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THESIS

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**

by

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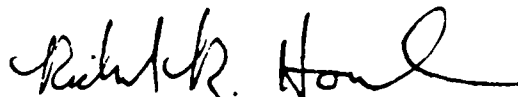
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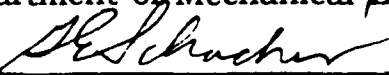
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ABSTRACT

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 phenonema 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 _{pm}	Mean Isobaric Heat Capacity
CURV	Curvature Term (Eqns. 3.25-3.26)
CURVN	Orthogonal Curvature Term (Eqns. 3.30-3.31)
F _{Ai-Aj}	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 _i	Scaling Term (Eqn. 2.8)
g _{ij}	Covariant Metric Tensor (Eqn. 2.16)
g ^{ij}	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 _t	Turbulent Prandtl Number
q	Heat Flux
q _r	Thermal Radiation Energy
R	Universal Gas Constant
R ₋	Source Term Variable (Eqn. 3.71)
RR ₋	Source Term Variable (Eqn. 3.75)
Ri	Richardson Number (Eqn. 2.30)
r	Distance between Two Surfaces
S _f	Source Term (Eqn. 2.25)
S _{hs}	Heat Source
S _{mp}	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

β	Angles Formed by Radiation Surface Normals
χ	Term Used in Radiation Model (Eqn. 2.37)
δ_{ij}	Kronecker Delta
ϵ	Emissivity
Φ	Dissipation Function
μ	Dynamic Viscosity
θ	Directions θ , r , and ϕ or Z
ρ	Fluid Density
σ	Stress
σ	Stefan-Boltzmann Constant
Ψ	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.

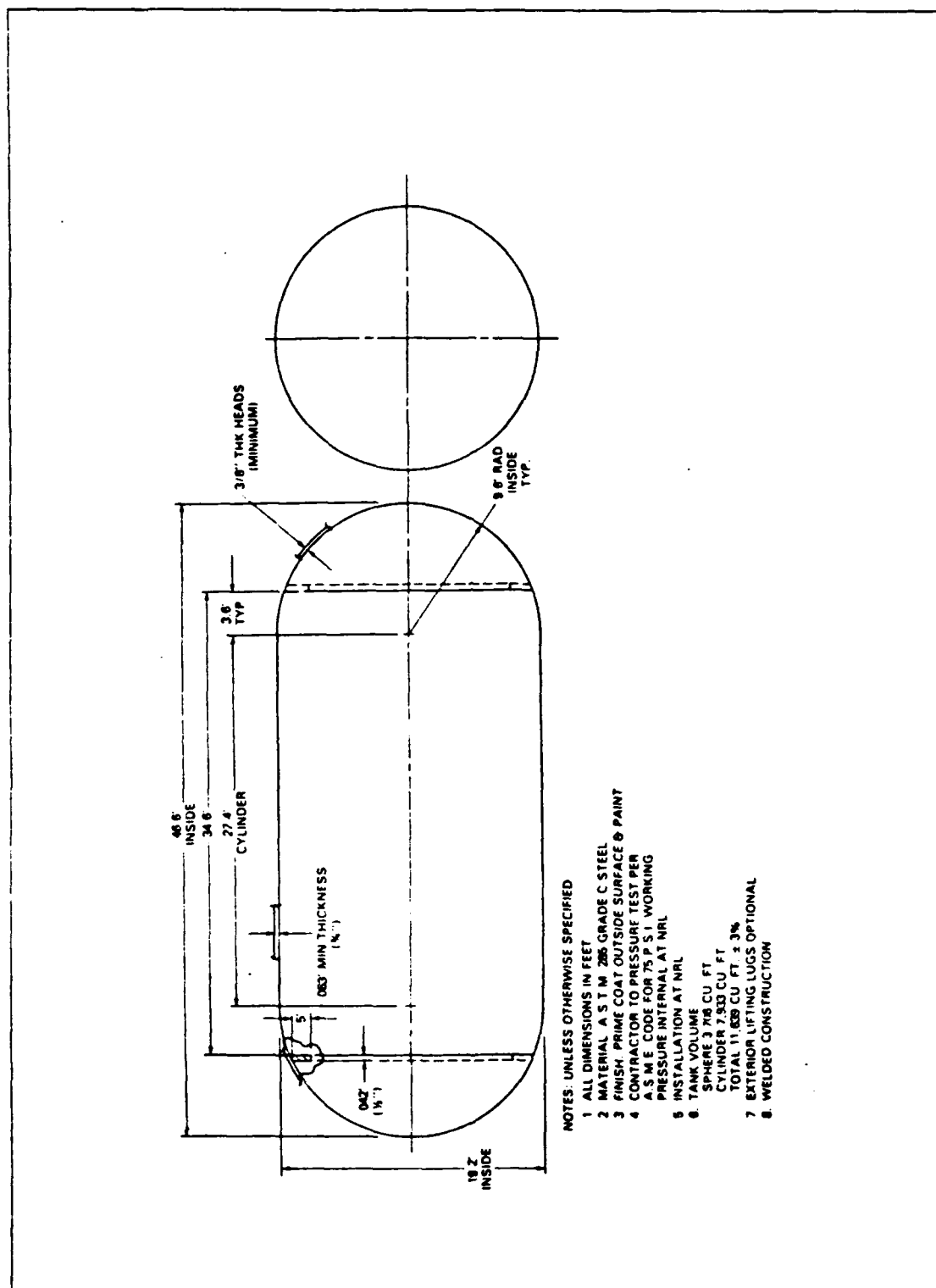


Figure 1-1. Drawing of the FIRE-1 Test Vessel

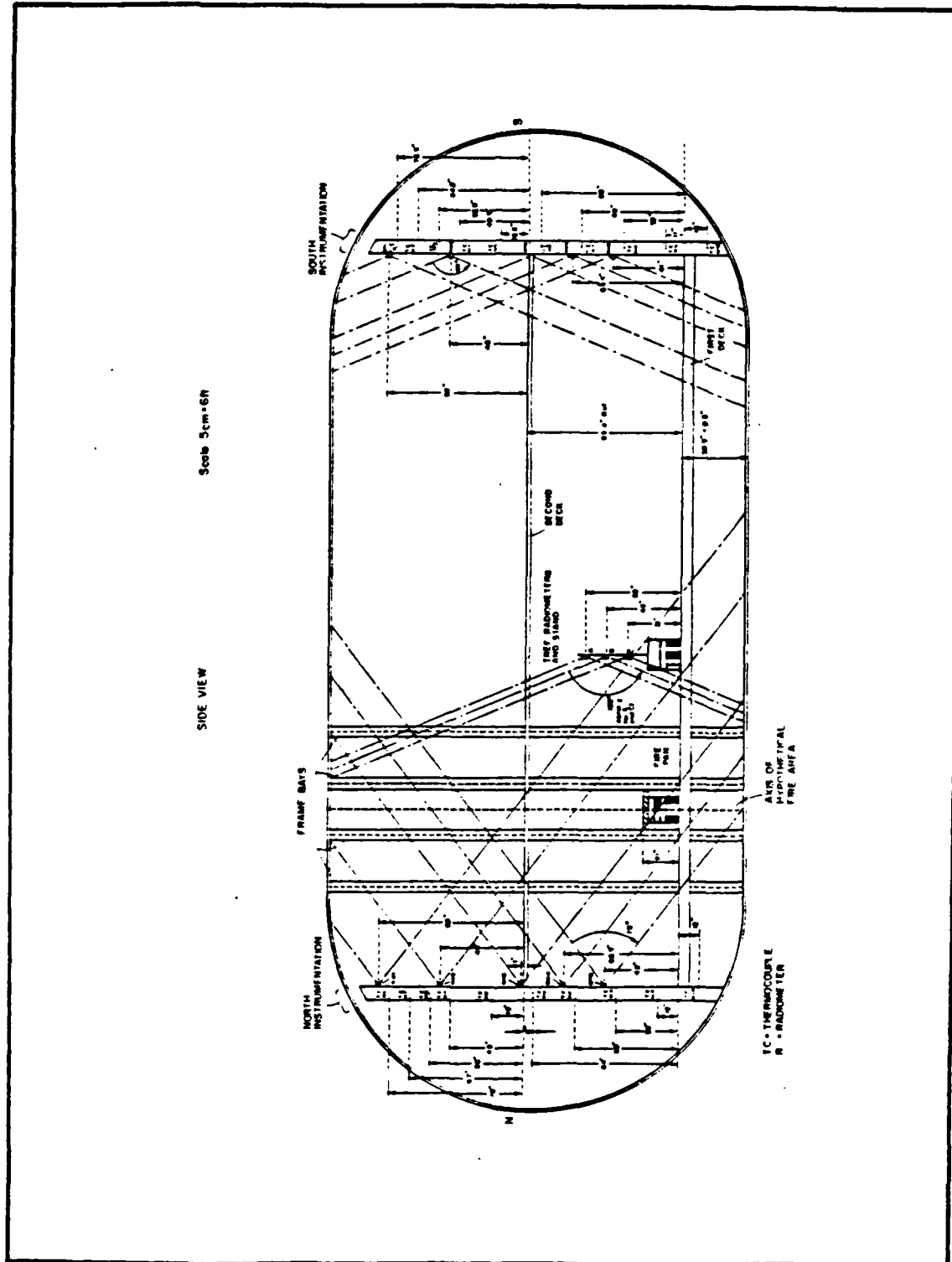


Figure 1-2. Side View of FIRE-1 With Sensor Locations

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 δ_{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:

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

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:

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

with the momentum equation given as:

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

The stress tensor is:

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

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:

$$S_f = \mu \Phi + P \frac{1}{\sqrt{g}} \frac{\partial}{\partial \theta^1} \left(\sqrt{g} \frac{u^1}{h_1} \right) + S_{hs} \quad (2.25)$$

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, μ_{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, μ_{eff} , in recirculating buoyant flows with large variations in turbulence levels. The equation, after being transformed to the generalized orthogonal coordinate system, is:

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

where Pr_t is the turbulent Prandtl Number and the Richardson Number, Ri , is given as:

$$Ri = \frac{H}{u_1^2} \frac{\left(\frac{\partial T}{\partial n}\right) \vec{n} \cdot \vec{g}}{\left[\left(\frac{\partial u^1}{\partial n}\right) \vec{n} \cdot \vec{g}\right]^2 + \left[\left(\frac{\partial u^2}{\partial n}\right) \vec{n} \cdot \vec{g}\right]^2 + \left[\left(\frac{\partial u^3}{\partial n}\right) \vec{n} \cdot \vec{g}\right]^2} \quad (2.30)$$

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_i^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.

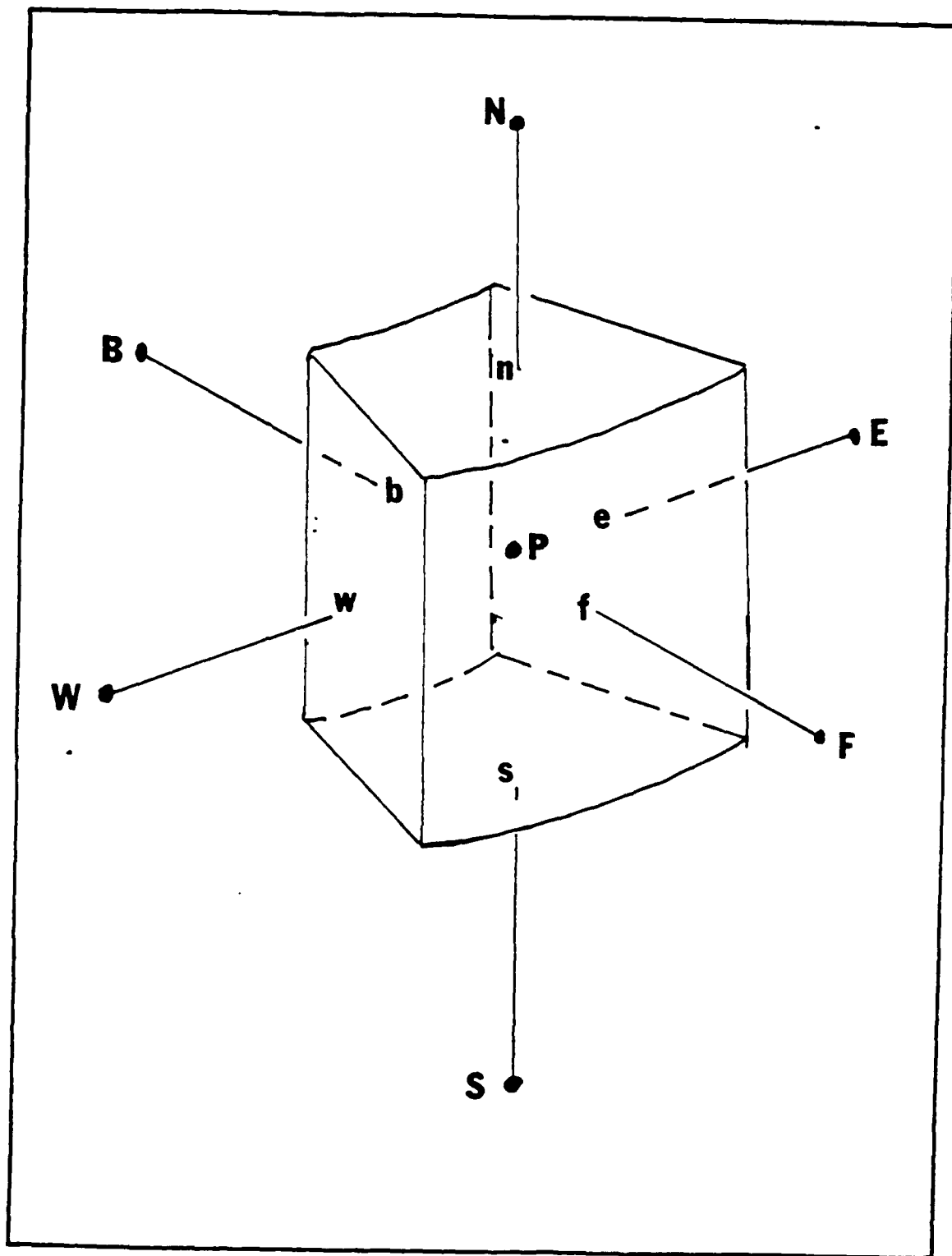


Figure 3-1. Basic Cylindrical Cell

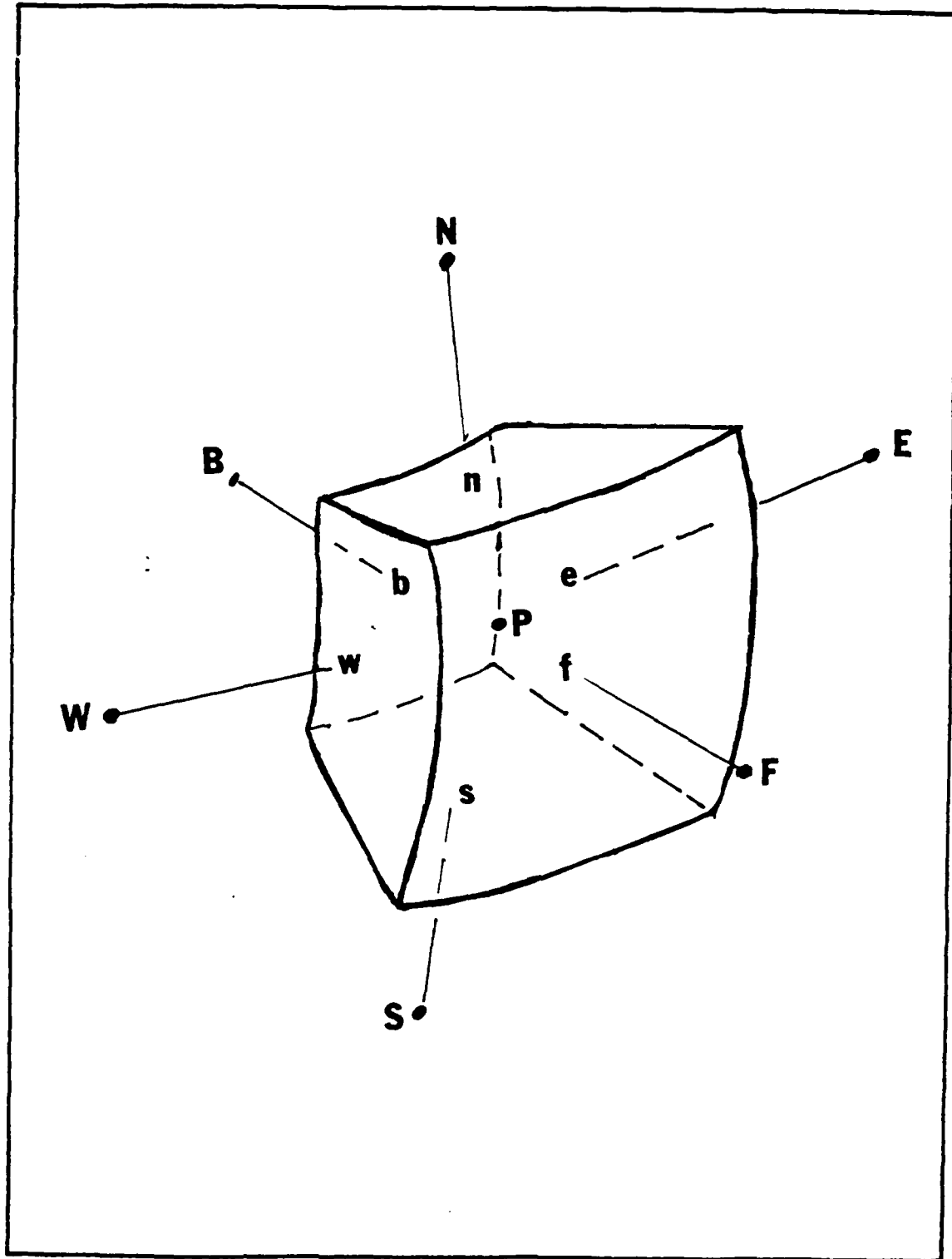


Figure 3-2. Basic Spherical Cell

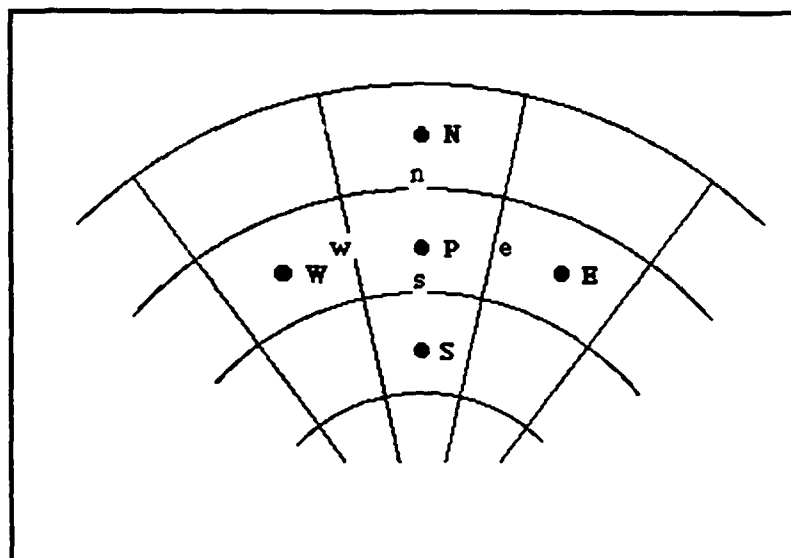


Figure 3-3. Two-Dimensional Basic Cell

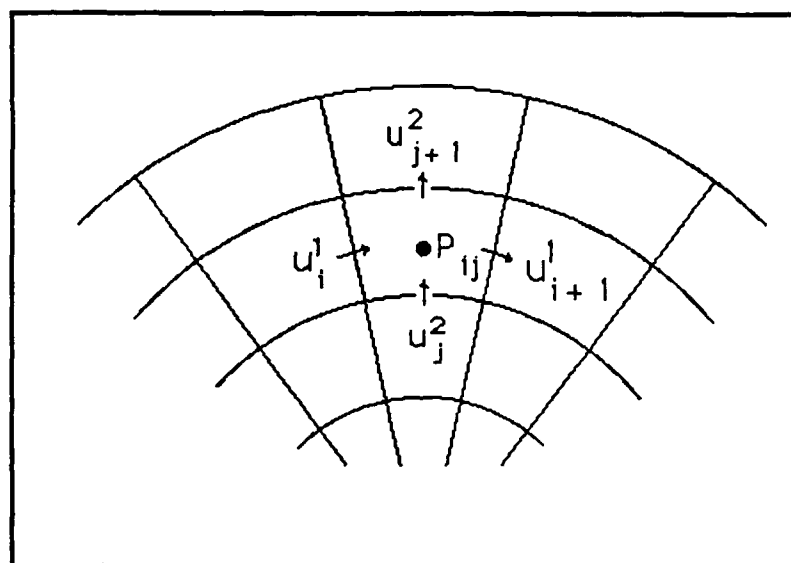


Figure 3-4. Two-Dimensional Staggered Cell

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:

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

and the energy equation is:

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

with:

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

The momentum equations are:

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

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 ρ^{n-1} representing the present value of density, m is the rate of change, ρ^n is the future value, and Δt 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:

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

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 θ^1 , θ^2 , and θ^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} , ρ , 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:

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

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

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

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

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

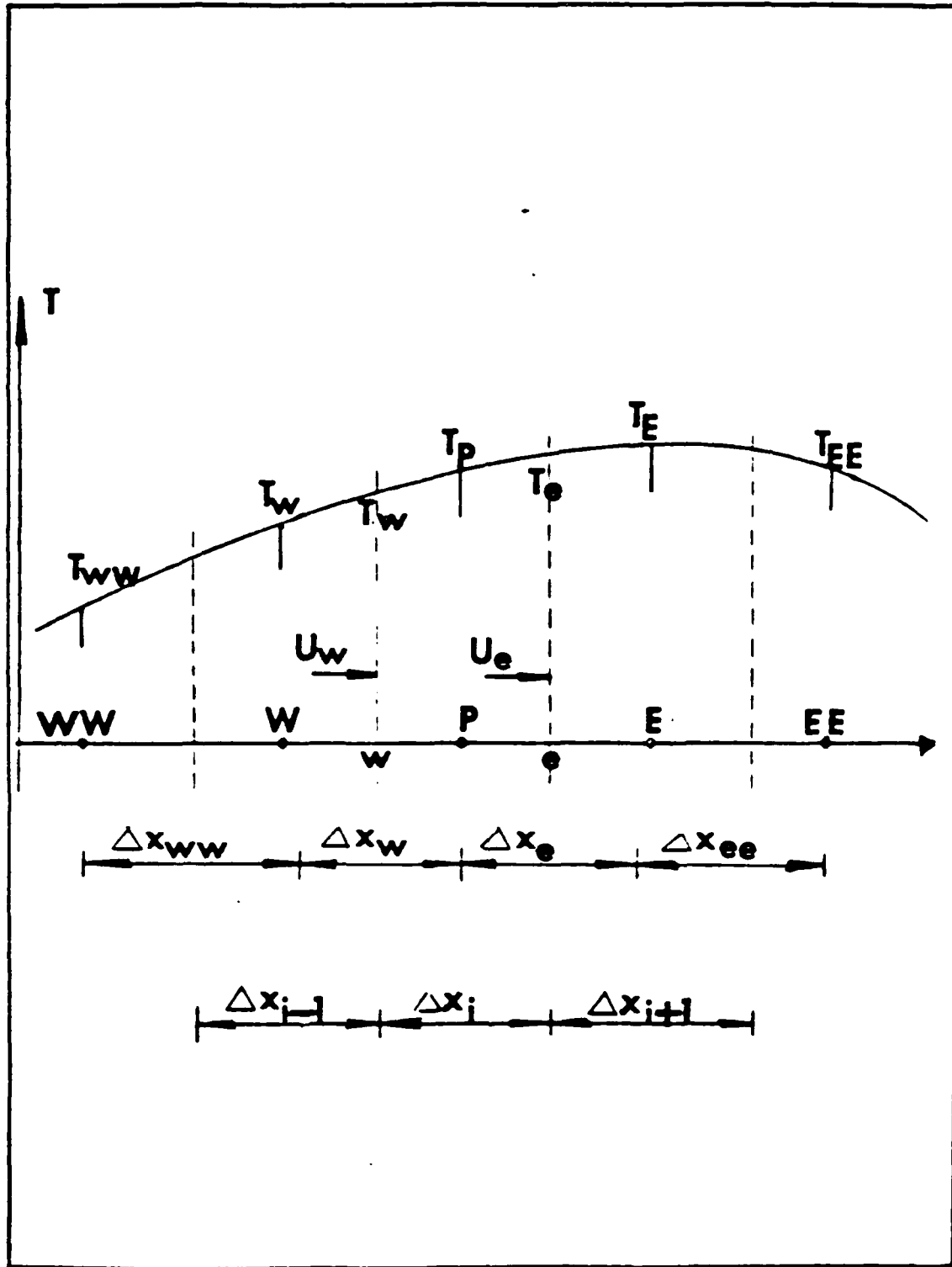


Figure 3-5. One-Dimensional Quadratic Interpolation Scheme

with

$$\Delta X_e = 0.5 (\Delta X_i + \Delta X_{i+1})$$

$$\Delta X_w = 0.5 (\Delta X_i + \Delta X_{i-1})$$

$$\Delta X_{ee} = 0.5 (\Delta X_{i+1} + \Delta X_{i+2}) \quad (3.27)$$

$$\Delta X_{ww} = 0.5 (\Delta X_{i-1} + \Delta X_{i-2})$$

In generalized orthogonal coordinates, the equations becomes:

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

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

with

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

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

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

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,

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

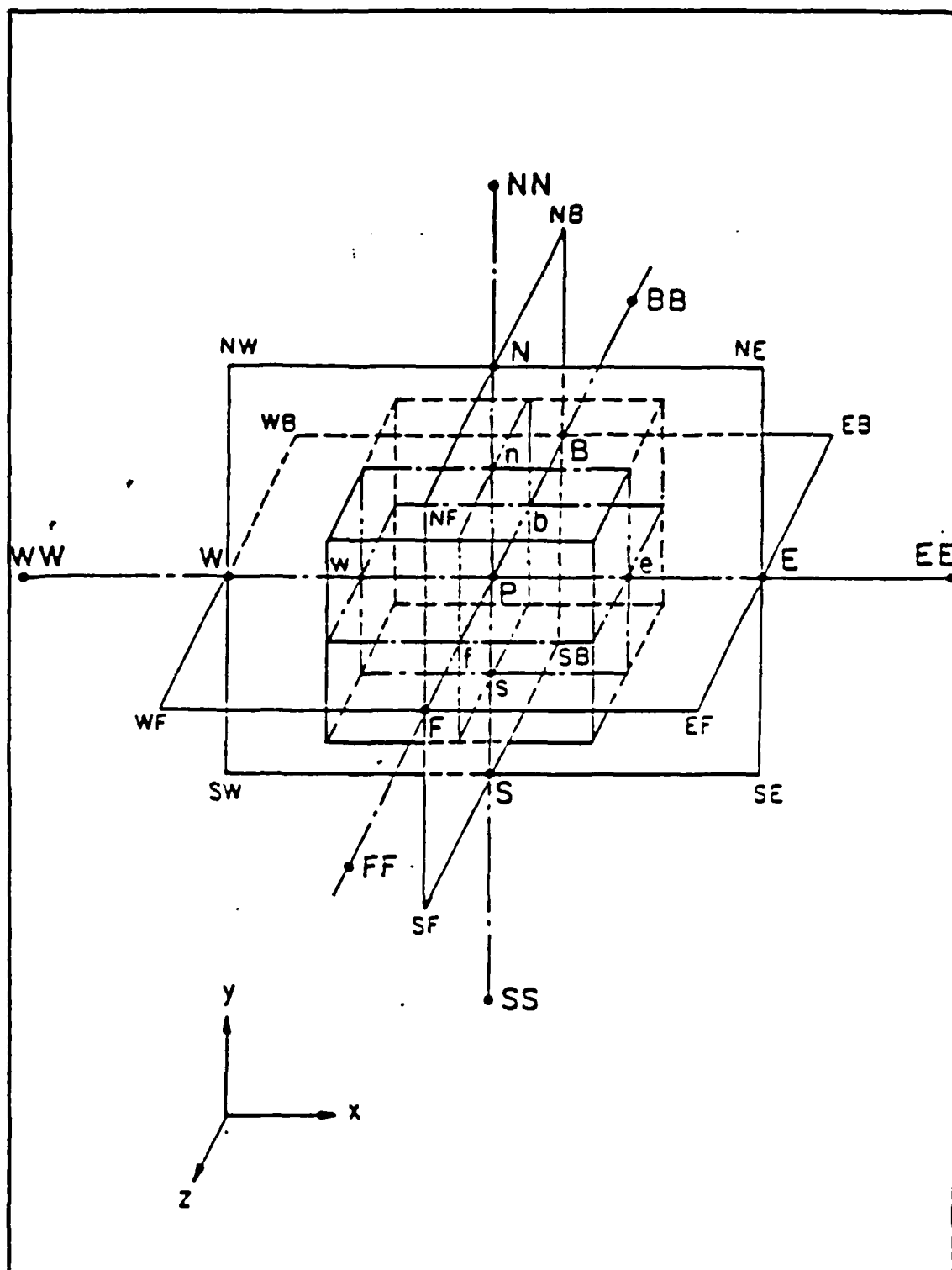


Figure 3-6. Calculation Cell for a Uniform Rectangular Grid

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

Thermal conductivity is:

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

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

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

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

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

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

$$k_w = \frac{1}{\frac{1}{k_1 * (h_1 \Delta\theta^1)_1} + \frac{1}{k_{i-1} * (h_1 \Delta\theta^1)_{i-1}}} \\ \frac{(h_1 \Delta\theta^1)_1 + (h_1 \Delta\theta^2)_{i-1}}$$

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

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

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

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

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

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

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

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

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

$$\text{CEP} = \frac{|CE| + CE}{16} \frac{(h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_i}$$

$$\text{CEM} = \frac{|CE| - CE}{16} \frac{(h_1 \Delta\theta^1)_e}{(h_1 \Delta\theta^1)_{i+1}}$$

$$\text{CWP} = \frac{|CW| + CW}{16} \frac{(h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_{i-1}}$$

$$\text{CWM} = \frac{|CW| - CW}{16} \frac{(h_1 \Delta\theta^1)_w}{(h_1 \Delta\theta^1)_i}$$

$$\text{CNP} = \frac{|CN| + CN}{16} \frac{(h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_j}$$

$$\text{CNM} = \frac{|CN| - CN}{16} \frac{(h_2 \Delta\theta^2)_n}{(h_2 \Delta\theta^2)_{j+1}} \quad (3.43)$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The intermediate coefficients are :

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

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

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

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

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

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

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

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

The coefficients are:

$$A_E^T = A_{EI} * C_{pm,E} + CONDE1$$

$$A_W^T = A_{WI} * C_{pm,W} + CONDW1$$

$$A_N^T = A_{NI} * C_{pm,N} + CONDN1 \quad (3.52)$$

$$A_S^T = A_{SI} * C_{pm,S} + CONDS1$$

$$A_F^T = A_{FI} * C_{pm,F} + CONDF1$$

$$A_B^T = A_{BI} * C_{pm,B} + CONDB1$$

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

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

F. MOMENTUM EQUATION

The integrated momentum equation is given as:

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

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 θ^j 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 :

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

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:

$$M^j = \hat{M}^j + (\hat{\theta}_1^j - \sigma_1^j) \quad (3.57)$$

with

$$\hat{\theta}_1^j = \frac{\mu}{\left[h_j \left(\frac{\partial u^j}{\partial \theta^j} \right) \right]} \quad (3.58)$$

$$\hat{M}^j = \rho u^i u^j - \hat{\theta}_1^j \quad (3.59)$$

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 θ^1 is given as:

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

The intermediate mass flow rates per unit area are:

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

$$\begin{aligned}
G_{fe} &= u_{k+1}^3 \left\{ \frac{[\rho_{k+1} (h_3 \Delta\theta^3)_k + \rho_k (h_3 \Delta\theta^3)_{k+1}]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k+1}} \right\} \\
G_{fw} &= u_{i-1, k+1}^3 \left\{ \frac{[\rho_{i-1, k+1} (h_3 \Delta\theta^3)_k + \rho_{i-1} (h_3 \Delta\theta^3)_{k+1}]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k+1}} \right\} \\
G_{be} &= u^3 \left\{ \frac{[\rho_{k-1} (h_3 \Delta\theta^3)_k + \rho_k (h_3 \Delta\theta^3)_{k-1}]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k-1}} \right\} \\
G_{bw} &= u_{i-1}^3 \left\{ \frac{[\rho_{i-1, k-1} (h_3 \Delta\theta^3)_k + \rho_{i-1} (h_3 \Delta\theta^3)_{k-1}]}{(h_3 \Delta\theta^3)_k + (h_3 \Delta\theta^3)_{k-1}} \right\}
\end{aligned}$$

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

$$\begin{aligned}
CE &= 0.5 (G_e + G_p) * (h_2 \Delta\theta^2)_e * (h_3 \Delta\theta^3)_e \\
CW &= 0.5 (G_p + G_w) * (h_2 \Delta\theta^2)_w * (h_3 \Delta\theta^3)_w \quad (3.64) \\
CN &= (h_1 \Delta\theta^1)_n (h_3 \Delta\theta^3)_n \left\{ \frac{[G_{ne} (h_1 \Delta\theta^1)_w + G_{nw} (h_1 \Delta\theta^1)_e]}{[(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e]} \right\} \\
CS &= (h_1 \Delta\theta^1)_s (h_3 \Delta\theta^3)_s \left\{ \frac{[G_{se} (h_1 \Delta\theta^1)_w + G_{sw} (h_1 \Delta\theta^1)_e]}{[(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e]} \right\} \\
CF &= (h_1 \Delta\theta^1)_f (h_2 \Delta\theta^2)_f \left\{ \frac{[G_{fe} (h_1 \Delta\theta^1)_w + G_{fw} (h_1 \Delta\theta^1)_e]}{[(h_1 \Delta\theta^1)_w + (h_1 \Delta\theta^1)_e]} \right\}
\end{aligned}$$

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

The local viscosity becomes:

$$VIS_c = VIS$$

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

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

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

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

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

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

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

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

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

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

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

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:

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

$$A_W^u = A_{\text{w1}} + \text{VISW1}$$

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

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

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

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

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.

