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ABSTRACT

A three-dimensional numerical model is used to calculate ground-level air concentration and deposition (due to precipitation scavenging) after a hypothetical tornado strike at a plutonium fabrication facility in Pennsylvania. Plutonium particles less than 10 μm in diameter are assumed to be lifted into the tornadic storm cell by the vortex. The rotational characteristics of the tornadic storm are embedded within the larger mesoscale flow of the storm system. The design-basis translational wind values are based on probabilities associated with existing records of tornado strikes in the vicinity of the plant site. Turbulence exchange coefficients are based on empirical values deduced from experimental data in severe storms and from theoretical assumptions obtained from the literature. The quasi-Lagrangian method of moments is used to model the transport of concentration within a grid cell volume.

In all case studies, the effects of updrafts and downdrafts, coupled with scavenging of the particulates by precipitation, account for most of the material being deposited within 20-45 km downwind of the plant site. Ground-level isopleths in the x-y plane show that most of the material is deposited behind and slightly to the left of the centerline trajectory of the storm. Approximately 5% of the material is dispersed into the stratosphere and anvil section of the storm.

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PREFACE

The risks and consequences of a tornado striking a nuclear facility and dispersing radioactive pollutants to the atmosphere are extremely difficult to determine. The mechanisms of formation and air motions associated with tornadoes and severe thunderstorms are not precisely known. The problem is compounded by the fact that the physics of dispersion in a severe storm is even less known. The scales of motion and degree of turbulence intensity vary dramatically from the tornado to the thunderstorm cell. The inability of a tornado-thunderstorm cell model to accurately account for this variability prevents exact predictions of radioactive dispersion. However, based on available knowledge, estimates and crude assumptions have been made to describe the general dispersion of a pollutant following a tornado strike. The hypotheses remain untested and the dispersion patterns unverified.

I. INTRODUCTION

A series of studies, sponsored by the U.S. Nuclear Regulatory Commission and managed by Argonne National Laboratory, have been conducted regarding the radiological consequences of a hypothetical tornado striking a plutonium fabrication facility located within the contiguous U.S. A numerical model was developed to aid in the analysis of the meteorological dispersion of radioactive particulates following breachment of the facility. This report deals principally with the theoretical development of the tornado dispersion model.

Wind storm risk assessments and site characterizations for six plutonium fabrication facilities have been made by Fujita[1] based on existing extreme wind and tornado records surrounding each individual plant site. The individual storm characteristics were computed as a function of yearly probabilities in an effort to determine a design-basis storm representative to each specific site.

The design-basis storm used in this study is based on the wind field model and site characteristics for one of the nuclear fabrication facilities near Leechburg, PA. The facility is assumed to be breached and a unit source of plutonium particles (∿10 μm in diameter) released into the tornado.

II. SITE CHARACTERISTICS AND DESIGN BASIS TORNADO

Site topography and characteristics along with wind speed values and probability of occurrence for each of the plutonium fuel fabrication sites are discussed in detail by Fujita.[1] Report number WASH-1300 uses a probability of 10^{-7} per year in determining the frequency of design-basis tornadoes for nuclear power plants throughout the contiguous U.S.[2] However, the wind speeds associated with the 10^{-7} probability in WASH-1300 are considered to be too high (Mehta, et al.[3] and Fujita*).

This study uses a series of wind speeds associated with specific probabilities per year of a tornadic storm striking the nuclear facility. These values are based on the study conducted by Mehta, et al.[3], who analyzed the structural responses of the

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* T. T. Fujita, Personal Communication, 1977.

buildings at each of the six sites in terms of threshold values of wind speed and consequences of damage (see Table 1). The radius of the tornado is assumed to be 150 m with the vortex extending to 1000 m. Fujita[1] reported that numerous tornadoes with wind speeds corresponding to the probabilities used in this report have actually occurred in the vicinity of the plant site. It is assumed that the design-basis tornado causes enough damage to the facility (Mishima, et al.[4]) to allow unencapsulated plutonium particles to be lifted into the vortex.

