_3}{h_i h_j} \cdot \left[ \frac{\partial h_i}{\partial \theta^j} (\rho u^j u^i - \sigma^{ij}) \right] d\theta^1 d\theta^2 d\theta^3 \\
& \quad + \int \frac{h_1 h_2 h_3}{h_j h_i} \cdot \left[ \frac{\partial h_j}{\partial \theta^i} (\rho u^j u^i - \sigma^{ij}) \right] d\theta^1 d\theta^2 d\theta^3 \tag{3.4}
\end{aligned}$$

#### D. CONTINUITY EQUATION

Once the governing equations have been integrated, the differential elements are replaced with finite quantities. Three separate differencing methods are used in the computer model: forward differencing for time, central differencing for the diffusion terms, and QUICK for the convection terms.

In forward differencing, the future value of a given parameter is found by adding its present value to the net change over a finite time. This change is described by the rate of change (slope) multiplied by the time step. For example,

$$\rho^n = \rho^{n-1} + m \Delta t \quad (3.5)$$

with  $\rho^{n-1}$  representing the present value of density,  $m$  is the rate of change,  $\rho^n$  is the future value, and  $\Delta t$  is the time step. Substituting this into the continuity equation (3.1) results in:

$$\frac{\partial \rho}{\partial t} dV = \frac{\rho^n - \rho^{n-1}}{\Delta t} h_1 h_2 h_3 \Delta \theta^1 \Delta \theta^2 \Delta \theta^3 = \frac{\rho^n - \rho^{n-1}}{\Delta t} \Delta V \quad (3.6)$$

By evaluating the integral, the continuity equation becomes:

$$\begin{aligned} (\rho^n - \rho^{n-1}) \frac{\Delta V}{\Delta t} + [\rho u^1 h_2 h_3 d\theta^2 d\theta^3]_e - [\rho u^1 h_2 h_3 d\theta^2 d\theta^3]_w \\ + [\rho u^2 h_1 h_3 d\theta^1 d\theta^3]_n - [\rho u^2 h_1 h_3 d\theta^1 d\theta^3]_s + \\ + [\rho u^3 h_1 h_2 d\theta^1 d\theta^2]_f - [\rho u^3 h_1 h_2 d\theta^1 d\theta^2]_b = 0 \end{aligned} \quad (3.7)$$

The mass flux rate,  $G$ , is evaluated at each of the six cell faces:

$$G_e = (\rho u^1)_e = u_e^1 \left[ \frac{(\rho_p (h_1 \Delta \theta^1)_{i+1} + \rho_E (h_1 \Delta \theta^1)_i)}{((h_1 \Delta \theta^1)_{i+1} + (h_1 \Delta \theta^1)_i)} \right] \quad (3.8)$$

$$G_w = (\rho u^1)_w = u_w^1 \left[ \frac{(\rho_p (h_1 \Delta \theta^1)_{i-1} + \rho_W (h_1 \Delta \theta^1)_i)}{((h_1 \Delta \theta^1)_{i-1} + (h_1 \Delta \theta^1)_i)} \right] \quad (3.9)$$

$$G_n = (\rho u^2)_n = u_n^2 \left[ \frac{(\rho_p (h_2 \Delta \theta^2)_{j+1} + \rho_N (h_2 \Delta \theta^2)_j)}{((h_2 \Delta \theta^2)_{j+1} + (h_2 \Delta \theta^2)_j)} \right] \quad (3.10)$$

$$G_s = (\rho u^2)_s = u_s^2 \left[ \frac{(\rho_p (h_2 \Delta\theta^2)_{j-1} + \rho_N (h_2 \Delta\theta^2)_j)}{((h_2 \Delta\theta^2)_{j-1} + (h_2 \Delta\theta^2)_j)} \right] \quad (3.11)$$

$$G_f = (\rho u^3)_f = u_f^3 \left[ \frac{(\rho_p (h_3 \Delta\theta^3)_{k+1} + \rho_F (h_3 \Delta\theta^3)_k)}{((h_3 \Delta\theta^3)_{k+1} + (h_3 \Delta\theta^3)_k)} \right] \quad (3.12)$$

$$G_b = (\rho u^3)_b = u_b^3 \left[ \frac{(\rho_p (h_3 \Delta\theta^3)_{k-1} + \rho_B (h_3 \Delta\theta^3)_k)}{((h_3 \Delta\theta^3)_{k-1} + (h_3 \Delta\theta^3)_k)} \right] \quad (3.13)$$

with the area of the faces given as:

$$A_{e,w} = (h_2 \Delta\theta^2 h_3 \Delta\theta^3)_{e,w} \quad (3.14)$$

$$A_{n,s} = (h_1 \Delta\theta^1 h_3 \Delta\theta^3)_{n,s} \quad (3.15)$$

$$A_{f,b} = (h_1 \Delta\theta^1 h_2 \Delta\theta^2)_{f,b} \quad (3.16)$$

In the finite difference format, the continuity equation becomes:

$$\frac{(\rho^n - \rho^{n-1}) \Delta V}{\Delta t} + G_e - G_w + G_n - G_s + G_f - G_B = S_{mp} \quad (3.17)$$

with  $S_{mp}$  defined as the mass source term. In an analytical solution, this mass source term is zero, but in numerical solutions it is a finite nonzero term. Through iteration, the numerical solution converges and the mass source term approaches zero. Instead of converging to

zero, the source term is set equal to zero when it is less than or equal to  $10^{-70}$ .

## E. ENERGY EQUATION

The integrated energy equation is:

$$\begin{aligned}
 & \left[ (\rho C_{pm} T)^n - (\rho C_{pm} T)^{n-1} \right] \frac{\Delta V}{\Delta t} + G_e (C_{pm} T)_e A_e - G_w (C_{pm} T)_w A_w + \\
 & G_n (C_{pm} T)_n A_n - G_s (C_{pm} T)_s A_s + G_f (C_{pm} T)_f A_f - G_b (C_{pm} T)_b A_b = \\
 & = k_e A_e \left( \frac{\partial T}{h_1 \partial \theta^1} \right)_e - k_w A_w \left( \frac{\partial T}{h_1 \partial \theta^1} \right)_w + k_n A_n \left( \frac{\partial T}{h_2 \partial \theta^2} \right)_n - \\
 & - k_s A_s \left( \frac{\partial T}{h_2 \partial \theta^2} \right)_s - k_f A_f \left( \frac{\partial T}{h_3 \partial \theta^3} \right)_f + k_b A_b \left( \frac{\partial T}{h_3 \partial \theta^3} \right)_b + S_f \Delta V \quad (3.18)
 \end{aligned}$$

where all  $k$ 's represent effective values.  $S_f$  is the source term and includes dissipation, radiation, pressure work, and all internal heat sources.  $J$  is the total heat flux resulting from convection and conduction.

$$J_{e,w}^1 = \left[ (\rho C_{pm} u^1 T) - k_{eff} \frac{\partial T}{h_1 \partial \theta^1} \right]_{e,w} \quad (3.19)$$

$$J_{n,s}^2 = \left[ (\rho C_{pm} u^2 T) - k_{eff} \frac{\partial T}{h_2 \partial \theta^2} \right]_{n,s} \quad (3.20)$$



$$J_{f,b}^3 = \left[ (\rho C_{pm} u^3 T) - k_{eff} \frac{\partial T}{h_3 \partial \theta^3} \right]_{f,b} \quad (3.21)$$

These equations are the  $\theta^1$ ,  $\theta^2$ , and  $\theta^3$  components of the total heat flux. The subscripts refer to the face to which they correspond. The term  $(\rho C_{pm} u^1 T)$  causes problems since  $u$  is evaluated at the cell surface, but all other values are evaluated at the cell center. Because of this, when using these equations, the fluxes must be expressed in terms of  $C_{pm}$ ,  $\rho$ , and  $T$  at the point  $P$  and its neighbors. Substituting these equations into the integrated energy equation, the finite difference energy equation is:

$$\begin{aligned} & \left[ (\rho C_{pm} T)^n - (\rho C_{pm} T)^{n-1} \right] \frac{\Delta V}{\Delta t} + J_e^1 A_e - J_w^1 A_w + \\ & + J_n^2 A_n - J_s^2 A_s + J_f^3 A_f - J_b^3 A_b = S \Delta V \end{aligned} \quad (3.22)$$

Of the many finite differencing methods, the QUICK scheme is used with the convective terms because it accurately predicts the dependent variable values at the control volume surfaces with stable properties. QUICK has the relative accuracy of the central differencing scheme coupled with the stability of an upwind scheme. It uses a parabolic polynomial interpolation to fit the control volume at three adjacent nodes. Yang [Ref.13:pp. 77-89] describes QUICK in one, two, and three dimensions. Raycraft [Ref. 30:pp. 63-74] developed the finite difference energy equations using the QUICK scheme. Since

this method is used in the computer model, the derivation is repeated here.

The quadratic interpolation for a nonuniform grid is given as:

$$(\rho C_{pm} u T)_e = G_e C_{pm,e} \left[ \left( \frac{T_p + T_e}{2} \right) - \frac{1}{8} CURV_e \right] \quad (3.23)$$

$$(\rho C_{pm} v T)_w = G_w C_{pm,w} \left[ \left( \frac{T_p + T_w}{2} \right) - \frac{1}{8} CURV_w \right] \quad (3.24)$$

Figure 3.5 shows the one-dimensional scheme. The upstream weighted curvature terms CURV are:

$$\begin{aligned} CURV_e &= \frac{\Delta X_e^2}{\Delta X_i} \left( \frac{T_E - T_p}{\Delta X_e} - \frac{T_p - T_w}{\Delta X_w} \right) \text{ if } G_e > 0 \\ &= \frac{\Delta X_e^2}{\Delta X_{i+1}} \left( \frac{T_{EE} - T_E}{\Delta X_{ee}} - \frac{T_E - T_p}{\Delta X_e} \right) \text{ if } G_e < 0 \end{aligned} \quad (3.25)$$

$$\begin{aligned} CURV_w &= \frac{\Delta X_w^2}{\Delta X_{i+1}} \left( \frac{T_p - T_w}{\Delta X_w} - \frac{T_w - T_{ww}}{\Delta X_{ww}} \right) \text{ if } G_w > 0 \\ &= \frac{\Delta X_w^2}{\Delta X_i} \left( \frac{T_E - T_p}{\Delta X_e} - \frac{T_p - T_w}{\Delta X_w} \right) \text{ if } G_w < 0 \end{aligned} \quad (3.26)$$

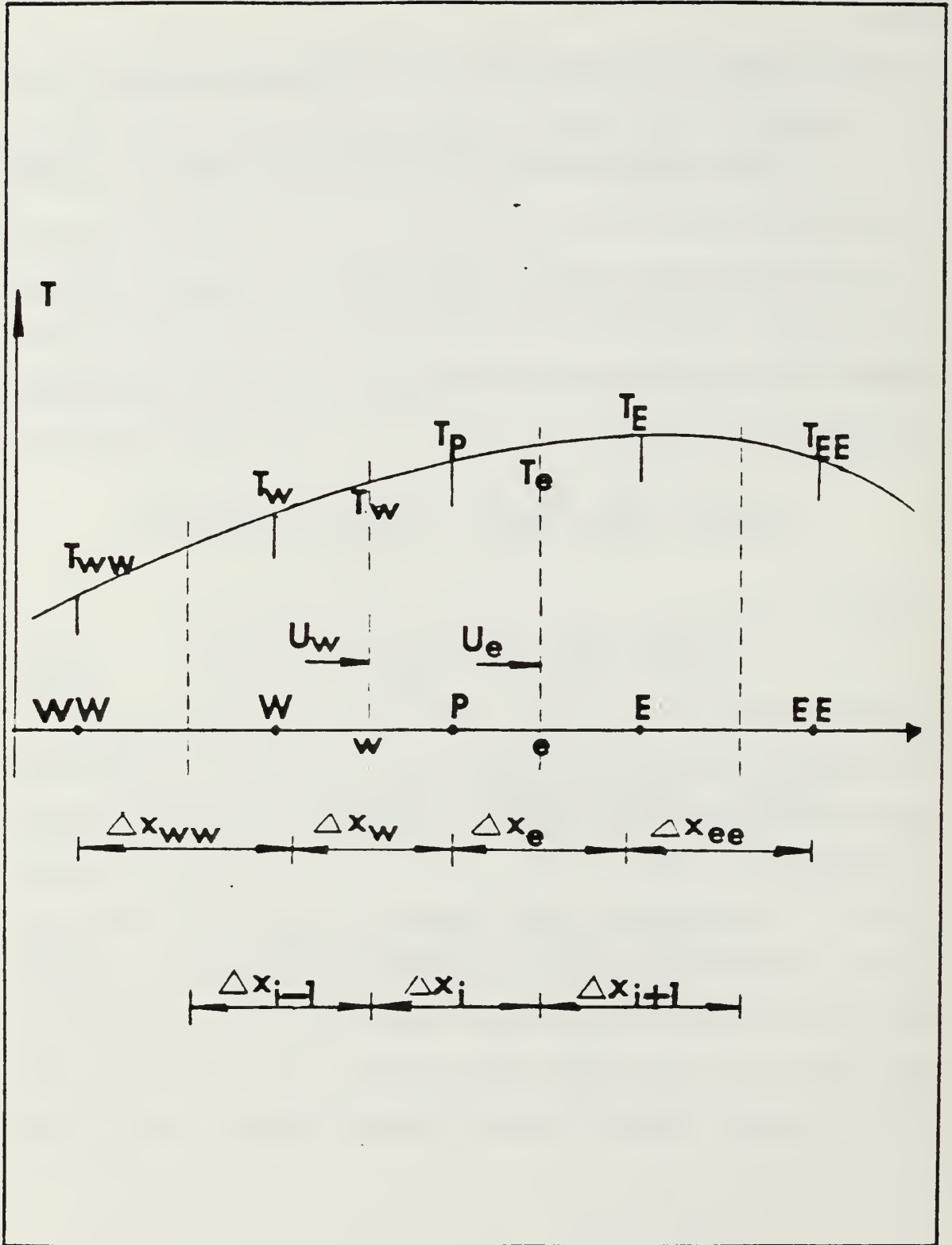


Figure 3-5. One-Dimensional Quadratic Interpolation Scheme

with

$$\begin{aligned}\Delta X_e &= 0.5 (\Delta X_i + \Delta X_{i+1}) \\ \Delta X_w &= 0.5 (\Delta X_i + \Delta X_{i-1}) \\ \Delta X_{ee} &= 0.5 (\Delta X_{i+1} + \Delta X_{i+2}) \\ \Delta X_{ww} &= 0.5 (\Delta X_{i-1} + \Delta X_{i-2})\end{aligned}\tag{3.27}$$

In generalized orthogonal coordinates, the equations becomes:

$$(\rho C_{pm} u^1 T)_e = G_e C_{pm,e} \left( \frac{T_p + T_E}{2} - \frac{1}{8} \text{CURVN}_e \right)\tag{3.28}$$

$$(\rho C_{pm} u^2 T)_w = G_w C_{pm,w} \left( \frac{T_p + T_w}{2} - \frac{1}{8} \text{CURVN}_w \right)\tag{3.29}$$

with

$$\begin{aligned}\text{CURVN}_e &= \frac{(h_1 \Delta \theta^1)_e^2}{(h_1 \Delta \theta^1)_i} \left( \frac{T_E - T_p}{(h_1 \Delta \theta^1)_e} - \frac{T_p - T_w}{(h_1 \Delta \theta^1)_w} \right) \text{ if } G_e > 0 \\ &= \frac{(h_1 \Delta \theta^1)_e^2}{(h_1 \Delta \theta^1)_{i+1}} \left( \frac{T_{EE} - T_E}{(h_1 \Delta \theta^1)_{ee}} - \frac{T_E - T_p}{(h_1 \Delta \theta^1)_e} \right) \text{ if } G_e < 0\end{aligned}\tag{3.30}$$

$$\text{CURVN}_w = \frac{(h_1 \Delta \theta^1)_w^2}{(h_1 \Delta \theta^1)_{i+1}} \left( \frac{T_p - T_w}{(h_1 \Delta \theta^1)_w} - \frac{T_w - T_{ww}}{(h_1 \Delta \theta^1)_{ww}} \right) \text{ if } G_w > 0$$

$$= \frac{(h_1 \Delta\theta^1)_w^2}{(h_1 \Delta\theta^1)_i} \left( \frac{T_E - T_P}{(h_1 \Delta\theta^1)_e} - \frac{T_P - T_w}{(h_1 \Delta\theta^1)_w} \right) \text{ if } G_w < 0 \quad (3.31)$$

and

$$\begin{aligned} (h_1 \Delta\theta^1)_e &= 0.5 \left[ (h_1 \Delta\theta^1)_i + (h_1 \Delta\theta^1)_{i+1} \right] \\ (h_1 \Delta\theta^1)_w &= 0.5 \left[ (h_1 \Delta\theta^1)_i + (h_1 \Delta\theta^1)_{i-1} \right] \\ (h_1 \Delta\theta^1)_{ee} &= 0.5 \left[ (h_1 \Delta\theta^1)_{i+1} + (h_1 \Delta\theta^1)_{i+2} \right] \\ (h_1 \Delta\theta^1)_{ww} &= 0.5 \left[ (h_1 \Delta\theta^1)_{i-1} + (h_1 \Delta\theta^1)_{i-2} \right] \end{aligned} \quad (3.32)$$

The conventional finite difference form of Eqn. 3.22 for a one-dimension system is:

$$\begin{aligned} & \left[ (\rho C_{pm} T)^n - (\rho C_{pm} T)^{n-1} \right] h_1 \frac{\Delta V}{\Delta t} = \\ & = A_E T_E + A_W T_W - A_P T_P + S(h_1 \Delta\theta^1) \end{aligned} \quad (3.33)$$

Using a semi-implicit tri-diagonal solution procedure, both  $T_{EE}$  and  $T_{WW}$  are included in the source term. The remaining coefficients are:

$$A_E = \frac{C_{pm,e} (-7 G_e + 3 |G_e|)}{16} + C_{pm,w} (-G_w + |G_w|) + \frac{k_e}{h_1 \Delta\theta^1} \quad (3.34)$$

$$A_W = \frac{C_{pm,w} (9 G_w + 3 |G_w|)}{16} + C_{pm,e} (G_e + |G_e|) + \frac{k_w}{h_1 \Delta\theta^1} \quad (3.35)$$

$$A_p = \frac{9}{16} (G_w C_{pm,w} - G_e C_{pm,e}) + 3 (|G_w| C_{pm,w} + |G_e|) + \frac{k_w + k_e}{h_1 \Delta \theta^1} \quad (3.36)$$

$$S_p = S h_1 \Delta \theta^1 - C_{pm,e} (|G_e| - G_e) T_{EE} - C_{pm,w} (|G_w| + G_w) T_{WW} \quad (3.37)$$

The three-dimensional QUICK algorithm uses locally quadratic interpolation of temperature through each control volume. Figure 3.6 shows the calculation cell for a three-dimensional uniform rectangular grid. The cylindrical/spherical grid system used in the computer model is more complex, although conceptually the same. Yang [Ref. 13] discusses the evaluation of the curvilinear and temperature terms. Basically, curvature terms are calculated for each of the temperatures and substituted for the convective heat flux terms. Heat flux is calculated and substituted into Eqn. 3.22.

After separation of variables, the energy equation becomes:

$$\begin{aligned} \left[ A_p^T + (\rho C_{pm,p})^{n-1} \right] \frac{\Delta V}{\Delta t} T_p &= A_E^T T_E + A_W^T T_W + A_N^T T_N \\ &+ A_S^T T_S + A_F^T T_F + A_B^T T_B + S_u^T \end{aligned} \quad (3.38)$$

with the additional source term,

$$\begin{aligned} S_u^T &= (\rho C_{pm,p} T)^{n-1} \frac{\Delta V}{\Delta t} - A_{EER} + A_{WWR} + A_{NNR} \\ &+ A_{SSR} + A_{FFR} + A_{BBR} \end{aligned} \quad (3.39)$$

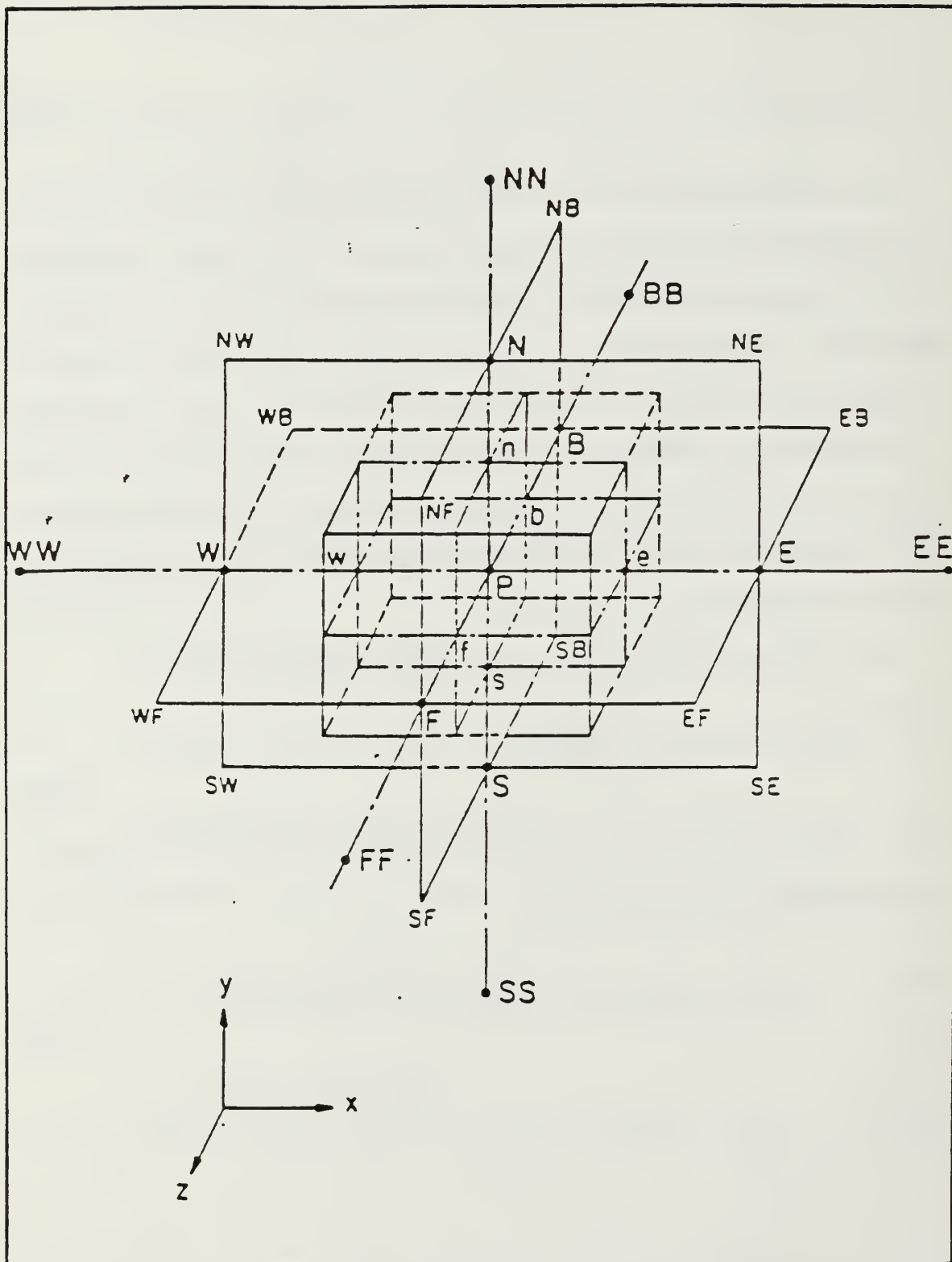


Figure 3-6. Calculation Cell for a Uniform Rectangular Grid

$$\begin{aligned}
CN &= G_n * u_{j+1}^2 * (h_3 \Delta \theta^3)_n * (h_1 \Delta \theta^1)_n \\
CS &= G_s * u_j^2 * (h_3 \Delta \theta^3)_s * (h_1 \Delta \theta^1)_s \\
CE &= G_e * u_{i+1}^1 * (h_3 \Delta \theta^3)_e * (h_2 \Delta \theta^2)_e \\
CW &= G_w * u_i^1 * (h_3 \Delta \theta^3)_w * (h_2 \Delta \theta^2)_w \\
CF &= G_f * u_{k+1}^3 * (h_1 \Delta \theta^1)_f * (h_2 \Delta \theta^2)_f \\
CB &= G_b * u_k^3 * (h_1 \Delta \theta^1)_b * (h_2 \Delta \theta^2)_b
\end{aligned} \tag{3.40}$$

Thermal conductivity is:

$$k_n = \frac{1}{\frac{1}{k_j * (h_2 \Delta \theta^2)_j} + \frac{1}{k_{j+1} * (h_2 \Delta \theta^2)_{j+1}}} \tag{3.41}$$

$$\frac{(h_2 \Delta \theta^2)_j + (h_2 \Delta \theta^2)_{j+1}}{1}$$

$$k_s = \frac{1}{\frac{1}{k_j * (h_2 \Delta \theta^2)_j} + \frac{1}{k_{j-1} * (h_2 \Delta \theta^2)_{j-1}}}$$

$$\frac{(h_2 \Delta \theta^2)_j + (h_2 \Delta \theta^2)_{j-1}}{1}$$

$$k_e = \frac{1}{\frac{1}{k_i * (h_1 \Delta \theta^1)_i} + \frac{1}{k_{i+1} * (h_1 \Delta \theta^1)_{i+1}}}$$

$$\frac{(h_1 \Delta \theta^1)_i + (h_1 \Delta \theta^1)_{i+1}}{1}$$



$$k_w = \frac{1}{\frac{1}{k_i * (h_1 \Delta\theta^1)_i} + \frac{1}{k_{i-1} * (h_1 \Delta\theta^1)_{i-1}}} \frac{1}{(h_1 \Delta\theta^1)_i + (h_1 \Delta\theta^1)_{i-1}}$$

$$k_f = \frac{1}{\frac{1}{k_k * (h_3 \Delta\theta^3)_k} + \frac{1}{k_{k+1} * (h_3 \Delta\theta^3)_{k+1}}} \frac{1}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k+1}}$$

$$k_b = \frac{1}{\frac{1}{k_k * (h_3 \Delta\theta^3)_k} + \frac{1}{k_{k-1} * (h_3 \Delta\theta^3)_{k-1}}} \frac{1}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k-1}}$$

$$\text{CONDN1} = k_n * \left( \frac{h_3 \Delta\theta^3 * h_1 \Delta\theta^1}{h_2 \Delta\theta^2} \right)_n$$

$$\text{CONDS1} = k_s * \left( \frac{h_3 \Delta\theta^3 * h_1 \Delta\theta^1}{h_2 \Delta\theta^2} \right)_s$$

$$\text{CONDE1} = k_e * \left( \frac{h_3 \Delta\theta^3 * h_2 \Delta\theta^2}{h_1 \Delta\theta^1} \right)_e \quad (3.42)$$

$$\text{CONDW1} = k_w * \left( \frac{h_3 \Delta\theta^3 * h_2 \Delta\theta^2}{h_1 \Delta\theta^1} \right)_w$$

$$\text{CONDF 1} = k_f * \left( \frac{h_1 \Delta\theta^1 * h_2 \Delta\theta^2}{h_3 \Delta\theta^3} \right)_f$$

$$\text{CONDB 1} = k_b * \left( \frac{h_1 \Delta\theta^1 * h_2 \Delta\theta^2}{h_3 \Delta\theta^3} \right)_b$$

In equations (3.41) and (3.42), all k's are the effective values.

$$\begin{aligned} \text{CEP} &= \frac{|\text{CE}| + \text{CE}}{16} \frac{(h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_i} \\ \text{CEM} &= \frac{|\text{CE}| - \text{CE}}{16} \frac{(h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_{i+1}} \\ \text{CWP} &= \frac{|\text{CW}| + \text{CW}}{16} \frac{(h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_{i-1}} \\ \text{CWM} &= \frac{|\text{CW}| - \text{CW}}{16} \frac{(h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_i} \\ \text{CNP} &= \frac{|\text{CN}| + \text{CN}}{16} \frac{(h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_j} \\ \text{CNM} &= \frac{|\text{CN}| - \text{CN}}{16} \frac{(h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_{j+1}} \end{aligned} \quad (3.43)$$

$$CSP = \frac{|CS| + CS}{16} \frac{(h_2 \Delta\theta^2)_s}{(h_2 \Delta\theta^2)_{j-1}}$$

$$CSM = \frac{|CS| - CS}{16} \frac{(h_2 \Delta\theta^2)_s}{(h_2 \Delta\theta^2)_j}$$

$$CFP = \frac{|CF| + CF}{16} \frac{(h_3 \Delta\theta^3)_f}{(h_3 \Delta\theta^3)_k}$$

$$CFM = \frac{|CF| - CF}{16} \frac{(h_3 \Delta\theta^3)_f}{(h_3 \Delta\theta^3)_{k+1}}$$

$$CBP = \frac{|CB| + CB}{16} \frac{(h_3 \Delta\theta^3)_b}{(h_3 \Delta\theta^3)_{k-1}}$$

$$CBM = \frac{|CB| - CB}{16} \frac{(h_3 \Delta\theta^3)_b}{(h_3 \Delta\theta^3)_k}$$

$$A_{EE}^T = \frac{-CEM * (h_1 \Delta\theta^1)_c}{(h_1 \Delta\theta^1)_{\infty}}$$

$$A_{ww}^T = \frac{-CWP * (h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_{ww}}$$

$$A_{NN}^T = \frac{-CNM * (h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_{nn}}$$

$$A_{SS}^T = \frac{-CSP * (h_2 \Delta\theta^2)_s}{(h_2 \Delta\theta^2)_{ss}} \quad (3.44)$$

$$A_{FF}^T = \frac{-CFM * (h_3 \Delta\theta^3)_f}{(h_3 \Delta\theta^3)_{ff}}$$

$$A_{BB}^T = \frac{-CBP * (h_3 \Delta\theta^3)_b}{(h_3 \Delta\theta^3)_{bb}}$$

$$A_{EER} = A_{EE}^T * T_{i+2} * C_{pm_{i+2}}$$

$$A_{WWR} = A_{WW}^T * T_{i-2} * C_{pm_{i-2}}$$

$$A_{NNR} = A_{NN}^T * T_{j+2} * C_{pm_{j+2}}$$

$$A_{SSR} = A_{SS}^T * T_{j-2} * C_{pm_{j-2}} \quad (3.45)$$

$$A_{FFR} = A_{FF}^T * T_{k+2} * C_{pm_{k+2}}$$

$$A_{BBR} = A_{BB}^T * T_{k-2} * C_{pm_{k-2}}$$

The intermediate coefficients are :

$$\begin{aligned}
A_{EI} = & -0.5 * CE + CEP + CEM * \left[ 1 + \frac{(h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_{ce}} \right] + \\
& + CWM * \frac{(h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_c}
\end{aligned} \tag{3.46}$$

$$\begin{aligned}
A_{WI} = & 0.5 * CW + CWM + CWP * \left[ 1 + \frac{(h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_{ww}} \right] + \\
& + CEP * \frac{(h_1 \Delta\theta^1)_c}{(h_1 \Delta\theta^1)_w}
\end{aligned} \tag{3.47}$$

$$\begin{aligned}
A_{NI} = & -0.5 * CN + CNP + CNM * \left[ 1 + \frac{(h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_{nn}} \right] + \\
& + CSM * \frac{(h_2 \Delta\theta^2)_s}{(h_2 \Delta\theta^2)_n}
\end{aligned} \tag{3.48}$$

$$\begin{aligned}
A_{SI} = & 0.5 * CS + CSM + CSP * \left[ 1 + \frac{(h_2 \Delta\theta^2)_s}{(h_2 \Delta\theta^2)_{ss}} \right] + \\
& + CNP * \frac{(h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_s}
\end{aligned} \tag{3.49}$$

$$A_{FI} = -0.5 * CF + CFP + CFM * \left[ 1 + \frac{(h_3 \Delta\theta^3)_f}{(h_3 \Delta\theta^3)_{ff}} \right] +$$

$$+ CBM * \frac{(h_3 \Delta\theta^3)_b}{(h_3 \Delta\theta^3)_f} \quad (3.50)$$

$$A_{BI} = 0.5 * CB + CBM + CBP * \left[ 1 + \frac{(h_3 \Delta\theta^3)_b}{(h_3 \Delta\theta^3)_{bb}} \right] +$$

$$+ CFP * \frac{(h_3 \Delta\theta^3)_f}{(h_3 \Delta\theta^3)_b} \quad (3.51)$$

The coefficients are:

$$A_E^T = A_{EI} * C_{pm.E} + CONDE 1$$

$$A_W^T = A_{WI} * C_{pm.W} + CONDW 1$$

$$A_N^T = A_{NI} * C_{pm.N} + CONDN 1 \quad (3.52)$$

$$A_S^T = A_{SI} * C_{pm.S} + CONDS 1$$

$$A_F^T = A_{FI} * C_{pm.F} + CONDF 1$$

$$A_B^T = A_{BI} * C_{pm.B} + CONDB 1$$

$A_p^T$  is the sum of all the values of A.

$$\begin{aligned}
A_P^T = & C_{pm.p} * (A_E^T + A_W^T + A_N^T + A_S^T + A_F^T + A_B^T + A_{EE}^T + A_{WW}^T + \\
& + A_{NN}^T + A_{SS}^T + A_{FF}^T + A_{BB}^T) + CONDE1 + CONDW1 + \quad (3.53) \\
& + CONDN2 + CONDS1 + CONDF1 + CONDB1
\end{aligned}$$

## F. MOMENTUM EQUATION

The integrated momentum equation is given as:

$$\begin{aligned}
(\rho u^i)_t V + M_c^{i1} A_c - M_w^{i1} A_w + M_n^{i2} A_n - M_s^{i2} A_s + \\
+ M_f^{i3} A_f - M_b^{i3} A_b = S^i \quad (3.54)
\end{aligned}$$

with  $A_i$ , the area of the staggered cell given by Eqns. 3.14 through 3.16.  $M^{ij}$  represents the total momentum flux in the  $\theta^{ij}$  direction due to convection and diffusion for the  $u^i$  velocity component.  $M$  is evaluated at the face noted and is given by:

$$M^{ij} = (\rho u^i u^j - \sigma_i^j) \quad (3.55)$$

The source term includes body force, pressure gradient, centrifugal, and Coriolis forces and for  $u^1$  is :

$$\begin{aligned}
S^1 = -P_c A_c + P_w A_w + \rho G^1 \Delta V - M_p^{12} (A_n - A_s) - \\
- M_p^{13} (A_f - A_b) + (M_p^{22} + M_p^{33}) (A_c - A_w) \quad (3.56)
\end{aligned}$$

Yang et al. [Ref. 20: pp. 11-13] describes the concept of a “stress-flex formulation” as it applies to a curvilinear coordinate system.

Stresses are calculated from previous information and the source is given in the current iteration. The momentum flux is:

$$M^{ij} = \hat{M}^{ij} + (\hat{\theta}_i^j - \sigma_i^j) \quad (3.57)$$

with

$$\hat{\theta}_i^j = \frac{\mu}{\left[ h_j \left( \frac{\partial u^i}{\partial \theta^j} \right) \right]} \quad (3.58)$$

$$\hat{M}^{ij} = \rho u^i u^j - \hat{\theta}_i^j \quad (3.59)$$

The  $u^1$  momentum equation becomes:

$$\begin{aligned} (\rho u)_t + \hat{M}_e^{11} A_e - \hat{M}_w^{11} A_w + \hat{M}_n^{12} A_n - \hat{M}_s^{12} A_s + \\ + \hat{M}_f^{13} A_f - \hat{M}_b^{13} A_b = \hat{S} \end{aligned} \quad (3.60)$$

$$\begin{aligned} \hat{S} = S - (\hat{\theta}_1^1 - \sigma_1^1)_e A_e + (\hat{\theta}_1^1 - \sigma_1^1)_w A_w - \\ - (\hat{\theta}_1^2 - \sigma_1^2)_n A_n + (\hat{\theta}_1^2 - \sigma_1^2)_s A_s - \\ - (\hat{\theta}_1^3 - \sigma_1^3)_f A_f + (\hat{\theta}_1^3 - \sigma_1^3)_b A_b \end{aligned} \quad (3.61)$$

The momentum equation for  $\theta^i$  is given as:



$$\begin{aligned}
\left( A_p^{u^1} + \rho^{n-1} \frac{\Delta V}{\Delta t} \right) u_p^1 &= A_c^{u^1} u_c^1 + A_w^{u^1} u_w^1 + \\
&+ A_n^{u^1} u_n^1 + A_s^{u^1} u_s^1 + A_f^{u^1} u_f^1 + A_b^{u^1} u_b^1 + S^{u^1} u^1
\end{aligned} \tag{3.62}$$

The intermediate mass flow rates per unit area are:

$$\begin{aligned}
G_{nc} &= u_{j+1}^2 \left\{ \frac{\left[ \rho_{j+1} (h_2 \Delta \theta^2)_j + \rho_j (h_2 \Delta \theta^2)_{j+1} \right]}{(h_2 \Delta \theta^2)_j + (h_2 \Delta \theta^2)_{j+1}} \right\} \\
G_{nw} &= u_{i-1, j+1}^2 \left\{ \frac{\left[ \rho_{i-1, j+1} (h_2 \Delta \theta^2)_j + \rho_{i-1} (h_2 \Delta \theta^2)_{j+1} \right]}{(h_2 \Delta \theta^2)_j + (h_2 \Delta \theta^2)_{j+1}} \right\} \\
G_{sc} &= u^2 \left\{ \frac{\left[ \rho_{j-1} (h_2 \Delta \theta^2)_j + \rho_j (h_2 \Delta \theta^2)_{j-1} \right]}{(h_2 \Delta \theta^2)_j + (h_2 \Delta \theta^2)_{j+1}} \right\} \\
G_{sw} &= u_{i-1}^2 \left\{ \frac{\left[ \rho_{i-1, j-1} (h_2 \Delta \theta^2)_j + \rho_{i-1} (h_2 \Delta \theta^2)_{j-1} \right]}{(h_2 \Delta \theta^2)_j + (h_2 \Delta \theta^2)_{j-1}} \right\} \\
G_c &= u_{i+1}^1 \left\{ \frac{\left[ \rho_{i+1} (h_1 \Delta \theta^1)_c + \rho_i (h_1 \Delta \theta^1)_{cc} \right]}{(h_1 \Delta \theta^1)_c + (h_1 \Delta \theta^1)_{cc}} \right\} \\
G_p &= u^1 \left\{ \frac{\left[ \rho_{i-1} (h_1 \Delta \theta^1)_c + \rho_i (h_1 \Delta \theta^1)_w \right]}{(h_1 \Delta \theta^1)_c + (h_1 \Delta \theta^1)_w} \right\} \\
G_w &= u_{i-1}^1 \left\{ \frac{\left[ \rho_{i-2} (h_1 \Delta \theta^1)_w + \rho_{i-1} (h_1 \Delta \theta^1)_{ww} \right]}{(h_1 \Delta \theta^1)_w + (h_1 \Delta \theta^1)_{ww}} \right\}
\end{aligned} \tag{3.63}$$

$$G_{fe} = u_{k+1}^3 \left\{ \frac{\left[ \rho_{k+1} (h_3 \Delta\theta^3)_k + \rho_k (h_3 \Delta\theta^3)_{k+1} \right]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k+1}} \right\}$$

$$G_{fw} = u_{i-1, k+1}^3 \left\{ \frac{\left[ \rho_{i-1, k+1} (h_3 \Delta\theta^3)_k + \rho_{i-1} (h_3 \Delta\theta^3)_{k+1} \right]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k+1}} \right\}$$

$$G_{be} = u^3 \left\{ \frac{\left[ \rho_{k-1} (h_3 \Delta\theta^3)_k + \rho_k (h_3 \Delta\theta^3)_{k-1} \right]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k-1}} \right\}$$

$$G_{bw} = u_{i-1}^3 \left\{ \frac{\left[ \rho_{i-1, k-1} (h_3 \Delta\theta^3)_k + \rho_{i-1} (h_3 \Delta\theta^3)_{k-1} \right]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k-1}} \right\}$$

The final mass flow rates for the control volume surfaces are:

$$CE = 0.5 (G_e + G_p) * (h_2 \Delta\theta^2)_e * (h_3 \Delta\theta^3)_e$$

$$CW = 0.5 (G_p + G_w) * (h_2 \Delta\theta^2)_w * (h_3 \Delta\theta^3)_w \quad (3.64)$$

$$CN = (h_1 \Delta\theta^1)_n (h_3 \Delta\theta^3)_n \left\{ \frac{\left[ G_{ne} (h_1 \Delta\theta^1)_w + G_{nw} (h_1 \Delta\theta^1)_e \right]}{\left[ (h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e \right]} \right\}$$

$$CS = (h_1 \Delta\theta^1)_s (h_3 \Delta\theta^3)_s \left\{ \frac{\left[ G_{se} (h_1 \Delta\theta^1)_w + G_{sw} (h_1 \Delta\theta^1)_e \right]}{\left[ (h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e \right]} \right\}$$

$$CF = (h_1 \Delta\theta^1)_f (h_2 \Delta\theta^2)_f \left\{ \frac{\left[ G_{fe} (h_1 \Delta\theta^1)_w + G_{fw} (h_1 \Delta\theta^1)_e \right]}{\left[ (h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e \right]} \right\}$$

$$CB = (h_1 \Delta\theta^1)_b (h_2 \Delta\theta^2)_b \left\{ \frac{[G_{bx} (h_1 \Delta\theta^1)_w + G_{bw} (h_1 \Delta\theta^1)_e]}{[(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e]} \right\}$$

The local viscosity becomes:

$$VIS_e = VIS$$

$$VIS_w = VIS_{i-1}$$

$$VIS_n = \frac{(VIS_{j+1} + VIS + VIS_{i-1, j+1} + VIS_{i-1})}{4.0} \quad (3.65)$$

$$VIS_s = \frac{(VIS_{j-1} + VIS + VIS_{i-1, j-1} + VIS_{i-1})}{4.0}$$

$$VIS_f = \frac{(VIS_{k+1} + VIS + VIS_{i-1, k+1} + VIS_{i-1})}{4.0}$$

$$VIS_b = \frac{(VIS_{k-1} + VIS + VIS_{i-1, k-1} + VIS_{i-1})}{4.0}$$

$$VISNI = VIS_n * \left[ \frac{(h_3 \Delta\theta^3) (h_1 \Delta\theta^1)}{h_2 \Delta\theta^2} \right]_n$$

$$VISSI = VIS_s * \left[ \frac{(h_3 \Delta\theta^3) (h_1 \Delta\theta^1)}{h_2 \Delta\theta^2} \right]_s$$

$$VISEI = VIS_e * \left[ \frac{(h_2 \Delta\theta^2) (h_3 \Delta\theta^3)}{h_1 \Delta\theta^1} \right]_e \quad (3.66)$$

$$\text{VISW1} = \text{VIS}_w * \left[ \frac{(h_2 \Delta\theta^2) (h_3 \Delta\theta^3)}{h_1 \Delta\theta^1} \right]_w$$

$$\text{VISF1} = \text{VIS}_f * \left[ \frac{(h_1 \Delta\theta^1) (h_2 \Delta\theta^2)}{h_3 \Delta\theta^3} \right]_f$$

$$\text{VISB1} = \text{VIS}_b * \left[ \frac{(h_1 \Delta\theta^1) (h_2 \Delta\theta^2)}{h_3 \Delta\theta^3} \right]_b$$

The coefficients for the momentum equations are:

$$A_{\text{EER}} = A_{\text{EE}}^u * u_{i+2}^1$$

$$A_{\text{WWR}} = A_{\text{WW}}^u * u_{i-2}^1$$

$$A_{\text{NNR}} = A_{\text{NN}}^u * u_{j+2}^1 \quad (3.67)$$

$$A_{\text{SSR}} = A_{\text{SS}}^u * u_{j-2}^1$$

$$A_{\text{FFR}} = A_{\text{FF}}^u * u_{k+2}^1$$

$$A_{\text{BBR}} = A_{\text{BB}}^u * u_{k-2}^1$$

The values of the coefficients A are given as:

$$A_{\text{E}}^u = A_{\text{E1}} + \text{VISE1}$$

$$A_{\text{W}}^u = A_{\text{W1}} + \text{VISW1}$$

$$A_N^u = A_{NI} + VISNI \quad (3.68)$$

$$A_S^u = A_{SI} + VISSI$$

$$A_F^u = A_{FI} + VISFI$$

$$A_B^u = A_{BI} + VISBI$$

The value of  $A_p^u$  is the summation of all of the values of A:

$$\begin{aligned} A_p^u = & A_E^u + A_W^u + A_N^u + A_S^u + A_F^u + A_B^u + A_{EE}^u + A_{WW}^u + \\ & + A_{NN}^u + A_{SS}^u + A_{FF}^u + A_{BB}^u \end{aligned} \quad (3.69)$$

The source term is given as:

$$\begin{aligned} S_u^u = & \frac{[\rho (h_1 \Delta\theta^1)_w + \rho_{i-1} (h_1 \Delta\theta^1)_e]}{[(h_1 \Delta\theta^1)_e + (h_1 \Delta\theta^1)_w]} * \frac{\Delta V}{\Delta t} * u^1 + \\ & + (h_2 \Delta\theta^2)_j (h_3 \Delta\theta^3)_k (P_{i-1} - P_i) + A_{EER} + A_{WWR} + A_{NNR} + \\ & + A_{SSR} + A_{FFR} + A_{BBR} + RE - RW + RN - RS = RF - RB + \\ & + RRY + RRZ - RRX - \text{Buoy} * \{ \sin [ZC (K)] * (\rho - \rho_{EQ}) * \\ & * (h_1 \Delta\theta^1)_w * \cos [XC (I)] \} + \{ (\rho_{i-1} - \rho_{EQ_{i-1}}) (h_1 \Delta\theta^1)_e * \\ & * \cos [XC (I - 1)] \} / [(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e] \Delta V \end{aligned} \quad (3.70)$$

with XZ and ZC as the center of the basic cell. The additional parameters are given below.

$$\begin{aligned}
 RE &= (h_2 \Delta\theta^2 \ h_3 \Delta\theta^3)_c \left[ \frac{\sigma^{11} - (u_{i+1}^1 - u_i^1) * VIS_c}{(h_1 \Delta\theta^1)_c} \right] \\
 RW &= (h_2 \Delta\theta^2 \ h_3 \Delta\theta^3)_w \left[ \frac{\sigma_{i-1}^{11} - (u^1 - u_{i-1}^1) * VIS_w}{(h_1 \Delta\theta^1)_w} \right] \\
 RN &= (h_1 \Delta\theta^1 \ h_3 \Delta\theta^3)_n \left[ \frac{\sigma_{j+1}^{12} - (u_{j+1}^1 - u_j^1) * VIS_n}{(h_2 \Delta\theta^2)_n} \right] \\
 RS &= (h_1 \Delta\theta^1 \ h_3 \Delta\theta^3)_s \left[ \frac{\sigma^{12} - (u^1 - u_{j-1}^1) * VIS_s}{(h_3 \Delta\theta^3)_s} \right] \\
 RF &= (h_1 \Delta\theta^1 \ h_2 \Delta\theta^2)_f \left[ \frac{\sigma_{k+1}^{13} - (u_{k+1}^1 - u_k^1) * VIS_f}{(h_3 \Delta\theta^3)_f} \right] \\
 RB &= (h_1 \Delta\theta^1 \ h_2 \Delta\theta^2)_b \left[ \frac{\sigma^{13} - (u^1 - u_{k-1}^1) * VIS_b}{(h_3 \Delta\theta^3)_b} \right]
 \end{aligned} \tag{3.71}$$

$$\bar{\sigma}^{12} = 0.5 (\sigma_{j+1}^{12} + \sigma_j^{12})$$

$$\bar{\sigma}^{13} = 0.5 (\sigma_{k+1}^{13} + \sigma_k^{13})$$

$$\bar{\sigma}^{22} = \frac{\sigma^{22} (h_1 \Delta\theta^1)_w + \sigma_{i-1}^{22} (h_1 \Delta\theta^1)_c}{(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_c} \tag{3.72}$$

$$\bar{\sigma}^{33} = \frac{\sigma^{13} (h_1 \Delta\theta^1)_w + \sigma_{i-1}^{33} (h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e}$$

$$AU1 = u^1$$

$$AU2 = \left\{ \left[ \frac{u_{j+1}^2 (h_2 \Delta\theta^2)_j + u_j^2 (h_2 \Delta\theta^2)_j}{2 (h_2 \Delta\theta^2)_j} \right] (h_1 \Delta\theta^1)_w + \left[ \frac{u_{i-1, j+1}^2 (h_2 \Delta\theta^2)_j + u_{i-1}^2 (h_2 \Delta\theta^2)_j}{2 (h_2 \Delta\theta^2)_j} \right] (h_1 \Delta\theta^1)_e \right\} / \quad (3.73)$$

$$/ \left[ (h_1 \Delta\theta^1)_e + (h_1 \Delta\theta^1)_w \right]$$

$$AU3 = \left\{ \left[ \frac{u_{k+1}^3 (h_3 \Delta\theta^3)_k + u_k^3 (h_3 \Delta\theta^3)_k}{2 (h_3 \Delta\theta^3)_k} \right] (h_1 \Delta\theta^1)_w + \left[ \frac{u_{i-1, k+1}^3 (h_3 \Delta\theta^3)_k + u_{i-1}^3 (h_3 \Delta\theta^3)_k}{2 (h_3 \Delta\theta^3)_k} \right] (h_1 \Delta\theta^1)_e \right\} /$$

$$/ \left[ (h_1 \Delta\theta^1)_e + (h_1 \Delta\theta^1)_w \right]$$

$$AR = \frac{\rho (h_1 \Delta\theta^1)_w + \rho_{i-1} (h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e}$$

$$ARU12 = AR * AU1 * AU2$$

$$ARU13 = AR * AU1 * AU3 \quad (3.74)$$

$$ARU22 = AR * AU2 * AU2$$

$$ARU33 = AR * AU3 * AU3$$

$$RRY = (\bar{\sigma}^{12} - ARU12) (h_3 \Delta\theta^3)_k \left[ (h_1 \Delta\theta^1)_n - (h_1 \Delta\theta^1)_s \right]$$

$$RRZ = (\bar{\sigma}^{13} - ARU13) (h_2 \Delta\theta^2)_j \left[ (h_1 \Delta\theta^1)_f - (h_1 \Delta\theta^1)_b \right]$$

$$RRX = (\bar{\sigma}^{22} - ARU22) (h_3 \Delta\theta^3)_k \left[ (h_2 \Delta\theta^2)_c - (h_2 \Delta\theta^2)_w \right] +$$

$$+ (\bar{\sigma}^{33} - ARU33) (h_2 \Delta\theta^2)_j \left[ (h_3 \Delta\theta^3)_e - (h_3 \Delta\theta^3)_w \right] \quad (3.75)$$

The momentum equations in the other two directions can be similarly obtained.

### G. PRESSURE CORRECTION

One difficulty encountered in employing primitive variables is the difficulty in calculating pressure. In a closed system, such as FIRE-1, there are two causes of changes in pressure. First, there are pressure changes throughout the field due to a net energy change in the system. To account for these changes, a global pressure correction is applied. Second, there are pressure changes locally which determine the velocity field. A local pressure correction is included to account for these changes.



## 1. Global Pressure Correction

A global pressure correction follows from the two-dimensional scheme developed by Nicolette, et al. [Ref. 4]. Overall pressure levels are increased or decreased depending upon whether energy is added or removed from the system. Since the volume and mass of the system are constant, the sum of the local density times the local volume will be constant, and equal to the equilibrium mass. Summing over all of the cells,

$$\sum \rho_i^n (\Delta V)_i = \sum \rho_{EQ, i} (\Delta V)_i \quad (3.76)$$

with n indicating any time and EQ indicating equilibrium.

Assuming a perfect gas, density is a function of pressure and temperature only, since volume is constant. The actual values of pressure and temperature at any time are the sum of an estimated value and the global correction.

$$P = P^* + P'_g \quad (3.77)$$

$$T = T^* + T'_g \quad (3.78)$$

with superscript \* indicating the estimated value and superscript ' indicating the global correction. By applying these two equations and the perfect gas law along with Eqn. 3.76, the global pressure correction becomes:

$$P'_g = \frac{\sum P_{\text{eq}} \left( \frac{\Delta V}{T_i} - \frac{\Delta V}{T^*} \right) - \sum \left( P^* \frac{\Delta V}{T^*} \right)}{\sum \frac{\Delta V}{T^*}} \quad (3.79)$$

This correction is added to the estimated value from the previous time step, and iterated until a globally corrected pressure is obtained which conserves mass in every cell.

## 2. Local Pressure Correction

An iterative method involving the mass conservation equation is used to find the local pressure. Patankar [Ref. 35:pp. 120–126] and Doria [Ref. 34:pp. 26–32] describe the method for determining the local pressure correction. Initially, the pressure field is guessed or the previous pressure field is assumed. Then velocities are calculated based upon this assumed pressure distribution. Knowing the velocities, the mass source term,  $S_{\text{mp}}$  (also called residual mass), is calculated for each cell. The magnitude of the mass source term and the sum of the absolute values of every cell's residual mass serves as a check on the conservation of mass within each cell and through the entire flow field. If  $S_{\text{mp}}$  is close to zero, the guessed pressure field is satisfactory; if not, a local pressure correction is calculated and the process is repeated until  $S_{\text{mp}}$  is within the desired range. Once a satisfactory pressure field is found, the densities for the next time step can be found using the equation of state.

Similar to the global pressure correction, the actual pressure equals a guessed pressure (superscript \*) plus the local pressure correction (superscript ').

$$P = P^{\circ} + P' \quad (3.80)$$

The finite difference equation for the pressure correction takes on a form similar to the other finite difference conservation equations. The equation for  $P'$  is:

$$\begin{aligned} A_P P'_P = & A_E P'_E + A_W P'_W + A_N P'_N + A_S P'_S + A_F P'_F + \\ & + A_B P'_B - S_{mp} \Delta V \end{aligned} \quad (3.81)$$

with

$$A_E = \frac{\rho_c * (h_2 \Delta\theta^2 h_3 \Delta\theta^3)_c^2}{\left( A_{P_{j+1}}^{u^1} + \rho_c \frac{\Delta V}{\Delta t} \right)} \quad (3.82)$$

$$A_W = \frac{\rho_w * (h_2 \Delta\theta^2 h_3 \Delta\theta^3)_w^2}{\left( A_P^{u^1} + \rho_w \frac{\Delta V}{\Delta t} \right)} \quad (3.83)$$

$$A_N = \frac{\rho_n * (h_1 \Delta\theta^1 h_3 \Delta\theta^3)_n^2}{\left( A_{P_{j+1}}^{u^2} + \rho_n \frac{\Delta V}{\Delta t} \right)} \quad (3.84)$$

$$A_S = \frac{\rho_s * (h_1 \Delta\theta^1 h_3 \Delta\theta^3)_s^2}{\left( A_P^{u^2} + \rho_s \frac{\Delta V}{\Delta t} \right)} \quad (3.85)$$

$$A_F = \frac{\rho_f * (h_1 \Delta\theta^1 h_2 \Delta\theta^2)_f^2}{\left( A_P^{u^3} + \rho_f \frac{\Delta V}{\Delta t} \right)} \quad (3.86)$$

$$A_B = \frac{\rho_b * (h_1 \Delta\theta^1 h_2 \Delta\theta^2)_b^2}{\left( A_P^{u^3} + \rho_b \frac{\Delta V}{\Delta t} \right)} \quad (3.87)$$

$$A_P = A_E + A_W + A_N + A_S + A_F + A_B \quad (3.88)$$

At the solid boundaries where the mass flux is zero, the coefficient A which corresponds to the boundary is equal to zero. When the final corrected pressure field has been calculated, new velocities are found from the following equations.

$$u^1 = u^{1*} + u^{1'} \quad (3.89)$$

$$u^2 = u^{2*} + u^{2'} \quad (3.90)$$

$$u^3 = u^{3*} + u^{3'} \quad (3.91)$$

with

$$u^{1'} = \frac{(P_p - P_w) (h_2 \Delta\theta^2 h_3 \Delta\theta^3)}{A_P^{u^1} + \rho_w \frac{\Delta V}{\Delta t}} \quad (3.92)$$

$$u^{2'} = \frac{(P_p - P_s) (h_1 \Delta\theta^1 h_3 \Delta\theta^3)}{A_p^{u^2} + \rho_s \frac{\Delta V}{\Delta t}} \quad (3.93)$$

$$u^{3'} = \frac{(P_p - P_b) (h_1 \Delta\theta^1 h_2 \Delta\theta^2)}{A_p^{u^3} + \rho_b \frac{\Delta V}{\Delta t}} \quad (3.94)$$

$S_{mp}$  is then computed; if it is within the desired range, the calculation is complete. Otherwise a new  $P'$  is calculated and the procedure is repeated.