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

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

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

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

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

$$AU1 = u^1$$

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

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

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

$$ARU12 = AR * AU1 * AU2$$

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

$$ARU22 = AR * AU2 * AU2$$

$$ARU33 = AR * AU3 * AU3$$

$$\begin{aligned} RRY &= (\bar{\sigma}^{12} - ARU12) (h_3 \Delta\theta^3)_k \left[(h_1 \Delta\theta^1)_n - (h_1 \Delta\theta^1)_s \right] \\ RRZ &= (\bar{\sigma}^{13} - ARU13) (h_2 \Delta\theta^2)_j \left[(h_1 \Delta\theta^1)_f - (h_1 \Delta\theta^1)_b \right] \\ RRX &= (\bar{\sigma}^{22} - ARU22) (h_3 \Delta\theta^3)_k \left[(h_2 \Delta\theta^2)_e - (h_2 \Delta\theta^2)_w \right] + \\ &+ (\bar{\sigma}^{33} - ARU33) (h_2 \Delta\theta^2)_j \left[(h_3 \Delta\theta^3)_e - (h_3 \Delta\theta^3)_w \right] \end{aligned} \quad (3.75)$$

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:

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

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_{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_{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_{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 ').

$$P = P^* + P' \quad (3.80)$$

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

$$A_E = \frac{\rho_e * (h_2 \Delta\theta^2 h_3 \Delta\theta^3)_e^2}{\left(A_{p_{i+1}}^{u^1} + \rho_e \frac{\Delta V}{\Delta t} \right)} \quad (3.82)$$

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

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

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

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

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

$$A_p = A_E + A_w + A_N + A_S + A_F + A_B \quad (3.88)$$

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

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

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

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

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

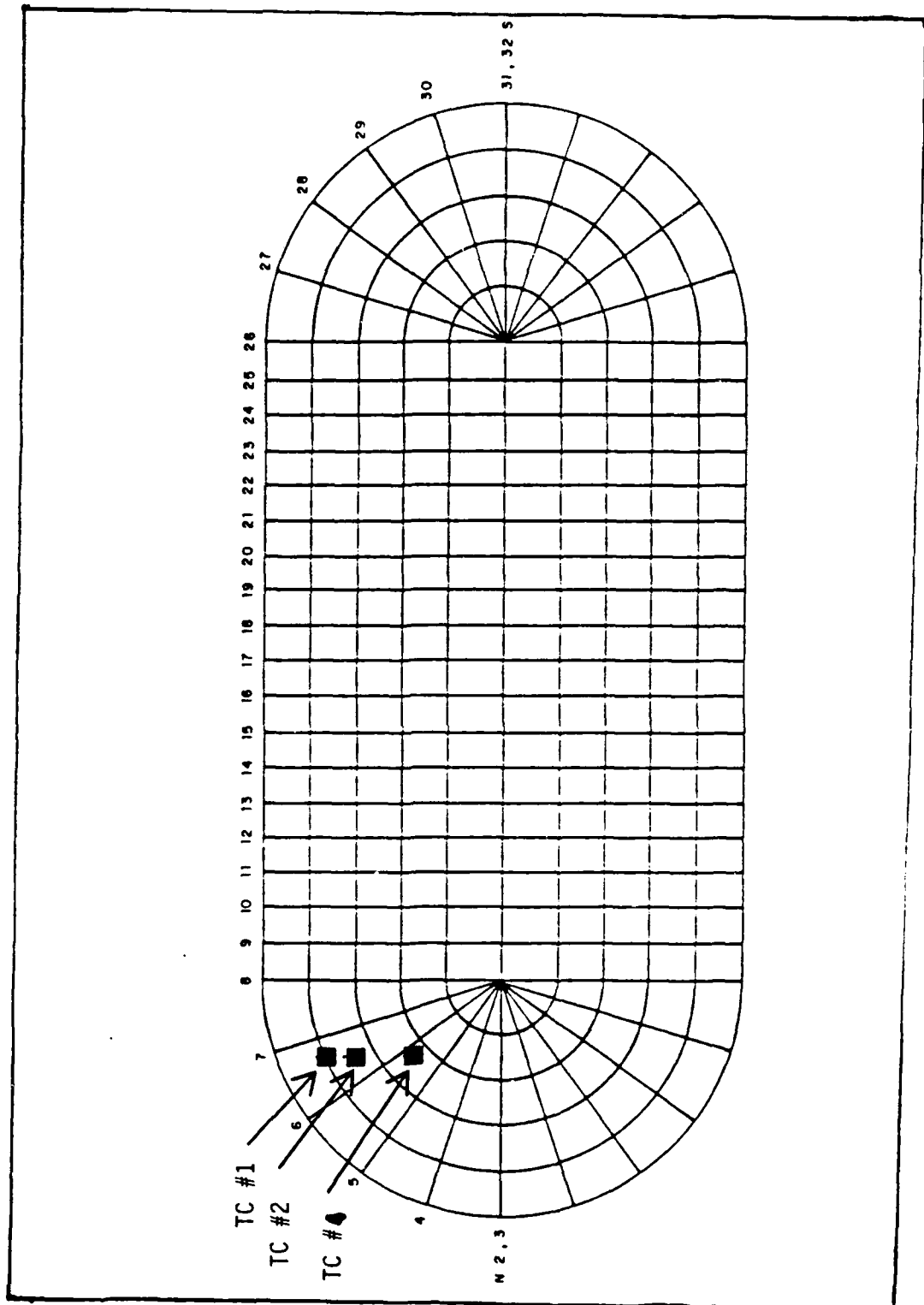


Figure 4-1. Thermocouple Locations

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 θ , R , and ϕ directions, and cylindrical in the mid-section, with θ , 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 ϕ cells; again, one cell is used to avoid singularity. The mid-section has 18 Z (or ϕ) cells and there are 20 cells in the θ direction oriented counterclockwise. Although a finer grid could be used to

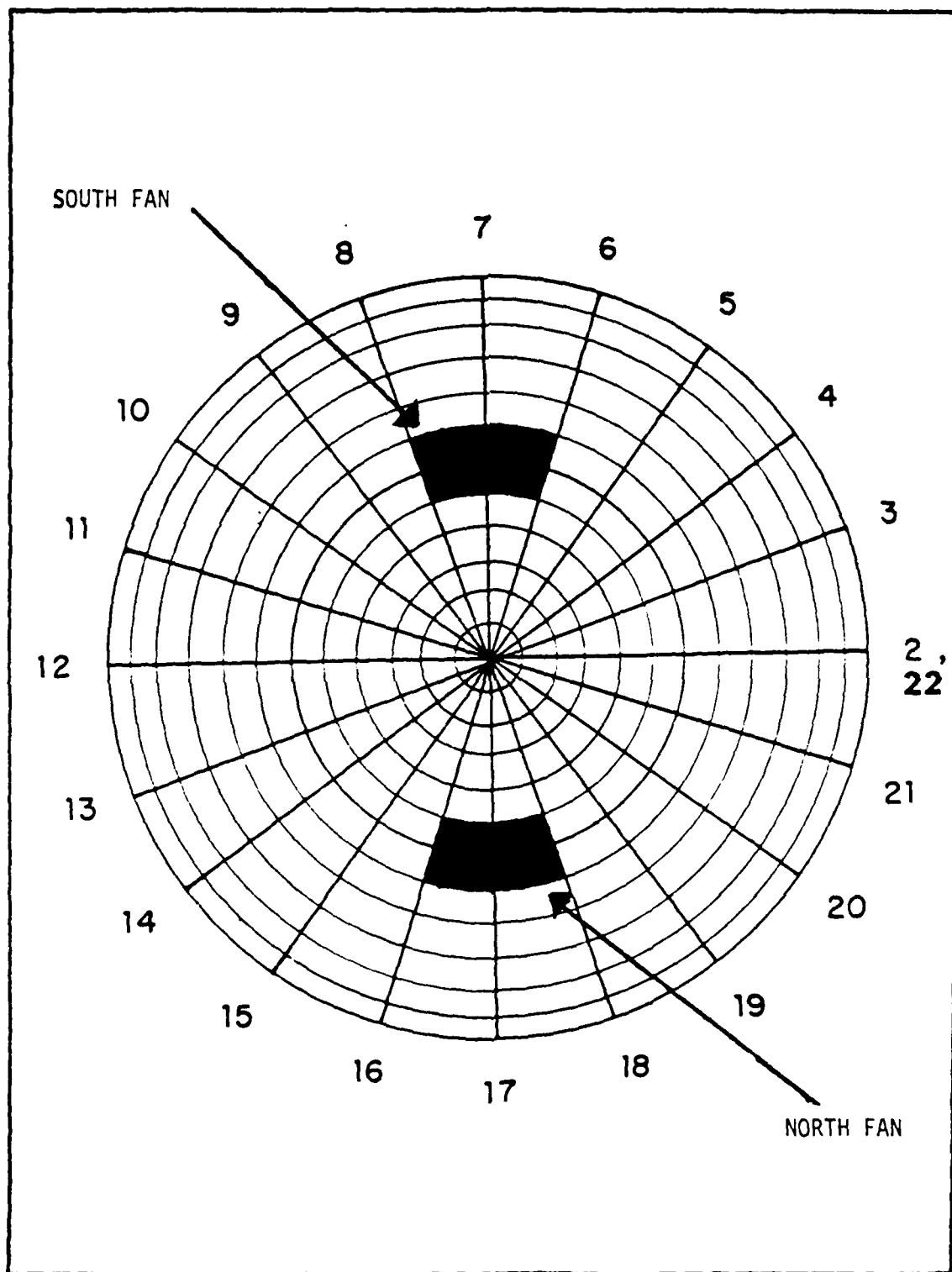


Figure 4-2. Ventilation Location in Computer Model (End View)

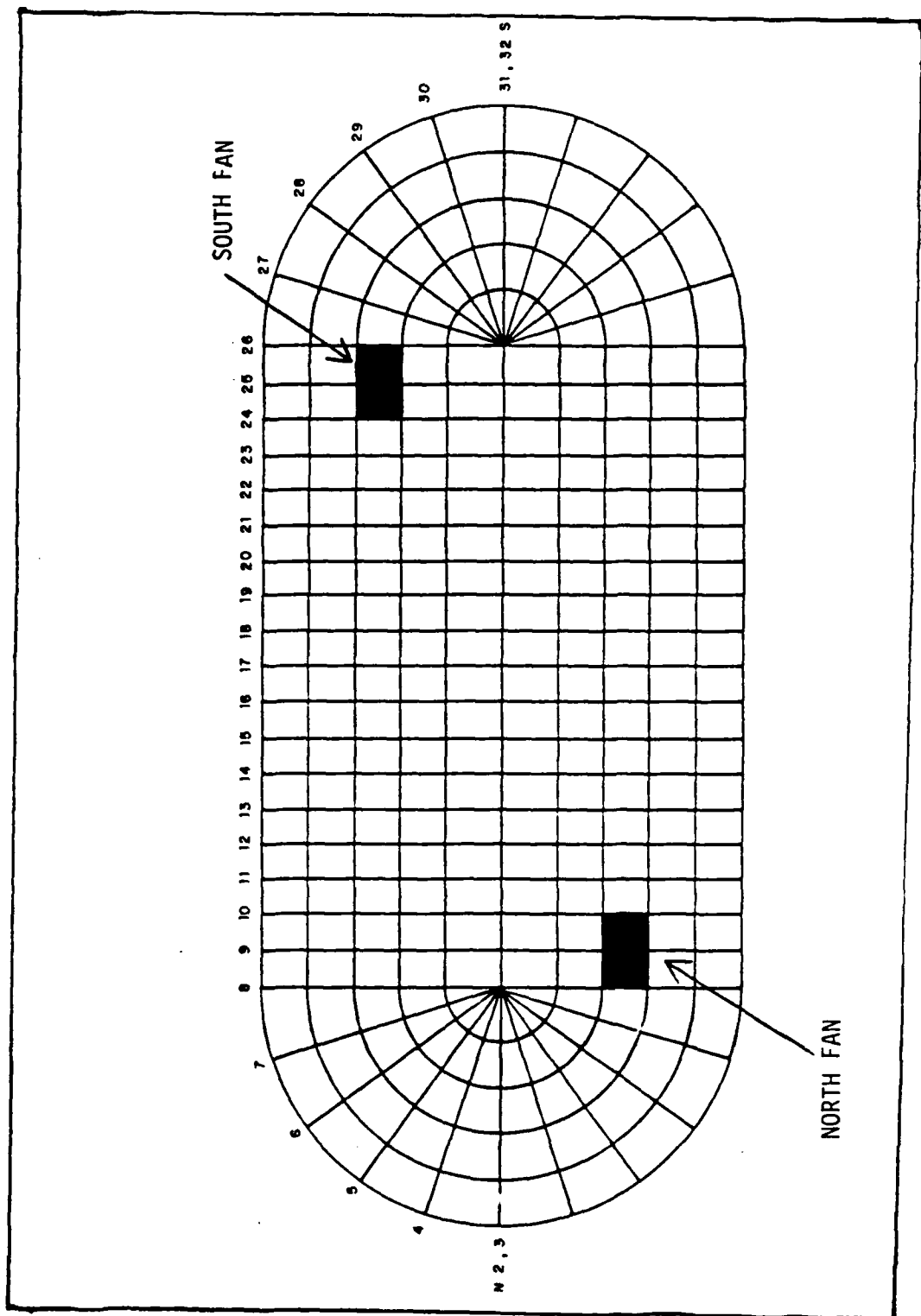


Figure 4-3. Ventilation Location in Computer Model (Front View)

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 ³

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 θ Direction	20
Cells in the R Direction	14
Cells in the ϕ 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
CPU Time (1 CPU hour)	0.6–0.8 sec fire time
External Heat Transfer Coefficient	15.0 Btu/ (hr ft ² 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

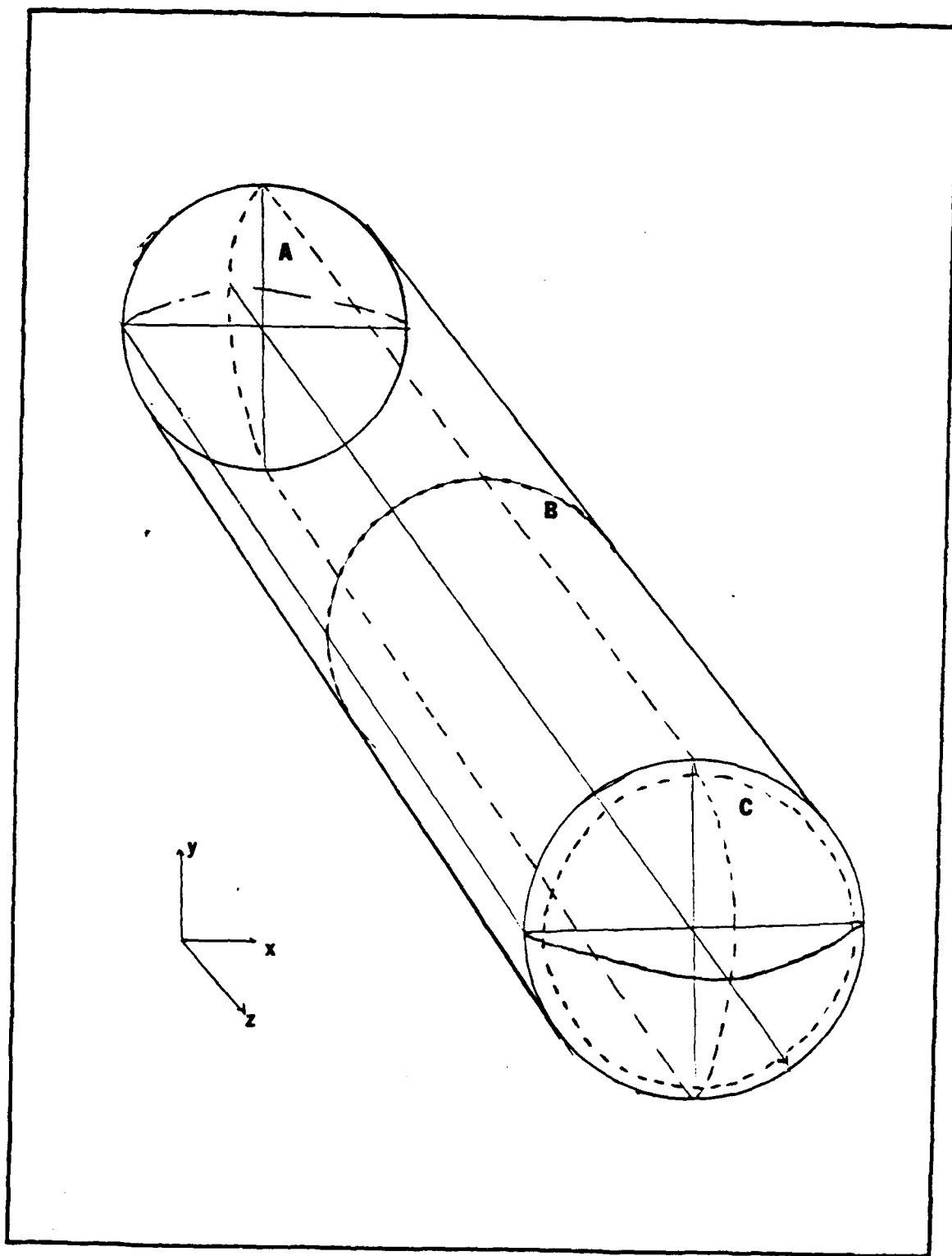


Figure 4-4. Location of Cross-Sections Used for Isotherm and Velocity Field Plots