Fujita[1] shows that most small- and medium-sized tornadoes have moved in an east-northeast direction near the site, while large-sized tornadoes (F4-F5) have moved in an east-southeast direction. Large-scale tornado strikes in the vicinity of each site are only based on a few years of data. In this study, a normalized direction for the hypothetical tornado is used to define the trajectory of the design-basis storm and pollutant cloud center. As more precise information on wind speeds and the directions of tornado-bearing storms becomes available, a more realistic estimate of the downwind dispersion patterns can be made. Normalization of the mean direction of transport enables the model to be used for other locations within the U.S.

A design-basis tornado model has been developed by Fujita[5,6] based on empirical evidence and analytical solutions to the governing equations of motion describing actual tornadoes. The model predicts flow fields and pressure drops surrounding the vortex and can account for how vertical velocity varies with height in the core of the tornado. The translational motion of the vortex can also be taken into account. Required input into the model has been kept to a minimum with maximum tangential wind speed and radius of the vortex key input parameters. The model also includes the presence of satellite (suction) vortices within the tornado. This tornado model should permit a more thorough analysis to be made with regards to residence time and uptake of debris within the vortex. In this study, the pollutant source is assumed to be totally lifted into the thunderstorm cell. The problem of dispersal about the vortex has been considered assuming only rather idealized concepts (Pepper[7]).

TABLE 1

Windspeed Values (m/sec) and Probabilities of Occurrence

Probability per year	10^{-7}	10^{-6}	7.2×10^{-6}
Maximum total	125	96.5	67.0
Translational	25	19.2	13.4
Tangential	100	77.3	53.6

III. MATHEMATICAL MODEL

The model developed for this study is based on the solution of the three-dimensional time-dependent equation for pollutant transport

$$\frac{\partial \chi}{\partial t} + \vec{U} \cdot \nabla \chi = \nabla \cdot (\hat{K} \nabla \chi) + S \qquad (1)$$

where χ is the concentration (g/m^3), $\vec{U}$ is the vector velocity field (m/sec), $\hat{K}$ is the directionally dependent eddy diffusivity (exchange coefficient of diffusion, m^2/sec), and S represents the sink terms associated with rainout, washout, and particle deposition (g/m^3-sec). The complexity of the flow fields associated with tornadic storms and the numerous scales of turbulence involved (which characterize the diffusion processes) do not permit simple solutions to Equation 1.

Analytical methods, used in the past to solve Equation 1 under ideal steady-state conditions, are not flexible enough to include variations in updrafts and downdrafts or vertical shear within the thunderstorm cell. A study by Pepper[7] assumed that a pollutant cloud (puff) reached a specific height in the thunderstorm cell, and then diffused in a Gaussian manner as if originating from that height. The effects of wind shear were neglected. Eddy diffusivities were based on energy dissipation rates measured in thunderstorms. The downwind diffusion following decay of the tornadic storm was calculated from extrapolations of the similarity theory.

It is unlikely that such extrapolations are entirely accurate for severe thunderstorms. If a model has to accommodate the temporal and spatial variations of numerous meteorological parameters, including the effects of wind shear and wet deposition, a more realistic approach must be made. The effects of wind shear on the pollutant cloud and in-cloud scavenging can contribute dramatically to the early deposition of radioactive particles downwind of the plant site (Davis[8], Hane[9]).

A set of boundary conditions must be specified so the solution will be constrained to the domain of interest. In order to facilitate the solution of Equation 1, the following set of boundary conditions is used

$$\left.\begin{aligned} K_{zz}\frac{\partial \chi}{\partial z} &= 0 \qquad z = 0, H \\ \frac{\partial^2 \chi}{\partial x^2} &= 0 \qquad x = 0, x_{max} \\ \frac{\partial^2 \chi}{\partial y^2} &= 0 \qquad y = 0, y_{max} \end{aligned}\right\} \qquad (2)$$

where H = height of the thunderstorm cell and acts as a partial lid to the concentration. The lack of well-posed boundary conditions does not cause serious problems since the advection terms tend to dominate the diffusion terms in Equation 1.