## H. VENTILATION EQUATIONS

When forced ventilation is introduced, the velocity equation for the control volume containing the ventilation becomes:

$$A_p u_p = A_e u_e + A_w u_w + A_n u_n + A_s u_s + \\ + A_f u_f + A_b u_b + S_u \quad (3.95)$$

with

$$A_p = 10^{20} \quad (3.96)$$

$$S_u = \text{specified velocity} * 10^{20} \quad (3.97)$$

this causes the velocity in the control volume to be equal to the desired values for ventilation, and not be affected by the upwind or other adjacent velocities.

The boundaries of the control volumes with specified velocity require special consideration. The equation for the downwind control volume becomes:

$$A_p u_p = A_e u_e + A_w u_w + A_n u_n + A_s u_s + \\ + A_f u_f + A_b^* u_b + S_u^* \quad (3.98)$$

with the starred values defined as:

$$A_b^* = 0.0 \quad (3.99)$$

$$S_u^* = S_u + A_b u_b \quad (3.100)$$

This causes the ventilation to be the only effect from the upwind cell and represents a fixed velocity internal ventilation system. The equations for the adjacent control volumes whose boundaries are parallel to the flow must also change. For example, the equation for the control volume north of the specified ventilation control volume becomes

$$A_p u_p = A_e u_e + A_w u_w + A_n u_n + A_s^* u_s + \\ + A_f u_f + A_b u_b + S_u^* \quad (3.101)$$

with

$$S_u^* = S_u + 2 u_s A_s \quad (3.102)$$

$$A_s^* = 0.0 \quad (3.103)$$

This boundary equation makes the velocity in the entire volume constant, rather than varying between the staggered cell center and the boundary.

## IV. EVALUATION OF NUMERICAL DATA

### A. INTRODUCTION

The computer model presented here was designed to model fires in the experimental pressure vessel FIRE-1. The theory of the model has been given in previous chapters. This chapter will describe the modeling of a fire with internal ventilation in FIRE-1. Although such a fire test has yet to be experimentally run, this study will demonstrate the feature of internal ventilation in the computer model. This is one step to make the model more accurately represent real fires. The parameters used in the study will be presented in this chapter and the numerical solution process will be summarized. The effects of different time steps in the computation will also be discussed.

Two trials were conducted, one with internal ventilation and one without ventilation. A third trial was conducted using the ventilated case, but with different time steps for the iterations.

Pressure, temperature, and velocity fields are generated from the computer code. The temperature and velocity fields for various times will be discussed for both the ventilated and nonventilated cases. The global pressure and thermocouple temperatures will also be evaluated. The thermocouple temperatures correspond to the temperatures found at the location of the actual thermocouples in FIRE-1, in the north end cap (shown in Figure 4.1). Additionally, the global pressure



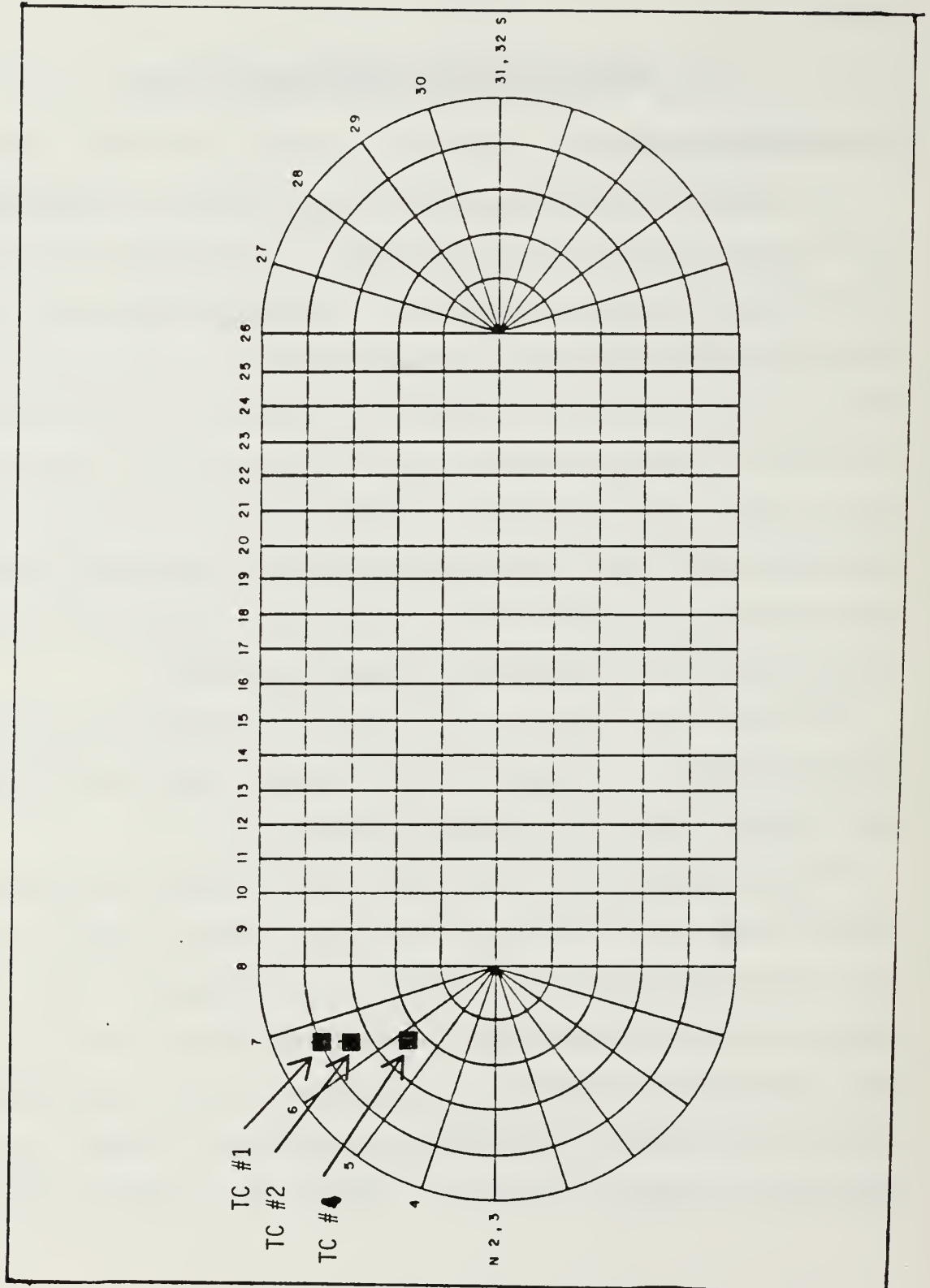


Figure 4-1. Thermocouple Locations

and one thermocouple temperature will be compared for the cases with different time steps.

## **B. NUMERICAL SOLUTION PARAMETERS**

Various parameters are input into the numerical model in order to model a particular fire. These parameters include: initial conditions, fuel heat release rate, location of the fire, geometry of the enclosure, and physical characteristics of the enclosure, including heat transfer coefficient and fluid properties inside the enclosure. Other items could be added, depending upon the complexity of the model: decks, equipment, fire extinguishing systems, and combustion parameters. These are planned to be added to this model in the future. The location of sensors and the physical description of FIRE-1 is given in Chapter 1. The ventilation fan locations are shown in Figures 4.2 and 4.3. The material properties used in this thesis are listed in Table 4.1.

The numerical model of FIRE-1 uses a cylindrical/spherical coordinate system shown in Figures 4.2 and 4.3. The grid is spherical in the end caps, with  $\theta$ ,  $R$ , and  $\phi$  directions, and cylindrical in the mid-section, with  $\theta$ ,  $R$ , and  $Z$  directions. There are 14 cells in the  $R$  direction; one cell represents the tank wall and another is in the vicinity of  $R = 0$  and is used to avoid singularity at the origin. Each end cap has six  $\phi$  cells; again, one cell is used to avoid singularity. The mid-section has 18  $Z$  (or  $\phi$ ) cells and there are 20 cells in the  $\theta$  direction oriented counterclockwise. Although a finer grid could be used to

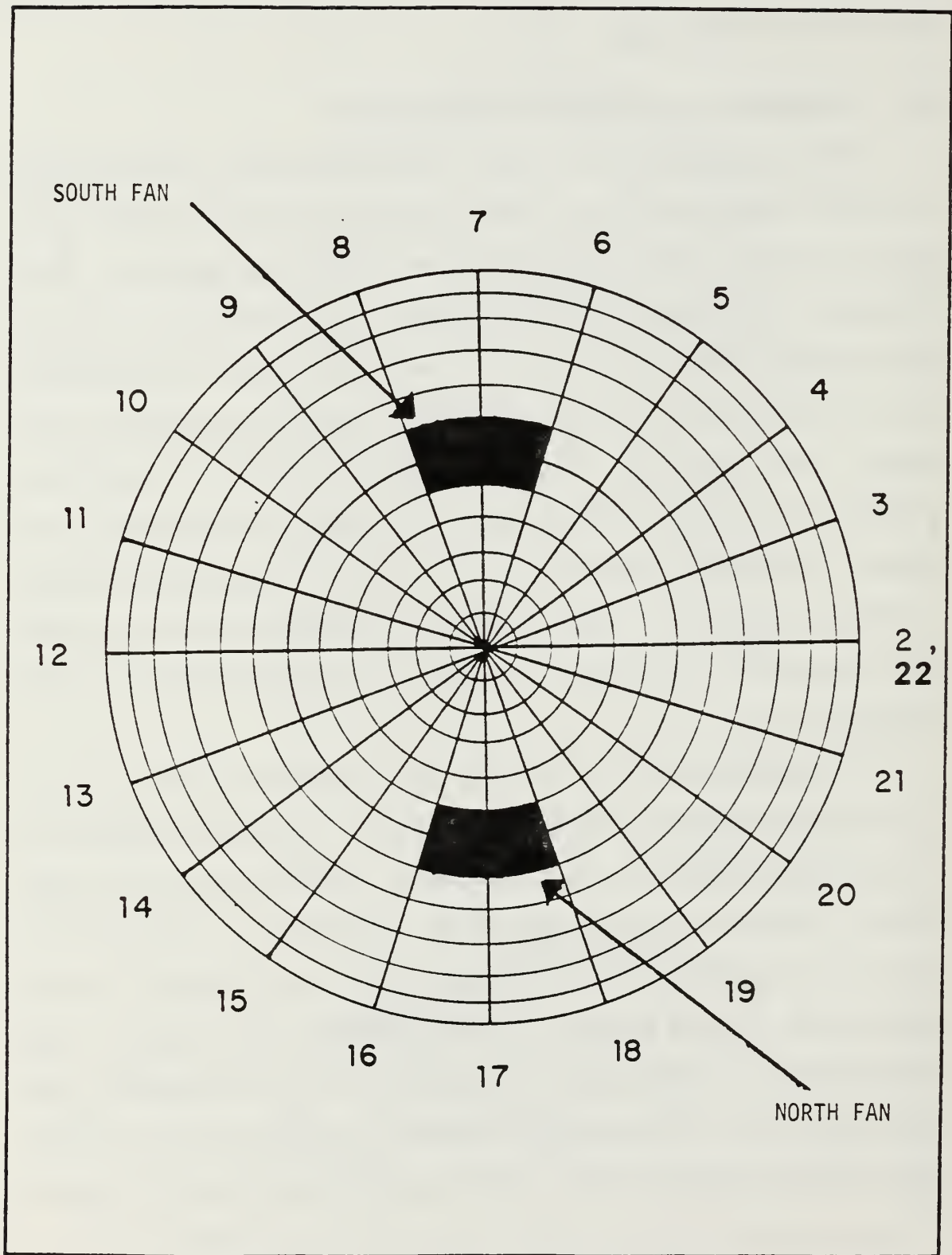


Figure 4-2. Ventilation Location in Computer Model (End View)

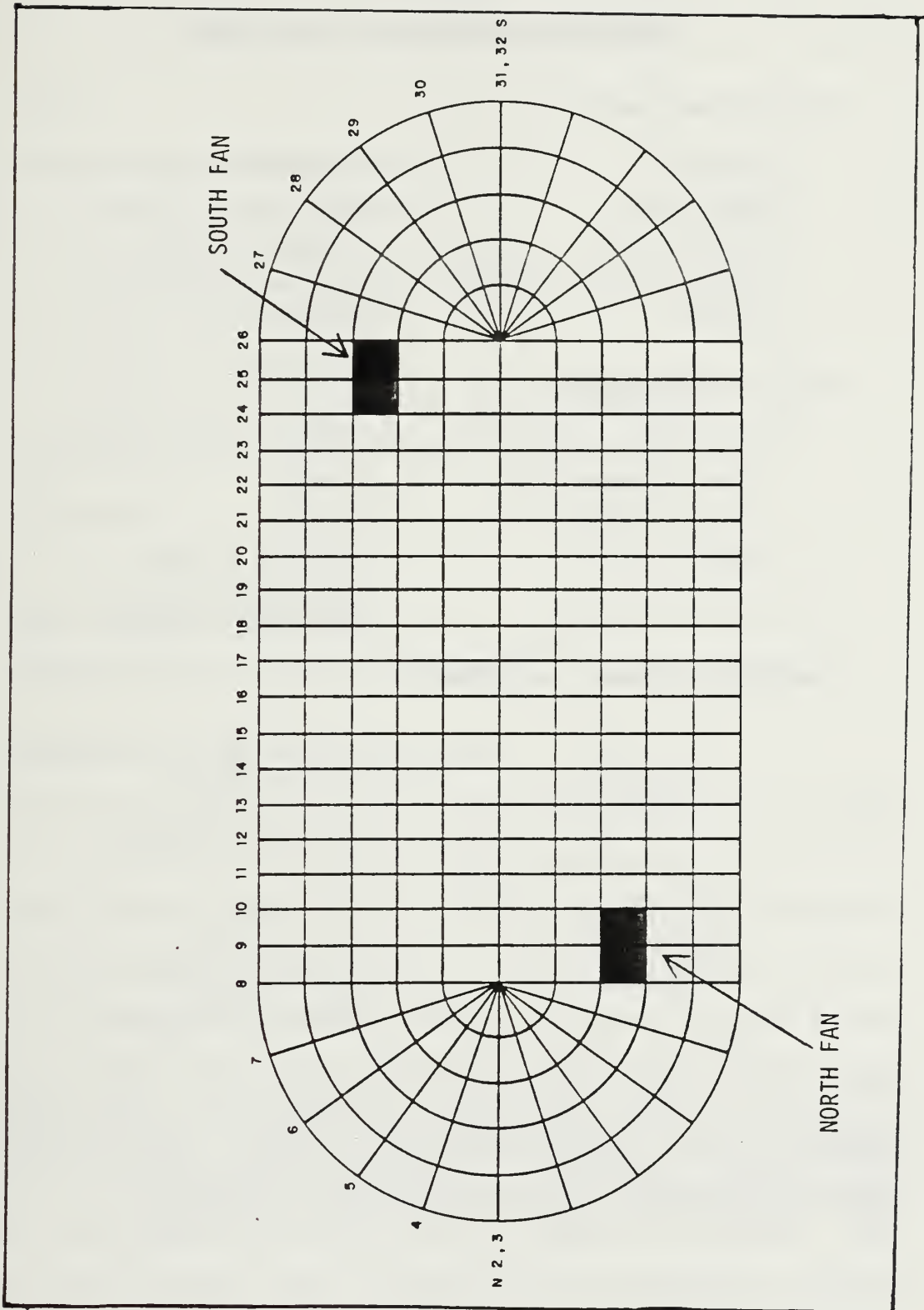


Figure 4-3. Ventilation Location in Computer Model (Front View)

TABLE 4.1

**SPECIFIC MODEL PARAMETERS****Wall Characteristics**

Material	ASTM 285 Grade C Steel
Thickness	3/8 inch
Specific Heat	0.1 Btu/ (lbm F)
Thermal Conductivity	25 Btu/ (hr ft F)
Density	487 lbm/ ft <sup>3</sup>

**Fire Characteristics**

Burn rate	A Given Function of Time
Initial Temperature	35.6 C.
Initial Pressure	1.0 Atm
Location	Center of FIRE-1 23.1 ft from end 3.21 ft from bottom

**Ventilation Characteristics**

1. Velocity	3.18 ft/ sec
Direction	South to North
Location	11.1 ft from end 4.0 ft from bottom
2. Velocity	3.18 ft/ sec
Direction	North to South
Location	35.5 ft from end 13.6 ft from bottom

give more accurate solutions, the limitations of the computer resources required that the grid not be enlarged. Table 4.2 presents additional information concerning the model parameters.

TABLE 4.2  
GENERAL MODEL PARAMETERS

**Grid**

Number of Interior Cells	6,720
Number of Tank Wall Cells	560
Number of Wall Radiation Zones	560
Number of Fire Radiation Zones	19
Cells in the $\theta$ Direction	20
Cells in the R Direction	14
Cells in the $\phi$ Direction (six in each end cap)	12
Cells in the Z direction (in the mid-section)	18

**Time Step**

Varied	0.0192-0.0288 Sec
<b>CPU Time (1 CPU hour)</b>	0.6-0.8 sec fire time
<b>External Heat Transfer Coefficient</b>	15.0 Btu/ (hr ft <sup>2</sup> F)

**C. NUMERICAL SOLUTION PROCESS**

Two separate programs comprise this model; the first is a surface radiation preprocessor program which calculates the view factors. The main program is similar to that presented by Nies [Ref. 29:pp. 54-57] and Raycraft [Ref. 30:pp. 96-97]. The first part of the main program establishes the initial parameters and inputs the view factors. Then the effective viscosity is computed in Subroutine CALVIS. Every two time steps, the wall radiation flux is recalculated. Temperature, pressure and velocity are computed in subroutines using a semi-implicit technique which solves the finite difference equations. Subroutine CALT is then called to determine the temperatures, followed

by the computation of the pressure and global pressure correction. Then the velocities and local pressure corrections are computed; the local pressure correction updates the velocities. With the corrected velocities, continuity is applied to each cell and the residual mass is found. The sum of the absolute value of every cell's residual mass is called the residual mass source, RESORM. The magnitude of RESORM indicates whether the pressure corrections are sufficient. If RESORM is too large, the program recalculates the velocities and pressures until RESORM comes within the desired range. If RESORM is greater than 10.0, the program stops because this only happens when there is a stability problem. If this occurs, the time step must be reduced and the program restarted using data from a previous step. To economize computer time, the temperature, global pressure, and density are only calculated every third iteration. The iterations continue until: (1) RESORM is below the predetermined value, (2) the maximum number of iterations has been reached, or (3) the CPU time presently available is insufficient to complete another iteration.

#### **D. VENTILATION RESULTS**

The numerical model was used to evaluate two fire scenarios: one included internal ventilation and the other did not. The specific parameters of the model were discussed previously. The validity of the ventilation model will be evaluated and the numerical results of the internal ventilation case will be compared to the nonventilated case.

A direct comparison can be made by looking at the spatial and temporal variations of the velocity and temperature fields. Although these fields are three-dimensional, they are presented in a two-dimensional form at three representative sections in the tank, shown in Figure 4.4. Section A is the mid-section front view, which cuts the vessel vertically along the axis (Y-Z plane). Section B is the mid-section end view from the south end, cutting the vessel through the middle of the vessel, perpendicular to the axis (X-Y plane). Section C is the section view at the base of the end cap from the south end, which is also cut perpendicular to the axis but at the intersection of the cylindrical and spherical portions of the tank (X-Y plane). The ventilated and nonventilated temperature and pressure fields for the times 30, 60, 90, 120 and 150 seconds are shown in Figures 4.5 through 4.35.

Many observations can be made in analyzing the field plots, but only the major phenomena will be discussed here. Raycraft, et al. [Ref. 38] discuss the results of the nonventilated computer model. In this thesis, discussion will be limited to comparisons of the two cases and some general comments. Particularly interesting phenomena include the flame plume, global velocity field, ventilation effects, temperature stratification, and the velocity field in a small region near the base of the flame plume during the beginning of the fire.

As can be seen in Figures 4.5 through 4.8, the flame plume is well formed early in the fire in both the nonventilated and ventilated cases



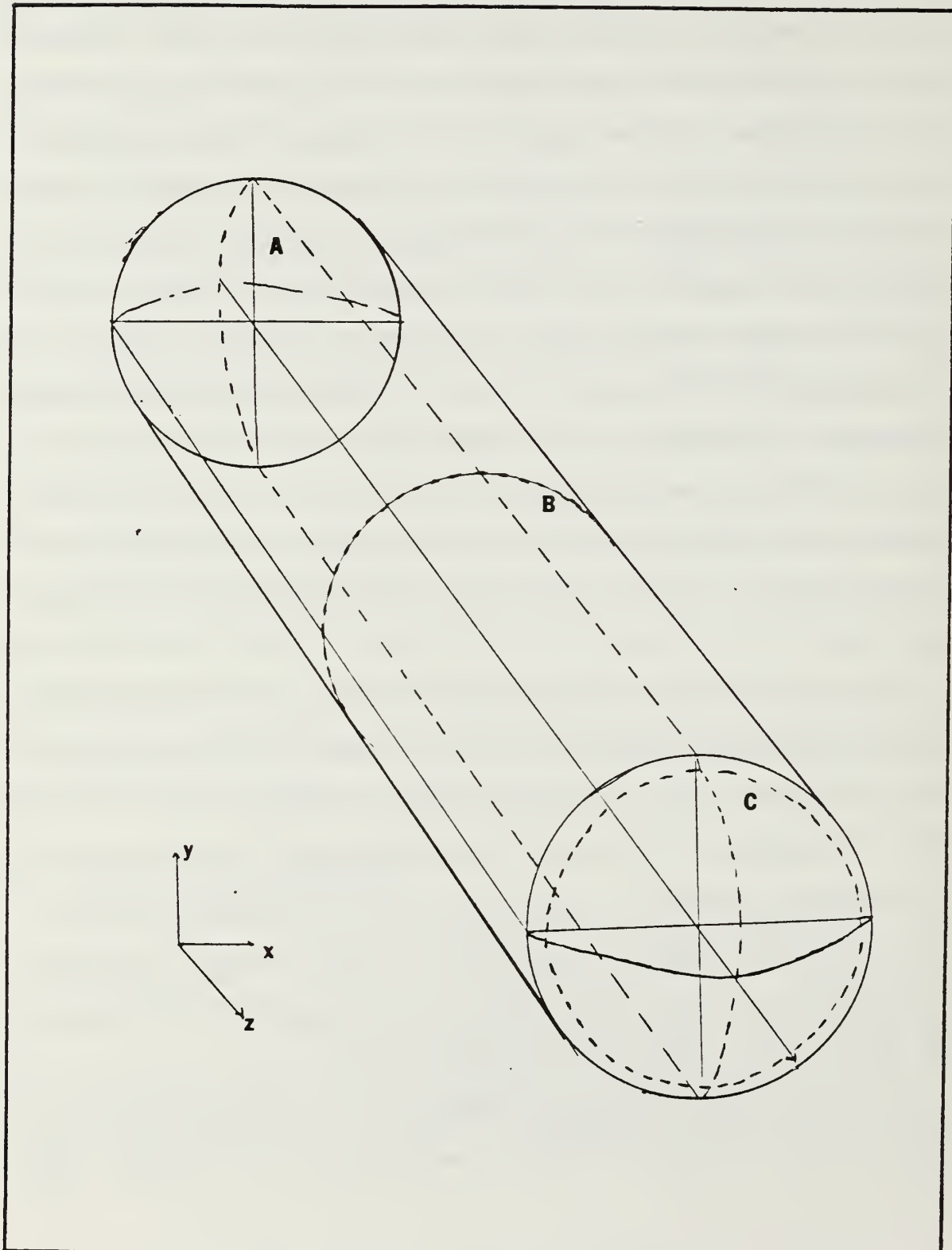


Figure 4-4. Location of Cross-Sections Used for Isotherm and Velocity Field Plots