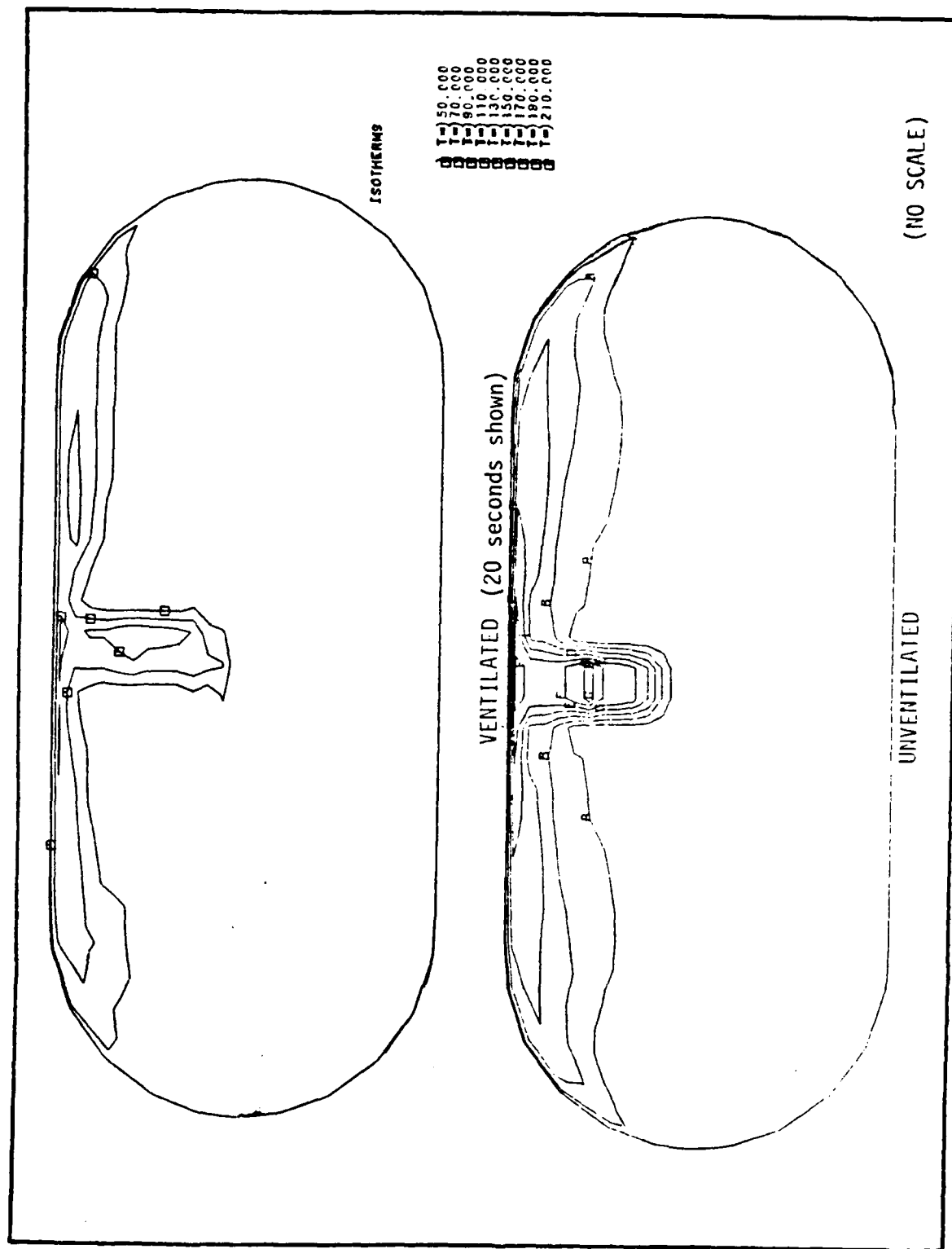


Figure 4-5. Mid-Section Front Views of Isotherms at 30 Seconds

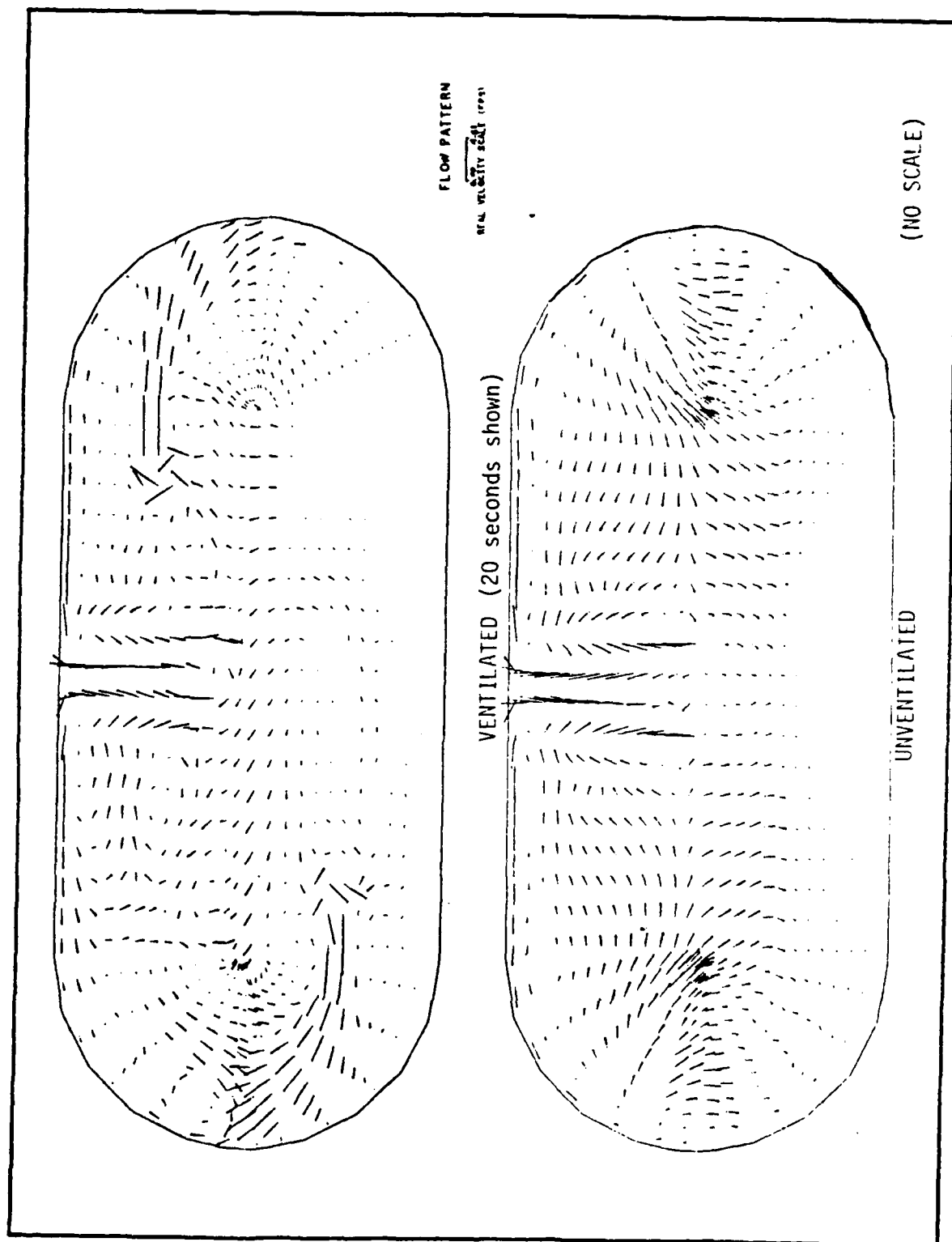


Figure 4-6. Mid-Section Front Views of
Velocity Field at 30 Seconds

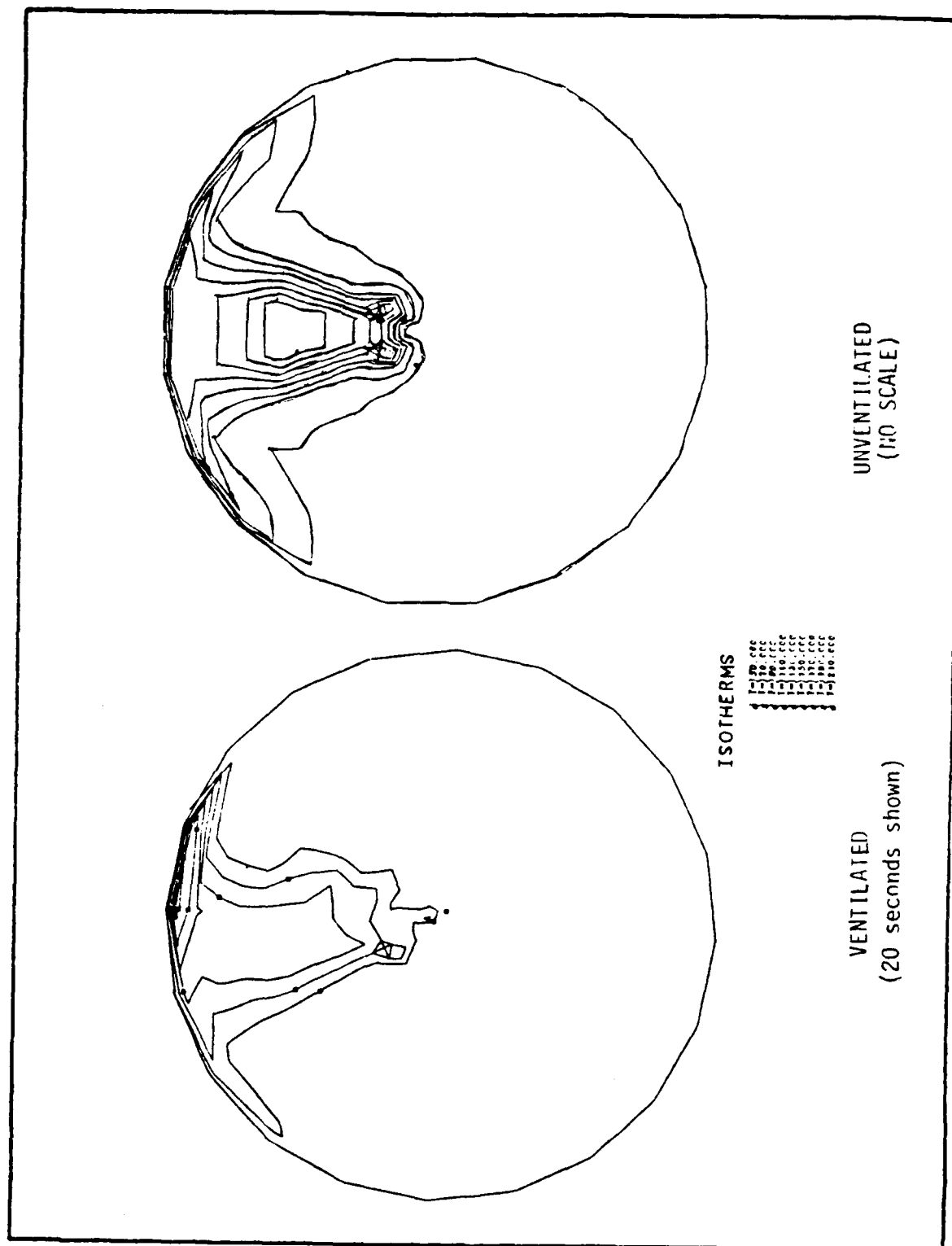


Figure 4-7. Mid-Section End Views of Isotherms at 30 Seconds

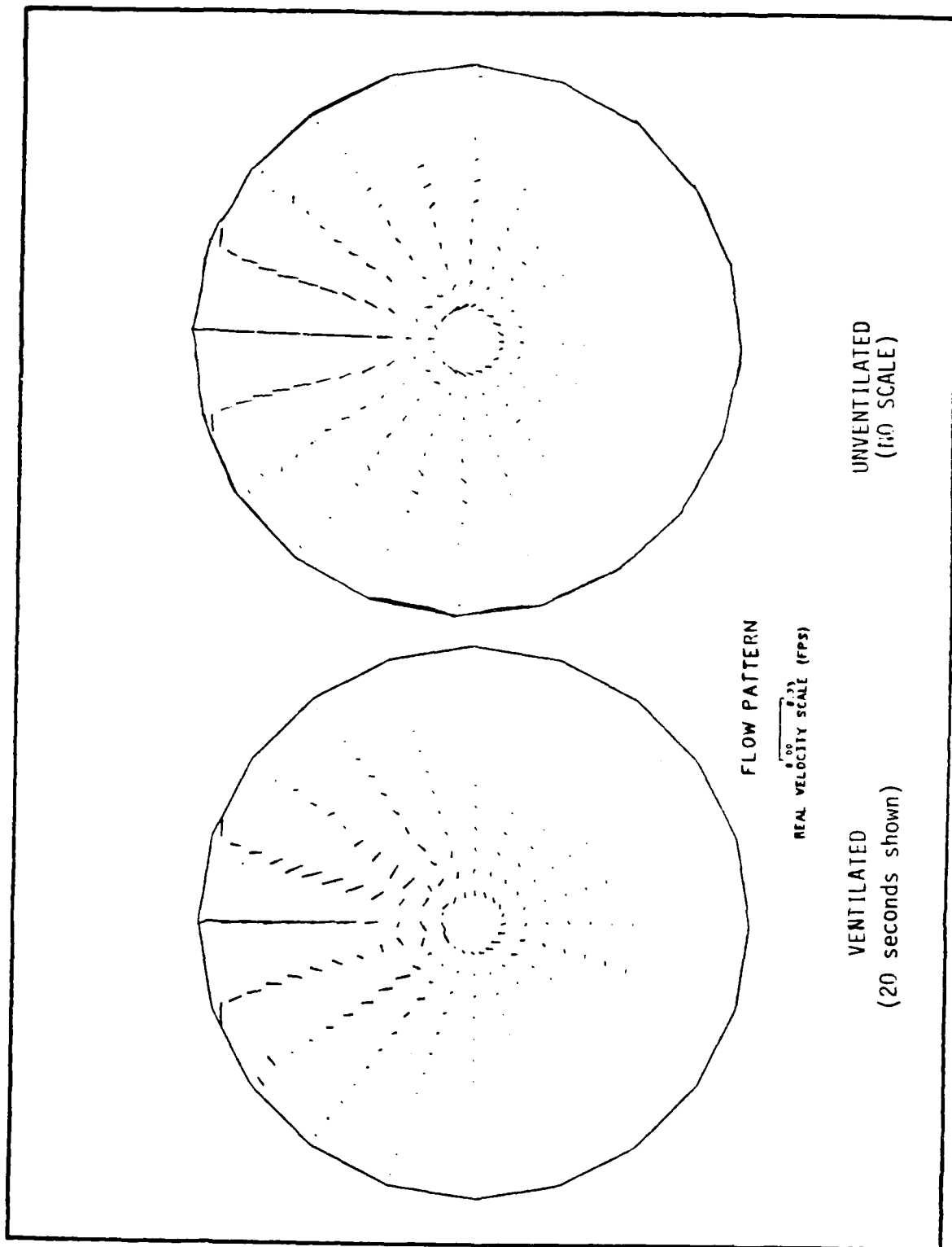


Figure 4-8. Mid-Section End Views of Velocity Field at 30 Seconds

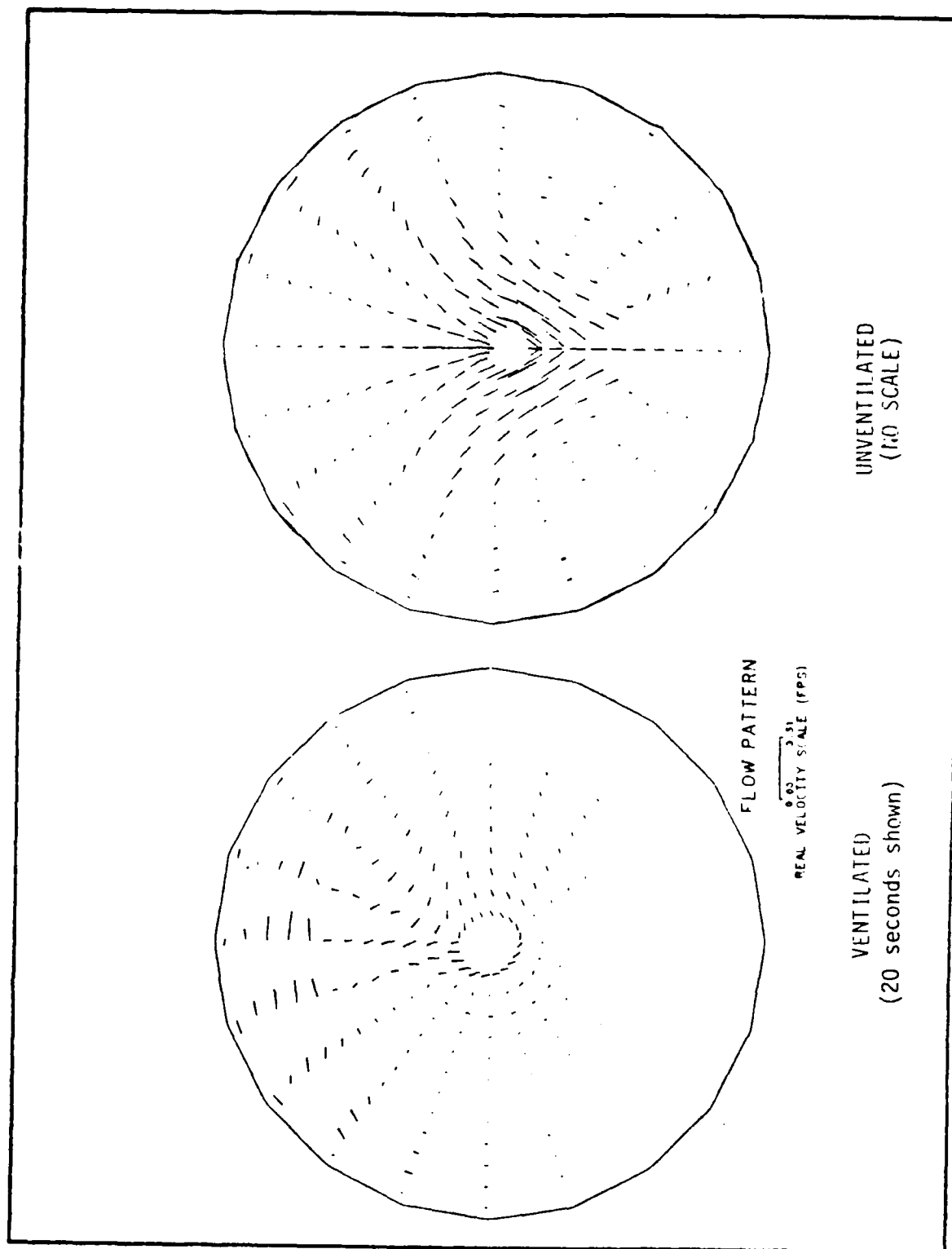


Figure 4-10. Section View at Base of End Cap of Velocity Field at 30 Seconds

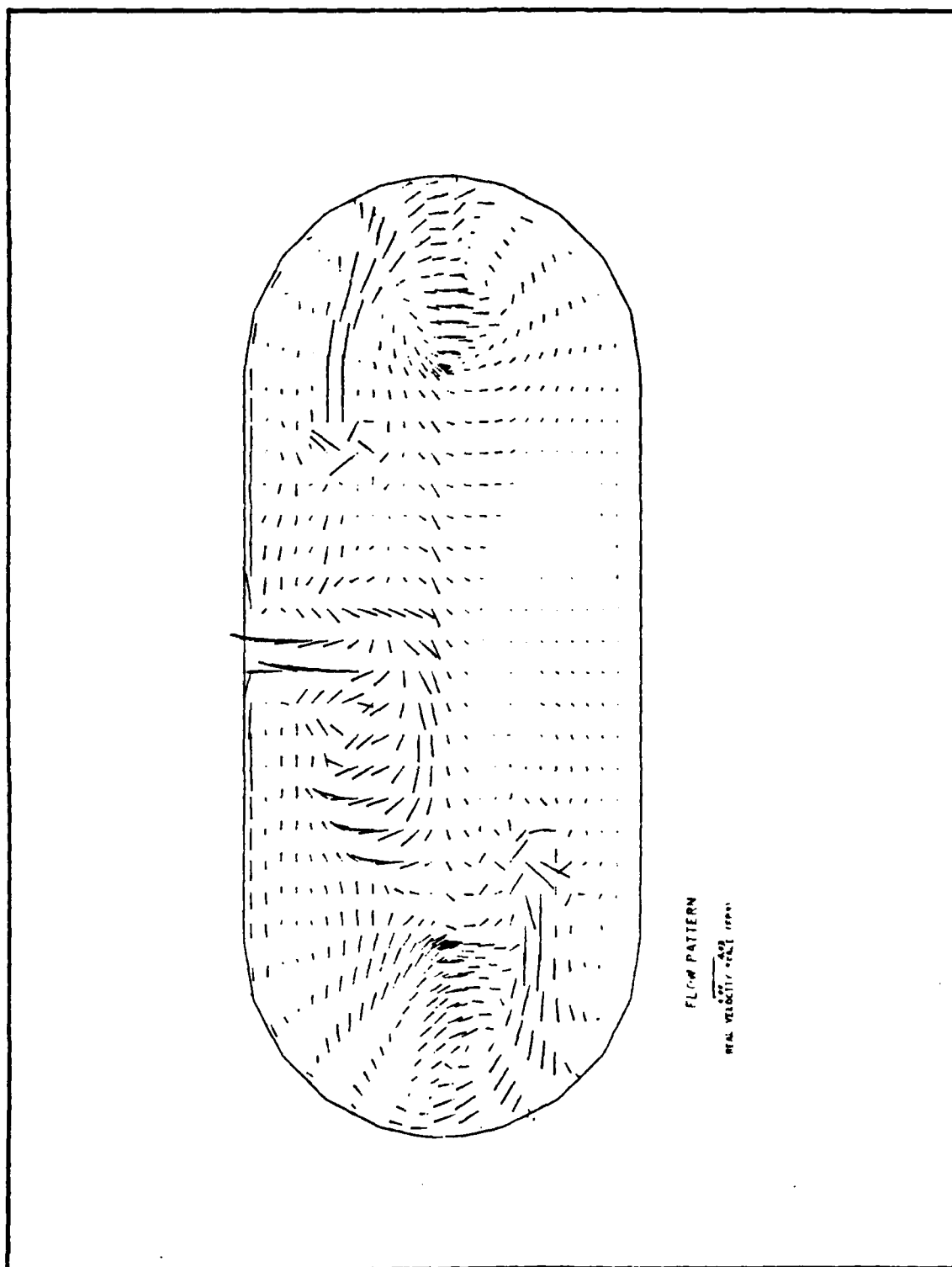


Figure 4-11. Mid-Section Front View of
Velocity Field at 40 Seconds

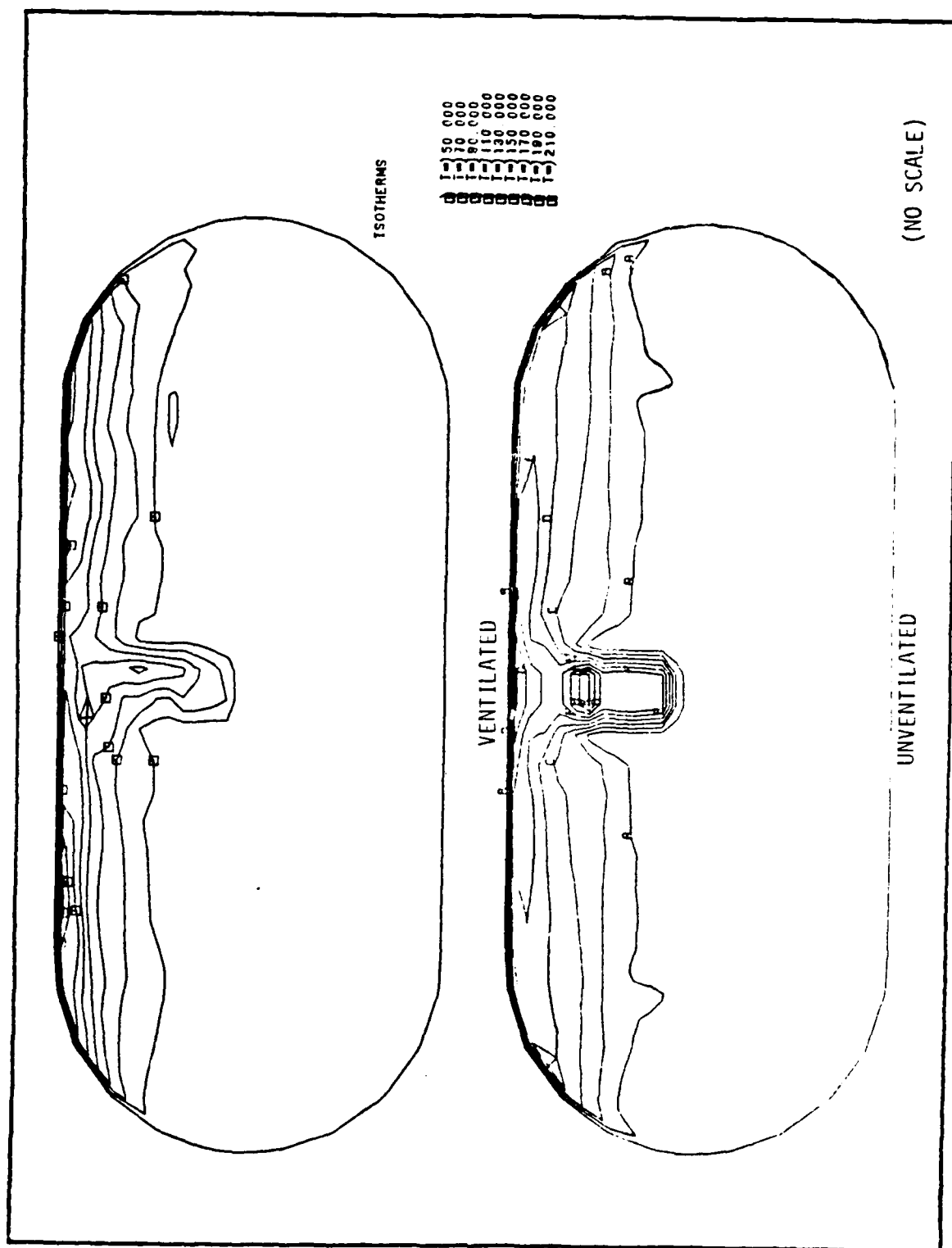


Figure 4-12. Mid-Section Front Views of Isotherms at 60 Seconds

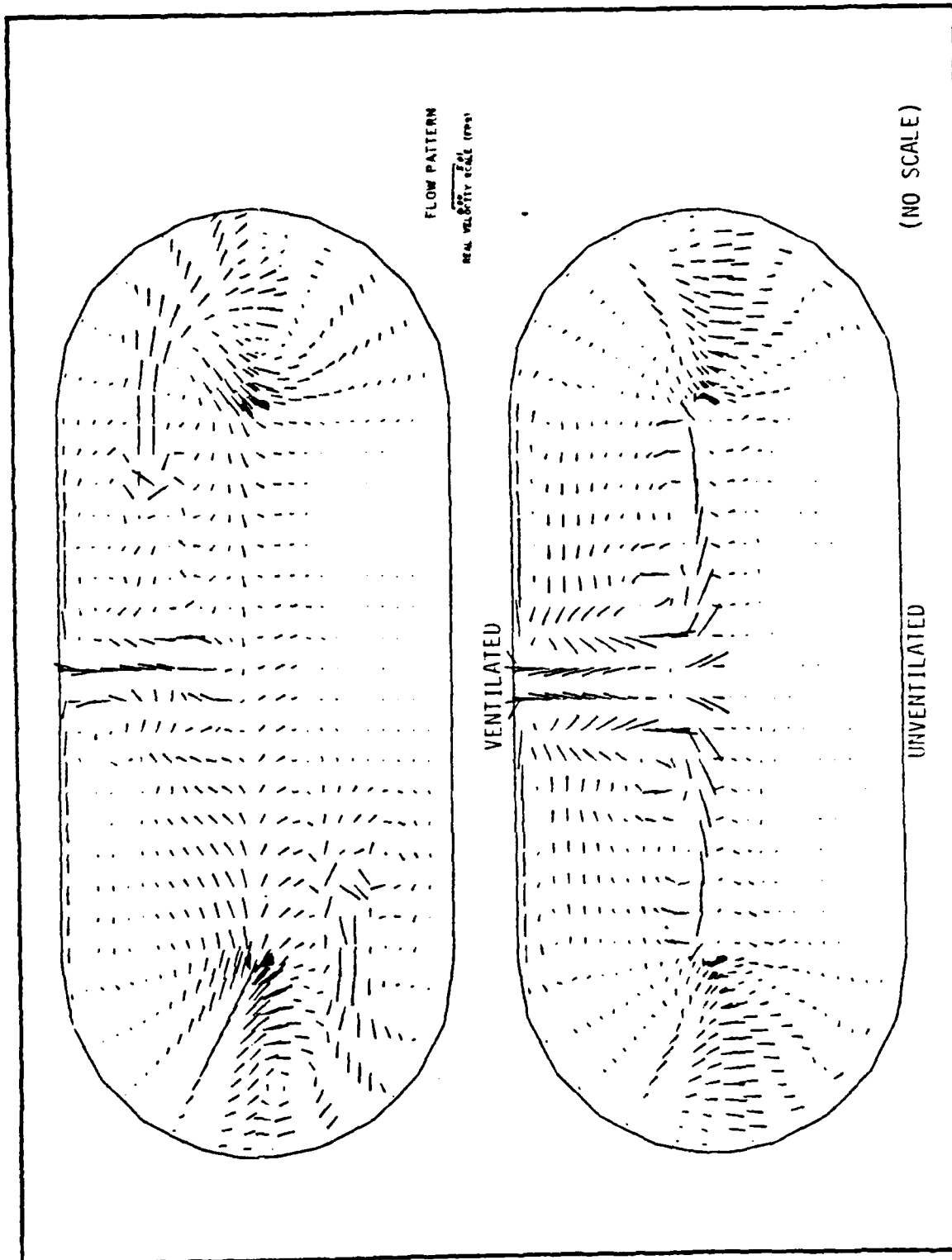


Figure 4-13. Mid-Section Front Views of
Velocity Field at 60 Seconds

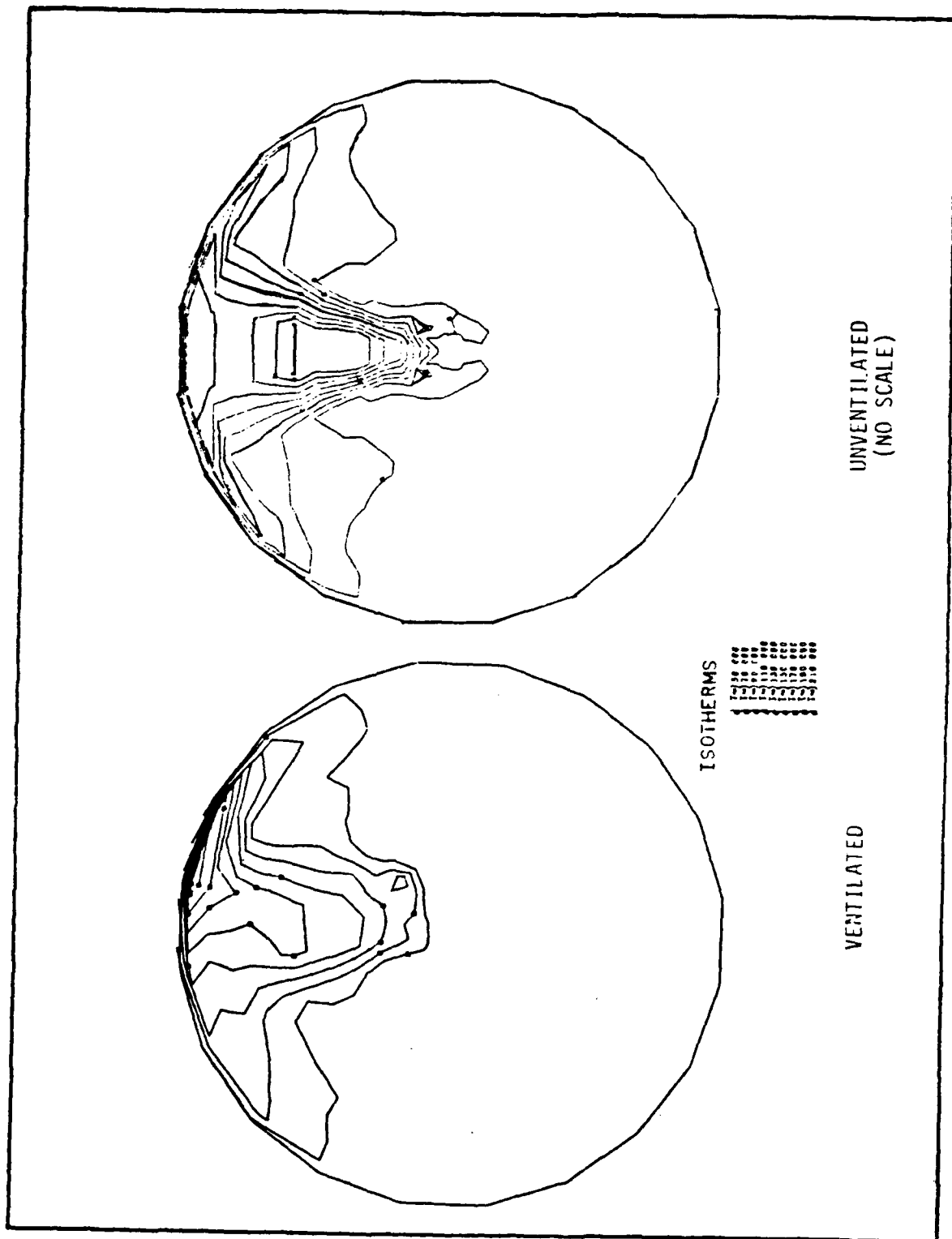


Figure 4-14. Mid-Section End Views of Isotherms at 60 Seconds

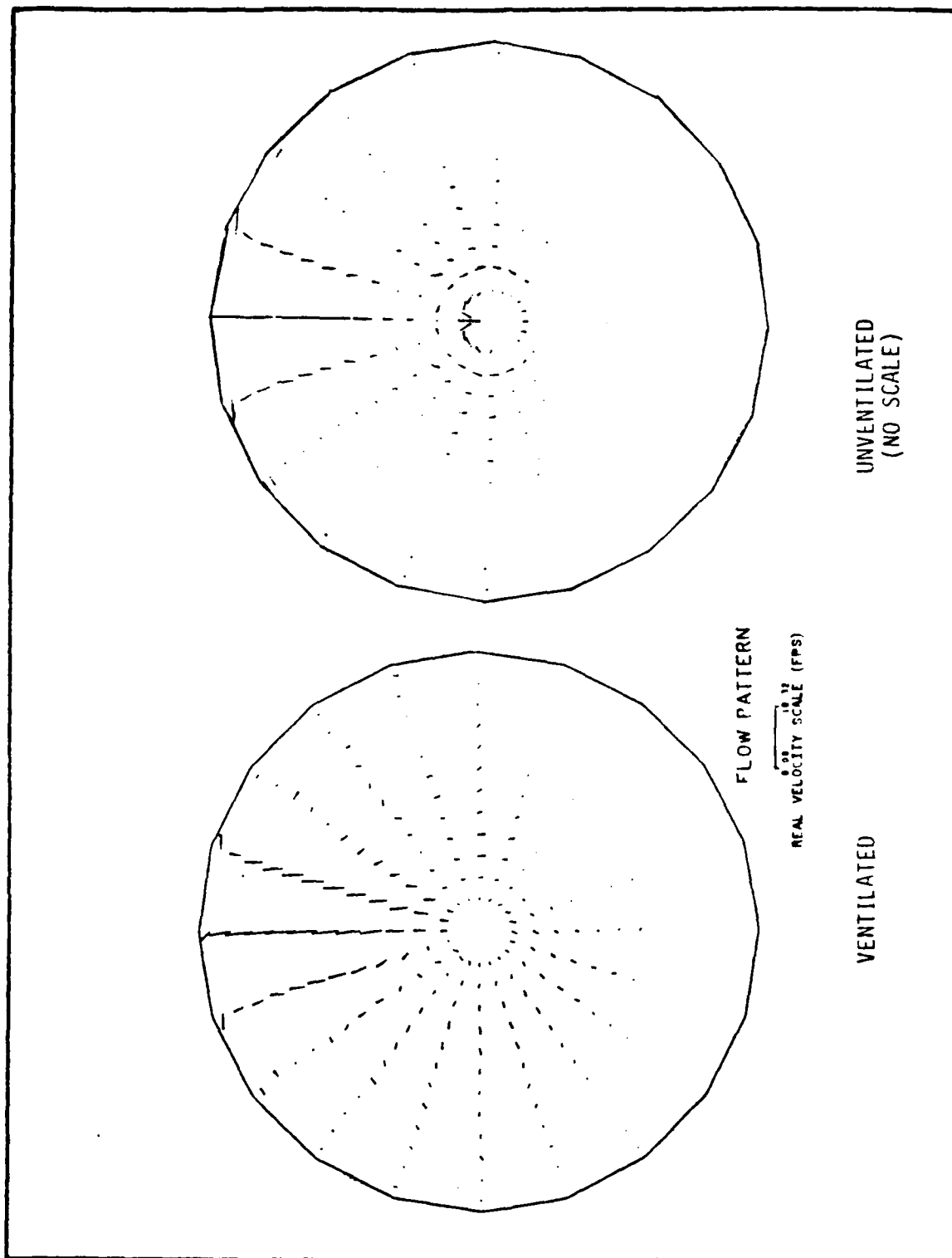


Figure 4-15. Mid-Section End Views of
Velocity Field at 60 Seconds

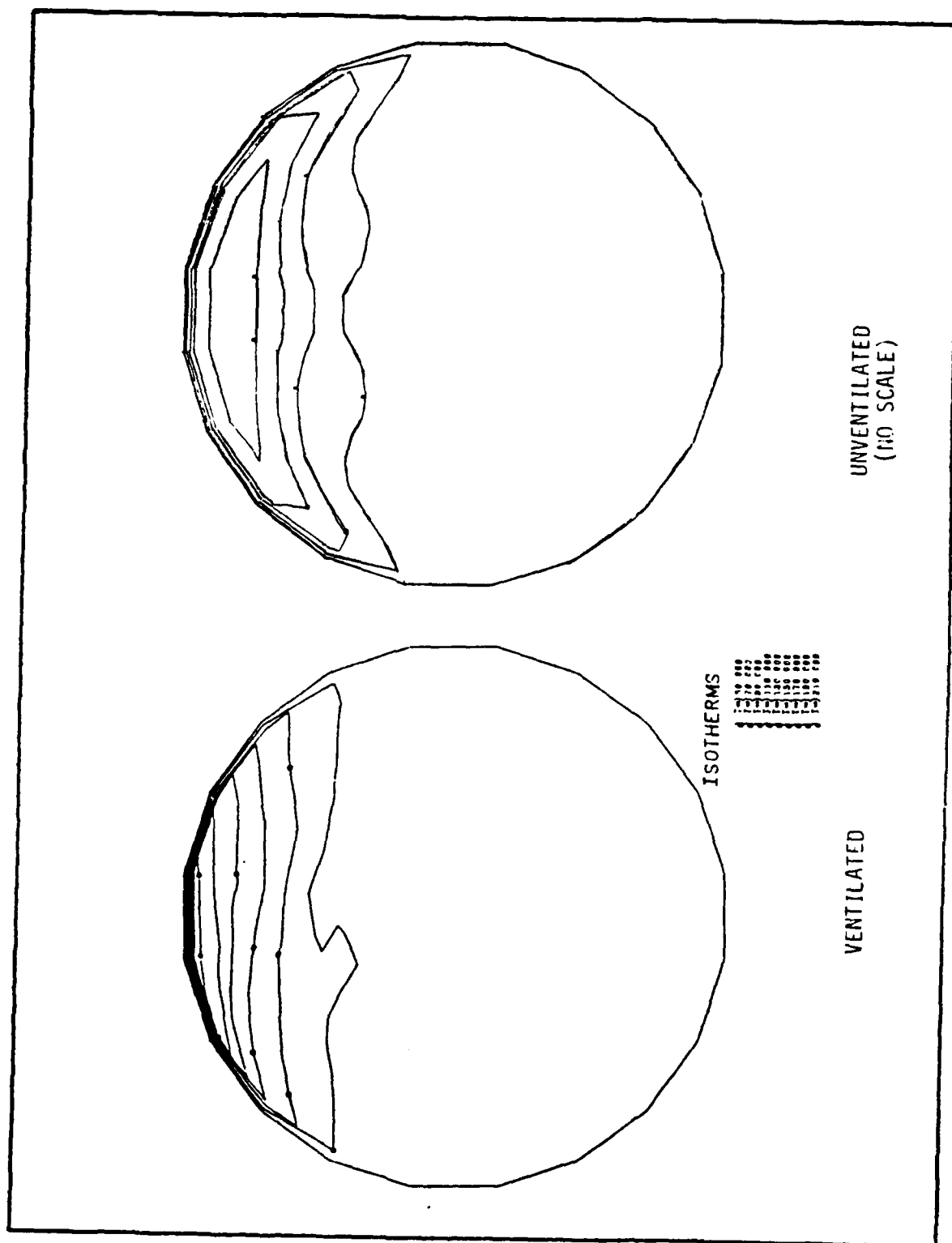


Figure 4-16. Section View at Base of End Cap of
Isotherms at 60 Seconds

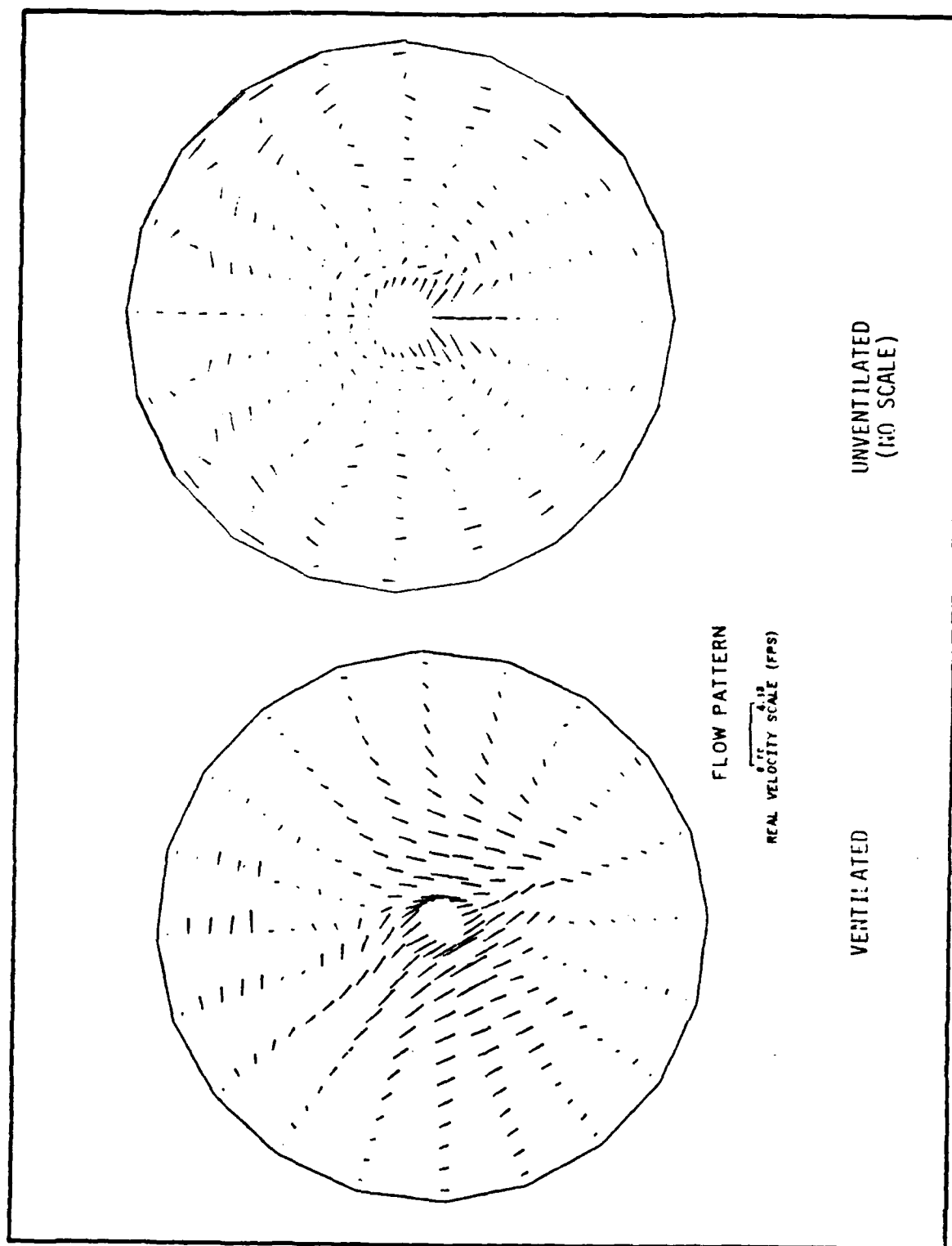


Figure 4-17. Section View at Base of End Cap of
Velocity Field at 60 Seconds

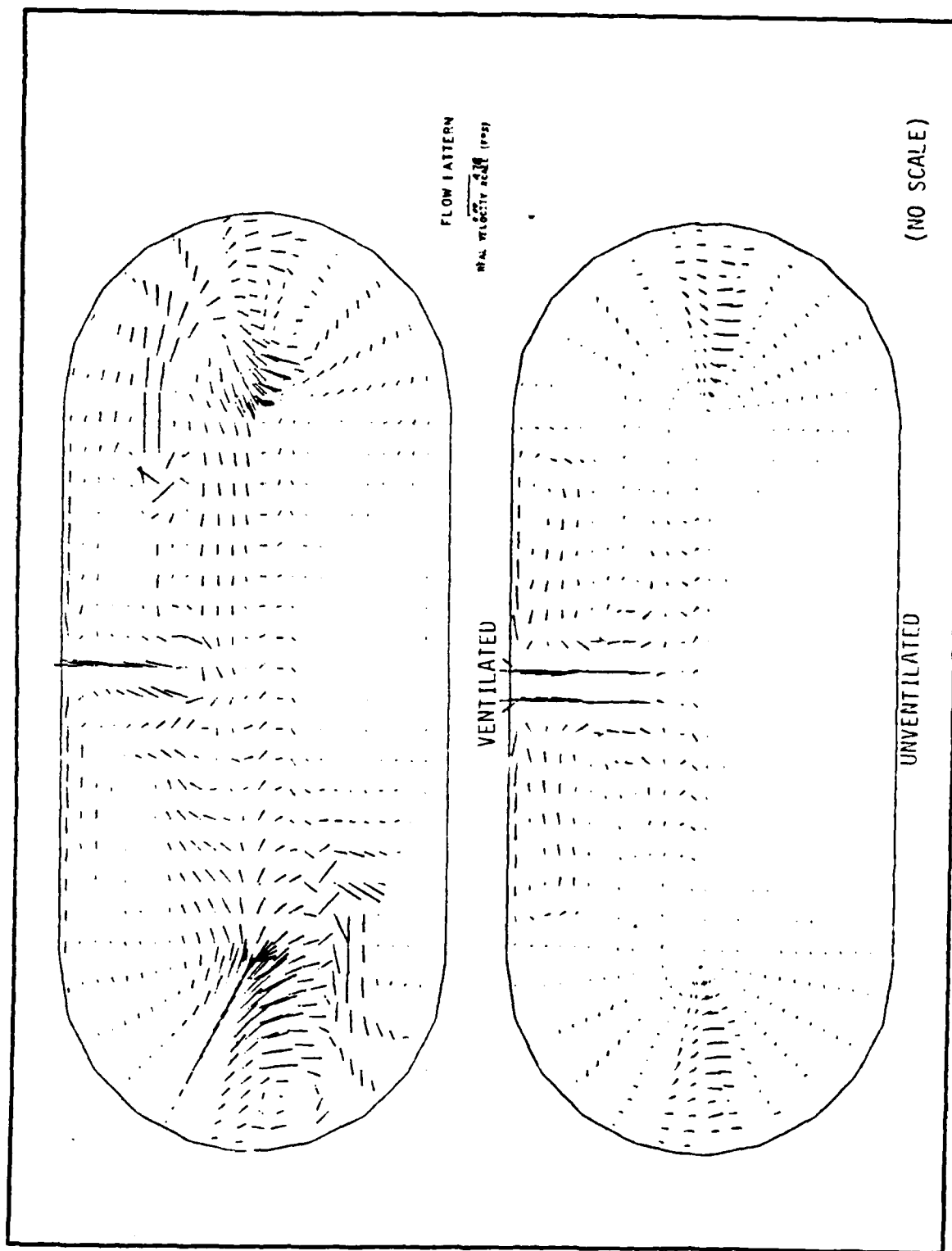


Figure 4-19. Mid-Section Front Views of
Velocity Field at 90 Seconds

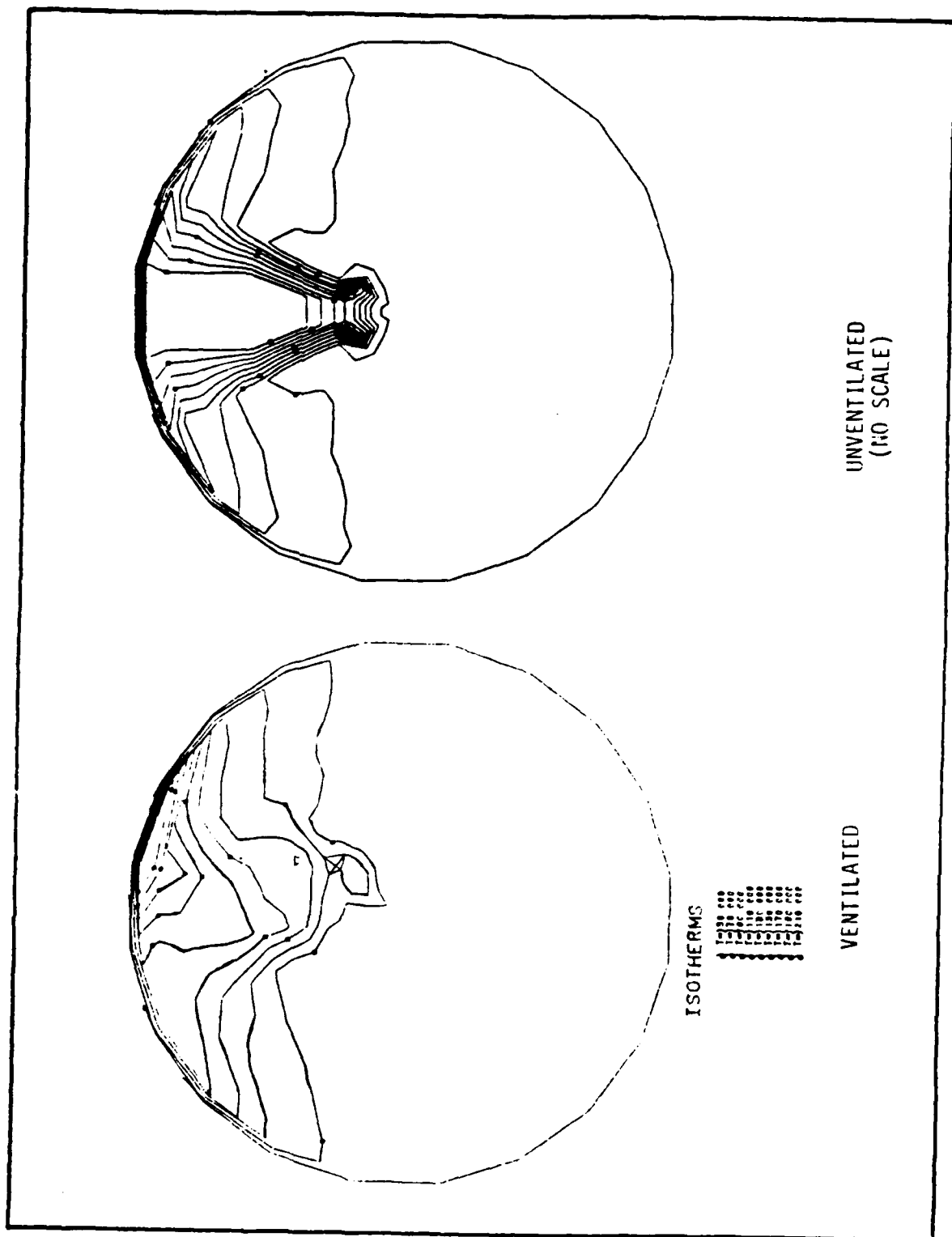


Figure 4-20. Mid-Section End Views of Isotherms at 90 Seconds

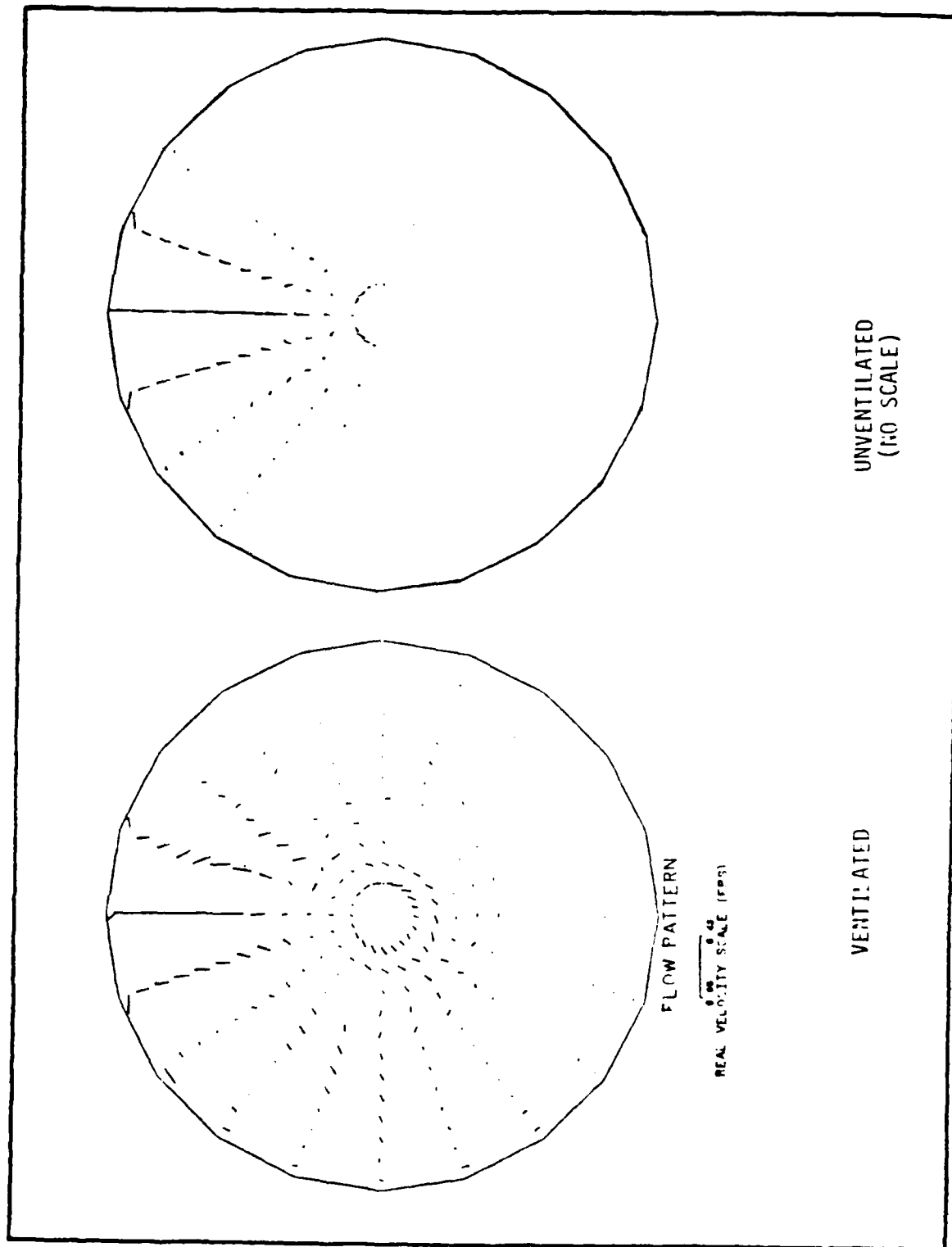


Figure 4-21. Mid-Section End Views of
Velocity Field at 90 Seconds

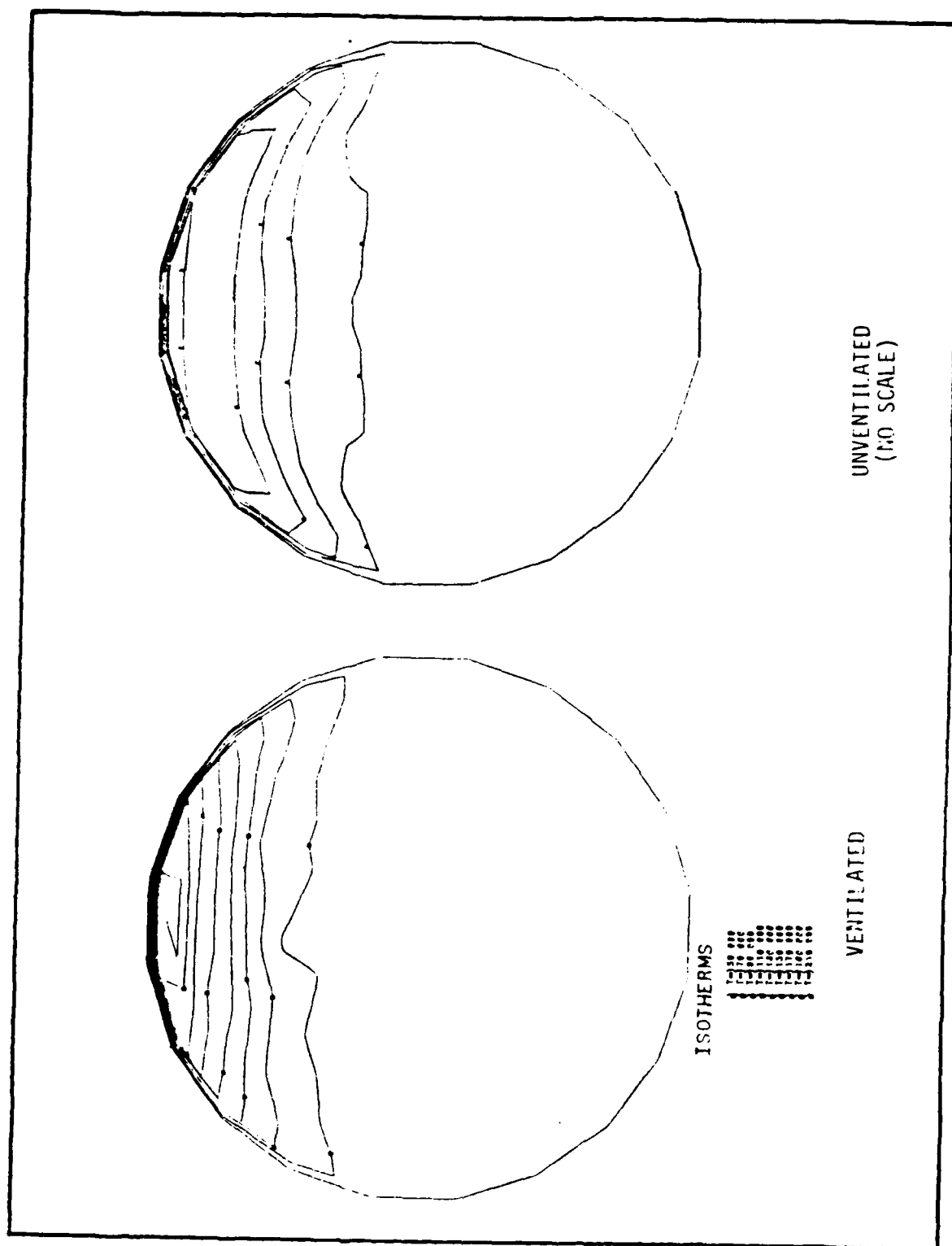


Figure 4-22. Section View at Base of End Cap of Isotherms at 90 Seconds

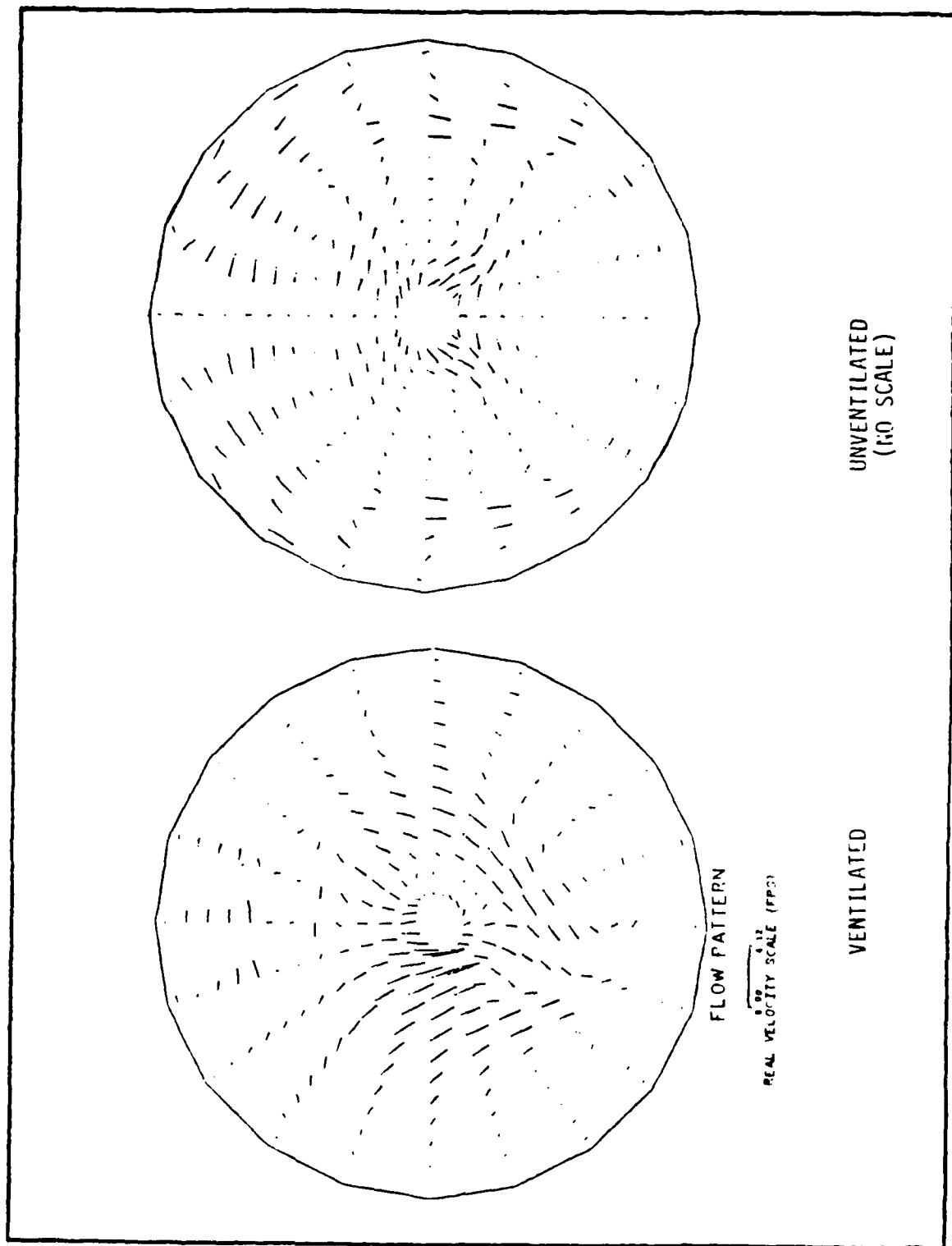


Figure 4-23. Section View at Base of End Cap of Velocity Field at 90 Seconds

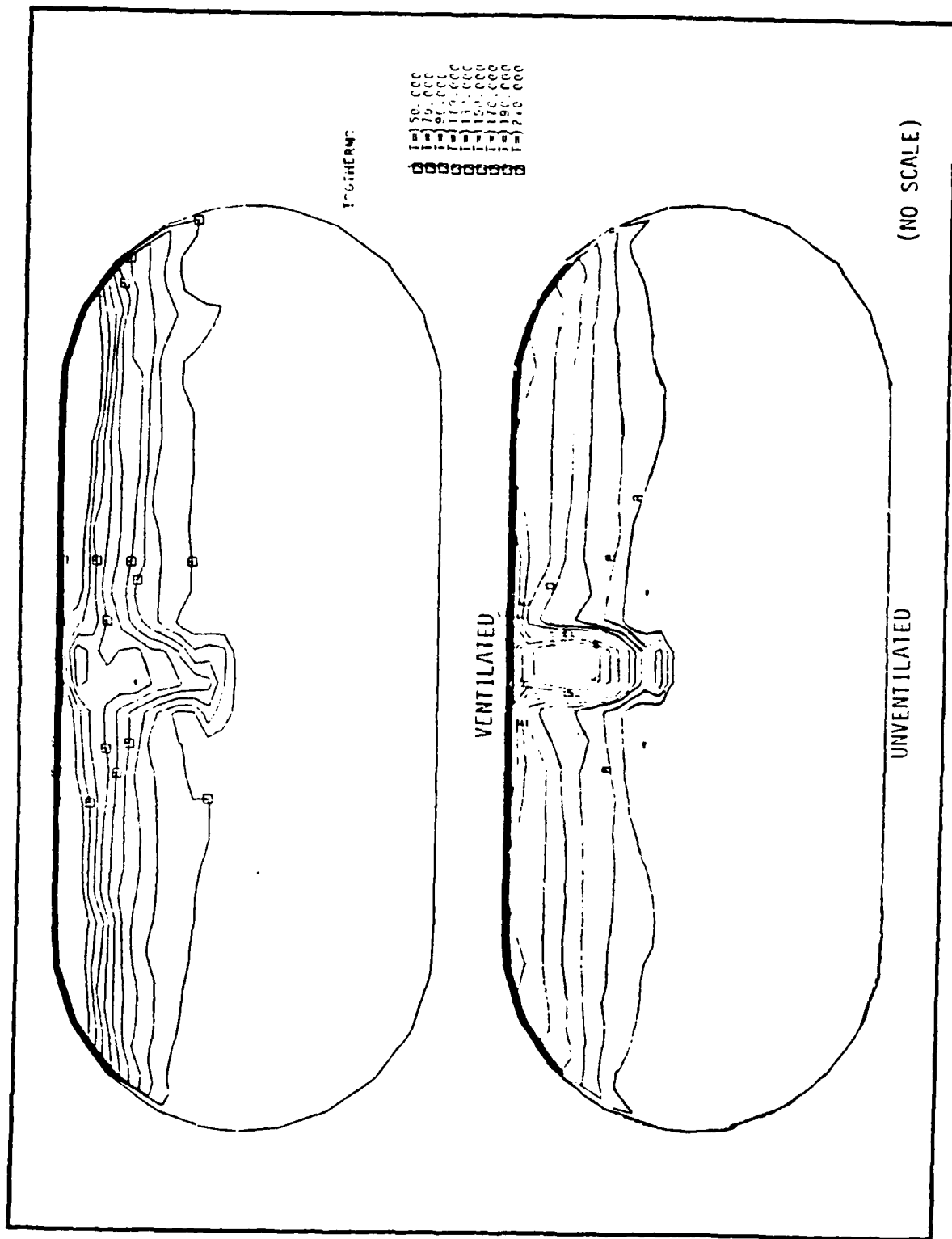


Figure 4-24. Mid-Section Front Views of Isotherms at 120 Seconds

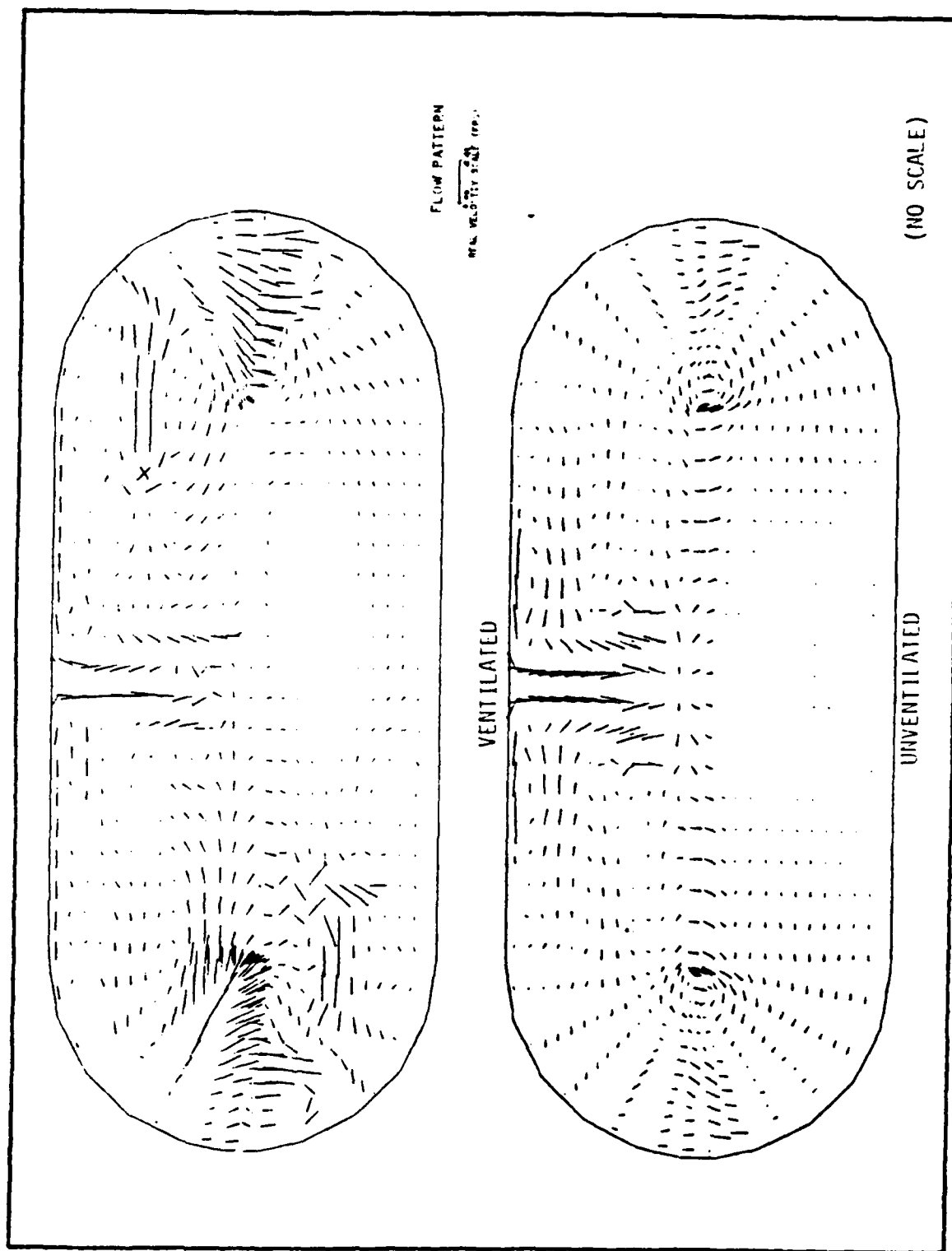


Figure 4-25. Mid-Section Front Views of
Velocity Field at 120 Seconds

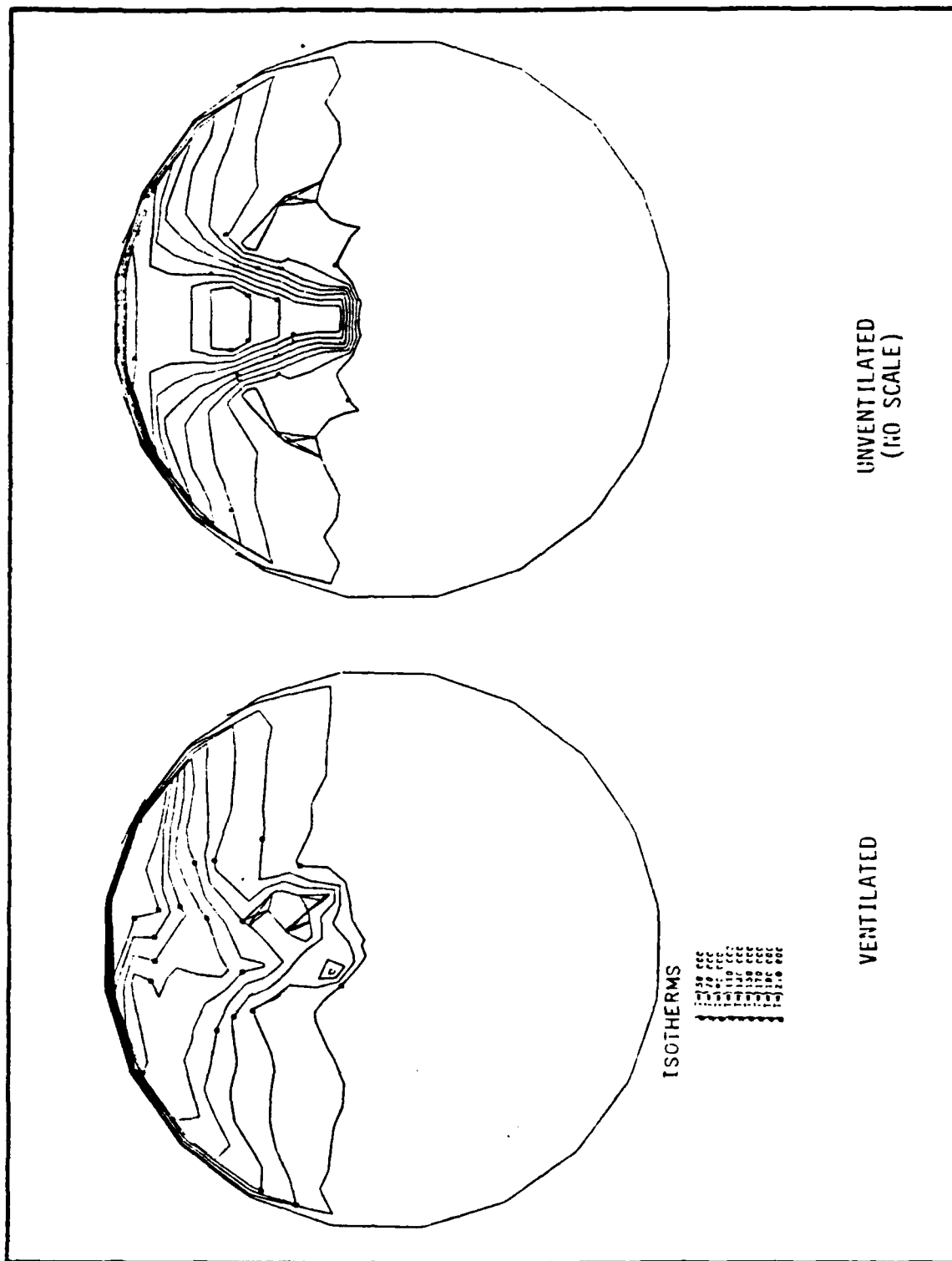


Figure 4-26. Mid-Section End Views of Isotherms at 120 Seconds

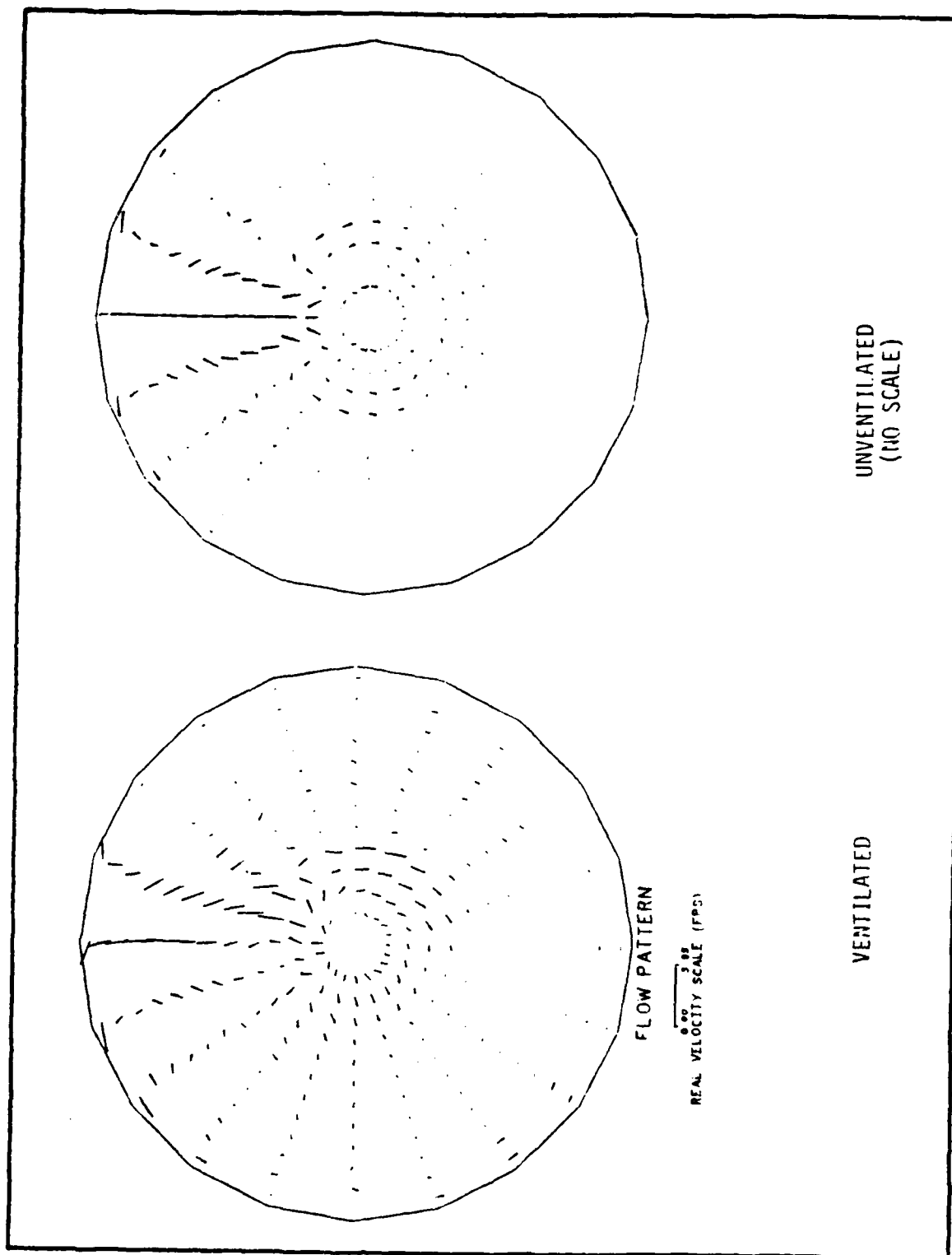


Figure 4-27. Mid-Section End Views of
Velocity Field at 120 Seconds

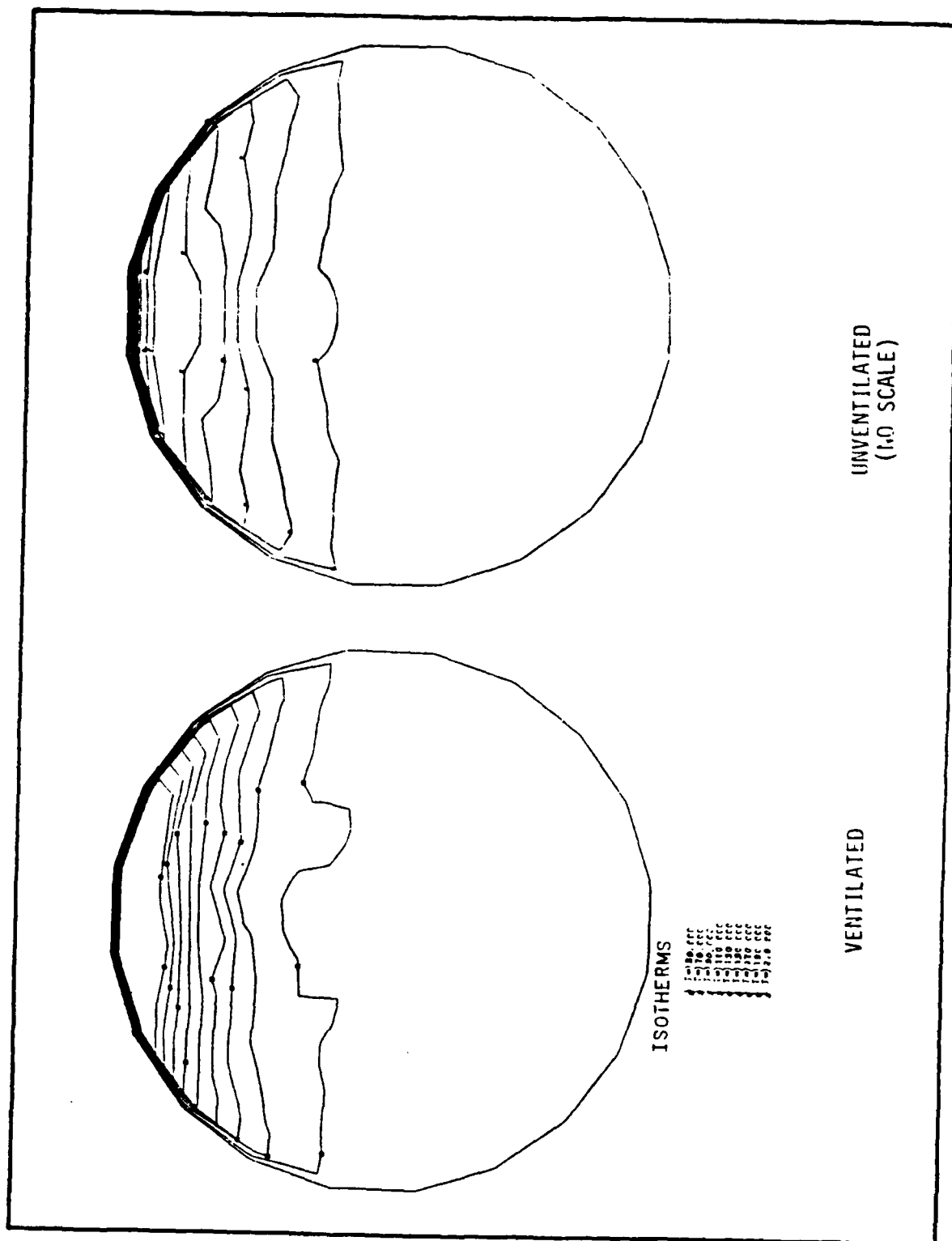


Figure 4-28. Section View at Base of End Cap of Isotherms at 120 Seconds

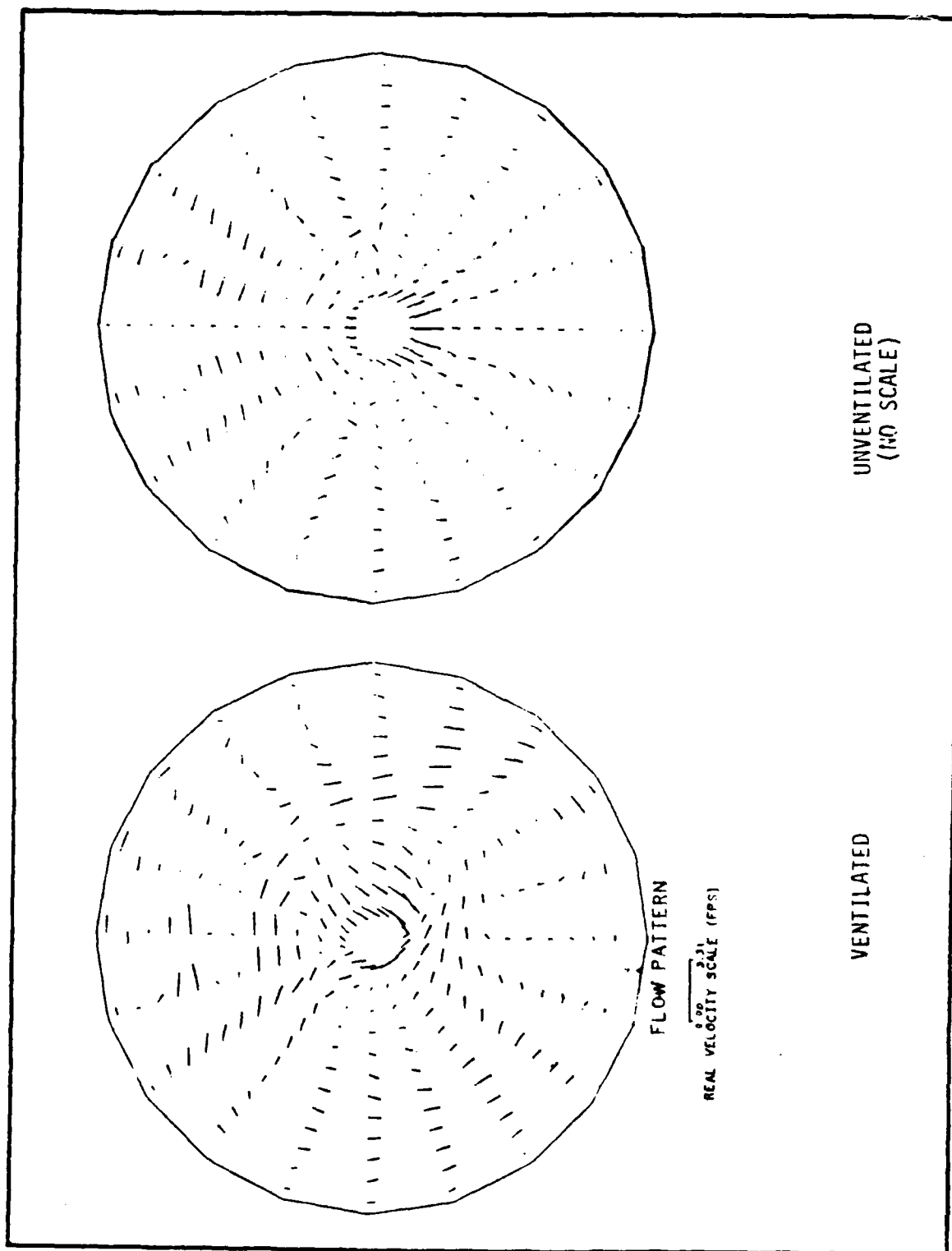


Figure 4-29. Section View at Base of End Cap of Velocity Field at 120 Seconds

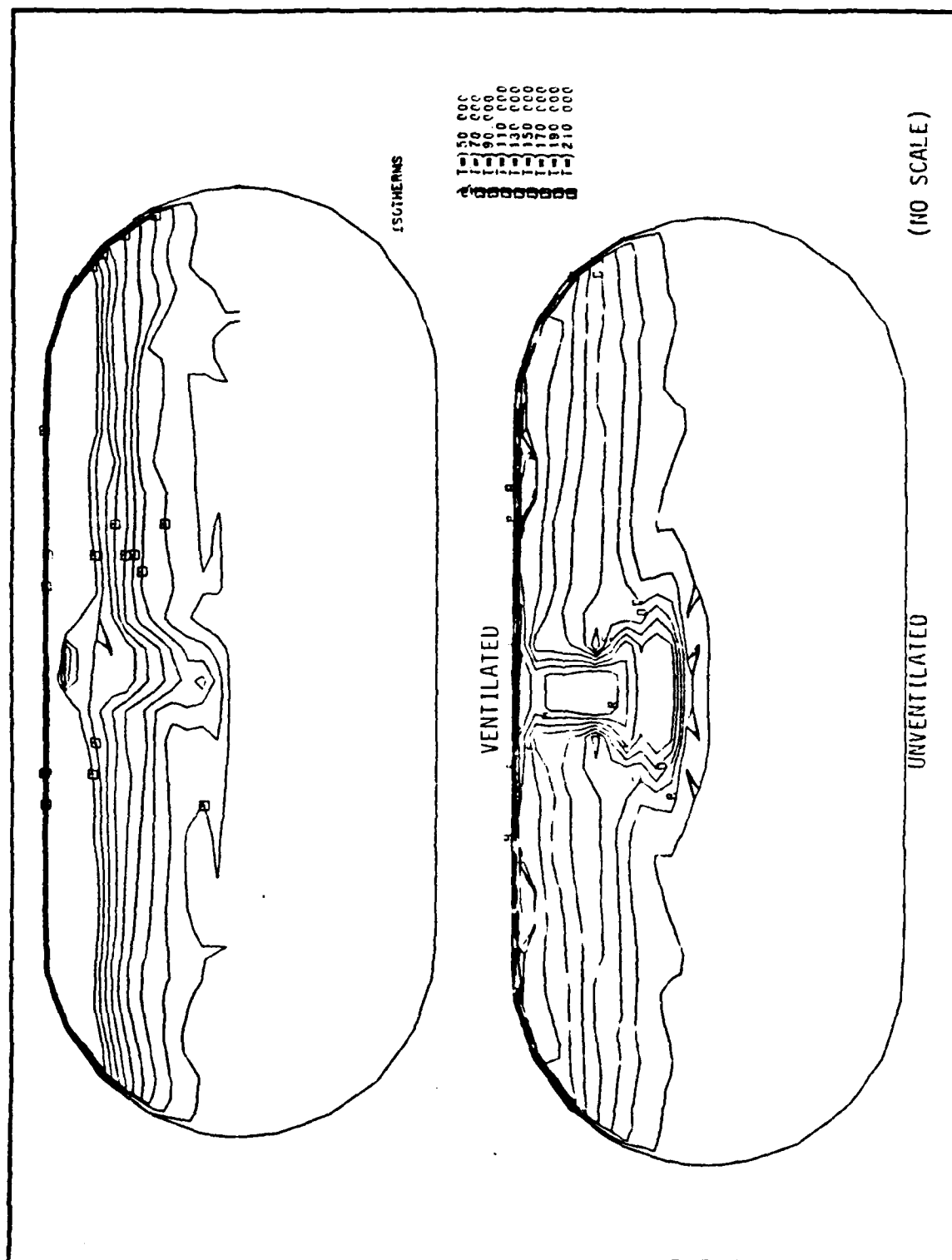


Figure 4-30. Mid-Section Front Views of Isotherms at 150 Seconds

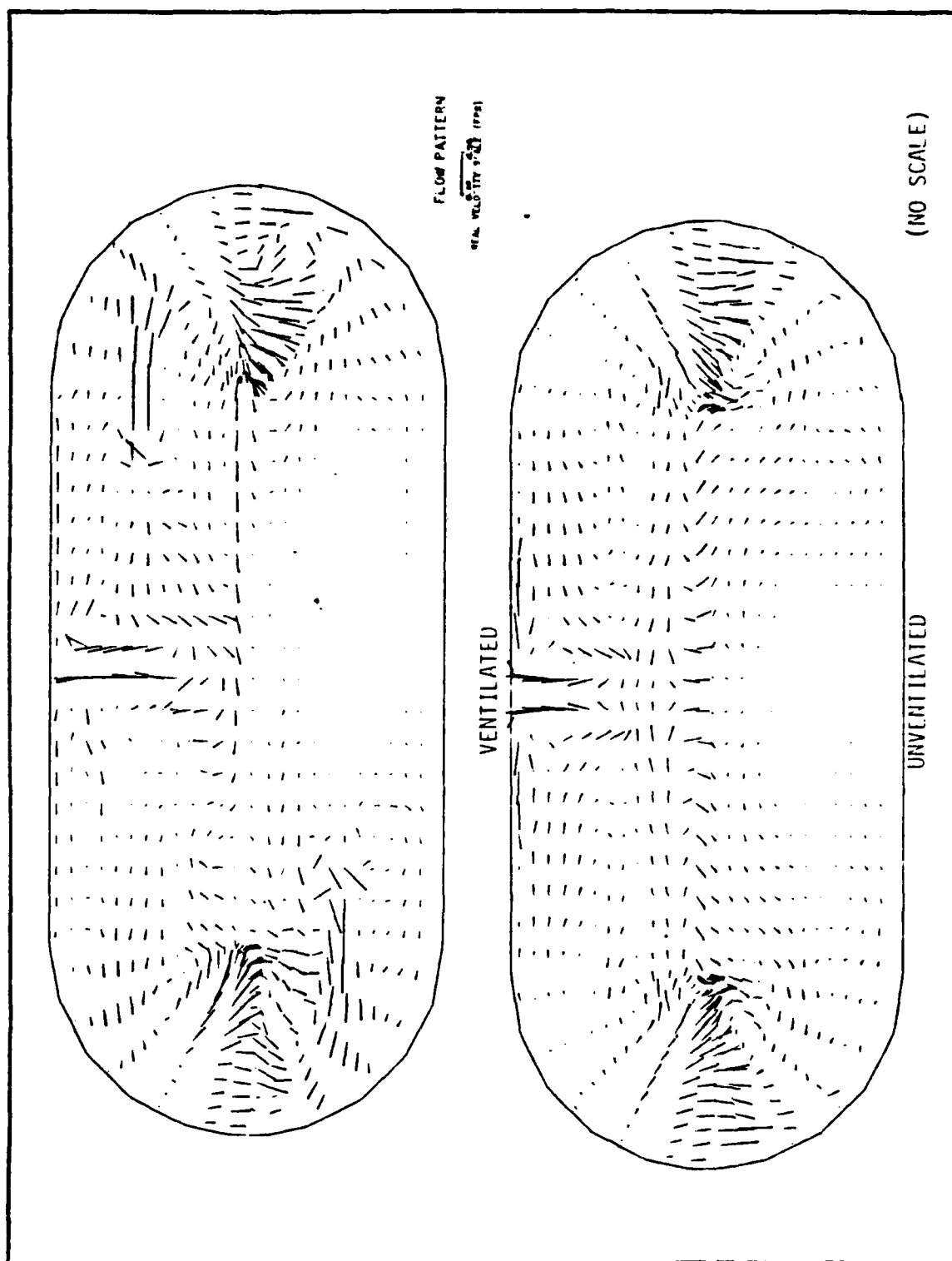


Figure 4-31. Mid-Section Front Views of
Velocity Field at 150 Seconds

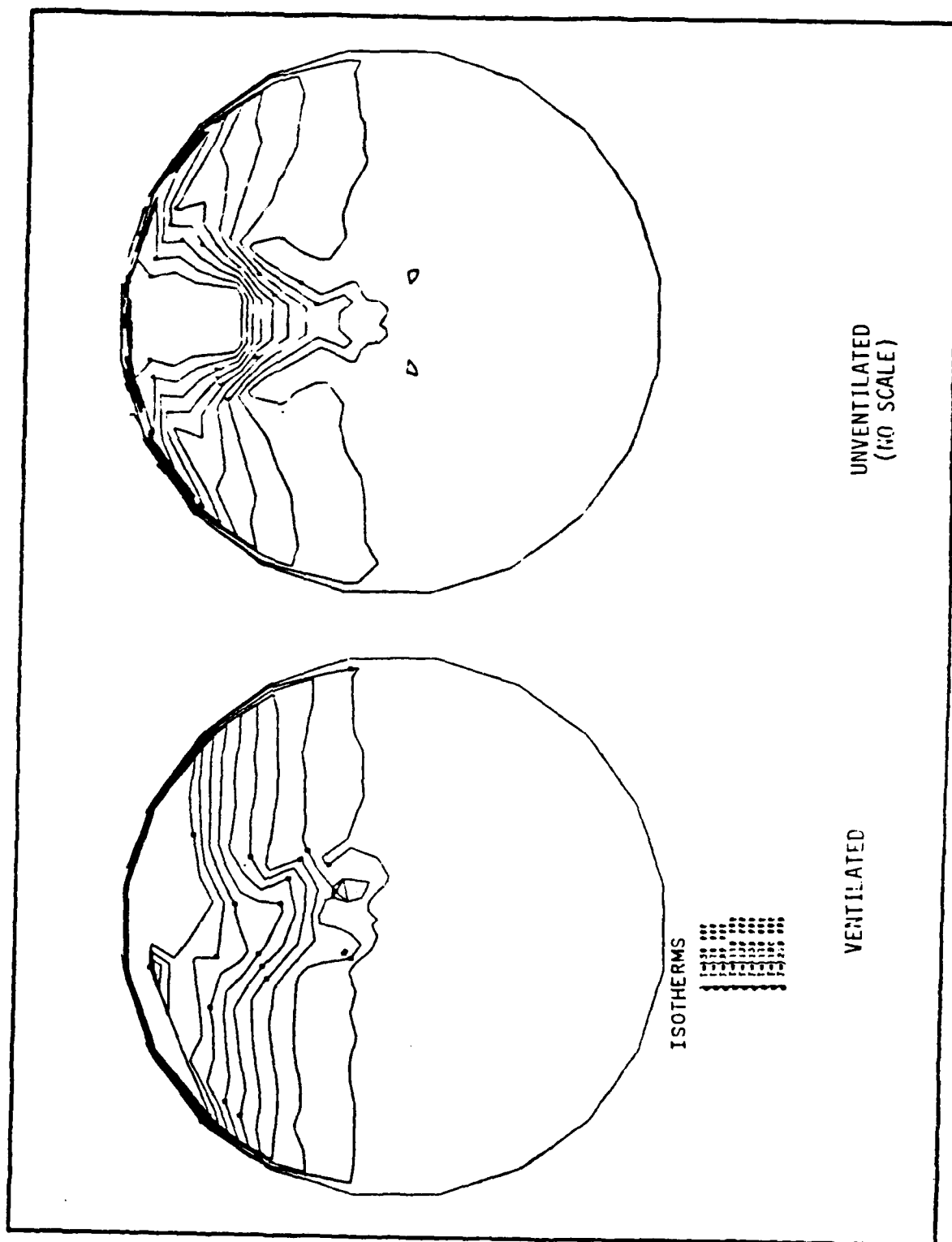


Figure 4-32. Mid-Section End Views of Isotherms at 150 Seconds

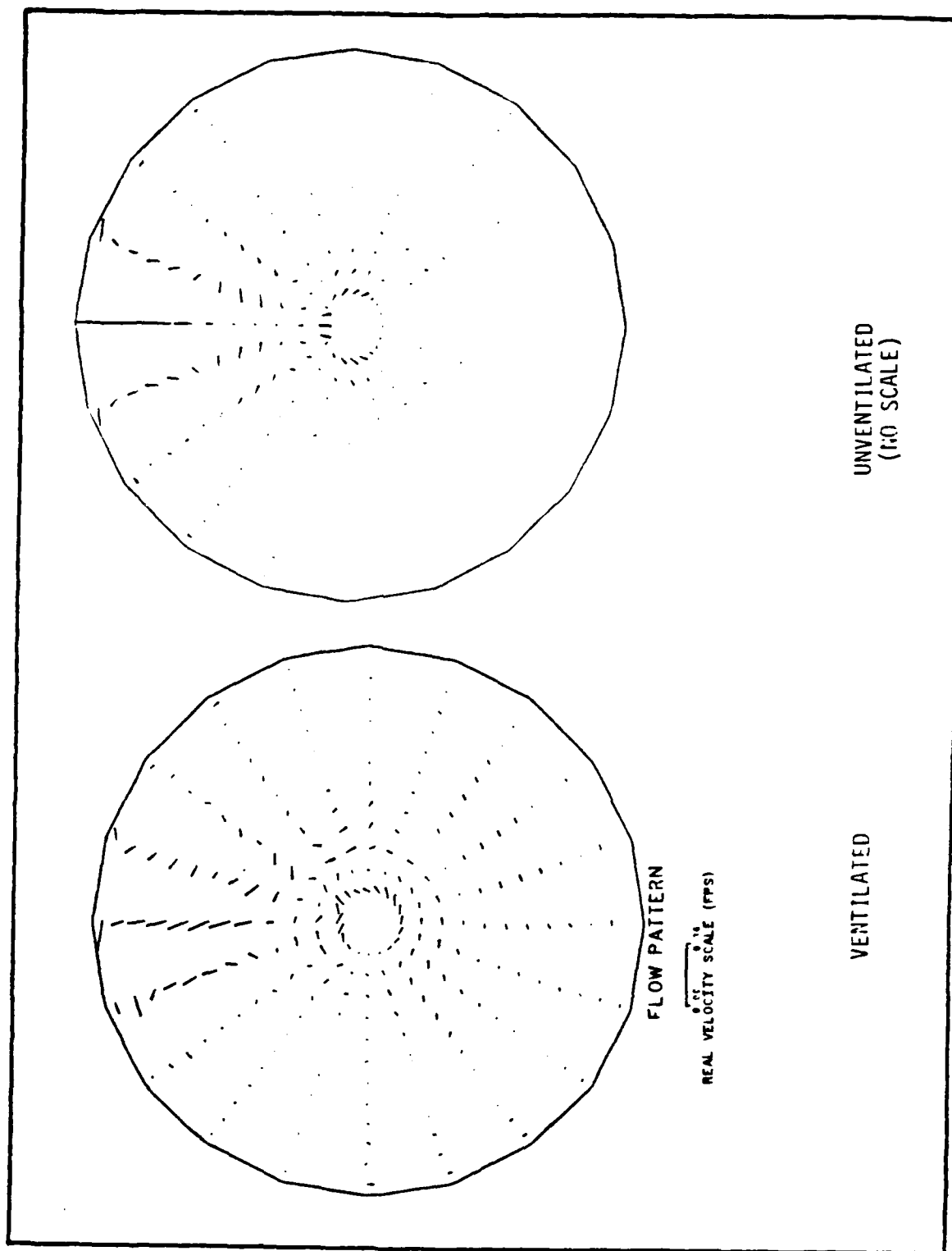


Figure 4-33. Mid-Section End Views of
Velocity Field at 150 Seconds

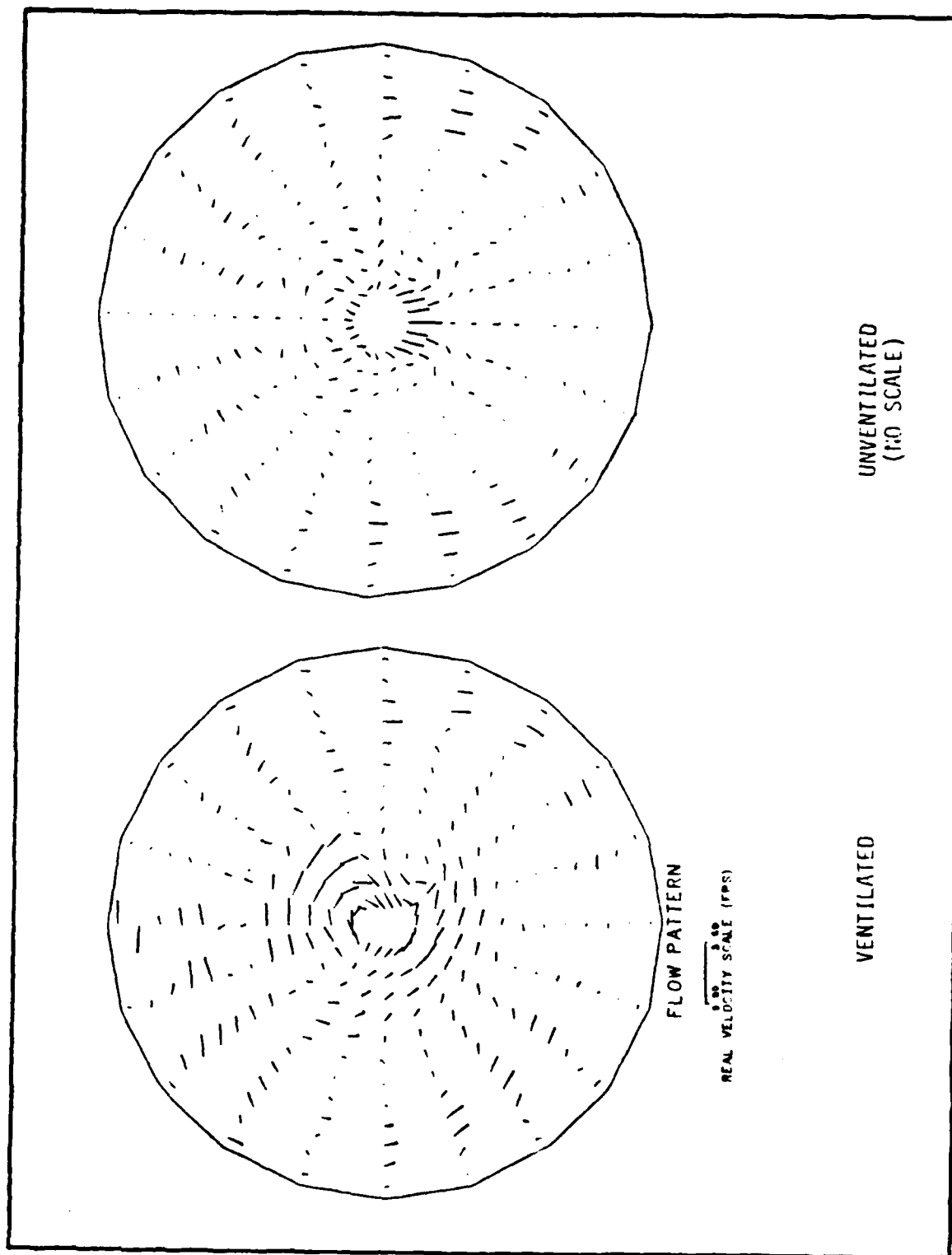


Figure 4-35. Section View at Base of End Cap of Velocity Field at 150 Seconds

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,

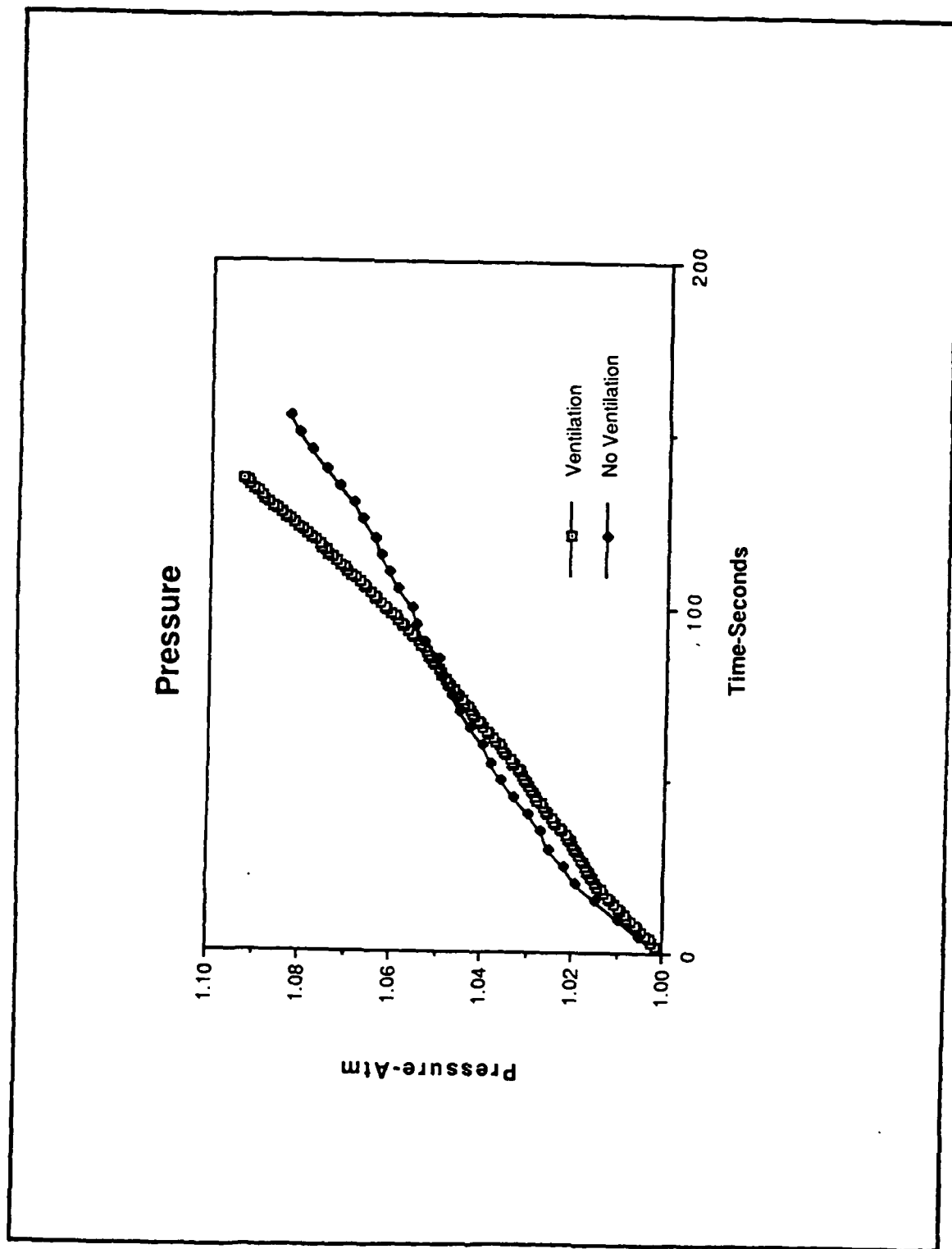


Figure 4-36. Pressure Curves for the Ventilated and Nonventilated Cases

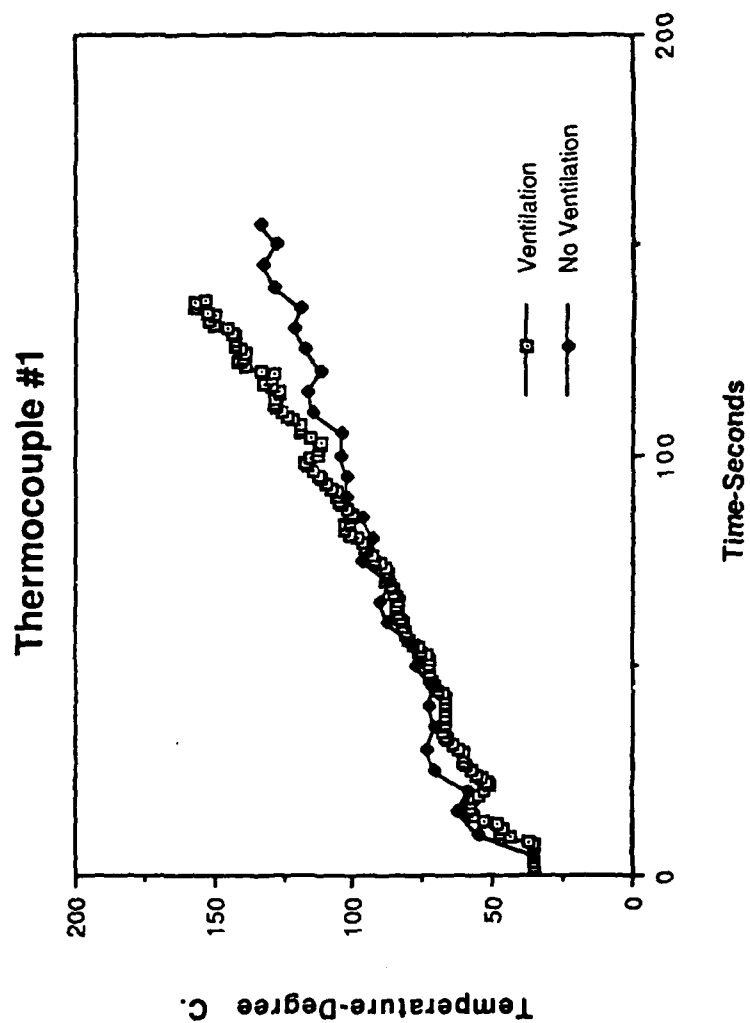


Figure 4-37. Thermocouple #1 Curves for the
Ventilated and Nonventilated Cases

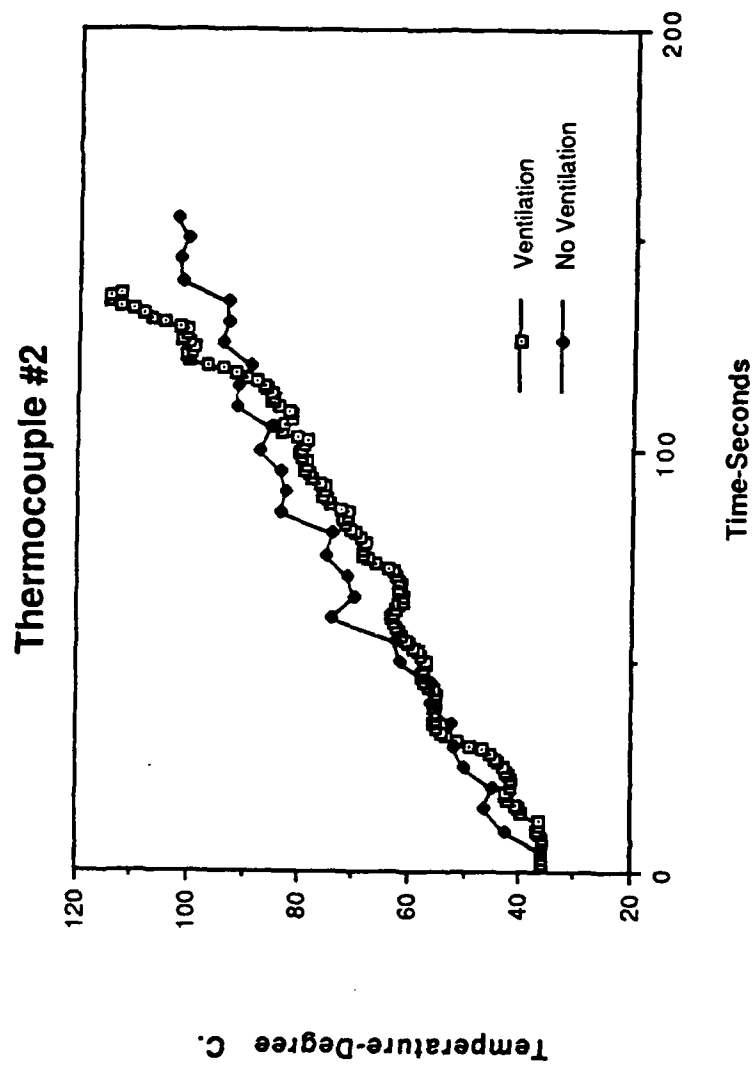


Figure 4-38. Thermocouple #2 Curves for the
Ventilated and Nonventilated Cases

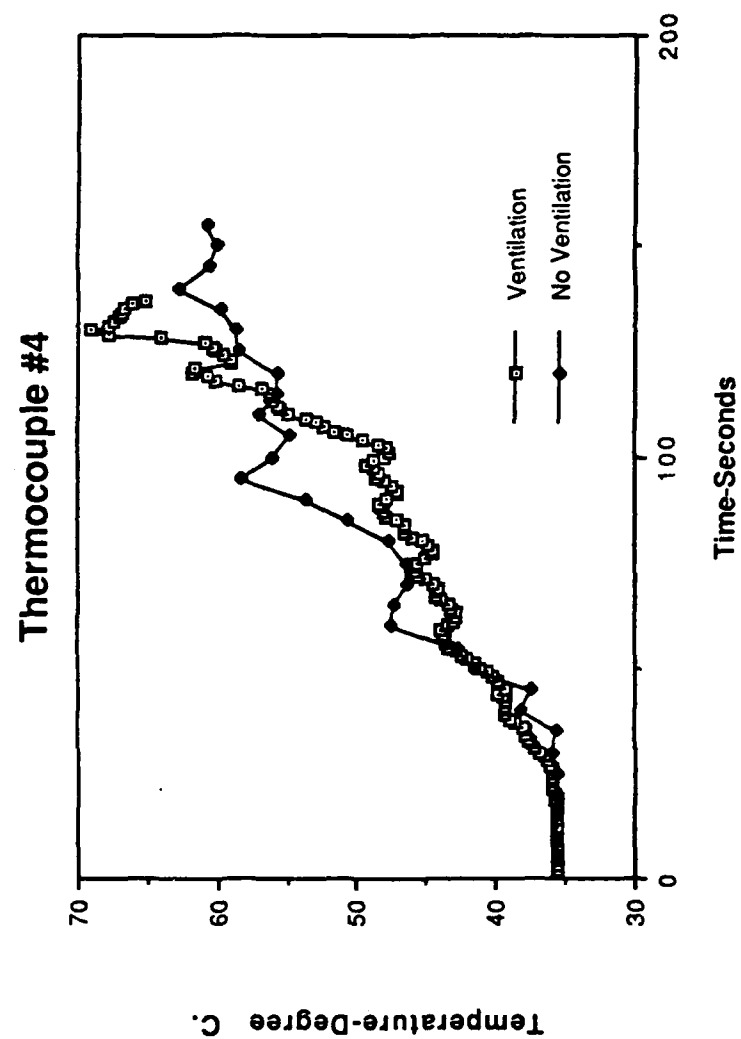


Figure 4-39. Thermocouple #4 Curves for the Ventilated and Nonventilated Cases

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

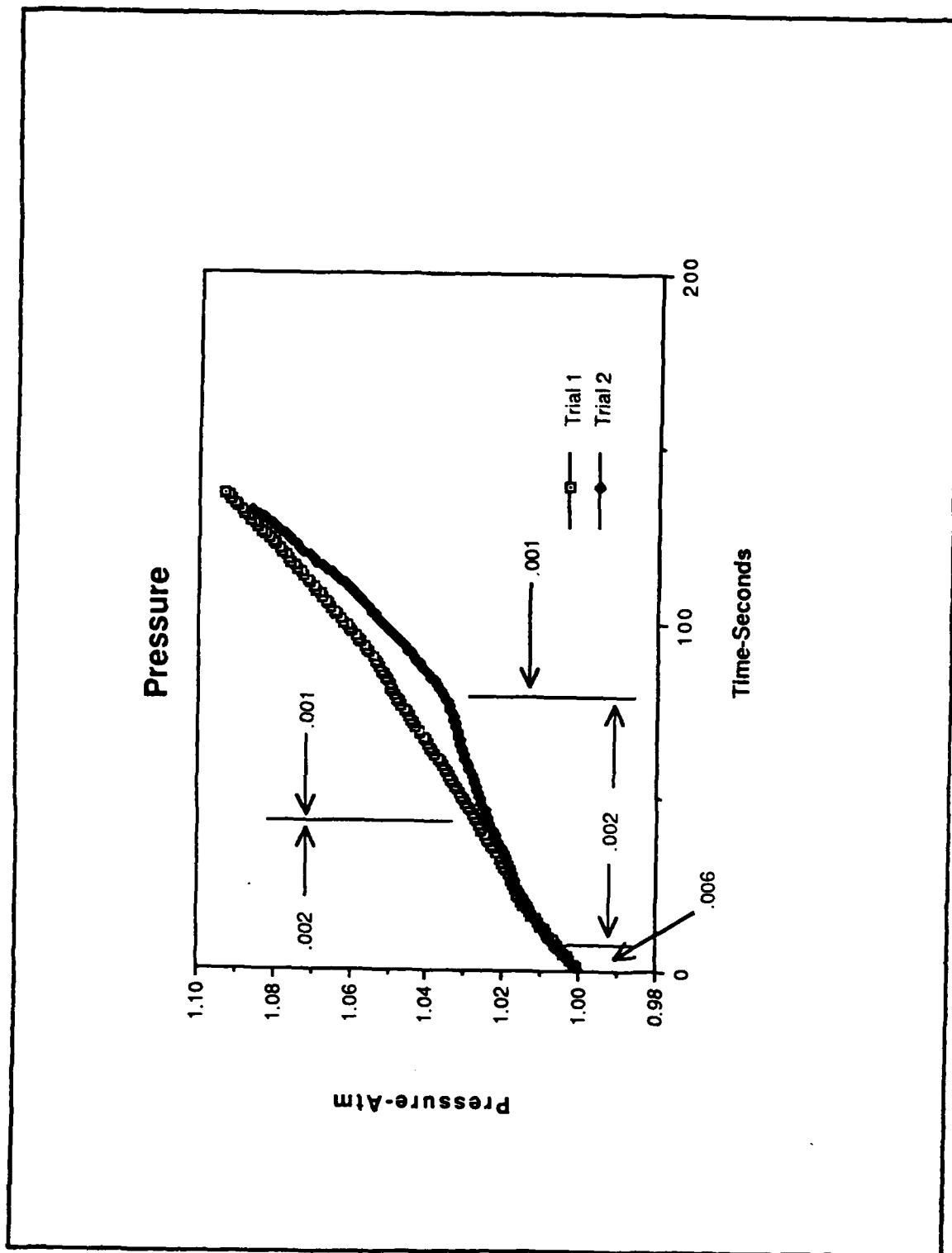


Figure 4-40. Pressure Curves for Trials 1 and 2

Thermocouple #1

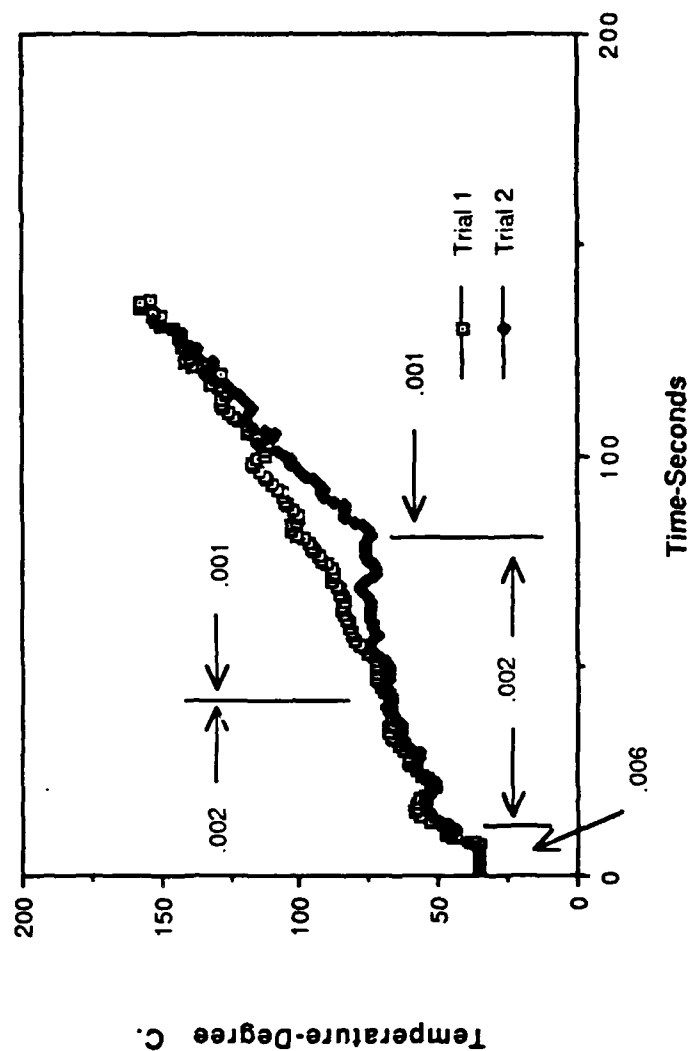


Figure 4-41. Thermocouple #1 Curve for Trials 1 and 2

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),
& DXXC(93),DYXC(93),DZXC(93),DXXS(93),DYXS(93),DZXS(93) 00001700
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR 00001800
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00001900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NEP1,NBM1,KRUN,NCHIP,NJRA,NWRP 00002000
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SCRSUM,ITER 00002100
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200002300
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00002400
& CPG,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00002500
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),DW(22,16,32) 00003800
COMMON/BL36/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
& SP(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),RMALL(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,CONSRA,PCURM1,PSOUTH,QCORR,PERROR 00004500
DIMENSION VFMXC(579,579),T4MALL(579) 00004600
DATA N,ITLEFT,SORMAX,XTIME,ITMAX/20,400000,0.40,0.0,4/ 00004700
00004800
00004900
00005000
00005100

```

122

998 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
	00011900
NT=0	00012000
NTIM=0	00012100
	00012200
300 CONTINUE	00012300
	00012400
NT=NT+1	00012500
	00012600
C *** NTMAX0 HAS THE MEANING AS "NTREAL" WHEN IT IS READ FROM	00012700
C DISK OR TAPE.	00012800
	00012900
IF(XTIME .GT. TMAX) GO TO 303	00013000
NTREAL=NT+NTMAX0	00013100
TIME=TIME+DTIME	00013200
XTIME=TIME*H/U0	00013300
	00013400
	00013500
C#####	00013600
C CALCULATE THE TRANSIENT HEAT INPUT	00013700
C NOTE IF 1 IN PARENTHESIS, 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 UPDI(I,J,K) AND VPD(I,J,K) FOR THE USE OF CALVIS AND SU(I,J,K)	00015100
	00015200
DO 48 K=1,NKP1	00015300
DO 48 J=1,NJP1	00015400
DO 48 I=1,NIP1	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
UPDI(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 GLOBE 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 DENSITY *	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 (INCHIP.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
%%	00022700
C CALCULATE THE VELOCITY U,V,AND W	00022800
%%	00022900
CALL CALU	00023000
CC CALL STRESS	00023100
C *** *****	00023200
CALL CALV	00023300
CC CALL STRESS	00023400
C *** *****	00023500
CALL CALW	00023600
CC CALL STRESS	00023700
C *** *****	00023800
	00023900
	00024000
%%	00024100
C CALCULATE THE PRESSURE AND STRESS	00024200
%%	00024300
CALL CALP	00024400
CALL STRESS	00024500
	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
IF(RESORM(ITER) .LE. SORMAX) GO TO 49	00025400
IF(ITER .EQ. 1) GO TO 302	00025500
ITERM1=ITER-1	00025600
IF(RESORM(ITER) .LE. RESORM(ITERM1)) GO TO 302	00025700
GO TO 304	00025800
302 IF(ITERM1.GE. 2) GO TO 37	00025900
SOURCE=RESORM(ITER)	00026000
GO TO 39	00026100
37 IF(RESORM(ITER) .LE. SOURCE) GO TO 38	00026200
GO TO 304	00026300
38 SOURCE=RESORM(ITER)	00026400
39 CONTINUE	00026500
WRITE(6,95) ITER,RESORM(ITER),SORMAX	00026600
95 FORMAT(53X,'ITER=',I2,2X,'SOURCE=',F9.6,2X,'SORMAX=',F9.6)	00026700
DO 23 K=1,NKP1	00026800
DO 23 J=1,NJP1	00026900
DO 23 I=1,NIP1	00027000
TPD(I,J,K)=T(I,J,K)	00027100

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(JTERM .EQ. 2) GO TO 35	00028100
IF(ITER .EQ. 4) GO TO 29	00028200
35 CONTINUE	00028300
IF(JTERM .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(JTERM .EQ. 1) GO TO 41	00029200
IF(JTERM .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	00032300
*****	00032400
C GO TO THE PRESSURE TRACKING SUBROUTINE ,PRINT OUT *	00032500
	00032600

522 CONTINUE	00038200
	00038300
	00038400
C *** *****	00038500
C CALL TLEFT(IT)	00038600
C IF(IT.LT.ITLEFT) GO TO 166	00038700