The initial dispersion conditions are crucial to the downwind dispersal patterns following breachment of the facility. In order to simplify the source term requirements of the model, a unit source of radioactive pollutant per m^3 (uniformly distributed) is used. This unit source of radioactive pollutant is assumed to be picked up by the tornado and lifted into the thunderstorm cell. The puff consists of particles which have diameters less than 10μ. Once the pollutant reaches the thunderstorm cell (at a point where the vertical velocity of the tornado is less than the updraft velocity of the thunderstorm cell), the puff is assumed to be dispersed by dynamics of the thunderstorm cell (Jessup[10]). The puff becomes dispersed throughout the thunderstorm cell within about 20 minutes according to the mass balance assumptions suggested by Fujita*. Figure 1 shows the initial source distribution after 20 minutes within the thunderstorm.

The concentration pattern is limited to the size of the thunderstorm cloud with a maximum peak at each level near the position of the tornado axis. Since the values of advection velocities and atmospheric turbulence are high, it seems reasonable to assume the pollutant will become well mixed throughout the thunderstorm cell (Pasquill**). The initial concentration within the thunderstorm cell is obtained by using a skewed log-normal distribution with maximum values centered on the axis of the tornado. Once the initial distributions are established, advection, turbulent diffusion, and rainout scavenging act on the pollutant cloud.

The three-dimensional wind vector, U, is required at each time-step of integration. Unfortunately, the mesoscale wind field associated with the tornadic storm is a difficult problem to accurately model. Correct calculation of the trajectory of the storm and pollutant dispersion pattern is directly dependent upon the wind field structure (Davies-Jones[11]). Subsequently, knowledge of the thunderstorm cell dynamics is also essential to the transport of the polluant. Considerable effort has been spent in recent years to analyze the surrounding wind field structure (Fankhauser,[12] and Burgess, et al.[13]). The use of Doppler radar has enabled researchers to actually measure the three-dimensional wind components in severe and tornadic storms, including the surrounding mesoscale flow field (Eagleman and Lin[14], Kropfli and Miller[15], Brandes[16], Heymsfield[17], Barnes[18], Ray[19], Miller[15], Hoxit, et al.[20],

* T. T. Fujita, Personal Communication, 1977.

** F. Pasquill, Personnal Communication, 1976.

Skewed Log-Normal Cell Values

0	0	0	0	0	0	0
0	.230	.130	.050	.022	.009	.004
0	.130	.090	.040	.020	.009	.004
0	.050	.040	.030	.010	.006	.003
0	.022	.020	.010	.008	.004	.002
0	.009	.009	.006	.004	.003	0
0	.004	.004	.003	.002	0	0