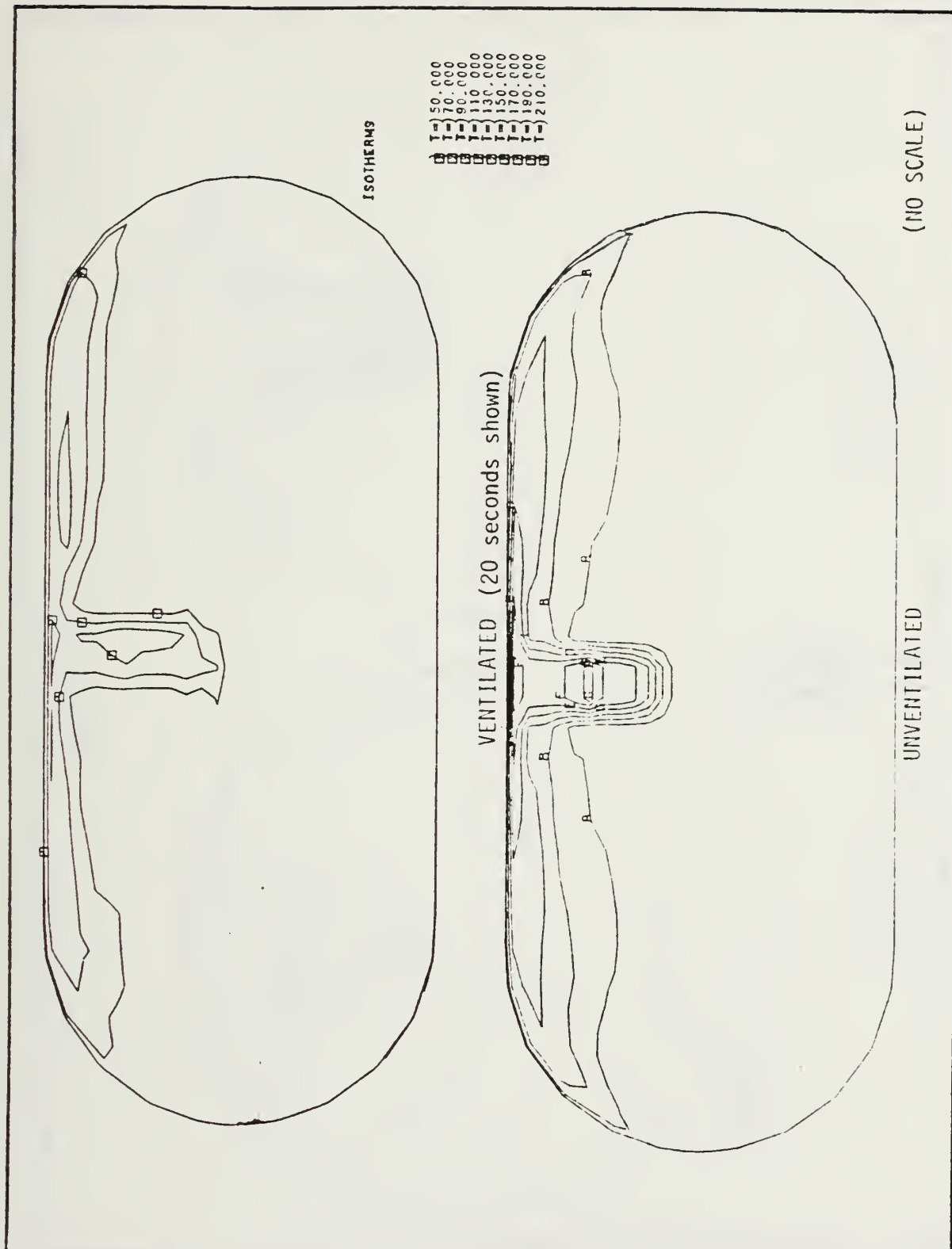


Figure 4-5. Mid-Section Front Views of Isotherms at 30 Seconds

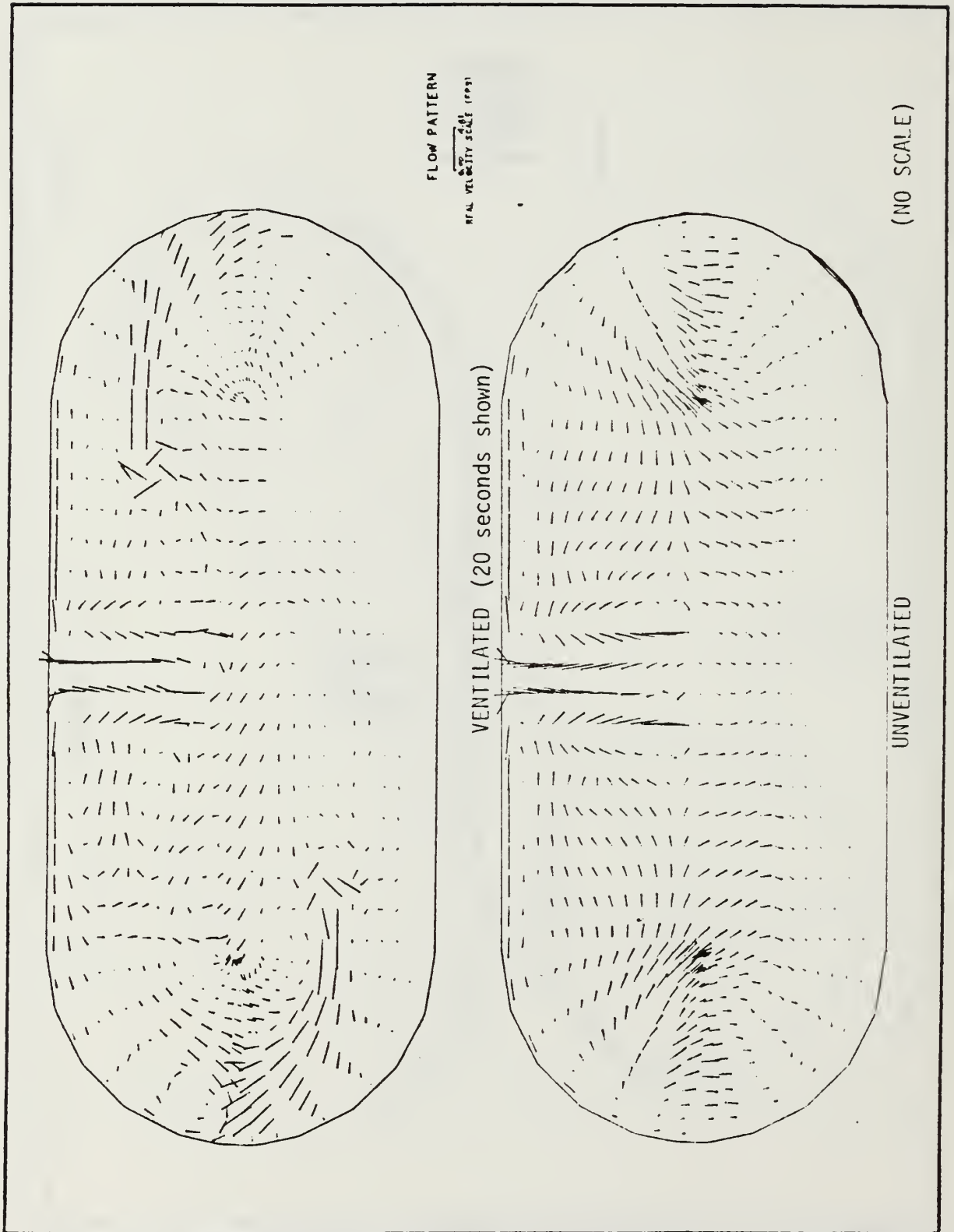


Figure 4-6. Mid-Section Front Views of Velocity Field at 30 Seconds

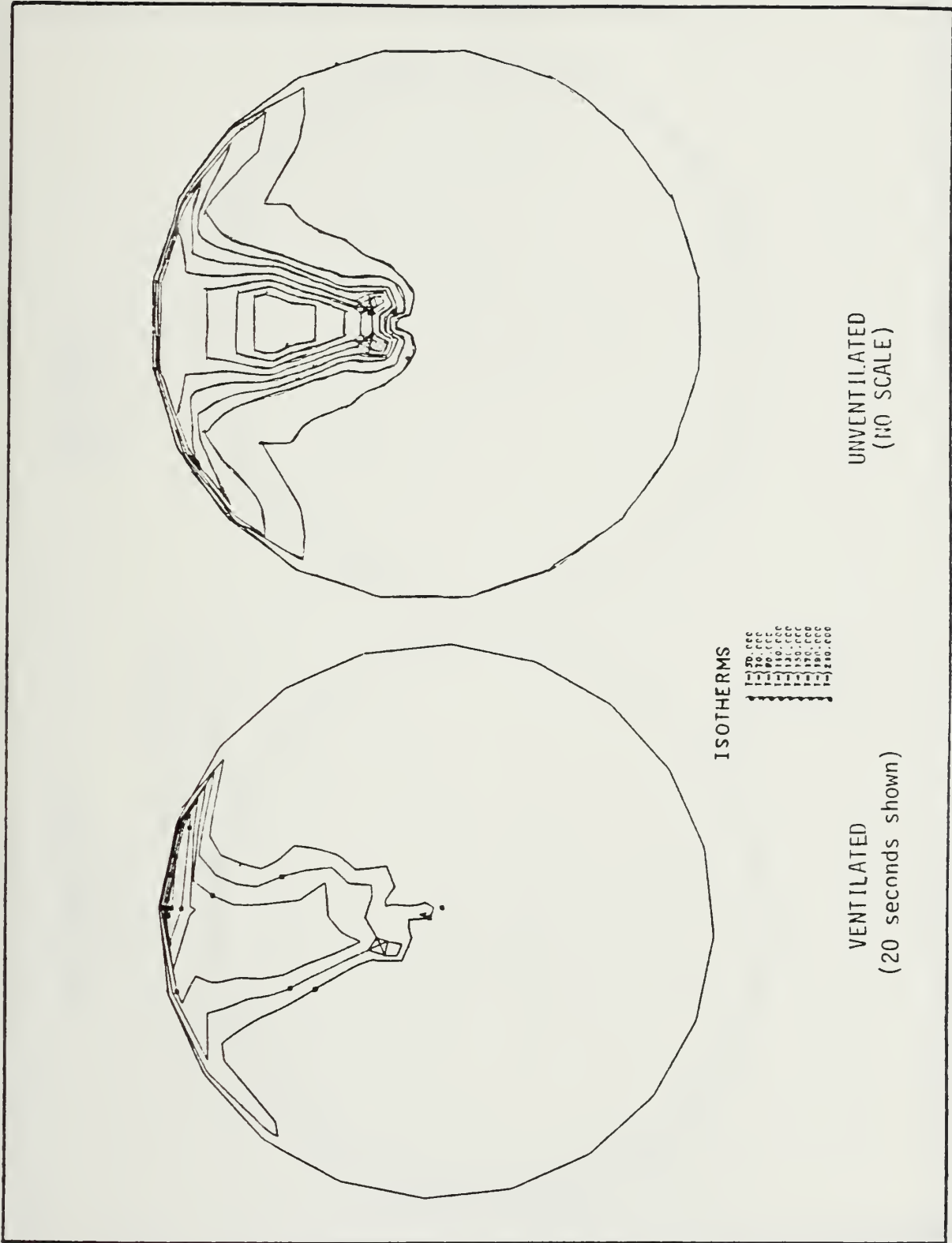


Figure 4-7. Mid-Section End Views of Isotherms at 30 Seconds

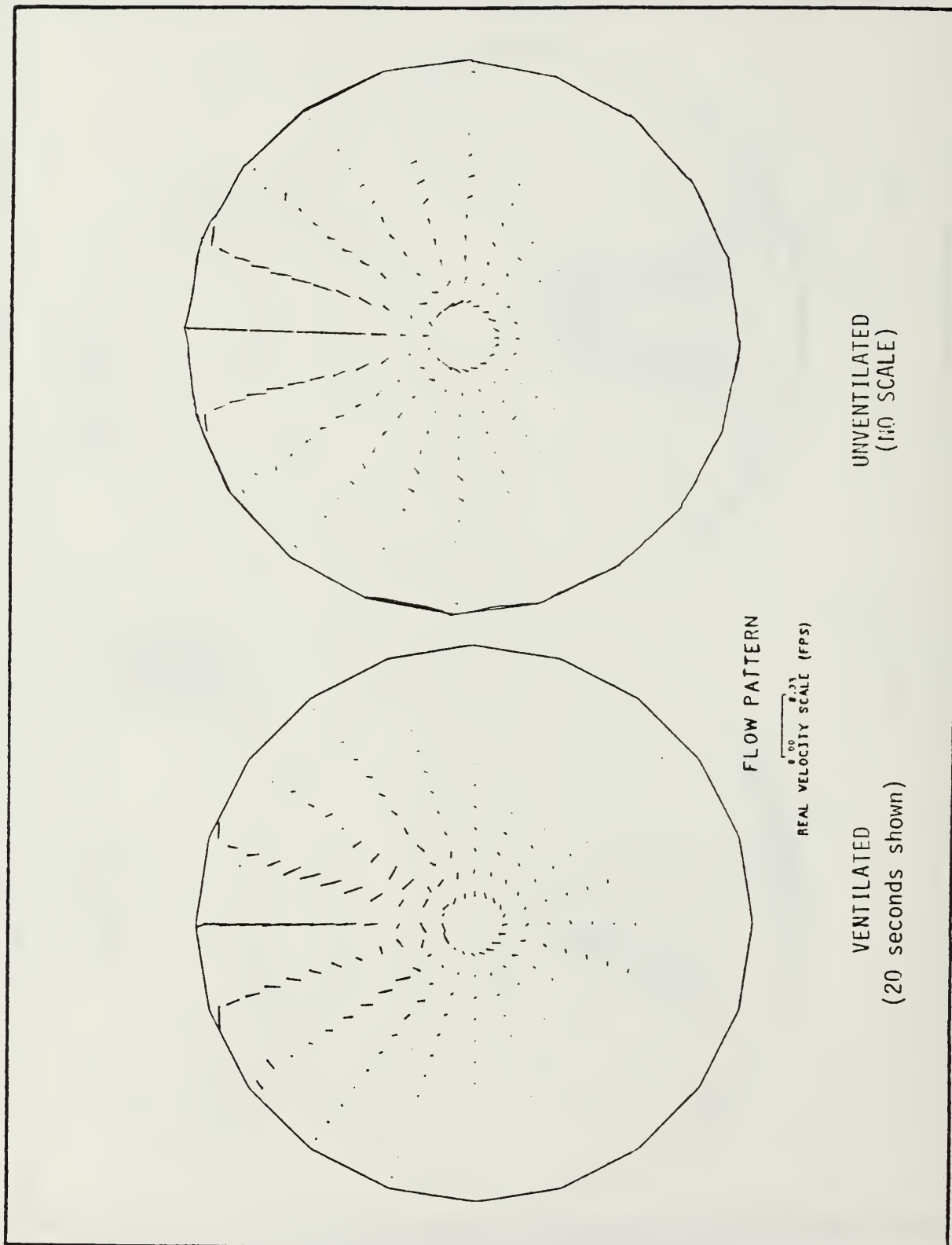


Figure 4-8. Mid-Section End Views of Velocity Field at 30 Seconds

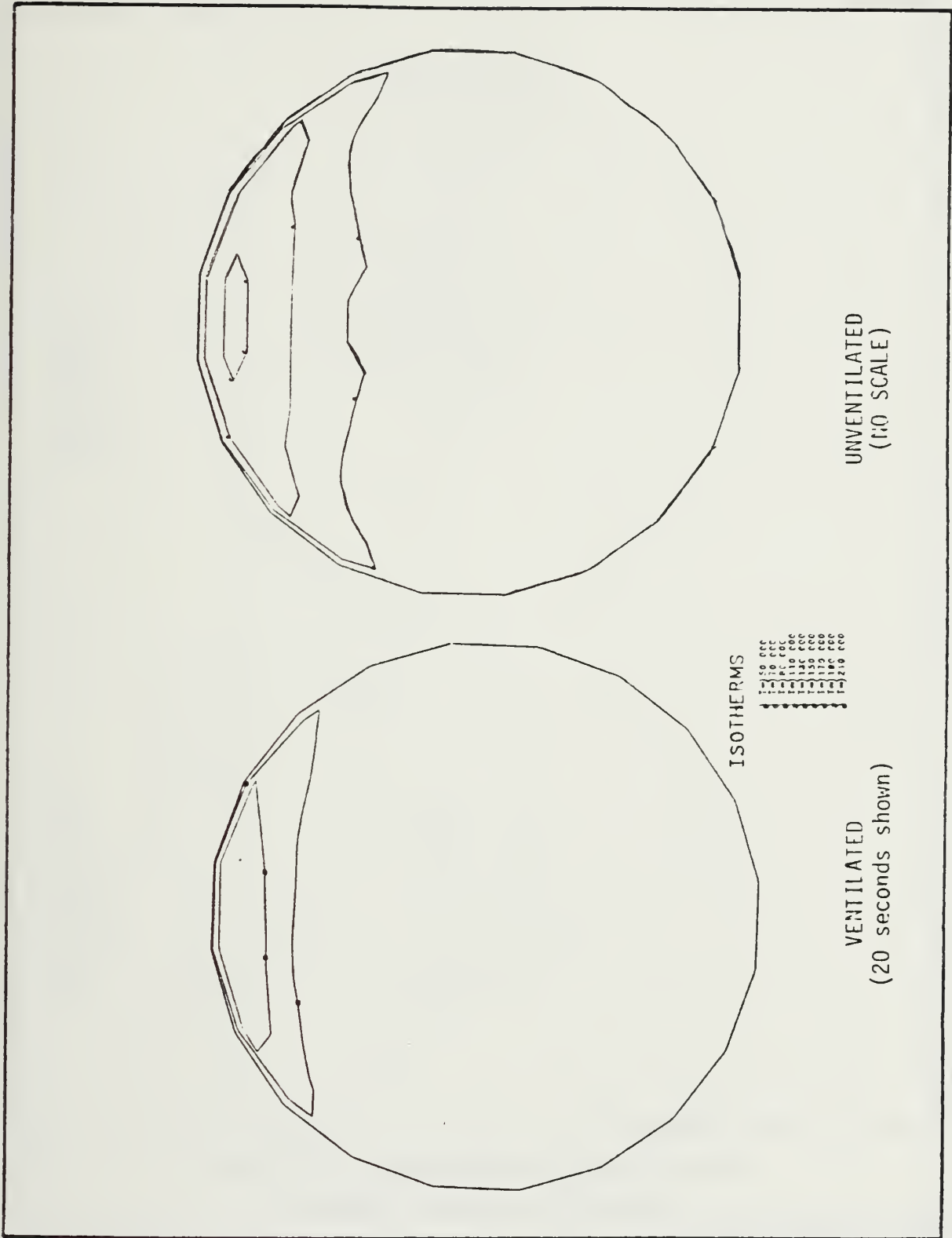


Figure 4-9. Section View at Base of End Cap of Isotherms at 30 Seconds

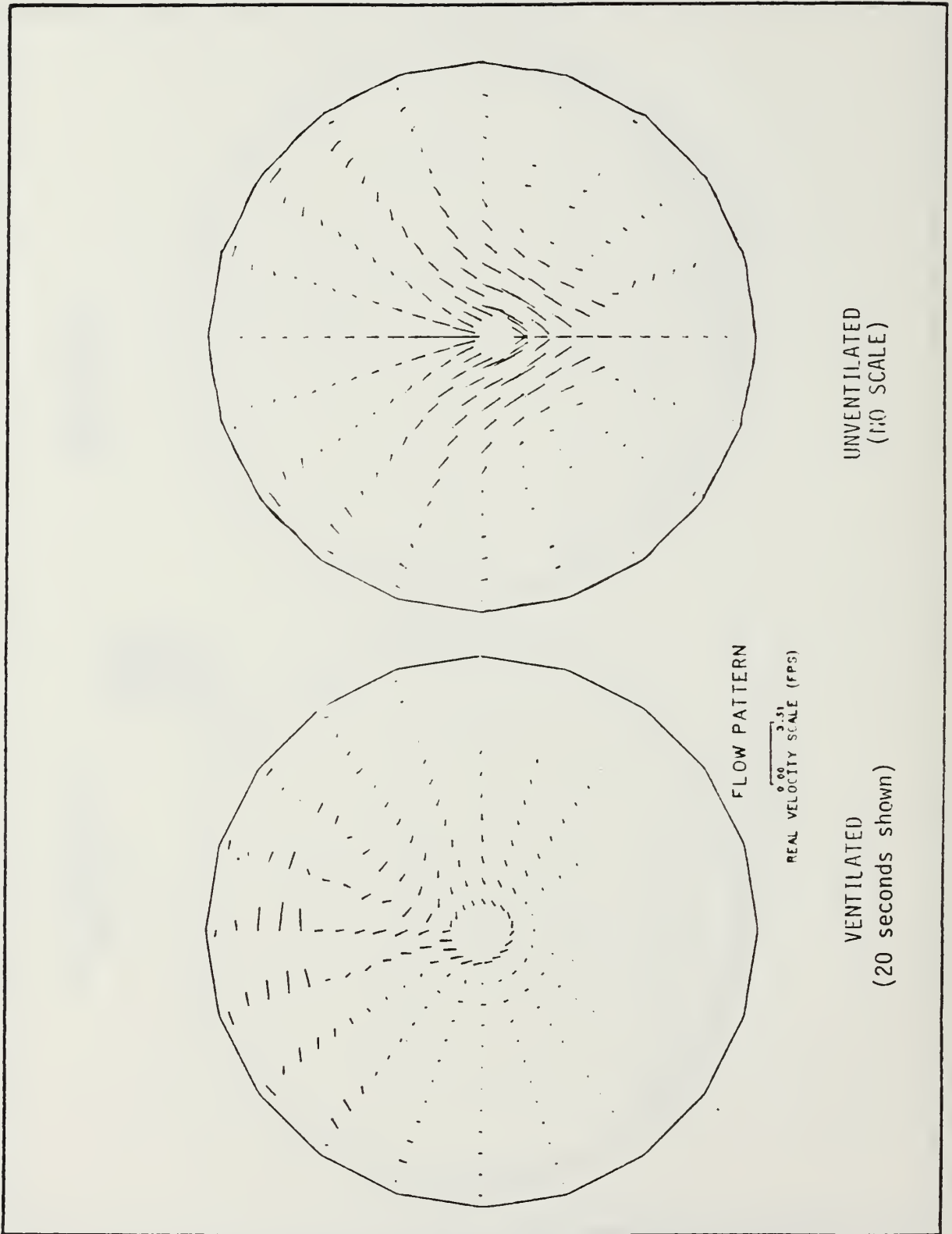


Figure 4-10. Section View at Base of End Cap of Velocity Field at 30 Seconds

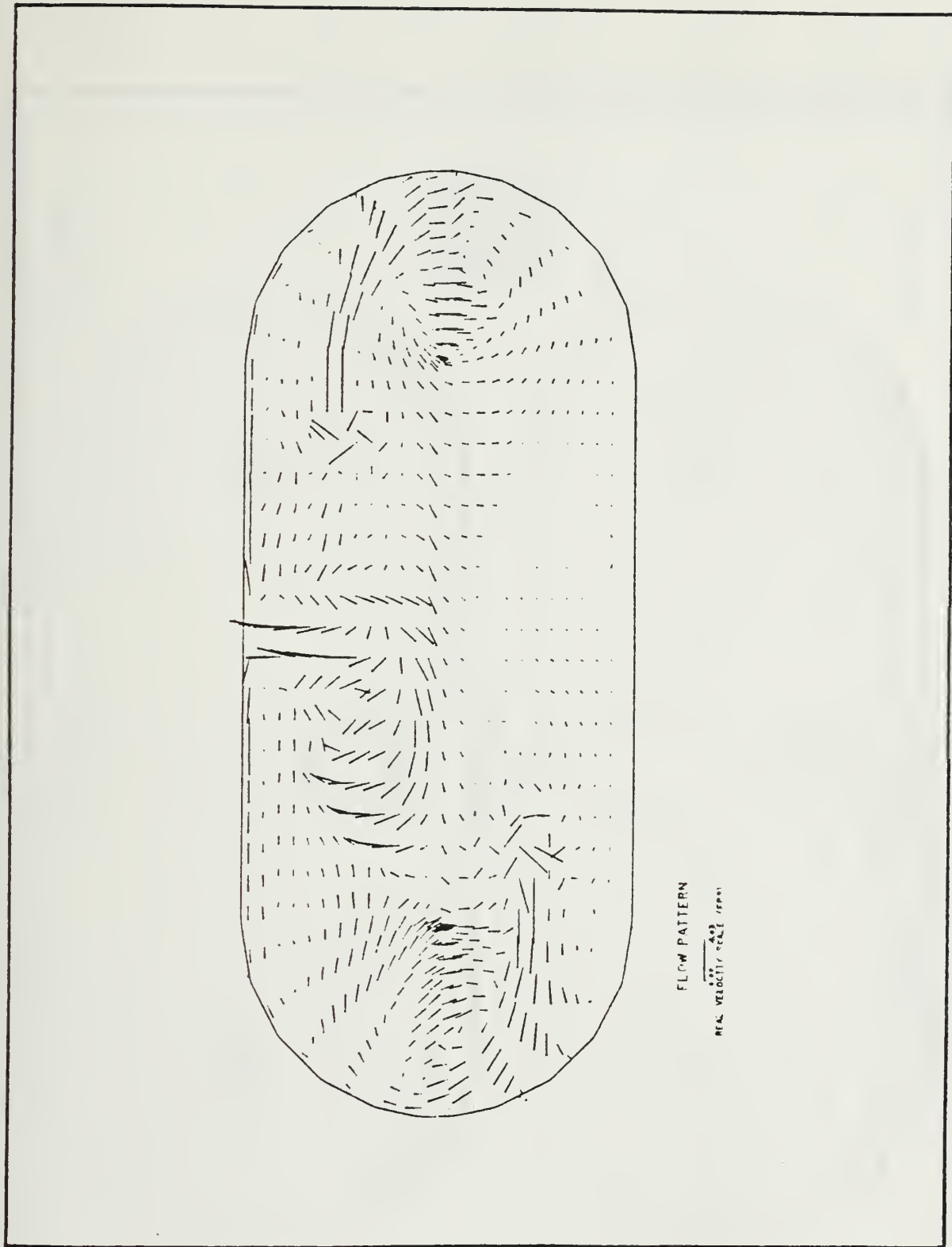


Figure 4-11. Mid-Section Front View of  
Velocity Field at 40 Seconds



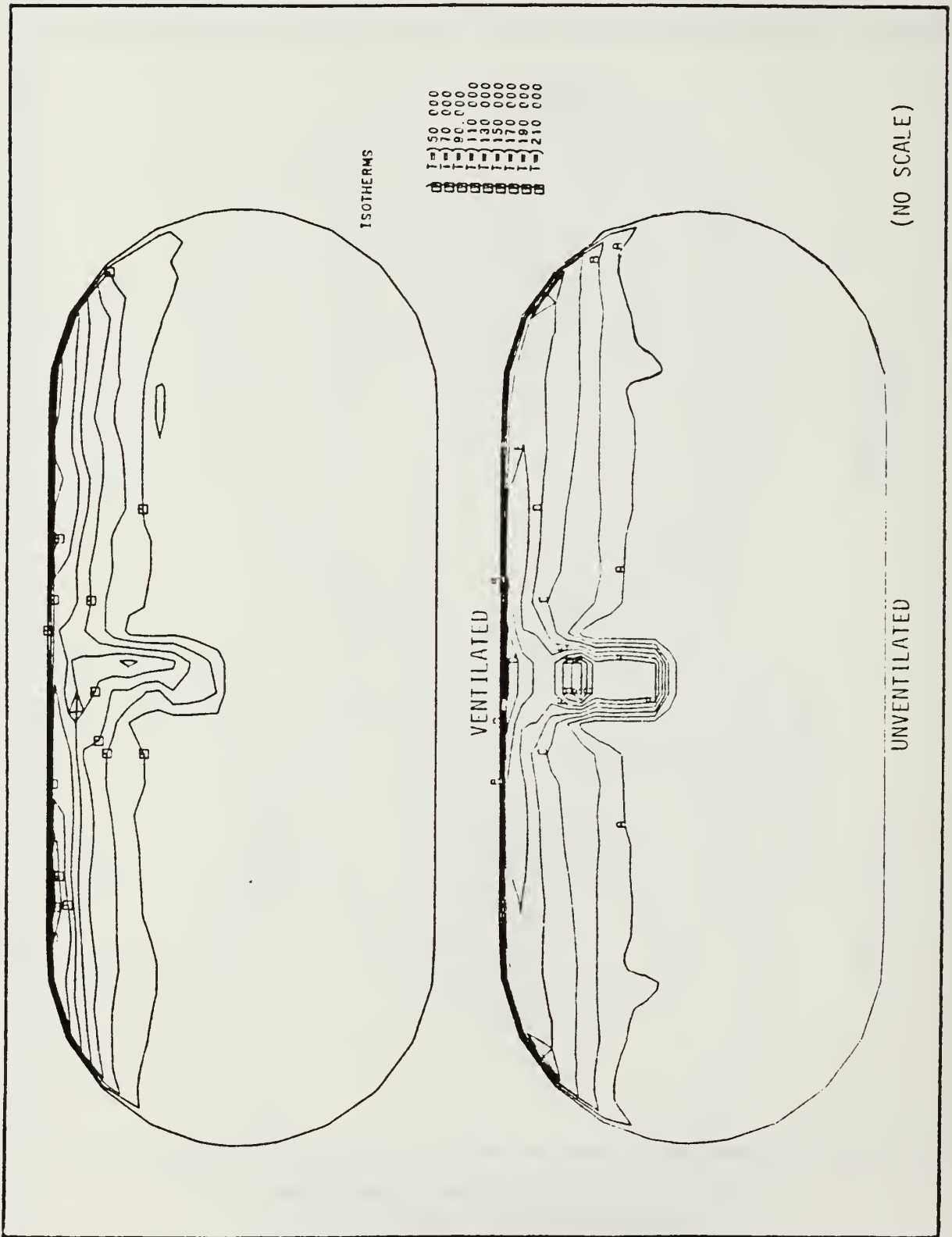


Figure 4-12. Mid-Section Front Views of Isotherms at 60 Seconds

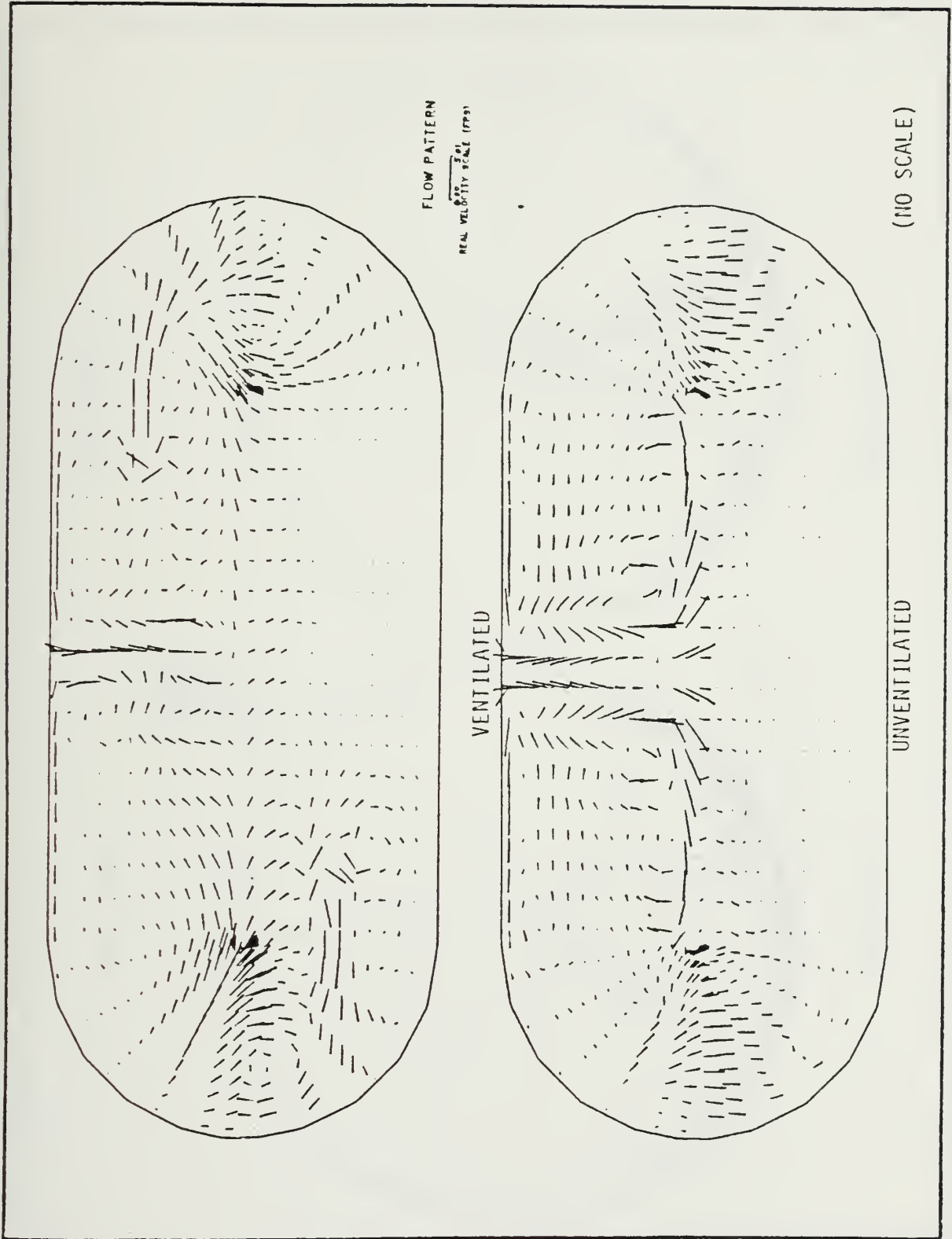


Figure 4-13. Mid-Section Front Views of Velocity Field at 60 Seconds

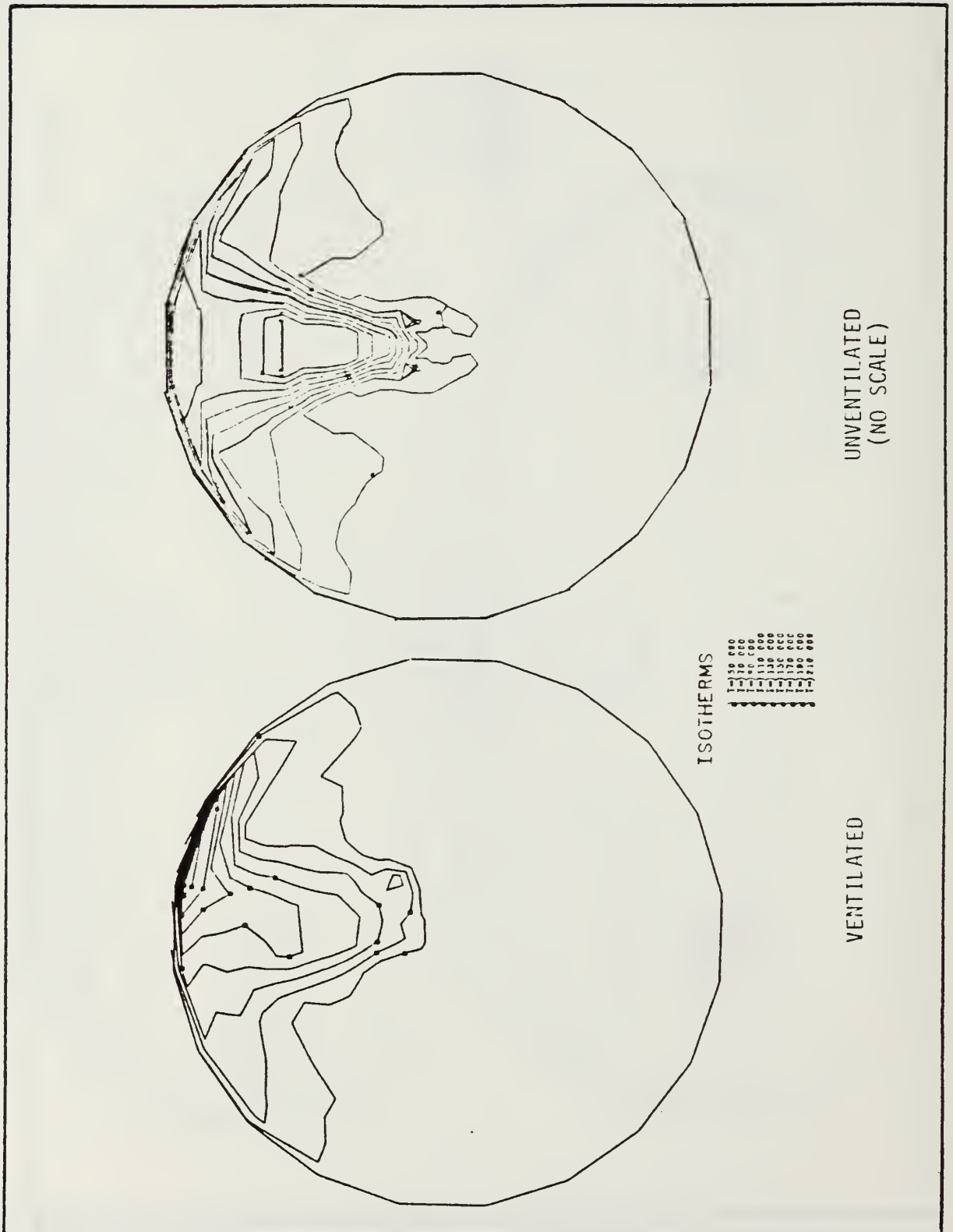


Figure 4-14. Mid-Section End Views of Isotherms at 60 Seconds

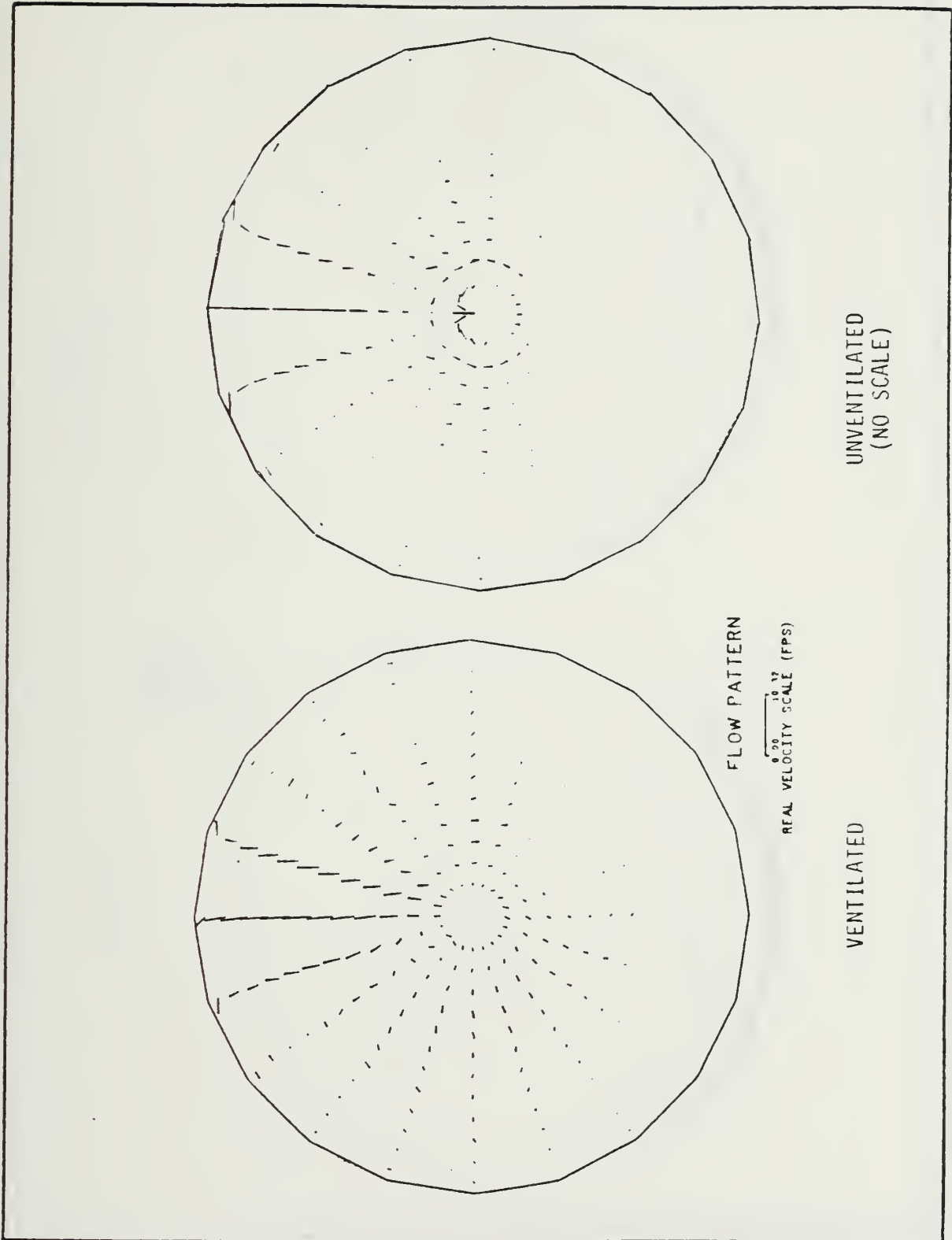


Figure 4-15. Mid-Section End Views of Velocity Field at 60 Seconds

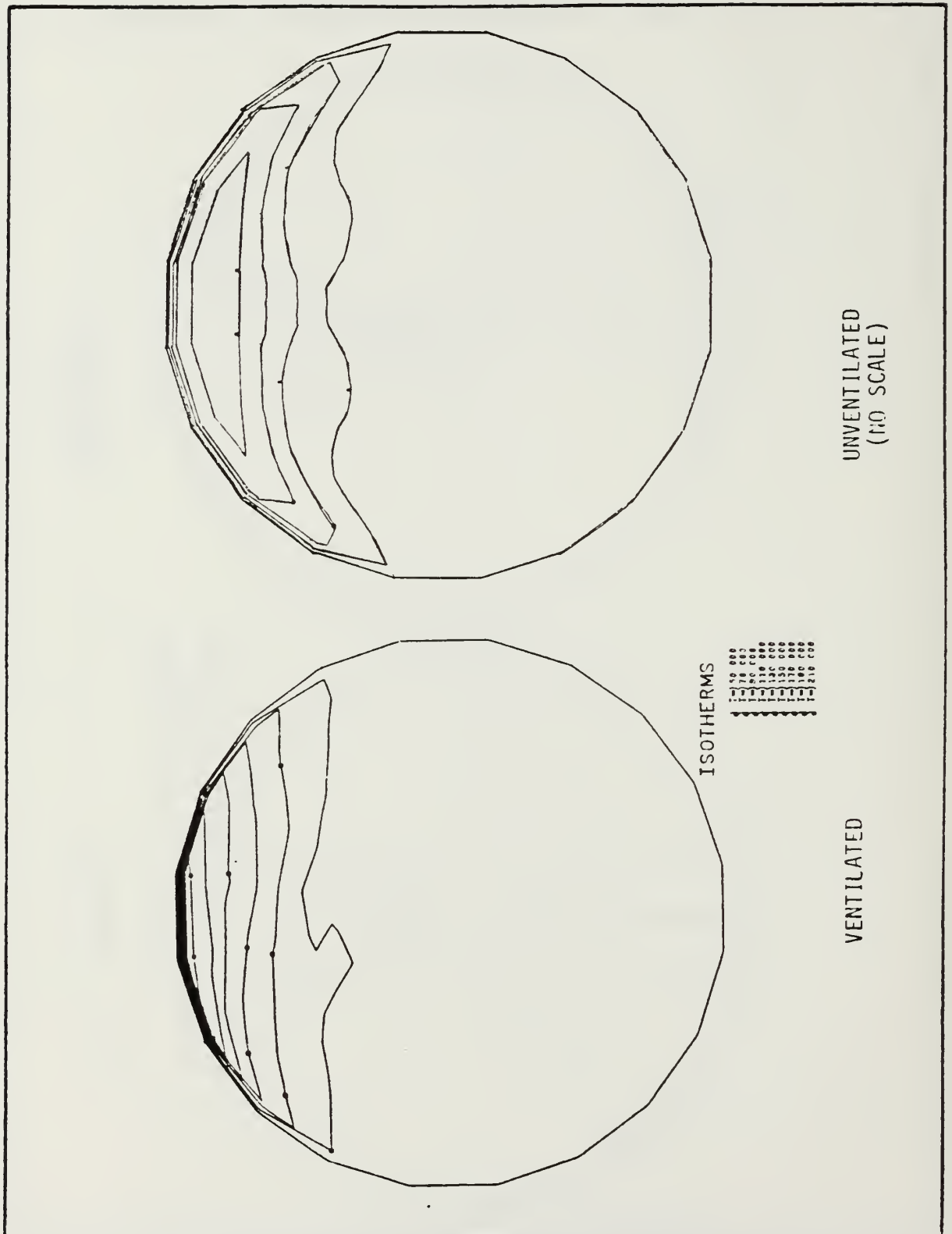


Figure 4-16. Section View at Base of End Cap of Isotherms at 60 Seconds

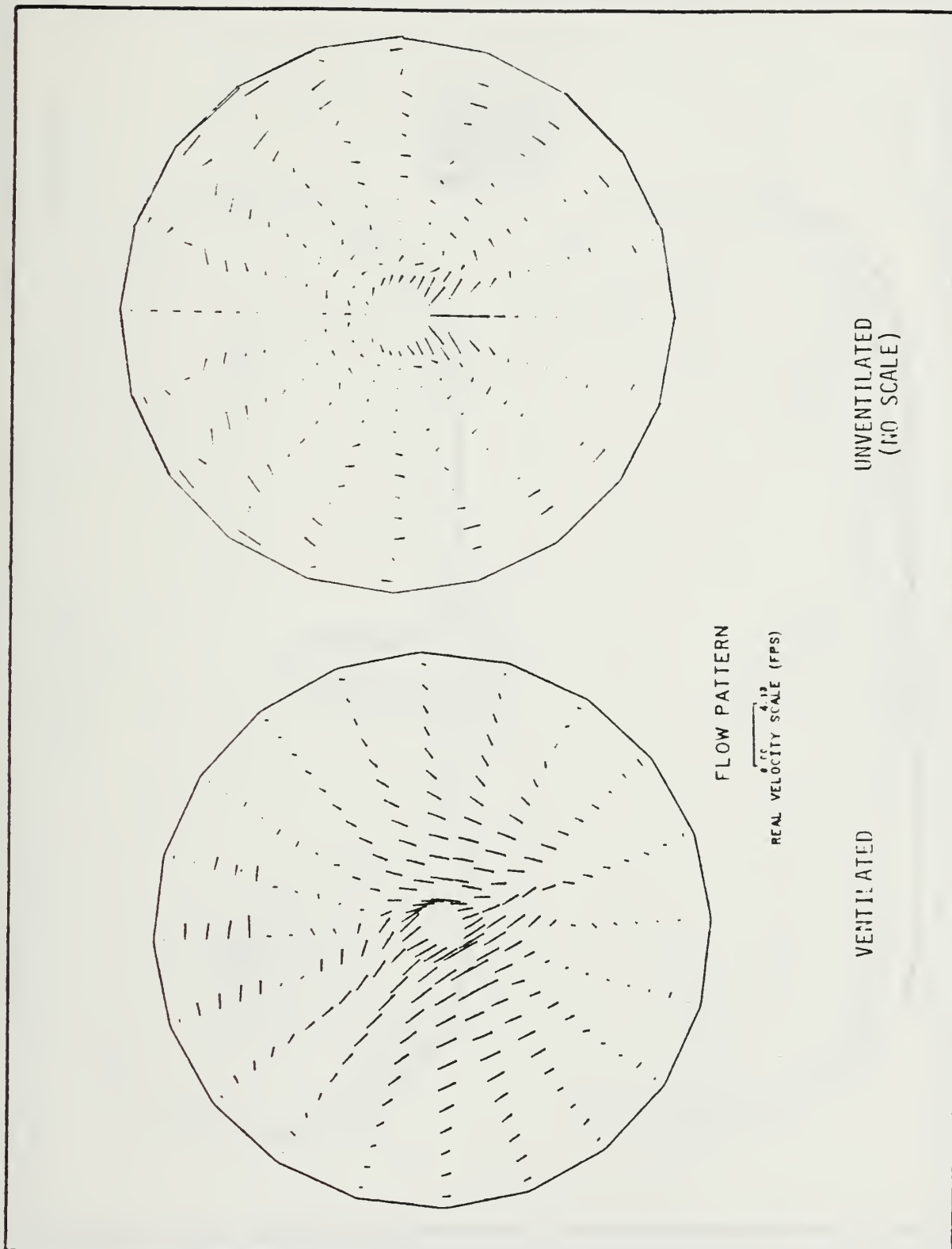


Figure 4-17. Section View at Base of End Cap of Velocity Field at 60 Seconds

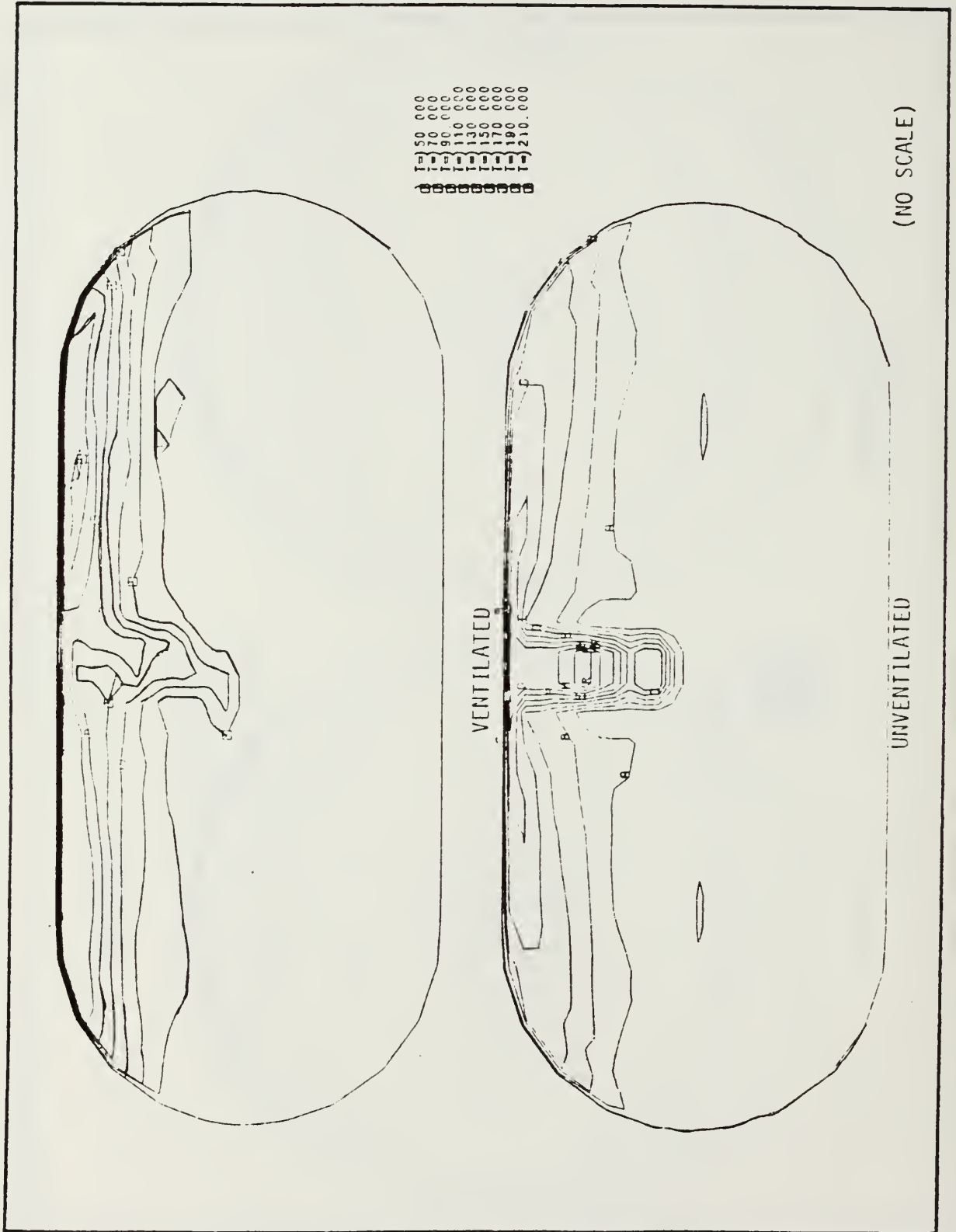


Figure 4-18. Mid-Section Front Views of Isotherms at 90 Seconds

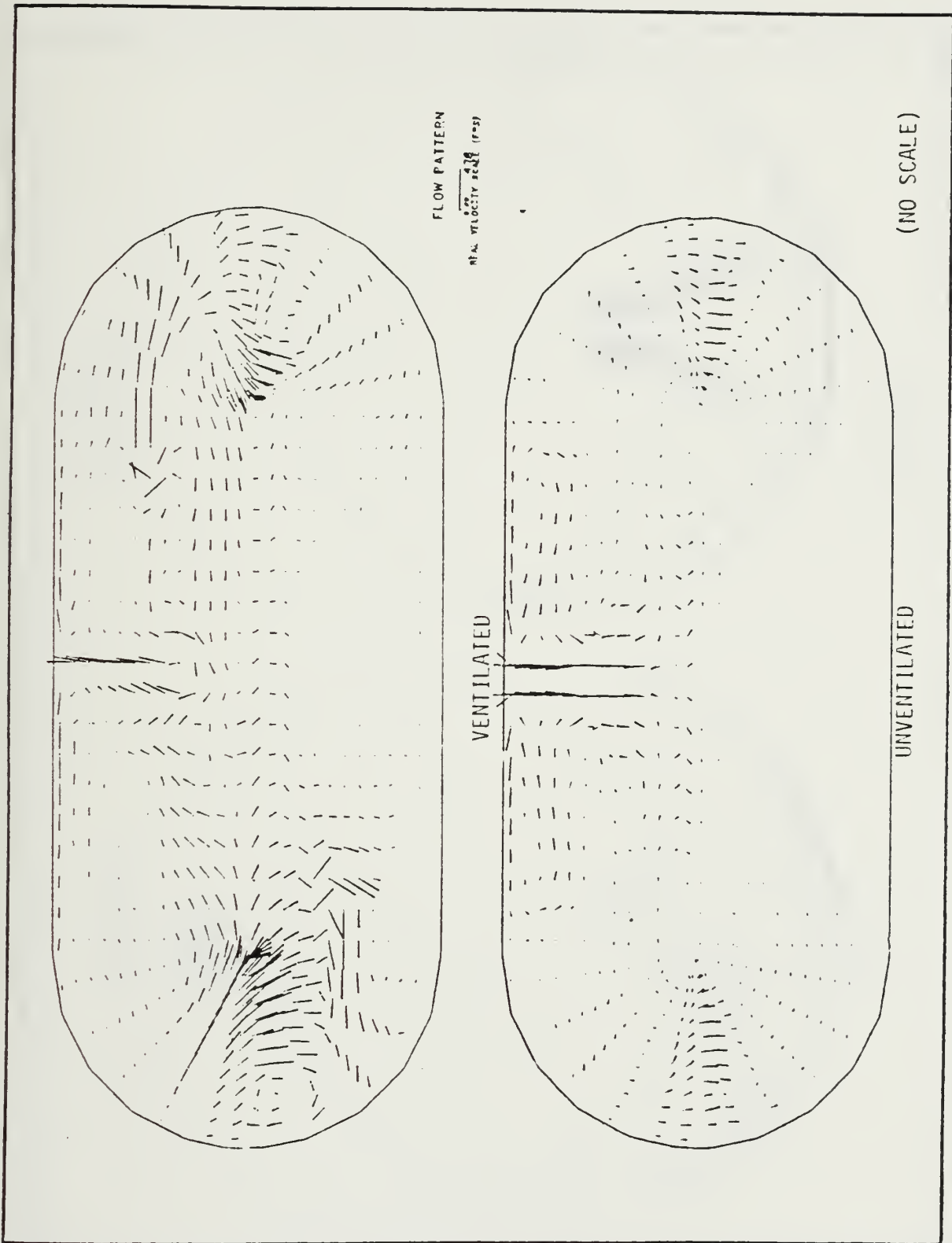


Figure 4-19. Mid-Section Front Views of Velocity Field at 90 Seconds



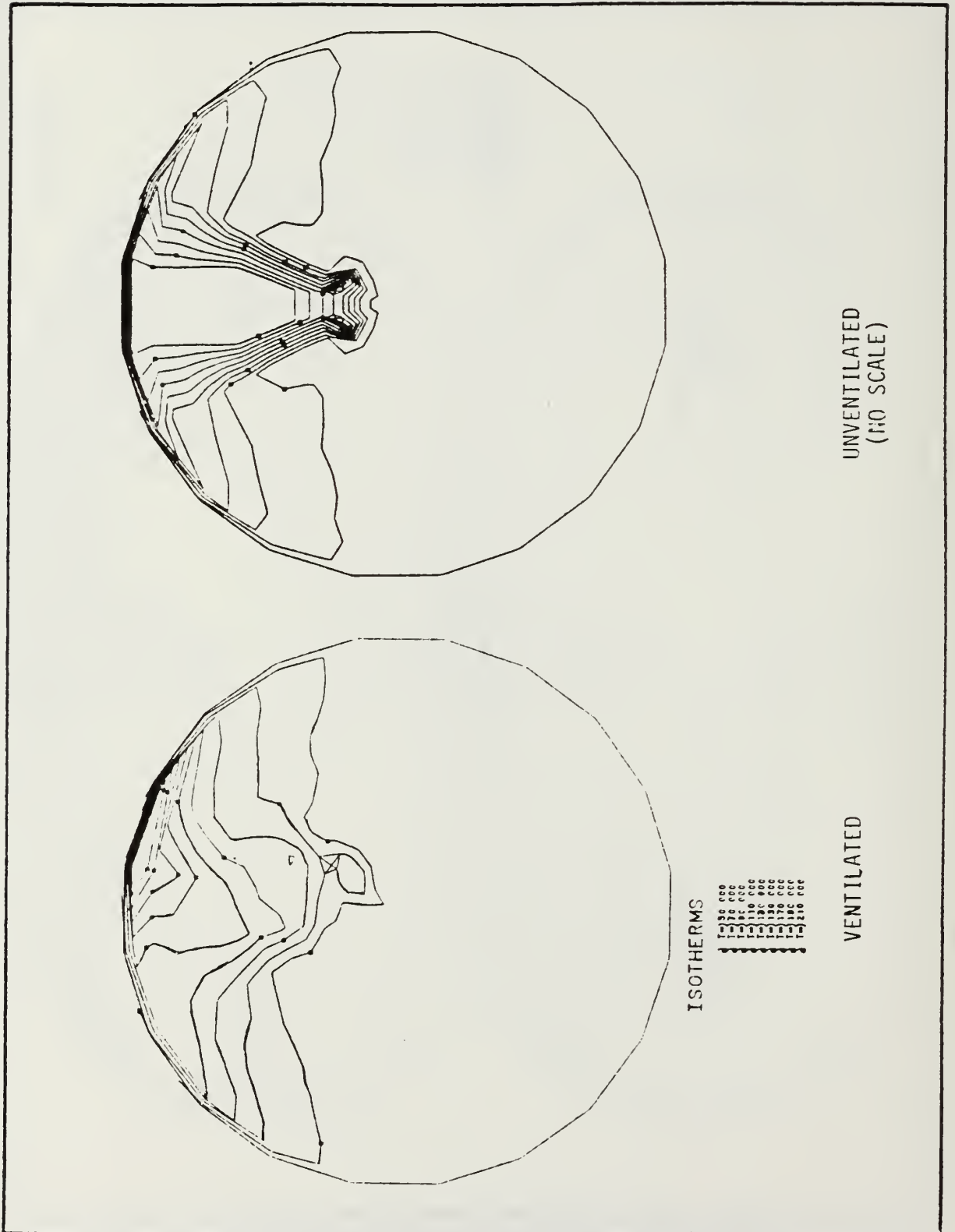


Figure 4-20. Mid-Section End Views of Isotherms at 90 Seconds

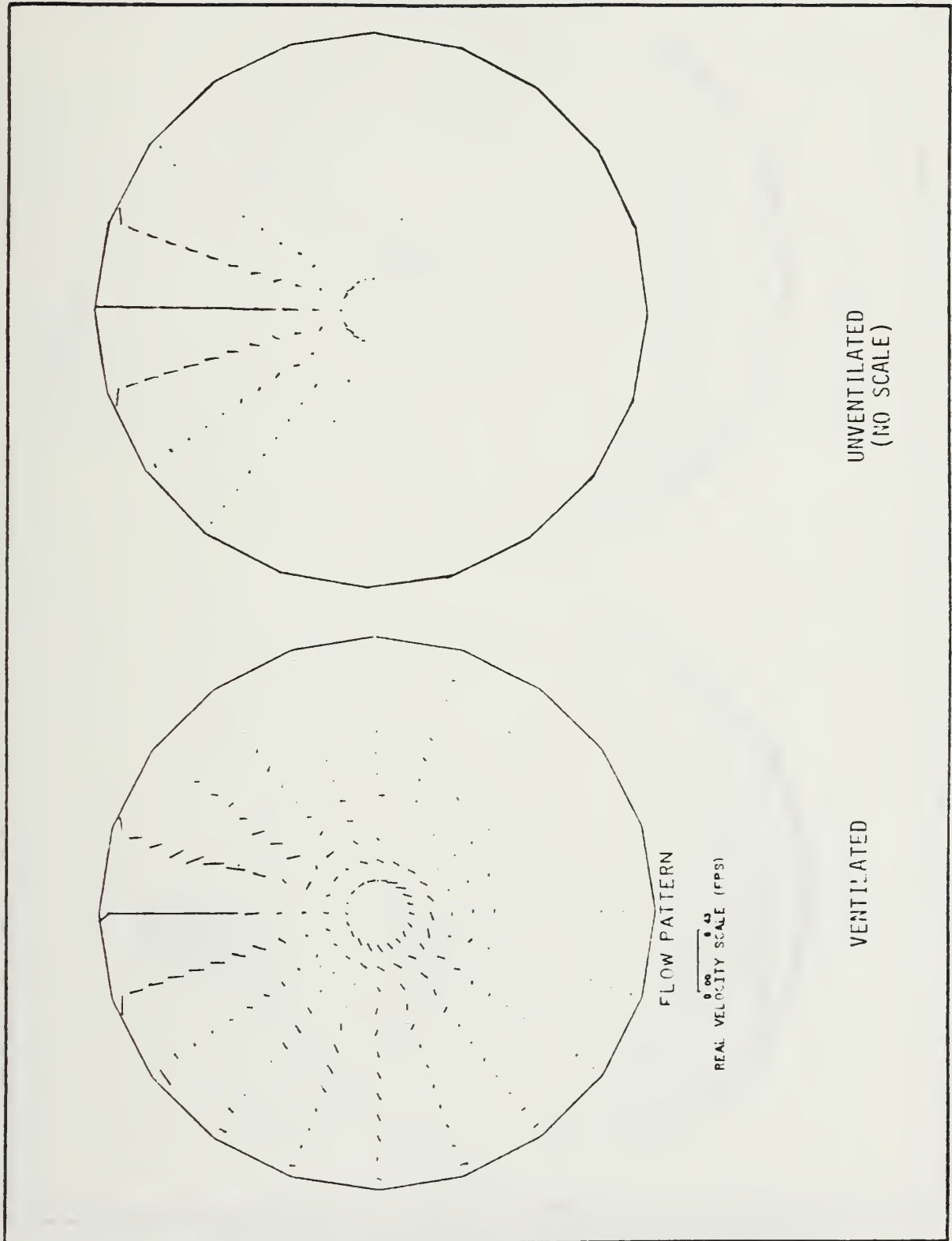


Figure 4-21. Mid-Section End Views of Velocity Field at 90 Seconds

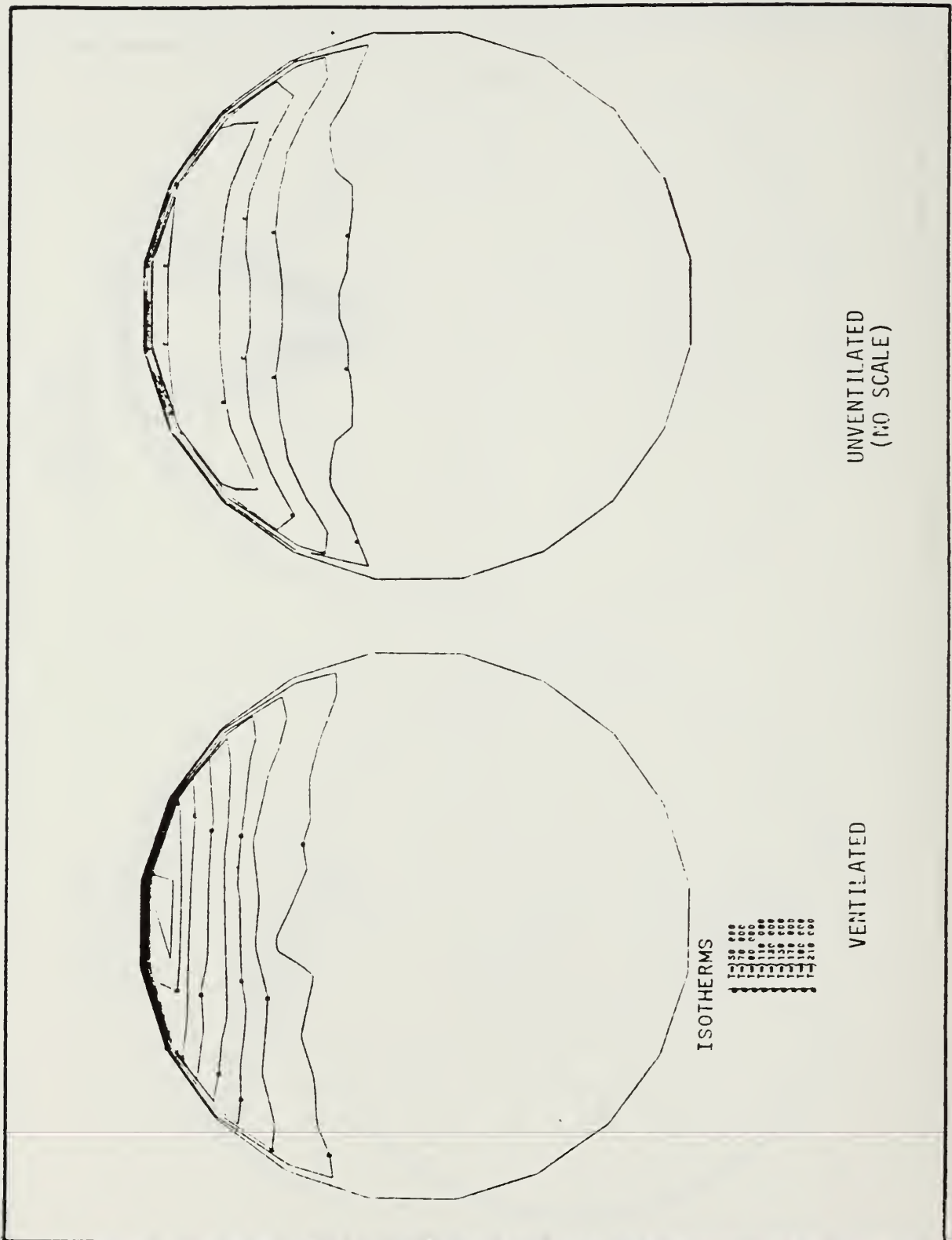


Figure 4-22. Section View at Base of End Cap of Isotherms at 90 Seconds

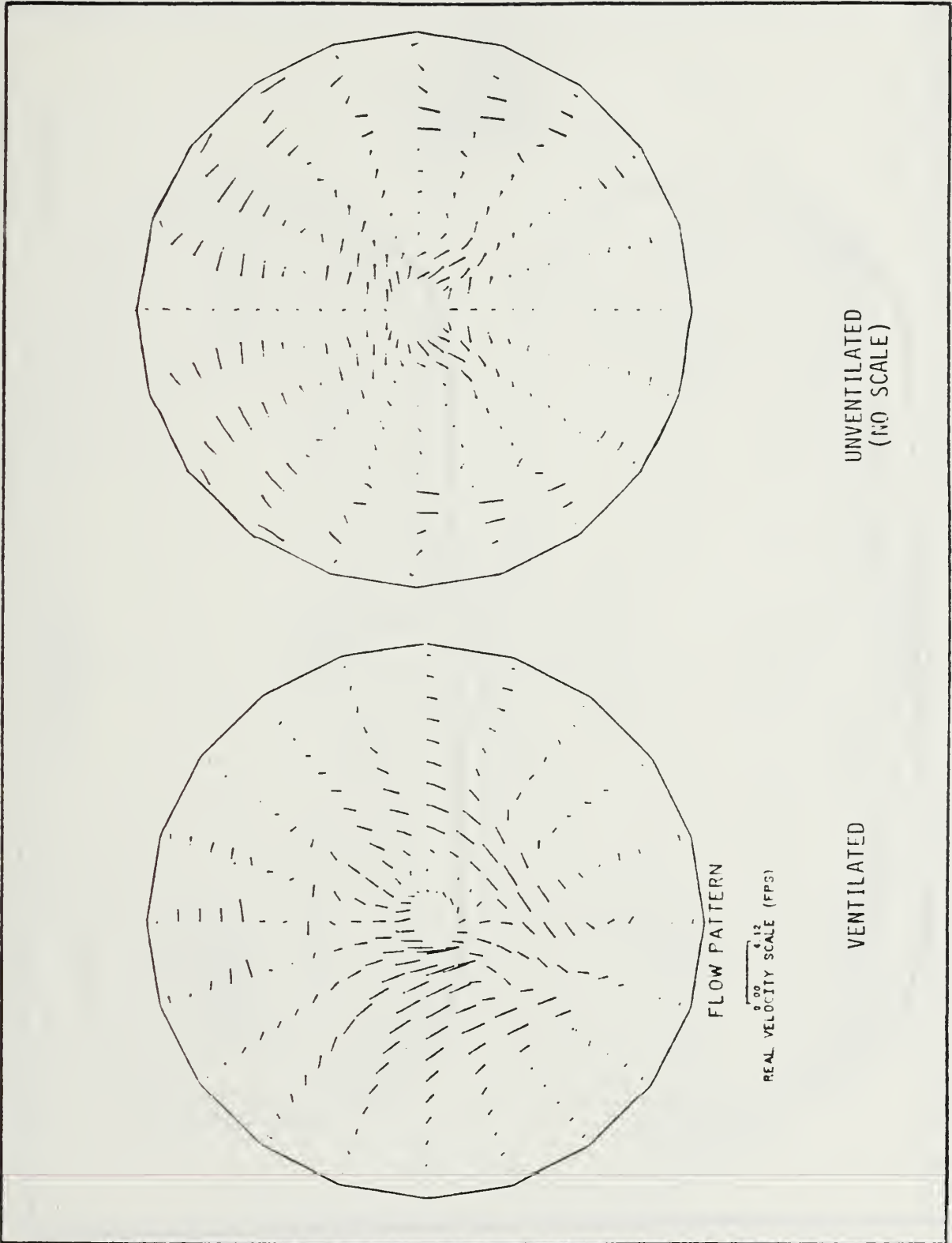


Figure 4-23. Section View at Base of End Cap of Velocity Field at 90 Seconds

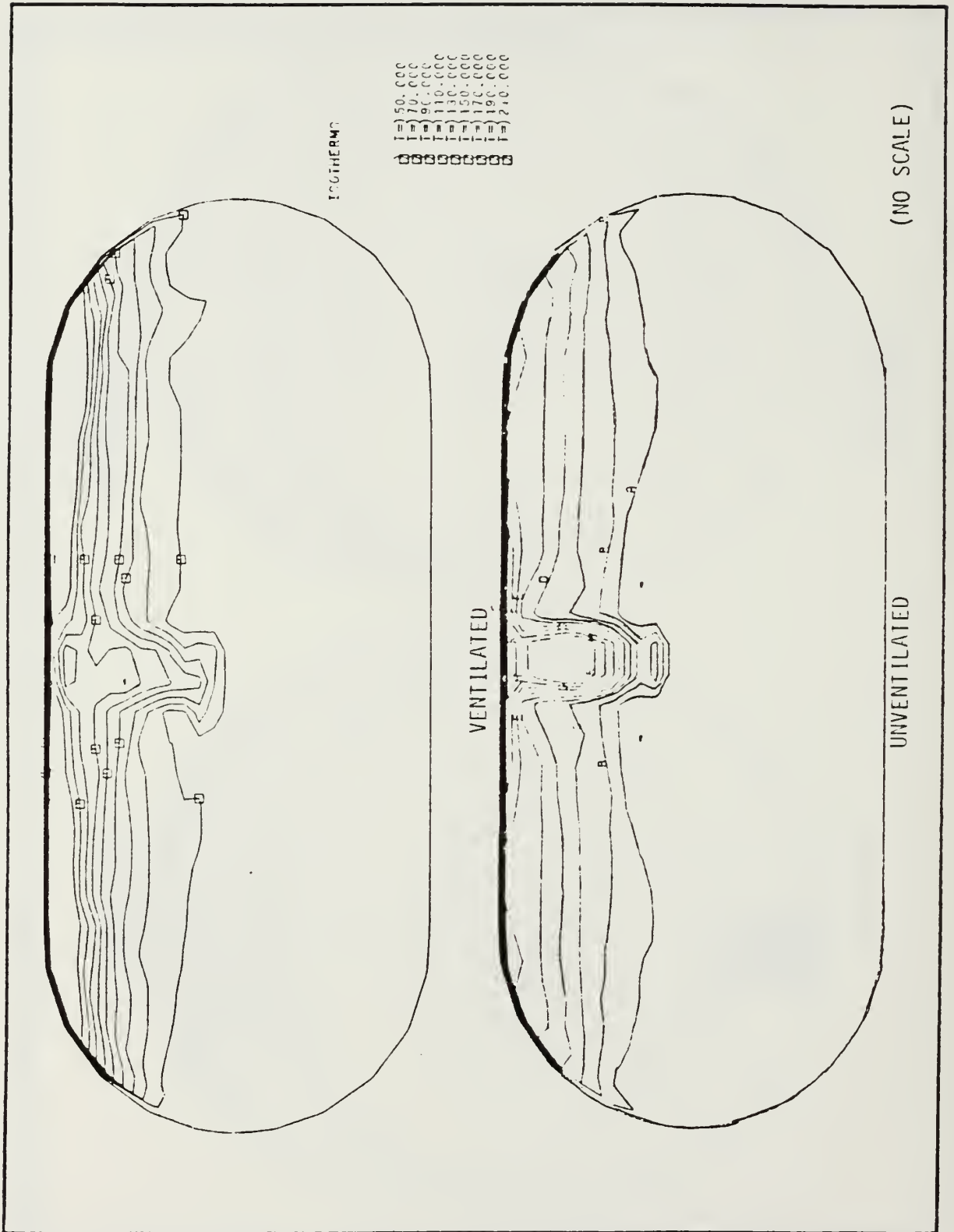


Figure 4-24. Mid-Section Front Views of Isotherms at 120 Seconds

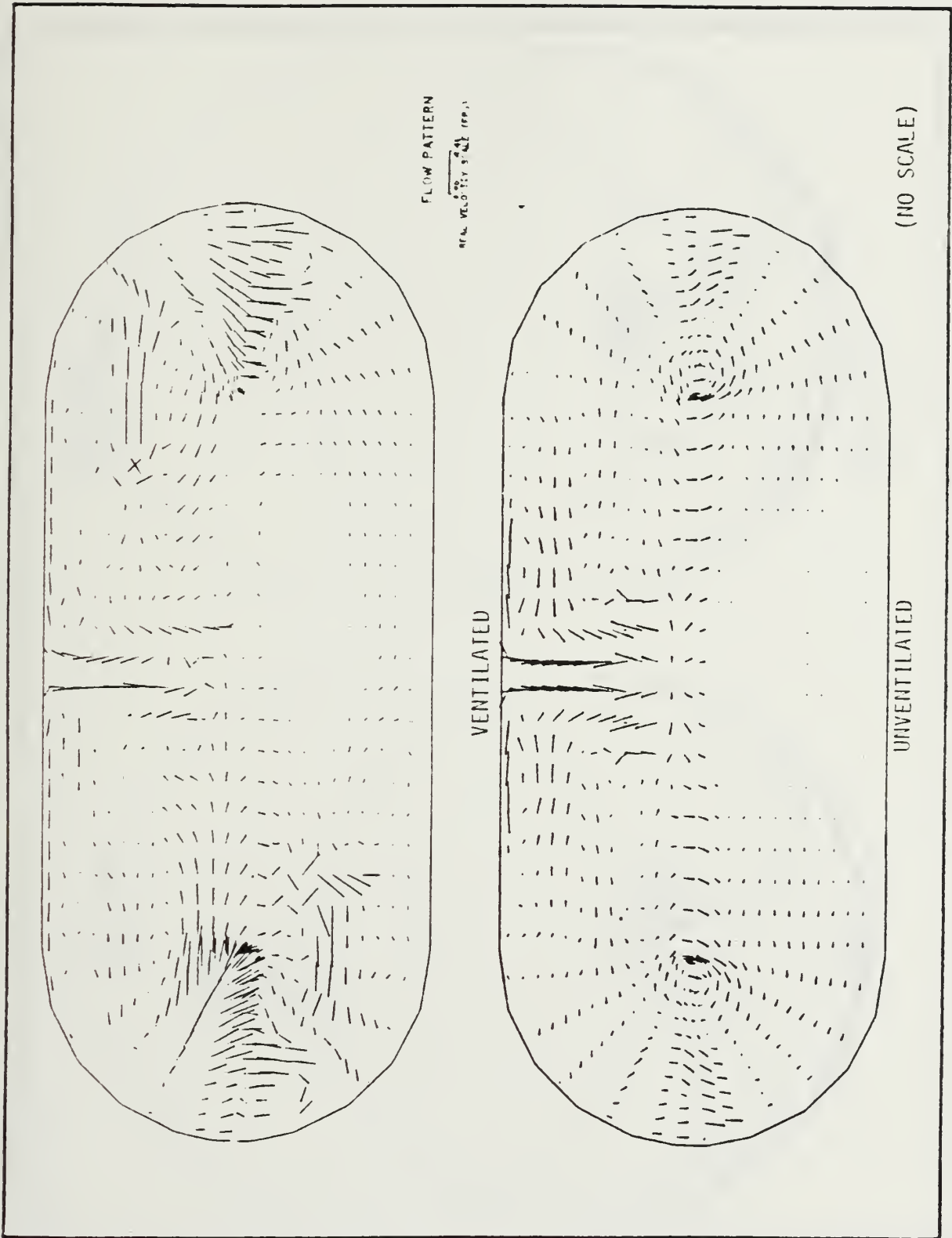


Figure 4-25. Mid-Section Front Views of Velocity Field at 120 Seconds



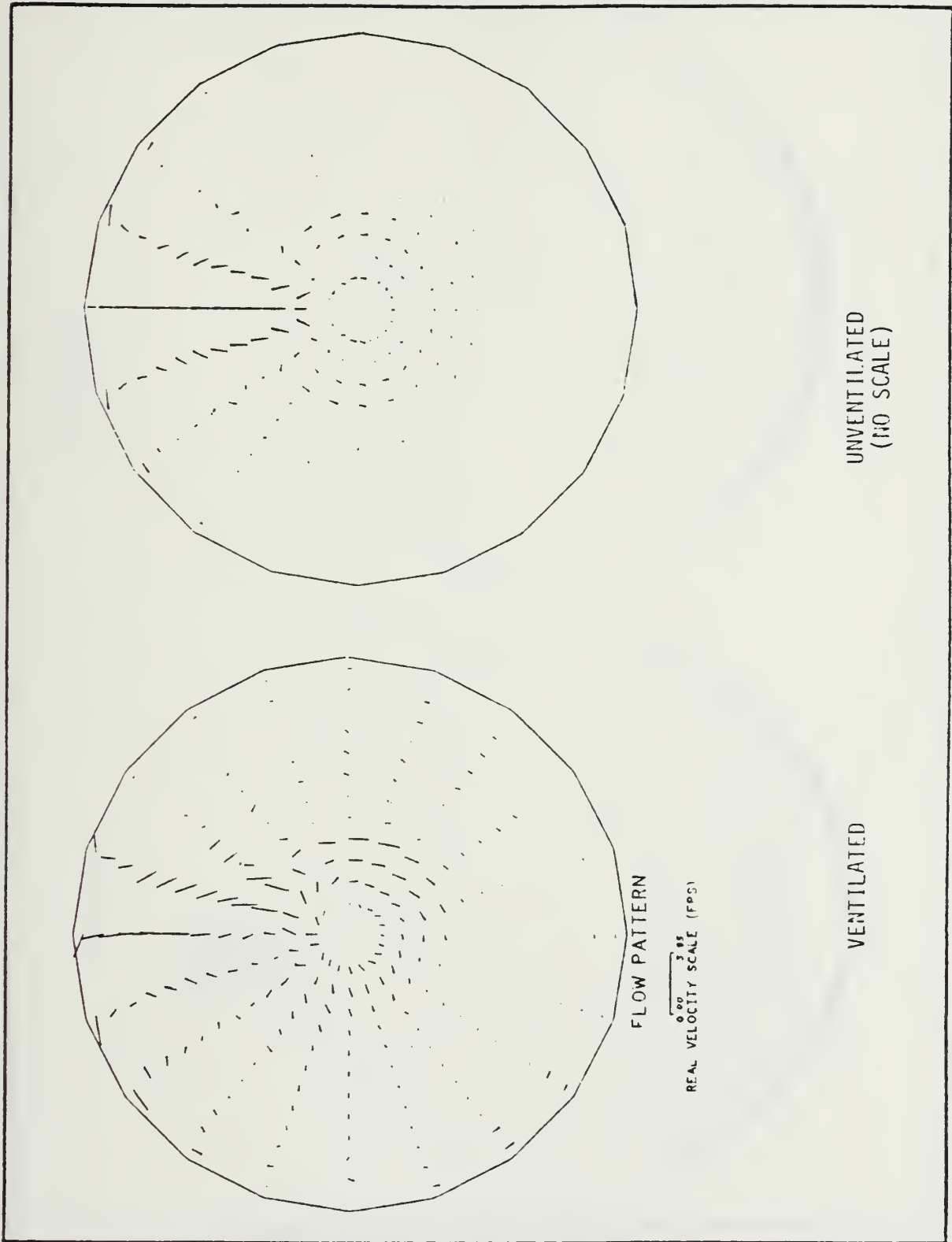


Figure 4-27. Mid-Section End Views of Velocity Field at 120 Seconds



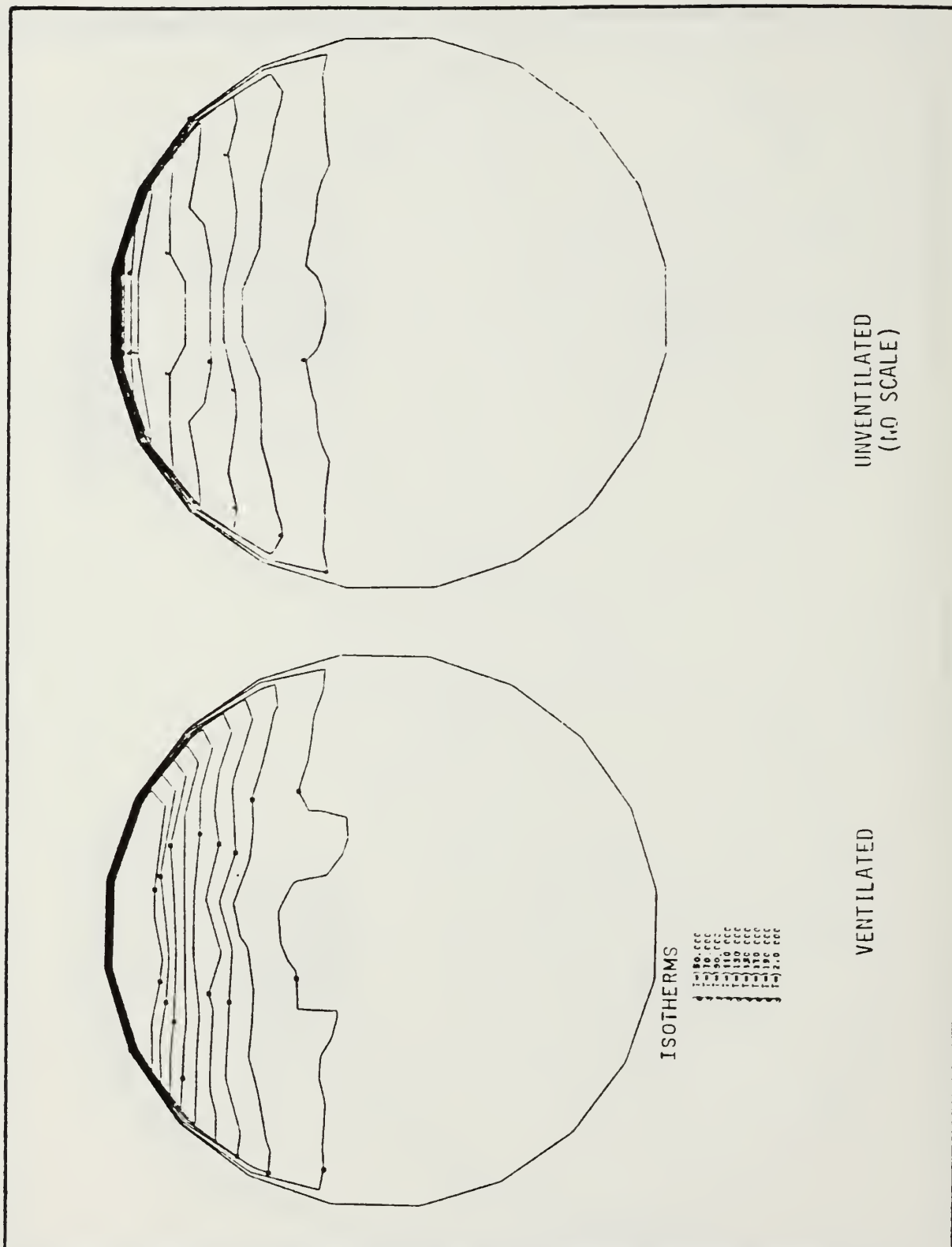


Figure 4-28. Section View at Base of End Cap of Isotherms at 120 Seconds

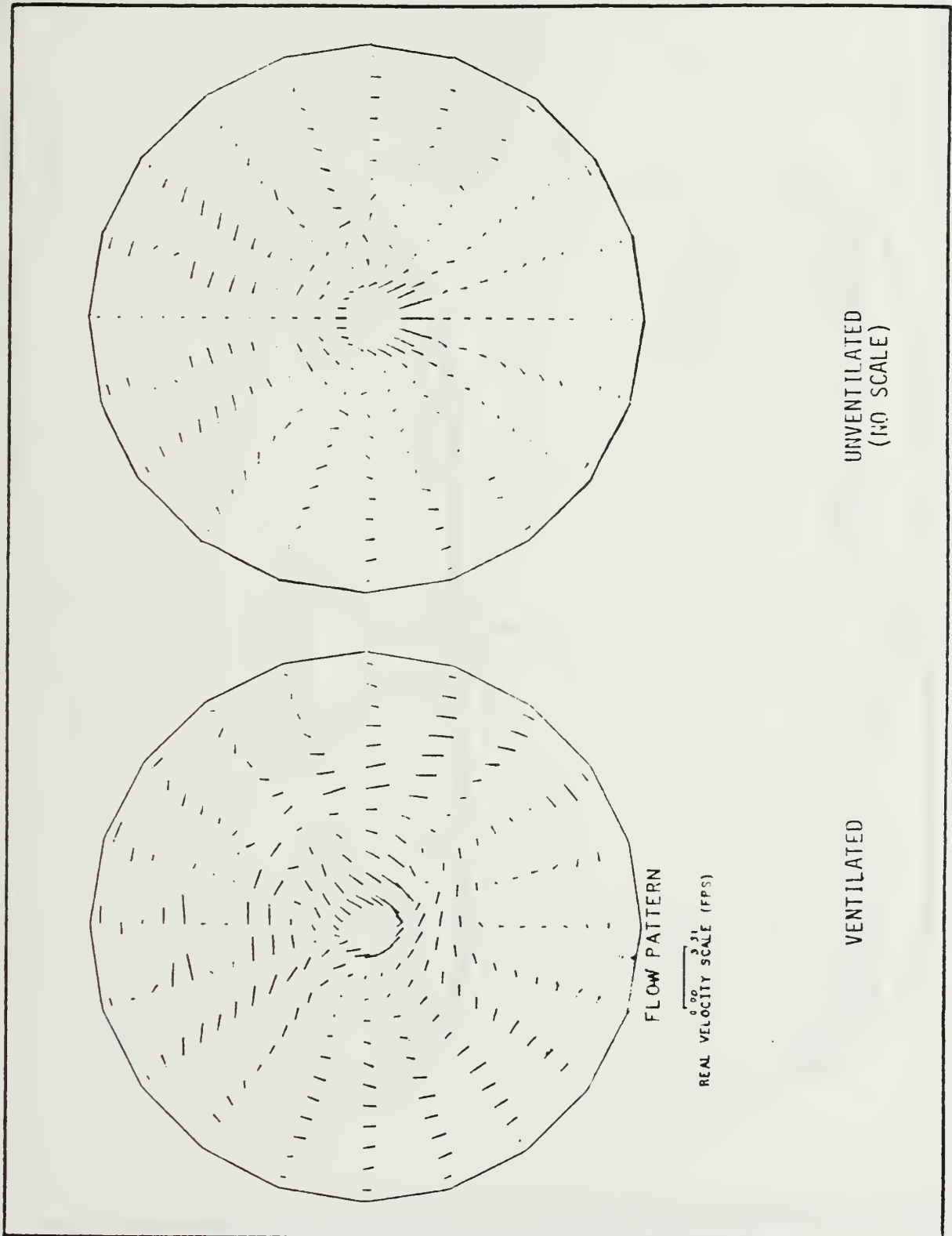


Figure 4-29. Section View at Base of End Cap of Velocity Field at 120 Seconds

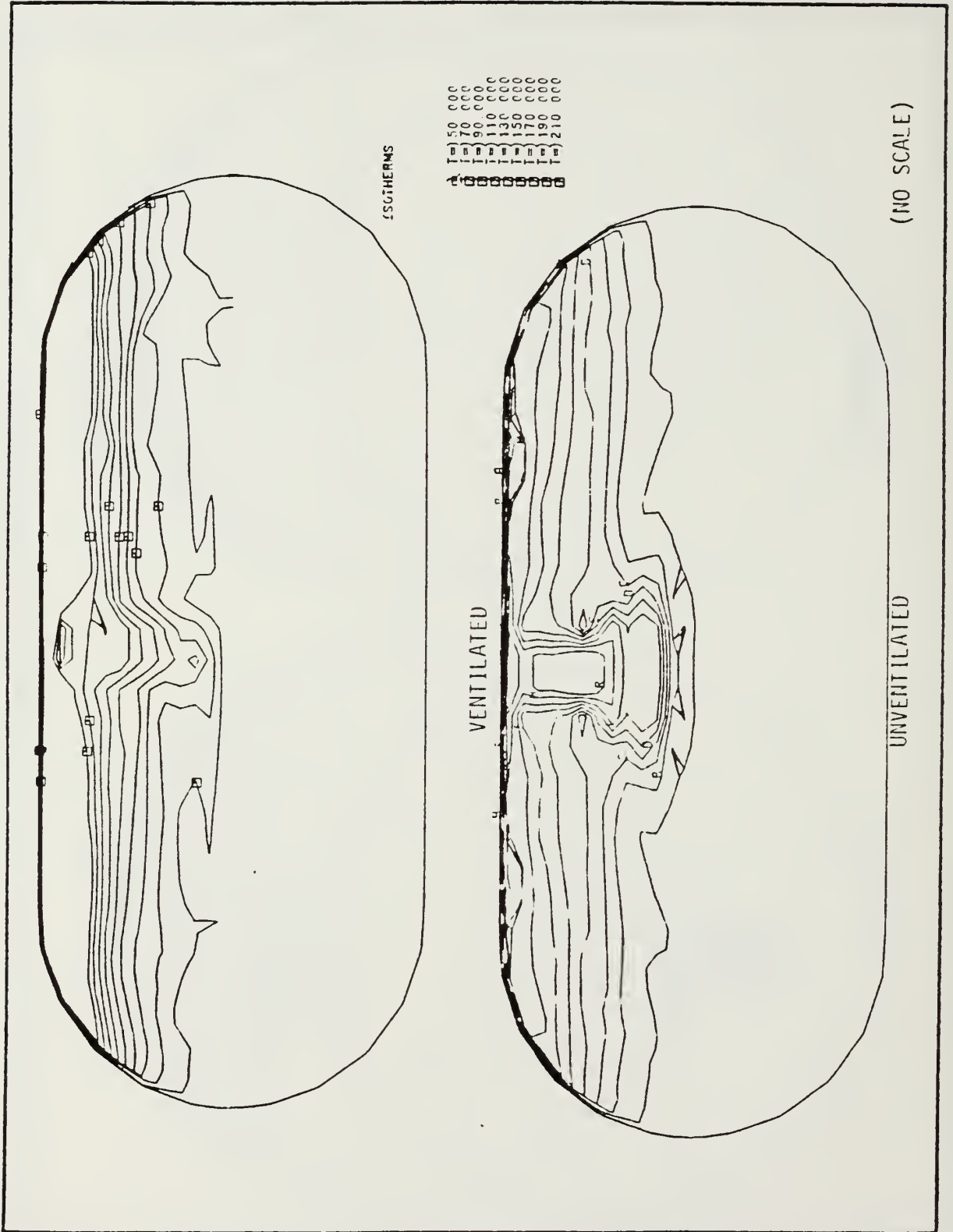


Figure 4-30. Mid-Section Front Views of Isotherms at 150 Seconds

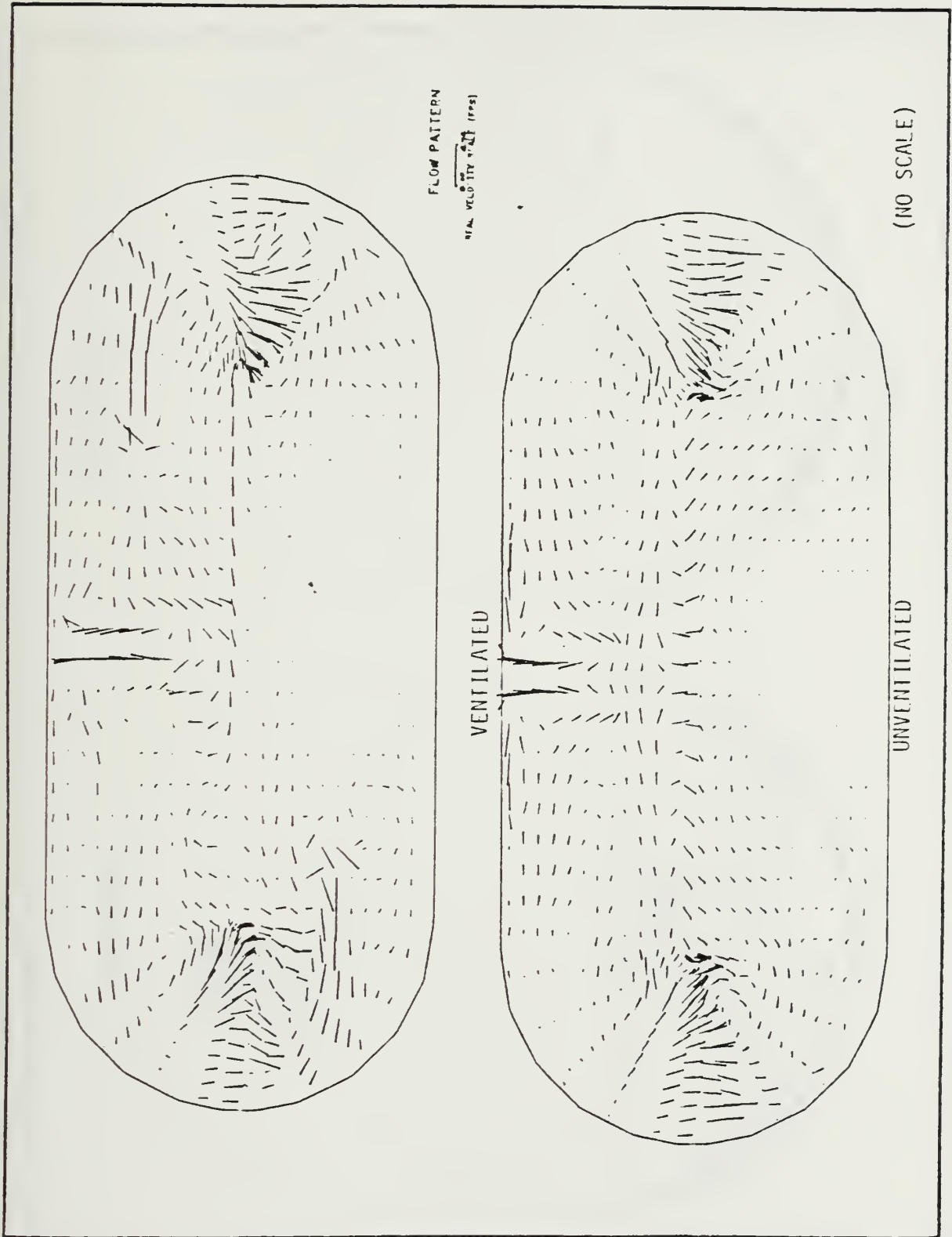


Figure 4-31. Mid-Section Front Views of Velocity Field at 150 Seconds

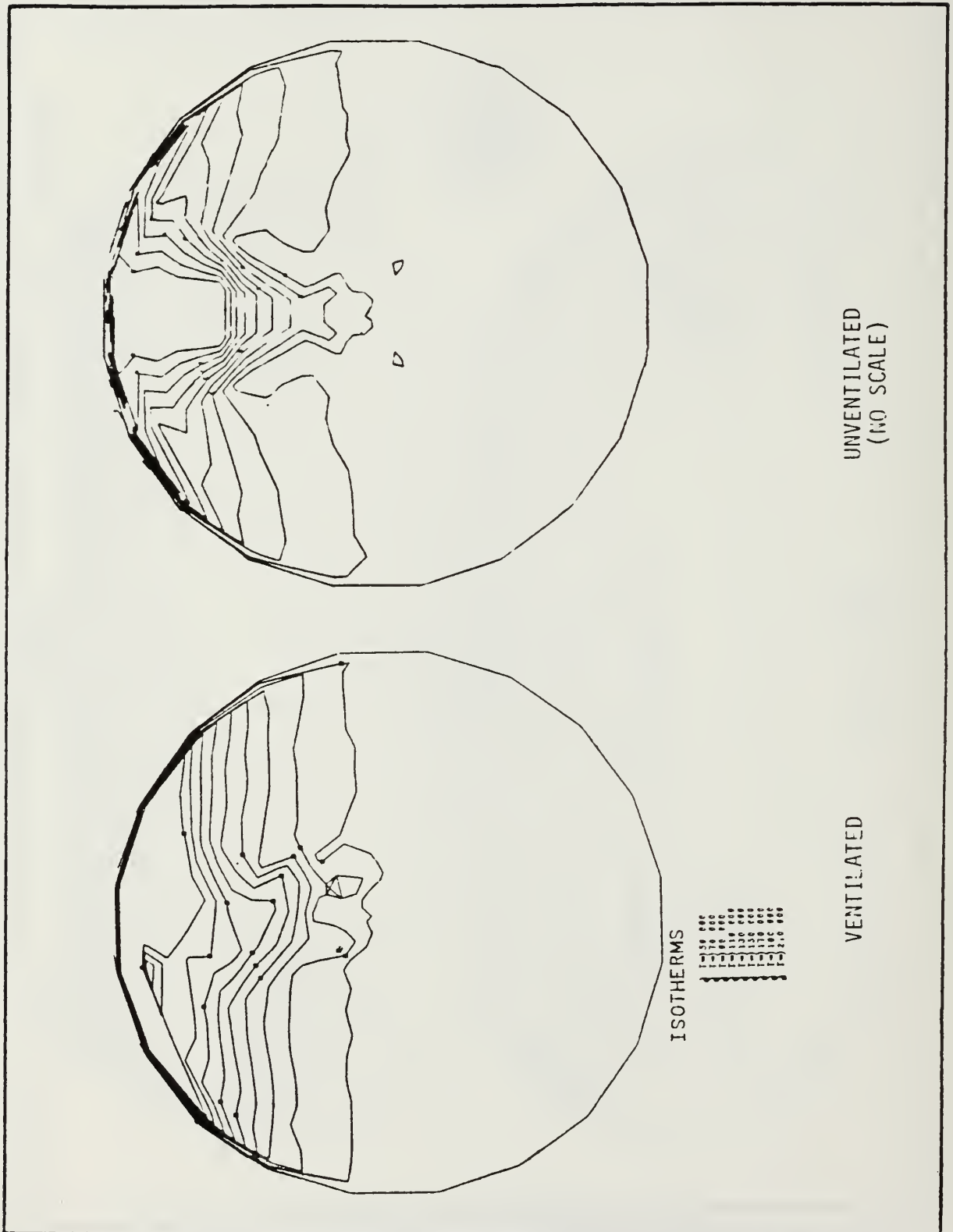


Figure 4-32. Mid-Section End Views of Isotherms at 150 Seconds

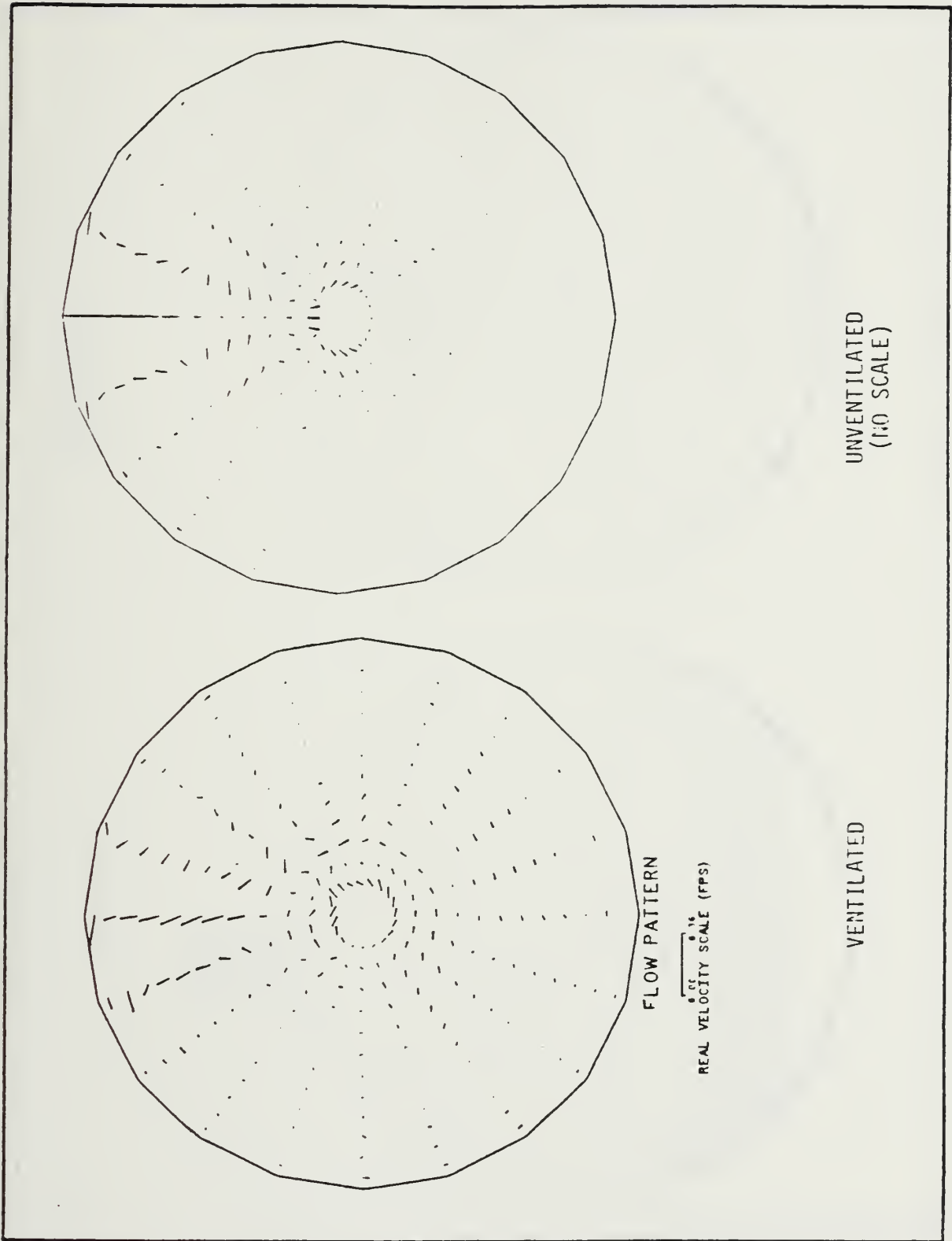


Figure 4-33. Mid-Section End Views of Velocity Field at 150 Seconds

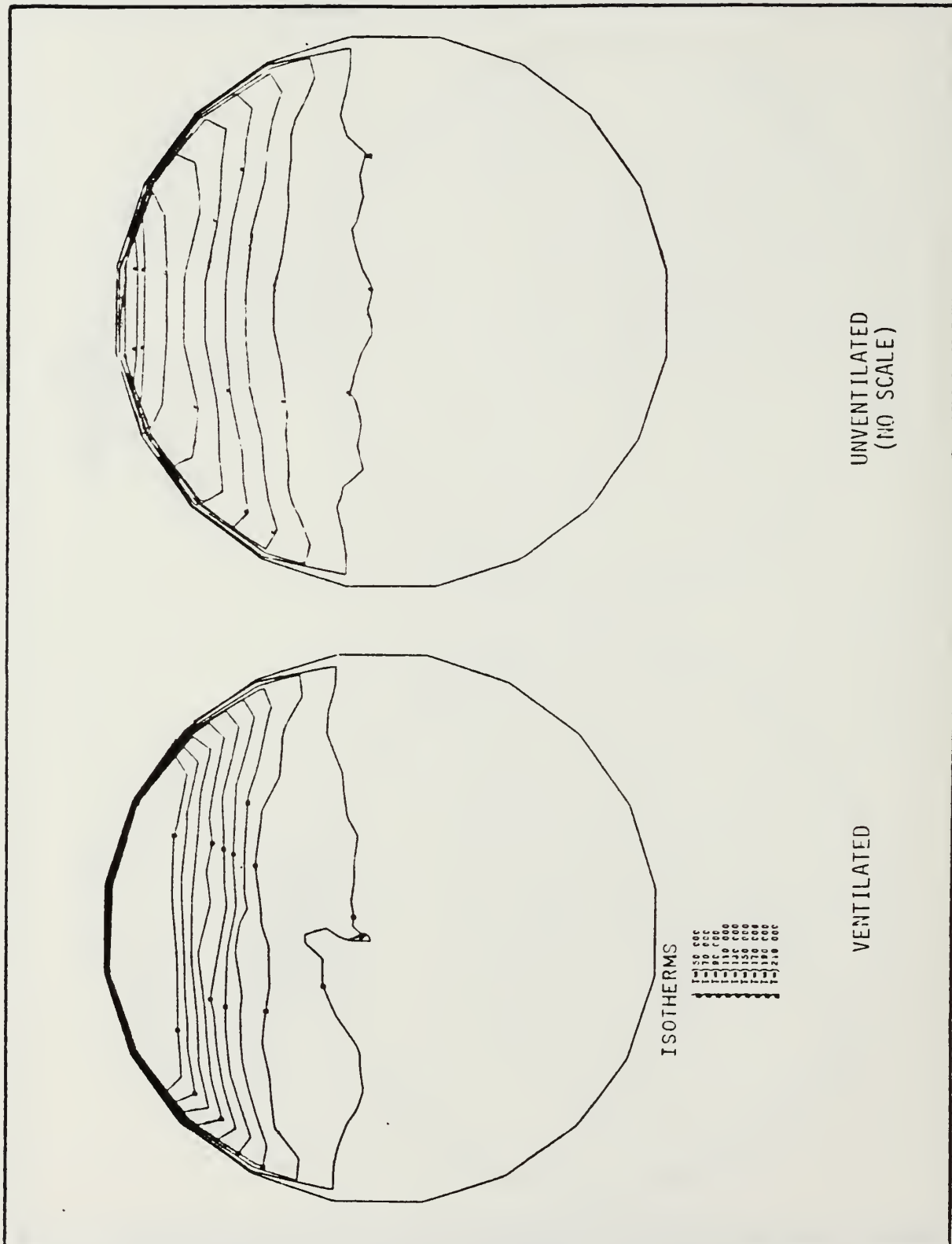


Figure 4-34. Section View at Base of End Cap of Isotherms at 150 Seconds

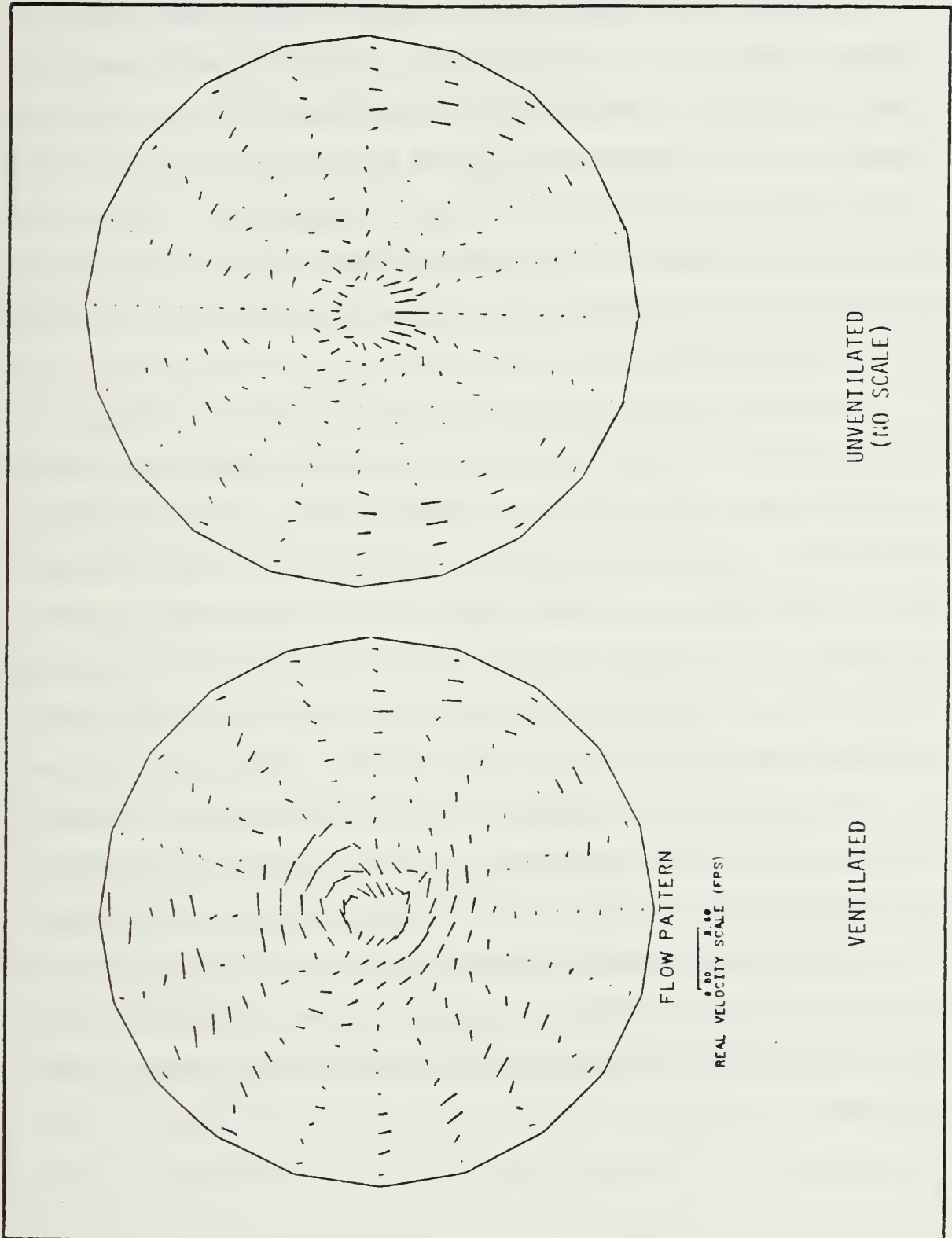


Figure 4-35. Section View at Base of End Cap of Velocity Field at 150 Seconds



and it dominates the local velocity field. As can be seen in Figures 4.12 through 4.33, the plume continues to dominate the field throughout the fire. The plume begins at the heat source and flows straight up until it reaches the ceiling, then it divides and flows towards either end of the vessel. In the local area of the fire, there is some entrainment of the field due to the plume flow. Due to the strength of the plume velocity, and the absence of any strong global circulation, the flame plume divides the velocity field in half, isolating the north and south regions.

The flow in the hot ceiling layer does not appear to have strong enough momentum to carry it into the lower half of the tank, even in the south end, where the fan augments the flow. Instead, the flow recirculates into the tank interior, resulting in a downward-biased flow. It then returns to the fire region in a somewhat spatially oscillatory path. As can be seen in Figures 4.8, 4.10, and the other end views of the velocity field, there is a spiral flow circulation pattern in the ventilated case. This creates a more stagnant region to the right of the vertical center line. Figures 4.7, 4.9, and the other end views of isotherms show higher temperatures in this stagnant region because the heated fluid is not being convectively transferred. It also makes the conductive heat transfer through the tank wall in the region more important, as the temperature is higher. In the nonventilated case, the flow fields and isotherms appears to be symmetric about the vertical plane.

As mentioned previously, the velocity of the fans is a constant 3.18 feet per second. This velocity is on the same order of magnitude as the flame plume, but since each fan is directed only toward the end caps, their impact on the global velocity field is not significant. The fan entrainment creates only a small local disturbance to the global flow pattern. The north fan outlet, in the lower region of the vessel, has little effect upon the global velocity since the global velocity in the region is very small, as seen in the nonventilated case. The fans effect the heat distribution locally, as discussed in the next paragraph.

Figure 4.5 shows a hot layer along the ceiling of the tank, with the temperature highly stratified in the upper region. The lower two-thirds of the tank are still near the initial temperature. This temperature distribution is exactly what the velocity field suggests, flow only in the upper third of the tank, and little flow in the bottom two-thirds. In Figures 4.12, 4.18, 4.24, and 4.30, the temperature stratification continues, but the heated fluid is slowly progressing toward the bottom of the tank. Even at 150 seconds, Figure 4.30 shows that the first isotherm, representing 15 degrees Centigrade above ambient, is only at the middle of the tank. The bottom half of the tank experiences very little temperature increase. In the ventilated case, the isotherms in the north end cap are higher than in the south. This can be attributed to the fans at either end which push up the heated fluid in the north end and push down the heated fluid in the south end. The effect is limited to a small region in the end cap because the fan velocity is relatively low and the flow is parallel to the isotherms.