C *** *****	00038800
C TIMREM IS USED TO CALCULATE THE CPU TIME REMAINING AT NPS	00038900
	00039000
IF (TIMREM(0.).LE.80.) GOTO 166	00039100
	00039200
GO TO 300	00039300
303 CONTINUE	00039400
277 CONTINUE	00039500
	00039600
WRITE(6,1111)	00039700
1111 FORMAT(2X,'***** THE MAXIMUM TIME HAS BEEN REACHED *****',I8)	00039800
GO TO 172	00039900
	00040000
C *** *****	00040100
166 IF(INTREAL.NE. NTREAL/NTAPE*NTAPE) WRITE(9)	00040200
& TIME,NTREAL,T,R,U,V,W,P,CPM,COND,VIS,QRNET,ITERT,QCORRT,PM1,PM2,	00040300
& H,TA,UO,CONDO,VISO,RHOO,NI,NJ,NK,NIP1,NJP1,NKP1,NIM1,NJM1,NKM1,	00040400
& XC,YC,ZC,XS,YS,ZS,DXXC,DYYC,DZZC,DXXS,DYYS,DZZS	00040500
REWIND 9	00040600
C *** *****	00040700
	00040800
GOTO 172	00040900
2020 CONTINUE	00041000
WRITE (6,*) ' RESIDUAL MASS IS LARGER THAN 10.0, PROGRAM STOPS'	00041100
172 CCNTINUE	00041200
STOP	00041300
END	00041400
	00041500
	00041600
C	00041700
* *****	00041800
SUBROUTINE INPUT	00041900
* *****	00042000
* THIS SUBROUTINE SETS UP REQUIRED VALUES TO BEGIN THE PROGRAM.	*00042100
* VARIABLES ARE:	*00042200
* KRUN = WHEN EQUAL TO ONE,READ FROM THE	*00042300
* RESTART DISK, ELSE FROM THE JCL	*00042400
* NCHIP = NUMBER OF SOLID PIECES	*00042500
* NWRP = NUMBER OF TIME STEPS TO WRITE ON THE	*00042600
* PAPER	*00042700
* NTHCO = NUMBER OF THERMOCOUPLES TO PRINT OUT	*00042800
* TMAX = MAXIMUM TIME ALLOKED (REAL)	*00042900
* TWRITE = SECONDS IN REAL TIME TO PRINT THE	*00043000
* P,V,T FIELDS ON PAPER	*00043100
* TTAPE = TIME INTERVAL TO WRITE ON THE TAPE	*00043200
* DTIME = TIME STEP (DIMENSIONLESS)	*00043300
* HSZ = HEAT SOURCE SIZE, USED TO CALCULATE	*00043400
* THE VOLUME OF THE FIRE CELL	*00043500
* ICHPB = FIRST SOLID NODE IN THETA DIRECTION	*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
*          *****#00044400
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) #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,BUDY,00045200
&      CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0045300
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), #00045600
&      NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10) #00045700
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32) #00045800
&      ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32) #00045900
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) #00046000
&      ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) #00046100
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32) #00046200
&      ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32) #00046300
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), #00046400
&      SMP(22,16,32),SMPP(22,16,32),PPI(22,16,32), #00046500
&      DU(22,16,32),DV(22,16,32),DW(22,16,32) #00046600
COMMON/BL36/API(22,16,32),AE(22,16,32),AW(22,16,32),ANI(22,16,32), #00046700
&      AS(22,16,32),AF(22,16,32),AB(22,16,32), #00046800
&      SP(22,16,32),SUI(22,16,32),RI(22,16,32) #00046900
COMMON/BL37/ VISI(22,16,32),CONDI(22,16,32),MODI(22,16,32),RHALL(579)00047000
&      ,CPMI(22,16,32),HSZ(3,2),NHSHZ(22,16,32),RESORM(93) #00047100
COMMON/BL38/NTHCO,CXI(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), 00049800
  & NCHPK(N),TCHP(N),CPS(N),CONS(N),WFAN(N)            00049900
  WRITE (6,10) N,ICHPB(N),NCHPI(N),JCHPB(N),NCHPJ(N),KCHPB(N), 00050000
  & NCHPK(N),TCHP(N),CPS(N),WFAN(N),CONS(N)            00050100
10 FORMAT (2X,'N= ',I2,' ICHPB= ',I2,' NCHPI= ',I2,' JCHPB= ',I2, 00050200
  & ' NCHPJ= ',I2,' KCHPB= ',I2,' NCHPK= ',I2,' TCHP= ',F8.5, 00050300
  & ' CPS= ',F8.5,' /', ' WFAN = ',F12.5,' CONS= ',F12.5,/) 00050400
19 CONTINUE                                             00050500
16 CONTINUE                                             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 *** SUBROUTINE INIT ***                               00052500
SUBROUTINE INIT                                         00052600
C *** *** *** *** *** *** *** *** *** *** *** *** *** *** 00052700
*** THIS SUBROUTINE INITIALIZES THE FIELD AND CONSTANTS WITH RESPECT *** 00052800
* TO INITIAL START OR RESTARTING CAPABILITY.          *00052900
* VARIABLES ARE :                                     *00053000
*   TIME = DIMENSIONLESS TIME                        *00053100
*   UO = CHARACTERISTIC VELOCITY (1 FT/SEC)          *00053200
*   H = CHARACTERISTIC LENGTH (RADIUS(9.6FT))        *00053300
*   TR = TEMP IN DEGREES KELVIN                      *00053400
*   TA = TEMP IN DEGREES RANKINE                     *00053500
*   VISO = REFERENCE VISCOSITY (NONDIM)              *00053600
*   VISL = MINIMUM VISCOSITY (NONDIM)                *00053700
*   VISMAL = MAXIMUM VISCOSITY (NONDIM)              *00053800
*   HR = RADIUS IN CM                                *00053900
*   CONDO = REFERENCE CONDUCTIVITY                   *00054000
*   CO = INITIAL SMOKE CONCENTRATION                 *00054100
*   NJRA = POINT OF RADIATION IN J DIRECTION         *00054200
*   LOCATED ON THE INNER SOLID BOUNDARY              *00054300
*   HCONV = HEAT TRANSFER COEFFICIENT                *00054400
*   HCOEF = DIMENSIONLESS HEAT TRANSFER COEF        *00054500
*                                                     *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      *00055600
*      _PD         =      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
*
*      AP          =      COEFFICIENT AT NODAL POINT                *00056700
*      AE,AW,AN    =      COEFFICIENTS AT PTS EAST,WEST,NORTH,      *00056800
*      AS,AF,AB    =      SOUTH, FRONT, AND BACK                    *00056900
*      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
*
*      NOD         =      NO HEAT SOURCE LOCATED AT THE NODE        *00057700
*
*      NOD         =      IF EQUAL TO ZERO, LIQUID                   *00057800
*
*      NOD         =      IF EQUAL TO ONE, SOLID                      *00057900
*
*      _B,_E       =      BEGINNING AND ENDING NODAL POINT FOR      *00058000
*
*      _B,_E       =      THE SOLID IN I,J,K                         *00059100
*
*      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
*
*      XC,YC,ZC    =      A CENTER CELL                             *00058500
*
*      DXXC,DYYC   =      LENGTH AROUND THE CENTER CELL            *00058600
*
*      DZZC        =      LENGTH AROUND THE CENTER CELL            *00058700
*
*      XS,YS,ZS    =      THETA,R,PHI LOCATION OF NODAL POINT OF    *00058800
*
*      XS,YS,ZS    =      A STAGGERED CELL                          *00058900
*
*      DXXS,DYYS   =      LENGTH AROUND THE STAGGERED CELL          *00059000
*
*      DZZS        =      LENGTH AROUND THE STAGGERED CELL          *00059100
*
*      CX,CY,CZ    =      LOCATION OF THERMOCOUPLE IN THETA,R,PHI *00059200
*
*****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 00059500
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1 00059600
&      ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NMRP 00059700
COMMON/BL12/ NWRITE,NTAPE,NTMAXO,NTREAL,TIME,SORSUM,ITER 00059800
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200060000
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/ICHPI(10),NCHPI(10),JCHPI(10),NCHPJ(10),KCHPI(10), 00060500
& NCHPK(10),TCHPI(10),CPS(10),CONS(10),WFAN(10) 00060600
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32) 00060700
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(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/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32) 00061100
& ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),MPD(22,16,32) 00061200
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00061300