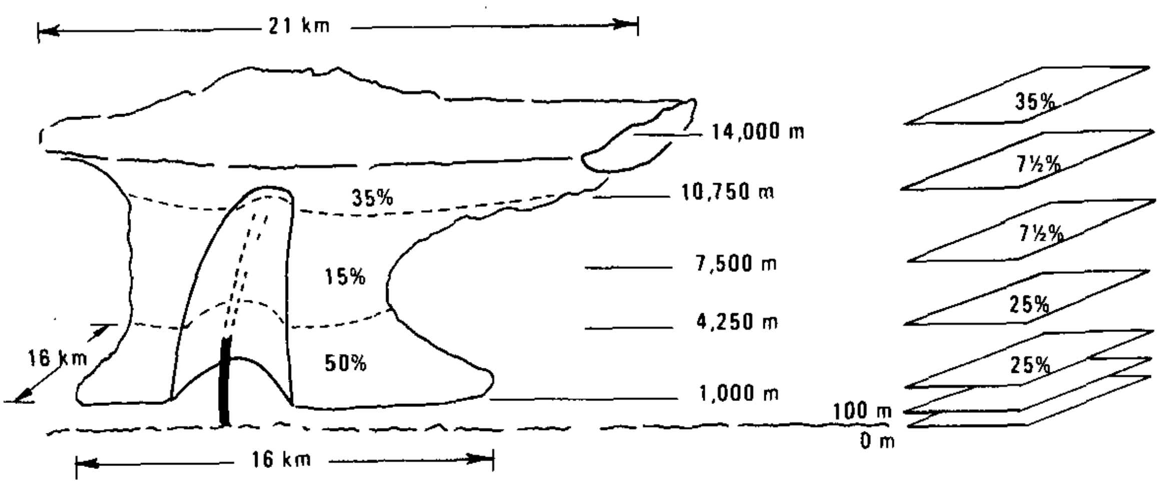

Figure 1. Initial Dispersion Pattern Within the Tornadic Storm

Ray, et al.[21]). Similarly, work on modeling the three dimensional structure of severe storms has also been undertaken with some success (Klemp and Wihelmson[22], Thorpe and Miller[23], Lin and Chang[24] Schlesinger[25]). In this study, a three-dimensional solution of the equations of motion governing the thunderstorm cell dynamics was not undertaken. In further studies regarding dispersion within severe storms, emphasis should be placed on establishing more accurate storm cell and mesoscale wind fields surrounding the vortex.

The three-dimensional wind structure of the tornado (vortex) has been analyzed extensively by numerous investigators (see Golden and Purcell[26], Fujita[6], Davies-Jones and Kessler[27], and Rotunno[28] for a more complete review of the laboratory, field measurements, and numerical simulation experiments). Unfortunately the scales of motion involved in the vortex are much less than those within the thunderstorm cell. It is the large scale flow field of the thunderstorm which ultimately determines the dispersion pattern of the pollutant, not the uptake and radial inflow of the shorter lived tornado.

The variation of the vertical velocity within the core of the tornado (Fujita[6]) is shown in Figure 2. This velocity variation was used as a guide to determine the amount of time required for the vortex to lift the pollutant source into the thunderstorm cell.

In order to create a plausible mesoscale three-dimensional wind field of the design-basis tornadic storm striking the nuclear facility, a set of empirical relations are used based on the work of Fujita[6], Orville[29], Newton[30], and Eagleman and Lin[13]. A subjective analysis and interpolation scheme was used to generate a mass-consistent three-dimensional wind field (Pepper and Baker[31]). The horizontal winds outside the storm cell are assumed to be a function of height (z) and distance (x) such that

$$u(z,t) = 2.2z^{.18}(\mathrm{m/sec}); \quad z < 1000(\mathrm{m})$$

$$u(z,t) = \begin{cases} 25.0(\mathrm{m/sec}) \\ 19.2(\mathrm{m/sec}) & 1000 \leq Z < H \\ 13.4(\mathrm{m/sec}) \end{cases} \tag{3}$$

$$u(z,t) = 1.25\begin{cases} 25.0(\mathrm{m/sec}) \\ 19.2(\mathrm{m/sec}) & z \geq H \\ 13.4(\mathrm{m/sec}) \end{cases}$$

Accurate knowledge of the lateral wind field values would more correctly introduce the meandering and lateral shifting of the storm's actual direction. However, information regarding this velocity component is limited (with regards to describing the general nature of tornadic storms). In this study, the translational velocities of the three tornadic storm cells are assumed to be constant.