Since flow is along the stratification, very little mixing of different temperature gases occurs except in the end caps, where flow is forced into a single region. Had the fans been oriented in a direction not parallel to the isotherms, one would expect the temperatures in the lower portion of the tank to be more affected.

One anomaly which appears in the ventilated case is the second circulation at the base of the flame plume on the north side seen in Figure 4.11. The flow in this region is flowing away from the flame plume until it turns upward as it hits the flow returning to the plume from the end caps. It is believed that this is a transient phenomena due to the interaction between the fan and flame plume entrainments. As can be seen in Figures 4.6 and 4.13, the phenomenon has disappeared. Additional data for a time of 45 seconds, not included herein, shows no indication of the second circulation pattern. The effects of this second circulation pattern can be easily seen in the temperature field in Figure 4.11.

Figures 4.36 through 4.39 present the data from the ventilated and nonventilated cases. Figure 4.36 shows that the global pressure in both cases is not very different. The differences can be attributed to two causes. First, the entire field is not at a thermodynamic equilibrium state, and the relationship between the global pressure and a field not in thermodynamic equilibrium is only an estimation. Any change to the field which would closer approach equilibrium, such as the mixing due to the fans, would affect the global pressure. Second,

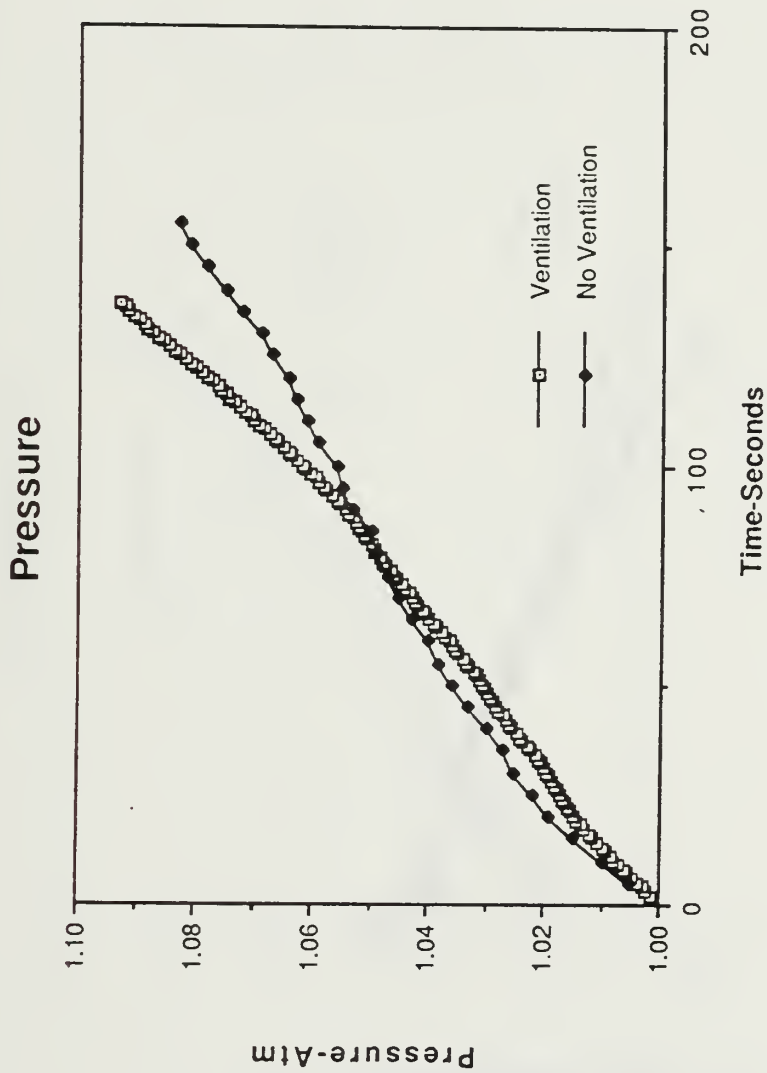


Figure 4-36. Pressure Curves for the Ventilated and Nonventilated Cases

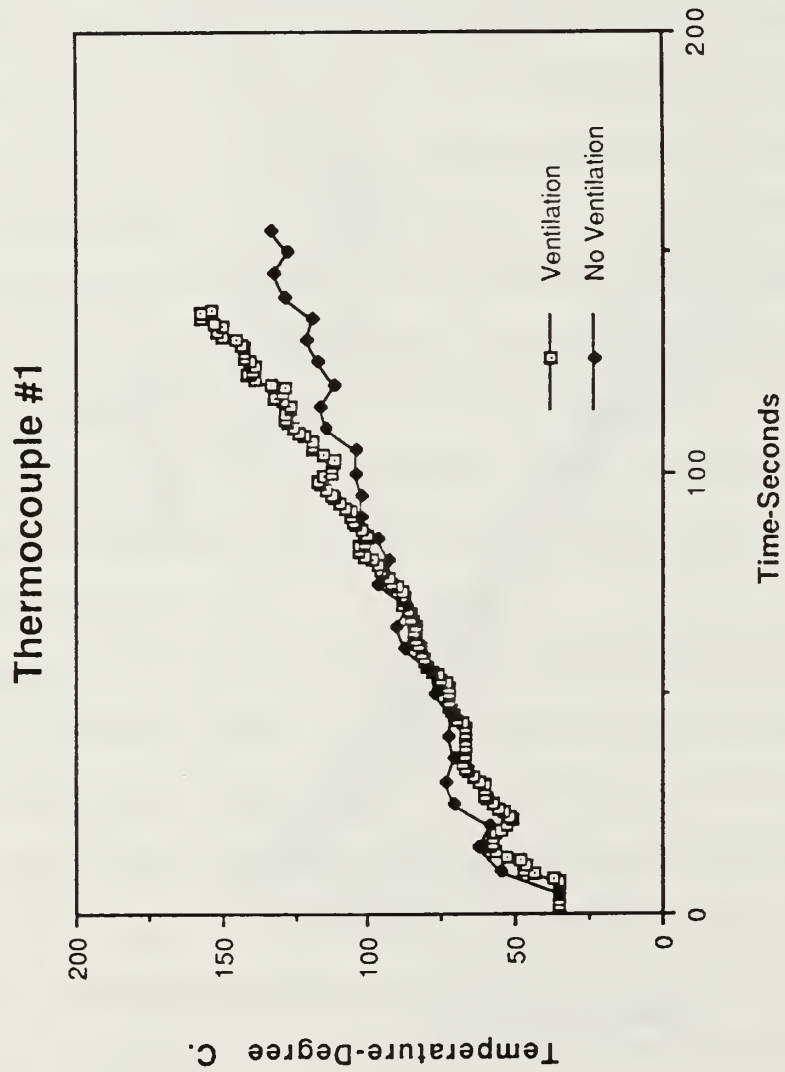


Figure 4-37. Thermocouple #1 Curves for the Ventilated and Nonventilated Cases

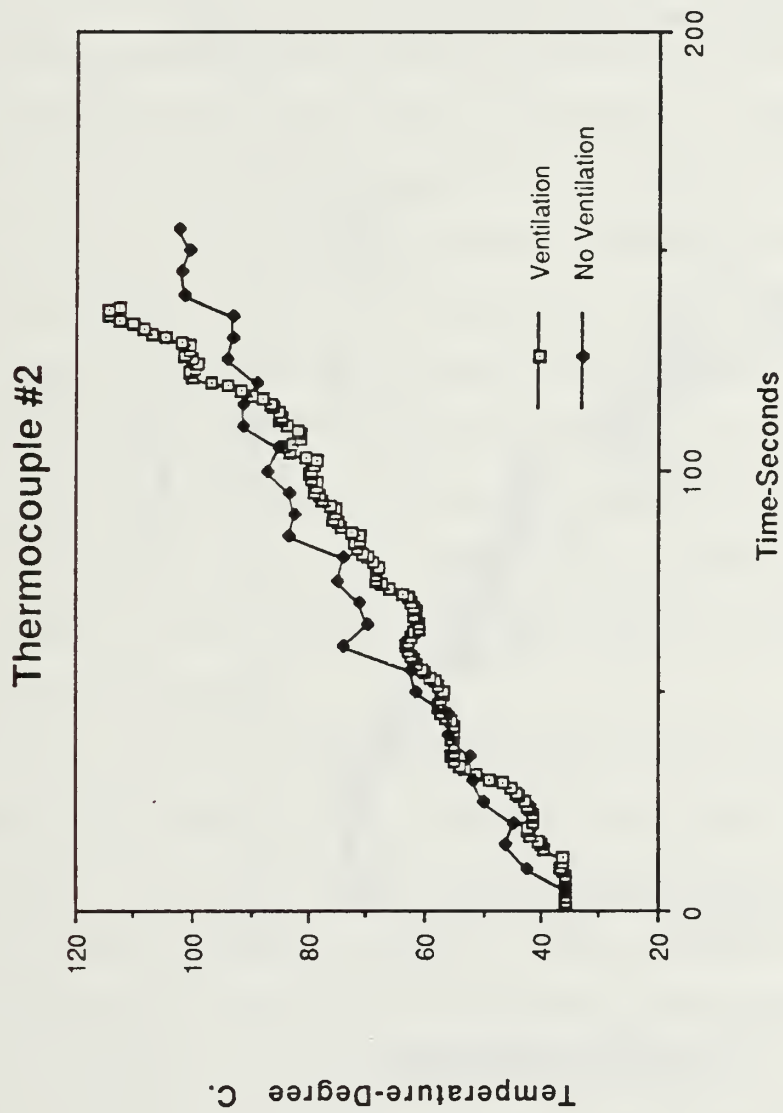


Figure 4-38. Thermocouple #2 Curves for the Ventilated and Nonventilated Cases

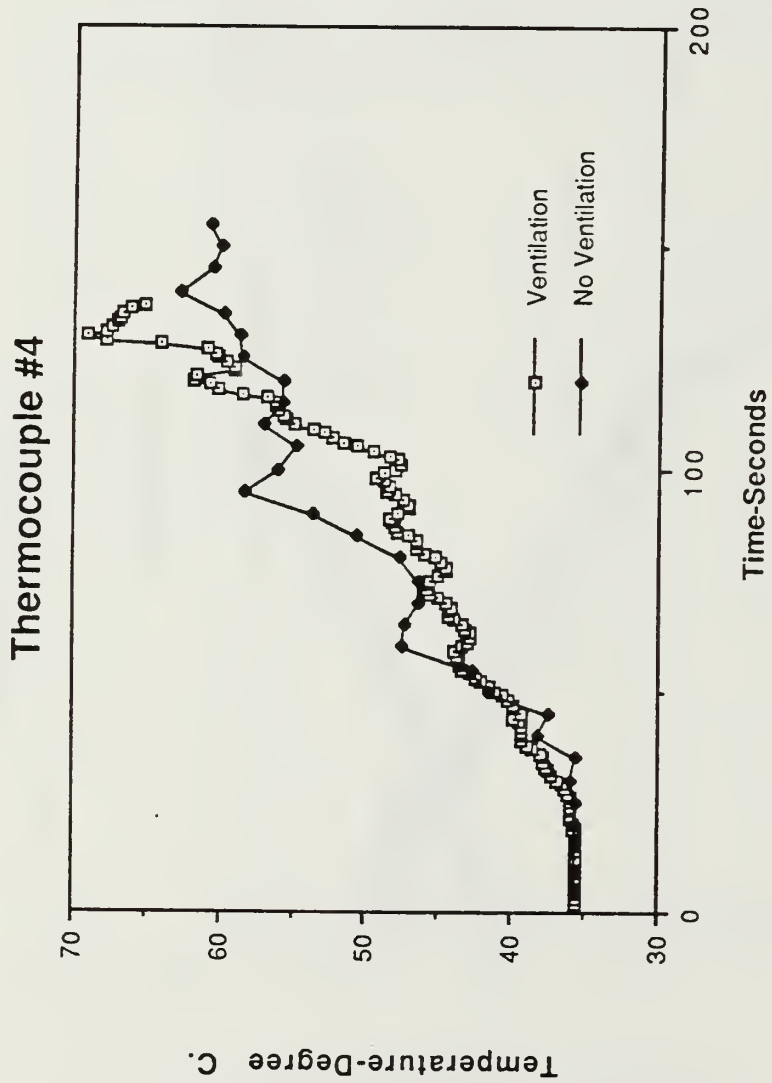


Figure 4-39. Thermocouple #4 Curves for the Ventilated and Nonventilated Cases

the fire is still in its first stages, and the entire field is rapidly changing. This dynamic situation, along with the approximations inherent in modeling, can also account for differences in the ventilated and nonventilated fields.

Figures 4.37 through 4.39 show the thermocouple temperatures versus time; the results are similar to the pressure, with the ventilated case increasing more slowly but then catching up to the nonventilated case, exceeding it at around 80 to 110 seconds. Since the thermocouples are in the north end cap, they are in the area in which the isotherms are pushed upward by the fan. This could explain why the temperatures are lower in the ventilated case. The temperatures exhibit some local fluctuations which could be the result of thermal instability associated with thermal plumes [Ref. 37]. In Figure 4.39 it appears that there are large oscillations, but the scale on the graph is smaller so that the temperature oscillation of all three thermocouples is in the same range. These oscillations appear in both the ventilated and nonventilated cases.

In most numerical models, the time step is an important factor. A small time step uses too much computer time, while too large a time step results in instability of the model. In this study, two trials were conducted with different time steps. In the first trial, a time step of 0.0288 seconds was used up to 40 seconds of fire time, and then the step was reduced to 0.0192. In the second trial, the beginning time step was 0.1152 seconds until 6 seconds of fire time, when the model



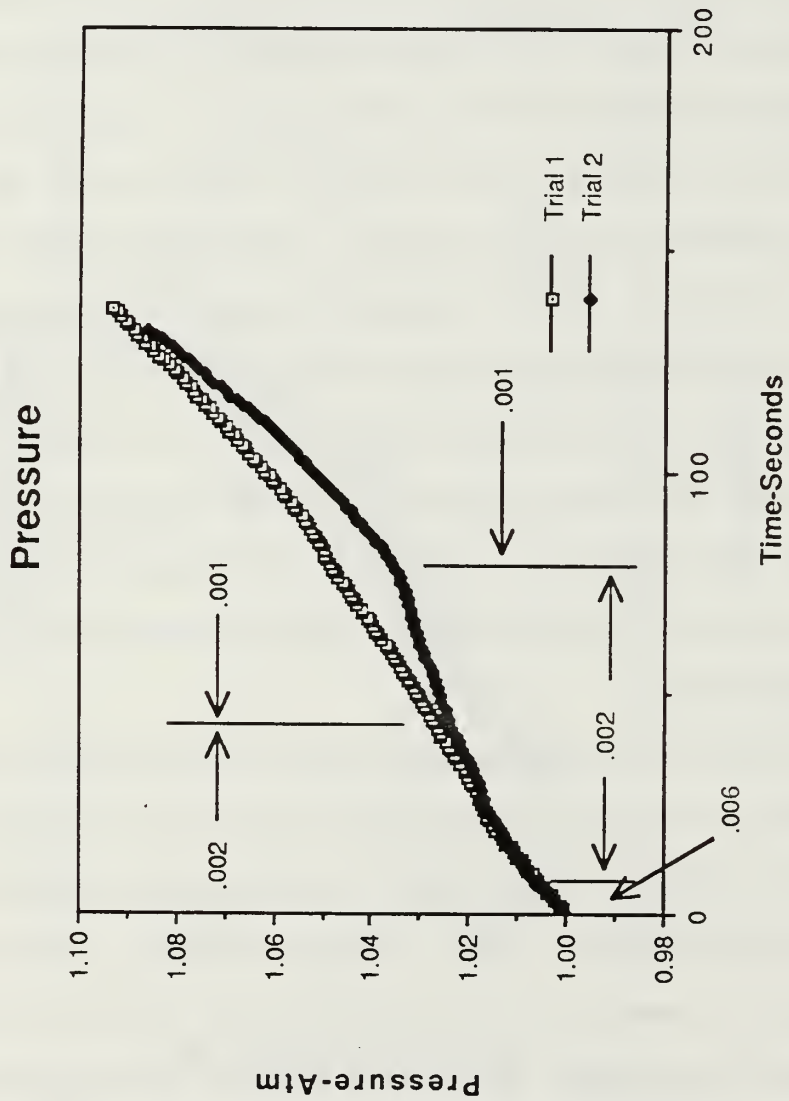


Figure 4-40. Pressure Curves for Trials 1 and 2

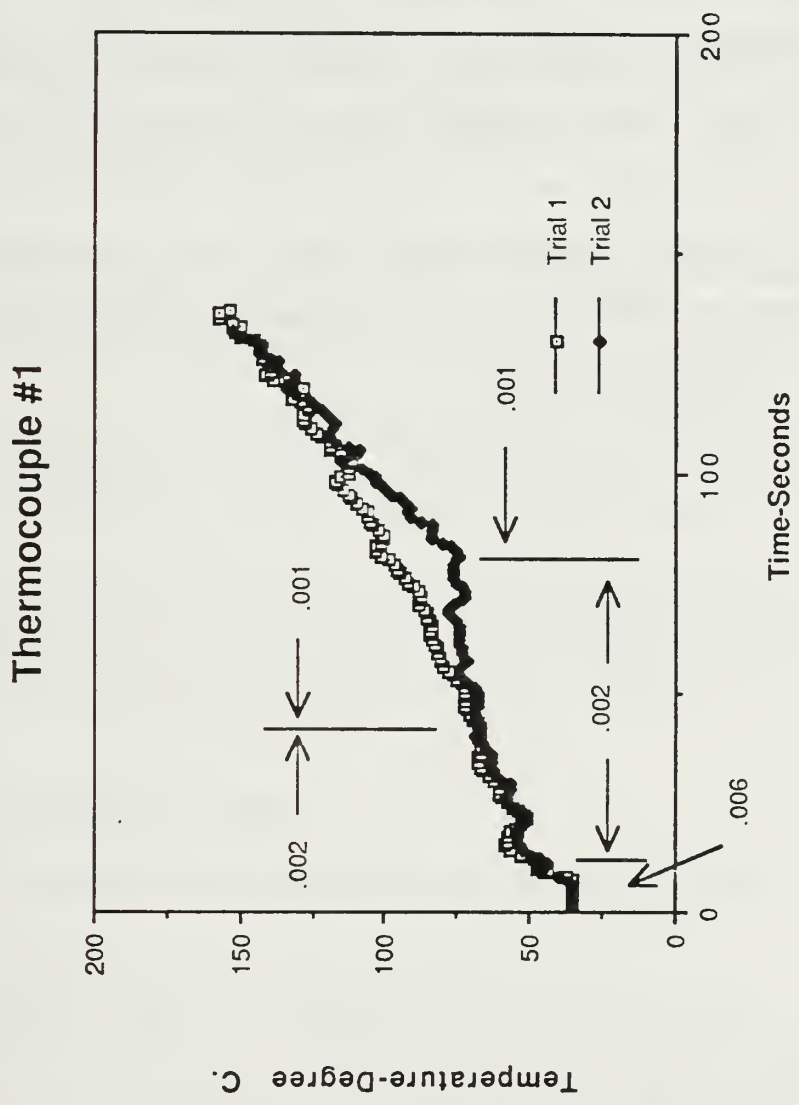


Figure 4-41. Thermocouple #1 Curve for Trials 1 and 2

became unstable. At that time, the time step was reduced to 0.0288 and further reduced to 0.0192 near 80 seconds, when it again became unstable. Figures 4.40 and 4.41 show the global pressure and temperature of thermocouple number 1 versus time for both trials. Note that the curves are coincident for the first 20 seconds, then diverge until approximately 90 seconds, when they begin to converge. At the end of the runs, both the pressure and temperature appear to become coincident once again. Since the only difference between these two runs was the time step difference, it is evident that time step does affect the transient results in this computer model. Also interesting is that it appears that solutions using different time steps would become the same after a long period of time.

## **V. CONCLUSIONS AND RECOMMENDATIONS**

### **A. CONCLUSIONS**

Several conclusions may be drawn from this simulation model of the FIRE-1 test facility with ventilation:

1. The ventilation model has been successfully incorporated into the numerical model of FIRE-1. The local velocity fields in the region of the fans exhibit a realistic behavior. The global effect of the fans is small due to the relatively low velocity and because the flow is parallel to the isotherms.
2. The global flow field exhibited appears realistic. The fire plume increases the gas velocity upward, resulting in a ceiling jet which is the dominant flow in the field. The flow recirculates within the field with minor variations caused by the ventilation.
3. The isotherms depict the concentration of hot gases in the top of the field. These hot gases stratify and slowly diffuse downward as time progresses. The isotherms are affected by the ventilation in the end cap region, where they are pushed upward or downward.
4. A small change in the time step makes a discernable difference in the transient solution. With different time steps, the transient solutions are different. When the time steps are the same, the previously diverging transient solutions appear to converge and become coincident.

### **B. RECOMMENDATIONS**

The following recommendations are made for future work on the numerical model:

1. Additional FIRE-1 experiments are needed to better validate the numerical model. Accurate heat-release rate data must be obtained and included in the model, instead of using a synthesized rate. Additionally, sensors should be placed at different locations in the vessel to better validate the numerical results throughout the field.

2. Develop and incorporate additional models to simulate physical phenomena such as gaseous radiation and combustion.
3. Continue to expand and validate the model to include decks, equipment in the space, and fire-extinguishing systems.
4. Since the model uses an extensive amount of computer time, it is imperative that the numerical model be transferred to a super-computer or a dedicated mini-computer.
5. The ultimate goal of this project is to develop a computer model for predicting fire and smoke phenomena in shipboard situations. Completion of this goal will offer ship designers and engineers with a valuable tool to design and build safer ships and submarines.