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32), 00061400
& 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), 00061600
& 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),RMALL(579) 00061900
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESOR(193) 00062000
COMMON/BL38/NTHCO,CX(12),CY(12),CZ(12),NTH(12,3),TCOUP(12) 00062100
COMMON/BL39/ALEW,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR 00062200
DATA GRAY/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
VISM=400.*VISL 00063200
HR=H*30.48 00063300
CONDO=VISO/PRT 00063400
PI=4.*ATAN(1.) 00063500
ALEN = 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
CC = 0.0 00064200
00064300
00064400
CONST1=RH00*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
BUOY=GRAV*H/(U0*U0) 00065100
UGRT=U0*U0/(GC*RAIR*TA) 00065200
TCOOL=1.0 00065300
CONSRA=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, 'DTIME = ',E12.6,	00066100
& /,5X, 'HCONV = ',E12.6,/)	00066200
	00066300
NWRITE=TWRITE*UO/DTIME/H	00066400
NTAPE=TTAPE*UO/DTIME/H	00066500
C *** PRINT OUT INPUT INFORMATION	00066600
	00066700
WRITE(6,61) (STAR,I=1,90),KRUN,TMAX,TWRITE,TTAPE,NWRP	00066800
61 FORMAT(///,90A1,/,5X,'KRUN = ',I2,/,5X,	00066900
& 'TMAX = ',F8.3,' SECONDS',/5X,'TWRITE = ',F8.3,	00067000
& 'SECONDO',/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
XPD(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
DX(I,J,K)=0.	00069600
SUI(I,J,K)=0.	00069700
SPI(I,J,K)=0.	00069800
PP(I,J,K)=0.	00069900
AP(I,J,K)=0.	00070000
AW(I,J,K)=0.	00070100
AE(I,J,K)=0.	00070200
AN(I,J,K)=0.	00070300
AS(I,J,K)=0.	00070400
AF(I,J,K)=0.	00070500
AB(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)=1.0E0	00071100

TOD(I,J,K)=1.0E0	00071200
T(I,J,K)=TOD(I,J,K)	00071300
TPD(I,J,K)=TOD(I,J,K)	00071400
COD(I,J,K)=CO	00071500
C(I,J,K)=COD(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
C *** DEFINE THERMAL PROPERTIES OF DECK AND SOLID	00074400
	00074500
IF (NCHIP.EQ.0) GOTO 410	00074600
DO 402 N=1,NCHIP	00074700
IB=ICHPB(N)	00074800
IE=IB+NCHPI(N)-1	00074900
JB=JCHPB(N)	00075000
JE=JB+NCHPJ(N)-1	00075100
KB=KCHPB(N)	00075200
KE=KB+NCHPK(N)-1	00075300
DO 405 I=IB,IE-1	00075400
DO 405 J=JB,JE-1	00075500
DO 405 K=KB,KE-1	00075600
COND(I,J,K)=CONDO*CONS(N)	00075700
CPM(I,J,K)=CPO*CPS(N)	00075800
NOD(I,J,K)=1	00075900
405 CONTINUE	00076000
402 CONTINUE	00076100
410 CONTINUE	00076200
	00076300
	00076400
	00076500
C *** FOR CONTINUING RUN, READ DATA FROM TAPE OR DISK	00076600

IF(KRUN .EQ. 1) GO TO 9997	00076700
GO TO 15	00076800
9997 READ(8,END=9998)	00076900
& TIME,NTMAXO,TOD,ROD,UOD,VOD,WOD,POD,CPH,COND,VIS,QRNET,ITERT,QCOR	00077000
&RT,PM1,PM2,XX,XX,XX,XX,XX,XX,NI,NJ,NK,NIP1,NJP1,NKP1,NIM1,NJM1	00077100
& ,NKM1,XC,YC,ZC,XS,YS,ZS,DXXC,DYYC,DZZC,DXXS,DYYS,DZZS	00077200
GO TO 9997	00077300
9998 CONTINUE	00077400
REWIND 8	00077500
CLOSE (8)	00077600
WRITE(6,*)INTMAXO	00077700
15 CONTINUE	00077800
	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
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 *** *****
* THIS SUBROUTINE CALCULATES THE TURBULENT VISCOSITY AND UPDATES*
* THE VISCOSITY MATRIX
* *****

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,U0,H,UGRT,BUOY,
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO
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),
& SMPI(22,16,32),SMPP(22,16,32),PP(22,16,32),
& DUI(22,16,32),DVI(22,16,32),DWI(22,16,32)
COMMON/BL36/API(22,16,32),AE(22,16,32),AWI(22,16,32),ANI(22,16,32),
& ASI(22,16,32),AFI(22,16,32),ABI(22,16,32),
& SPI(22,16,32),SUI(22,16,32),RI(22,16,32)
COMMON/BL37/ VISI(22,16,32),CONDI(22,16,32),HODI(22,16,32),RWALL(579)
& ,CPMI(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(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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00082200
00082300
00082400
00082500
00082600
00082700
00082800
00082900
00083000
00083100
00083200
00083300
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00083600
00083700
00083800
00083900
00084000
00084100
00084200
00084300
00084400
00084500
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00084800
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00085700
00085800
00085900
00086000
00086100
00086200
00086300
00086400
00086500
00086600
00086700
00086800
00086900
00087000
00087100
00087200
00087300
00087400
00087500
00087600

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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
C CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00089400
DXP1=XL(I,JP1,J,K,0,0)	00089500
DXI =XL(I ,J,K,0,0)	00089600
DXM1=XL(IM1,J,K,0,0)	00089700
	00089800
DYP1=YL(I,JP1,K,0,0)	00089900
DYJ =YL(I,J ,K,0,0)	00090000
DYM1=YL(I,JM1,K,0,0)	00090100
	00090200
DZP1=ZL(I,J,KP1,0,0)	00090300
DZK =ZL(I,J,K ,0,0)	00090400
DZM1=ZL(I,J,KM1,0,0)	00090500
	00090600
CC IF (J.EQ.2) DYS=DYS/2.	00090700
CC IF (K.EQ.2) DZB=DZB/2.	00090800
IF (J.NE.NJ) GOTO 101	00090900
JP2=JP1	00091000
DYN=DYN/2.	00091100
101 IF (K.NE.NK) GOTO 102	00091200
KP2=KP1	00091300
DZF=DZF/2.	00091400
102 CONTINUE	00091500
	00091600
	00091700
	00091800
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00091900
DXE =XL(IP1,J,K,0,1)	00092000
DXM =XL(I ,J,K,0,1)	00092100
	00092200
DYN =YL(I,JP1,K,0,2)	00092300
DYS =YL(I,J ,K,0,2)	00092400
	00092500
DZF =ZL(I,J,KP1,0,3)	00092600
DZB =ZL(I,J,K ,0,3)	00092700
	00092800
	00092900
C *** CACULATE DV/DX,D2V/DX2,DU/DX,D2U/DX2,DW/DX AND D2W/DX2	00093000
	00093100

DUDX=(U(IP1,J,K)-U(I,J,K))/DXI	00093200
DUDXM=0.5*(U(IP1,J,K)-U(IM1,J,K))/DXM	00093300
DUDXE=0.5*(U(IP2,J,K)-U(I,J,K))/DXE	00093400
D2UDX2=(DUDXE-DUDXM)/DXI	00093500
	00093600
	00093700
	00093800
DVDXM=0.5*(V(I,JP1,K)+V(I,J,K)-V(IM1,JP1,K)-V(IM1,J,K))/DXM	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+DVDXM)	00094100
D2VDX2=(DVDXE-DVDXM)/DXI	00094200
	00094300
	00094400
DWDXM=0.5*(W(I,J,KP1)+W(I,J,K)-W(IM1,J,KP1)-W(IM1,J,K))/DXM	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+DWDXM)	00094700
D2WDX2=(DWDXE-DWDXM)/DXI	00094800
	00094900
	00095000
602 CONTINUE	00095100
C *** CALCULATE DU/DY,D2U/DY2,DV/DY,D2V/DY2,DW/DY AND D2W/DY2	00095200
	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
606 CONTINUE	00097300
C *** CALCULATE DU/DZ,D2U/DZ2,DV/DZ,D2V/DZ2,DW/DZ AND D2W/DZ2	00097400
	00097500
	00097600
	00097700
DWDZ=(W(I,J,KP1)-W(I,J,K))/DZK	00097800
DWDZF=0.5*(W(I,J,KP2)-W(I,J,K))/DZF	00097900
DWDZB=0.5*(W(I,J,KP1)-W(I,J,KM1))/DZB	00098000
D2WDZ2=(DWDZF-DWDZB)/DZK	00098100
	00098200
	00098300
DVDZB=0.5*(V(I,JP1,K)+V(I,J,K)-V(I,JP1,KM1)-V(I,J,KM1))/DZB	00098400
DVDZF=0.5*(V(I,JP1,KP1)+V(I,J,KP1)-V(I,JP1,K)-V(I,J,K))/DZF	00098500
DVDZ=0.5*(DVDZF+DVDZB)	00098600


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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)
00099500
DRDY=((R(I,JP1,K)-REQ(I,JP1,K))-(R(I,JM1,K)-REQ(I,JM1,K)))/
& (DYN+DYS)
00099600
DRDZ=((R(I,J,KP1)-REQ(I,J,KP1))-(R(I,J,KM1)-REQ(I,J,KM1)))/
& (DZF+DZB)
00099700
DRDGA=SIN(ZC(K))*(SIN(XC(I))*DRDY+COS(XC(I))*DRDX)
00099800
& +COS(ZC(K))*DRDZ
00099900
00100000
00100100
00100200
00100300
C *** CALCULATE RICHARDSON NUMBER
00100400
00100500
STRAIN=DUDY**2+DVDX**2+DWDY**2+DVDZ**2+DWDY**2+DUDZ**2
00100600
DDO2 = SQRT(DUDY*DUDY+DUDX*DUDX+DUDZ*DUDZ+DVDY*DVDY+DVDX*DVDX+
& DVDZ*DVDZ+DWDX*DWDX+DWDY*DWDY+DWDZ*DWDZ)
00100700
IF(DDO2.EQ.0.)GO TO 600
00100800
00100900
C *** CALCULATE TURBULENT LENGTH SCALE SMPP(I,J)
00101000
00101100
00101200
SMPI23=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
00101300
SMPP12=DDO2 /SQRT(D2UDX2*D2UDX2+D2UDY2*D2UDY2
00101400
& +D2UDZ2*D2UDZ2+D2VDX2*D2VDX2+D2VDY2*D2VDY2+D2VDZ2*D2VDZ2+
00101500
& D2WDZ2*D2WDZ2+D2WDX2*D2WDX2+D2WDY2*D2WDY2)
00101600