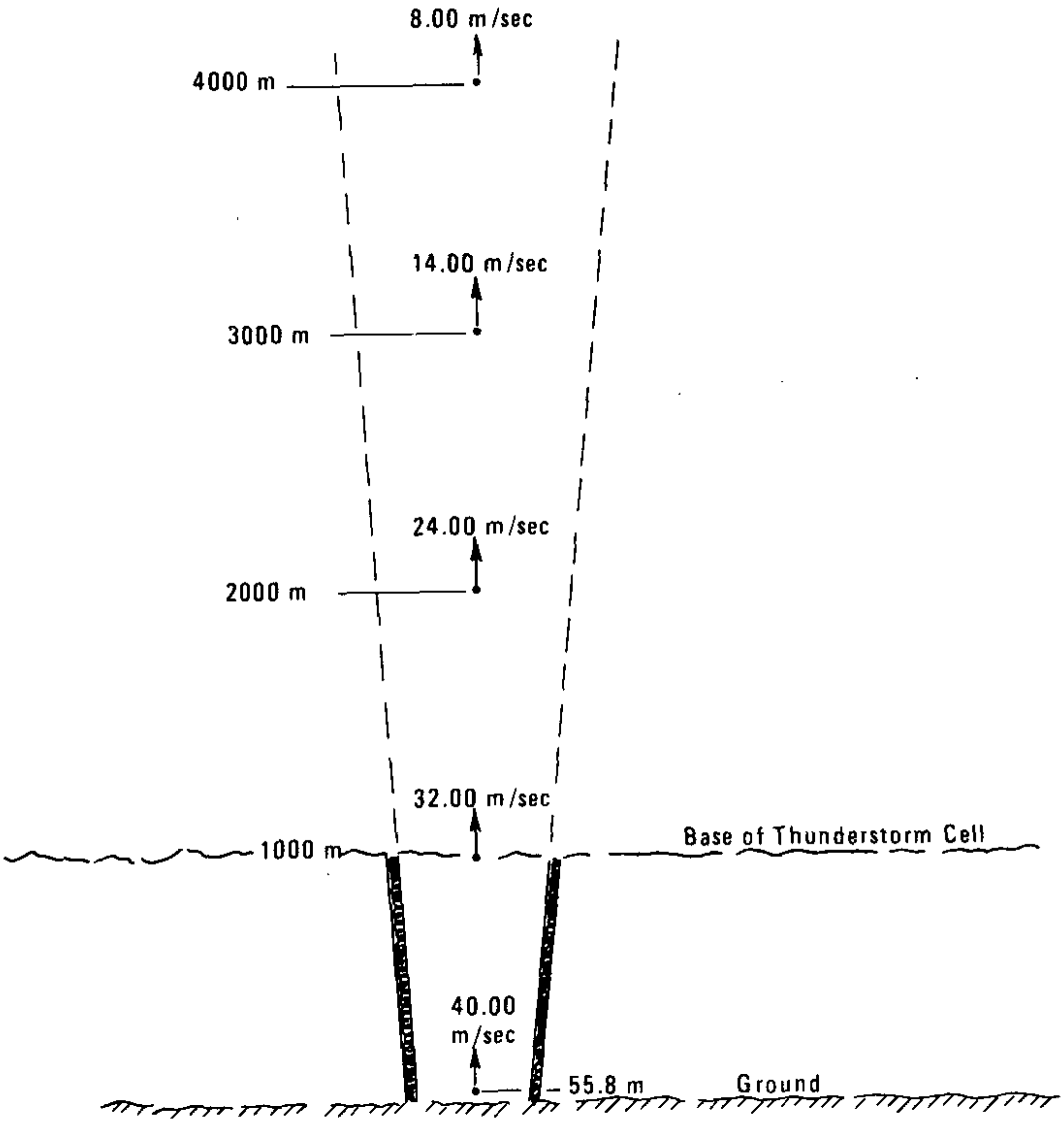

Figure 2. Variation of Vertical Velocity Within the Core of the Design Basis tornado

The distribution of vertical winds in the tornadic storm cell is shown in Figure 3. The updraft and downdraft velocities are both allowed to increase logarithmically to specific heights within the thunderstorm cell and then decrease to zero at the top of the anvil, H. The magnitudes of the vertical wind speeds were chosen to be appropriate for the intensity of the tornadic storms and are comparable to observations and measurements of vertical velocities within severe storms (Browning and Donaldson,[32] Fujita[6]). The horizontal distribution of the vertical velocity field is shown in Figure 4 for the 1000 m level (corresponding to the base of the thunderstorm cell). The vertical distribution of the updraft and downdraft velocities is multiplied by the appropriate horizontal contour values to obtain the vertical component of the wind throughout the cell.

Advection and diffusion of the horizontal distribution of the vertical velocity field (at the 1000 m level of the cloud) enable the updraft and downdraft regions of the storm to be propagated with the trajectory of the storm. The rotational characteristics of the horizontal wind field within the storm cell are similarly progagated with the trajectory of the storm (analogous to the vertical velocity field calculation). The role of the vertical wind distribution tends to keep the pollutant well mixed initially throughout the storm cell. The rotational characteristics of the storm cell, on the other hand, continually shift the pollutant into the rearward and downdraft regions of the storm. This coupling of the two wind fields tends to create a somewhat unrealistic decoupling of the pollutant distribution, i.e., the downdraft velocities act more to bring the pollutant to the ground than keep it well mixed within the storm. Subsequent work on a more accurate velocity distribution within the storm cell may alleviate this characteristic of the present model. As a result of this decoupling effect, pollutant amount and time in reaching the surface is considered to be conservative.