# APPENDIX

## COMPUTER PROGRAM

```

C ***** 00000100
C ** ** 00000200
C ** THREE-DIMENSIONAL NUMERICAL SIMULATION ** 00000300
C ** OF A FIRE SPREAD INSIDE A NAVY STORAGE TANK ** 00000400
C ** ** 00000500
C ** DEVELOPED BY : ** 00000600
C ** H.Q. YANG AND K.T. YANG ** 00000700
C ** ** 00000800
C ** DEPARTMENT OF AEROSPACE & MECHANICAL ENGINEERING ** 00000900
C ** UNIVERSITY OF NOTRE DAME ** 00001000
C ** NOTRE DAME, INDIANA, 46556 ** 00001100
C ** ** 00001200
C ** DEC. 1986 ** 00001300
C ** ** 00001400
C ***** 00001500
C 00001600
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93), 00001700
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93) 00001800
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR 00001900
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00002000
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NEM1,KRUN,NCHIP,NJRA,NWRP 00002100
COMMON/BL12/ NWRITE,NTAPE,NTMAX,NTREAL,TIME,SORSUM,ITER 00002200
COMMON/BL14/HCOEF,TINF,CNT,ASTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM2 00002300
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST5,NT,UO,H,UGRT,BUOY,00002400
& CPO,PRT,CONDO,VISO,RHOO,HR,TP,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0002500
COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32) 00002600
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32) 00002700
COMMON/BL22/ICHFB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10), 00002800
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10) 00002900
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32) 00003000
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32) 00003100
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) 00003200
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00003300
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32) 00003400
& ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32) 00003500
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00003600
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32), 00003700
& DU(22,16,32),DV(22,16,32),DN(22,16,32) 00003800
COMMON/BL35/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32), 00003900
& AS(22,16,32),AF(22,16,32),AB(22,16,32), 00004000
& SPI(22,16,32),SU(22,16,32),RI(22,16,32) 00004100
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579) 00004200
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00004300
COMMON/BL38/NTHCO,CX(12),CY(12),CZ(12),NTH(12,3),TCOUP(12) 00004400
COMMON/BL39/ALEW,PCURVE,CONSR,PCURM1,PSOUTH,QCORR,PERROR 00004500
DIMENSION VFMXC(579,579),T4WALL(579) 00004600
DATA N,ITLEFT,SORMAX,XTIME,ITMAX/20,400000,0.40,0.0,4/ 00004700
00004800
00004900
00005000
00005100

```



```

999 CONTINUE                                00010700
      REWIND 11                              00010800
      CLOSE (11)                             00010900
                                          00011000
C #####                                00011100
C      INITIALIZE THE WHOLE FIELD            & 00011200
C #####                                00011300
      CALL INIT                              00011400
                                          00011500
C #####                                00011600
C      START CALCULATION                    & 00011700
C #####                                00011800
      NT=0                                   00011900
      NTIM=0                                00012000
                                          00012100
300 CONTINUE                                00012200
                                          00012300
      NT=NT+1                               00012400
                                          00012500
C ***      NTMAX0 HAS THE MEANING AS "NTREAL" WHEN IT IS READ FROM
C          DISK OR TAPE.                    00012600
                                          00012700
      IF(XTIME .GT. TMAX) GO TO 303         00012800
      NTREAL=NT+NTMAX0                     00012900
      TIME=TIME+DTIME                       00013000
      XTIME=TIME*H/UO                       00013100
                                          00013200
                                          00013300
                                          00013400
                                          00013500
C#####                                00013600
C      CALCULATE THE TRANSIENT HEAT INPUT  & 00013700
C      NOTE IF 1 IN PARENTHESES, THE BURN RATE IS CALCULATED & 00013800
C      BY THE PRESSURE CURVE. IF EQUAL TO TWO, THE BURN RATE & 00013900
C      CURVE IS EITHER GIVEN OR ESTIMATED & 00014000
C#####                                00014100
      CALL CALQ(2)                          00014200
                                          00014300
C ***      START CALCULATION                00014400
                                          00014500
      ITER=0                                00014600
      JTERM=0                               00014700
      JJTERM=0                             00014800
                                          00014900
C      DEFINE THE UPDATED TPD(I,J,K), CPD(I,J,K),RPD(I,J,K) 00015000
C      UPD(I,J,K) AND VPD(I,J,K) FOR THE USE OF CALVIS AND SU(I,J,K) 00015100
                                          00015200
      DO 48 K=1,NKPI                         00015300
      DO 48 J=1,NJPI                         00015400
      DO 48 I=1,NIPI                         00015500
      TPD(I,J,K)=T(I,J,K)                   00015600
      CPD(I,J,K)=C(I,J,K)                   00015700
      RPD(I,J,K)=R(I,J,K)                   00015800
      UPD(I,J,K)=U(I,J,K)                   00015900
      VPD(I,J,K)=V(I,J,K)                   00016000
      WPD(I,J,K)=W(I,J,K)                   00016100

```



48 CONTINUE	00016200
29 CONTINUE	00016300
JTERM=JTERM+1	00016400
301 CONTINUE	00016500
	00016600
	00016700
C#####	00016800
C CALCULATE THE RADIATION HEAT FLUX AT EVERY NRAD TIME STEPS &	00016900
C#####	00017000
	00017100
NRAD = 2	00017200
IF (MOD(INT,NRAD).NE.0) GOTO 4000	00017300
CALL RADHT(T4WALL,VFMXC)	00017400
4000 CONTINUE	00017500
	00017600
C#####	00017700
C CALCULATE THE TEMPERATURE	00017800
C#####	00017900
CALL CALT	00018000
	00018100
C#####	00018200
C CALCULATE THE SMOKE CONCENTRATION	00018300
C#####	00018400
C CALL CALC	00018500
	00018600
DO 2000 J=1,NJP1	00018700
DO 2000 I=1,NIP1	00018800
DO 2000 K=1,NKP1	00018900
IF(T(I,J,K).LT.TCOOL) T(I,J,K)=TCOOL	00019000
2000 CONTINUE	00019100
C#####	00019200
C GLOBLE PRESSURE CORRECTION FOR ENCLOSED TANK AIR	00019300
C#####	00019400
CALL GLOBE	00019500
	00019600
C#####	00019700
C CALCULATE THE TURBULENT VISCOSITY AND CONDUCTIVITY	00019800
C#####	00019900
CALL CALVIS	00020000
	00020100
C#####	00020200
C CALCULATE THE OENSIY	00020300
C#####	00020400
DO 100 J=1,NJP1	00020500
DO 100 I=1,NIP1	00020600
DO 100 K=1,NKP1	00020700
IF (MOD(I,J,K).EQ.1) GOTO 100	00020800
AAAA=BUOY*UGRT*HEIGHT(I,J,K)	00020900
R(I,J,K)=(UGRT*P(I,J,K)+(1./EXP(AAAA)))/T(I,J,K)	00021000
100 CONTINUE	00021100
	00021200
C#####	00021300
C CORRECT CONDUCTIVITY OF THE SOLID	00021400
C#####	00021500
IF (NCHIP.EQ.0) GOTO 410	00021600

CALL SOLCON	00021700
410 CONTINUE	00021800
////////////////////////////////////	00021900
C START PRESSURE CORRECTION ITERATIVE LOOP, IT IS THE MAJOR %	00022000
C PART OF THE ERROR CONTROL ROUTINE %	00022100
////////////////////////////////////	00022200
ITER=ITER+1	00022300
	00022400
	00022500
	00022600
CC	00022700
C CALCULATE THE VELOCITY U,V,AND W	00022800
CC	00022900
	00023000
CALL CALU	00023100
CC CALL STRESS	00023200
C *** *****	00023300
CALL CALV	00023400
CC CALL STRESS	00023500
C *** *****	00023600
CALL CALW	00023700
CC CALL STRESS	00023800
C *** *****	00023900
	00024000
CC	00024100
C CALCULATE THE PRESSURE AND STRESS	00024200
CC	00024300
	00024400
CALL CALP	00024500
CALL STRESS	00024600
	00024700
////////////////////////////////////	00024800
C IF SOURCE TERM IS LARGER THAN 10.0, STOP PROGRAM %	00024900
////////////////////////////////////	00025000
IF (RESORM(ITER).GT.10.0) GOTO 2020	00025100
	00025200
	00025300
	00025400
IF(RESORM(ITER) .LE. SORMAX) GO TO 49	00025500
IF(ITER .EQ. 1) GO TO 302	00025600
ITERM1=ITER-1	00025700
IF(RESORM(ITER) .LE. RESORM(ITERM1)) GO TO 302	00025800
GO TO 304	00025900
302 IF(JTERM .GE. 2) GO TO 37	00026000
SOURCE=RESORM(ITER)	00026100
GO TO 36	00026200
37 IF(RESORM(ITER) .LE. SOURCE) GO TO 38	00026300
GO TO 304	00026400
38 SOURCE=RESORM(ITER)	00026500
39 CONTINUE	00026600
WRITE(6,95) ITER,RESORM(ITER),SORSUM	00026700
95 FORMAT(53X,'ITER=',I2,2X,'SOURCE=',F9.6,2X,'SORMUP=',F9.6)	00026800
DO 23 K=1,NKP1	00026900
DO 23 J=1,NJP1	00027000
DO 23 I=1,NIP1	00027100
TPD(I,J,K)=T(I,J,K)	

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CPD(I,J,K)=C(I,J,K) 00027200
RPD(I,J,K)=R(I,J,K) 00027300
UPD(I,J,K)=U(I,J,K) 00027400
VPD(I,J,K)=V(I,J,K) 00027500
WPD(I,J,K)=W(I,J,K) 00027600
PPD(I,J,K)=P(I,J,K) 00027700
23 CONTINUE 00027800
JJTERM=0 00027900
IF(ITER .EQ. ITMAX) GO TO 49 00028000
IF(JJTERM .EQ. 2) GO TO 35 00028100
IF(ITER .EQ. 4) GO TO 29 00028200
35 CONTINUE 00028300
IF(JJTERM .EQ. 3) GO TO 58 00028400
IF(ITER .EQ. 7) GO TO 29 00028500
58 CONTINUE 00028600
JJTERM=0 00028700
GO TO 301 00028800
304 CONTINUE 00028900
JJTERM=JJTERM+1 00029000
IF(JJTERM .EQ. 1) WRITE(6,95) ITER,RESORM(ITER),SORSUM 00029100
IF(JJTERM .EQ. 1) GO TO 41 00029200
IF(JJTERM .EQ. 2 .AND. JJTERM .EQ. 1 .AND. ITER .NE. 5) GO TO 41 00029300
GO TO 82 00029400
41 CONTINUE 00029500
DO 40 K=1,NKP1 00029600
DO 40 J=1,NJP1 00029700
DO 40 I=1,NIP1 00029800
R(I,J,K)=RPD(I,J,K) 00029900
U(I,J,K)=UPD(I,J,K) 00030000
V(I,J,K)=VPD(I,J,K) 00030100
W(I,J,K)=WPD(I,J,K) 00030200
P(I,J,K)=PPD(I,J,K) 00030300
40 CONTINUE 00030400
IF(ITER .EQ. ITMAX) GO TO 49 00030500
GO TO 29 00030600
82 CONTINUE 00030700
DO 43 K=1,NKP1 00030800
DO 43 J=1,NJP1 00030900
DO 43 I=1,NIP1 00031000
T(I,J,K)=TPD(I,J,K) 00031100
C(I,J,K)=CPD(I,J,K) 00031200
R(I,J,K)=RPD(I,J,K) 00031300
U(I,J,K)=UPD(I,J,K) 00031400
V(I,J,K)=VPD(I,J,K) 00031500
W(I,J,K)=WPD(I,J,K) 00031600
P(I,J,K)=PPD(I,J,K) 00031700
43 CONTINUE 00031800
IF(ITER .EQ. ITMAX) GO TO 49 00031900
IF((JJTERM .EQ. 3 .AND. ITER .NE. 8) .OR. JJTERM .EQ. 2) GO TO 49 00032000
GO TO 301 00032100
49 CONTINUE 00032200
ITERT=ITERT+ITER 00032400
C##### 00032500
C GO TO THE PRESSURE TRACKING SUBROUTINE ,PRINT OUT # 00032600

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C RESULTS IF AT THE RIGHT TIME INTERVAL # 00032700
C##### 00032800
CALL PTRACK 00032900
IF (MOD(NTREAL,NWRP).EQ.0) CALL OUT(1) 00033000
C// 00033100
C FIND TEMPERATURES AT THERMOCOUPLE POINTS AND PRINT OUT % 00033200
C IF AT THE RIGHT TIME INTERVAL % 00033300
C// 00033400
CALL TCP 00033500
IF (MOD(NTREAL,NWRP).EQ.0) CALL OUT(2) 00033600
2422 CONTINUE 00033700
IF (MOD(NTREAL,NWRITE).EQ.0) CALL OUT(3) 00033800
C IF(NTREAL .EQ. NTREAL/NWRITE*NWRITE) CALL OUT(3) 00033900
505 CONTINUE 00034000
IF((XTIME+DTIME*H/UO) .GE. TMAX) GO TO 277 00034100
C *** 00034200
C CALL TLEFT(IT) 00034300
C 123 FORMAT(' ILEFT = ',I10) 00034400
C ITD=IT 00034500
C IF(IT.LT.ILEFT) CALL OUT(3) 00034600
C *** 00034700
C *** 00034800
C *** 00034900
C *** 00035000
C *** 00035100
C *** 00035200
C *** 00035300
C *** 00035400
C *** 00035500
C *** 00035600
C *** 00035700
C *** 00035800
C *** 00035900
C *** 00036000
C *** 00036100
C *** 00036200
C *** 00036300
C *** 00036400
C *** 00036500
C *** 00036600
C *** 00036700
C *** 00036800
C *** 00036900
C *** 00037000
C *** 00037100
C *** 00037200
C *** 00037300
C *** 00037400
C *** 00037500
C *** 00037600
C *** 00037700
C *** 00037800
C *** 00037900
C *** 00038000
C *** 00038100

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522 CONTINUE
C *** *****
C CALL TLEFT(IT)
C IF(IT.LT.ITLEFT) GO TO 166
C *** *****
C TIMREM IS USED TO CALCULATE THE CPU TIME REMAINING AT NPS
      IF (TIMREM(0.).LE.80.) GOTO 166
      GO TO 300
303 CONTINUE
277 CONTINUE
      WRITE(6,1111)
1111 FORMAT(2X,'***** THE MAXIMUM TIME HAS BEEN REACHED *****',I8)
      GO TO 172
C *** *****
166 IF(NTREAL .NE. NTREAL/NTAPE*NTAPE) WRITE(9)
      & TIME,NTREAL,T,R,U,V,W,P,CPM,COND,VIS,QRNET,ITERT,QCORRT,PM1,PM2,
      & H,TA,UO,CONDO,VISO,RHOO,NI,NJ,NK,NIP1,NJP1,NKP1,NIM1,NJM1,NKM1,
      & XC,YC,ZC,XS,YS,ZS,DXXC,DYYC,DZZC,DXXS,DYYS,DZZS
      REWIND 9
C *** *****
      GOTO 172
2020 CONTINUE
      WRITE (6,*) ' RESIDUAL MASS IS LARGER THAN 10.0, PROGRAM STOPS'
172 CONTINUE
      STOP
      END
C
* *****
SUBROUTINE INPUT
* *****
* THIS SUBROUTINE SETS UP REQUIRED VALUES TO BEGIN THE PROGRAM.
* VARIABLES ARE:
*      KRUN      =      WHEN EQUAL TO ONE,READ FROM THE
*                   RESTART DISK, ELSE FROM THE JCL
*      NCHIP     =      NUMBER OF SOLID PIECES
*      NWRP      =      NUMBER OF TIME STEPS TO WRITE ON THE
*                   PAPER
*      NTHCO     =      NUMBER OF THERMOCOUPLES TO PRINT OUT
*      TMAX      =      MAXIMUM TIME ALLOWED (REAL)
*      TWRITE    =      SECONDS IN REAL TIME TO PRINT THE
*                   P,V,T FIELDS ON PAPER
*      TTAPE     =      TIME INTERVAL TO WRITE ON THE TAPE
*      DTIME     =      TIME STP (DIMENSIONLESS)
*      HSZ       =      HEAT SOURCE SIZE, USED TO CALCULATE
*                   THE VOLUME OF THE FIRE CELL
*      ICHPB     =      FIRST SOLID NODE IN THETA DIRECTION

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00038200
00038300
00038400
00038500
00038600
00038700
00038800
00038900
00039000
00039100
00039200
00039300
00039400
00039500
00039600
00039700
00039800
00039900
00040000
00040100
00040200
00040300
00040400
00040500
00040600
00040700
00040800
00040900
00041000
00041100
00041200
00041300
00041400
00041500
00041600
00041700
00041800
00041900
00042000
*00042100
*00042200
*00042300
*00042400
*00042500
*00042600
*00042700
*00042800
*00042900
*00043000
*00043100
*00043200
*00043300
*00043400
*00043500
*00043600

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*          JCHPB      =      FIRST SOLID NODE IN R DIRECTION      *00043700
*          KCHPB      =      FIRST SOLID NODE IN PHI DIRECTION   *00043800
*          NCHPI      =      NUMBER OF NODES IN THETA DIRECTION  *00043900
*          NCHPJ      =      NUMBER OF NODES IN R DIRECTION      *00044000
*          NCHPK      =      NUMBER OF NODES IN PHI DIRECTION     *00044100
*          CX,CY,CZ   =      THERMOCOUPLE POSITIONS IN THETA,R,PHI *00044200
> *****00044300
COMMON/R4/XC( 93 ),YC( 93 ),ZC( 93 ),XS( 93 ),YS( 93 ),ZS( 93 ),
&      DXXC( 93 ),DYXC( 93 ),DZZC( 93 ),DXXS( 93 ),DYYS( 93 ),DZZS( 93 ) 00044500
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR 00044600
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00044700
&      ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00044800
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER 00044900
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200045100
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00045200
&      CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00045300
COMMON/BL20/SIG11( 22,16,32 ),SIG12( 22,16,32 ),SIG22( 22,16,32 ) 00045400
&      ,SIG13( 22,16,32 ),SIG23( 22,16,32 ),SIG33( 22,16,32 ) 00045500
COMMON/BL22/ICHPB( 10 ),NCHPI( 10 ),JCHPB( 10 ),NCHPJ( 10 ),KCHPB( 10 ),
&      NCHPK( 10 ),TCHP( 10 ),CPS( 10 ),CONS( 10 ),WFAN( 10 ) 00045600
COMMON/BL31/ TODI( 22,16,32 ),ROD( 22,16,32 ),PODI( 22,16,32 ) 00045700
&      ,CODI( 22,16,32 ),UOD( 22,16,32 ),VOD( 22,16,32 ),WOD( 22,16,32 ) 00045800
COMMON/BL32/ T( 22,16,32 ),R( 22,16,32 ),P( 22,16,32 ) 00045900
&      ,C( 22,16,32 ),U( 22,16,32 ),V( 22,16,32 ),W( 22,16,32 ) 00046000
COMMON/BL33/ TPDI( 22,16,32 ),RPDI( 22,16,32 ),PPDI( 22,16,32 ) 00046100
&      ,CPDI( 22,16,32 ),UPDI( 22,16,32 ),VPDI( 22,16,32 ),WPD( 22,16,32 ) 00046200
COMMON/BL34/ HEIGHT( 22,16,32 ),REQI( 22,16,32 ),
&      SMP( 22,16,32 ),SMPP( 22,16,32 ),PP( 22,16,32 ), 00046300
&      DU( 22,16,32 ),DV( 22,16,32 ),DW( 22,16,32 ) 00046400
COMMON/BL36/AP( 22,16,32 ),AE( 22,16,32 ),AH( 22,16,32 ),AN( 22,16,32 ),
&      AS( 22,16,32 ),AF( 22,16,32 ),AB( 22,16,32 ), 00046500
&      SP( 22,16,32 ),SU( 22,16,32 ),RI( 22,16,32 ) 00046600
COMMON/BL37/ VIS( 22,16,32 ),COND( 22,16,32 ),NOD( 22,16,32 ),RWALL( 579)00047000
&      ,CPM( 22,16,32 ),HSZ( 3,2 ),NHSZ( 22,16,32 ),RESORM( 93 ) 00047100
COMMON/BL38/NTHCO,CX( 12 ),CY( 12 ),CZ( 12 ),NTH( 12,3 ),TCOUP( 12 ) 00047200
00047300
00047400
C #1. READ IN DATA TO INDICATE EITHER KRUN=0 OR 1 00047500
READ( 5,* ) KRUN,NCHIP,NWRP,NTHCO 00047600
00047700
C #2. READ IN DATA SET 1 - 6 DATA 00047800
READ( 5,* ) TMAX,TWRITE,TTAPE,DTIME 00047900
00048000
C #3. READ IN DATA FOR HEAT SOURCE 00048100
00048200
READ( 5,* ) HSZ( 1,1 ),HSZ( 1,2 ),HSZ( 2,1 ),HSZ( 2,2 ),HSZ( 3,1 ),HSZ( 3,2 ) 00048300
WRITE( 6,20 ) HSZ( 1,1 ),HSZ( 1,2 ),HSZ( 2,1 ),HSZ( 2,2 ),HSZ( 3,1 ),HSZ( 3,2 ) 00048400
20 FORMAT ( /,20X,'HEAT SOURCE LOCATION IS IN THE VOLUME (NON-DIME', 00048500
&      'NSIGNAL WITH RESPECT TO RADIUS)', 00048600
&      /,5X,'FROM ',F8.4,' TO ',F8.4,' IN X-DIRECTION', 00048700
&      /,5X,'FROM ',F8.4,' TO ',F8.4,' IN Y-DIRECTION', 00048800
&      /,5X,'FROM ',F8.4,' TO ',F8.4,' IN Z-DIRECTION',/) 00048900
00049000
00049100

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C #4. READ IN DECK DATA                                00049200
                                                         00049300
IF (NCHIP.EQ.0) GOTO 16                                00049400
PRINT *                                                00049500
PRINT *, '      THE REGION BOUNDED BY SOLID'          00049600
DO 19 N=1,NCHIP                                       00049700
READ (5,*) ICHPB(N),NCHPI(N),JCHPB(N),NCHPJ(N),KCHPB(N),
& NCHPK(N),TCHP(N),CPS(N),CONS(N),WFAN(N)           00049800
& WRITE (6,10) N,ICHPB(N),NCHPI(N),JCHPB(N),NCHPJ(N),KCHPB(N),
& NCHPK(N),TCHP(N),CPS(N),WFAN(N),CONS(N)          00049900
& 10 FORMAT (2X,'N= ',I2,' ICHPB= ',I2,' NCHPI= ',I2,' JCHPB= ',I2,
& ' NCHPJ= ',I2,' KCHPB= ',I2,' NCHPK= ',I2,' TCHP= ',F8.5,
& ' CPS= ',F8.5,/, ' WFAN = ',F12.5,' CONS= ',F12.5,/) 00050000
19 CONTINUE                                           00050100
16 CONTINUE                                           00050200
                                                         00050300
                                                         00050400
                                                         00050500
                                                         00050600
                                                         00050700
                                                         00050800
C #5. INPUT THERMOCOUPLE COORDINATE                   00050900
C IN TERMS OF X(THETA), Y(RADIUS),Z(PHI)              00051000
                                                         00051100
PRINT *                                                00051200
PRINT *, '      THERMOCOUPLE POSITION IN TERMS OF THETA, R, PHI' 00051300
PRINT *                                                00051400
DO 110 I=1,NTHCO                                       00051500
READ (5,*) CX(I),CY(I),CZ(I)                          00051600
WRITE (6,*) I, CX(I),CY(I),CZ(I)                      00051700
110 CONTINUE                                           00051800
                                                         00051900
RETURN                                                 00052000
END                                                    00052100
                                                         00052200
                                                         00052300
                                                         00052400
C _____ 00052500
C *** SUBROUTINE INIT 00052600
C *** 00052700
***** 00052800
* THIS SUBROUTINE INITIALIZES THE FIELD AND CONSTANTS WITH RESPECT *00052900
* TO INITIAL START OR RESTARTING CAPABILITY. *00053000
* VARIABLES ARE : *00053100
* TIME = DIMENSIONLESS TIME *00053200
* UO = CHARACTERISTIC VELOCITY (1 FT/SEC) *00053300
* H = CHARACTERISTIC LENGTH (RADIUS(9.6FT)) *00053400
* TR = TEMP IN DEGREES KELVIN *00053500
* TA = TEMP IN DEGREES RANKINE *00053600
* VISO = REFERENCE VISCOSITY (NONDIM) *00053700
* VISL = MINIMUM VISCOSITY (NONDIM) *00053800
* VISMAX = MAXIMUM VISCOSITY (NONDIM) *00053900
* HR = RADIUS IN CM *00054000
* CONDO = REFERENCE CONDUCTIVITY *00054100
* CO = INITIAL SMOKE CONCENTRATION *00054200
* NJRA = POINT OF RADIATION IN J DIRECTION *00054300
* LOCATED ON THE INNER SOLID BOUNDARY *00054400
* HCONV = HEAT TRANSFER COEFFICIENT *00054500
* HCOEF = DIMENSIONLESS HEAT TRANSFER COEF *00054600

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*          CONST1      =          USED TO NONDIMENSIONALIZE PRESSURE      *00054700
*          RHO0        =          REFERENCE DENSITY                       *00054800
*          GC          =          GRAVITY CONSTANT                        *00054900
*          BUOY        =          BUOYANCY FORCE CONSTANT                 *00055000
*          UGRT        =          PERFECT GAS LAW NONDIMENSIONAL CONSTANT*00055100
*          CPO         =          REFERENCE SPECIFIC HEAT                 *00055200
*          NWRITE/     =          NONDIMENSIONAL FORMS OF TWRITE AND      *00055300
*          NTAPE       =          TTAPE                                  *00055400
*
* MATRICES OF THE FORM
*   _OD              =          DIMENSIONLESS PARAMETER AT OLD TIME      *00055500
*   _                =          DIMENSIONLESS PARAMETER                 *00055700
*   _PD             =          UPDATED DIMENSIONLESS PARAMETER           *00055800
*
* WHERE THE PARAMETERS ARE
*   U,V,W          =          VELOCITY IN THETA, R , PHI DIRECTION       *00056000
*   T,P,C          =          TEMP, PRESSURE, AND SMOKE CONCENTRATION*00056100
*
*   DU,DV,DZ      =          USED IN PRESSURE CORRECTION SUBROUTINE     *00056300
*   PP            =          CORRECTED PRESSURE (P')                     *00056400
*   SU            =          SOURCE TERM                                  *00056500
*   SP            =          TERM AT P NODAL POINT FOR BOUNDARY          *00056600
*                   CONDITIONS                                         *00056700
*   AP            =          COEFFICIENT AT NODAL POINT                   *00056800
*   AE,AH,AN      =          COEFFICIENTS AT PTS EAST,WEST,NORTH,        *00056900
*   AS,AF,AB      =          SOUTH, FRONT, AND BACK                      *00057000
*   SMP           =          RESIDUAL MASS SUMMATION OF NODAL POINT      *00057100
*   SMPP          =          LENGTH SCALE FOR TURBULENCE                 *00057200
*   CPM           =          MEAN SPECIFIC HEAT                          *00057300
*   VIS           =          VISCOSITY                                    *00057400
*   COND          =          CONDUCTIVITY MATRIX                         *00057500
*   NHSZ          =          WHEN THIS VALUE EQUALS ZERO, THERE IS       *00057600
*                   NO HEAT SOURCE LOCATED AT THE NODE                 *00057700
*   NOD           =          IF EQUAL TO ZERO, LIQUID                    *00057800
*                   IF EQUAL TO ONE, SOLID                              *00057900
*   _B,_E         =          BEGINNING AND ENDING NODAL POINT FOR        *00058000
*                   THE SOLID IN I,J,K                                  *00058100
*   REQ           =          DENSITY AT EQUILIBRIUM                      *00058200
*   NIP1          =          NODAL POINT IN I PLUS 1 (OTHERS SIMILAR)    *00058300
*   XC,YC,ZC      =          THETA,R,PHI LOCATION OF NODAL POINT OF     *00058400
*                   A CENTER CELL                                       *00058500
*   DXXC,DYYC    =          LENGTH AROUND THE CENTER CELL              *00058600
*   DZZC          =          THETA,R,PHI LOCATION OF NODAL POINT OF     *00058700
*                   A STAGGERED CELL                                    *00058800
*   XS,YS,ZS     =          THETA,R,PHI LOCATION OF NODAL POINT OF     *00058900
*                   A STAGGERED CELL                                    *00059000
*   DXXS,DYYS    =          LENGTH AROUND THE STAGGERED CELL           *00059100
*   DZZS          =          LOCATION OF THERMOCOUPLE IN THETA,R,PHI    *00059200
*   CX,CY,CZ     =          *****00059300
*
* COMMON/R4/XC( 93 ),YC( 93 ),ZC( 93 ),XS( 93 ),YS( 93 ),ZS( 93 ),
&      DXXC( 93 ),DYYC( 93 ),DZZC( 93 ),DXXS( 93 ),DYYS( 93 ),DZZS( 93 ) 00059400
*
* COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR 00059600
* COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00059700
&      ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00059800
* COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER 00059900
* COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM20060000
* COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00060100

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& CP0,PRT,CONDO,VISO,RH00,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00060200
COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32) 00060300
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32) 00060400
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10) 00060500
COMMON/BL31/ T00(22,16,32),ROD(22,16,32),POD(22,16,32) 00060700
& ,CO0(22,16,32),U00(22,16,32),V00(22,16,32),W00(22,16,32) 00060800
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) 00060900
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00061000
COMMON/BL33/ TPO(22,16,32),RPD(22,16,32),PPD(22,16,32) 00061100
& ,CPO(22,16,32),UPO(22,16,32),VPO(22,16,32),WPO(22,16,32) 00061200
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),
& DU(22,16,32),DV(22,16,32),DW(22,16,32) 00061500
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32),
& AS(22,16,32),AF(22,16,32),AB(22,16,32), 00061700
& SP(22,16,32),SU(22,16,32),RI(22,16,32) 00061800
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RHALL(579)00061900
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00062000
COMMON/BL38/NTHCO,CX(12),CY(12),CZ(12),NTH(12,3),TCOUP(12) 00062100
COMMON/BL39/ALEW,PCURVE,CONSR,PCURM1,PSOUTH,QCORR,PERROR 00062200
DATA GRAV/32.17/ 00062300
00062400
C *** INTRODUCE GIVEN PARAMETERS 00062500
00062600
TIME=0. 00062700
TR=TA/1.8 00062800
H=9.6 00062900
VISO=VISO/U0/H 00063000
VISL=VISO 00063100
VISMAX=400.*VISL 00063200
HR=H*30.48 00063300
CONDO=VISO/PRT 00063400
PI=4.*ATAN(1.) 00063500
ALEW = 1.0 00063600
NJRA=15 00063700
00063800
C THE HEAT TRANSFER COEFFICIENT IS IN BTU/HR/FT**2/F 00063900
HCONV=15.0 00064000
HCOEF=HCONV/(3600.*CP0*RH00*U0) 00064100
CO = 0.0 00064200
00064300
00064400
CONST1=RH00*U0*U0/(GC*14.696*144.) 00064500
CONST3=1.8/TA 00064600
CONST4=H*30.48 00064700
CONST6=U0*30.48 00064800
NTMAX0=0 00064900
00065000
BL0Y=GRAV*H/(U0*U0) 00065100
UGRT=U0*U0/(GC*RAIR*TA) 00065200
TCOOL=1.0 00065300
CONSR=TA*TA*TA/(RH00*CP0*U0*3600.)*1.714E-9 00065400
00065500
WRITE(6,200) TR,CONDO,VISO,CP0,HR,DTEMP,HCONV 00065600

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200	FORMAT(5X, 'THE REFERENCE TEMPERATURE AND THERMAL PROPERTIES',/,	00065700
&	/,5X, 'T = ',F10.4,'K, CONDO = ',E12.6,	00065800
&	/,5X, 'VISO = ',E12.6,' CPO = ',E12.6,	00065900
&	/,5X, 'RADIUS = ',E12.6,' CM',	00066000
&	/,5X, 'DIME = ',E12.6,	00066100
&	/,5X, 'HCONV = ',E12.6,/) )	00066200
		00066300
	NWRITE=TWRITE*UO/DIME/H	00066400
	NTAPE=TTAPE*UO/DIME/H	00066500
C ***	PRINT OUT INPUT INFORMATION	00066600
		00066700
	WRITE(6,61) (STAR,I=1,90),KRUN,TMAX,TWRITE,TTAPE,NMRP	00066800
61	FORMAT(///,90A1,/,5X, 'KRUN = ',I2,/,5X,	00066900
&	'TMAX = ',F8.3, ' SECONDS',/5X, 'TWRITE = ',F8.3,	00067000
&	' SECONDS',/5X, 'TTAPE = ',F8.3, ' SECONDS',	00067100
&	/,5X, ' NUMBER INTERVALS OF WRITING ON PAPER ', I5,/) )	00067200
		00067300
C ***	INITIALIZE VARIABLE FIELD	00067400
		00067500
	DO 220 J=1,NJP1	00067600
	DO 220 I=1,NIP1	00067700
	DO 220 K=1,NKP1	00067800
	ROD(I,J,K)=1.	00067900
	RI(I,J,K)=1.	00068000
	RPD(I,J,K)=1.	00068100
	UOD(I,J,K)=0.	00068200
	UI(I,J,K)=0.	00068300
	UPD(I,J,K)=0.	00068400
	VOD(I,J,K)=0.	00068500
	VI(I,J,K)=0.	00068600
	VPD(I,J,K)=0.	00068700
	WI(I,J,K)=0.	00068800
	WPD(I,J,K)=0.	00068900
	XOD(I,J,K)=0.	00069000
	POD(I,J,K)=0.	00069100
	PI(I,J,K)=0.	00069200
	PPD(I,J,K)=0.	00069300
	DUI(I,J,K)=0.	00069400
	DVI(I,J,K)=0.	00069500
	DXI(I,J,K)=0.	00069600
	SUI(I,J,K)=0.	00069700
	SPI(I,J,K)=0.	00069800
	PPI(I,J,K)=0.	00069900
	API(I,J,K)=0.	00070000
	AXI(I,J,K)=0.	00070100
	AEI(I,J,K)=0.	00070200
	AXI(I,J,K)=0.	00070300
	ASI(I,J,K)=0.	00070400
	AFI(I,J,K)=0.	00070500
	ABI(I,J,K)=0.	00070600
	SMP(I,J,K)=0.	00070700
	SMPP(I,J,K)=0.	00070800
	VIS(I,J,K)=VISL	00070900
	COND(I,J,K)=CONDO	00071000
	CPM(I,J,K)=1.0EO	00071100

TOO(I,J,K)=1.0E0	00071200
T(I,J,K)=TOO(I,J,K)	00071300
TPD(I,J,K)=TOD(I,J,K)	00071400
COO(I,J,K)=CO	00071500
C(I,J,K)=COO(I,J,K)	00071600
CPD(I,J,K)=COD(I,J,K)	00071700
NHSZ(I,J,K)=0	00071800
NOD(I,J,K)=0	00071900
220 CONTINUE	00072000
	00072100
	00072200
	00072300
C *** DETERMINE THE POSITION OF HEAT SOURCE	00072400
	00072500
DO 300 I=2,NI	00072600
DO 300 J=2,NJ	00072700
	00072800
C CHANGE TO RECTANGULAR COORDINATES	00072900
XX=YC(J)*COS(XC(I))	00073000
YY=YC(J)*SIN(XC(I))	00073100
	00073200
C CHECK TO SEE IF IN HS CONTROL VOLUME, IF SO SET NHSZ=1	00073300
IF (XX.LT.HSZ(1,1).OR.XX.GT.HSZ(1,2)) GOTO 310	00073400
IF (YY.LT.HSZ(2,1).OR.YY.GT.HSZ(2,2)) GOTO 310	00073500
NHSZ(I,J,16)=1	00073600
NHSZ(I,J,17)=1	00073700
315 FORMAT (2X,10(4X,I4,2X,I4))	00073800
GOTO 300	00073900
310 CONTINUE	00074000
300 CONTINUE	00074100
	00074200
	00074300
	00074400
C *** DEFINE THERMAL PROPERTIES OF DECK AND SOLID	00074500
	00074600
IF (NCHIP.EQ.0) GOTO 410	00074700
DO 402 N=1,NCHIP	00074800
IB=ICHPB(N)	00074900
IE=IB+NCHPI(N)-1	00075000
JB=JCHPB(N)	00075100
JE=JB+NCHPJ(N)-1	00075200
KB=KCHPB(N)	00075300
KE=KB+NCHPK(N)-1	00075400
DO 405 I=IB,IE-1	00075500
DO 405 J=JB,JE-1	00075600
DO 405 K=KB,KE-1	00075700
CONO(I,J,K)=CONOO*CONS(N)	00075800
CPM(I,J,K)=CPO*CPS(N)	00075900
NCO(I,J,K)=1	00076000
405 CONTINUE	00076100
402 CONTINUE	00076200
410 CONTINUE	00076300
	00076400
	00076500
	00076600
C *** FOR CONTINUING RUN, READ DATA FROM TAPE OR DISK	

IF(KRUN .EQ. 1) GO TO 9997	00076700
GO TO 15	00076800
9997 READ(8,END=9998)	00076900
& TIME,NTMAX0,TOD,ROD,UOD,VOD,WOD,POD,CPM,COND,VIS,QRNET,ITERT,GCOR00077100	00077000
&RT,PM1,PM2,XX,XX,XX,XX,XX,XX,NI,NJ,NK,NIP1,NJP1,NKP1,NIM1,NJM1	00077200
& ,NKM1,XC,YC,ZC,XS,YS,ZS,DXXC,DYYC,DZZC,DXXS,DYYS,DZZS	00077300
GO TO 9997	00077400
9998 CONTINUE	00077500
REWIND 8	00077600
CLOSE (8)	00077700
WRITE(6,*)NTMAX0	00077800
15 CONTINUE	00077900
	00078000
	00078100
C *** DEFINE HEIGHT OF NODE POINTS AND COMPUTE HYDROSTATIC	00078200
C EQUILIBRIUM DENSITY REQ(I,J,K)	00078300
	00078400
	00078500
DO 13 K=1,NKP1	00078600
DO 13 I=1,NIP1	00078700
DO 13 J=1,NJP1	00078800
DHY=YC(J)*SIN(XC(I))*SIN(ZC(K))	00078900
HEIGHT(I,J,K)=DHY	00079000
13 CONTINUE	00079100
C	00079200
	00079300
DO 229 J=1,NJP1	00079300
DO 229 I=1,NIP1	00079400
DO 229 K=1,NKP1	00079500
AAAA=-BUOY*UGRT*HEIGHT(I,J,K)	00079600
REQ(I,J,K)=EXP(AAAA)	00079700
IF(KRUN .NE. 0) GO TO 229	00079800
RPD(I,J,K)=REQ(I,J,K)/TPD(I,J,K)	00079900
ROD(I,J,K)=RPD(I,J,K)	00080000
R(I,J,K)=RPD(I,J,K)	00080100
229 CONTINUE	00080200
	00080300
C *** INITIALIZE U,V,T,R,P FIELD	00080400
	00080500
DO 210 K=1,NKP1	00080600
DO 210 J=1,NJP1	00080700
DO 210 I=1,NIP1	00080800
T(I,J,K)=TOD(I,J,K)	00080900
C(I,J,K)=COD(I,J,K)	00081000
R(I,J,K)=ROD(I,J,K)	00081100
U(I,J,K)=UOD(I,J,K)	00081200
V(I,J,K)=VOD(I,J,K)	00081300
W(I,J,K)=WOD(I,J,K)	00081400
P(I,J,K)=POD(I,J,K)	00081500
210 CONTINUE	00081600
	00081700
C *** FOLLOWING IS FOR DETERMINING THE THERMOCOUPLE POSITIONS	00081800
	00081900
DO 5000 N=1,NTHCO	00082000
DO 5001 I=1,NIP1	00082100

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      IF (XC(I).LT.CX(N).AND.XC(I+1).GE.CX(N)) GOTO 5002
5001 CONTINUE
5002 II=I
      DO 5003 J=1,NJP1
      IF (YC(J).LT.CY(N).AND.YC(J+1).GE.CY(N)) GOTO 5004
5003 CONTINUE
5004 JJ=J
      DO 5005 K=1,NKP1
      IF (ZC(K).LT.CZ(N).AND.ZC(K+1).GE.CZ(N)) GOTO 5006
5005 CONTINUE
5006 KK=K
      NTH(N,1)=II
      NTH(N,2)=JJ
      NTH(N,3)=KK
5000 CONTINUE
      RETURN
      END
C
C ***
C *****
SUBROUTINE CALVIS
C *****
C *** THIS SUBROUTINE CALCULATES THE TURBULENT VISCOSITY AND UPDATES*
* THE VISCOSITY MATRIX *
C *****
COMMON/R4/XC( 93 ),YC( 93 ),ZC( 93 ),XS( 93 ),YS( 93 ),ZS( 93 ),
& DXXC( 93 ),DYXC( 93 ),DZZC( 93 ),DXXS( 93 ),DYYS( 93 ),DZZS( 93 )
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM2
COMMON/BL16/CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR
COMMON/BL32/ T( 22,16,32 ),R( 22,16,32 ),P( 22,16,32 )
& ,C( 22,16,32 ),U( 22,16,32 ),V( 22,16,32 ),W( 22,16,32 )
COMMON/BL34/ HEIGHT( 22,16,32 ),REQ( 22,16,32 ),
& SMP( 22,16,32 ),SMPP( 22,16,32 ),PP( 22,16,32 ),
& DU( 22,16,32 ),DV( 22,16,32 ),DW( 22,16,32 )
COMMON/BL36/AP( 22,16,32 ),AE( 22,16,32 ),AW( 22,16,32 ),AN( 22,16,32 ),
& AS( 22,16,32 ),AF( 22,16,32 ),AB( 22,16,32 ),
& SP( 22,16,32 ),SU( 22,16,32 ),RI( 22,16,32 )
COMMON/BL37/ .VIS( 22,16,32 ),COND( 22,16,32 ),NOD( 22,16,32 ),RWALL( 579 )
& ,CPM( 22,16,32 ),HSZ( 3,2 ),NHSZ( 22,16,32 ),RESDRM( 93 )
C *** CALCULATE LOCAL SHEAR AND VISCOSITY VIS(I,J,K)
C
C *** SPECIFY LOCAL TURBULENT LENGTH SCALES SMPP(I,J,K)
DO 611 K=2,NK

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KP2=K+2	00087700
KP1=K+1	00087800
KM1=K-1	00087900
KM2=K-2	00088000
DO 611 J=2,NJ	00088100
JP2=J+2	00088200
JP1=J+1	00088300
JM1=J-1	00088400
JM2=J-2	00088500
DO 611 I=2,NI	00088600
IP2=I+2	00088700
IP1=I+1	00088800
IM1=I-1	00088900
IM2=I-2	00089000
IF (I.EQ.2) IM2=NIM1	00089100
IF (I.EQ.NI) IP2=3	00089200
IF (MOD(I,J,K).EQ.1) GOTO 611	00089300
	00089400
C CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00089500
	00089600
DXP1=XL(IP1,J,K,0,0)	00089700
DXI =XL(I ,J,K,0,0)	00089800
DXM1=XL(IM1,J,K,0,0)	00089900
	00090000
DYP1=YL(I,JP1,K,0,0)	00090100
DYJ =YL(I,J ,K,0,0)	00090200
DYM1=YL(I,JM1,K,0,0)	00090300
	00090400
DZP1=ZL(I,J,KP1,0,0)	00090500
DZK =ZL(I,J,K ,0,0)	00090600
DZM1=ZL(I,J,KM1,0,0)	00090700
	00090800
CC IF (J.EQ.2) DYS=DYS/2.	00090900
CC IF (K.EQ.2) DZB=DZB/2.	00091000
IF (J.NE.NJ) GOTO 101	00091100
JP2=JP1	00091200
DYN=DYN/2.	00091300
101 IF (K.NE.NK) GOTO 102	00091400
KP2=KP1	00091500
DZF=DZF/2.	00091600
102 CONTINUE	00091700
	00091800
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00091900
	00092000
DXE =XL(IP1,J,K,0,1)	00092100
DXW =XL(I ,J,K,0,1)	00092200
	00092300
DYN =YL(I,JP1,K,0,2)	00092400
DYS =YL(I,J ,K,0,2)	00092500
	00092600
DZF =ZL(I,J,KP1,0,3)	00092700
DZB =ZL(I,J,K ,0,3)	00092800
	00092900
C *** CACULATE DV/DX,D2V/DX2,DU/DX,D2U/DX2,DW/DX AND D2W/DX2	00093000
	00093100

	00093200
DUDX=(U(IP1,J,K)-U(I,J,K))/DXI	00093300
DUDXW=0.5*(U(IP1,J,K)-U(IM1,J,K))/DXW	00093400
DUDXE=0.5*(U(IP2,J,K)-U(I,J,K))/DXE	00093500
D2UDX2=(DUDXE-DUDXW)/DXI	00093600
	00093700
	00093800
DVDXW=0.5*(V(I,JP1,K)+V(I,J,K)-V(IM1,JP1,K)-V(IM1,J,K))/DXW	00093900
DVDXE=0.5*(V(IP1,JP1,K)+V(IP1,J,K)-V(I,JP1,K)-V(I,J,K))/DXE	00094000
DVDX=0.5*(DVDXE+DVDXW)	00094100
D2VDX2=(DVDXE-DVDXW)/DXI	00094200
	00094300
	00094400
DWDXW=0.5*(W(I,J,KP1)+W(I,J,K)-W(IM1,J,KP1)-W(IM1,J,K))/DXW	00094500
DWDXE=0.5*(W(IP1,J,KP1)+W(IP1,J,K)-W(I,J,KP1)-W(I,J,K))/DXE	00094600
DWDX=0.5*(DWDXE+DWDXW)	00094700
D2WDX2=(DWDXE-DWDXW)/DXI	00094800
	00094900
	00095000
602 CONTINUE	00095100
	00095200
C *** CALCULATE DU/DY,D2U/DY2,DV/DY,D2V/DY2,DW/DY AND D2W/DY2	00095300
	00095400
	00095500
DVDY=(V(I,JP1,K)-V(I,J,K))/DYJ	00095600
DVDYS=0.5*(V(I,JP1,K)-V(I,JM1,K))/DYS	00095700
DVDYN=0.5*(V(I,JP2,K)-V(I,J,K))/DYN	00095800
D2VDY2=(DVDYN-DVDYS)/DYJ	00095900
	00096000
	00096100
DUDYS=0.5*(U(IP1,J,K)+U(I,J,K)-U(IP1,JM1,K)-U(I,JM1,K))/DYS	00096200
DUDYN=0.5*(U(IP1,JP1,K)+U(I,JP1,K)-U(IP1,J,K)-U(I,J,K))/DYN	00096300
DUDY=0.5*(DUDYN+DUDYS)	00096400
D2UDY2=(DUDYN-DUDYS)/DYJ	00096500
	00096600
	00096700
DWDYS=0.5*(W(I,J,KP1)+W(I,J,K)-W(I,JM1,KP1)-W(I,JM1,K))/DYS	00096800
DWDYN=0.5*(W(I,JP1,KP1)+W(I,JP1,K)-W(I,J,KP1)-W(I,J,K))/DYN	00096900
DWDY=0.5*(DWDYN+DWDYS)	00097000
D2WDY2=(DWDYN-DWDYS)/DYJ	00097100
	00097200
	00097300
	00097400
606 CONTINUE	00097500
	00097600
C *** CALCULATE DU/DZ,D2U/DZ2,DV/DZ,D2V/DZ2,DW/DZ AND D2W/DZ2	00097700
	00097800
	00097900
DWDZ=(W(I,J,KP1)-W(I,J,K))/DZK	00098000
DWDZF=0.5*(W(I,J,KP2)-W(I,J,K))/DZF	00098100
DWDZB=0.5*(W(I,J,KP1)-W(I,J,KM1))/DZB	00098200
D2WDZ2=(DWDZF-DWDZB)/DZK	00098300
	00098400
	00098500
	00098600
DVDZB=0.5*(V(I,JP1,K)+V(I,J,K)-V(I,JP1,KM1)-V(I,J,KM1))/DZB	
DVDZF=0.5*(V(I,JP1,KP1)+V(I,J,KP1)-V(I,JP1,K)-V(I,J,K))/DZF	
DVDZ=0.5*(DVDZF+DVDZB)	

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D2VDZ2= (DVDZF-DVDZB)/DZK                                00098700
                                                                00098800
                                                                00098900
DUDZB=0.5*(U(IP1,J,K)+U(I,J,K)-U(IP1,J,KM1)-W(I,J,KM1))/DZB 00099000
DUDZF=0.5*(U(IP1,J,KP1)+U(I,J,KP1)-U(IP1,J,K)-U(I,J,K))/DZF 00099100
DUDZ=0.5*(DUDZF+DUDZB)                                    00099200
D2UDZ2= (DUDZF-DUDZB)/DZK                                00099300
                                                                00099400
DRDX=((R(IP1,J,K)-REQ(IP1,J,K))-(R(IM1,J,K)-REQ(IM1,J,K)))/
& (DXE+DXW)                                                00099600
DRDY=((R(I,JP1,K)-REQ(I,JP1,K))-(R(I,JM1,K)-REQ(I,JM1,K)))/
& (DYN+DYS)                                                00099700
DRDZ=((R(I,J,KP1)-REQ(I,J,KP1))-(R(I,J,KM1)-REQ(I,J,KM1)))/
& (DZF+DZB)                                                00099800
DRDGA=SIN(ZC(K))*(SIN(XC(I))*DRDY+COS(XC(I))*DRDX)
& +COS(ZC(K))*DRDZ                                        00099900
                                                                00100000
                                                                00100100
                                                                00100200
                                                                00100300
C *** CALCULATE RICHARDSON NUMBER                            00100400
                                                                00100500
STRAIN=DUDY**2+DUDX**2+DUDZ**2+DWDY**2+DWDZ**2
DDO2 = SQRT(DUDY*DUDY+DUDX*DUDX+DUDZ*DUDZ+DWDY*DWDY+DWDZ*DWDZ)
& DVDZ*DVDZ+DWDY*DWDY+DWDZ*DWDZ)
IF(DDO2.EQ.0.)GO TO 600
                                                                00100600
                                                                00100700
                                                                00100800
                                                                00100900
                                                                00101000
C *** CALCULATE TURBULENT LENGTH SCALE SMPP(I,J)          00101100
                                                                00101200
SMPP123=SQRT(((U(IP1,J,K)+U(I,J,K))*0.5)**2+((V(I,JP1,K)+V(I,J,K))
& 0.5)**2+((W(I,J,KP1)+W(I,J,K))*0.5)**2)/DDO2
SMPP12=DDO2 /SQRT(D2UDX2*D2UDX2+D2UDY2*D2UDY2
& +D2UDZ2*D2UDZ2+D2UOX2*D2UOX2+D2VOY2*D2VOY2+D2VDZ2*D2VDZ2+
& D2WDX2*D2WDX2+D2WDY2*D2WDY2)
SMPP(I,J,K)=CNT*(SMPP123+SMPP12)*.5
RI(I,J,K)=-BUOY*DRDGA/(R(I,J,K)*STRAIN)
ABRIPR=ABTURB+RI(I,J,K)/PRT
IF(ABRIPR.LT.0.)GO TO 600
IF(ABRIPR.EQ.0.)GO TO 613
GO TO 610
600 VIS(I,J,K)=VISL
GO TO 611
613 VIS(I,J,K)=VISMAX
GO TO 611
610 VIS(I,J,K)=VISL+R(I,J,K)*SMPP(I,J,K)*SMPP(I,J,K)*SQRT(STRAIN)/
& (BTURB*ABRIPR)
IF(VIS(I,J,K).GT.VISMAX)VIS(I,J,K)=VISMAX
611 CONTINUE
                                                                00101300
                                                                00101400
                                                                00101500
                                                                00101600
                                                                00101700
                                                                00101800
                                                                00101900
                                                                00102000
                                                                00102100
                                                                00102200
                                                                00102300
                                                                00102400
                                                                00102500
                                                                00102600
                                                                00102700
                                                                00102800
                                                                00102900
                                                                00103000
                                                                00103100
                                                                00103200
                                                                00103300
                                                                00103400
                                                                00103500
                                                                00103600
                                                                00103700
                                                                00103800
                                                                00103900
                                                                00104000
                                                                00104100
DO 110 I=1,NIP1
DO 110 J=1,NJP1
VIS(I,J,NKP1)=VIS(I,J,NK)
VIS(I,J,1)=VIS(I,J,2)
110 CONTINUE
DO 120 J=1,NJP1
DO 120 K=1,NKP1

```



VIS(NIP1,J,K)=VIS(2,J,K)	00104200
VIS(1 ,J,K)=VIS(NI,J,K)	00104300
120 CONTINUE	00104400
	00104500
DO 130 K=1,NKP1	00104600
DO 130 I=1,NIP1	00104700
VIS(I,NJP1,K)=VIS(I,NJ,K)	00104800
VIS(I,2 ,K)=VIS(I,3 ,K)	00104810
VIS(I,1 ,K)=VIS(I,2 ,K)	00104900
130 CONTINUE	00105000
	00105100
DO 135 K=1,16	00105110
KK=NKP1-K	00105120
DO 135 I=1,NIP1	00105130
DO 135 J=1,NJP1	00105140
VIS(I,J,KK)=VIS(I,J,K)	00105150
135 CONTINUE	00105160
	00105170
DO 140 I=1,NIP1	00105200
DO 140 J=1,NJP1	00105300
DO 140 K=1,NKP1	00105400
IF (MOD(I,J,K).EQ.1) GOTO 140	00105500
COND(I,J,K)=VIS(I,J,K)/PRT	00105600
140 CONTINUE	00105700
	00105800
RETURN	00105900
END	00106000
	00106100
	00106200
	00106300
	00106400
C	00106400
C *** *****	00106500
SUBROUTINE CALT	00106600
C *** *****	00106700
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00106800
&    DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00106900
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00107000
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00107100
&    ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00107200
COMMON/BL12/ NWRITE,NTAPE,NTMAXO,NTREAL,TIME,SORSUM,ITER	00107300
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM2	00107400
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00107500
&    CPO,PRT,CONDO,VISO,RHO0,HR,TR,TA,DEMP,TWRITE,TTAPE,TMAX,GC,RAIR	00107600
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00107700
&    NCHPK(10),TCHP(10),CPS(10),CONS(10),HFAN(10)	00107800
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00107900
&    ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32)	00108000
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00108100
&    ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)	00108200
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32)	00108300
&    ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32)	00108400
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00108500
&    SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00108600
&    DU(22,16,32),DVI(22,16,32),DW(22,16,32)	00108700
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32),	00108800

&	AS(22,16,32),AF(22,16,32),AB(22,16,32),	00108900
&	SP(22,16,32),SU(22,16,32),RI(22,16,32)	00109000
	COMMON/BL37/VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RHALL(579)	00109100
&	,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00109200
C ***	CALCULATE COEFFICIENTS	00109300
	DO 100 K=2,NK	00109400
	KP2=K+2	00109500
	KP1=K+1	00109600
	KM1=K-1	00109700
	KM2=K-2	00109800
	DO 100 J=2,NJ	00109900
	JP2=J+2	00110000
	JP1=J+1	00110100
	JM1=J-1	00110200
	JM2=J-2	00110300
	DO 100 I=2,NI	00110400
	IP2=I+2	00110500
	IP1=I+1	00110600
	IM1=I-1	00110700
	IM2=I-2	00110800
	IF (I.EQ.2) IM2=NIM1	00110900
	IF (I.EQ.NI) IP2=3	00111000
		00111100
		00111200
		00111300
C	CENTRAL LENGTH OF THE TEMPERATURE CONTROL VOLUME	00111400
	DXP1=XL(IP1,J,K,0,0)	00111500
	DXI =XL(I ,J,K,0,0)	00111600
	DXM1=XL(IM1,J,K,0,0)	00111700
		00111800
		00111900
	DYP1=YL(I,JP1,K,0,0)	00112000
	DYJ =YL(I,J ,K,0,0)	00112100
	DYM1=YL(I,JM1,K,0,0)	00112200
		00112300
	DZP1=ZL(I,J,KP1,0,0)	00112400
	DZK =ZL(I,J,K ,0,0)	00112500
	DZM1=ZL(I,J,KM1,0,0)	00112600
		00112700
C ***	SURFACE LENGTH OF THE CONTROL VOLUME	00112800
	DXN=XL(I,JP1,K,0,2)	00112900
	DXS=XL(I,J ,K,0,2)	00113000
	DXF=XL(I,J,KP1,0,3)	00113100
	DXB=XL(I,J,K ,0,3)	00113200
		00113300
	DYF=YL(I,J,KP1,0,3)	00113400
	DYB=YL(I,J,K ,0,3)	00113500
	DYE=YL(IP1,J,K,0,1)	00113600
	DYH=YL(I ,J,K,0,1)	00113700
		00113800
		00113900
	DZE=ZL(IP1,J,K,0,1)	00114000
	DZH=ZL(I ,J,K,0,1)	00114100
	DZN=ZL(I,JP1,K,0,2)	00114200
	DZS=ZL(I,J ,K,0,2)	00114300

C ***	CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00114400
		00114500
		00114600
	DXEE=XL(IP2,J,K,0,1)	00114700
	DXE =XL(IP1,J,K,0,1)	00114800
	DXW =XL(I ,J,K,0,1)	00114900
	DXWW=XL(IM1,J,K,0,1)	00115000
		00115100
	DYNN=YL(I,JP2,K,0,2)	00115200
	DYN =YL(I,JP1,K,0,2)	00115300
	DYS =YL(I,J ,K,0,2)	00115400
	DYSS=YL(I,JM1,K,0,2)	00115500
		00115600
	DZFF=ZL(I,J,KP2,0,3)	00115700
	DZF =ZL(I,J,KP1,0,3)	00115800
	DZB =ZL(I,J,K ,0,3)	00115900
	DZBB=ZL(I,J,KM1,0,3)	00116000
		00116100
C ***	DEFINE THE AREA OF THE CONTROL VOLUME	00116200
		00116300
	DXYF=DXF*DYF	00116400
	DXYB=DXB*DYB	00116500
	DYZE=DYE*DZE	00116600
	DYZW=DYW*DZW	00116700
	DZXN=DZN*DXN	00116800
	DZXS=DZS*DXS	00116900
		00117000
	VOL=DXI*DYJ*DZK	00117100
	VOLDT=VOL/DTIME	00117200
		00117300
	ZXOYN=DZXN/DYN	00117400
	ZXOYS=DZXS/DYS	00117500
	XYOZF=DXYF/DZF	00117600
	XYOZB=DXYB/DZB	00117700
	YZOXE=DYZE/DXE	00117800
	YZOXW=DYZW/DXW	00117900
		00118000
	GN=(R(I,J,K)*DYP1+R(I,JP1,K)*DYJ)/(DYP1+DYJ)	00118100
	GS=(R(I,J,K)*DYM1+R(I,JM1,K)*DYJ)/(DYM1+DYJ)	00118200
	GE=(R(I,J,K)*DXP1+R(IP1,J,K)*DXI)/(DXP1+DXI)	00118300
	GH=(R(I,J,K)*DXM1+R(IM1,J,K)*DXI)/(DXM1+DXI)	00118400
	GF=(R(I,J,K)*DZP1+R(I,J,KP1)*DZK)/(DZP1+DZK)	00118500
	GB=(R(I,J,K)*DZM1+R(I,J,KM1)*DZK)/(DZM1+DZK)	00118600
		00118700
	CN=GN*V(I,JP1,K)*DZXN	00118800
	CS=GS*V(I,J ,K)*DZXS	00118900
	CE=GE*U(IP1,J,K)*DYZE	00119000
	CH=GH*U(I ,J,K)*DYZW	00119100
	CF=GF*W(I,J,KP1)*DXYF	00119200
	CB=GB*W(I,J,K )*DXYB	00119300
		00119400
		00119500
	CONDN=1./((1./COND(I,J,K)*DYJ+1./COND(I,JP1,K)*DYP1)/(DYP1+DYJ))	00119600
	CONDS=1./((1./COND(I,J,K)*DYJ+1./COND(I,JM1,K)*DYM1)/(DYM1+DYJ))	00119700
	CONDE=1./((1./COND(I,J,K)*DXI+1./COND(IP1,J,K)*DXP1)/(DXP1+DXI))	00119800

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CONDW=1./((1./COND(I,J,K)*DXI+1./COND(IM1,J,K)*DXM1)/(DXM1+DXI)) 00119900
CONDF=1./((1./COND(I,J,K)*DZK+1./COND(I,J,KP1)*DZP1)/(DZP1+DZK)) 00120000
CONDB=1./((1./COND(I,J,K)*DZK+1./COND(I,J,KM1)*DZM1)/(DZM1+DZK)) 00120100
00120200
CONDN1=ZXOYN*CONDN 00120300
CONDS1=ZXOYS*CONDS 00120400
CONDE1=YZOXE*CONDE 00120500
CONDI1=YZOXW*CONDW 00120600
CONDF1=XYOZF*CONDF 00120700
CONCB1=XYOZB*CONDB 00120800
00120900
00123110
CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW))/8. 00123120
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXE))/8. 00123130
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXW))/8. 00123140
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE))/8. 00123150
00123160
CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS))/8. 00123170
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYN))/8. 00123180
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYSS))/8. 00123190
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN))/8. 00123191
00123192
CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB))/8. 00123193
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF))/8. 00123194
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZB))/8. 00123195
CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF))/8. 00123196
00123197
AE(I,J,K)=-.5*DXI/DXE*CE+CEP+CEM*(1.+DXE/DXE)+CWM*DXW/DXE 00123198
AH(I,J,K)=.5*DXI/DXW*CH+CWM+CWP*(1.+DXW/DXW)+CEP*DXE/DXW 00123199
AN(I,J,K)=-.5*DYJ/DYN*CN+CNP+CNM*(1.+DYN/DYN)+CSM*DYS/DYN 00123200
AS(I,J,K)=.5*DYJ/DYS*CS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS 00123201
AF(I,J,K)=-.5*DZK/DZF*CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF 00123202
AB(I,J,K)=.5*DZK/DZB*CB+CBM+CBP*(1.+DZB/DZB)+CFP*DZF/DZB 00123203
00123204
C 801 AEE=-CEM*DXE/DXE 00123210
AEEER=AEE*TPD(IP2,J,K)*CPM(IP2,J,K) 00123300
802 CONTINUE 00123400
00123500
803 AWW=-CWP*DXW/DXW 00123600
AWWR=AWW*TPD(IM2,J,K)*CPM(IM2,J,K) 00123700
804 CONTINUE 00123800
00123900
IF(J.LT.NJ)GOTO 805 00124000
ANN=0. 00124100
ANNR=0. 00124200
GOTO 806 00124300
805 ANN=-CNM*DYN/DYNN 00124400
ANNR=ANN*TPD(I,JP2,K)*CPM(I,JP2,K) 00124500
806 CONTINUE 00124600
00124700
IF(J.GT.2)GOTO 807 00124800
ASS=0. 00124900
ASSR=0. 00125000
GOTO 808 00125100
807 ASS=-CSP*DYS/DYSS 00125200

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ASSR=ASS*TPD(I,JM2,K)*CPM(I,JM2,K)	00125300
808 CONTINUE	00125400
IF (K.LT.NK) GOTO 809	00125500
AFF=0.	00125600
AFFR=0.	00125700
GOTO 810	00125800
809 AFF=-CFM*DZF/DZFF	00125900
AFFR=AFF*TPD(I,J,KP2)*CPM(I,J,KP2)	00126000
810 CONTINUE	00126100
IF (K.GT.2) GOTO 811	00126200
ABB=0.	00126300
ABBR=0.	00126400
GOTO 812	00126500
811 ABB=-CBP*DZB/DZBB	00126600
ABBR=ABB*TPD(I,J,KM2)*CPM(I,J,KM2)	00126700
812 CONTINUE	00126800
	00126900
	00127000
	00127100
	00127200
	00127300
C #####	00127400
C #####	00127500
C *** MODIFICATION FOR DECK BOUNDARIES	00127600
	00127700
900 CONTINUE	00127800
IF (NOD(IM1,J,K).EQ.0) GOTO 901	00127900
AMM=0.0	00128000
AMNR=0.0	00128100
	00128200
901 CONTINUE	00128300
IF (NOD(IP1,J,K).EQ.0) GOTO 902	00128400
AEE=0.0	00128500
AEER=0.0	00128600
	00128700
902 CONTINUE	00128800
IF (NOD(I,JM1,K).EQ.0) GOTO 903	00128900
ASS=0.0	00129000
ASSR=0.0	00129100
	00129200
903 CONTINUE	00129300
IF (NOD(I,JP1,K).EQ.0) GOTO 904	00129400
ANN=0.0	00129500
ANNR=0.0	00129600
	00129700
904 CONTINUE	00129800
IF (NOD(I,J,KM1).EQ.0) GOTO 905	00129900
ABB=0.0	00130000
ABBR=0.0	00130100
	00130200
905 CONTINUE	00130300
IF (NOD(I,J,KP1).EQ.0) GOTO 906	00130400
AFF=0.0	00130500
AFFR=0.0	00130600
	00130700