SMPP(I,J,K)=CNT*(SMPI23+SMPP12)*.5
00101700
RI(I,J,K)=-BUOY*DRDGA/(R(I,J,K)*STRAIN)
00101800
ABRIPR=ABTURB+RI(I,J,K)/PRT
00101900
IF(ABRIPR.LT. 0.) GO TO 600
00102000
IF(ABRIPR.EQ. 0.) GO TO 613
00102100
GO TO 610
00102200
600 VIS(I,J,K)=VISL
00102300
GO TO 611
00102400
613 VIS(I,J,K)=VISMAL
00102500
GO TO 611
00102600
610 VIS(I,J,K)=VISL+R(I,J,K)*SMPP(I,J,K)*SMPP(I,J,K)*SQRT(STRAIN)/
00102700
& (BTURB*ABRIPR)
00102800
IF(VIS(I,J,K).GT. VISMAL) VIS(I,J,K)=VISMAL
00102900
611 CONTINUE
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

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VIS(NIP1,J,K)=VIS(2,J,K)	00104200
VIS(1,J,K)=VIS(NI,J,K)	00104300
120 CONTINUE	00104400
DO 130 K=1,NKP1	00104500
DO 130 I=1,NIP1	00104600
VIS(I,NJP1,K)=VIS(I,NJ,K)	00104700
VIS(I,2,K)=VIS(I,3,K)	00104800
VIS(I,1,K)=VIS(I,2,K)	00104810
130 CONTINUE	00104900
DO 135 K=1,16	00105000
KK=NKP1-K	00105100
DO 135 I=1,NIP1	00105110
DO 135 J=1,NJP1	00105120
VIS(I,J,KK)=VIS(I,J,K)	00105130
135 CONTINUE	00105140
DO 140 I=1,NIP1	00105150
DO 140 J=1,NJP1	00105160
DO 140 K=1,NKP1	00105170
IF (MOD(I,J,K).EQ.1) GOTO 140	00105200
COND(I,J,K)=VIS(I,J,K)/PRT	00105300
140 CONTINUE	00105400
RETURN	00105500
END	00105600
	00105700
	00105800
	00105900
	00106000
	00106100
	00106200
	00106300
	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,NMRP	00107200
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00107300
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200	00107400
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00107500
& CPO,PRT,CONDO,VISO,RHO0,HR,TR,TA,DTEMP,TWRITE,TTAPE,THAX,GC,RAIRO	00107600
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00107700
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAH(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),MPD(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),DV(22,16,32),DW(22,16,32)	00108700
COMMON/BL36/AP(22,16,32),AE(22,16,32),AM(22,16,32),AN(22,16,32),	00108800

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

C ***	CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00114400
	DXEE=XL(IP2,J,K,0,1)	00114500
	DXE =XL(IP1,J,K,0,1)	00114600
	DXM =XL(I ,J,K,0,1)	00114700
	DXMM=XL(IM1,J,K,0,1)	00114800
		00114900
		00115000
	DYMN=YL(I,JP2,K,0,2)	00115100
	DYN =YL(I,JP1,K,0,2)	00115200
	DYS =YL(I,J ,K,0,2)	00115300
	DYSS=YL(I,JM1,K,0,2)	00115400
		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
	DXYF=DXF*DYF	00116300
	DXYB=DXB*DYB	00116400
	DYZE=DYE*DZE	00116500
	DYZW=DYW*DZW	00116600
	DZXN=DZN*DXN	00116700
	DZXS=DZS*DXS	00116800
		00116900
	VOL=DXI*DYJ*DZK	00117000
	VOLDT=VOL/DTIME	00117100
		00117200
	ZXOYN=DZXN/DYN	00117300
	ZXOYS=DZXS/DYS	00117400
	XYOZF=DXYF/DZF	00117500
	XYOZB=DXYB/DZB	00117600
	YZOXE=DYZE/DXE	00117700
	YZOXW=DYZW/DXM	00117800
		00117900
	GN=(R(I,J,K)*DYP1+R(I,JP1,K)*DYJ)/(DYP1+DYJ)	00118000
	GS=(R(I,J,K)*DYM1+R(I,JM1,K)*DYJ)/(DYM1+DYJ)	00118100
	GE=(R(I,J,K)*DXP1+R(IP1,J,K)*DXI)/(DXP1+DXI)	00118200
	GW=(R(I,J,K)*DXM1+R(IM1,J,K)*DXI)/(DXM1+DXI)	00118300
	GF=(R(I,J,K)*DZP1+R(I,J,KP1)*DZK)/(DZP1+DZK)	00118400
	GB=(R(I,J,K)*DZM1+R(I,J,KM1)*DZK)/(DZM1+DZK)	00118500
		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=GW*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

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
CONDN1=YZOXN*CONDN	00120600
CONDF1=XYOZF*CONDF	00120700
CONDB1=XYOZB*CONDB	00120800
	00120900
	00123110
CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXM))/8.	00123120
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXEE))/8.	00123130
CMP=(ABS(CM)+CM)*DXM1*DXI/(DXM*(DXM+DXM1))/8.	00123140
CMH=(ABS(CM)-CM)*DXM1*DXI/(DXM*(DXM+DXE))/8.	00123150
	00123160
CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS))/8.	00123170
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYN1))/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+DZB5))/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/DXEE)+CMH*DXM/DXE	00123198
AM(I,J,K)=.5*DXI/DXM*CH+CMH+CMH*(1.+DXM/DXM1)+CEP*DXE/DXM	00123199
AN(I,J,K)=-.5*DYJ/DYN*CN+CNP+CMH*(1.+DYN/DYN1)+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/DZB5)+CFP*DZF/DZB	00123203
	00123204
801 AEE=-CEM*DXE/DXEE	00123210
AEER=AEE*TPD(IP2,J,K)*CPM(IP2,J,K)	00123300
802 CONTINUE	00123400
	00123500
803 AMH=-CMP*DXM/DXM1	00123600
AMHR=AMH*TPD(IM2,J,K)*CPM(IM2,J,K)	00123700
804 CONTINUE	00123800
	00123900
IF (J.LT.NJ) GOTO 805	00124000
ANN=0.	00124100
AMHR=0.	00124200
GOTO 806	00124300
805 ANN=-CNP*DYN/DYN1	00124400
AMHR=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

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 (MOD(IM1,J,K).EQ.0) GOTO 901	00127900
AMN=0.0	00128000
AMNR=0.0	00128100
	00128200
901 CONTINUE	00128300
IF (MOD(IP1,J,K).EQ.0) GOTO 902	00128400
AEE=0.0	00128500
AEER=0.0	00128600
	00128700
902 CONTINUE	00128800
IF (MOD(I,JM1,K).EQ.0) GOTO 903	00128900
ASS=0.0	00129000
ASSR=0.0	00129100
	00129200
903 CONTINUE	00129300
IF (MOD(I,JP1,K).EQ.0) GOTO 904	00129400
ANN=0.0	00129500
ANNR=0.0	00129600
	00129700
904 CONTINUE	00129800
IF (MOD(I,J,KM1).EQ.0) GOTO 905	00129900
ABB=0.0	00130000
ABBR=0.0	00130100
	00130200
905 CONTINUE	00130300
IF (MOD(I,J,KP1).EQ.0) GOTO 906	00130400
AFF=0.0	00130500
AFFR=0.0	00130600
	00130700

906 CONTINUE	00130800
	00130900
C *****	00131000
C *****	00131100
	00131200
AP(I,J,K)=(AE(I,J,K)+AM(I,J,K)+AN(I,J,K)+AS(I,J,K)	00131300
1 +AF(I,J,K)+AB(I,J,K)+AEE+AMW+ANN+ASS+AFF+ABB)*CPM(I,J,K)	00131400
2 +CONDE1+CONDW1+CONDN1+CONDS1+CONDF1+CONDB1	00131500
	00131600
AE(I,J,K)=AE(I,J,K)*CPM(IP1,J,K)+CONDE1	00131700
AM(I,J,K)=AM(I,J,K)*CPM(IM1,J,K)+CONDW1	00131800
AN(I,J,K)=AN(I,J,K)*CPM(IN1,J,K)+CONDN1	00131900
AS(I,J,K)=AS(I,J,K)*CPM(IS1,J,K)+CONDS1	00132000
AF(I,J,K)=AF(I,J,K)*CPM(IF1,J,K)+CONDF1	00132100
AB(I,J,K)=AB(I,J,K)*CPM(IB1,J,K)+CONDB1	00132200
	00132300
SP(I,J,K)=-ROD(I,J,K)*VOLDT*CPM(I,J,K)	00132400
SU(I,J,K)=ROD(I,J,K)*VOLDT*TOD(I,J,K)*CPM(I,J,K)	00132500
SU(I,J,K)=SU(I,J,K)+AEER+AMWR+ANNR+ASSR+AFR+ABBR	00132600
100 CONTINUE	00132700
	00132800
C *** TAKE CARE OF B.C. THRU AN,AS,AE,AM,AF,AB,SP AND SU	00132900
	00133000
C *** RADIUS DIRECTION	00133100
	00133200
DO 500 I=2,N1	00133300
DO 500 K=2,NK	00133400
SP(I,2,K)=SP(I,2,K)+AS(I,2,K)	00133500
CC SP(I,2,K)=SP(I,2,K)-AS(I,2,K)	00133600
CC SU(I,2,K)=SU(I,2,K)+2.0*AS(I,2,K)*TPD(I,1,K)	00133700
SP(I,NJ,K)=SP(I,NJ,K)-AN(I,NJ,K)	00133800
SU(I,NJ,K)=SU(I,NJ,K)+2.0*TPD(I,NJ1,K)*AN(I,NJ,K)	00133900
AS(I,2,K)=0.	00134000
AN(I,NJ,K)=0.	00134100
500 CONTINUE	00134200
	00134300
C *** CYLIC CONDITIONS	00134400
	00134500
DO 600 J=2,NJ	00134600
DO 600 K=2,NK	00134700
SU(2,J,K)=SU(2,J,K)+AM(2,J,K)*T(I1,J,K)	00134800
SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*T(INI1,J,K)	00134900
AM(2,J,K)=0.0	00135000
AE(NI,J,K)=0.0	00135100
600 CONTINUE	00135200
	00135300
C *** END OF SPHERE	00135400
	00135500
DO 700 I=2,N1	00135600
DO 700 J=2,NJ	00135700
SP(I,J,2)=SP(I,J,2)+AB(I,J,2)	00135800
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)	00135900
AB(I,J,2)=0.	00136000
AF(I,J,NK)=0.	00136100
700 CONTINUE	00136200

C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS

```
DO 300 K=2,NK
DO 300 J=2,NJ
DO 300 I=2,NI
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)
300 CONTINUE
```

C *** VOLUME HEAT SOURCE INPUT

```
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)
DYJ =YL(I,J ,K,0,0)
DZK =ZL(I,J,K ,0,0)
VOL=DXI*DYJ*DZK*H*H*H
VOLT=VOLT+VOL
113 CONTINUE

DO 111 I=2,NI
DO 111 J=2,NJ
DO 111 K=16,17
IF (NHSZ(I,J,K).EQ.0) GOTO 111
DXI =XL(I ,J,K,0,0)
DYJ =YL(I,J ,K,0,0)
DZK =ZL(I,J,K ,0,0)
QQQ=Q*H/(UO*CPO*RHOO*TA)
VOL=DXI*DYJ*DZK
SU(I,J,K)=SU(I,J,K)+VOL*QQQ/VOLT
111 CONTINUE
```

C *** RADIATION INTO THE WALL