```

906 CONTINUE                                00130800
C #####                                00130900
C #####                                00131000
C #####                                00131100
C #####                                00131200
AP(I,J,K)=(AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)
&          +AF(I,J,K)+AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB)*CPM(I,J,K)
&          +CONDE1+CONDW1+CONDN1+CONDS1+CONDF1+CONDB1
00131300
00131400
00131500
00131600
00131700
00131800
00131900
00132000
00132100
00132200
00132300
00132400
00132500
00132600
00132700
00132800
00132900
00133000
00133100
00133200
00133300
00133400
00133500
00133600
00133700
00133800
00133900
00134000
00134100
00134200
00134300
00134400
00134500
00134600
00134700
00134800
00134900
00135000
00135100
00135200
00135300
00135400
00135500
00135600
00135700
00135800
00135900
00136000
00136100
00136200
100 CONTINUE
C *** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU
C *** RADIUS DIRECTION
DO 500 I=2,NI
DO 500 K=2,NK
SP(I,2,K)=SP(I,2,K)+AS(I,2,K)
CC SP(I,2,K)=SP(I,2,K)-AS(I,2,K)
CC SU(I,2,K)=SU(I,2,K)+2.0*AS(I,2,K)*TPD(I,1,K)
SP(I,NJ,K)=SP(I,NJ,K)-AN(I,NJ,K)
SU(I,NJ,K)=SU(I,NJ,K)+2.*TPD(I,NJP1,K)*AN(I,NJ,K)
AS(I,2,K)=0.
AN(I,NJ,K)=0.
500 CONTINUE
C *** CYLIC CONDITIONS
DO 600 J=2,NJ
DO 600 K=2,NK
SU(2 ,J,K)=SU(2 ,J,K)+AW(2 ,J,K)*T(1 ,J,K)
SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*T(NIPI1,J,K)
AW(2 ,J,K)=0.0
AE(NI,J,K)=0.0
600 CONTINUE
C *** END OF SPHERE
DO 700 I=2,NI
DO 700 J=2,NJ
SP(I,J,2)=SP(I,J,2)+AB(I,J,2)
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)
AB(I,J,2)=0.
AF(I,J,NK)=0.
700 CONTINUE

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	00136300
	00136400
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00136500
	00136600
DO 300 K=2,NK	00136700
DO 300 J=2,NJ	00136800
DO 300 I=2,NI	00136900
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00137000
300 CONTINUE	00137100
	00137200
	00137300
	00137400
C *** VOLUME HEAT SOURCE INPUT	00137500
	00137600
VOLT=0.0	00137700
DO 113 I=2,NI	00137800
DO 113 J=2,NJ	00137900
DO 113 K=16,17	00138000
IF (NHSZ(I,J,K).EQ.0) GOTO 113	00138100
DXI =XL(I ,J,K,0,0)	00138200
DYJ =YL(I,J ,K,0,0)	00138300
DZK =ZL(I,J,K ,0,0)	00138400
VOL=DXI*DYJ*DZK*H*H*H	00138500
VOLT=VOLT+VOL	00138600
113 CONTINUE	00138700
	00138800
	00138900
DO 111 I=2,NI	00139000
DO 111 J=2,NJ	00139100
DO 111 K=16,17	00139200
IF (NHSZ(I,J,K).EQ.0) GOTO 111	00139300
DXI =XL(I ,J,K,0,0)	00139400
DYJ =YL(I,J ,K,0,0)	00139500
DZK =ZL(I,J,K ,0,0)	00139600
QQQ=Q*H/(UO*CP0*RHO0*TA)	00139700
VOL=DXI*DYJ*DZK	00139800
SU(I,J,K)=SU(I,J,K)+VOL*QQQ/VOLT	00139900
111 CONTINUE	00140000
	00140100
	00140200
C *** RADIATION INTO THE WALL	00140300
	00140400
DO 310 K=3,NKM1	00140500
DO 310 I=2,NI	00140501
DXN =XL(I ,NJRA,K,0,2)	00140503
DZN =ZL(I,NJRA,K ,0,2)	00140504
DZXN=DZN*DXN	00140600
II=(K-3)*(NI-1)+I-1	00140700
SU(I,NJRA,K)=SU(I,NJRA,K)-RWALL(II)*DZXN	00140800
310 CONTINUE	00140900
	00141000
C *** END OF RADIATION	00141100
	00141200
C *** SOLVE FOR T	00141300
	00141400
CALL TRID (2,2,2,NI,NJ,NK,T)	

C **** RESET TEMPERATURE AT R=0.0 AND END OF SPHERE	00141500
DO 81 K=1,NKP1	00141600
AVT=0.0	00141700
DO 82 I=2,NI	00141800
AVT=AVT+(T(I,2,K)/NIM1)	00141900
82 CONTINUE	00142000
DO 83 I=1,NIP1	00142100
T(I,1,K)=AVT	00142200
83 CONTINUE	00142300
81 CONTINUE	00142400
C	00142500
DO 74 I=1,NIP1	00142600
DO 74 J=1,NJP1	00142700
T(I,J,1)=T(I,J,2)	00142800
T(I,J,NKP1)=T(I,J,NK)	00142900
74 CONTINUE	00143000
C *** FOR SURFACE HEAT EXCHANGE WITH SURROUNDING	00143100
DO 84 I=2,NI	00143200
DO 84 K=2,NK	00143300
DYJ=YL(I,NJ,K,0,0)	00143400
T(I,NJP1,K)=(2.0*COND(I,NJ,K)*T(I,NJ,K)/DYJ+HCOEF*TINF)/	00143500
& (HCOEF+2.0*COND(I,NJ,K)/DYJ)	00143600
84 CONTINUE	00143700
C *** FOR CYLIC CONDITION	00143800
DO 80 J=1,NJP1	00143900
DO 80 K=1,NKP1	00144000
T(1,J,K)=T(NI,J,K)	00144100
T(NIP1,J,K)=T(2,J,K)	00144200
80 CONTINUE	00144300
RETURN	00144400
END	00144500
C	00144600
C *** *****	00144700
SUBROUTINE CALC	00144800
C *** *****	00144900
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00145000
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00145100
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00145200
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00145300
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NHRP	00145400
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00145500
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200146900	00145600
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00147000	00145700
& CPO,PRT,CONDO,VISO,RH00,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0147100	00145800
	00145900
	00146000
	00146100
	00146200
	00146300
	00146400
	00146500
	00146600
	00146700
	00146800
	00146900
	00147000
	00147100



COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00147200
& NCHPK(10),TCHPI(10),CPS(10),CONS(10),MFAN(10)	00147300
COMMON/BL31/ TOO(22,16,32),ROD(22,16,32),POO(22,16,32)	00147400
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32)	00147500
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00147600
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)	00147700
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32)	00147800
& ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32)	00147900
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00148000
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00148100
& DU(22,16,32),OV(22,16,32),DH(22,16,32)	00148200
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32),	00148300
& AS(22,16,32),AF(22,16,32),AB(22,16,32),	00148400
& SP(22,16,32),SU(22,16,32),RI(22,16,32)	00148500
COMMON/BL37/VIS(22,16,32),COND(22,16,32),NOO(22,16,32),RWALL(579)	00148600
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00148700
COMMON/BL39/ALEN,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR	00148800
	00148900
C *** CALCULATE COEFFICIENTS	00149000
	00149100
OO 100 K=2,NK	00149200
KP2=K+2	00149300
KP1=K+1	00149400
KM1=K-1	00149500
KM2=K-2	00149600
DO 100 J=2,NJ	00149700
JP2=J+2	00149800
JP1=J+1	00149900
JM1=J-1	00150000
JM2=J-2	00150100
DO 100 I=2,NI	00150200
IP2=I+2	00150300
IP1=I+1	00150400
IM1=I-1	00150500
IM2=I-2	00150600
IF (I.EQ.2) IM2=NIM1	00150700
IF (I.EQ.NI) IP2=3	00150800
	00150900
C CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00151000
	00151100
DXP1=XL(IP1,J,K,0,0)	00151200
DXI =XL(I ,J,K,0,0)	00151300
DXM1=XL(IM1,J,K,0,0)	00151400
	00151500
DYP1=YL(I,JP1,K,0,0)	00151600
DYJ =YL(I,J ,K,0,0)	00151700
DYM1=YL(I,JM1,K,0,0)	00151800
	00151900
DZP1=ZL(I,J,KP1,0,0)	00152000
DZK =ZL(I,J,K ,0,0)	00152100
DZM1=ZL(I,J,KM1,0,0)	00152200
	00152300
C *** SURFACE LENGTH OF THE CONTROL VOLUME	00152400
	00152500
DXN=XL(I,JP1,K,0,2)	00152600

DXS=XL(I,J ,K,0,2)	00152700
DXF=XL(I,J,KP1,0,3)	00152800
DXB=XL(I,J,K ,0,3)	00152900
	00153000
DYF=YL(I,J,KP1,0,3)	00153100
DYB=YL(I,J,K ,0,3)	00153200
DYE=YL(IP1,J,K,0,1)	00153300
DYW=YL(I ,J,K,0,1)	00153400
	00153500
DZE=ZL(IP1,J,K,0,1)	00153600
DZW=ZL(I ,J,K,0,1)	00153700
DZN=ZL(I,JP1,K,0,2)	00153800
DZS=ZL(I,J ,K,0,2)	00153900
	00154000
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00154100
	00154200
DXEE=XL(IP2,J,K,0,1)	00154300
DXE =XL(IP1,J,K,0,1)	00154400
DXW =XL(I ,J,K,0,1)	00154500
DXHW=XL(IM1,J,K,0,1)	00154600
	00154700
DYNN=YL(I,JP2,K,0,2)	00154800
DYN =YL(I,JP1,K,0,2)	00154900
DYS =YL(I,J ,K,0,2)	00155000
DYSS=YL(I,JM1,K,0,2)	00155100
	00155200
DZFF=ZL(I,J,KP2,0,3)	00155300
DZF =ZL(I,J,KP1,0,3)	00155400
DZB =ZL(I,J,K ,0,3)	00155500
DZBB=ZL(I,J,KM1,0,3)	00155600
	00155700
C *** DEFINE THE AREA OF THE CONTROL VOLUME	00155800
	00155900
DXYF=DXF*DYF	00156000
DXYB=DXB*DYB	00156100
DYZE=DYE*DZE	00156200
DYZW=DYW*DZW	00156300
DZXN=DZN*DZN	00156400
DZXS=DZS*DZS	00156500
	00156600
VOL=DXI*DYJ*DZK	00156700
VOLDT=VOL/DTIME	00156800
	00156900
ZXOYN=DZXN/DYN	00157000
ZXOYS=DZXS/DYS	00157100
XYOZF=DXYF/DZF	00157200
XYOZB=DXYB/DZB	00157300
YZOXE=DYZE/DXE	00157400
YZOXW=DYZW/DXW	00157500
	00157600
GN=(R(I,J,K)*DYP1+R(I,JP1,K)*DYJ)/(DYP1+DYJ)	00157700
GS=(R(I,J,K)*DYM1+R(I,JM1,K)*DYJ)/(DYM1+DYJ)	00157800
GE=(R(I,J,K)*DXP1+R(IP1,J,K)*DXI)/(DXP1+DXI)	00157900
GW=(R(I,J,K)*DXM1+R(IM1,J,K)*DXI)/(DXM1+DXI)	00158000
GF=(R(I,J,K)*DZP1+R(I,J,KP1)*DZK)/(DZP1+DZK)	00158100

GB=(R(I,J,K)*DZM1+R(I,J,KM1)*DZK)/(DZM1+DZK)	00158200
CN=GN*V(I,JP1,K)*DZXN	00158300
CS=GS*V(I,J,K)*DZXS	00158400
CE=GE*U(IP1,J,K)*DYZE	00158500
CW=GW*U(I,J,K)*DYZH	00158600
CF=GF*H(I,J,KP1)*DXYF	00158700
CB=GB*W(I,J,K)*DXYB	00158800
	00158900
	00159000
	00159100
CONDN=1./((1./COND(I,J,K)*DYJ+1./COND(I,JP1,K)*DYP1)/(DYP1+DYJ))	00159200
CONDS=1./((1./COND(I,J,K)*DYJ+1./COND(I,JP1,K)*DYM1)/(DYM1+DYJ))	00159300
CONDE=1./((1./COND(I,J,K)*DXI+1./COND(IP1,J,K)*DXP1)/(DXP1+DXI))	00159400
CONDH=1./((1./COND(I,J,K)*DXI+1./COND(IM1,J,K)*DXM1)/(DXM1+DXI))	00159500
CONDF=1./((1./COND(I,J,K)*DZK+1./COND(I,J,KP1)*DZP1)/(DZP1+DZK))	00159600
CONDB=1./((1./COND(I,J,K)*DZK+1./COND(I,J,KM1)*DZM1)/(DZM1+DZK))	00159700
	00159800
CONDN1=ZXOYN*CONDN*ALEW	00159900
CONDS1=ZXOYS*CONDS*ALEW	00160000
CONDE1=YZOXE*CONDE*ALEW	00160100
CONDH1=YZOXH*CONDH*ALEW	00160200
CONDF1=XYOZF*CONDF*ALEW	00160300
CONDB1=XYOZB*CONDB*ALEW	00160400
	00162700
	00162800
CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW))/8.	00162801
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXE))/8.	00162802
CKP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXW))/8.	00162803
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE))/8.	00162804
	00162805
CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS))/8.	00162806
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYN))/8.	00162807
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYS))/8.	00162808
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN))/8.	00162809
	00162810
CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB))/8.	00162811
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF))/8.	00162812
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB))/8.	00162813
CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF))/8.	00162814
	00162815
AE(I,J,K)=-.5*DXI/DXE+CE+CEP+CEM*(1.+DXE/DXEE)+CWM*DXW/DXE	00162816
AH(I,J,K)=-.5*DXI/DXW+CW+CWM+CWP*(1.+DXW/DXWW)+CEP*DXE/DXW	00162817
AN(I,J,K)=-.5*DYJ/DYN+CN+CNP+CNM*(1.+DYN/DYNN)+CSM*DYS/DYN	00162818
AS(I,J,K)=-.5*DYJ/DYS+CS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS	00162819
AF(I,J,K)=-.5*DZK/DZF+CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF	00162820
AB(I,J,K)=-.5*DZK/DZB+CB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB	00162821
	00162822
	00162823
801 AEE=-CEM*DXE/DXEE	00162830
AEER=AEE*CPD(IP2,J,K)	00162900
802 CONTINUE	00163000
	00163100
803 AWW=-CWP*DXW/DXWW	00163200
AWWR=AWW*CPD(IM2,J,K)	00163300
804 CONTINUE	00163400

IF (J.LT.NJ) GOTO 805	00163500
ANN=0.	00163600
ANNR=0.	00163700
GOTO 806	00163800
805 ANN=-CNM*DYN/DYNN	00163900
ANNR=ANN*CPD(I,JP2,K)	00164000
806 CONTINUE	00164100
	00164200
	00164300
IF (J.GT.2) GOTO 807	00164400
ASS=0.	00164500
ASSR=0.	00164600
GOTO 808	00164700
807 ASS=-CSP*DYS/DYSS	00164800
ASSR=ASS*CPD(I,JM2,K)	00164900
808 CONTINUE	00165000
	00165100
IF (K.LT.NK) GOTO 809	00165200
AFF=0.	00165300
AFFR=0.	00165400
GOTO 810	00165500
809 AFF=-CFM*DZF/DZFF	00165600
AFFR=AFF*CPD(I,J,KP2)	00165700
810 CONTINUE	00165800
	00165900
IF (K.GT.2) GOTO 811	00166000
ABB=0.	00166100
ABBR=0.	00166200
GOTO 812	00166300
811 ABB=-CBP*DZB/DZBB	00166400
ABBR=ABB*CPD(I,J,KM2)	00166500
812 CONTINUE	00166600
	00166700
	00166800
	00166900
	00167000
C #####	00167100
C #####	00167200
C *** MODIFICATION FOR DECK BOUNDARIES	00167300
	00167400
900 CONTINUE	00167500
IF (NOD(IM1,J,K).EQ.0) GOTO 901	00167600
AWW=0.0	00167700
AWWR=0.0	00167800
	00167900
901 CONTINUE	00168000
IF (NOD(IP1,J,K).EQ.0) GOTO 902	00168100
AEE=0.0	00168200
AEER=0.0	00168300
	00168400
902 CONTINUE	00168500
IF (NOD(I,JM1,K).EQ.0) GOTO 903	00168600
ASS=0.0	00168700
ASSR=0.0	00168800
	00168900
903 CONTINUE	

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IF (MOD(I,J*PI,K).EQ.0) GOTO 904                                00169000
ANN=0.0                                                            00169100
ANNR=0.0                                                            00169200
                                                                    00169300
904 CONTINUE                                                       00169400
IF (MOD(I,J,KM1).EQ.0) GOTO 905                                  00169500
ABB=0.0                                                            00169600
ABBR=0.0                                                            00169700
                                                                    00169800
905 CONTINUE                                                       00169900
IF (MOD(I,J,KP1).EQ.0) GOTO 906                                  00170000
AFF=0.0                                                            00170100
AFFR=0.0                                                            00170200
                                                                    00170300
906 CONTINUE                                                       00170400
                                                                    00170500
C #####                                                            00170600
C #####                                                            00170700
                                                                    00170800
      AP(I,J,K)=(AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)
&          +AF(I,J,K)+AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB)        00171000
&          +CONDE1+CONDW1+CONDN1+CONDS1+CONDF1+CONDB1          00171100
                                                                    00171200
      AE(I,J,K)=AE(I,J,K)+CONDE1                                    00171300
      AW(I,J,K)=AW(I,J,K)+CONDW1                                    00171400
      AN(I,J,K)=AN(I,J,K)+CONDN1                                    00171500
      AS(I,J,K)=AS(I,J,K)+CONDS1                                    00171600
      AF(I,J,K)=AF(I,J,K)+CONDF1                                    00171700
      AB(I,J,K)=AB(I,J,K)+CONDB1                                    00171800
                                                                    00171900
      SP(I,J,K)=-ROD(I,J,K)*VOLDT                                   00172000
      SU(I,J,K)= ROD(I,J,K)*VOLDT*TOD(I,J,K)                       00172100
      SU(I,J,K)=SU(I,J,K)+AEER+AWWR+ANNR+ASSR+AFFR+ABBR          00172200
100 CONTINUE                                                       00172300
                                                                    00172400
C ***   TAKE CARE OF B.C. THRU AN,AS,AE,AH,AF,AB,SP AND SU      00172500
C                                                                 00172600
C ***   RADIUS DIRECTION                                          00172700
                                                                    00172800
      DO 500 I=2,NI                                                00172900
      DO 500 K=2,NK                                                00173000
CC  SP(I,2,K)=SP(I,2,K)+AS(I,2,K)                                  00173100
      SP(I,2,K)=SP(I,2,K)-AS(I,2,K)                                00173200
      SU(I,2,K)=SU(I,2,K)+2.0*AS(I,2,K)*CPD(I,1,K)                00173300
      SP(I,NJ,K)=SP(I,NJ,K)-AN(I,NJ,K)                            00173400
      SU(I,NJ,K)=SU(I,NJ,K)+2.*CPD(I,NJ*PI,K)*AN(I,NJ,K)         00173500
      AS(I,2,K)=0. .                                               00173600
      AN(I,NJ,K)=0. .                                               00173700
500 CONTINUE                                                       00173800
                                                                    00173900
C ***   CYLIC CONDITIONS                                          00174000
                                                                    00174100
      DO 600 J=2,NJ                                                00174200
      DO 600 K=2,NK                                                00174300
      SU(2 ,J,K)=SU(2 ,J,K)+AW(2 ,J,K)*C(1 ,J,K)                 00174400

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SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*C(NIPI,J,K)	00174500
AW(2,J,K)=0.0	00174600
AE(NI,J,K)=0.0	00174700
600 CONTINUE	00174800
C *** END OF SPHERE	00174900
	00175000
DO 700 I=2,NI	00175100
DO 700 J=2,NJ	00175200
SP(I,J,2)=SP(I,J,2)+AB(I,J,2)	00175300
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)	00175400
AB(I,J,2)=0.	00175500
AF(I,J,NK)=0.	00175600
700 CONTINUE	00175700
	00175800
	00175900
	00176000
	00176100
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00176200
	00176300
DO 300 K=2,NK	00176400
DO 300 J=2,NJ	00176500
DO 300 I=2,NI	00176600
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00176700
300 CONTINUE	00176800
	00176900
	00177000
	00177100
C *** VOLUME MASS SOURCE INPUT	00177200
	00177300
VOLT=0.0	00177400
DO 113 I=2,NI	00177500
DO 113 J=2,NJ	00177600
DO 113 K=16,17	00177700
IF (NHSZ(I,J,K).EQ.0) GOTO 113	00177800
DXI =XL(I,J,K,0,0)	00177900
DYJ =YL(I,J,K,0,0)	00178000
DZK =ZL(I,J,K,0,0)	00178100
VOL=DXI*DYJ*DZK*H*H*H	00178200
VOLT=VOLT+VOL	00178300
113 CONTINUE	00178400
	00178500
DO 111 I=2,NI	00178600
DO 111 J=2,NJ	00178700
DO 111 K=16,17	00178800
IF (NHSZ(I,J,K).EQ.0) GOTO 111	00178900
DXI =XL(I,J,K,0,0)	00179000
DYJ =YL(I,J,K,0,0)	00179100
DZK =ZL(I,J,K,0,0)	00179200
QQQ=Q*H/(UO*CP0*RHO0*TA)	00179300
QMS= 1.0	00179400
QMS = QMS*H/(UO*RHO0)	00179500
VOL=DXI*DYJ*DZK	00179600
SU(I,J,K)=SU(I,J,K)+VOL*QMS/VOLT	00179700
111 CONTINUE	00179800
	00179900

```

C *** SOLVE FOR C                                00180000
                                                    00180100
CALL TRID (2,2,2,NI,NJM1,NK,C)                    00180200
                                                    00180300
C **** RESET CONCENTRATION AT R=0.0 AND END OF SPHERE 00180400
                                                    00180500
DO 81 K=1,NKP1                                     00180600
AVT=0.0                                             00180700
DO 82 I=2,NI                                       00180800
AVT=AVT+(C(I,2,K)/NIM1)                            00180900
82 CONTINUE                                         00181000
DO 83 I=1,NIP1                                     00181100
C(I,1,K)=AVT                                        00181200
83 CONTINUE                                         00181300
81 CONTINUE                                         00181400
                                                    00181500
DO 74 I=1,NIP1                                     00181600
DO 74 J=1,NJP1                                     00181700
C(I,J,1)=C(I,J,2)                                  00181800
C(I,J,NKP1)=C(I,J,NK)                             00181900
74 CONTINUE                                         00182000
                                                    00182100
C *** FOR SURFACE MASS EXCHANGE WITH SURROUNDING 00182200
                                                    00182300
DO 84 I=2,NI                                       00182400
DO 84 K=2,NK                                       00182500
C(I,NJP1,K)=C(I,NJ,K)                              00182600
84 CONTINUE                                         00182700
                                                    00182800
                                                    00182900
C *** FOR CYLIC CONDITION                          00183000
                                                    00183100
DO 80 J=1,NJP1                                     00183200
DO 80 K=1,NKP1                                     00183300
C(1,J,K)=C(NI,J,K)                                 00183400
C(NIP1,J,K)=C(2,J,K)                              00183500
80 CONTINUE                                         00183600
                                                    00183700
RETURN                                              00183800
END                                                  00183900
                                                    00184000
                                                    00184100
C _____ 00184200
C *-----* 00184300
SUBROUTINE CALU 00184400
C *-----* 00184500
COMMON/R4/XC( 93 ),YC( 93 ),ZC( 93 ),XS( 93 ),YS( 93 ),ZS( 93 ),
& DXXC( 93 ),DYXC( 93 ),DZZC( 93 ),DXXS( 93 ),DYYS( 93 ),DZZS( 93 )
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR 00184600
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00184700
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00184800
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER 00184900
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURE,VISL,VISMAX,QCORRT,PM1,PM2 00185000
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY, 00185100
& CPO,PRT,CONDO,VISO,RHO0,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00 00185200
00185300
00185400

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COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)	00185500
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32)	00185600
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00185700
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10)	00185800
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00185900
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32)	00186000
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00186100
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)	00186200
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32)	00186300
& ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32)	00186400
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00186500
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00186600
& DU(22,16,32),DV(22,16,32),DW(22,16,32)	00186700
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32),	00186800
& AS(22,16,32),AF(22,16,32),AB(22,16,32),	00186900
& SP(22,16,32),SU(22,16,32),RI(22,16,32)	00187000
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)	00187100
& ,CPH(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00187200
	00187300
C *** CALCULATE COEFFICIENTS	00187400
	00187500
DO 100 K=2,NK	00187600
KP2=K+2	00187700
KP1=K+1	00187800
KM1=K-1	00187900
KM2=K-2	00188000
DO 100 J=2,NJ	00188100
JP2=J+2	00188200
JP1=J+1	00188300
JM1=J-1	00188400
JM2=J-2	00188500
DO 100 I=2,NI	00188600
IP2=I+2	00188700
IP1=I+1	00188800
IM1=I-1	00188900
IM2=I-2	00189000
IF (I.EQ.2) IM1=NI	00189100
IF (I.EQ.2) IM2=NIM1	00189200
IF (I.EQ.3) IM2=NI	00189300
IF (I.EQ.NI) IP2=3	00189400
	00189500
	00189600
C CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00189700
	00189800
DXP1=XL(IP1,J,K,1,0)	00189900
DXI =XL(I ,J,K,1,0)	00190000
DXM1=XL(IM1,J,K,1,0)	00190100
	00190200
DYP1=YL(I,JP1,K,1,0)	00190300
DYJ =YL(I,J ,K,1,0)	00190400
DYM1=YL(I,JM1,K,1,0)	00190500
	00190600
DZP1=ZL(I,J,KP1,1,0)	00190700
DZK =ZL(I,J,K ,1,0)	00190800
DZM1=ZL(I,J,KM1,1,0)	00190900



C ***	SURFACE LENGTH OF THE CONTROL VOLUME	00191000
		00191100
	DXN=XL(I,JP1,K,1,2)	00191200
	DXS=XL(I,J,K,1,2)	00191300
	DXF=XL(I,J,KP1,1,3)	00191400
	DXB=XL(I,J,K,1,3)	00191500
		00191600
		00191700
	DYF=YL(I,J,KP1,1,3)	00191800
	DYB=YL(I,J,K,1,3)	00191900
	DYE=YL(IP1,J,K,1,1)	00192000
	DYH=YL(I,J,K,1,1)	00192100
		00192200
	DZE=ZL(IP1,J,K,1,1)	00192300
	DZH=ZL(I,J,K,1,1)	00192400
	DZN=ZL(I,JP1,K,1,2)	00192500
	DZS=ZL(I,J,K,1,2)	00192600
C ***	CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR U	00192700
		00192800
		00192900
	DXEE=XL(IP2,J,K,1,1)	00193000
	DXE =XL(IP1,J,K,1,1)	00193100
	DXW =XL(I,J,K,1,1)	00193200
	DXHW=XL(IM1,J,K,1,1)	00193300
		00193400
	DYNN=YL(I,JP2,K,1,2)	00193500
	DYN =YL(I,JP1,K,1,2)	00193600
	DYS =YL(I,J,K,1,2)	00193700
	DYSS=YL(I,JM1,K,1,2)	00193800
		00193900
	DZFF=ZL(I,J,KP2,1,3)	00194000
	DZF =ZL(I,J,KP1,1,3)	00194100
	DZB =ZL(I,J,K,1,3)	00194200
	DZBB=ZL(I,J,KM1,1,3)	00194300
		00194400
C ***	DEFINE THE AREA OF THE CONTROL VOLUME	00194500
		00194600
	DXYF=DXF*DYF	00194700
	DXYB=DXB*DYB	00194800
	DYZE=DYE*DZE	00194900
	DYZH=DYH*DZH	00195000
	DZXH=DZH*DXN	00195100
	DZXS=DZS*DXS	00195200
		00195300
	VOL=DXI*DYJ*DZK	00195400
	VOLDT=VOL/DTIME	00195500
		00195600
	ZXOYN=DZXN/DYN	00195700
	ZXOYS=DZXS/DYS	00195800
	XYOZF=DXYF/DZF	00195900
	XYOZB=DXYB/DZB	00196000
	YZOXE=DYZE/DXE	00196100
	YZOXH=DYZH/DXH	00196200
		00196300
		00196400

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C ***      USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE      00196500
C          PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.          00196600
                                                                00196700
                                                                00196800
GNE=SILIN(R(I ,JP1,K),R(I ,J,K),DYP1,DYJ)*V(I ,JP1,K)      00196900
GNW=SILIN(R(IM1,JP1,K),R(IM1,J,K),DYP1,DYJ)*V(IM1,JP1,K)    00197000
GSE=SILIN(R(I ,JM1,K),R(I ,J,K),DYM1,DYJ)*V(I ,J ,K)      00197100
GSW=SILIN(R(IM1,JM1,K),R(IM1,J,K),DYM1,DYJ)*V(IM1,J ,K)    00197200
                                                                00197300
GE =SILIN(R(IP1,J,K),R(I ,J,K),DXEE,DXE)*U(IP1,J,K)        00197400
GP =SILIN(R(IM1,J,K),R(I ,J,K),DXW ,DXE)*U(I ,J,K)          00197500
GW =SILIN(R(IM2,J,K),R(IM1,J,K),DXW,DXW)*U(IM1,J,K)         00197600
                                                                00197700
GFE=SILIN(R(I ,J,KP1),R(I ,J,K),DZP1,DZK)*W(I ,J,KP1)     00197800
GFW=SILIN(R(IM1,J,KP1),R(IM1,J,K),DZP1,DZK)*W(IM1,J,KP1)   00197900
GBE=SILIN(R(I ,J,KM1),R(I ,J,K),DZM1,DZK)*W(I ,J,K )      00198000
GBW=SILIN(R(IM1,J,KM1),R(IM1,J,K),DZM1,DZK)*W(IM1,J,K )    00198100
                                                                00198200
CE=0.5*(GE+GP)*DYZE      00198300
CW=0.5*(GP+GW)*DYZW     00198400
                                                                00198500
CN=SILIN(GNE,GNW,DXE,DXW)*DZXN      00198600
CS=SILIN(GSE,GSW,DXE,DXW)*DZXS     00198700
                                                                00198800
CF=SILIN(GFE,GFW,DXE,DXW)*DXYF     00198900
CB=SILIN(GBE,GBW,DXE,DXW)*DXYB     00199000
                                                                00199100
VISE=VIS(I ,J,K)          00199200
VISW=VIS(IM1,J,K)         00199300
                                                                00199400
VISN=      (VIS(I ,JP1,K)+VIS(I ,J,K)+      00199500
&          VIS(IM1,JP1,K)+VIS(IM1,J,K))/4.0  00199600
VISS=      (VIS(I ,JM1,K)+VIS(I ,J,K)+      00199700
&          VIS(IM1,JM1,K)+VIS(IM1,J,K))/4.0  00199800
                                                                00199900
VISF=      (VIS(I ,J,KP1)+VIS(I ,J,K)+      00200000
&          VIS(IM1,J,KP1)+VIS(IM1,J,K))/4.0  00200100
VISB=      (VIS(I ,J,KM1)+VIS(I ,J,K)+      00200200
&          VIS(IM1,J,KM1)+VIS(IM1,J,K))/4.0  00200300
                                                                00200400
                                                                00200500
VISN1=ZXOYN*VISN        00200600
VISS1=ZXOYS*VISS        00200700
VISE1=YZOXE*VISE        00200800
VISW1=YZOXW*VISW        00200900
VISF1=XYOZF*VISF        00201000
VISB1=XYOZB*VISB        00201100
                                                                00201200
                                                                00201300
CEP=(ABS(CE)+CE)*DXE/DXI/16.      00201400
CEM=(ABS(CE)-CE)*DXE/DXP1/16.     00201500
CNP=(ABS(CW)+CW)*DXW/DXM1/16.     00201600
CWM=(ABS(CW)-CW)*DXW/DXI/16.     00201700
                                                                00201800
CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS ))/8. 00201900

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CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYNN))/8.	00202000
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYSS))/8.	00202100
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN))/8.	00202200
	00202300
CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB))/8.	00202400
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF))/8.	00202500
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB))/8.	00202600
CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF))/8.	00202700
	00202800
AE(I,J,K)=-.5*CE+CEP+CEM*(1.+DXE/DXEE)+CWM*DXW/DXE+VISE1	00202900
AW(I,J,K)=.5*CW+CWM+CWP*(1.+DXW/DXWW)+CEP*DXE/DXW+VISW1	00203000
	00203100
	00203200
AN(I,J,K)=-.5*DYJ/DYN*CN+CNP+CNM*(1.+DYN/DYNN)+CSM*DYS/DYN+VISN1	00203300
AS(I,J,K)=.5*DYJ/DYS*CS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS+VISS1	00203310
AF(I,J,K)=-.5*DZK/DZF*CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF+VISF1	00203320
AB(I,J,K)=.5*DZK/DZB*CB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB+VISB1	00203330
	00203340
	00203400
801 AEE=-CEM*DXE/DXEE	00203500
AEER=AEE*UPD(IP2,J,K)	00203600
802 CONTINUE	00203700
	00203800
803 AWW=-CWP*DXW/DXWW	00203900
AWNR=AWW*UPD(IM2,J,K)	00204000
804 CONTINUE	00204100
	00204200
IF(J.LT.NJ)GOTO 805	00204300
ANN=0.	00204400
ANNR=0.	00204500
GOTO 806	00204600
805 ANN=-CNM*DYN/DYNN	00204700
ANNR=ANN*UPD(I,JP2,K)	00204800
806 CONTINUE	00204900
	00205000
	00205100
IF(J.GT.2)GOTO 807	00205200
ASS=0.	00205300
ASSR=0.	00205400
GOTO 808	00205500
807 ASS=-CSP*DYS/DYSS	00205600
ASSR=ASS*UPD(I,JM2,K)	00205700
808 CONTINUE	00205800
	00205900
	00206000
IF(K.LT.NK)GOTO 809	00206100
AFF=0.	00206200
AFFR=0.	00206300
GOTO 810	00206400
809 AFF=-CFM*DZF/DZFF	00206500
AFFR=AFF*UPD(I,J,KP2)	00206600
810 CONTINUE	00206700
	00206800
	00206900
	00207000
IF(K.GT.2)GOTO 811	
ABB=0.	
ABBR=0.	
GOTO 812	

811	ABB=-CBP*DZB/DZBB	00207100
	ABBR=ABB*UPD(I,J,KM2)	00207200
812	CONTINUE	00207300
		00207400
		00207500
C	#####	00207600
C	#####	00207700
C	*** MODIFICATION FOR DECK BOUNDARIES	00207800
		00207900
900	CONTINUE	00208000
	IF (NOD(IM2,J,K).EQ.0) GOTO 901	00208100
	AWW=0.0	00208200
	AWWR=0.0	00208300
		00208400
901	CONTINUE	00208500
	IF (NOD(IP1,J,K).EQ.0) GOTO 902	00208600
	AEE=0.0	00208700
	AEER=0.0	00208800
		00208900
902	CONTINUE	00209000
	IF (NOD(I,JM1,K).EQ.0) GOTO 903	00209100
	ASS=0.0	00209200
	ASSR=0.0	00209300
		00209400
903	CONTINUE	00209500
	IF (NOD(I,JP1,K).EQ.0) GOTO 904	00209600
	ANN=0.0	00209700
	ANNR=0.0	00209800
904	CONTINUE	00209900
	IF (NOD(I,J,KM1).EQ.0) GOTO 905	00210000
	ABB=0.0	00210100
	ABBR=0.0	00210200
		00210300
905	CONTINUE	00210400
	IF (NOD(I,J,KP1).EQ.0) GOTO 906	00210500
	AFF=0.0	00210600
	AFFR=0.0	00210700
		00210800
906	CONTINUE	00210900
C	#####	00211000
C	#####	00211100
		00211200
		00211300
		00211400
		00211500
C	*** SU FROM NORMAL STRESS	00211600
		00211700
	RE=(SIG11(I ,J,K)-(U(IP1,J,K)-U(I ,J,K))*VISE/DXE)*DYZE	00211800
	RW=(SIG11(IM1,J,K)-(U(I ,J,K)-U(IM1,J,K))*VISH/DXW)*DYZW	00211900
	RN=(SIG12(I,JP1,K)-(U(I,JP1,K)-U(I,J ,K))*VISN/DYN)*DZXN	00212000
	RS=(SIG12(I,J ,K)-(U(I,J ,K)-U(I,JM1,K))*VISS/DYS)*DZXS	00212100
	RF=(SIG13(I,J,KP1)-(U(I,J,KP1)-U(I,J,K ))*VISF/DZF)*DXYF	00212200
	RB=(SIG13(I,J,K )-(U(I,J,K )-U(I,J,KM1))*VISB/DZB)*DXYB	00212300
		00212400
C	*** SU FROM CURVED STRESSES AND ACCELERATIONS	00212500

		00212600
	AVG12=0.5*(SIG12(I,JP1,K)+SIG12(I,J,K))	00212700
	AVG13=0.5*(SIG13(I,J,KP1)+SIG13(I,J,K))	00212800
	AVG22=SILIN(SIG22(I,J,K),SIG22(IM1,J,K),DXE,DXW)	00212900
	AVG33=SILIN(SIG33(I,J,K),SIG33(IM1,J,K),DXE,DXW)	00213000
		00213100
	AU1=U(I,J,K)	00213200
	AU2=BILIN(V(I ,JP1,K),V(I ,J,K),DYJ,DYJ,	00213300
&	V(IM1,JP1,K),V(IM1,J,K),DYJ,DYJ, DXE,DXW)	00213400
	AU3=BILIN(W(I ,J,KP1),W(I ,J,K),DZK,DZK,	00213500
&	W(IM1,J,KP1),W(IM1,J,K),DZK,DZK, DXE,DXW)	00213600
		00213700
	AR=SILIN(R(I,J,K),R(IM1,J,K),DXE,DXW)	00213800
		00213900
	ARU12=AR*AU1*AU2	00214000
	ARU13=AR*AU1*AU3	00214100
	ARU22=AR*AU2*AU2	00214200
	ARU33=AR*AU3*AU3	00214300
		00214400
	RRY=(AVG12-ARU12)*DZK*(DXN-DXS)	00214500
	RRZ=(AVG13-ARU13)*DYJ*(DXF-DXB)	00214600
	RRX=(AVG22-ARU22)*DZK*(DYE-DYW)+	00214700
&	(AVG33-ARU33)*DYJ*(DZE-DZW)	00214800
		00214900
	AP(I,J,K)=AE(I,J,K)+AH(I,J,K)+AN(I,J,K)+AS(I,J,K)	00215000
&	+AF(I,J,K)+AB(I,J,K)+AEE+AHW+ANN+ASS+AFF+ABB	00215100
	SP(I,J,K)=- (ROD(I,J,K)*DXW+ROD(IM1,J,K)*DXE)/(DXW+DXE)*VOLDT	00215200
	SU(I,J,K)= (ROD(I,J,K)*DXW+ROD(IM1,J,K)*DXE)/(DXW+DXE)*VOLDT	00215300
&	*UOD(I,J,K)	00215400
	SU(I,J,K)=SU(I,J,K)+DYJ*DZK*(P(IM1,J,K)-P(I,J,K))	00215500
&	+AEER+AHWR+ANNR+ASSR+AFFR+ABBR	00215600
&	+RE-RW+RN-RS+RF-RB+RRY+RRZ-RRX	00215700
&	2-BUOY*SIN(ZC(K))*((R(I,J,K)-REQ(I,J,K))*DXW*COS(XC(I)))+(R(IM1,	00215800
&	J,K)-REQ(IM1,J,K))*DXE*COS(XC(IM1)))/(DXW+DXE)*VOL	00215900
100	CONTINUE	00216000
		00216100
C ***	TAKE CARE OF B.C. THRU AN,AS,AE,AH,AF,AB,SP AND SU	00216200
C		00216300
C ***	RADIUS DIRECTION	00216400
		00216500
	DO 500 K=2,NK	00216600
	DO 500 I=2,NI	00216700
CC	SP(I,2,K)=SP(I,2,K)+AS(I,2,K)	00216800
	SP(I,2,K)=SP(I,2,K)-AS(I,2,K)	00216900
	SU(I,2,K)=SU(I,2,K)+2.0*U(I,1,K)*AS(I,2,K)	00217000
	SP(I,NJ,K)=SP(I,NJ,K)-AN(I,NJ,K)	00217100
	AN(I,NJ,K)=0.	00217200
	AS(I,2,K)=0.	00217300
500	CONTINUE	00217400
		00217500
C ***	CYLIC CONDITION	00217600
		00217700
	DO 502 K=2,NK	00217800
	DO 502 J=2,NJ	00217900
	SU(2 ,J,K)=SU(2 ,J,K)+AW(2 ,J,K)*U(1 ,J,K)	00218000

SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*U(NIP1,J,K)	00218100
AW(2,J,K)=0.0	00218200
AE(NI,J,K)=0.0	00218300
502 CONTINUE	00218400
C *** FRONT AND BACK WALLS	00218500
DO 600 I=2,NI	00218600
DO 600 J=2,NJ	00218700
	00218800
	00218900
	00219000
C *** SLIP WALLS	00219100
SP(I,J,2)=SP(I,J,2)+AB(I,J,2)	00219200
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)	00219300
	00219400
AF(I,J,NK)=0.	00219500
AB(I,J,2)=0.	00219600
600 CONTINUE	00219700
	00219800
	00219900
	00220000
	00220100
IF (NCHIP.EQ.0) GOTO 105	00220200
C #####	00220300
C #####	00220400
C *** MODIFICATION FOR DECK BOUNDARIES	00220500
DO 101 N=1,NCHIP	00220600
IB=ICHPB(N)	00220700
IE=IB+NCHPI(N)-1	00220800
IBM1=IB-1	00220900
IEP1=IE+1	00221000
JB=JCHPB(N)	00221100
JE=JB+NCHPJ(N)-1	00221200
JB11=JB-1	00221300
JEP1=JE+1	00221400
KB=KCHPB(N)	00221500
KE=KB+NCHPK(N)-1	00221600
KBM1=KB-1	00221700
KEP1=KE+1	00221800
	00221900
	00222000
DO 102 J=JB,JE-1	00222100
DO 102 K=KB,KE-1	00222200
AE(IBM1,J,K)=0.0	00222300
AW(IEP1,J,K)=0.0	00222400
	00222500
102 CONTINUE	00222600
	00222700
DO 103 I=IB,IE	00222800
DO 103 K=KB,KE-1	00222900
SP(I,JBM1,K)=SP(I,JBM1,K)-AN(I,JBM1,K)	00223000
AN(I,JBM1,K)=0.0	00223100
	00223200
SP(I,JE,K)=SP(I,JE,K)-AS(I,JE,K)	00223300
AS(I,JE,K)=0.0	00223400
103 CONTINUE	00223500

DO 106 I=IB,IE	00223600
DO 106 J=JB,JE-1	00223700
SP(I,J,KBM1)=SP(I,J,KBM1)-AF(I,J,KBM1)	00223800
AF(I,J,KBM1)=0.0	00223900
	00224000
	00224100
SP(I,J,KE)=SP(I,J,KE)-AB(I,J,KE)	00224200
AB(I,J,KE)=0.0	00224300
106 CONTINUE	00224400
	00224500
	00224600
C *** FOR THE CELLS INSIDE OF THE DECKS	00224700
	00224800
DO 104 I=IB,IE	00224900
DO 104 J=JB,JE-1	00225000
DO 104 K=KB,KE-1	00225100
SP(I,J,K)=-1.0E20	00225200
AW(I,J,K)=0.	00225300
AE(I,J,K)=0.	00225400
AS(I,J,K)=0.	00225500
AN(I,J,K)=0.	00225600
SU(I,J,K)=0.	00225700
104 CONTINUE	00225800
101 CONTINUE	00225900
105 CONTINUE	00226000
	00226100
C #####	00226200
C #####	00226300
	00226400
	00226500
	00226600
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00226700
	00226800
DO 301 K=2,NK	00226900
DO 301 J=2,NJ	00227000
DO 301 I=2,NI	00227100
DYJ=YL(I,J,K,1,0)	00227200
DZK=ZL(I,J,K,1,0)	00227300
DYZ=DYJ*DZK	00227400
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00227500
DU(I,J,K)=DYZ/AP(I,J,K)	00227600
301 CONTINUE	00227700
	00227800
	00227900
	00228000
C *** SOLVE FOR U	00228100
	00228200
CALL TRID (2,2,2,NI,NJ,NK,U)	00228300
	00228400
DO 74 I=2,NIP1	00228500
DO 74 J=2,NJP1	00228600
U(I,J,1)=U(I,J,2)	00228700
U(I,J,NKP1)=U(I,J,NK)	00228800
74 CONTINUE	00228900
	00229000

		00229100
	DO 79 I=1,NIP1	00229200
	OO 79 K=1,NKP1	00229300
C	U(I,1,K)=U(I,2,K)	00229400
	79 CONTINUE	00229500
		00229600
		00229700
	IF (NCHIP.EQ.0) GOTO 112	00229800
C	#####	00229900
C	#####	00230000
C	*** RESET THE VELOCITY INSIOE OF DECK	00230100
		00230200
	DO 110 N=1,NCHIP	00230300
	IB=ICHPB(N)	00230400
	IE=IB+NCHPI(N)-1	00230500
	JB=JCHPB(N)	00230600
	JE=JB+NCHPJ(N)-1	00230700
	KB=KCHPB(N)	00230800
	KE=KB+NCHPK(N)-1	00230900
	DO 108 I=IB,IE	00231000
	OO 108 J=JB,JE-1	00231100
	DO 108 K=KB,KE-1	00231200
	U(I,J,K)=0.0	00231300
	108 CONTINUE	00231400
	110 CONTINUE	00231500
	112 CONTINUE	00231600
C	#####	00231700
C	#####	00231800
		00231900
	RETURN	00232000
	END	00232100
		00232200
		00232300
		00232400
C	-----	00232500
C	*****	00232600
	SUBROUTINE CALV	00232700
C	*****	00232800
	COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00233000
	& OXXC(93),OYYC(93),OZZC(93),OXXS(93),OYYs(93),OZZS(93)	00233100
	COMMON/BL1/OX,DY,DZ,VOL,OTIME,VOLOT,THOT,TCOOL,PI,Q,QR	00233200
	COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00233300
	& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00233400
	COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00233500
	COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,	00233600
	& CPO,PRT,CON00,VISO,RH00,HR,TR,TA,OTEMP,TWRITE,TTAPE,TMAX,GC,RAIR	00233700
	COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)	00233800
	& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32)	00233900
	COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00234000
	& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10)	00234100
	COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00234200
	& ,COO(22,16,32),U00(22,16,32),V00(22,16,32),W00(22,16,32)	00234300
	COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00234400
	& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)	00234500



COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),FPD(22,16,32)	00234600
& ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32)	00234700
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00234800
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00234900
& DU(22,16,32),DV(22,16,32),DW(22,16,32)	00235000
COMMON/BL36/AP(22,16,32),AE(22,16,32),AH(22,16,32),AN(22,16,32),	00235100
& AS(22,16,32),AF(22,16,32),AB(22,16,32),	00235200
& SP(22,16,32),SU(22,16,32),RI(22,16,32)	00235300
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)	00235400
& ,CPH(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00235500
	00235600
	00235700
C *** CALCULATE COEFFICIENTS	00235800
	00235900
DO 100 K=2,NK	00236000
KP2=K+2	00236100
KP1=K+1	00236200
KM1=K-1	00236300
KM2=K-2	00236400
DO 100 J=3,NJ	00236500
JP2=J+2	00236600
JP1=J+1	00236700
JM1=J-1	00236800
JM2=J-2	00236900
DO 100 I=2,NI	00237000
IP2=I+2	00237100
IP1=I+1	00237200
IM1=I-1	00237300
IM2=I-2	00237400
IF (I.EQ.2) IM2=NIM1	00237500
IF (I.EQ.NI) IP2=3	00237600
	00237700
	00237800
C CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00237900
	00238000
DXP1=XL(IP1,J,K,2,0)	00238100
DXI =XL(I ,J,K,2,0)	00238200
DXM1=XL(IM1,J,K,2,0)	00238300
	00238400
DYP1=YL(I,JP1,K,2,0)	00238500
DYJ =YL(I,J ,K,2,0)	00238600
DYM1=YL(I,JM1,K,2,0)	00238700
	00238800
DZP1=ZL(I,J,KP1,2,0)	00238900
DZK =ZL(I,J,K ,2,0)	00239000
DZM1=ZL(I,J,KM1,2,0)	00239100
	00239200
C *** SURFACE LENGTH OF THE CONTROL VOLUME	00239300
	00239400
DXN=XL(I,JP1,K,2,2)	00239500
DXS=XL(I,J ,K,2,2)	00239600
DXF=XL(I,J,KP1,2,3)	00239700
DXB=XL(I,J,K ,2,3)	00239800
	00239900
DYF=YL(I,J,KP1,2,3)	00240000

DYB=YL(I,J,K ,2,3)	00240100
DYE=YL(IP1,J,K,2,1)	00240200
DYW=YL(I ,J,K,2,1)	00240300
	00240400
DZE=ZL(IP1,J,K,2,1)	00240500
DZW=ZL(I ,J,K,2,1)	00240600
DZN=ZL(I,JP1,K,2,2)	00240700
DZS=ZL(I,J ,K,2,2)	00240800
	00240900
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME	00241000
	00241100
DXEE=XL(IP2,J,K,2,1)	00241200
DXE =XL(IP1,J,K,2,1)	00241300
DXW =XL(I ,J,K,2,1)	00241400
DXN=XL(IM1,J,K,2,1)	00241500
	00241600
DYNN=YL(I,JP2,K,2,2)	00241700
DYN =YL(I,JP1,K,2,2)	00241800
DYS =YL(I,J ,K,2,2)	00241900
DYSS=YL(I,JM1,K,2,2)	00242000
	00242100
DZFF=ZL(I,J,KP2,2,3)	00242200
DZF =ZL(I,J,KP1,2,3)	00242300
DZB =ZL(I,J,K ,2,3)	00242400
DZBB=ZL(I,J,KM1,2,3)	00242500
	00242600
C *** DEFINE THE AREA OF THE CONTROL VOLUME	00242700
	00242800
DXYF=DXF*DYF	00242900
DXYB=DXB*DYB	00243000
DYZE=DYE*DZE	00243100
DYZW=DYW*DZW	00243200
DZXN=DZN*DXN	00243300
DZXS=DZS*DXS	00243400
	00243500
VOL=DXI*DYJ*DZK	00243600
VOLDT=VOL/DTIME	00243700
	00243800
ZXOYN=DZXN/DYN	00243900
ZXOYS=DZXS/DYS	00244000
XYOZF=DXYF/DZF	00244100
XYOZB=DXYB/DZB	00244200
YZOXE=DYZE/DXE	00244300
YZOXW=DYZW/DXW	00244400
	00244500
	00244600
C *** USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE	00244700
C & PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.	00244800
	00244900
	00245000
GEN=SILIN(R(IP1,J ,K),R(I,J ,K),DXP1,DXI)*U(IP1,J ,K)	00245100
GES=SILIN(R(IP1,JM1,K),R(I,JM1,K),DXP1,DXI)*U(IP1,JM1,K)	00245200
GWN=SILIN(R(IM1,J ,K),R(I,J ,K),DXM1,DXI)*U(I ,J ,K)	00245300
GWS=SILIN(R(IM1,JM1,K),R(I,JM1,K),DXM1,DXI)*U(I ,JM1,K)	00245400
	00245500

GN =SILIN(R(I,JP1,K),R(I,J ,K),DYN,DYN)*V(I,JP1,K)	00245600
GP =SILIN(R(I,JM1,K),R(I,J ,K),DYS ,DYN)*V(I,J ,K)	00245700
GS =SILIN(R(I,JM2,K),R(I,JM1,K),DYSS,DYS)*V(I,JM1,K)	00245800
	00245900
GFN=SILIN(R(I,J ,KP1),R(I,J ,K),DZP1,DZK)*W(I,J ,KP1)	00246000
GFS=SILIN(R(I,JM1,KP1),R(I,JM1,K),DZP1,DZK)*W(I,JM1,KP1)	00246100
GBN=SILIN(R(I,J ,KM1),R(I,J ,K),DZM1,DZK)*W(I,J ,K )	00246200
GBS=SILIN(R(I,JM1,KM1),R(I,JM1,K),DZM1,DZK)*W(I,JM1,K )	00246300
	00246400
CN=0.5*(GN+GP)*DZXN	00246500
CS=0.5*(GP+GS)*DZXS	00246600
	00246700
CE=SILIN(GEN,GES,DYN,DYS)*DYZE	00246800
CW=SILIN(GMN,GMS,DYN,DYS)*DYZW	00246900
	00247000
CF=SILIN(GFN,GFS,DYN,DYS)*DXYF	00247100
CB=SILIN(GBN,GBS,DYN,DYS)*DXYB	00247200
	00247300
VISN=VIS(I,J ,K)	00247400
VISS=VIS(I,JM1,K)	00247500
	00247600
WISE= (VIS(IP1,J ,K)+VIS(I,J ,K)+	00247700
& VIS(IP1,JM1,K)+VIS(I,JM1,K))/4.0	00247800
VISH= (VIS(IM1,J ,K)+VIS(I,J ,K)+	00247900
& VIS(IM1,JM1,K)+VIS(I,JM1,K))/4.0	00248000
	00248100
VISF= (VIS(I,J ,KP1)+VIS(I,J ,K)+	00248200
& VIS(I,JM1,KP1)+VIS(I,JM1,K))/4.0	00248300
VISB= (VIS(I,J ,KM1)+VIS(I,J ,K)+	00248400
& VIS(I,JM1,KM1)+VIS(I,JM1,K))/4.0	00248500
	00248600
	00248700
	00248800
VISN1=ZXOYN*VISN	00248900
VISS1=ZXOYS*VISS	00249000
WISE1=YZOXE*WISE	00249100
VISH1=YZOXW*VISH	00249200
VISF1=XYOZF*VISF	00249300
VISB1=XYOZB*VISB	00249400
	00249500
	00249600
C	00249700
CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW))/8.	00249800
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXE))/8.	00249900
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXW))/8.	00250000
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE))/8.	00250100
	00250200
C	00250300
CNP=(ABS(CN)+CN)*DYN/DYJ/16.	00250400
CNM=(ABS(CN)-CN)*DYN/DYP1/16.	00250500
CSP=(ABS(CS)+CS)*DYS/DYM1/16.	00250600
CSM=(ABS(CS)-CS)*DYS/DYJ/16.	00250700
	00250800
C	00250900
CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB))/8.	00251000
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF))/8.	
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB))/8.	

	CBM=(ABS(CB)-CB)*DZM1*DZK/(DZB*(DZB+DZF))/8.	00251100
C		00251200
C		00251300
	AE(I,J,K)=-.5*DXI/DXE*CE+CEP+CEM*(1.+DXE/DXEE)+CWM*DXW/DXE+VISE1	00251400
	AH(I,J,K)=.5*DXI/DXW*CH+CWM+CWP*(1.+DXW/DXWW)+CEP*DXE/DXW+VISH1	00251500
C		00251600
	AN(I,J,K)=-.5*CN+CNP+CNM*(1.+DYN/DYNN)+CSM*DYS/DYN+VISN1	00251700
	AS(I,J,K)=.5*CS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS+VISS1	00251800
C		00251810
	AF(I,J,K)=-.5*DZK/DZF*CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF+VISF1	00251820
	AB(I,J,K)=.5*DZK/DZB*CB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB+VISB1	00251830
C		00251840
		00251900
801	AEE=-CEM*DXE/DXEE	00252000
	AEER=AEE*VPD(IP2,J,K)	00252100
802	CONTINUE	00252200
		00252300
803	AHW=-CWP*DXW/DXWW	00252400
	AHWR=AHW*VPD(IM2,J,K)	00252500
804	CONTINUE	00252600
		00252700
	IF(J.LT.NJ) GOTO 805	00252800
	ANN=0.	00252900
	ANNR=0.	00253000
	GOTO 806	00253100
805	ANN=-CNM*DYN/DYNN	00253200
	ANNR=ANN*VPD(I,JP2,K)	00253300
806	CONTINUE	00253400
		00253500
	IF(J.GT.3) GOTO 807	00253600
	ASS=0.	00253700
	ASSR=0.	00253800
	GOTO 808	00253900
807	ASS=-CSP*DYS/DYSS	00254000
	ASSR=ASS*VPD(I,JM2,K)	00254100
808	CONTINUE	00254200
		00254300
	IF(K.LT.NK) GOTO 809	00254400
	AFF=0.	00254500
	AFFR=0.	00254600
	GOTO 810	00254700
809	AFF=-CFM*DZF/DZFF	00254800
	AFFR=AFF*VPD(I,J,KP2)	00254900
810	CONTINUE	00255000
		00255100
	IF(K.GT.2) GOTO 811	00255200
	ABB=0.	00255300
	ABBR=0.	00255400
	GOTO 812	00255500
811	ABB=-CBP*DZB/DZBB	00255600
	ABBR=ABB*VPD(I,J,KM2)	00255700
812	CONTINUE	00255800
		00255900
		00256000
		00256100

C #####	00256200
C #####	00256300
C *** MODIFICATION FOR OECK BOUNDARIES	00256400
900 CONTINUE	00256500
IF (NOD(IM1,J,K).EQ.0) GOTO 901	00256600
AKW=0.0	00256700
AWHR=0.0	00256800
	00256900
	00257000
901 CONTINUE	00257100
IF (NOO(IP1,J,K).EQ.0) GOTO 902	00257200
AEE=0.0	00257300
AEER=0.0	00257400
	00257500
902 CONTINUE	00257600
IF (NOO(I,JM2,K).EQ.0) GOTO 903	00257700
ASS=0.0	00257800
ASSR=0.0	00257900
	00258000
903 CONTINUE	00258100
IF (NOO(I,JP1,K).EQ.0) GOTO 904	00258200
ANN=0.0	00258300
ANNR=0.0	00258400
	00258500
904 CONTINUE	00258600
IF (NOD(I,J,KM1).EQ.0) GOTO 905	00258700
ABB=0.0	00258800
ABBR=0.0	00258900
	00259000
905 CONTINUE	00259100
IF (NOO(I,J,KP1).EQ.0) GOTO 906	00259200
AFF=0.0	00259300
AFFR=0.0	00259400
906 CONTINUE	00259500
	00259600
C #####	00259700
C #####	00259800
	00259900
	00260000
C *** SU FROM NORMAL STRESS	00260100
	00260200
RN=(SIG22(I,J ,K)-(V(I,JP1,K)-V(I,J ,K))*VISN/DYN)*DZXN	00260300
RS=(SIG22(I,JM1,K)-(V(I,J ,K)-V(I,JM1,K))*VISS/OYS)*DZXS	00260400
RE=(SIG12(IP1,J,K)-(V(IP1,J,K)-V(I,J ,K))*VISE/DXE)*DYZE	00260500
RW=(SIG12(I ,J,K)-(V(I ,J,K)-V(IM1,J,K))*VISH/OXW)*DYZW	00260600
RF=(SIG23(I,J,KP1)-(V(I,J,KP1)-V(I,J,K ))*VISF/DZF)*OXYF	00260700
RB=(SIG23(I,J,K )-(V(I,J,K )-V(I,J,KM1))*VISB/DZB)*OXYB	00260800
	00260900
C *** SU FROM CURVED STRESSES AND ACCELERATIONS	00261000
	00261100
AVG12=0.5*(SIG12(IP1,J,K)+SIG12(I,J,K))	00261200
AVG23=0.5*(SIG23(I,J,KP1)+SIG23(I,J,K))	00261300
AVG11=SILIN(SIG11(I,J,K),SIG11(I,JM1,K),DYN,DYS)	00261400
AVG33=SILIN(SIG33(I,J,K),SIG33(I,JM1,K),DYN,OYS)	00261500
	00261600

AU2=V(I,J,K)	00261700
AU1=BILIN(U(IP1,J ,K),U(I,J ,K),DXI,DXI,	00261800
& U(IP1,JM1,K),U(I,JM1,K),DXI,DXI, DYN,DYS)	00261900
AU3=BILIN(W(I ,J,KP1),W(I ,J,K),DZK,DZK,	00262000
& W(I,JM1,KP1),W(I,JM1,K),DZK,DZK, DYN,DYS)	00262100
AR=SILIN(R(I,J,K),R(I,JM1,K),DYN,DYS)	00262200
	00262300
	00262400
ARU12=AR*AU1*AU2	00262500
ARU23=AR*AU2*AU3	00262600
ARU11=AR*AU1*AU1	00262700
ARU33=AR*AU3*AU3	00262800
	00262900
RRX=(AVG12-ARU12)*DZK*(DYE-DYW)	00263000
RRZ=(AVG23-ARU23)*DXI*(DYF-DYB)	00263100
RRY=(AVG11-ARU11)*DZK*(DXN-DXS)+	00263200
& (AVG33-ARU33)*DXI*(DZN-DZS)	00263300
	00263400
	00263500
	00263600
AP(I,J,K)=AE(I,J,K)+AW(I,J,K)+AN(I,J,K)+AS(I,J,K)	00263700
& +AF(I,J,K)+AB(I,J,K)+AEE+AWH+ANN+ASS+AFF+ABB	00263800
SP(I,J,K)=- (ROD(I,J,K)*DYS+ROD(I,JM1,K)*DYN)/(DYS+DYN)*VOLDT	00263900
SU(I,J,K)= (ROD(I,J,K)*DYS+ROD(I,JM1,K)*DYN)/(DYS+DYN)*VOLDT	00264000
& *VOD(I,J,K)	00264100
	00264200
SU(I,J,K)=SU(I,J,K)+DZK*DXI*(P(I,JM1,K)-P(I,J,K))	00264300
& +AEER+AWWR+ANNR+ASSR+AFFR+ABBR	00264400
& +RE-RW+RN-RS+RF-RB+RRX+RRZ-RRY	00264500
& -BUOY*((R(I,J,K)-REQ(I,J,K))*DYS+(R(I,JM1,K)	00264600
& -REQ(I,JM1,K))*DYN)/(DYS+DYN)*VOL*SIN(ZC(K))*SIN(XC(I))	00264700
100 CONTINUE	00264800
	00264900
	00265000
C *** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU	00265100
C	00265200
C *** RADIUS DIRECTION	00265300
	00265400
DO 500 K=2,NK	00265500
DO 500 I=2,NI	00265600
CC SP(I,3,K)=SP(I,3,K)+AS(I,3,K)	00265700
SU(I,3,K)=SU(I,3,K)+AS(I,3,K)*V(I,2,K)	00265800
AS(I,3,K)=0.	00265900
AN(I,NJ,K)=0.	00266000
500 CONTINUE	00266100
	00266200
	00266300
C *** CYLIC CONDITIONS	00266400
	00266500
DO 502 K=2,NK	00266600
DO 502 J=3,NJ	00266700
SU(2 ,J,K)=SU(2 ,J,K)+AW(2 ,J,K)*V(1 ,J,K)	00266800
SU(NI ,J,K)=SU(NI ,J,K)+AE(NI ,J,K)*V(NIP1,J,K)	00266900
AW(2 ,J,K)=0.0	00267000
AE(NI ,J,K)=0.0	00267100
502 CONTINUE	

C ***	FRONT AND BACK WALL	00267200
		00267300
	DO 600 I=2,NI	00267400
	DO 600 J=3,NJ	00267500
	JM1=J-1	00267600
		00267700
		00267800
C ***	SLIP WALLS	00267900
	SP(I,J,2)=SP(I,J,2)+AB(I,J,2)	00268000
	SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)	00268100
		00268200
	AF(I,J,NK)=0.	00268300
	AB(I,J,2)=0.	00268400
	600 CONTINUE	00268500
		00268600
		00268700
		00268800
C *****		00268900
C ***	MODIFICATION FOR DECK BOUNDARIES	00269000
		00269100
	DO 101 N=1,NCHIP	00269200
	IB=ICHPB(N)	00269300
	IE=IB+NCHPI(N)-1	00269400
	IBM1=IB-1	00269500
	IEP1=IE+1	00269600
	JB=JCHPB(N)	00269700
	JE=JB+NCHPJ(N)-1	00269800
	JBM1=JB-1	00269900
	JEP1=JE+1	00270000
	KB=KCHPB(N)	00270100
	KE=KB+NCHPK(N)-1	00270200
	KBM1=KB-1	00270300
	KEP1=KE+1	00270400
		00270500
	DO 102 J=JB,JE	00270600
	DO 102 K=KB,KE-1	00270700
	SP(IBM1,J,K)=SP(IBM1,J,K)-AE(IBM1,J,K)	00270800
	AE(IBM1,J,K)=0.0	00270900
		00271000
	SP(IE,J,K)=SP(IE,J,K)-AW(IE,J,K)	00271100
	AW(IE,J,K)=0.0	00271200
	102 CONTINUE	00271300
		00271400
	DO 103 I=IB,IE-1	00271500
	DO 103 K=KB,KE-1	00271600
	AN(I,JBM1,K)=0.0	00271700
	AS(I,JEP1,K)=0.0	00271800
	103 CONTINUE	00271900
		00272000
	DO 106 I=IB,IE-1	00272100
	DO 106 J=JB,JE	00272200
	SP(I,J,KBM1)=SP(I,J,KBM1)-AF(I,J,KBM1)	00272300
	AF(I,J,KBM1)=0.0	00272400
		00272500
	SP(I,J,KE)=SP(I,J,KE)-AB(I,J,KE)	00272600

AB(I,J,KE)=0.0	00272700
106 CONTINUE	00272800
	00272900
	00273000
C *****	00273100
C *****	00273200
C *** MODIFICATION FOR THE CELLS INSIDE OF THE DECKS	00273300
	00273400
DO 104 I=IB,IE-1	00273500
DO 104 J=JB,JE	00273600
DO 104 K=KB,KE-1	00273700
SP(I,J,K)=-1.0E20	00273800
AW(I,J,K)=0.	00273900
AE(I,J,K)=0.	00274000
AS(I,J,K)=0.	00274100
AN(I,J,K)=0.	00274200
SU(I,J,K)=0.	00274300
104 CONTINUE	00274400
101 CONTINUE	00274500
105 CONTINUE	00274600
	00274700
	00274800
	00274900
	00275000
C *****	00275100
C *****	00275200
C	00275300
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00275400
	00275500
DO 300 K=2,NK	00275600
DO 300 J=3,NJ	00275700
DO 300 I=2,NI	00275800
DXI=XL(I,J,K,2,0)	00275900
DZK=ZL(I,J,K,2,0)	00276000
DZX=DZK/DXI	00276100
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00276200
DV(I,J,K)=DZX/AP(I,J,K)	00276300
300 CONTINUE	00276400
	00276500
C *** SOLVE FOR V	00276600
	00276700
	00276800
CALL TRID (2,3,2,NI,NJ,NK,V)	00276900
	00277000
	00277100
DO 74 I=2,NIP1	00277200
DO 74 J=2,NJP1	00277300
V(I,J,1)=V(I,J,2)	00277400
V(I,J,NKP1)=V(I,J,NK)	00277500
74 CONTINUE	00277600
DO 79 I=1,NIP1	00277700
DO 79 K=1,NKP1	00277800
C V(I,2,K)=V(I,3,K)	00277900
79 CONTINUE	00278000
	00278100



		00278200
	IF (NCHIP.EQ.0) GOTO 112	00278300
C	#####	00278400
C	#####	00278500
C	*** RESET THE VELOCITY INSIDE OF THE DECKS	00278600
		00278700
	DO 110 N=1,NCHIP	00278800
	IB=ICHPB(N)	00278900
	IE=IB+NCHPI(N)-1	00279000
	JB=JCHPB(N)	00279100
	JE=JB+NCHPJ(N)-1	00279200
	KB=KCHPB(N)	00279300
	KE=KB+NCHPK(N)-1	00279400
	DO 108 I=IB,IE-1	00279500
	DO 108 J=JB,JE	00279600
	DO 108 K=KB,KE-1	00279700
	V(I,J,K)=0.0	00279800
	108 CONTINUE	00279900
	110 CONTINUE	00280000
	112 CONTINUE	00280100
		00280200
C	#####	00280300
C	#####	00280400
	RETURN	00280500
	END	00280600
		00280700
		00280800
		00280900
C		00281000
C	*****	00281100
	SUBROUTINE CALW	00281200
C	*****	00281300
	COMMON/R4/XC( 93 ),YC( 93 ),ZC( 93 ),XS( 93 ),YS( 93 ),ZS( 93 ),	00281400
	& DXXC( 93 ),DYXC( 93 ),DZZC( 93 ),DXXS( 93 ),DYYS( 93 ),DZZS( 93 )	00281500
	COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00281600
	COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJ11,NK,NKP1,NKM1	00281700
	& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00281800
	COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00281900
	COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00282000
	& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO	00282100
	COMMON/BL20/SIG11( 22,16,32 ),SIG12( 22,16,32 ),SIG22( 22,16,32 )	00282200
	& ,SIG13( 22,16,32 ),SIG23( 22,16,32 ),SIG33( 22,16,32 )	00282300
	COMMON/BL22/ICHPB( 10 ),NCHPI( 10 ),JCHPB( 10 ),NCHPJ( 10 ),KCHPB( 10 ),	00282400
	& NCHPK( 10 ),TCHP( 10 ),CPS( 10 ),CONS( 10 ),WFAN( 10 )	00282500
	COMMON/BL31/ TOD( 22,16,32 ),ROD( 22,16,32 ),POD( 22,16,32 )	00282600
	& ,COD( 22,16,32 ),UOD( 22,16,32 ),VOD( 22,16,32 ),WOD( 22,16,32 )	00282700
	COMMON/BL32/ T( 22,16,32 ),R( 22,16,32 ),P( 22,16,32 )	00282800
	& ,C( 22,16,32 ),U( 22,16,32 ),V( 22,16,32 ),W( 22,16,32 )	00282900
	COMMON/BL33/ TPD( 22,16,32 ),RPD( 22,16,32 ),PPD( 22,16,32 )	00283000
	& ,CPD( 22,16,32 ),UPD( 22,16,32 ),VPD( 22,16,32 ),WPD( 22,16,32 )	00283100
	COMMON/BL34/ HEIGHT( 22,16,32 ),REQ( 22,16,32 ),	00283200
	& SMP( 22,16,32 ),SMPP( 22,16,32 ),PP( 22,16,32 ),	00283300
	& DUI( 22,16,32 ),DVI( 22,16,32 ),DWI( 22,16,32 )	00283400
	COMMON/BL36/AP( 22,16,32 ),AE( 22,16,32 ),AW( 22,16,32 ),AN( 22,16,32 ),	00283500
	& AS( 22,16,32 ),AF( 22,16,32 ),AB( 22,16,32 ),	00283600

&	SP(22,16,32),SUI(22,16,32),RI(22,16,32)	00283700
	COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)	00283800
&	,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00283900
		00284000
		00284100
C ***	CALCULATE COEFFICIENTS	00284200
		00284300
	DO 100 K=3,NK	00284400
	KP2=K+2	00284500
	KP1=K+1	00284600
	KM1=K-1	00284700
	KM2=K-2	00284800
	DO 100 J=2,NJ	00284900
	JP2=J+2	00285000
	JP1=J+1	00285100
	JM1=J-1	00285200
	JM2=J-2	00285300
	DO 100 I=2,NI	00285400
	IP2=I+2	00285500
	IP1=I+1	00285600
	IM1=I-1	00285700
	IM2=I-2	00285800
	IF (I.EQ.2) IM2=NIM1	00285900
	IF (I.EQ.NI) IP2=3	00286000
		00286100
		00286200
C	CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00286300
		00286400
	DXP1=XL(IP1,J,K,3,0)	00286500
	DXI =XL(I ,J,K,3,0)	00286600
	DXM1=XL(IM1,J,K,3,0)	00286700
		00286800
	DYP1=YL(I,JP1,K,3,0)	00286900
	DYJ =YL(I,J ,K,3,0)	00287000
	DYM1=YL(I,JM1,K,3,0)	00287100
		00287200
	DZP1=ZL(I,J,KP1,3,0)	00287300
	DZK =ZL(I,J,K ,3,0)	00287400
	DZM1=ZL(I,J,KM1,3,0)	00287500
		00287600
C ***	SURFACE LENGTH OF THE CONTROL VOLUME	00287700
		00287800
	DXN=XL(I,JP1,K,3,2)	00287900
	DXS=XL(I,J ,K,3,2)	00288000
	DXF=XL(I,J,KP1,3,3)	00288100
	DXB=XL(I,J,K ,3,3)	00288200
		00288300
	DYF=YL(I,J,KP1,3,3)	00288400
	DYB=YL(I,J,K ,3,3)	00288500
	DYE=YL(IP1,J,K,3,1)	00288600
	DYH=YL(I ,J,K,3,1)	00288700
		00288800
	DZE=ZL(IP1,J,K,3,1)	00288900
	DZW=ZL(I ,J,K,3,1)	00289000
	DZN=ZL(I,JP1,K,3,2)	00289100

	DZS=ZL(I,J ,K,3,2)	00289200
C ***	CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME	00289300
		00289400
	DXEE=XL(IP2,J,K,3,1)	00289500
	DXE =XL(IP1,J,K,3,1)	00289600
	DXW =XL(I ,J,K,3,1)	00289700
	DXW=XL(IM1,J,K,3,1)	00289800
		00289900
		00290000
	DYNN=YL(I,JP2,K,3,2)	00290100
	DYN =YL(I,JP1,K,3,2)	00290200
	DYS =YL(I,J ,K,3,2)	00290300
	DYSS=YL(I,JM1,K,3,2)	00290400
		00290500
	DZFF=ZL(I,J,KP2,3,3)	00290600
	DZF =ZL(I,J,KP1,3,3)	00290700
	DZB =ZL(I,J,K ,3,3)	00290800
	DZBB=ZL(I,J,KM1,3,3)	00290900
		00291000
C ***	DEFINE THE AREA OF THE CONTROL VOLUME	00291100
		00291200
	DXYF=DXF*DYF	00291300
	DXYB=DXB*DYB	00291400
	DYZE=DYE*DZE	00291500
	DYZW=DYW*DZW	00291600
	DZXN=DZN*DXN	00291700
	DZXS=DZS*DXS	00291800
		00291900
	VOL=DXI*DYJ*DZK	00292000
	VOLDT=VOL/DTIME	00292100
		00292200
	ZXOYN=DZXN/DYN	00292300
	ZXOYS=DZXS/DYS	00292400
	XYOZF=DXYF/DZF	00292500
	XYOZB=DXYB/DZB	00292600
	YZOXE=DYZE/DXE	00292700
	YZOXW=DYZW/DXW	00292800
		00292900
		00293000
C ***	USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE	00293100
C &	PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.	00293200
		00293300
		00293400
	GNF=SILIN(R(I,JP1,K ),R(I,J,K ),DYP1,DYJ)*V(I,JP1,K )	00293500
	GNB=SILIN(R(I,JP1,KM1),R(I,J,KM1),DYP1,DYJ)*V(I,JP1,KM1)	00293600
	GSF=SILIN(R(I,JM1,K ),R(I,J,K ),DYM1,DYJ)*V(I,J ,K )	00293700
	GSB=SILIN(R(I,JM1,KM1),R(I,J,KM1),DYM1,DYJ)*V(I,J ,KM1)	00293800
		00293900
	GF =SILIN(R(I,J,KP1),R(I,J,K ),DZFF,DZF)*W(I,J,KP1)	00294000
	GP =SILIN(R(I,J,KM1),R(I,J,K ),DZB ,DZF)*W(I,J,K )	00294100
	GB =SILIN(R(I,J,KM2),R(I,J,KM1),DZBB,DZB)*W(I,J,KM1)	00294200
		00294300
	GEF=SILIN(R(IP1,J,K ),R(I,J,K ),DXP1,DXI)*U(IP1,J,K )	00294400
	GEB=SILIN(R(IP1,J,KM1),R(I,J,KM1),DXP1,DXI)*U(IP1,J,KM1)	00294500
	GEF=SILIN(R(IM1,J,K ),R(I,J,K ),DXM1,DXI)*U(I ,J,K )	00294600

GWB=SILIN(R(IM1,J,KM1),R(I,J,KM1),DXM1,DXI)*U(I ,J,KM1)	00294700
CF=0.5*(GF+GP)*DXYF	00294800
CB=0.5*(GP+GB)*DXYB	00294900
	00295000
CN=SILIN(GNF,GNB,DZF,DZB)*DZXN	00295100
CS=SILIN(GSF,GSB,DZF,DZB)*DZXN	00295200
	00295300
CE=SILIN(GEF,GEB,DZF,DZB)*DYZE	00295400
CW=SILIN(GWF,GWB,DZF,DZB)*DYZW	00295500
	00295600
VISF=VIS(I,J,K )	00295700
VISB=VIS(I,J,KM1)	00295800
	00295900
VISN= (VIS(I,JP1,K )+VIS(I,J,K )+& VIS(I,JP1,KM1)+VIS(I,J,KM1))/4.0	00296000
VISS= (VIS(I,JP1,K )+VIS(I,J,K )+& VIS(I,JP1,KM1)+VIS(I,J,KM1))/4.0	00296100
	00296200
VISE= (VIS(IP1,J,K )+VIS(I,J,K )+& VIS(IP1,J,KM1)+VIS(I,J,KM1))/4.0	00296300
VISW= (VIS(IM1,J,K )+VIS(I,J,K )+& VIS(IM1,J,KM1)+VIS(I,J,KM1))/4.0	00296400
	00296500
	00296600
	00296700
	00296800
	00296900
	00297000
VISN1=ZXOYN*VISN	00297100
VISS1=ZXOYS*VISS	00297200
VISE1=YZOXE*VISE	00297300
VISH1=YZOXW*VISW	00297400
VISF1=XYCZF*VISF	00297500
VISB1=XYCZB*VISB	00297600
	00297700
	00297800
	00297900
C CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW))/8.	00298000
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXE))/8.	00298100
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXW))/8.	00298200
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE))/8.	00298300
	00298400
C CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS))/8.	00298500
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYN))/8.	00298600
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYSS))/8.	00298700
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN))/8.	00298800
	00298900
	00299000
C CFP=(ABS(CF)+CF)*DZF/DZK/16.	00299100
CFM=(ABS(CF)-CF)*DZF/DZP/16.	00299200
CBP=(ABS(CB)+CB)*DZB/DZM/16.	00299300
CBM=(ABS(CB)-CB)*DZB/DZK/16.	00299400
	00299500
C AE(I,J,K)=-.5*DXI/DXE*CE+CEP+CEM*(1.+DXE/DXE)+CWM*DXW/DXE+VISE1	00299600
AH(I,J,K)=.5*DXI/DXW*CW+CWM+CWP*(1.+DXW/DXW)+CEP*DXE/DXW+VISH1	00299700
AN(I,J,K)=-.5*DYJ/DYN*CN+CNP+CNM*(1.+DYN/DYN)+CSM*DYS/DYN+VISN1	00299800
AS(I,J,K)=.5*DYJ/DYS*CS+CSM+CSP*(1.+DYS/DYS)+CNP*DYN/DYS+VISS1	00299900
	00300000
C AF(I,J,K)=-.5*CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF+VISF1	00300100

	AB(I,J,K) = .5*CB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB+VISD1	00300110
C		00300120
		00300200
801	AEE=-CEM*DXE/DXEE	00300300
	AEER=AEE*WPD(IP2,J,K)	00300400
802	CONTINUE	00300500
		00300600
803	AWH=-CWP*DXW/DXWW	00300700
	AWWR=AWH*WPD(IM2,J,K)	00300800
804	CONTINUE	00300900
		00301000
	IF (J.LT.NJ) GOTO 805	00301100
	ANN=0.	00301200
	ANNR=0.	00301300
	GOTO 806	00301400
805	ANN=-CNP*DYN/DYNN	00301500
	ANNR=ANN*WPD(I,JP2,K)	00301600
806	CONTINUE	00301700
		00301800
	IF (J.GT.2) GOTO 807	00301900
	ASS=0.	00302000
	ASSR=0.	00302100
	GOTO 808	00302200
807	ASS=-CSP*DYS/DYSS	00302300
	ASSR=ASS*WPD(I,JM2,K)	00302400
808	CONTINUE	00302500
		00302600
	IF (K.LT.NK) GOTO 809	00302700
	AFF=0.	00302800
	AFFR=0.	00302900
	GOTO 810	00303000
809	AFF=-CFM*DZF/DZFF	00303100
	AFFR=AFF*WPD(I,J,KP2)	00303200
810	CONTINUE	00303300
		00303400
	IF (K.GT.3) GOTO 811	00303500
	ABB=0.	00303600
	ABBR=0.	00303700
	GOTO 812	00303800
811	ABB=-CBP*DZB/DZBB	00303900
	ABBR=ABB*WPD(I,J,KM2)	00304000
812	CONTINUE	00304100
		00304200
		00304300
C	#####	00304400
C	#####	00304500
C	*** MODIFICATION FOR DECK BOUNDARIES	00304600
		00304700
900	CONTINUE	00304800
	IF (NOD(IM1,J,K).EQ.0) GOTO 901	00304900
	AWH=0.0	00305000
	AWWR=0.0	00305100
		00305200
901	CONTINUE	00305300
	IF (NOD(IP1,J,K).EQ.0) GOTO 902	00305400

AEE=0.0	00305500
AEER=0.0	00305600
	00305700
902 CONTINUE	00305800
IF (NOD(I,JM1,K).EQ.0) GOTO 903	00305900
ASS=0.0	00306000
ASSR=0.0	00306100
	00306200
903 CONTINUE	00306300
IF (NOD(I,JP1,K).EQ.0) GOTO 904	00306400
ANN=0.0	00306500
ANNR=0.0	00306600
	00306700
904 CONTINUE	00306800
IF (NOD(I,J,KM2).EQ.0) GOTO 905	00306900
ABB=0.0	00307000
ABBR=0.0	00307100
	00307200
905 CONTINUE	00307300
IF (NOD(I,J,KP1).EQ.0) GOTO 906	00307400
AFF=0.0	00307500
AFFR=0.0	00307600
906 CONTINUE	00307700
	00307800
C *****	00307900
C *****	00308000
	00308100
	00308200
C *** SU FROM NORMAL STRESS	00308300
	00308400
RF=(SIG33(I,J,K)-(W(I,J,KP1)-W(I,J,K))*VISF/DZF)*OXYF	00308500
RB=(SIG33(I,J,KM1)-(W(I,J,K)-W(I,J,KM1))*VISB/DZB)*OXYB	00308600
RN=(SIG23(I,JP1,K)-(W(I,JP1,K)-W(I,J,K))*VISN/OYN)*DZXN	00308700
RS=(SIG23(I,J,K)-(W(I,J,K)-W(I,JM1,K))*VISS/OYS)*DZXS	00308800
RE=(SIG13(IP1,J,K)-(W(IP1,J,K)-W(I,J,K))*VISE/DXE)*DYZE	00308900
RW=(SIG13(I,J,K)-(W(I,J,K)-W(IM1,J,K))*VISH/OXH)*DYZW	00309000
	00309100
C *** SU FROM CURVED STRESSES AND ACCELERATIONS	00309200
	00309300
AVG23=0.5*(SIG23(I,JP1,K)+SIG23(I,J,K))	00309400
AVG13=0.5*(SIG13(IP1,J,K)+SIG13(I,J,K))	00309500
AVG22=SILIN(SIG22(I,J,K),SIG22(I,J,KM1),OZF,OZB)	00309600
AVG11=SILIN(SIG11(I,J,K),SIG11(I,J,KM1),OZF,OZB)	00309700
	00309800
AU3=W(I,J,K)	00309900
AU2=BILIN(V(I,JP1,K),V(I,J,K),OYJ,OYJ,	00310000
& V(I,JP1,KM1),V(I,J,KM1),DYJ,DYJ,OZF,OZB)	00310100
AU1=BILIN(U(IP1,J,K),U(I,J,K),DXI,DXI,	00310200
& U(IP1,J,KM1),U(I,J,KM1),DXI,DXI,OZF,OZB)	00310300
	00310400
AR=SILIN(R(I,J,K),R(I,J,KM1),DZF,OZB)	00310500
	00310600
ARU23=AR*AU2*AU3	00310700
ARU13=AR*AU1*AU3	00310800
ARU22=AR*AU2*AU2	00310900

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ARU11=AR*AU1*AU1
00311000
RRY=(AVG23-ARU23)*DXI*(DZN-DZS)
00311100
RRX=(AVG13-ARU13)*DYJ*(DZE-DZW)
00311200
RRZ=(AVG22-ARU22)*DXI*(DYF-DYB)+
00311300
& (AVG11-ARU11)*DYJ*(DXF-DXB)
00311400
00311500
00311600
00311700
AP(I,J,K)=AE(I,J,K)+AH(I,J,K)+AN(I,J,K)+AS(I,J,K)
00311800
& +AF(I,J,K)+AB(I,J,K)+AEE+AWW+ANN+ASS+AFF+ABB
00311900
SP(I,J,K)=- (ROD(I,J,K)*DZB+ROD(I,J,KM1)*DZF)/(DZB+DZF)*VOLDT
00312000
SU(I,J,K)= (ROD(I,J,K)*DZB+ROD(I,J,KM1)*DZF)/(DZB+DZF)*VOLDT
00312100
& *WOD(I,J,K)
00312200
SU(I,J,K)=SU(I,J,K)+DXI*DYJ*(P(I,J,KM1)-P(I,J,K))
00312300
& +AEER+AWHR+ANNR+ASSR+AFFR+ABBR
00312400
& +RE-RH+RN-RS+RF-RB+RRY+RRX-RRZ
00312500
& -BUOY*((R(I,J,K)-REQ(I,J,K))*DZB*COS(ZC(K)))+(R(I,J,
00312600
& KM1)-REQ(I,J,KM1))*DZF*COS(ZC(KM1)))/(DZB+DZF)*VOL*SIN(XC(I))
00312700
100 CONTINUE
00312800
00312900
C *** TAKE CARE OF B.C. THRU AN,AS,AE,AH,AP AND SU
00313000
C
00313100
C *** RADIUS DIRECTION
00313200
00313300
DO 500 K=3,NK
00313400
DO 500 I=2,NI
00313500
KM1=K-1
00313600
CC SP(I,2,K)=SP(I,2,K)+AS(I,2,K)
00313700
SP(I,2,K)=SP(I,2,K)-AS(I,2,K)
00313800
SU(I,2,K)=SU(I,2,K)+2.0*W(I,1,K)*AS(I,2,K)
00313900
SP(I,NJ,K)=SP(I,NJ,K)-AN(I,NJ,K)
00314000
AS(I,2,K)=0.
00314100
AN(I,NJ,K)=0.
00314200
500 CONTINUE
00314300
00314400
C *** CYLIC CONDITIONS
00314500
00314600
DO 502 K=3,NK
00314700
DO 502 J=2,NJ
00314800
SU(2,J,K)=SU(2,J,K)+AH(2,J,K)*W(1,J,K)
00314900
SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*W(NIPI1,J,K)
00315000
AH(2,J,K)=0.0
00315100
AE(NI,J,K)=0.0
00315200
502 CONTINUE
00315300
00315400
C *** FRONT AND BACK WALL
00315500
DO 600 I=2,NI
00315600
DO 600 J=2,NJ
00315700
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)
00315800
SP(I,J,3)=SP(I,J,3)+AB(I,J,3)
00315900
AF(I,J,NK)=0.
00316000
AB(I,J,3)=0.
00316100
600 CONTINUE
00316200
00316300
00316400

```

```

IF (NCHIP.EQ.0) GOTO 105
C #####
C #####
C *** MODIFICATION FOR DECK BOUNDARIES
DO 101 N=1,NCHIP
  IB=IHPB(N)
  IE=IB+NCHI(N)-1
  IBM1=IB-1
  IEP1=IE+1
  JB=JHPB(N)
  JE=JB+NCHPJ(N)-1
  JBM1=JB-1
  JEP1=JE+1
  KB=KHPB(N)
  KE=KB+NCHPK(N)-1
  KBM1=KB-1
  KEP1=KE+1

DO 102 J=JB,JE-1
DO 102 K=KB,KE
SP(IBM1,J,K)=SP(IBM1,J,K)-AE(IBM1,J,K)
SU(IBM1,J,K)=SU(IBM1,J,K)+AE(IBM1,J,K)*WFAN(N)*2.0
AE(IBM1,J,K)=0.0

SP(IE,J,K)=SP(IE,J,K)-AN(IE,J,K)
SU(IE,J,K)=SU(IE,J,K)+AN(IE,J,K)*WFAN(N)*2.0
AN(IE,J,K)=0.0

102 CONTINUE

DO 103 I=IB,IE-1
DO 103 K=KB,KE
SP(I,JBM1,K)=SP(I,JBM1,K)-AN(I,JBM1,K)
SU(I,JBM1,K)=SU(I,JBM1,K)+AN(I,JBM1,K)*WFAN(N)*2.0
AN(I,JBM1,K)=0.0

SP(I,JE,K)=SP(I,JE,K)-AS(I,JE,K)
SU(I,JE,K)=SU(I,JE,K)+AS(I,JE,K)*WFAN(N)*2.0
AS(I,JE,K)=0.0

103 CONTINUE

DO 106 I=IB,IE-1
DO 106 J=JB,JE-1
SU(I,J,KBM1)=SU(I,J,KBM1)+AF(I,J,KBM1)*WFAN(N)
SU(I,J,KEP1)=SU(I,J,KEP1)+AB(I,J,KEP1)*WFAN(N)
AF(I,J,KBM1)=0.0
AB(I,J,KEP1)=0.0

106 CONTINUE

C *** FOR THE CELLS INSIDE OF THE DECKS

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```

00316500
00316600
00316700
00316800
00316900
00317000
00317100
00317200
00317300
00317400
00317500
00317600
00317700
00317800
00317900
00318000
00318100
00318200
00318300
00318400
00318493
00318500
00318600
00318700
00318710
00318800
00318900
00319000
00319100
00319110
00319200
00319300
00319400
00319500
00319600
00319700
00319800
00319810
00319900
00320000
00320100
00320110
00320200
00320300
00320400
00320500
00320600
00320610
00320620
00320700
00320800
00320900
00321000
00321100
00321200

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DO 104 I=IB,IE-1	00321300
DO 104 J=JB,JE-1	00321400
DO 104 K=KB,KE	00321500
SP(I,J,K)=-1.0E2	00321600
AW(I,J,K)=0.	00321700
AE(I,J,K)=0.	00321800
AS(I,J,K)=0.	00321900
AN(I,J,K)=0.	00322000
AB(I,J,K) = 0.	
AF(I,J,K) = 0.	
SU(I,J,K)=1.0E2 * WFAN(N)	00322100
104 CONTINUE	00322200
101 CONTINUE	00322300
105 CONTINUE	00322400
	00322500
C #####	00322600
C #####	00322700
	00322800
	00322900
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00323000
	00323100
	00323200
DO 301 K=3,NK	00323300
DO 301 J=2,NJ	00323400
DO 301 I=2,NI	00323500
DXI=XL(I,J,K,3,0)	00323600
DYJ=YL(I,J,K,3,0)	00323700
DXY=DXI*DYJ	00323800
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00323900
DW(I,J,K)=DXY/AP(I,J,K)	00324000
301 CONTINUE	00324100
	00324200
	00324300
C *** SOLVE FOR W	00324400
	00324500
CALL TRID (2,2,3,NI,NJ,NK,W)	00324600
	00324700
C	00324800
DO 76 I=1,NI	00324900
DO 76 J=1,NJ	00325000
W(I,J,2)=W(I,J,3)	00325100
W(I,J,NKP1)=W(I,J,NK)	00325200
76 CONTINUE	00325300
	00325400
	00325500
IF (NCHIP.EQ.0) GOTO 112	00325600
C #####	00325700
C #####	00325800
C *** RESET THE VELOCITY INSIDE OF THE DECKS	00325900
	00326000
DO 110 N=1,NCHIP	00326100
IB=ICHPB(N)	00326200
IE=IB+NCHPI(N)-1	00326300
JB=JCHPB(N)	00326400
JE=JB+NCHPJ(N)-1	00326500

KB=KCHPB(N)	00326600
KE=KB+NCHPK(N)-1	00326700
	00326791
DO 108 I=IB,IE-1	00326800
DO 109 J=JB,JE-1	00326900
DO 103 K=KB,KE	00327000
W(I,J,K)=WFAN(N)	00327100
108 CONTINUE	00327200
110 CONTINUE	00327300
112 CONTINUE	00327400
	00327500
RETURN	00327600
END	00327700
	00327800
	00327900
C -----	00328000
C *****	00328100
SUBROUTINE CALP	00328200
C *****	00328300
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00328400
&  DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00328500
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00328600
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00328700
&  ,NIP2,NJP2,NKP2,NA,NAP1,NAH1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NHRP	00328800
COMMON/BL12/ NWRITE,NTAPE,NTHAX0,NTREAL,TIME,SORSUM,ITER	00328900
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00329000
&  CPO,PRT,CONDO,VISO,RHCO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR	00329100
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00329200
&  NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10)	00329300
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00329400
&  ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32)	00329500
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00329600
&  ,C(22,16,32),U(22,16,32),V(22,16,32),H(22,16,32)	00329700
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32)	00329800
&  ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),HPD(22,16,32)	00329900
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00330000
&  SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00330100
&  DU(22,16,32),DV(22,16,32),DW(22,16,32)	00330200
COMMON/BL36/AP(22,16,32),AE(22,16,32),AH(22,16,32),AN(22,16,32),	00330300
&  AS(22,16,32),AF(22,16,32),AB(22,16,32),	00330400
&  SPI(22,16,32),SU(22,16,32),RI(22,16,32)	00330500
COMMON/BL37/ VISI(22,16,32),CONDI(22,16,32),NODI(22,16,32),RHALL(579)	00330600
&  ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORNI(93)	00330700
	00330800
C ***  CALCULATE COEFFICIENTS	00330900
	00331000
DO 100 K=2,NK	00331100
KP2=K+2	00331200
KP1=K+1	00331300
KM1=K-1	00331400
KM2=K-2	00331500
DO 100 J=2,NJ	00331600
JP2=J+2	00331700
JP1=J+1	00331800
JM1=J-1	00331900

JM2=J-2	00332000
DO 100 I=2,NI	00332100
IP2=I+2	00332200
IP1=I+1	00332300
IM1=I-1	00332400
IM2=I-2	00332500
IF (I.EQ.NI) IP1=2	00332600
	00332700
	00332800
C           CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00332900
	00333000
DXP1=XL(IP1,J,K,0,0)	00333100
DXI =XL(I ,J,K,0,0)	00333200
DXM1=XL(IM1,J,K,0,0)	00333300
	00333400
DYP1=YL(I,JP1,K,0,0)	00333500
DYJ =YL(I,J ,K,0,0)	00333600
DYM1=YL(I,JM1,K,0,0)	00333700
	00333800
DZP1=ZL(I,J,KP1,0,0)	00333900
DZK =ZL(I,J,K ,0,0)	00334000
DZM1=ZL(I,J,KM1,0,0)	00334100
	00334200
C ***       SURFACE LENGTH OF THE CONTROL VOLUME	00334300
	00334400
DXN=XL(I,JP1,K,0,2)	00334500
DXS=XL(I,J ,K,0,2)	00334600
DXF=XL(I,J,KP1,0,3)	00334700
DXB=XL(I,J,K ,0,3)	00334800
	00334900
DYF=YL(I,J,KP1,0,3)	00335000
DYB=YL(I,J,K ,0,3)	00335100
DYE=YL(IP1,J,K,0,1)	00335200
DYW=YL(I ,J,K,0,1)	00335300
	00335400
DZE=ZL(IP1,J,K,0,1)	00335500
DZH=ZL(I ,J,K,0,1)	00335600
DZN=ZL(I,JP1,K,0,2)	00335700
DZS=ZL(I,J ,K,0,2)	00335800
	00335900
	00336000
C ***       DEFINE AREA OF THE CONTROL VOLUME	00336100
	00336200
DXYF=DXF*DYF	00336300
DXYB=DXB*DYB	00336400
DYZE=DYE*DZE	00336500
DYZH=DYW*DZH	00336600
DZXN=DZN*DXN	00336700
DZXS=DZS*DXS	00336800
	00336900
VOL=DXI*DYJ*DZK	00337000
VOLDT=VOL/DTIME	00337100
	00337200
RN=(R(I,J,K)*DYP1+R(I,JP1,K)*DYJ)/(DYP1+DYJ)	00337300
RS=(R(I,J,K)*DYM1+R(I,JM1,K)*DYJ)/(DYM1+DYJ)	00337400

RE=(R(I,J,K)*DXP1+R(IP1,J,K)*DXI)/(DXP1+DXI)	00337500
RW=(R(I,J,K)*DXM1+R(IM1,J,K)*DXI)/(DXM1+DXI)	00337600
RF=(R(I,J,K)*DZP1+R(I,J,KP1)*DZK)/(DZP1+DZK)	00337700
RB=(R(I,J,K)*DZM1+R(I,J,KM1)*DZK)/(DZM1+DZK)	00337800
C *** DU ON VERTICAL WALLS AND DV ON HORIZONTAL WALLS ARE ZERO	00337900
	00338000
AN(I,J,K)=RN*DZXN*DV(I,JP1,K)	00338100
AS(I,J,K)=RS*DZXS*DV(I,J,K)	00338200
AE(I,J,K)=RE*DYZE*OU(IP1,J,K)	00338300
AW(I,J,K)=RW*OYZW*OU(I,J,K)	00338400
AF(I,J,K)=RF*DXYF*OH(I,J,KP1)	00338500
AB(I,J,K)=RB*DXYB*OH(I,J,K)	00338600
	00338700
	00338800
CN=RN*V(I,JP1,K)*DZXN	00338900
CS=RS*V(I,J,K)*DZXS	00339000
CE=RE*U(IP1,J,K)*DYZE	00339100
CW=RW*U(I,J,K)*DYZW	00339200
CF=RF*W(I,J,KP1)*DXYF	00339300
CB=RB*W(I,J,K)*DXYB	00339400
	00339500
SMP(I,J,K)=- (R(I,J,K)-ROO(I,J,K))*VOL/DTIME-CE+CW-CN+CS-CF+CB	00339600
C SMP(I,J,K)=-CE+CW-CN+CS-CF+CB	00339700
SU(I,J,K)=SMP(I,J,K)	00339800
SP(I,J,K)=0.	00339900
100 CONTINUE	00340000
	00340100
C *** TAKE CARE OF B.C. THRU AN,AS,AE,AW,AF,AB,SP AND SU	00340200
C	00340300
C *** RADIUS DIRECTION	00340400
	00340500
DO 500 K=2,NK	00340600
DO 500 I=2,NI	00340700
AS(I,2,K)=0.	00340800
AN(I,NJ,K)=0.	00340900
500 CONTINUE	00341000
	00341100
C *** LEFT WALL AND RIGHT WALL	00341200
	00341300
DO 501 K=2,NK	00341400
DO 501 J=2,NJ	00341500
C AW(2,J,K)=0.	00341600
C AE(NI,J,K)=0.	00341700
501 CONTINUE	00341800
	00341900
C *** FRONT AND BACK WALL	00342000
	00342100
DO 502 I=2,NI	00342200
DO 502 J=2,NJ	00342300
AB(I,J,2)=0.0	00342400
AF(I,J,NK)=0.0	00342500
502 CONTINUE	00342600
	00342700
	00342800
	00342900

IF (NCHIP.EQ.0) GOTO 105	00343000
	00343100
	00343200
C #####	00343300
C #####	00343400
C *** MODIFICATION FOR DECK BOUNDARIES	00343500
DO 101 N=1,NCHIP	00343600
IB=ICHPB(N)	00343700
IE=IB+NCHPI(N)-1	00343800
IBM1=IB-1	00343900
IEP1=IE+1	00344100
JB=JCHPB(N)	00344200
JE=JB+NCHPJ(N)-1	00344300
JBM1=JB-1	00344400
JEP1=JE+1	00344500
KB=KCHPB(N)	00344600
KE=KB+NCHPK(N)-1	00344700
KBM1=KB-1	00344800
KEP1=KE+1	00344900
	00345000
DO 102 J=JB,JE-1	00345100
DO 102 K=KB,KE-1	00345200
AE(IBM1,J,K)=0.0	00345300
AH(IE,J,K)=0.0	00345400
	00345500
102 CONTINUE	00345600
	00345700
DO 103 I=IB,IE-1	00345800
DO 103 K=KB,KE-1	00345900
AN(I,JBM1,K)=0.0	00346000
AS(I,JE,K)=0.0	00346100
103 CONTINUE	00346200
	00346300
DO 106 I=IB,IE-1	00346400
DO 106 J=JB,JE-1	00346500
AF(I,J,KBM1)=0.0	00346600
AB(I,J,KE)=0.0	00346700
106 CONTINUE	00346800
	00346900
C *** FOR THE CELLS INSIDE OF THE DECKS	00347000
	00347100
DO 104 I=IB,IE-1	00347200
DO 104 J=JB,JE-1	00347300
DO 104 K=KB,KE-1	00347400
SP(I,J,K)=-1.0E20	00347500
AH(I,J,K)=0.	00347600
AE(I,J,K)=0.	00347700
AS(I,J,K)=0.	00347800
AN(I,J,K)=0.	00347900
SU(I,J,K)=0.	00348000
104 CONTINUE	00348100
101 CONTINUE	00348200
105 CONTINUE	00348300
	00348400

C *****	00348500
C *****	00348600
C *****	00348700
	00348800
	00348900
	00349000
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00349100
DO 300 J=2,NJ	00349200
DO 300 I=2,NI	00349300
DO 300 K=2,NK	00349400
AP(I,J,K)=AN(I,J,K)+AS(I,J,K)+AE(I,J,K)+AW(I,J,K)-SP(I,J,K)	00349500
& +AF(I,J,K)+AB(I,J,K)	00349600
300 CONTINUE	00349700
	00349800
	00349900
C *** SOLUTION OF FINITE DIFFERENCE EQUATION	00350000
CALL TRID (2,2,2,NI,NJ,NK,PP)	00350100
	00350200
	00350300
C *** THIS IS FOR CKECKING	00350400
	00350500
	00350600
	00350700
DO 161 I=1,NIP1	00350800
C WRITE (6,*) I	00350900
949 FORMAT ( ' AW ' )	00351000
C WRITE (6,949)	00351100
C WRITE (6,999) ((AW(I,J,K),K=1,NKP1),J=1,NJP1)	00351200
161 CONTINUE	00351300
DO 160 I=1,NIP1	00351400
C WRITE (6,*) I	00351500
948 FORMAT ( ' AE ' )	00351600
C WRITE (6,948)	00351700
C WRITE (6,999) ((AE(I,J,K),K=1,NKP1),J=1,NJP1)	00351800
160 CONTINUE	00351900
DO 170 I=1,NIP1	00352000
C WRITE (6,*) I	00352100
958 FORMAT ( ' AB ' )	00352200
C WRITE (6,958)	00352300
C WRITE (6,999) ((AB(I,J,K),K=1,NKP1),J=1,NJP1)	00352400
170 CONTINUE	00352500
DO 180 I=1,NIP1	00352600
C WRITE (6,*) I	00352700
968 FORMAT ( ' AF ' )	00352800
C WRITE (6,968)	00352900
C WRITE (6,999) ((AF(I,J,K),K=1,NKP1),J=1,NJP1)	00353000
180 CONTINUE	00353100
C WRITE (6,999) ((SU(I,5,K),K=1,NKP1),I=1,NIP1)	00353200
DO 190 I=1,NIP1	00353300
C WRITE (6,*) I	00353400
978 FORMAT ( ' SU ' )	00353500
C WRITE (6,978)	00353600
C WRITE (6,999) ((SU(I,J,K),K=1,NKP1),J=1,NJP1)	00353700
190 CONTINUE	00353800
DO 191 I=1,NIP1	00353900
C WRITE (6,*) I	

C	WRITE (6,988)	00354000
988	FORMAT ( ' PP ' )	00354100
C	WRITE (6,999) ((PP(I,J,K),J=1,NJP1),K=7,7)	00354200
191	CONTINUE	00354300
999	FORMAT (12E10.3)	00354400
		00354500
		00354600
		00354700
C ***	CORRECT VELOCITIES AND PRESSURE	00354800
C		00354900
C ***	CORRECTION FOR VELOCITY U	00355000
		00355100
	DO 600 I=2,NI	00355200
	IM1=I-1	00355300
	IF (I.EQ.2) IM1=NI	00355400
	DO 600 J=2,NJ	00355500
	DO 600 K=2,NK	00355600
	U(I,J,K)=U(I,J,K)+DU(I,J,K)*(PP(IM1,J,K)-PP(I,J,K))	00355700
600	CONTINUE	00355800
		00355900
C ***	CORRECTION FOR VELOCITY V	00356000
		00356100
	DO 603 J=3,NJ	00356200
	JM1=J-1	00356300
	DO 603 K=2,NK	00356400
	DO 603 I=2,NI	00356500
	V(I,J,K)=V(I,J,K)+DV(I,J,K)*(PP(I,JM1,K)-PP(I,J,K))	00356600
603	CONTINUE	00356700
		00356800
C ***	CORRECTION OF VELOCITY W	00356900
		00357000
	DO 604 K=3,NK	00357100
	KM1=K-1	00357200
	DO 604 I=2,NI	00357300
	DO 604 J=2,NJ	00357400
	W(I,J,K)=W(I,J,K)+DW(I,J,K)*(PP(I,J,KM1)-PP(I,J,K))	00357500
604	CONTINUE	00357600
		00357700
		00357800
C ***	CORRECTION FOR PRESSURE P	00357900
		00358000
	DO 606 J=2,NJ	00358100
	DO 606 I=1,NIP1	00358200
	DO 606 K=1,NK	00358300
	P(I,J,K)=P(I,J,K)+PP(I,J,K)	00358400
	PP(I,J,K)=0.	00358500
606	CONTINUE	00358600
		00358700
C ***	THIS IS FOR R=0.0 CASE	00358800
		00358900
	DO 75 I=1,NIP1	00359000
	DO 75 K=1,NKP1	00359100
C	U(I,1,K)=U(I,2,K)	00359200
C	W(I,1,K)=W(I,2,K)	00359300
C	V(I,2,K)=V(I,3,K)	00359400

75	CONTINUE	00359500
		00359600
C ***	MODIFICATION FOR R=0.0	00359700
C		00359800
	DO 55 K=2,NK	00359900
	VY=0.0	00360000
	VX=0.0	00360100
	VZ=0.0	00360200
	DO 50 I=2,NI	00360300
	VY=VY+U(I,2,K)*COS(XS(I))	00360400
	VX=VX-U(I,2,K)*SIN(XS(I))	00360500
50	CONTINUE	00360600
		00360700
		00360800
	DO 51 I=2,NI	00360900
	VY=VY+V(I,3,K)*SIN(XC(I))	00361000
	VX=VX+V(I,3,K)*COS(XC(I))	00361100
	VZ=VZ+W(I,2,K)	00361200
51	CONTINUE	00361300
		00361400
		00361500
C ***	FIND THE VELOCITIES AT R=0.0	00361600
		00361700
	DO 52 I=1,NIP1	00361800
	U(I,1,K)=(-VX*SIN(XS(I))+VY*COS(XS(I)))/NIM1	00361900
	V(I,2,K)=(VX*COS(XC(I))+VY*SIN(XC(I)))/NIM1	00362000
	W(I,1,K)=VZ/NIM1	00362100
52	CONTINUE	00362200
55	CONTINUE	00362300
		00362400
		00362500
		00362600
C ***	THIS IS FOR THE CYLINDER ONLY (CYLIC CONDITION)	00362700
		00362800
	DO 76 J=1,NJP1	00362900
	DO 76 K=1,NKP1	00363000
	U(1,J,K)=U(NI,J,K)	00363100
	U(NIP1,J,K)=U(2,J,K)	00363200
	V(1,J,K)=V(NI,J,K)	00363300
	V(NIP1,J,K)=V(2,J,K)	00363400
	W(1,J,K)=W(NI,J,K)	00363500
	W(NIP1,J,K)=W(2,J,K)	00363600
76	CONTINUE	00363700
		00363800
		00363900
C ***	THIS FOR SPHERE ONLY	00364000
		00364100
	DO 77 I=1,NIP1	00364200
	DO 77 J=1,NJP1	00364300
	U(I,J,1)=U(I,J,2)	00364400
	V(I,J,1)=V(I,J,2)	00364500
	W(I,J,2)=W(I,J,3)	00364600
	U(I,J,NKP1)=U(I,J,NK)	00364700
	V(I,J,NKP1)=V(I,J,NK)	00364800
	W(I,J,NKP1)=W(I,J,NK)	00364900
77	CONTINUE	



	00365000
	00365100
	00365200
IF (NCHIP.EQ.0) GOTO 116	00365300
C #####	00365400
C #####	00365500
C *** RESET THE VELOCITY INSIDE OF OECK	00365600
	00365700
DO 120 N=1,NCHIP	00365800
IB=ICHPB(N)	00365900
IE=IB+NCHPI(N)-1	00366000
JB=JCHPB(N)	00366100
JE=JB+NCHPJ(N)-1	00366200
KB=KCHPB(N)	00366300
KE=KB+NCHPK(N)-1	00366310
	00366392
	00366394
	00366400
DO 109 I=IB,IE	00366500
DO 109 J=JB,JE-1	00366600
DO 109 K=KB,KE-1	00366700
U(I,J,K)=0.0	00366800
109 CONTINUE	00366900
	00367000
DO 118 I=IB,IE-1	00367100
DO 118 J=JB,JE	00367200
DO 118 K=KB,KE-1	00367300
V(I,J,K)=0.0	00367400
118 CONTINUE	00367500
	00367600
DO 119 I=IB,IE-1	00367700
DO 119 J=JB,JE-1	00367800
DO 119 K=KB,KE	00367900
W(I,J,K)=WFAN(N)	00368000
119 CONTINUE	00368100
120 CONTINUE	00368200
116 CONTINUE	00368300
C #####	00368400
C #####	00368500
C *** RECALCULATE THE ERROR SOURCE AFTER CORRECTIONS OF U, V, P	00368600
	00368700
SORSUM=0.	00368800
RESORM(ITER)=0.	00368900
DO 700 J=2,NJ	00369000
JP1=J+1	00369100
JM1=J-1	00369200
DO 700 I=2,NI	00369300
IP1=I+1	00369400
IM1=I-1	00369500
DO 700 K=2,NK	00369600
KP1=K+1	00369700
KM1=K-1	00369800
	00369900
	00370000
C CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME	00370100

DXP1=XL(IP1,J,K,0,0)	00370200
DXI =XL(I ,J,K,0,0)	00370300
DXM1=XL(IM1,J,K,0,0)	00370400
	00370500
	00370600
DYP1=YL(I,JP1,K,0,0)	00370700
DYJ =YL(I,J ,K,0,0)	00370800
DYM1=YL(I,JM1,K,0,0)	00370900
	00371000
DZP1=ZL(I,J,KP1,0,0)	00371100
DZK =ZL(I,J,K ,0,0)	00371200
DZM1=ZL(I,J,KM1,0,0)	00371300
	00371400
	00371500
C *** SURFACE LENGTH OF THE CONTROL VOLUME	00371600
	00371700
DXN=XL(I,JP1,K,0,2)	00371800
DXS=XL(I,J ,K,0,2)	00371900
DXF=XL(I,J,KP1,0,3)	00372000
DXB=XL(I,J,K ,0,3)	00372100
	00372200
DYF=YL(I,J,KP1,0,3)	00372300
DYB=YL(I,J,K ,0,3)	00372400
DYE=YL(IP1,J,K,0,1)	00372500
DYH=YL(I ,J,K,0,1)	00372600
	00372700
DZE=ZL(IP1,J,K,0,1)	00372800
DZH=ZL(I ,J,K,0,1)	00372900
DZN=ZL(I,JP1,K,0,2)	00373000
DZS=ZL(I,J ,K,0,2)	00373100
	00373200
	00373300
C *** DEFINE AREA OF THE CONTROL VOLUME	00373400
	00373500
DXYF=DXF*DYF	00373600
DXYB=DXB*DYB	00373700
DYZE=DYE*DZE	00373800
DYZH=DYH*DZH	00373900
DZXN=DZN*DXN	00374000
DZXS=DZS*DXS	00374100
	00374200
VOL=DXI*DYJ*DZK	00374300
VOLDT=VOL/DTIME	00374400
	00374500
	00374600
	00374700
RN=(R(I,J,K)*DYP1+R(I,JP1,K)*DYJ)/(DYP1+DYJ)	00374800
RS=(R(I,J,K)*DYM1+R(I,JM1,K)*DYJ)/(DYM1+DYJ)	00374900
RE=(R(I,J,K)*DXP1+R(IP1,J,K)*DXI)/(DXP1+DXI)	00375000
RW=(R(I,J,K)*DXM1+R(IM1,J,K)*DXI)/(DXM1+DXI)	00375100
RF=(R(I,J,K)*DZP1+R(I,J,KP1)*DZK)/(DZP1+DZK)	00375200
RB=(R(I,J,K)*DZM1+R(I,J,KM1)*DZK)/(DZM1+DZK)	00375300
	00375400
CN=RN*V(I,JP1,K)*DZXN	00375500
CS=RS*V(I,J ,K)*DZXS	00375600

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CE=RE*U(IP1,J,K)*DYZE 00375700
CW=RW*U(I ,J,K)*DYZH 00375800
CF=RF*W(I,J,KP1)*DXYF 00375900
CB=RB*W(I,J,K )*DXYB 00376000
C SMP(I,J,K )=-CE+CW-CN+CS-CF+CB 00376100
SMP(I,J,K )=-(R(I,J,K)-ROD(1,J,K))*VOL/DTIME-CE+CW-CN+CS-CF+CB 00376200
00376300
C *** SORSUM IS ACTUAL MASS INCREASE OR DECREASE FROM CONTINUITY 00376400
C EQUATUON , THIS WILL COMPARE TO SOURCE 00376500
00376600
SORSUM=SORSUM+SMP(I,J,K) 00376700
00376800
C *** RESORM IS SUM OF THE ABSOLUTE VALUE OF SMP(I,J,K) 00376900
00377000
RESORM(ITER)=RESORM(ITER)+ABS(SMP(I,J,K)) 00377100
700 CONTINUE 00377200
RETURN 00377300
END 00377400
00377500
00377600
00377700
C *****00377800
SUBROUTINE TRID(IST,JST,KST,ISP,JSP,KSP,PHI) 00377900
C *****00378000
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00378100
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00378200
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32), 00378300
& AS(22,16,32),AF(22,16,32),AB(22,16,32), 00378400
& SP(22,16,32),SU(22,16,32),RI(22,16,32) 00378500
DIMENSION A(99),B(99),C(99),PHI(22,16,32) 00378600
00378700
C GOTO 405 00378800
ISTM1=IST-1 00378900
A(ISTM1)=0. 00379000
C(ISTM1)=0. 00379100
DO 100 J=JST,JSP 00379200
DO 100 K=KST,KSP 00379300
DO 101 I=IST,ISP 00379400
A(I)=AE(I,J,K) 00379500
B(I)=AW(I,J,K) 00379600
C(I)=AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K) 00379700
& +AF(I,J,K)*PHI(1,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K) 00379800
TERM=1./(AP(I,J,K)-B(I)*A(I-1)) 00379900
IF (ABS(A(I)).LE.1.0E-70) A(I)=0.0 00380001
IF (ABS(B(I)).LE.1.0E-70) B(I)=0.0 00380002
IF (ABS(C(I)).LE.1.0E-70) C(I)=0.0 00380003
IF (ABS(TERM).LE.1.0E-70) TERM=0.0 00380010
A(I)=A(I)*TERM 00380020
C(I)=(C(I)+B(I)*C(I-1))*TERM 00380100
101 CONTINUE 00380500
PHI(ISP,J,K)=C(ISP) 00380600
ISTA=IST+1 00380700
DO 102 II=ISTA,ISP 00380800
I=IST+ISP-II 00380900
IP1=I+1 00381000

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PHI(I,J,K)=A(I)*PHI(IP1,J,K)+C(I)	00381100
102 CONTINUE	00381200
100 CONTINUE	00381300
DO 2000 J=JST,JSP	00381400
DO 2000 K=KST,KSP	00381500
PHI(IST-1,J,K)=PHI(ISP,J,K)	00381600
PHI(ISP+1,J,K)=PHI(IST,J,K)	00381700
2000 CONTINUE	00381800
	00381900
	00382000
	00382100
JSTM1=JST-1	00382200
A(JSTM1)=0.	00382300
C(JSTM1)=0.	00382400
DO 200 K=KST,KSP	00382500
DO 200 I=IST,ISP	00382600
DO 201 J=JST,JSP	00382700
A(J)=AN(I,J,K)	00382800
B(J)=AS(I,J,K)	00382900
C(J)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K)	00383000
& +AF(I,J,K)*PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)	00383100
TERM=1./(AP(I,J,K)-B(J)*A(J-1))	00383200
IF (ABS(A(J)).LE.1.0E-70) A(J)=0.0	00383210
IF (ABS(B(J)).LE.1.0E-70) B(J)=0.0	00383220
IF (ABS(C(J)).LE.1.0E-70) C(J)=0.0	00383230
IF (ABS(TERM).LE.1.0E-70) TERM=0.0	00383240
A(J)=A(J)*TERM	00383300
C(J)=(C(J)+B(J)*C(J-1))*TERM	00383400
201 CONTINUE	00383800
PHI(I,JSP,K)=C(JSP)	00383900
JSTA=JST+1	00384000
DO 202 JJ=JSTA,JSP	00384100
J=JST+JSP-JJ	00384200
JP1=J+1	00384300
PHI(I,J,K)=A(J)*PHI(I,JP1,K)+C(J)	00384400
202 CONTINUE	00384500
200 CONTINUE	00384600
	00384700
	00384800
DO 2001 J=JST,JSP	00384900
DO 2001 K=KST,KSP	00385000
PHI(IST-1,J,K)=PHI(ISP,J,K)	00385100
PHI(ISP+1,J,K)=PHI(IST,J,K)	00385200
2001 CONTINUE	00385300
	00385400
	00385500
KSTM1=KST-1	00385600
A(KSTM1)=0.	00385700
C(KSTM1)=0.	00385800
DO 300 I=IST,ISP	00385900
DO 300 J=JST,JSP	00386000
DO 301 K=KST,KSP	00386100
A(K)=AF(I,J,K)	00386200
B(K)=AB(I,J,K)	00386300
C(K)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K)	00386400
& +AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+SU(I,J,K)	

	TERM=1./(AP(I,J,K)-B(K)*A(K-1))	00386500
	IF (ABS(A(K)).LE.1.0E-70) A(K)=0.0	00386510
	IF (ABS(B(K)).LE.1.0E-70) B(K)=0.0	00386520
	IF (ABS(C(K)).LE.1.0E-70) C(K)=0.0	00386530
	IF (ABS(TERM)).LE.1.0E-70) TERM=0.0	00386540
	A(K)=A(K)*TERM	00386600
	C(K)=(C(K)+B(K)*C(K-1))*TERM	00386700
301	CONTINUE	00387100
	PHI(I,J,KSP)=C(KSP)	00387200
	KSTA=KST+1	00387300
	DO 302 KK=KSTA,KSP	00387400
	K=KST+KSP-KK	00387500
	KP1=K+1	00387600
	PHI(I,J,K)=A(K)*PHI(I,J,KP1)+C(K)	00387700
302	CONTINUE	00387800
300	CONTINUE	00387900
		00388000
	DO 2002 J=JST,JSP	00388100
	DO 2002 K=KST,KSP	00388200
	PHI(IST-1,J,K)=PHI(ISP,J,K)	00388300
	PHI(ISP+1,J,K)=PHI(IST,J,K)	00388400
2002	CONTINUE	00388500
		00388600
		00388700
	GOTO 700	00388800
		00388900
4405	CONTINUE	00389000
405	KSP1=KSP+1	00389100
	B(KSP1)=0.	00389200
	C(KSP1)=0.	00389300
	DO 600 II=IST,ISP	00389400
	I=IST+ISP-II	00389500
	DO 600 JJ=JST,JSP	00389600
	J=JST+JSP-JJ	00389700
	DO 601 KK=KST,KSP	00389800
	K=KSP+KST-KK	00389900
	KP1=K+1	00390000
	A(K)=AF(I,J,K)	00390100
	B(K)=AB(I,J,K)	00390200
	C(K)=AE(I,J,K)*PHI(I+1,J,K)+AH(I,J,K)*PHI(I-1,J,K)+AN(I,J,K)*	00390300
8	PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+SU(I,J,K)	00390400
	TERM=1./(AP(I,J,K)-A(K)*B(K+1))	00390500
	B(K)=B(K)*TERM	00390600
	C(K)=(C(K)+A(K)*C(K+1))*TERM	00390700
	IF (ABS(A(K)).LE.1.0E-70) A(K)=0.0	00390800
	IF (ABS(B(K)).LE.1.0E-70) B(K)=0.0	00390900
	IF (ABS(C(K)).LE.1.0E-70) C(K)=0.0	00391000
601	CONTINUE	00391100
	PHI(I,J,KST)=C(KST)	00391200
	KSTP1=KST+1	00391300
	DO 602 K=KSTP1,KSP	00391400
	PHI(I,J,K)=B(K)*PHI(I,J,K-1)+C(K)	00391500
602	CONTINUE	00391600
600	CONTINUE	00391700
		00391800

DO 2003 J=JST,JSP	00391900
DO 2003 K=KST,KSP	00392000
PHI(IST-1,J,K)=PHI(ISP,J,K)	00392100
PHI(ISP+1,J,K)=PHI(IST,J,K)	00392200
2003 CONTINUE	00392300
	00392400
	00392500
JSP1=JSP+1	00392600
B(JSP1)=0.	00392700
C(JSP1)=0.	00392800
DO 500 KK=KST,KSP	00392900
K=KST+KSP-KK	00393000
DO 500 II=IST,ISP	00393100
I=IST+ISP-II	00393200
DO 501 JJ=JST,JSP	00393300
J=JSP+JST-JJ	00393400
JP1=J+1	00393500
A(J)=AN(I,J,K)	00393600
B(J)=AS(I,J,K)	00393700
C(J)=AE(I,J,K)*PHI(I+1,J,K)+AW(I,J,K)*PHI(I-1,J,K)+AF(I,J,K)*	00393800
& PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)	00393900
TERM=1./(AP(I,J,K)-A(J)*B(J+1))	00394000
B(J)=B(J)*TERM	00394100
C(J)=(C(J)+A(J)*C(J+1))*TERM	00394200
IF (ABS(A(J))).LE.1.0E-70) A(J)=0.0	00394300
IF (ABS(B(J))).LE.1.0E-70) B(J)=0.0	00394400
IF (ABS(C(J))).LE.1.0E-70) C(J)=0.0	00394500
501 CONTINUE	00394600
PHI(I,JST,K)=C(JST)	00394700
JSTP1=JST+1	00394800
DO 502 J=JSTP1,JSP	00394900
PHI(I,J,K)=B(J)*PHI(I,J-1,K)+C(J)	00395000
502 CONTINUE	00395100
500 CONTINUE	00395200
	00395300
	00395400
DO 2004 J=JST,JSP	00395500
DO 2004 K=KST,KSP	00395600
PHI(IST-1,J,K)=PHI(ISP,J,K)	00395700
PHI(ISP+1,J,K)=PHI(IST,J,K)	00395800
2004 CONTINUE	00395900
	00396000
	00396100
ISP1=ISP+1	00396200
B(ISP1)=0.	00396300
C(ISP1)=0.	00396400
DO 400 JJ=JST,JSP	00396500
J=JST+JSP-JJ	00396600
DO 400 KK=KST,KSP	00396700
K=KST+KSP-KK	00396800
DO 401 II=IST,ISP	00396900
I=ISP+IST-II	00397000
IP1=I+1	00397100
A(I)=AE(I,J,K)	00397200
B(I)=AW(I,J,K)	00397300
C(I)=AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+AF(I,J,K)*	00397300

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&      PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)      00397400
TERM=1./(AP(I,J,K)-A(I)*B(I+1))      00397500
B(I)=B(I)*TERM      00397600
C(I)=(C(I)+A(I)*C(I+1))*TERM      00397700
IF (ABS(A(I)).LE.1.0E-70) A(I)=0.0      00397800
IF (ABS(B(I)).LE.1.0E-70) B(I)=0.0      00397900
IF (ABS(C(I)).LE.1.0E-70) C(I)=0.0      00398000
401 CONTINUE      00398100
PHI(IST,J,K)=C(IST)      00398200
ISTP1=IST+1      00398300
DO 402 I=ISTP1,ISP      00398400
PHI(I,J,K)=B(I)*PHI(I-1,J,K)+C(I)      00398500
402 CONTINUE      00398600
400 CONTINUE      00398700
      00398800
DO 2005 J=JST,JSP      00398900
DO 2005 K=KST,KSP      00399000
PHI(IST-1,J,K)=PHI(ISP,J,K)      00399100
PHI(ISP+1,J,K)=PHI(IST,J,K)      00399200
2005 CONTINUE      00399300
      00399400
      00399500
700 CONTINUE      00399600
RETURN      00399700
END      00399800
      00399900
C *****      00400000
BLOCK DATA      00400100
C *****      00400200
      00400300
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1      00400400
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUI,NCHIP,NJRA,NWRP      00400500
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER      00400600
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200400700
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00400800
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0400900
DATA NIP2,NIP1,NI,NIM1/23,22,21,20/      00401000
DATA NJP2,NJP1,NJ,NJM1/17,16,15,14/      00401100
DATA NKP2,NKP1,NK,NKM1/33,32,31,30/      00401200
DATA NAP1,NA,NAM1,NBP1,NB,NBM1/9,8,7,27,26,25/      00401300
DATA U0,TA,PRT,RHOO,CPO,VISO,NTMAX0/      00401400
& 1.0,555.86,1.0,0.0714,0.24,1.56E-4,0/      00401500
DATA TINF,CNT,ABTURB,BTURB/1.0,0.2,2.0,1.0/      00401600
DATA GC,RAIR/32.17,53.34/      00401700
DATA QCORRT,PM1/1.0,0.9/      00401800
END      00401900
      00402000
      00402100
      00402200
C *****      00402300
SUBROUTINE GRID      00402400
C *****      00402500
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)      00402600
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR      00402700
      00402800

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COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00402900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NHRP	00403000
C *** REGENERATION OF GRID	00403100
PI=4.*ATAN(1.)	00403200
DX=1.0/FLOAT(NIM1)	00403300
C DY=1./FLOAT(NJM1-2)	00403400
DY=1./FLOAT(NJM1-1)	00403500
DZ=PI/FLOAT(NKM1-NB+NA-2)	00403600
	00403700
	00403800
	00403900
	00404000
DO 19 I=1,NIP2	00404100
XS(I)=(I-2)*DX*2.0*PI	00404200
19 CONTINUE	00404300
	00404400
C XS(1)=-DX*2.0*PI	00404500
C XS(2)=0.0	00404600
C XS(3)=0.01*2.0*PI	00404700
C DO 19 I=4,13	00404800
C XS(I)=(I-3)*DX*2.0*PI	00404900
C 19 CONTINUE	00405000
C	00405100
C XS(14)=XS(13)	00405200
C XS(13)=XS(14)-0.01*2.0*PI	00405300
C DO 18 I=15,NIP1	00405400
C XS(I)=XS(14)+(I-14)*DX*2.0*PI	00405500
C 18 CONTINUE	00405600
C XS(NIP2)=XS(NIP1)+XS(3)	00405700
	00405800
	00405900
YS(1)=0.000	00406000
YS(2)=0.025	00406100
C YS(3)=0.05	00406200
DO 3 J=3,NJ	00406300
YS(J)=(J-2)*DY	00406400
3 CONTINUE	00406500
YS(NJP1)=YS(NJ)	00406600
YS(NJ )=YS(NJP1)-3./8./12./9.6	00406700
YS(NJP2)=YS(NJP1)+3./8./12./9.6	00406800
	00406900
CC DO 3 J=4,NJP2	00407000
CC YS(J)=(J-3)*DY	00407100
CC 3 CONTINUE	00407200
DO 4 I=1,NIP1	00407300
IP1=I+1	00407400
DXXC(I)=XS(IP1)-XS(I)	00407500
4 CONTINUE	00407600
	00407700
DXXC(NIP2)=DXXC(NIP1)	00407800
DO 5 I=2,NIP2	00407900
IM1=I-1	00408000
DXXS(I)=.5*(DXXC(I)+DXXC(IM1))	00408100
5 CONTINUE	00408200
DXXS(1)=DXXS(2)	00408300



	DO 7 J=1,NJP1	00408400
	JP1=J+1	00408500
	DYYC(J)=YS(JP1)-YS(J)	00408600
7	CONTINUE	00408700
		00408800
	DYYC(NJP2)=DYYC(NJP1)	00408900
	DO 8 J=2,NJP2	00409000
	JM1=J-1	00409100
	DYYS(J)=.5*(DYYC(J)+DYYC(JM1))	00409200
8	CONTINUE	00409300
	DYYS(1)=DYYS(2)	00409400
		00409500
		00409600
	DO 20 I=1,NIP2	00409700
	XC(I)=XS(I)+DXXC(I)/2.0	00409800
20	CONTINUE	00409900
		00410000
	DO 21 J=1,NJP2	00410100
	YC(J)=YS(J)+DYYC(J)/2.0	00410200
21	CONTINUE	00410300
		00410400
		00410500
	DO 9 K=4,NA	00410600
	ZS(K)=(K-3)*DZ	00410700
9	CONTINUE	00410800
		00410900
	DO 30 K=NBP1,NK	00411000
	ZS(K)=ZS(NA)+(K-NB)*DZ	00411100
30	CONTINUE	00411200
		00411300
	DO 31 K=NAP1,NB	00411400
	ZS(K)=PI/2.	00411500
31	CONTINUE	00411600
		00411700
	ZS(1)=0.0	00411800
	ZS(2)=0.05	00411900
	ZS(3)=0.10	00412000
C	ZS(NKP1)=ZS(NKM1)	00412100
C	ZS(NK)=ZS(NKP1)-0.05	00412200
C	ZS(NKM1)=ZS(NKP1)-0.10	00412300
C	ZS(NKP2)=ZS(NKP1)+0.05	00412400
		00412500
	ZS(NKP2)=ZS(NK)	00412600
	ZS(NKP1)=ZS(NKP2)-0.05	00412700
	ZS(NK)=ZS(NKP2)-0.10	00412800
		00412900
		00413000
	DO 10 K=1,NKP1	00413100
	IF (K.GE.NA.AND.K.LT.NB) GOTO 10	00413200
	KP1=K+1	00413300
	DZZC(K)=ZS(KP1)-ZS(K)	00413400
10	CONTINUE	00413500
		00413600
	DO 32 K=NA,NBM1	00413700
	DZZC(K)=2.854/(NB-NA)	00413800

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30 CONTINUE                                00413900
                                           00414000
      DZZC(NKP2)=DZZC(NKP1)                00414100
                                           00414200
      DO 11 K=2,NKP2                        00414300
C     IF (K.EQ.NA.OR.K.EQ.NB) GOTO 11      00414400
      KMI=K-1                               00414500
      DZZS(K)=.5*(DZZC(K)+DZZC(KMI))      00414600
11 CONTINUE                                00414700
                                           00414800
      DZZS(1)=DZZS(2)                      00414900
      DO 22 K=1,NKP2                        00415000
      IF (K.GE.NA.AND.K.LT.NB) GOTO 22     00415100
      ZC(K)=ZS(K)+DZZC(K)/2.0              00415200
22 CONTINUE                                00415300
                                           00415400
      DO 33 K=NA,NBM1                       00415500
      ZC(K)=PI/2.                           00415600
33 CONTINUE                                00415700
                                           00415800
      IF (YS(1).LT.0.0) YS(1)=0.0          00415900
      IF (YC(1).LT.0.0) YC(1)=0.0          00416000
      PRINT *                                00416100
      PRINT *, '      INPUT COORDINATE OF THE TANK IN THE ORDER OF ' 00416200
      PRINT *, '      I      XS      YS      ZS      XC      YC', 00416300
      & , '      ZC      DXXS      DYYS      DZZS      DXXC      ' 00416400
      & , 'DYXC      DZZC'                 00416500
      DO 12 I=1,NKP2                        00416600
      WRITE(6,102) I,XS(I),YS(I),ZS(I),XC(I),YC(I),ZC(I), 00416700
      & DXXS(I),DYYS(I),DZZS(I),DXXC(I),DYXC(I),DZZC(I) 00416800
102 FORMAT(2X,I4,12(2X,F8.5))              00416900
12 CONTINUE                                00417000
                                           00417100
      RETURN                                 00417200
      END                                    00417300
                                           00417400
                                           00417500
                                           00417600
C     *****                               00417700
      FUNCTION XL(I,J,K,M,N)                00417800
C     *****                               00417900
C*****                                     00418000
C     WHEN M OR N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE* 00418100
C           HALF CELL (STAGGERED CELL) * 00418200
C     WHEN M OR N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE* 00418300
C           HALF CELL (STAGGERED CELL) * 00418400
C     WHEN M OR N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE* 00418500
C           HALF CELL (STAGGERED CELL) * 00418600
C     WHEN M = N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE* 00418700
C           WHOLE CELL * 00418800
C     WHEN M = N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE* 00418900
C           WHOLE CELL * 00419000
C     WHEN M = N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE* 00419100
C           WHOLE CELL * 00419200
C*****                                     00419300

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	COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00419400
	& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00419500
	X1=XC(I)	00419600
	X2=YC(J)	00419700
	X3=ZC(K)	00419800
	DXL=DXXC(I)	00419900
	IF(M.EQ.N) GOTO 100	00420000
		00420100
		00420200
	IF(M.EQ.1.OR.N.EQ.1) X1=XS(I)	00420300
	IF(M.EQ.1.OR.N.EQ.1) DXL=DXXS(I)	00420400
	IF(M.EQ.2.OR.N.EQ.2) X2=YS(J)	00420500
	IF(M.EQ.3.OR.N.EQ.3) X3=ZS(K)	00420600
	GOTO 1000	00420700
100	IF(M.EQ.1) X1=XC(I-1)	00420800
	IF(M.EQ.1) DXL=DXXC(I-1)	00420900
	IF(M.EQ.2) X2=YC(J-1)	00421000
	IF(M.EQ.3) X3=ZC(K-1)	00421100
1000	CONTINUE	00421200
	XL=X2*SIN(X3)*DXL	00421300
	RETURN	00421400
	END	00421500
		00421600
		00421700
C	*****	00421800
	FUNCTION YL(I,J,K,M,N)	00421900
C	*****	00422000
C	*****	00422100
C	WHEN M OR N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00422200
C	HALF CELL (STAGGERED CELL) *	00422300
C	WHEN M OR N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00422400
C	HALF CELL (STAGGERED CELL) *	00422500
C	WHEN M OR N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00422600
C	HALF CELL (STAGGERED CELL) *	00422700
C	WHEN M = N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00422800
C	WHOLE CELL *	00422900
C	WHEN M = N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00423000
C	WHOLE CELL *	00423100
C	WHEN M = N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00423200
C	WHOLE CELL *	00423300
C	*****	00423400
	COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00423500
	& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00423600
	X1=XC(I)	00423700
	X2=YC(J)	00423800
	X3=ZC(K)	00423900
	DYL=DYXC(J)	00424000
	IF(M.EQ.N) GOTO 100	00424100
		00424200
	IF(M.EQ.2.OR.N.EQ.2) X2=YS(J)	00424300
	IF(M.EQ.2.OR.N.EQ.2) DYL=DYYS(J)	00424400
	IF(M.EQ.1.OR.N.EQ.1) X1=XS(I)	00424500
	IF(M.EQ.3.OR.N.EQ.3) X3=ZS(K)	00424600
	GOTO 1000	00424700
100	IF(M.EQ.2) X2=YC(J-1)	00424800

IF(M.EQ.2) DYL=DYYC(J-1)	00424900
IF(M.EQ.1) X1=XC(I-1)	00425000
IF(M.EQ.3) X3=ZC(K-1)	00425100
1000 CONTINUE	00425200
YL=1.00*DYL	00425300
RETURN	00425400
END	00425500
	00425600
	00425700
C *****	00425800
FUNCTION ZL(I,J,K,M,N)	00425900
C *****	00426000
C*****	00426100
C WHEN M OR N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00426200
C HALF CELL (STAGGERED CELL) *	00426300
C WHEN M OR N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00426400
C HALF CELL (STAGGERED CELL) *	00426500
C WHEN M OR N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00426600
C HALF CELL (STAGGERED CELL) *	00426700
C WHEN M = N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00426800
C WHOLE CELL *	00426900
C WHEN M = N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00427000
C WHOLE CELL *	00427100
C WHEN M = N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00427200
C WHOLE CELL *	00427300
C*****	00427400
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00427500
& DXXC(93),DYYC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00427600
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00427700
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00427800
X1=XC(I)	00427900
X2=YC(J)	00428000
X3=ZC(K)	00428100
DZL=DZZC(K)	00428200
IF(M.EQ.N) GOTO 100	00428300
	00428400
IF(M.EQ.2.OR.N.EQ.2) X2=YS(J)	00428500
IF(M.EQ.1.OR.N.EQ.1) X1=XS(I)	00428600
IF(M.EQ.3.OR.N.EQ.3) GOTO 200	00428700
GOTO 1000	00428800
	00428900
200 CONTINUE	00429000
IF (K.EQ.NA.OR.K.EQ.NB) GOTO 2000	00429100
X3=ZS(K)	00429200
DZL=DZZS(K)	00429300
GOTO 1000	00429400
	00429500
100 IF(M.EQ.3) X3=ZC(K-1)	00429600
IF(M.EQ.3) DZL=DZZC(K-1)	00429700
IF(M.EQ.2) X2=YS(J-1)	00429800
IF(M.EQ.1) X1=XC(I-1)	00429900
1000 CONTINUE	00430000
ZL=X2*DZL	00430100
GOTO 300	00430200
2000 CONTINUE	00430300

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DZL1=DZZC(K-1)
DZL2=DZZC(K)
IF (K.EQ.NB) DZL1=DZZC(K)
IF (K.EQ.NB) DZL2=DZZC(K-1)
ZL=(X2*DZL1+DZL2)/2.
300 CONTINUE
RETURN
END

C *****
FUNCTION SILIN(V1,V2,D1,D2)
C *****
C IF (D1.EQ.0.0.AND.D2.EQ.0.0) D1=0.1
C IF (D1.EQ.0.0.AND.D2.EQ.0.0) D2=0.1
SILIN=(V1*D2+V2*D1)/(D1+D2)
RETURN
END

C *****
FUNCTION BILIN(V1,V2,D1,D2,V3,V4,D3,D4,D5,D6)
C *****
V12=(V1*D2+V2*D1)/(D1+D2)
V34=(V3*D4+V4*D3)/(D3+D4)
BILIN=(V12*D6+V34*D5)/(D5+D6)
END

C *****
SUBROUTINE STRESS
C *****
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP
COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32)
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFANI(10)
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RHALL(579)
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)

DO 100 K=2,NK
KP2=K+2
KP1=K+1
KM1=K-1
KM2=K-2
DO 100 J=2,NJ
JP2=J+2
JP1=J+1

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JM1=J-1	00435900
JM2=J-2	00436000
DO 100 I=2,NI	00436100
IP2=I+2	00436200
IP1=I+1	00436300
IM1=I-1	00436400
IM2=I-2	00436500
	00436600
C        CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME	00436700
	00436800
DXP1=XL(IP1,J,K,0,0)	00436900
DXI =XL(I ,J,K,0,0)	00437000
DXM1=XL(IM1,J,K,0,0)	00437100
	00437200
DYP1=YL(I,JP1,K,0,0)	00437300
DYJ =YL(I,J ,K,0,0)	00437400
DYM1=YL(I,JM1,K,0,0)	00437500
	00437600
DZP1=ZL(I,J,KP1,0,0)	00437700
DZK =ZL(I,J,K ,0,0)	00437800
DZM1=ZL(I,J,KM1,0,0)	00437900
	00438000
C ***     SURFACE LENGTH OF THE CONTROL VOLUME	00438100
	00438200
DXN=XL(I,JP1,K,0,2)	00438300
DXS=XL(I,J ,K,0,2)	00438400
DXF=XL(I,J,KP1,0,3)	00438500
DXB=XL(I,J,K ,0,3)	00438600
	00438700
DYF=YL(I,J,KP1,0,3)	00438800
DYB=YL(I,J,K ,0,3)	00438900
DYE=YL(IP1,J,K,0,1)	00439000
DYW=YL(I ,J,K,0,1)	00439100
	00439200
DZE=ZL(IP1,J,K,0,1)	00439300
DZW=ZL(I ,J,K,0,1)	00439400
DZN=ZL(I,JP1,K,0,2)	00439500
DZS=ZL(I,J ,K,0,2)	00439600
	00439700
C ***     CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00439800
	00439900
DXEE=XL(IP2,J,K,0,1)	00440000
DXE =XL(IP1,J,K,0,1)	00440100
DXW =XL(I ,J,K,0,1)	00440200
DXWW=XL(IM1,J,K,0,1)	00440300
	00440400
DYNN=YL(I,JP2,K,0,2)	00440500
DYN =YL(I,JP1,K,0,2)	00440600
DYS =YL(I,J ,K,0,2)	00440700
DYSS=YL(I,JM1,K,0,2)	00440800
	00440900
DZFF=ZL(I,J,KP2,0,3)	00441000
DZF =ZL(I,J,KP1,0,3)	00441100
DZB =ZL(I,J,K ,0,3)	00441200
DZBB=ZL(I,J,KM1,0,3)	00441300

UBAR=0.5*(U(IP1,J,K)+U(I,J,K))	00441400
VBAR=0.5*(V(I,JP1,K)+V(I,J,K))	00441500
WBAR=0.5*(W(I,J,KP1)+W(I,J,K))	00441600
	00441700
	00441800
DXY=DXI*DYJ	00441900
DYZ=DYJ*DZX	00442000
DZX=DZK*DXI	00442100
	00442200
SIG11(I,J,K)=2.*VIS(I,J,K)*((U(IP1,J,K)-U(I,J,K))/DXI	00442300
& +VBAR*(DXN-DXS)/DXY	00442400
& +WBAR*(DXF-DXB)/DZX	00442500
	00442600
SIG22(I,J,K)=2.*VIS(I,J,K)*((V(I,JP1,K)-V(I,J,K))/DYJ	00442700
& +WBAR*(DYF-DYB)/DYZ	00442800
& +UBAR*(DYE-DYW)/DXY	00442900
	00443000
SIG33(I,J,K)=2.*VIS(I,J,K)*((W(I,J,KP1)-W(I,J,K))/DZK	00443100
& +UBAR*(DZE-DZW)/DZX	00443200
& +VBAR*(DZN-DZS)/DYZ	00443300
100 CONTINUE	00443400
	00443500
DO 200 K=2,NKP1	00443600
KP2=K+2	00443700
KP1=K+1	00443800
KM1=K-1	00443900
KM2=K-2	00444000
DO 200 J=2,NJP1	00444100
JP2=J+2	00444200
JP1=J+1	00444300
JM1=J-1	00444400
JM2=J-2	00444500
DO 200 I=2,NIP1	00444600
IP2=I+2	00444700
IP1=I+1	00444800
IM1=I-1	00444900
IM2=I-2	00445000
	00445100
	00445200
C **** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CONTROL	00445300
C VOLUME FOR SIG12	00445400
	00445500
C IF (J.EQ.2) GOTO 300	00445600
DXN=XL(I,J ,K,1,0)	00445700
DXS=XL(I,JM1,K,1,0)	00445800
DYE=YL(I ,J,K,2,0)	00445900
DYW=YL(IM1,J,K,2,0)	00446000
DXI=XL(I ,J,K,1,2)	00446100
DYJ=YL(I ,J,K,2,1)	00446200
	00446300
DYN=YL(I,J ,K,1,0)	00446400
DYS=YL(I,JM1,K,1,0)	00446500
DXE=XL(I ,J,K,2,0)	00446600
DXW=XL(IM1,J,K,2,0)	00446700
	00446800

UBAR=SILIN(U(I,J,K),U(I,JM1,K),DYN,DYS)	00446900
VBAR=SILIN(V(I,J,K),V(IM1,J,K),DXE,DXH)	00447000
VIS12=BILIN(VIS(I,J,K),VIS(I,JM1,K),DYN,DYS,	00447100
& VIS(IM1,J,K),VIS(IM1,JM1,K),DYN,DYS,DXE,DXH)	00447200
SIG12(I,J,K)= VIS12*((V(I,J,K)-V(IM1,J,K))/DXI	00447300
& -VBAR*(DYE-DYH)/(DXI*DYJ))	00447400
SIG12(I,J,K)=SIG12(I,J,K)+VIS12*((U(I,J,K)-U(I,JM1,K))/DYJ	00447500
& -UBAR*(DXN-DXS)/(DXI*DYJ))	00447600
300 CONTINUE	00447700
	00447800
	00447900
	00448000
C **** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CONTROL	00448100
C VOLUME FOR SIG13	00448200
	00448300
DXF=XL(I,J,K,1,0)	00448400
DXB=XL(I,J,KM1,1,0)	00448500
DZE=ZL(I,J,K,3,0)	00448600
DZW=ZL(IM1,J,K,3,0)	00448700
DXI=XL(I,J,K,1,3)	00448800
DZK=ZL(I,J,K,3,1)	00448900
	00449000
	00449100
DZF=ZL(I,J,K,1,0)	00449200
DZB=ZL(I,J,KM1,1,0)	00449300
DXE=XL(I,J,K,3,0)	00449400
DXH=XL(IM1,J,K,3,0)	00449500
	00449600
IF (DZF.EQ.0.0.OR.DZB.EQ.0.0.OR.DZE.EQ.0.0.OR.DZW.EQ.0.0)	00449700
& WRITE (6,*) I,J,K, DZF,DZB,DZE,DZW	00449800
UBAR=SILIN(U(I,J,K),U(I,J,KM1),DZF,DZB)	00449900
VBAR=SILIN(V(I,J,K),V(IM1,J,K),DXE,DXH)	00450000
VIS13=BILIN(VIS(I,J,K),VIS(I,J,KM1),DZF,DZB,	00450100
& VIS(IM1,J,K),VIS(IM1,J,KM1),DZF,DZB,DXE,DXH)	00450200
	00450300
SIG13(I,J,K)= VIS13*((V(I,J,K)-V(IM1,J,K))/DXI	00450400
& -VBAR*(DZE-DZW)/(DXI*DZK))	00450500
SIG13(I,J,K)=SIG13(I,J,K)+VIS13*((U(I,J,K)-U(I,J,KM1))/DZK	00450600
& -UBAR*(DXF-DXB)/(DXI*DZK))	00450700
	00450800
	00450900
C **** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CONTROL	00451000
C VOLUME FOR SIG23	00451100
	00451200
DZN=ZL(I,J,K,3,0)	00451300
DZS=ZL(I,JM1,K,3,0)	00451400
DYF=YL(I,J,K,2,0)	00451500
DYB=YL(I,J,KM1,2,0)	00451600
DZK=ZL(I,J,K,3,2)	00451700
DYJ=YL(I,J,K,2,3)	00451800
	00451900
DYN=YL(I,J,K,3,0)	00452000
DYS=YL(I,JM1,K,3,0)	00452100
DZF=ZL(I,J,K,2,0)	00452200
DZB=ZL(I,J,KM1,2,0)	00452300