```
DO 310 K=3,NKM1
DO 310 I=2,NI
DXN =XL(I ,NJRA,K,0,2)
DZN =ZL(I,NJRA,K ,0,2)
DZXN=DZN*DXN
II=(K-3)*(NI-1)+I-1
SU(I,NJRA,K)=SU(I,NJRA,K)-RMALL(II)*DZXN
310 CONTINUE
```

C *** END OF RADIATION

C *** SOLVE FOR T

CALL TRID (2,2,2,NI,NJ,NK,T)

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00140100
00140200
00140300
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00140500
00140501
00140503
00140504
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00141200
00141300
00141400

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=YLI(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 *** SUBROUTINE CALC	00144700
C ***	00144800
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00144900
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00145000
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00145100
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00145200
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00145300
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00145400
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200146900	00145500
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00147000	00145600
& CPO,PRT,CONDO,VISO,RH00,HR,TR,TA,DTMP,TWRITE,TTAPE,TMAX,GC,RAIR00147100	00145700
	00145800
	00145900
	00146000
	00146100
	00146200
	00146300
	00146400
	00146500
	00146600
	00146700
	00146800

COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00147200
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10)	00147300
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00147400
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),MOD(22,16,32)	00147500
COMMON/BL32/ T(22,16,32),RI(22,16,32),P(22,16,32)	00147600
& ,CI(22,16,32),UI(22,16,32),VI(22,16,32),MI(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),MPD(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),DV(22,16,32),DW(22,16,32)	00148200
COMMON/BL36/AP(22,16,32),AE(22,16,32),AM(22,16,32),ANT(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),CONDI(22,16,32),NOD(22,16,32),RMALL(579)	00148600
& ,CPMI(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00148700
COMMON/BL39/ALEN,PCURVE,CONRA,PCURM1,PSOUTH,QCORR,PERROR	00148800
	00148900
C *** CALCULATE COEFFICIENTS	00149000
DO 100 K=2,NK	00149100
KP2=K+2	00149200
KP1=K+1	00149300
KM1=K-1	00149400
KM2=K-2	00149500
DO 100 J=2,NJ	00149600
JP2=J+2	00149700
JP1=J+1	00149800
JM1=J-1	00149900
JM2=J-2	00150000
DO 100 I=2,NI	00150100
IP2=I+2	00150200
IP1=I+1	00150300
IM1=I-1	00150400
IM2=I-2	00150500
IF (I.EQ.2) IM2=NIM1	00150600
IF (I.EQ.NI) IP2=3	00150700
	00150800
	00150900
C CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00151000
DXP1=XL(IP1,J,K,0,0)	00151100
DYI =XL(I ,J,K,0,0)	00151200
DXM1=XL(IM1,J,K,0,0)	00151300
	00151400
DYF1=YL(I,JP1,K,0,0)	00151500
DYJ =YL(I,J ,K,0,0)	00151600
DYM1=YL(I,JM1,K,0,0)	00151700
	00151800
DZP1=ZL(I,J,KP1,0,0)	00151900
OZK =ZL(I,J,K ,0,0)	00152000
DZM1=ZL(I,J,KM1,0,0)	00152100
	00152200
C *** SURFACE LENGTH OF THE CONTROL VOLUME	00152300
DXN=XL(I,JP1,K,0,2)	00152400
	00152500
	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
DYM=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
DXM =XL(I ,J,K,0,1)	00154500
DXMM=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=DYM*DZW	00156300
DZXN=DZN*DXN	00156400
DZXS=DZS*DYS	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
CH=GH*U(I,J,K)*DYZW	00158600
CF=GF*W(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,JM1,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=YZOXW*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
CHP=(ABS(CH)+CH)*DXM1*DXI/(DXW*(DXW+DXW))/8.	00162803
CHM=(ABS(CH)-CH)*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+DYSS))/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
AEE(I,J,K)=-.5*DXI/DXE*CE+CEP+CEM*(1.+DXE/DXE)+CHM*DXW/DXE	00162816
AH(I,J,K)=-.5*DXI/DXW*CH+CHM+CHP*(1.+DXW/DXW)+CEP*DXE/DXW	00162817
AN(I,J,K)=-.5*DYJ/DYN*CN+CNP+CNM*(1.+DYN/DYN)+CSM*DYS/DYN	00162818
AS(I,J,K)=-.5*DYJ/DYS*CS+CSM+CSP*(1.+DYS/DYS)+CNP*DYN/DYS	00162819
AF(I,J,K)=-.5*DZK/DZF*CF+CFP+CFM*(1.+DZF/DZF)+CBM*DZB/DZF	00162820
AB(I,J,K)=-.5*DZK/DZB*CB+CBM+CBP*(1.+DZB/DZB)+CFP*DZF/DZB	00162821
	00162822
	00162823
801 AEE=-CEM*DXE/DXEE	00162830
AEER=AEE*CPD(IP2,J,K)	00162900
802 CONTINUE	00163000
	00163100
803 AHW=-CHP*DXW/DXW	00163200
AHWR=AHW*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
	00165200
IF (K.LT.NK) GOTO 809	00165300
AFF=0.	00165400
AFFR=0.	00165500
GOTO 810	00165600
809 AFF=-CFM*DZF/DZFF	00165700
AFFR=AFF*CPD(I,J,KP2)	00165800
810 CONTINUE	00165900
	00166000
	00166100
IF (K.GT.2) GOTO 811	00166200
ABB=0.	00166300
ABBR=0.	00166400
GOTO 812	00166500
811 ABC=-CBP*DZB/DZBB	00166600
ABBR=ABB*CPD(I,J,KM2)	00166700
812 CONTINUE	00166800
	00166900
	00167000
C *****	00167100
C *****	00167200
C *** MODIFICATION FOR DECK BOUNDARIES	00167300
	00167400
900 CONTINUE	00167500
IF (MOD(IM1,J,K).EQ.0) GOTO 901	00167600
AMW=0.0	00167700
AMWR=0.0	00167800
	00167900
901 CONTINUE	00168000
IF (MOD(IP1,J,K).EQ.0) GOTO 902	00168100
AEE=0.0	00168200
AEER=0.0	00168300
	00168400
902 CONTINUE	00168500
IF (MOD(I,JM1,K).EQ.0) GOTO 903	00168600
ASS=0.0	00168700
ASSR=0.0	00168800
	00168900
903 CONTINUE	

IF (MOD(I,JP1,K).EQ.0) GOTO 904	00169000
ANN=0.0	00169100
ANNR=0.0	00169200
904 CONTINUE	00169300
IF (MOD(I,J,KM1).EQ.0) GOTO 905	00169400
ABB=0.0	00169500
ABBR=0.0	00169600
905 CONTINUE	00169700
IF (MOD(I,J,KP1).EQ.0) GOTO 906	00169800
AFF=0.0	00169900
AFFR=0.0	00170000
906 CONTINUE	00170100
	00170200
	00170300
	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)	00170900
& +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
SUI(I,J,K)= ROD(I,J,K)*VOLDT*TOD(I,J,K)	00172100
SUI(I,J,K)=SUI(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,N1	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
SUI(I,2,K)=SUI(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
SUI(I,NJ,K)=SUI(I,NJ,K)+2.*CPD(I,NJP1,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
SUI2(J,K)=SUI2(J,K)+AW(2,J,K)*C(1,J,K)	00174400

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
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00176100
	00176200
DO 300 K=2,NK	00176300
DO 300 J=2,NJ	00176400
DO 300 I=2,NI	00176500
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00176600
300 CONTINUE	00176700
	00176800
	00176900
	00177000
C *** VOLUME MASS SOURCE INPUT	00177100
	00177200
VOLT=0.0	00177300
DO 113 I=2,NI	00177400
DO 113 J=2,NJ	00177500
DO 113 K=16,17	00177600
IF (NHSZ(I,J,K).EQ.0) GOTO 113	00177700
DXI =XL(I,J,K,0,0)	00177800
DYJ =YL(I,J,K,0,0)	00177900
DZK =ZL(I,J,K,0,0)	00178000
VOL=DXI*DYJ*DZK*H*H*H	00178100
VOLT=VOLT+VOL	00178200
113 CONTINUE	00178300
	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
CALL TRID (2,2,2,NI,NJ1,NK,C)	00180100
C **** RESET CONCENTRATION AT R=0.0 AND END OF SPHERE	00180200
DO 81 K=1,NKP1	00180300
AVT=0.0	00180400
DO 82 I=2,NI	00180500
AVT=AVT+(C(I,2,K)/NIM1)	00180600
82 CONTINUE	00180700
DO 83 I=1,NIP1	00180800
C(I,1,K)=AVT	00180900
83 CONTINUE	00181000
81 CONTINUE	00181100
	00181200
	00181300
	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
C *** FOR SURFACE MASS EXCHANGE WITH SURROUNDING	00182100
DO 84 I=2,NI	00182200
DO 84 K=2,NK	00182300
C(I,NJP1,K)=C(I,NJ,K)	00182400
84 CONTINUE	00182500
	00182600
	00182700
	00182800
	00182900
C *** FOR CYLIC CONDITION	00183000
DO 80 J=1,NJP1	00183100
DO 80 K=1,NKP1	00183200
C(1,J,K)=C(NI,J,K)	00183300
C(NIP1,J,K)=C(2,J,K)	00183400
80 CONTINUE	00183500
	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),	00184600
& DXXC(93),DYXC(93),DZXC(93),DXXS(93),DYYS(93),DZZS(93)	00184700
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00184800
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00184900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00185000
COMMON/BL12/NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00185100
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM2	00185200
COMMON/BL16/CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY	00185300
& CP0,PRT,CONDO,VISO,RH00,HR,TR,TA,DTMP,TWRITE,TTAPE,TMAX,GC,RAIR	00185400

COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)	00185500
2 ,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
2 NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAH(10)	00185800
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00185900
2 ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),MOD(22,16,32)	00186000
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00186100
2 ,C(22,16,32),U(22,16,32),V(22,16,32),M(22,16,32)	00186200
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32)	00186300
2 ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),MPD(22,16,32)	00186400
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00186500
2 SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00186600
2 DUI(22,16,32),DVI(22,16,32),DWI(22,16,32)	00186700
COMMON/BL36/AP(22,16,32),AE(22,16,32),AMI(22,16,32),AN(22,16,32),	00186800
2 AS(22,16,32),AF(22,16,32),AB(22,16,32),	00186900
2 SP(22,16,32),SU(22,16,32),RI(22,16,32)	00187000
COMMON/BL37/ VISI(22,16,32),CONDI(22,16,32),NODI(22,16,32),RWALL(579)	00187100
2 ,CPMI(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

DXN=XL(I,JP1,K,1,2)
 DXS=XL(I,J,K,1,2)
 DXF=XL(I,J,KP1,1,3)
 DXB=XL(I,J,K,1,3)

DYF=YL(I,J,KP1,1,3)
 DYB=YL(I,J,K,1,3)
 DYE=YL(IP1,J,K,1,1)
 DYW=YL(I,J,K,1,1)

DZE=ZL(IP1,J,K,1,1)
 DZW=ZL(I,J,K,1,1)
 DZN=ZL(I,JP1,K,1,2)
 DZS=ZL(I,J,K,1,2)

C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR U

DXEE=XL(IP2,J,K,1,1)
 DXE=XL(IP1,J,K,1,1)
 DXW=XL(I,J,K,1,1)
 DXWW=XL(IM1,J,K,1,1)

DYNN=YL(I,JP2,K,1,2)
 DYN=YL(I,JP1,K,1,2)
 DYS=YL(I,J,K,1,2)
 DYSS=YL(I,JM1,K,1,2)

DZFF=ZL(I,J,KP2,1,3)
 DZF=ZL(I,J,KP1,1,3)
 DZB=ZL(I,J,K,1,3)
 DZBB=ZL(I,J,KM1,1,3)

C *** DEFINE THE AREA OF THE CONTROL VOLUME

DXYF=DXF*DYF
 DXYB=DXB*DYB
 DYZE=DYE*DZE
 DYZW=DYW*DZW
 DZXN=DZN*DXN
 DZXS=DZS*DXS

VOL=DXI*DYJ*DZK
 VOLDT=VOL/DTIME

ZXOYN=DZXN/DYN
 ZXOYS=DZXS/DYS
 XYOZF=DXYF/DZF
 XYOZB=DXYB/DZB
 YZOXE=DYZE/DXE
 YZOXM=DYZW/DXM

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C *** USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE
C PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.

GNE=SILIN(R(I ,JP1,K),R(I ,J,K),DYP1,DYJ)*V(I ,JP1,K)
GNW=SILIN(R(IM1,JP1,K),R(IM1,J,K),DYP1,DYJ)*V(IM1,JP1,K)
GSE=SILIN(R(I ,JM1,K),R(I ,J,K),DYM1,DYJ)*V(I ,J ,K)
GSW=SILIN(R(IM1,JM1,K),R(IM1,J,K),DYM1,DYJ)*V(IM1,J ,K)

GE =SILIN(R(IP1,J,K),R(I ,J,K),DXE,DXE)*U(IP1,J,K)
GP =SILIN(R(IM1,J,K),R(I ,J,K),DXW,DXE)*U(I ,J,K)
GW =SILIN(R(IM2,J,K),R(IM1,J,K),DXW,DXW)*U(IM1,J,K)

GFE=SILIN(R(I ,J,KP1),R(I ,J,K),DZP1,DZK)*W(I ,J,KP1)
GFW=SILIN(R(IM1,J,KP1),R(IM1,J,K),DZP1,DZK)*W(IM1,J,KP1)
GBE=SILIN(R(I ,J,KM1),R(I ,J,K),DZM1,DZK)*W(I ,J,K)
GBW=SILIN(R(IM1,J,KM1),R(IM1,J,K),DZM1,DZK)*W(IM1,J,K)

CE=0.5*(GE+GP)*DYZE
CW=0.5*(GP+GW)*DYZW

CN=SILIN(GNE,GNW,DXE,DXW)*DZXN
CS=SILIN(GSE,GSW,DXE,DXW)*DZXS

CF=SILIN(GFE,GFW,DXE,DXW)*DXYF
CB=SILIN(GBE,GBW,DXE,DXW)*DXYB

VISE=VIS(I ,J,K)
VISW=VIS(IM1,J,K)

VISN= (VIS(I ,JP1,K)+VIS(I ,J,K)+
& VIS(IM1,JP1,K)+VIS(IM1,J,K))/4.0
VISS= (VIS(I ,JM1,K)+VIS(I ,J,K)+
& VIS(IM1,JM1,K)+VIS(IM1,J,K))/4.0
VISF= (VIS(I ,J,KP1)+VIS(I ,J,K)+
& VIS(IM1,J,KP1)+VIS(IM1,J,K))/4.0
VISB= (VIS(I ,J,KM1)+VIS(I ,J,K)+
& VIS(IM1,J,KM1)+VIS(IM1,J,K))/4.0

VISN1=ZXOYN*VISN
VISS1=ZXOYS*VISS
VISE1=YZOXE*VISE
VISW1=YZOXW*VISW
VISF1=XYOZF*VISF
VISB1=XYOZB*VISB

CEP=(ABS(CE)+CE)*DXE/DXI/16.
CEM=(ABS(CE)-CE)*DXE/DXP1/16.
CNP=(ABS(CW)+CW)*DXW/DXM1/16.
CWM=(ABS(CW)-CW)*DXW/DXI/16.

CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS))/8.

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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)+CMM*DXM/DXE+VISE1	00202900
AM(I,J,K)=.5*CH+CMM+CMP*(1.+DXM/DXMM)+CEP*DXE/DXM+VISM1	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 AMM=-CMP*DXM/DXMM	00203900
AMMR=AMM*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
IF (J.GT.2) GOTO 807	00205100
ASS=0.	00205200
ASSR=0.	00205300
GOTO 808	00205400
807 ASS=-CSP*DYS/DYSS	00205500
ASSR=ASS*UPD(I,JM2,K)	00205600
808 CONTINUE	00205700
	00205800
IF (K.LT.NK) GOTO 809	00205900
AFF=0.	00206000
AFFR=0.	00206100
GOTO 810	00206200
809 AFF=-CFM*DZF/DZFF	00206300
AFFR=AFF*UPD(I,J,KP2)	00206400
810 CONTINUE	00206500
	00206600
IF (K.GT.2) GOTO 811	00206700
ABB=0.	00206800
ABBR=0.	00206900
GOTO 812	00207000

811 ABB=-CBP*DZB/DZRB	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 (MOD(IM2,J,K).EQ.0) GOTO 901	00208100
AMW=0.0	00208200
AMWR=0.0	00208300
	00208400
901 CONTINUE	00208500
IF (MOD(IP1,J,K).EQ.0) GOTO 902	00208600
AEE=0.0	00208700
AEER=0.0	00208800
	00208900
902 CONTINUE	00209000
IF (MOD(I,JM1,K).EQ.0) GOTO 903	00209100
ASS=0.0	00209200
ASSR=0.0	00209300
	00209400
903 CONTINUE	00209500
IF (MOD(I,JP1,K).EQ.0) GOTO 904	00209600
ANN=0.0	00209700
ANNR=0.0	00209800
904 CONTINUE	00209900
IF (MOD(I,J,KM1).EQ.0) GOTO 905	00210000
ABB=0.0	00210100
ABBR=0.0	00210200
	00210300
905 CONTINUE	00210400
IF (MOD(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
RH=(SIG11(IM1,J,K)-(U(I,J,K)-U(IM1,J,K))*VISH/DXW)*DYZH	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

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

SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*U(NIPL,J,K)	00218100
AH(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
C *** SLIP WALLS	00218800
SP(I,J,2)=SP(I,J,2)+AB(I,J,2)	00218900
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)	00219000
AF(I,J,NK)=0.	00219100
AB(I,J,2)=0.	00219200
600 CONTINUE	00219300
	00219400
	00219500
	00219600
	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=IHPB(N)	00220700
IE=IB+NCHIP(N)-1	00220800
IBM1=IB-1	00220900
IEP1=IE+1	00221000
JB=JHPB(N)	00221100
JE=JB+NCHPJ(N)-1	00221200
JBM1=JB-1	00221300
JEP1=JE+1	00221400
KB=KHPB(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
AH(IEP1,J,K)=0.0	00222400
102 CONTINUE	00222500
	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
SP(I,J,KE)=SP(I,J,KE)-AB(I,J,KE)	00224100
AB(I,J,KE)=0.0	00224200
106 CONTINUE	00224300
	00224400
	00224500
C *** FOR THE CELLS INSIDE OF THE DECKS	00224600
	00224700
DO 104 I=IB,IE	00224800
DO 104 J=JB,JE-1	00224900
DO 104 K=KB,KE-1	00225000
SP(I,J,K)=-1.0E20	00225100
AN(I,J,K)=0.	00225200
AE(I,J,K)=0.	00225300
AS(I,J,K)=0.	00225400
AN(I,J,K)=0.	00225500
SU(I,J,K)=0.	00225600
104 CONTINUE	00225700
101 CONTINUE	00225800
105 CONTINUE	00225900
	00226000
C *****	00226100
C *****	00226200
	00226300
	00226400
	00226500
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00226600
	00226700
DO 301 K=2,NK	00226800
DO 301 J=2,NJ	00226900
DO 301 I=2,NI	00227000
DYJ=YI(I,J,K,1,0)	00227100
DZK=ZI(I,J,K,1,0)	00227200
DYZ=DYJ*DZK	00227300
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00227400
DU(I,J,K)=DYZ/AP(I,J,K)	00227500
301 CONTINUE	00227600
	00227700
	00227800
	00227900
C *** SOLVE FOR U	00228000
	00228100
CALL TRID (2,2,2,NI,NJ,NK,U)	00228200
	00228300
DO 74 I=2,NIP1	00228400
DO 74 J=2,NJP1	00228500
U(I,J,1)=U(I,J,2)	00228600
U(I,J,NKP1)=U(I,J,NK)	00228700
74 CONTINUE	00228800
	00228900
	00229000

DO 79 I=1,NIP1	00229100
DO 79 K=1,NKP1	00229200
C U(I,1,K)=U(I,2,K)	00229300
79 CONTINUE	00229400
	00229500
	00229600
	00229700
	00229800
IF (NCHIP.EQ.0) GOTO 112	00229900
C *****	00230000
C *****	00230100
C *** RESET THE VELOCITY INSIDE OF DECK	00230200
	00230300
DO 110 N=1,NCHIP	00230400
IB=ICHPI(N)	00230500
IE=IB+NCHPI(N)-1	00230600
JB=JCHPI(N)	00230700
JE=JB+NCHPJ(N)-1	00230800
KB=KCHPI(N)	00230900
KE=KB+NCHPK(N)-1	00231000
DO 108 I=IB,IE	00231100
DO 108 J=JB,JE-1	00231200
DO 108 K=KB,KE-1	00231300
UI,I,J,K=0.0	00231400
108 CONTINUE	00231500
110 CONTINUE	00231600
112 CONTINUE	00231700
C *****	00231800
C *****	00231900
RETURN	00232000
END	00232100
	00232200
	00232300
	00232400
	00232500
C *****	00232600
C SUBROUTINE CALV	00232700
C *****	00232800
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00232900
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00233000
COMMON/C1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00233100
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00233200
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NWRP	00233300
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00233400
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00233500
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO	00233600
COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)	00233700
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32)	00233800
COMMON/BL22/ICHPI(10),NCHPI(10),JCHPI(10),NCHPJ(10),KCHPI(10),	00233900
& NCHPK(10),TCHPI(10),CPSI(10),CONSI(10),WFAN(10)	00234000
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00234100
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),MOD(22,16,32)	00234200
COMMON/BL32/ TI(22,16,32),RI(22,16,32),PI(22,16,32)	00234300
& ,CI(22,16,32),UI(22,16,32),VI(22,16,32),MI(22,16,32)	00234400
	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/ API(22,16,32),AE(22,16,32),AN(22,16,32),ANI(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
DZE=ZL(IP1,J,K,2,1)	00240400
DZW=ZL(I,J,K,2,1)	00240500
DZN=ZL(I,JP1,K,2,2)	00240600
DZS=ZL(I,J,K,2,2)	00240700
	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
DXM=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*DZN	00243300
DZXS=DZS*DZS	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
YZOMW=DYZW/DXM	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(1,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
CM=SILIN(GMN,GMS,DYN,DYS)*DYZM	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
& VI-(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
VISG1=ZXOYS*VISS	00249000
VISE1=YZOXE*WISE	00249100
VISH1=YZOXW*VISH	00249200
VISF1=XYOZF*VISF	00249300
VISB1=XYOZB*VISB	00249400
	00249500
	00249600
C CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW))/8.	00249700
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXE))/8.	00249800
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXW))/8.	00249900
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE))/8.	00250000
	00250100
C CNP=(ABS(CN)+CN)*DYN/DYJ/16.	00250200
CNM=(ABS(CN)-CN)*DYN/DYJ/16.	00250300
CSP=(ABS(CS)+CS)*DYS/DYJ/16.	00250400
CSM=(ABS(CS)-CS)*DYS/DYJ/16.	00250500
	00250600
	00250700
C CFP=(ABS(CF)+CF)*DZP1*DZK/(DZF*(DZF+DZB))/8.	00250800
CFM=(ABS(CF)-CF)*DZP1*DZK/(DZF*(DZF+DZFF))/8.	00250900
CBP=(ABS(CB)+CB)*DZM1*DZK/(DZB*(DZB+DZBB))/8.	00251000

	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/DWE+VISE1	00251400
	AH(I,J,K)=.5*DXI/DXW*CH+CWM+CWP*(1.+DXW/DXWH)+CEP*DXE/DXW+VISH1	00251500
C		00251600
	AN(I,J,K)=-.5*CN+CNP+CNM*(1.+DYN/DYNN)+CSM*DYS/DYN+VISN1	00251700
C		00251800
	AS(I,J,K)=.5*CS+CSM+CSP*(1.+DYS/DYSS)+CNP*DYN/DYS+VISS1	00251810
	AF(I,J,K)=-.5*DZK/DZF*CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF+VISF1	00251820
C		00251830
	AB(I,J,K)=.5*DZK/DZB*CB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB+VISB1	00251840
		00251900
801	AEE=-CEM*DXE/DXEE	00252000
	AEER=AEE*VPD(IP2,J,K)	00252100
802	CONTINUE	00252200
		00252300
803	AMW=-CWP*DXW/DXWH	00252400
	AMWR=AMW*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 DECK BOUNDARIES	00256400
900 CONTINUE	00256500
IF (NOD(IM1,J,K).EQ.0) GOTO 901	00256600
AMW=0.0	00256700
AMWR=0.0	00256800
	00256900
	00257000
901 CONTINUE	00257100
IF (NOD(IP1,J,K).EQ.0) GOTO 902	00257200
AEE=0.0	00257300
AEER=0.0	00257400
	00257500
902 CONTINUE	00257600
IF (NOD(I,JM2,K).EQ.0) GOTO 903	00257700
ASS=0.0	00257800
ASSR=0.0	00257900
	00258000
903 CONTINUE	00258100
IF (NOD(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 (NOD(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
C *** SU FROM NORMAL STRESS	00260000
	00260100
RN=(SIG22(I,J,K)-(V(I,JP1,K)-V(I,J,K))*VISN/DYN)*DZXN	00260200
RS=(SIG22(I,JM1,K)-(V(I,J,K)-V(I,JM1,K))*VICS/DYS)*DZXS	00260300
RE=(SIG12(IP1,J,K)-(V(IP1,J,K)-V(I,J,K))*VISE/DXE)*DYZE	00260400
RW=(SIG12(I,J,K)-(V(I,J,K)-V(IM1,J,K))*VISW/DXW)*DYZW	00260500
RF=(SIG23(I,J,KP1)-(V(I,J,KP1)-V(I,J,K))*VISF/DZF)*DXYF	00260700
RB=(SIG23(I,J,K)-(V(I,J,K)-V(I,J,KM1))*VISB/DZB)*DXYB	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,DYS)	00261500
	00261600

AU2=V(I,J,K)	00261700
AU1=BILIN(U(IPI,J,K),U(I,J,K),DXI,DXI,	00261800
& U(IPI,JM1,K),U(I,JM1,K),UXI,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
	00262200
AR=SILIN(R(I,J,K),R(I,JM1,K),DYN,DYS)	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-DYM)	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+AMW+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+AMWR+ANNR+ASSR+AFFR+ABBR	00264400
& +RE-RH+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,IJ,K)=0.	00266000
500 CONTINUE	00266100
	00266200
C *** CYLIC CONDITIONS	00266300
	00266400
DO 502 K=2,NK	00266500
DO 502 J=3,NJ	00266600
SU(2,J,K)=SU(2,J,K)+AW(2,J,K)*V(1,J,K)	00266700
SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*V(NIPI1,J,K)	00266800
AW(2,J,K)=0.0	00266900
AE(NI,J,K)=0.0	00267000
502 CONTINUE	00267100

C *** FRONT AND BACK WALL	00267200
DO 600 I=2,NI	00267300
DO 600 J=3,NJ	00267400
JM1=J-1	00267500
	00267600
	00267700
C *** SLIP WALLS	00267800
SP(I,J,2)=SP(I,J,2)+AB(I,J,2)	00267900
SP(I,J,NK)=SP(I,J,NK)+AF(I,J,NK)	00268000
	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
DO 101 N=1,NCHIP	00269100
IB=ICHPB(N)	00269200
IE=IB+NCHIP(N)-1	00269300
IBM1=IB-1	00269400
IEP1=IE+1	00269500
JB=JCHPB(N)	00269600
JE=JB+NCHPJ(N)-1	00269700
JBM1=JB-1	00269800
JEP1=JE+1	00269900
KB=KCHPB(N)	00270000
KE=KB+NCHPK(N)-1	00270100
KBM1=KB-1	00270200
KEP1=KE+1	00270300
	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
C *****	00273000
C *****	00273100
C *** MODIFICATION FOR THE CELLS INSIDE OF THE DECKS	00273200
	00273300
DO 104 I=IB,IE-1	00273400
DO 104 J=JB,JE	00273500
DO 104 K=KB,KE-1	00273600
SP(I,J,K)=-1.0E20	00273700
AW(I,J,K)=0.	00273800
AE(I,J,K)=0.	00273900
AS(I,J,K)=0.	00274000
AN(I,J,K)=0.	00274100
SU(I,J,K)=0.	00274200
104 CONTINUE	00274300
101 CONTINUE	00274400
105 CONTINUE	00274500
	00274600
	00274700
	00274800
	00274900
C *****	00275000
C *****	00275100
C	00275200
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00275300
	00275400
DO 300 K=2,NK	00275500
DO 300 J=3,NJ	00275600
DO 300 I=2,NI	00275700
DXI=XL(I,J,K,2,0)	00275800
DZK=ZL(I,J,K,2,0)	00275900
DZX=DZK*DXI	00276000
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00276100
DV(I,J,K)=DZX/AP(I,J,K)	00276200
300 CONTINUE	00276300
	00276400
	00276500
C *** SOLVE FOR V	00276600
	00276700
CALL TRID (2,3,2,NI,NJ,NK,V)	00276800
	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

IF (NCHIP.EQ.0) GOTO 112	00278200
C *****	00278300
C *****	00278400
C *****	00278500
C *** RESET THE VELOCITY INSIDE OF THE DECKS	00278600
DO 110 N=1,NCHIP	00278700
IB=ICHPB(N)	00278800
IE=IB+NCHPI(N)-1	00278900
JB=JCHPB(N)	00279000
JE=JB+NCHPJ(N)-1	00279100
KB=KCHPB(N)	00279200
KE=KB+NCHPK(N)-1	00279300
DO 108 I=IB,IE-1	00279400
DO 108 J=JB,JE	00279500
DO 108 K=KB,KE-1	00279600
V(I,J,K)=0.0	00279700
108 CONTINUE	00279800
110 CONTINUE	00279900
112 CONTINUE	00280000
	00280100
	00280200
C *****	00280300
C *****	00280400
RETURN	00280500
END	00280600
	00280700
	00280800
	00280900
	00281000
C	00281100
C *****	00281200
SUBROUTINE CALW	00281300
C *****	00281400
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00281500
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYXS(93),DZZS(93)	00281600
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00281700
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00281800
& ,NIP2,NJP2,NKP2,NA,NAP1,NAH1,NS,NBP1,NBM1,KRUN,NCHIP,NJRA,NMRP	00281900
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00282000
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00282100
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR	00282200
COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)	00282300
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32)	00282400
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00282500
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10)	00282600
COMMON/BL31/ TOD(22,16,32),ROD(22,16,32),POD(22,16,32)	00282700
& ,COD(22,16,32),UOD(22,16,32),VOD(22,16,32),WOD(22,16,32)	00282800
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32)	00282900
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)	00283000
COMMON/BL33/ TPD(22,16,32),RPD(22,16,32),PPD(22,16,32)	00283100
& ,CPD(22,16,32),UPD(22,16,32),VPD(22,16,32),WPD(22,16,32)	00283200
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32),	00283300
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32),	00283400
& DU(22,16,32),DV(22,16,32),DW(22,16,32)	00283500
COMMON/BL36/AP(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32),	00283600
& AS(22,16,32),AF(22,16,32),AB(22,16,32),	

2	SP(22,16,32),SU(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
2	,CPH(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00283900
		00284000
		00284100
C ***	CALCULATE COEFFICIENTS	00284200
	DO 100 K=3,NK	00284300
	KP2=K+2	00284400
	KP1=K+1	00284500
	KM1=K-1	00284600
	KM2=K-2	00284700
	DO 100 J=2,NJ	00284800
	JP2=J+2	00284900
	JP1=J+1	00285000
	JM1=J-1	00285100
	JM2=J-2	00285200
	DO 100 I=2,NI	00285300
	IP2=I+2	00285400
	IP1=I+1	00285500
	IM1=I-1	00285600
	IM2=I-2	00285700
	IF (I.EQ.2) IM2=NIM1	00285800
	IF (I.EQ.NI) IP2=3	00285900
		00286000
		00286100
		00286200
C	CENTRAL LENGTH OF THE SCALE CONTROL VOLUME	00286300
	DXP1=XL(IP1,J,K,3,0)	00286400
	DXI =XL(I ,J,K,3,0)	00286500
	DXM1=XL(IM1,J,K,3,0)	00286600
		00286700
	DYP1=YL(I,JP1,K,3,0)	00286800
	DYJ =YL(I,J ,K,3,0)	00286900
	DYM1=YL(I,JM1,K,3,0)	00287000
		00287100
	DZP1=ZL(I,J,KP1,3,0)	00287200
	DZK =ZL(I,J,K ,3,0)	00287300
	DZM1=ZL(I,J,KM1,3,0)	00287400
		00287500
		00287600
C ***	SURFACE LENGTH OF THE CONTROL VOLUME	00287700
	DXN=XL(I,JP1,K,3,2)	00287800
	DXS=XL(I,J ,K,3,2)	00287900
	DXF=XL(I,J,KP1,3,3)	00288000
	DXB=XL(I,J,K ,3,3)	00288100
		00288200
	DYF=YL(I,J,KP1,3,3)	00288300
	DYB=YL(I,J,K ,3,3)	00288400
	DYE=YL(IP1,J,K,3,1)	00288500
	DYW=YL(I ,J,K,3,1)	00288600
		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
DXEE=XL(IP2,J,K,3,1)	00289400
DXE =XL(IP1,J,K,3,1)	00289500
DXW =XL(I ,J,K,3,1)	00289600
DXW=XL(IM1,J,K,3,1)	00289700
DYNN=YL(I,JP2,K,3,2)	00289800
DYN =YL(I,JP1,K,3,2)	00289900
DYS =YL(I,J ,K,3,2)	00290000
DYSS=YL(I,JM1,K,3,2)	00290100
DZFF=ZL(I,J,KP2,3,3)	00290200
DZF =ZL(I,J,KP1,3,3)	00290300
DZB =ZL(I,J,K ,3,3)	00290400
DZBB=ZL(I,J,KM1,3,3)	00290500
C *** DEFINE THE AREA OF THE CONTROL VOLUME	00290600
DXYF=DXF*DYF	00290700
DXYB=DXB*DYB	00290800
DYZE=DYE*DZE	00290900
DYZW=DYW*DZW	00291000
DZXN=DZN*DXN	00291100
DZXS=DZS*DXS	00291200
VOL=DXI*DYJ*DZK	00291300
VOLDT=VOL/DTIME	00291400
ZXOYN=DZXN/DYN	00291500
ZXOYS=DZXS/DYS	00291600
XYOZF=DXYF/DZF	00291700
XYOZB=DXYB/DZB	00291800
YZOZE=DYZE/DZE	00291900
YZOXW=DYZW/DXW	00292000
C *** USE SINGLE AND BI-LINEAR INTERPOLATION TO EVALUATE	00292100
C & PHYSICAL PROPERTIES AND FLUX ON THE SURFACES.	00292200
GNF=SILIN(R(I,JP1,K),R(I,J,K),DYP1,DYJ)*V(I,JP1,K)	00292300
GIB=SILIN(R(I,JP1,KM1),R(I,J,KM1),DYP1,DYJ)*V(I,JP1,KM1)	00292400
GSF=SILIN(R(I,JM1,K),R(I,J,K),DYM1,DYJ)*V(I,J ,K)	00292500
GSB=SILIN(R(I,JM1,KM1),R(I,J,KM1),DYM1,DYJ)*V(I,J ,KM1)	00292600
GF =SILIN(R(I,J,KP1),R(I,J,K),DZFF,DZF)*W(I,J,KP1)	00292700
GP =SILIN(R(I,J,KM1),R(I,J,K),DZB ,DZF)*W(I,J,K)	00292800
GB =SILIN(R(I,J,KM2),R(I,J,KM1),DZBB,DZB)*W(I,J,KM1)	00292900
GEF=SILIN(R(IP1,J,K),R(I,J,K),DXP1,DXI)*U(IP1,J,K)	00293000
GEB=SILIN(R(IP1,J,KM1),R(I,J,KM1),DXP1,DXI)*U(IP1,J,KM1)	00293100
GEF=SILIN(R(IM1,J,K),R(I,J,K),DXM1,DXI)*U(I ,J,K)	00293200
	00293300
	00293400
	00293500
	00293600
	00293700
	00293800
	00293900
	00294000
	00294100
	00294200
	00294300
	00294400
	00294500
	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
CN=SILIN(GNF,GNB,DZF,DZB)*DZXN	00295000
CS=SILIN(GSF,GSB,DZF,DZB)*DZXS	00295100
CE=SILIN(GEF,GEB,DZF,DZB)*DYZE	00295200
CM=SILIN(GMF,GMB,DZF,DZB)*DYZM	00295300
VISF=VIS(I,J,K)	00295400
VISB=VIS(I,J,KM1)	00295500
VISN=(VIS(I,JP1,K)+VIS(I,J,K)+	00295600
& VIS(I,JP1,KM1)+VIS(I,J,KM1))/4.0	00295700
VISS=(VIS(I,JM1,K)+VIS(I,J,K)+	00295800
& VIS(I,JM1,KM1)+VIS(I,J,KM1))/4.0	00295900
VISE=(VIS(IP1,J,K)+VIS(I,J,K)+	00296000
& VIS(IP1,J,KM1)+VIS(I,J,KM1))/4.0	00296100
VISM=(VIS(IM1,J,K)+VIS(I,J,K)+	00296200
& VIS(IM1,J,KM1)+VIS(I,J,KM1))/4.0	00296300
VISN1=ZXOYN*VISN	00296400
VISS1=ZXOYS*VISS	00296500
VISE1=YZOXE*VISE	00296600
VISM1=YZOXW*VISM	00296700
VISF1=XYOZF*VISF	00296800
VISB1=XYOZB*VISB	00296900
C	00297000
CEP=(ABS(CE)+CE)*DXP1*DXI/(DXE*(DXE+DXW))/8.	00297100
CEM=(ABS(CE)-CE)*DXP1*DXI/(DXE*(DXE+DXE))/8.	00297200
CWP=(ABS(CW)+CW)*DXM1*DXI/(DXW*(DXW+DXW))/8.	00297300
CWM=(ABS(CW)-CW)*DXM1*DXI/(DXW*(DXW+DXE))/8.	00297400
C	00297500
CNP=(ABS(CN)+CN)*DYP1*DYJ/(DYN*(DYN+DYS))/8.	00297600
CNM=(ABS(CN)-CN)*DYP1*DYJ/(DYN*(DYN+DYN))/8.	00297700
CSP=(ABS(CS)+CS)*DYM1*DYJ/(DYS*(DYS+DYSS))/8.	00297800
CSM=(ABS(CS)-CS)*DYM1*DYJ/(DYS*(DYS+DYN))/8.	00297900
C	00298000
CFP=(ABS(CF)+CF)*DZF/DZK/16.	00298100
CFM=(ABS(CF)-CF)*DZF/DZP1/16.	00298200
CBP=(ABS(CB)+CB)*DZB/DZM1/16.	00298300
CBM=(ABS(CB)-CB)*DZB/DZK/16.	00298400
C	00298500
AE(I,J,K)=-.5*DXI/DXE*CE+CEP+CEM*(1.+DXE/DXE)+CWM*DXW/DXE+VISE1	00298600
AM(I,J,K)=-.5*DXI/DXW*CW+CWM+CWP*(1.+DXW/DXW)+CEP*DXE/DXW+VISM1	00298700
AN(I,J,K)=-.5*DYJ/DYN*CN+CNP+CNM*(1.+DYN/DYN)+CSM*DYS/DYN+VISN1	00298800
AS(I,J,K)=-.5*DYJ/DYS*CS+CSM+CSP*(1.+DYS/DYS)+CNP*DYN/DYS+VISS1	00298900
C	00299000
AF(I,J,K)=-.5*CF+CFP+CFM*(1.+DZF/DZFF)+CBM*DZB/DZF+VISF1	00300000
	00300100

AB(I,J,K)= .5*CB+CBM+CBP*(1.+DZB/DZBB)+CFP*DZF/DZB+VISD1	00300110
C	00300120
801 AEE=-CEM*DXE/DXEE	00300200
AEER=AEE*WPD(IP2,J,K)	00300300
802 CONTINUE	00300400
	00300500
803 AMW=-CWP*DXW/DXWW	00300600
AMWR=AMW*WPD(IM2,J,K)	00300700
804 CONTINUE	00300800
	00300900
IF (J.LT.NJ) GOTO 805	00301000
ANN=0.	00301100
ANNR=0.	00301200
GOTO 806	00301300
805 ANN=-CNM*DYN/DYNN	00301400
ANNR=ANN*WPD(I,JP2,K)	00301500
806 CONTINUE	00301600
	00301700
IF (J.GT.2) GOTO 807	00301800
ASS=0.	00301900
ASSR=0.	00302000
GOTO 808	00302100
807 ASS=-CSP*DYS/DYSS	00302200
ASSR=ASS*WPD(I,JM2,K)	00302300
808 CONTINUE	00302400
	00302500
IF (K.LT.NK) GOTO 809	00302600
AFF=0.	00302700
AFFR=0.	00302800
GOTO 810	00302900
809 AFF=-CFM*DZF/DZFF	00303000
AFFR=AFF*WPD(I,J,KP2)	00303100
810 CONTINUE	00303200
	00303300
IF (K.GT.3) GOTO 811	00303400
ABB=0.	00303500
ABBR=0.	00303600
GOTO 812	00303700
811 ABB=-CBP*DZB/DZBB	00303800
ABBR=ABB*WPD(I,J,KM2)	00303900
812 CONTINUE	00304000
	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
AMW=0.0	00305000
AMWR=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
902 CONTINUE	00305700
IF (MOD(I,JM1,K).EQ.0) GOTO 903	00305800
ASS=0.0	00305900
ASSR=0.0	00306000
	00306100
	00306200
903 CONTINUE	00306300
IF (MOD(I,JP1,K).EQ.0) GOTO 904	00306400
ANN=0.0	00306500
ANNR=0.0	00306600
	00306700
	00306800
904 CONTINUE	00306900
IF (MOD(I,J,KM2).EQ.0) GOTO 905	00307000
ABB=0.0	00307100
ABBR=0.0	00307200
	00307300
905 CONTINUE	00307400
IF (MOD(I,J,KP1).EQ.0) GOTO 906	00307500
AFF=0.0	00307600
AFFR=0.0	00307700
906 CONTINUE	00307800
	00307900
C *****	00308000
C *****	00308100
	00308200
C *** SU FROM NORMAL STRESS	00308300
	00308400
RF=(SIG33(I,J,K)-(W(I,J,KP1)-W(I,J,K))*VISF/DZF)*DXYF	00308500
RB=(SIG33(I,J,KM1)-(W(I,J,K)-(W(I,J,KM1))*VISB/DZB)*DXYB	00308600
RN=(SIG23(I,JP1,K)-(W(I,JP1,K)-W(I,J,K))*VISN/DYN)*DZXN	00308700
RS=(SIG23(I,J,K)-(W(I,J,K)-W(I,JM1,K))*VISS/DYS)*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))*VISW/DXW)*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),DZF,DZB)	00309600
AVG11=SILIN(SIG11(I,J,K),SIG11(I,J,KM1),DZF,DZB)	00309700
	00309800
AU3=W(I,J,K)	00309900
AU2=BILIN(V(I,JP1,K),V(I,J,K),DYJ,DYJ,	00310000
& V(I,JP1,KM1),V(I,J,KM1),DYJ,DYJ, DZF,DZB)	00310100
AU1=BILIN(U(IP1,J,K),U(I,J,K),DXI,DXI,	00310200
& U(IP1,J,KM1),U(I,J,KM1),DXI,DXI, DZF,DZB)	00310300
	00310400
AR=SILIN(R(I,J,K),R(I,J,KM1),DZF,DZB)	00310500
	00310600
ARU23=AR*AU2*AU3	00310700
ARU13=AR*AU1*AU3	00310800
ARU22=AR*AU2*AU2	00310900

ARU11=AR*AU1*AU1	00311000
RRY=(AVG23-ARU23)*DXI*(DZN-DZS)	00311100
RRX=(AVG13-ARU13)*DYJ*(DZE-DZH)	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)+AM(I,J,K)+AN(I,J,K)+AS(I,J,K)	00311800
& +AF(I,J,K)+AB(I,J,K)+AEE+AMW+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
& *MOD(I,J,K)	00312200
SU(I,J,K)=SU(I,J,K)+DXI*DYJ*(P(I,J,KM1)-P(I,J,K))	00312300
& +AEER+AMWR+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*SINI(XC(I))	00312700
100 CONTINUE	00312800
	00312900
C *** TAKE CARE OF B.C. THRU AN,AS,AE,AM,AP AND SU	00313000
C	00313100
C *** RADIUS DIRECTION	00313200
	00313300
DO 500 K=3,NK	00313400
DO 500 I=2,NJ	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)+AM(2,J,K)*W(1,J,K)	00314900
SU(NI,J,K)=SU(NI,J,K)+AE(NI,J,K)*W(NIPI,J,K)	00315000
AM(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,NJ	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	00316500
C *****	00316600
C *****	00316700
C *** MODIFICATION FOR DECK BOUNDARIES	00316800
	00316900
DO 101 N=1,NCHIP	00317000
IB=ICHPB(N)	00317100
IE=IB+NCHPI(N)-1	00317200
IBM1=IB-1	00317300
IEP1=IE+1	00317400
JB=JCHPB(N)	00317500
JE=JB+NCHPJ(N)-1	00317600
JBM1=JB-1	00317700
JEP1=JE+1	00317800
KB=KCHPB(N)	00317900
KE=KB+NCHPK(N)-1	00318000
KBM1=KB-1	00318100
KEP1=KE+1	00318200
	00318300
	00318400
DO 102 J=JB,JE-1	00318493
DO 102 K=KB,KE	00318500
SP(IBM1,J,K)=SP(IBM1,J,K)-AE(IBM1,J,K)	00318600
SU(IBM1,J,K)=SU(IBM1,J,K)+AE(IBM1,J,K)*WFAN(N)*2.0	00318700
AE(IBM1,J,K)=0.0	00318710
	00318800
	00318900
SP(IE,J,K)=SP(IE,J,K)-AN(IE,J,K)	00319000
SU(IE,J,K)=SU(IE,J,K)+AN(IE,J,K)*WFAN(N)*2.0	00319100
AN(IE,J,K)=0.0	00319110
	00319200
102 CONTINUE	00319300
	00319400
	00319500
DO 103 I=IB,IE-1	00319600
DO 103 K=KB,KE	00319700
SP(I,JBM1,K)=SP(I,JBM1,K)-AN(I,JBM1,K)	00319800
SU(I,JBM1,K)=SU(I,JBM1,K)+AN(I,JBM1,K)*WFAN(N)*2.0	00319810
AN(I,JBM1,K)=0.0	00319900
	00320000
SP(I,JE,K)=SP(I,JE,K)-AS(I,JE,K)	00320100
SU(I,JE,K)=SU(I,JE,K)+AS(I,JE,K)*WFAN(N)*2.0	00320110
AS(I,JE,K)=0.0	00320200
103 CONTINUE	00320300
	00320400
DO 106 I=IB,IE-1	00320500
DO 106 J=JB,JE-1	00320600
SU(I,J,KBM1)=SU(I,J,KBM1)+AF(I,J,KBM1)*WFAN(N)	00320610
SU(I,J,KEP1)=SU(I,J,KEP1)+AB(I,J,KEP1)*WFAN(N)	00320620
AF(I,J,KBM1)=0.0	00320700
AB(I,J,KEP1)=0.0	00320800
106 CONTINUE	00320900
	00321000
C *** FOR THE CELLS INSIDE OF THE DECKS	00321100
	00321200

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
C *****	00322500
C *****	00322600
	00322700
	00322800
C *** ASSEMBLE COEFFICIENTS AND SOLVE DIFFERENCE EQUATIONS	00322900
	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=YI(I,J,K,3,0)	00323700
DXY=DXI*DYJ	00323800
AP(I,J,K)=AP(I,J,K)-SP(I,J,K)	00323900
DM(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 108 J=JB,JE-1	00326900
DO 108 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,NMRP	00328800
COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00328900
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,	00329000
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTIME,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),MOD(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),W(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),MPD(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/ API(22,16,32),AE(22,16,32),AW(22,16,32),AN(22,16,32),	00330300
& AS(22,16,32),AF(22,16,32),AB(22,16,32),	00330400
& SP(22,16,32),SU(22,16,32),RI(22,16,32)	00330500
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(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
DZN=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
DYZW=DYW*DZW	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
	00337900
C *** DU ON VERTICAL WALLS AND DV ON HORIZONTAL WALLS ARE ZERO	00338000
	00338100
AN(I,J,K)=RN*DZXN*DV(I,JP1,K)	00338200
AS(I,J,K)=RS*DZXS*DV(I,J,K)	00338300
AE(I,J,K)=RE*DYZE*DU(IP1,J,K)	00338400
AW(I,J,K)=RW*DYZN*DU(I,J,K)	00338500
AF(I,J,K)=RF*DXYF*DW(I,J,KP1)	00338600
AB(I,J,K)=RB*DXYB*DW(I,J,K)	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)*DYZN	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)-ROD(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(1,I,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
	00343600
DO 101 N=1,NCHIP	00343700
IB=ICHPB(N)	00343800
IE=IB+NCHPI(N)-1	00343900
IBM1=IB-1	00344000
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
SUI(I,J,K)=0.	00348000
104 CONTINUE	00348100
101 CONTINUE	00348200
105 CONTINUE	00348300
	00348400

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

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
	DO 600 I=2,NI	00355100
	IM1=I-1	00355200
	IF (I.EQ.2) IM1=NI	00355300
	DO 600 J=2,NJ	00355400
	DO 600 K=2,NK	00355500
	U(I,J,K)=U(I,J,K)+DU(I,J,K)*(PP(IM1,J,K)-PP(I,J,K))	00355600
600	CONTINUE	00355700
		00355800
		00355900
C ***	CORRECTION FOR VELOCITY V	00356000
	DO 603 J=3,NJ	00356100
	JM1=J-1	00356200
	DO 603 K=2,NK	00356300
	DO 603 I=2,NI	00356400
	V(I,J,K)=V(I,J,K)+DV(I,J,K)*(PP(I,JM1,K)-PP(I,J,K))	00356500
603	CONTINUE	00356600
		00356700
		00356800
C ***	CORRECTION OF VELOCITY W	00356900
	DO 604 K=3,NK	00357000
	KM1=K-1	00357100
	DO 604 I=2,NI	00357200
	DO 604 J=2,NJ	00357300
	W(I,J,K)=W(I,J,K)+DW(I,J,K)*(PP(I,J,KM1)-PP(I,J,K))	00357400
604	CONTINUE	00357500
		00357600
		00357700
		00357800
C ***	CORRECTION FOR PRESSURE P	00357900
	DO 606 J=2,NJ	00358000
	DO 606 I=1,NIP1	00358100
	DO 606 K=1,NK	00358200
	P(I,J,K)=P(I,J,K)+PP(I,J,K)	00358300
	PP(I,J,K)=0.	00358400
606	CONTINUE	00358500
		00358600
		00358700
C ***	THIS IS FOR R=0.0 CASE	00358800
	DO 75 I=1,NIP1	00358900
	DO 75 K=1,NKP1	00359000
C	U(I,1,K)=U(I,2,K)	00359100
C	W(I,1,K)=W(I,2,K)	00359200
C	V(I,2,K)=V(I,3,K)	00359300
		00359400

75	CONTINUE	00359500
		00359600
		00359700
C ***	MODIFICATION FOR R=0.0	00359800
C		00359900
	DO 55 K=2,NK	00360000
	VY=0.0	00360100
	VX=0.0	00360200
	VZ=0.0	00360300
	DO 50 I=2,NI	00360400
	VY=VY+U(I,2,K)*COS(XS(I))	00360500
	VX=VX-U(I,2,K)*SIN(XS(I))	00360600
50	CONTINUE	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
C ***	THIS FOR SPHERE ONLY	00363900
		00364000
	DO 77 I=1,NIP1	00364100
	DO 77 J=1,NJP1	00364200
	U(I,J,1)=U(I,J,2)	00364300
	V(I,J,1)=V(I,J,2)	00364400
	W(I,J,2)=W(I,J,3)	00364500
	U(I,J,NKP1)=U(I,J,NK)	00364600
	V(I,J,NKP1)=V(I,J,NK)	00364700
	W(I,J,NKP1)=W(I,J,NK)	00364800
77	CONTINUE	00364900

IF (NCHIP.EQ.0) GOTO 116	00365000
C *****	00365100
C *****	00365200
C *** RESET THE VELOCITY INSIDE OF DECK	00365300
	00365400
	00365500
DO 120 N=1,NCHIP	00365600
IB=ICHPB(N)	00365700
IE=IB+NCHPI(N)-1	00365800
JB=JCHPB(N)	00365900
JE=JB+NCHPJ(N)-1	00366000
KB=KCHPB(N)	00366100
KE=KB+NCHPK(N)-1	00366200
	00366300
	00366310
	00366392
	00366394
DO 109 I=IB,IE	00366400
DO 109 J=JB,JE-1	00366500
DO 109 K=KB,KE-1	00366600
U(I,J,K)=0.0	00366700
109 CONTINUE	00366800
	00366900
DO 118 I=IB,IE-1	00367000
DO 118 J=JB,JE	00367100
DO 118 K=KB,KE-1	00367200
V(I,J,K)=0.0	00367300
118 CONTINUE	00367400
	00367500
DO 119 I=IB,IE-1	00367600
DO 119 J=JB,JE-1	00367700
DO 119 K=KB,KE	00367800
W(I,J,K)=WFAN(N)	00367900
119 CONTINUE	00368000
120 CONTINUE	00368100
116 CONTINUE	00368200
C *****	00368300
C *****	00368400
C *** RECALCULATE THE ERROR SOURCE AFTER CORRECTIONS OF U, V, P	00368500
	00368600
SORSUM=0.	00368700
RESORM(ITER)=0.	00368800
DO 700 J=2,NJ	00368900
JP1=J+1	00369000
JM1=J-1	00369100
DO 700 I=2,NI	00369200
IP1=I+1	00369300
IM1=I-1	00369400
DO 700 K=2,NK	00369500
KP1=K+1	00369600
KM1=K-1	00369700
	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
DYP1=YL(I,JP1,K,0,0)	00370600
DYJ =YL(I,J ,K,0,0)	00370700
DYM1=YL(I,JM1,K,0,0)	00370800
	00370900
DZP1=ZL(I,J,KP1,0,0)	00371000
DZK =ZL(I,J,K ,0,0)	00371100
DZM1=ZL(I,J,KM1,0,0)	00371200
	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

CE=RE*U(IP1,J,K)*DYZE	00375700
CW=RW*U(I,J,K)*DYZW	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(I,J,K))*VOL/DTIME-CE+CW-CN+CS-CF+CB	00376200
	00376300
C *** SORSUM IS ACTUAL MASS INCREASE OR DECREASE FROM CONTINUITY	00376400
C EQUATION , 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/API(22,16,32),AE(22,16,32),AW(22,16,32),ANI(22,16,32),	00378300
& ASI(22,16,32),AF(22,16,32),AB(22,16,32),	00378400
& SPI(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(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)	00379800
TERM=1./(API(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

PHI(I,J,K)=A(I)*PHI(IP1,J,K)+C(I)	00381100
102 CONTINUE	00381200
100 CONTINUE	00381300
	00381400
DO 2000 J=JST,JSP	00381500
DO 2000 K=KST,KSP	00381600
PHI(IST-1,J,K)=PHI(ISP,J,K)	00381700
PHI(ISP+1,J,K)=PHI(IST,J,K)	00381800
2000 CONTINUE	00381900
	00382000
JSTM1=JST-1	00382100
A(JSTM1)=0.	00382200
C(JSTM1)=0.	00382300
DO 200 K=KST,KSP	00382400
DO 200 I=IST,ISP	00382500
DO 201 J=JST,JSP	00382600
A(I,J)=AN(I,J,K)	00382700
B(I,J)=AS(I,J,K)	00382800
C(I,J)=AE(I,J,K)*PHI(I+1,J,K)+AM(I,J,K)*PHI(I-1,J,K)	00382900
& +AF(I,J,K)*PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)	00383000
TERM=1./(API(I,J,K)-B(I,J)*A(J-1))	00383100
IF (ABS(A(I,J)).LE.1.0E-70) A(I,J)=0.0	00383200
IF (ABS(B(I,J)).LE.1.0E-70) B(I,J)=0.0	00383300
IF (ABS(C(I,J)).LE.1.0E-70) C(I,J)=0.0	00383400
IF (ABS(TERM).LE.1.0E-70) TERM=0.0	00383500
A(I,J)=A(I,J)*TERM	00383600
C(I,J)=(C(I,J)+B(I,J)*C(J-1))*TERM	00383700
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(I,J)*PHI(I,JP1,K)+C(J)	00384400
202 CONTINUE	00384500
200 CONTINUE	00384600
	00384700
DO 2001 J=JST,JSP	00384800
DO 2001 K=KST,KSP	00384900
PHI(IST-1,J,K)=PHI(ISP,J,K)	00385000
PHI(ISP+1,J,K)=PHI(IST,J,K)	00385100
2001 CONTINUE	00385200
	00385300
	00385400
KSTM1=KST-1	00385500
A(KSTM1)=0.	00385600
C(KSTM1)=0.	00385700
DO 300 I=IST,ISP	00385800
DO 300 J=JST,JSP	00385900
DO 301 K=KST,KSP	00386000
A(I,K)=AF(I,J,K)	00386100
B(I,K)=AB(I,J,K)	00386200
C(I,K)=AE(I,J,K)*PHI(I+1,J,K)+AM(I,J,K)*PHI(I-1,J,K)	00386300
& +AN(I,J,K)*PHI(I,J+1,K)+AS(I,J,K)*PHI(I,J-1,K)+SU(I,J,K)	00386400

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
DO 2002 J=JST,JSP	00388000
DO 2002 K=KST,KSP	00388100
PHI(IST-1,J,K)=PHI(ISP,J,K)	00388200
PHI(ISP+1,J,K)=PHI(IST,J,K)	00388300
2002 CONTINUE	00388400
	00388500
	00388600
	00388700
	00388800
	00388900
	00389000
	00389100
	00389200
	00389300
	00389400
	00389500
	00389600
	00389700
	00389800
	00389900
	00390000
	00390100
	00390200
	00390300
	00390400
	00390500
	00390600
	00390700
	00390800
	00390900
	00391000
	00391100
	00391200
	00391300
	00391400
	00391500
	00391600
	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
JSP1=JSP+1	00392500
B(JSP1)=0.	00392600
C(JSP1)=0.	00392700
DO 500 KK=KST,KSP	00392800
K=KST+KSP-KK	00392900
DO 500 II=IST,ISP	00393000
I=IST+ISP-II	00393100
DO 501 JJ=JST,JSP	00393200
J=JSP+JST-JJ	00393300
JP1=J+1	00393400
A(J)=AN(I,J,K)	00393500
B(J)=AS(I,J,K)	00393600
C(J)=AE(I,J,K)*PHI(I+1,J,K)+AN(I,J,K)*PHI(I-1,J,K)+AF(I,J,K)*	00393700
& PHI(I,J,K+1)+AB(I,J,K)*PHI(I,J,K-1)+SU(I,J,K)	00393800
TERM=1./(AP(I,J,K)-A(J)*B(J+1))	00393900
B(J)=B(J)*TERM	00394000
C(J)=(C(J)+A(J)*C(J+1))*TERM	00394100
IF (ABS(A(J)).LE.1.0E-70) A(J)=0.0	00394200
IF (ABS(B(J)).LE.1.0E-70) B(J)=0.0	00394300
IF (ABS(C(J)).LE.1.0E-70) C(J)=0.0	00394400
501 CONTINUE	00394500
PHI(I,JST,K)=C(JST)	00394600
JSTP1=JST+1	00394700
DO 502 J=JSTP1,JSP	00394800
PHI(I,J,K)=B(J)*PHI(I,J-1,K)+C(J)	00394900
502 CONTINUE	00395000
500 CONTINUE	00395100
	00395200
	00395300
DO 2004 J=JST,JSP	00395400
DO 2004 K=KST,KSP	00395500
PHI(IST-1,J,K)=PHI(ISP,J,K)	00395600
PHI(ISP+1,J,K)=PHI(IST,J,K)	00395700
2004 CONTINUE	00395800
	00395900
	00396000
ISP1=ISP+1	00396100
B(ISP1)=0.	00396200
C(ISP1)=0.	00396300
DO 400 JJ=JST,JSP	00396400
J=JST+JSP-JJ	00396500
DO 400 KK=KST,KSP	00396600
K=KST+KSP-KK	00396700
DO 401 II=IST,ISP	00396800
I=ISP+IST-II	00396900
IP1=I+1	00397000
A(I)=AE(I,J,K)	00397100
B(I)=AN(I,J,K)	00397200
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

&	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,KRUN,NCHIP,NJRA,NMRP	00400500
	COMMON/BL12/ NWRITE,NTAPE,NTMAX0,NTREAL,TIME,SORSUM,ITER	00400600
	COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200400700	00400700
	COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00400800	00400800
&	CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIR00400900	00400900
	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 UO,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),	00402600
&	DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00402700
	COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00402800

COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00402900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NMRP	00403000
	00403100
C *** RENERATION OF GRID	00403200
	00403300
PI=4.*ATAN(1.)	00403400
DX=1.0/FLOAT(NIM1)	00403500
C DY=1./FLOAT(NJM1-2)	00403600
DY=1./FLOAT(NJM1-1)	00403700
DZ=PI/FLOAT(NKM1-NB+NA-2)	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
DO 20 I=1,NIP2	00409600
XC(I)=XS(I)+DXXC(I)/2.0	00409700
20 CONTINUE	00409800
	00409900
DO 21 J=1,NJP2	00410000
YC(J)=YS(J)+DYYC(J)/2.0	00410100
21 CONTINUE	00410200
	00410300
	00410400
DO 9 K=4,NA	00410500
ZS(K)=(K-3)*DZ	00410600
9 CONTINUE	00410700
	00410800
DO 30 K=NBPI,NK	00410900
ZS(K)=ZS(NA)+(K-NB)*DZ	00411000
30 CONTINUE	00411100
	00411200
DO 31 K=NAP1,NB	00411300
ZS(K)=PI/2.	00411400
31 CONTINUE	00411500
	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

32	CONTINUE	00413900
	DZZC(NKP2)=DZZC(NKP1)	00414000
		00414100
	DO 11 K=2,NKP2	00414200
C	IF (K.EQ.NA.OR.K.EQ.NB) GOTO 11	00414300
	KM1=K-1	00414400
	DZZS(K)=.5*(DZZC(K)+DZZC(KM1))	00414500
11	CONTINUE	00414600
		00414700
	DZZS(1)=DZZS(2)	00414800
	DO 22 K=1,NKP2	00414900
	IF (K.GE.NA.AND.K.LT.NB) GOTO 22	00415000
	ZC(K)=ZS(K)+DZZC(K)/2.0	00415100
22	CONTINUE	00415200
		00415300
	DO 33 K=NA,NBM1	00415400
	ZC(K)=PI/2.	00415500
33	CONTINUE	00415600
		00415700
	IF (YS(1).LT.0.0) YS(1)=0.0	00415800
	IF (YC(1).LT.0.0) YC(1)=0.0	00415900
	PRINT *	00416000
	PRINT *, ' INPUT COORDINATE OF THE TANK IN THE ORDER OF '	00416100
	PRINT *, ' I XS YS ZS XC YC',	00416200
	& ' ZC DXXS DYYS DZZS DXXC '	00416300
	& , 'DYXC DZZC'	00416400
	DO 12 I=1,NKP2	00416500
	WRITE(6,102) I,XS(I),YS(I),ZS(I),XC(I),YC(I),ZC(I),	00416600
	& DXXS(I),DYYS(I),DZZS(I),DXXC(I),DYXC(I),DZZC(I)	00416700
102	FORMAT(2X,I4,12(2X,F8.5))	00416800
12	CONTINUE	00416900
		00417000
	RETURN	00417100
	END	00417200
		00417300
		00417400
		00417500
		00417600
		00417700
C	*****	00417800
	FUNCTION XL(I,J,K,M,N)	00417900
C	*****	00418000
C*****		00418100
C	WHEN M OR N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00418200
C	HALF CELL (STAGGERED CELL) *	00418300
C	WHEN M OR N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00418400
C	HALF CELL (STAGGERED CELL) *	00418500
C	WHEN M OR N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00418600
C	HALF CELL (STAGGERED CELL) *	00418700
C	WHEN M = N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00418800
C	WHOLE CELL *	00418900
C	WHEN M = N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00419000
C	WHOLE CELL *	00419100
C	WHEN M = N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00419200
C	WHOLE CELL *	00419300
C*****		

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
	00424300
IF(M.EQ.2.OR.N.EQ.2) X2=YS(J)	00424400
IF(M.EQ.2.OR.N.EQ.2) DYL=DYYS(J)	00424500
IF(M.EQ.1.OR.N.EQ.1) X1=XS(I)	00424600
IF(M.EQ.3.OR.N.EQ.3) X3=ZS(K)	00424700
GOTO 1000	00424800
100 IF(M.EQ.2) X2=YC(J-1)	

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
HALF CELL (STAGGERED CELL) *	00426300
C WHEN M OR N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00426400
HALF CELL (STAGGERED CELL) *	00426500
C WHEN M OR N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00426600
HALF CELL (STAGGERED CELL) *	00426700
C WHEN M = N = 1 THEN SHIFT CELL IN THE NEG X DIRECTION ONE*	00426800
WHOLE CELL *	00426900
C WHEN M = N = 2 THEN SHIFT CELL IN THE NEG Y DIRECTION ONE*	00427000
WHOLE CELL *	00427100
C WHEN M = N = 3 THEN SHIFT CELL IN THE NEG Z DIRECTION ONE*	00427200
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=YC(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

DZL1=DZZC(K-1)	00430400
DZL2=DZZC(K)	00430500
IF (K.EQ.NB) DZL1=DZZC(K)	00430600
IF (K.EQ.NB) DZL2=DZZC(K-1)	00430700
ZL=(X2*DZL1+DZL2)/2.	00430800
300 CONTINUE	00430900
RETURN	00431000
END	00431100
	00431200
	00431300
C *****	00431400
FUNCTION SILIN(V1,V2,D1,D2)	00431500
C *****	00431600
C IF (D1.EQ.0.0.AND.D2.EQ.0.0) D1=0.1	00431700
C IF (D1.EQ.0.0.AND.D2.EQ.0.0) D2=0.1	00431800
SILIN=(V1*D2+V2*D1)/(D1+D2)	00431900
RETURN	00432000
END	00432100
	00432200
	00432300
C *****	00432400
FUNCTION BILIN(V1,V2,D1,D2,V3,V4,D3,D4,D5,D6)	00432500
C *****	00432600
V12=(V1*D2+V2*D1)/(D1+D2)	00432700
V34=(V3*D4+V4*D3)/(D3+D4)	00432800
BILIN=(V12*D6+V34*D5)/(D5+D6)	00432900
END	00433000
	00433100
	00433200
C *****	00433300
SUBROUTINE STRESS	00433400
C *****	00433500
COMMON/R4/XC(93),YC(93),ZC(93),XS(93),YS(93),ZS(93),	00433600
& DXXC(93),DYXC(93),DZZC(93),DXXS(93),DYYS(93),DZZS(93)	00433700
COMMON/BL1/DX,DY,DZ,VOL,DTIME,VOLDT,THOT,TCOOL,PI,Q,QR	00433800
COMMON/BL7/NI,NIP1,NIM1,NJ,NJP1,NJM1,NK,NKP1,NKM1	00433900
& ,NIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NMRP	00434000
COMMON/BL20/SIG11(22,16,32),SIG12(22,16,32),SIG22(22,16,32)	00434100
& ,SIG13(22,16,32),SIG23(22,16,32),SIG33(22,16,32)	00434200
COMMON/BL22/ICHPB(10),NCHPI(10),JCHPB(10),NCHPJ(10),KCHPB(10),	00434300
& NCHPK(10),TCHP(10),CPS(10),CONS(10),WFAN(10)	00434400
COMMON/BL32/T(22,16,32),R(22,16,32),P(22,16,32)	00434500
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32)	00434600
COMMON/BL37/VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RWALL(579)	00434700
& ,CPMI(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93)	00434800
	00434900
	00435000
DO 100 K=2,NK	00435100
KP2=K+2	00435200
KP1=K+1	00435300
KM1=K-1	00435400
KM2=K-2	00435500
DO 100 J=2,NJ	00435600
JP2=J+2	00435700
JP1=J+1	00435800

JM1=J-1	00435900
JM2=J-2	00436000
DC 100 I=2,NI	00436100
IP2=I+2	00436200
IP1=I+1	00436300
IM1=I-1	00436400
IM2=I-2	00436500
C CENTRAL LENGTH OF THE SCALAR CONTROL VOLUME	00436600
DXP1=XL(IP1,J,K,0,0)	00436700
DXI =XL(I ,J,K,0,0)	00436800
DXM1=XL(IM1,J,K,0,0)	00436900
DYP1=YL(I,JP1,K,0,0)	00437000
DYJ =YL(I,J ,K,0,0)	00437100
DYM1=YL(I,JM1,K,0,0)	00437200
DZP1=ZL(I,J,KP1,0,0)	00437300
DZK =ZL(I,J,K ,0,0)	00437400
DZM1=ZL(I,J,KM1,0,0)	00437500
C *** SURFACE LENGTH OF THE CONTROL VOLUME	00437600
DXN=XL(I,JP1,K,0,2)	00437700
DXS=XL(I,J ,K,0,2)	00437800
DXF=XL(I,J,KP1,0,3)	00437900
DXB=XL(I,J,K ,0,3)	00438000
DYF=YL(I,J,KP1,0,3)	00438100
DYB=YL(I,J,K ,0,3)	00438200
DYE=YL(IP1,J,K,0,1)	00438300
DYW=YL(I ,J,K,0,1)	00438400
DZE=ZL(IP1,J,K,0,1)	00438500
DZW=ZL(I ,J,K,0,1)	00438600
DZN=ZL(I,JP1,K,0,2)	00438700
DZS=ZL(I,J ,K,0,2)	00438800
C *** CENTRAL LENGTH OF THE STAGGERED CONTROL VOLUME FOR T	00438900
DXEE=XL(IP2,J,K,0,1)	00439000
DYE =XL(IP1,J,K,0,1)	00439100
DXW =XL(I ,J,K,0,1)	00439200
DXWW=XL(IM1,J,K,0,1)	00439300
DYNN=YL(I,JP2,K,0,2)	00439400
DYN =YL(I,JP1,K,0,2)	00439500
DYS =YL(I,J ,K,0,2)	00439600
DYSS=YL(I,JM1,K,0,2)	00439700
DZFF=ZL(I,J,KP2,0,3)	00439800
DZF =ZL(I,J,KP1,0,3)	00439900
DZB =ZL(I,J,K ,0,3)	00440000
DZBB=ZL(I,J,KM1,0,3)	00440100
	00440200
	00440300
	00440400
	00440500
	00440600
	00440700
	00440800
	00440900
	00441000
	00441100
	00441200
	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
DXY=DXI*DYJ	00441800
DYZ=DYJ*DZK	00441900
DZX=DZK*DXI	00442000
	00442100
SIG11(I,J,K)=2.*VIS(I,J,K)*((U(IP1,J,K)-U(I,J,K))/DXI	00442200
& +VBAR*(DXN-DXS)/DXY	00442300
& +WBAR*(DXF-DXB)/DZX)	00442400
	00442500
SIG22(I,J,K)=2.*VIS(I,J,K)*((V(I,JP1,K)-V(I,J,K))/DYJ	00442600
& +WBAR*(DYF-DYB)/DYZ	00442700
& +UBAR*(DYE-DYW)/DXY)	00442800
	00442900
SIG33(I,J,K)=2.*VIS(I,J,K)*((W(I,J,KP1)-W(I,J,K))/DZX	00443000
& +UBAR*(DZE-DZW)/DZX	00443100
& +VBAR*(DZN-DZS)/DYZ)	00443200
100 CONTINUE	00443300
	00443400
DO 200 K=2,NKP1	00443500
KP2=K+2	00443600
KP1=K+1	00443700
KM1=K-1	00443800
KM2=K-2	00443900
DO 200 J=2,NJP1	00444000
JP2=J+2	00444100
JP1=J+1	00444200
JM1=J-1	00444300
JM2=J-2	00444400
DO 200 I=2,NIP1	00444500
IP2=I+2	00444600
IP1=I+1	00444700
IM1=I-1	00444800
IM2=I-2	00444900
	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
DXM=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,DXM)	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,DXM)	00447200
SIG12(I,J,K)=	00447300
& VIS12*((V(I,J,K)-V(IM1,J,K))/DXI	00447400
& -VBAR*(DYE-DYM)/(DXI*DYJ))	00447500
SIG12(I,J,K)=SIG12(I,J,K)+VIS12*((U(I,J,K)-U(I,JM1,K))/DYJ	00447600
& -UBAR*(DXN-DXS)/(DXI*DYJ))	00447700
300 CONTINUE	00447800
	00447900
C **** FOLLOWING DX, DY, DZ, ARE BASED ON THE LOCAL CONTROL	00448000
C VOLUME FOR SIG13	00448100
	00448200
DXF=XL(I,J,K,1,0)	00448300
DXB=XL(I,J,KM1,1,0)	00448400
DZE=ZL(I,J,K,3,0)	00448500
DZM=ZL(IM1,J,K,3,0)	00448600
DXI=XL(I,J,K,1,3)	00448700
DZK=ZL(I,J,K,3,1)	00448800
	00448900
DZF=ZL(I,J,K,1,0)	00449000
DZB=ZL(I,J,KM1,1,0)	00449100
DXE=XL(I,J,K,3,0)	00449200
DXM=XL(IM1,J,K,3,0)	00449300
	00449400
IF (DZF.EQ.0.0.OR.DZB.EQ.0.0.OR.DZE.EQ.0.0.OR.DZM.EQ.0.0)	00449500
& WRITE (6,*) I,J,K, DZF,DZB,DZE,DZM	00449600
UBAR=SILIN(U(I,J,K),U(I,J,KM1),DZF,DZB)	00449700
VBAR=SILIN(V(I,J,K),V(IM1,J,K),DXE,DXM)	00449800
	00449900
VIS13=BILIN(VIS(I,J,K),VIS(I,J,KM1),DZF,DZB,	00450000
& VIS(IM1,J,K),VIS(IM1,J,KM1),DZF,DZB, DXE,DXM)	00450100
	00450200
SIG13(I,J,K)=	00450300
& VIS13*((V(I,J,K)-V(IM1,J,K))/DXI	00450400
& -VBAR*(DZE-DZM)/(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

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MBAR=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),DYN,DYS,
& VIS(I,J,KM1),VIS(I,JM1,KM1),DYN,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*DYJ))

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,DY,DZ,VOL,DTIME,VOLDT,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,PM200455400
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00455500
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0455600
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/BL37/ VIS(22,16,32),CONDI(22,16,32),NODI(22,16,32),RWALL(579)00455910
& ,CPMI(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00455920
COMMON/BL39/ALEH,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR 00456000
00456100
C *** IN MANY OF THE FOLLOWING LINES A TEMPORARY CORRECTION FOR 00456200
C * ADJUSTING QQ TO AGREE WITH THE PRESSURE HAS BEEN APPLIED. 00456300
00456400
XTIME=TIME*H/UO 00456500
00456510
VOLT=0.0 00456520
DO 113 I=2,NI 00456530
DO 113 J=2,NJ 00456540
DO 113 K=16,17 00456550
IF (NHSZ(I,J,K).EQ.0) GOTO 113 00456560
DXI =XL(I,J,K,0,0) 00456570
DYJ =YL(I,J,K,0,0) 00456580
DZK =ZL(I,J,K,0,0) 00456590
VOL=DXI*DYJ*DZK*H*H*H 00456591

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VOLT=VOLT+VOL	00456592
113 CONTINUE	00456593
QRVOL=0.	00456594
DO 70 I=561,579	00456595
QRVOL=QRVOL+RHALL(I)*1./12.*0.2*PI	00456596
70 CONTINUE	00456597
C	00456598
QR=QRVOL/VOLT*UO*CP0*RH00*TA/H	00456599
IF (XTIME.LT.23.1) THEN	00456600
PCURVE=9.789522E-5*XTIME**2-2.388310E-6*XTIME**3+	00456700
8 REQ(10,9,16)	00456800
DPDT =9.789522E-5*XTIME**2-2.388310E-6*XTIME**2*3	00456900
ELSE	00457000
PCURVE=0.0052+.81264E-3*XTIME-.22604E-5*XTIME**2+.27262E-8*XTIME**3	00457100
8 3-.115621E-11*XTIME**4+REQ(10,9,16)	00457200
DPDT=.81264E-3-.22604E-5*XTIME**2+.27262E-8*XTIME**3	00457300
8 2*3.0-.115621E-11*XTIME**3*4	00457400
ENDIF	00457500
IF (LL .EQ. 1) THEN	00457600
QQ=1.0E8*DPDT	00457700
Q=CQ*3.4134/60./60.	00457710
65 CC:CONTINUE	00457800
Q=Q*QCORRT-QR	00457900
ELSE	00458000
C THIS USES A CURVE FIT THROUGH THE BURNRATE DATA GIVEN BY NRL	00458100
QCORRT=0.0	00458200
QCORR=0.0	00458300
ITEST = 0	00458400
BURNR1= 5.4576748 +0.18815346*XTIME-.20153996E-03*XTIME**2	00458410
BURNR2= -1.3116787 + .33158595*XTIME-.7342952E-03*XTIME**2	00458420
8 +.50945510E-06*XTIME**3	00458500
IF (XTIME .LT. 100) THEN	00458600
BURNR= BURNR2 + 1.3117-.013117*XTIME	00458700
ELSE	00458800
BURNR = BURNR2	00458900
ENDIF	00459000
IF(XTIME .LE. 300) GO TO 60	00459100
IF(BURNR2 .LT. BURNR1) THEN	00459200
BURNR = (BURNR1 + BURNR2) / 2	00459300
GO TO 60	00459400
ELSE	00459500
IF (XTIME .LT. 600.0) GO TO 60	00459600
IF (ITEST .EQ. 0) THEN	00459700
BURNR3 = BURNR2	00459800
ITEST = 1	00459900
ENDIF	00460000
BURNR = BURNR3	00460100
ENDIF	00460200
60 Q = BURNR*2.2046*9612./3600.-QR	00460300
CC THIS GIVES Q IN BTU/SEC	00460400
ENDIF	00460500
	00460600
	00460700
	00460800
	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,VFMXC)                                         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,NMRP    00462000
COMMON/BL16/CONST1,CONST2,CONST3,CONST4,CONST6,NT,U0,H,UGRT,BUOY,00462100
& CPD,PRT,CONDO,VISO,RH00,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/ALEH,PCURVE,CONSRA,PCURM1,PSOUTH,QCORR,PERROR            00462700
                                                                           00462800
                                                                           00462900
DIMENSION VFMXC(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
                                                                           00464400
C                                                                      00464500
DO 4012 J=3,14                                                         00464600
JJ=568+J-3                                                             00464700
AVT=0.25*(T(6,J,16)+T(7,J,16)+T(6,J,17)+T(7,J,17))                00464800
T4WALL(JJ)=CONSRA*AVT*AVT*AVT*AVT                                     00464900
4012 CONTINUE                                                         00465000
C                                                                      00465100
DO 4020 I=1,579                                                         00465200
RWALL(I)=0.0                                                            00465300
DO 4020 J=1,579                                                         00465400
RWALL(I)=RWALL(I)+VFMXC(I,J)*T4WALL(J)                                00465500
4020 CONTINUE                                                         00465600
RETURN                                                                  00465700
END                                                                      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,NMRP 00467500
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00467600
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,TEMP,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),DW(22,16,32) 00468200
COMMON/BL37/ VIS(22,16,32),CONDI(22,16,32),NOD(22,16,32),RWALL(579)00468300
& ,CPMI(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00468400
00468500
SUMT=0. 00468600
SUMPT=0. 00468700
SUMPET=0. 00468800
DO 370 I=2,NI 00468900
DO 370 J=2,NJ 00469000
DO 370 K=2,NK 00469100
IF (NOD(I,J,K).EQ.1) GOTO 370 00469200
DXI=XL(I,J,K,0,0,0) 00469300
DYJ=YI(I,J,K,0,0,0) 00469400
DZK=ZI(I,J,K,0,0,0) 00469500
VOL=DXI*DYJ*DZK 00469600
SUMT=SUMT+1./T(I,J,K)*VOL 00469700
SUMPT=SUMPT+P(I,J,K)/T(I,J,K)*VOL 00469800
SUMPET=SUMPET+REQ(I,J,K)*(1./1.0-1./T(I,J,K))*VOL 00469900
370 CONTINUE 00470000
SUMPET=SUMPET/UGRT 00470100
PCORR=(SUMPET-SUMPT)/SUMT 00470200
PCORRN=PCORR 00470300
00470400
DO 371 I=1,NIP1 00470500
DO 371 J=1,NJP1 00470600
DO 371 K=1,NKP1 00470700
P(I,J,K)=P(I,J,K)+PCORRN 00470800
371 CONTINUE 00470900
00471000
RETURN 00471100
END 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 00472000
& ,HIP2,NJP2,NKP2,NA,NAP1,NAM1,NB,NBP1,NBM1,KRUN,NCHIP,NJRA,NMRP 00472100
COMMON/BL12/ NWRITE,NTAPE,NTMAX,NTREAL,TIME,SORSUM,ITER 00472200
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00472300
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0472400
COMMON/BL22/ICHPI(10),NCHPI(10),JCHPI(10),NCHPJ(10),KCHPI(10), 00472500
& NCHPK(10),TCHPI(10),CPS(10),CONS(10),MFAN(10) 00472600
COMMON/BL37/ VIS(22,16,32),COND(22,16,32),NOD(22,16,32),RMALL(579)00472700
& ,CPM(22,16,32),HSZ(3,2),NHSZ(22,16,32),RESORM(93) 00472800

DO 402 N=1,NCHIP 00472900
IB=ICHPI(N) 00473000
IE=IB+NCHPI(N)-1 00473100
JB=JCHPI(N) 00473200
JE=JB+NCHPJ(N)-1 00473300
KB=KCHPI(N) 00473400
KE=KB+NCHPK(N)-1 00473500
DO 405 I=IB,IE-1 00473600
DO 405 J=JB,JE-1 00473700
DO 405 K=KB,KE-1 00473800
COND(I,J,K)=CCNDO*CONS(N) 00473900
CPM(I,J,K)=CPS(N) 00474000
NOD(I,J,K)=1 00474100
IF (J.EQ.NJ) COND(I,NJP1,K)=COND(I,NJ,K) 00474200
IF (I.EQ.2) COND(1,J,K)=COND(2,J,K) 00474300
IF (I.EQ.NI) COND(NIP1,J,K)=COND(NI,J,K) 00474400
IF (I.EQ.2.AND.J.EQ.NJ) COND(1,J+1,K)=COND(2,J,K) 00474500
IF (I.EQ.NI.AND.J.EQ.NJ) COND(NIP1,J+1,K)=COND(NI,J,K) 00474600
IF (J.EQ.NJ) CPM(I,NJP1,K)=CPM(I,NJ,K) 00474700
IF (I.EQ.2) CPM(1,J,K)=CPM(2,J,K) 00474800
IF (I.EQ.NI) CPM(NIP1,J,K)=CPM(NI,J,K) 00474900
IF (I.EQ.2.AND.J.EQ.NJ) CPM(1,J+1,K)=CPM(2,J,K) 00475000
IF (I.EQ.NI.AND.J.EQ.NJ) CPM(NIP1,J+1,K)=CPM(NI,J,K) 00475100
405 CONTINUE 00475200
402 CONTINUE 00475300
RETURN 00475400
END 00475500
00475600
00475700
00475800
00475900

C 00476000
*** *****00476100
SUBROUTINE PTRACK 00476200
*** *****00476300
COMMON/BL14/HCOEF,TINF,CNT,ABTURB,BTURB,VISL,VISMAX,QCORRT,PM1,PM200476400
COMMON/BL16/ CONST1,CONST2,CONST3,CONST4,CONST6,NT,UO,H,UGRT,BUOY,00476500
& CPO,PRT,CONDO,VISO,RHOO,HR,TR,TA,DTEMP,TWRITE,TTAPE,TMAX,GC,RAIRO0476600
COMMON/BL32/ T(22,16,32),R(22,16,32),P(22,16,32) 00476700
& ,C(22,16,32),U(22,16,32),V(22,16,32),W(22,16,32) 00476800
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00476900
& SMP(22,16,32),SMPP(22,16,32),PP(22,16,32), 00477000
& DU(22,16,32),DV(22,16,32),DW(22,16,32) 00477100
COMMON/BL39/ALEH,PCURVE,CONGRA,PCURM1,PSOUTH,QCORR,PERROR 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
*** 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),DZZC(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
MVOL=ABS((XC(I)-CX(N))*(YC(J)-CY(N))*(ZC(K)-CZ(N)))/VOL 00482200
TCOUP(N)=TCOUP(N)+MVOL*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
END
00482800
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,NMRP 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),RI(22,16,32),PI(22,16,32) 00484500
& ,C(22,16,32),UI(22,16,32),VI(22,16,32),MI(22,16,32) 00484600
COMMON/BL34/ HEIGHT(22,16,32),REQ(22,16,32), 00484700
& SMP(22,16,32),SMPP(22,16,32),PPI(22,16,32), 00484800
& DU(22,16,32),DV(22,16,32),DW(22,16,32) 00484900
COMMON/BL36/API(22,16,32),AE(22,16,32),AMI(22,16,32),ANI(22,16,32), 00484910
& ASI(22,16,32),AF(22,16,32),AB(22,16,32), 00484920
& SP(22,16,32),SUI(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/ALEH,PCURVE,CONSR,PCURM1,PSOUTH,QCORR,PERROR 00485300
XTIME=TIME*H/UO 00485400
IF( NN .EQ. 1 ) THEN 00485500
C 00485600
QRR=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,' QRR(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
ELSE 00487500
00487600
00487700
DO 502 L=25,25 00487800

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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 MOD',3X,'RIGH/C.C. '),2X,	00488300
& 'U(ICM/SEC)',2X,'V(ICM/SEC)',2X,'W(ICM/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)*RHO0/2.2048 *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)*RHO0*CP0*H*U0*1.48814	00489900
CC XCOND=COND(I,J,K)*RHO0*CP0*H*U0*1.48814	00490000
XVIS=VIS(I,J,K)/VISO	00490100
XCOND=COND(I,J,K)/VISO	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
END	00491300

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