```

WBAR=SILIN(W(I,J,K),W(I,JM1,K),DYN,DYS)
VBAR=SILIN(V(I,J,K),V(I,J,KM1),DZF,DZB)
VIS23=BILIN(VIS(I,J,K),VIS(I,JM1,K),OYN,DYS,
& VIS(I,J,KM1),VIS(I,JM1,KM1),OYN,DYS, DZF,DZB)
SIG23(I,J,K)= VIS23*((V(I,J,K)-V(I,J,KM1))/DZK
& -VBAR*(DYF-DYB)/(DZK*DYJ))
SIG23(I,J,K)=SIG23(I,J,K)+VIS23*((W(I,J,K)-W(I,JM1,K))/DYJ
& -WBAR*(DZN-DZS)/(DZK*OYJ))
200 CONTINUE
DO 110 I=1,NIP1
DO 110 J=1,NJP1
C WRITE (6,998) I,J,SIG11(I,J,5),SIG12(I,J,5),SIG13(I,J,5),
C & SIG22(I,J,5),SIG23(I,J,5),SIG33(I,J,5)
998 FORMAT (2X,I4,1X,I4,6(1X,E11.4))
110 CONTINUE
RETURN
END
C
*** *****
SUBROUTINE CALQ(LL)
*** *****
COMMON/BL1/DX,OY,DZ,VOL,DTIME,VOLOT,THOT,TCOOL,PI,Q,QR
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM2
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,OTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),
& SMP(22,16,32),SMPP(22,16,32),PPI(22,16,32),
& OU(22,16,32),OV(22,16,32),OH(22,16,32)
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOO(22,16,32),RWALL(579)
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)
COMMON/BL39/ALEH,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR
C *** IN MANY OF THE FOLLOWING LINES A TEMPORARY CORRECTION FOR
C * ADJUSTING QQ TO AGREE WITH THE PRESSURE HAS BEEN APPLIED.
XTIME=TIME*H/UO
VOLT=0.0
DO 113 I=2,NI
DO 113 J=2,NJ
DO 113 K=16,17
IF (NHSZ(I,J,K).EQ.0) GOTO 113
DXI =XL(I,J,K,0,0)
OYJ =YL(I,J,K,0,0)
DZK =ZL(I,J,K,0,0)
VOL=DXI*OYJ*DZK*H*H*H

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	VOLT=VOLT+VOL	00456592
113	CONTINUE	00456593
	QRVOL=0.	00456594
	DO 70 I=561,579	00456595
	QRVOL=QRVOL+RWALL(I)*1./12.*0.2*PI	00456596
70	CONTINUE	00456597
C		00456598
	QR=QRVOL/VOLT*U0*CP0*RHO0*TA/H	00456599
		00456600
	IF (XTIME.LT.23.1) THEN	00456700
	PCURVE=9.789522E-5*XTIME**2-2.388310E-6*XTIME**3+	00456800
&	REQ(10,9,16)	00456900
	DPDT =9.789522E-5*XTIME*2-2.388310E-6*XTIME**2*3	00457000
	ELSE	00457100
	PCURVE=0.0052+.81264E-3*XTIME-.22604E-5*XTIME**2+.27262E-8*XTIME**	00457200
&	3-.115621E-11*XTIME**4+REQ(10,9,16)	00457300
	DPDT=.81264E-5-.22604E-5*XTIME*2+.27262E-8*XTIME**	00457400
&	2*3.0-.115621E-11*XTIME**3*4	00457500
	ENDIF	00457600
	IF ( LL .EQ. 1 ) THEN	00457700
	QQ=1.0E8*OPDT	00457800
	Q=CQ*3.4134/60./60.	00457900
65	CONTINUE	00458000
	Q=Q*QCORRT-QR	00458100
		00458200
	ELSE	00458300
C	THIS USES A CURVE FIT THROUGH THE BURNRATE DATA GIVEN BY NRL	00458400
	QCORRT=0.0	00458410
	QCORR=0.0	00458420
	ITEST = 0	00458500
	BURNR1= 5.4576748 +0.16815346*XTIME-.20153996E-03*XTIME**2	00458600
	BURNR2= -1.3116787 +.33158595*XTIME-.7342952E-03*XTIME**2	00458700
&	+ .50945510E-06*XTIME**3	00458800
	IF (XTIME .LT. 100) THEN	00458900
	BURNR= BURNR2 + 1.3117-.013117*XTIME	00459000
	ELSE	00459100
	BURNR = BURNR2	00459200
	ENDIF	00459300
	IF(XTIME .LE. 300) GO TO 60	00459400
	IF(BURNR2 .LT. BURNR1) THEN	00459500
	BURNR = (BURNR1 + BURNR2) / 2	00459600
	GO TO 60	00459700
	ELSE	00459800
	IF ( XTIME .LT. 600.0) GO TO 60	00459900
	IF (ITEST .EQ. 0) THEN	00460000
	BURNR3 = BURNR2	00460100
	ITEST = 1	00460200
	ENDIF	00460300
	BURNR = BURNR3	00460400
	ENDIF	00460500
60	Q = BURNR*2.2046*9612./3600.-QR	00460600
CC	THIS GIVES Q IN BTU/SEC	00460700
		00460800
	ENDIF	00460900

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Q=59.313+0.7195*XTIME-0.1139E-2*XTIME**2-0.3367E-5*XTIME**3      00460910
Q=Q*3412/3600                                                         00460920
RETURN                                                                  00461000
END                                                                      00461100
                                                                           00461200
                                                                           00461300
                                                                           00461400
                                                                           00461500
C
*** *****00461600
SUBROUTINE RADHT(T4WALL,VFMC)                                         00461700
*** *****00461800
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1                    00461900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NHRP    00462000
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY, 00462100
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0462200
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)                    00462300
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)                00462400
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)00462500
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)                00462600
COMMON/BL39/ALEW,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR           00462700
                                                                           00462800
                                                                           00462900
DIMENSION VFMC(579,579),T4WALL(579)                                  00463000
DO 4010 K=3,NKM1                                                       00463100
DO 4010 I=2,NI                                                         00463200
II=(K-3)*(NI-1)+I-1                                                  00463300
T4WALL(II)=CONSRA*T(I,NJRA,K)*T(I,NJRA,K)*T(I,NJRA,K)*T(I,NJRA,K) 00463400
4010 CONTINUE                                                         00463500
                                                                           00463600
C RADIATION FROM THE FIRE TO THE WALL                                00463700
                                                                           00463800
DO 4011 J=3,9                                                         00463900
JJ=561+9-J                                                             00464000
AVT=0.25*(T(16,J,16)+T(17,J,16)+T(16,J,17)+T(17,J,17))           00464100
T4WALL(JJ)=CONSRA*AVT*AVT*AVT*AVT                                    00464200
4011 CONTINUE                                                         00464300
C
DO 4012 J=3,14                                                         00464400
JJ=568+J-3                                                             00464500
AVT=0.25*(T(6,J,16)+T(7,J,16)+T(6,J,17)+T(7,J,17))               00464600
T4WALL(JJ)=CONSRA*AVT*AVT*AVT*AVT                                    00464700
4012 CONTINUE                                                         00464800
                                                                           00464900
C
DO 4020 I=1,579                                                         00465000
RWALL(I)=0.0                                                           00465100
DO 4020 J=1,579                                                         00465200
RWALL(I)=RWALL(I)+VFMC(I,J)*T4WALL(J)                                00465300
4020 CONTINUE                                                         00465400
RETURN                                                                  00465500
END                                                                      00465600
                                                                           00465700
                                                                           00465800
                                                                           00465900
                                                                           00466000
C
*** *****00466100
*** *****00466200

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SUBROUTINE GLOBE
00466300
*** *****00466400
* THIS SUBROUTINE CALCULATES THE GLOBAL PRESSURE CORRECTION, *00466500
* WHEREBY THE PRESSURE MATRIX IS UPDATED. *00466600
* VARIABLES USED ARE: *00466700
* SUMT = SUM OF TEMPERATURES *00466800
* SUMPT = SUM OF PRESSURE OVER TEMPERATURE *00466900
* SUMPET = SUM OF EQUILIBRIUM PRESSURE OVER TEMP*00467000
* UGRT = CONSTANT *00467100
* PCORR = PRESSURE CORRECTION *00467200
*****00467300
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00467400
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00467500
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00467600
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00467700
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) 00467800
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00467900
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00468000
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32), 00468100
& DU(22,16,32),DV(22,16,32),DH(22,16,32) 00468200
COMMON/BL37/ VIS(22,16,32),CONDI(22,16,32),NOD(22,16,32),RWALL(579)00468300
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00468400
SUMT=0. 00468500
SUMPT=0. 00468600
SUMPET=0. 00468700
DO 370 I=2,NI 00468800
DO 370 J=2,NJ 00468900
DO 370 K=2,NK 00469000
IF (NOD(I,J,K).EQ.1) GOTO 370 00469100
DXI=XL(I,J,K,0,0,0) 00469200
DYJ=YL(I,J,K,0,0,0) 00469300
DZK=ZL(I,J,K,0,0,0) 00469400
VOL=DXI*DYJ*DZK 00469500
SUMT=SUMT+1./T(I,J,K)*VOL 00469600
SUMPT=SUMPT+P(I,J,K)/T(I,J,K)*VOL 00469700
SUMPET=SUMPET+REQ(I,J,K)*(1./1.0-1./T(I,J,K))*VOL 00469800
370 CONTINUE 00469900
SUMPET=SUMPET/UGRT 00470000
PCORR=(SUMPET-SUMPT)/SUMT 00470100
PCORRN=PCORR 00470200
DO 371 I=1,NIP1 00470300
DO 371 J=1,NJP1 00470400
DO 371 K=1,NKP1 00470500
P(I,J,K)=P(I,J,K)+PCORRN 00470600
371 CONTINUE 00470700
RETURN 00470800
END 00470900
00471000
00471100
00471200
00471300
00471400
00471500
C 00471600
*** *****00471700

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SUBROUTINE SOLCON                                00471800
*** *****00471900
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00472100
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER 00472200
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00472300
& CPO,PRT,CONDO,VISO,RH00,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00472400
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10), 00472500
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10) 00472600
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)00472700
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00472800
00472900
DO 402 N=1,NCHIP 00473000
IB=ICHPB(N) 00473100
IE=IB+NCHPI(N)-1 00473200
JB=JCHPB(N) 00473300
JE=JB+NCHPJ(N)-1 00473400
KB=KCHPB(N) 00473500
KE=KB+NCHPK(N)-1 00473600
DO 405 I=IB,IE-1 00473700
DO 405 J=JB,JE-1 00473800
DO 405 K=KB,KE-1 00473900
COND(I,J,K)=CCNDO*CONS(N) 00474000
CPM(I,J,K)=CPS(N) 00474100
NOD(I,J,K)=1 00474200
IF (J.EQ.NJ) COND(I,NJP1,K)=COND(I,NJ,K) 00474300
IF (I.EQ.2) COND(1,J,K)=COND(2,J,K) 00474400
IF (I.EQ.NI) COND(NIP1,J,K)=COND(NI,J,K) 00474500
IF (I.EQ.2.AND.J.EQ.NJ) COND(1,J+1,K)=COND(2,J,K) 00474600
IF (I.EQ.NI.AND.J.EQ.NJ) COND(NIP1,J+1,K)=COND(NI,J,K) 00474700
IF (J.EQ.NJ) CPM(I,NJP1,K)=CPM(I,NJ,K) 00474800
IF (I.EQ.2) CPM(1,J,K)=CPM(2,J,K) 00474900
IF (I.EQ.NI) CPM(NIP1,J,K)=CPM(NI,J,K) 00475000
IF (I.EQ.2.AND.J.EQ.NJ) CPM(1,J+1,K)=CPM(2,J,K) 00475100
IF (I.EQ.NI.AND.J.EQ.NJ) CPM(NIP1,J+1,K)=CPM(NI,J,K) 00475200
405 CONTINUE 00475300
402 CONTINUE 00475400
RETURN 00475500
END 00475600
00475700
00475800
00475900
C
*** *****00476000
SUBROUTINE PTRACK 00476100
*** *****00476200
COMMON/BL14/HCOEF,TINF,CNT,ABTURE,BTURB,VISL,VISMAX,QCORRT,PM1,PM200476300
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00476400
& CPO,PRT,CONDO,VISO,RH00,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00476500
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) 00476600
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00476700
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00476800
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32), 00476900
& DU(22,16,32),DV(22,16,32),DW(22,16,32) 00477000
COMMON/BL39/ALEH,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR 00477100
00477200

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CC ** THE FOLLOWING PRESSURE TEST IS A TEMPORARY MEASURE TO MODIFY THE 00477300
CC HEAT INPUT TO FORCE THE CALCULATED PRESSURE TO AGREE WITH THE 00477400
CC EXPERIMENTAL PRESSURE. IT WILL BE USED UNTIL ACCURATE HEAT INPUT 00477500
CC ** IS RECEIVED. 00477600
CC 00477700
PSOUTH=P(10,9,16)*CONST1+REQ(10,9,16) 00477800
PERROR=(PCURVE-PSOUTH)/PCURVE 00477900
QCORR=1.0+PERROR-(PSOUTH-PM1)/PCURVE 00478000
QCORR=1.0+PERROR-(PSOUTH-PM1)/PCURVE+(PSOUTH-PM1)/(PCURVE-PCURM1)* 00478100
& (PCURVE-PM1)/PCURVE 00478200
QCORRT=QCORRT*QCORR 00478300
PCURM1=PCURVE 00478400
PM1=PSOUTH 00478500
C 00478600
RETURN 00478700
END 00478800
00478900
00479000
00479100
00479200
C 00479300
*** *****00479300
SUBROUTINE TCP 00479400
*** *****00479500
00479600
*****00479700
* THIS SUBROUTINE CALCULATES THE TEMPERATURE AT THE THERMOCOUPLE *00479800
* POSITIONS. *00479900
*****00480000
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93), 00480100
& DXXC(93),DYXC(93),DZXC(93),DXXS(93),DYYS(93),DZZS(93) 00480200
COMMON/BL16/CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00480300
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00480400
COMMON/BL32/T(22,16,32),R(22,16,32),P(22,16,32) 00480500
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00480600
COMMON/BL38/NTHCO,CX(12),CY(12),CZ(12),NTH(12,3),TCOUP(12) 00480700
00480800
00480900
DO 5100 N=1,NTHCO 00481000
II=NTH(N,1) 00481100
JJ=NTH(N,2) 00481200
KK=NTH(N,3) 00481300
VOL=ABS((XC(II+1)-XC(II))*(YC(JJ+1)-YC(JJ))*(ZC(KK+1)-ZC(KK))) 00481400
TCOUP(N)=0. 00481500
DO 5101 I=II,II+1 00481600
III=II+II+1-I 00481700
DO 5101 J=JJ,JJ+1 00481800
JJJ=JJ+JJ+1-J 00481900
DO 5101 K=KK,KK+1 00482000
KKK=KK+KK+1-K 00482100
WVOL=ABS((XC(I)-CX(N))*(YC(J)-CY(N))*(ZC(K)-CZ(N)))/VOL 00482200
TCOUP(N)=TCOUP(N)+WVOL*T(III,JJJ,KKK) 00482300
5101 CONTINUE 00482400
TCOUP(N)=TCOUP(N)*TR-273.18 00482500
00482600
5100 CONTINUE 00482700

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RETURN 00482800
END 00482900
00483000
00483100
00483200
00483300
00483400
C
*** *****00483500
SUBROUTINE OUT(NN) 00483600
*** *****00483700
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR 00483800
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00483900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00484000
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER 00484100
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200484200
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00484300
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0484400
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) 00484500
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00484600
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00484700
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32), 00484800
& DU(22,16,32),DV(22,16,32),DW(22,16,32) 00484900
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32), 00484910
& AS(22,16,32),AF(22,16,32),AB(22,16,32), 00484920
& SP(22,16,32),SU(22,16,32),RI(22,16,32) 00484930
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)00485000
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00485100
COMMON/BL38/NTHCO,CX(12),CY(12),CZ(12),NTH(12,3),TCOUP(12) 00485200
COMMON/BL39/ALEW,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR 00485300
XTIME=TIME*H/UO 00485400
IF( NN .EQ. 1 ) THEN 00485500
C 00485600
QRR=60.*60./3.412/1000.*QR 00485610
WRITE(6,500) XTIME,NTREAL,TIME,ITER,RESORM(ITER),SORSUM,QRR 00485700
500 FORMAT(1X, 'TIME=',F7.3,' S',1X,'NTREAL=',I9,1X, 00485800
& 'TIME=',F7.2,'<0>',1X,'ITER=',I2,1X,'SOURCE=', 00485900
& F9.6,1X,'SORSUM=',F9.6,1X,' QR(KW) = ',F10.4) 00486000
C 00486100
QKW = ((60.*60.)/(3.412*1000.))* Q 00486200
PRINT * 00486300
PRINT *, ' PCURVE PSOUTH PERROR Q00486400
&CRR QCORRT Q(KW) ' 00486500
PRINT *, PCURVE,PSOUTH,PERROR,QCORR,QCORRT,QKW 00486600
PRINT * 00486700
C 00486800
ELSE IF( NN .EQ. 2 ) THEN 00486900
PRINT * 00487000
PRINT *, ' TEMPERATURES AT THERMOCOUPLE POSITION IN (C)' 00487100
WRITE (6,*) (TCOUP(N),N=1,NTHCO) 00487200
PRINT * 00487300
PRINT * 00487400
00487500
ELSE 00487600
00487700
DO 502 L=25,25 00487800

```

K=L	00487900
DO 502 M=1,NIP1	00488000
I=M	00488100
WRITE(6,504) I,K	00488200
504 FORMAT(/,2X,'I=',I2,5X,'K=',I2,/,10X,' T NOD',3X,'R(GM/C.C.)',2X,	00488300
& 'U(CM/SEC)',2X,'V(CM/SEC)',2X,'W(CM/SEC)', 'P (ATM)',5X,'SMP',5X,	00488400
& 'VIS(SEC/CM-CM)',3X,'COND(SEC/CM-CM)', 'XSMP',/)	00488500
513 DO 503 J=1,NJP1	00488600
C XTEMP=T(I,J,K)/CONST3-273.16	00488700
XTEMP=T(I,J,K)	00488800
C XR=R(I,J,K)*RH00/2.2048 *1000.*(0.0328)**3	00488900
XR=R(I,J,K)	00489000
C XU=U(I,J,K)*CONST6	00489100
C XV=V(I,J,K)*CONST6	00489200
C XW=W(I,J,K)*CONST6	00489300
C XP=(P(I,J,K)*CONST1+REQ(I,J,K)*PINT)	00489400
XP=P(I,J,K)	00489500
XU=U(I,J,K)	00489600
XV=V(I,J,K)	00489700
XW=W(I,J,K+1)	00489800
CC XVIS=VIS(I,J,K)*RH00*CP0*H*U0*1.48814	00489900
CC XCOND=COND(I,J,K)*RH00*CP0*H*U0*1.48814	00490000
XVIS=VIS(I,J,K)/VIS0	00490100
XCOND=COND(I,J,K)/VIS0	00490200
XSMP=RI(I,J,K)	00490300
DDYY=1./FLOAT(NJM1-2)	00490400
PE =SQRT(U(I,J,K)**2+V(I,J,K)**2+W(I,J,K)**2)*DDYY/COND(I,J,K)	00490500
WRITE(6,511)J,XTEMP,XR,XU,XV,XW,XP,SMP(I,J,K),XVIS,XCOND,XSMP	00490600
511 FORMAT(2X,'J=',I3,2X,F6.3,2X,F6.3,2X,F7.3,2X,F7.3,3X,F7.3,3X	00490700
& ',F12.3,3X,F9.6,2X,F6.2,2X,F6.2,2X,F6.3)	00490800
503 CONTINUE	00490900
502 CONTINUE	00491000
ENDIF	00491100
RETURN	00491200
ENC	00491300



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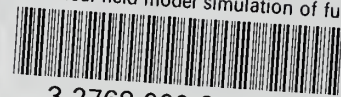
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