To calculate the eddy diffusivities of air pollutants under the simplest of conditions is a classical problem. Little is known about their behavior except near the earth's surface (Shir and Shieh[33]). A number of empirical relations have been obtained for varying atmospheric stabilities. However, essentially no information is available for eddy diffusivities associated with the highly unstable nature of tornadoes and thunderstorm cells. While some experiments have been conducted on the distribution of chaff in thunderstorms, the data is sparse and the chaff are much larger in size than the plutonium particles considered in this study. Hence the dispersion patterns in chaff could be markedly different than that of plutonium particulates. Since precise formulation of the diffusion coefficients is intractable, a set of empirical parameters is used. Based on the work of Ragland and

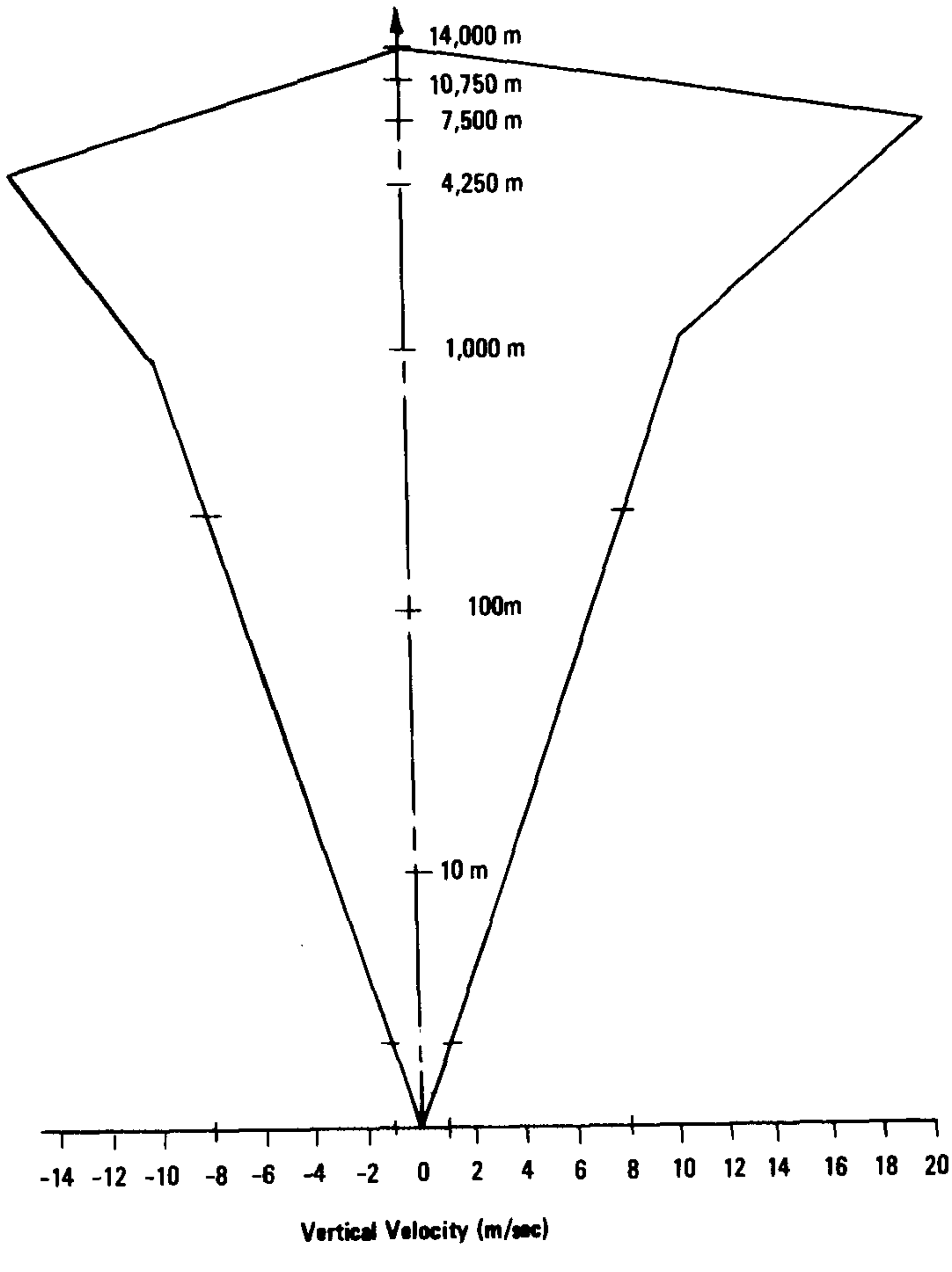

Figure 3. Distribution of Updraft and Downdraft Velocities with Height in the Thunderstorm

Typical Cell Values (m/sec)

-1.0	-3.5	-3.5	-1.0	0.	0.	0.
-3.5	-10.0	-3.5	-1.0	0.	0.	0.
-3.5	-1.0	0.	2.0	0.	0.	0.
-1.0	2.0	3.5	10.0	2.0	0.	0.
0.	1.0	3.0	3.5	3.5	2.0	0.
0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.

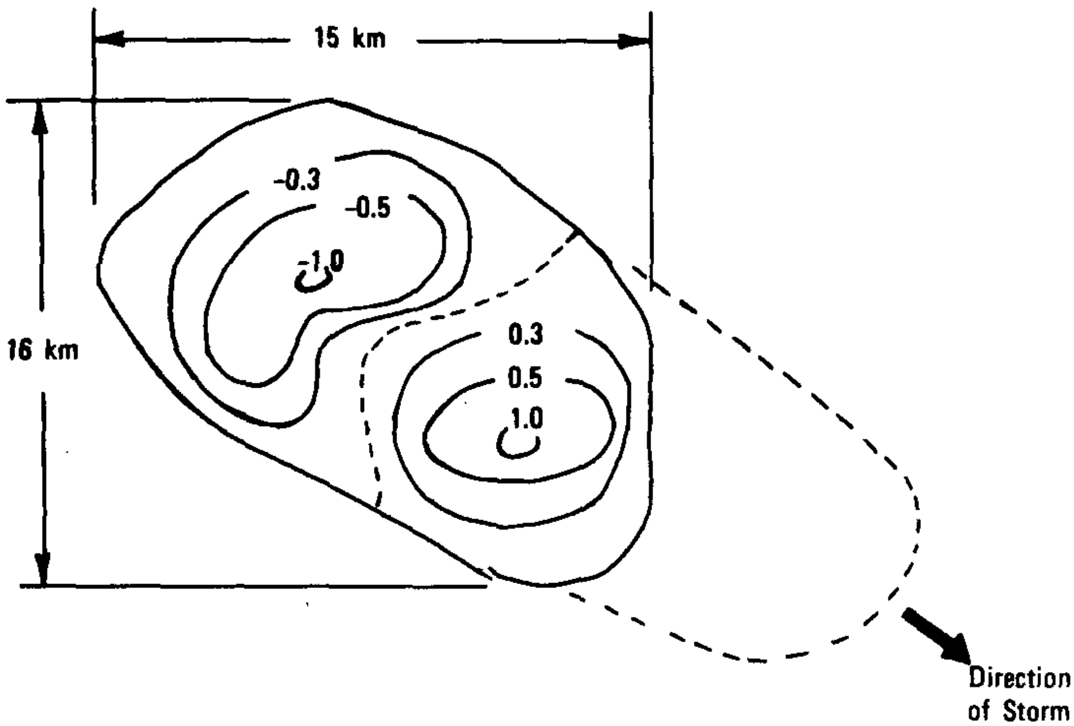

Figure 4. Distribution of Vertical Winds at 1000 m

Dennis[34], Pasquill[10], Crawford*, Pepper[7], Agee[35], Frisch[36], and Hildebrand[37], the following general equation is used to describe the turbulent diffusion coefficients within a thunderstorm cells

$$\hat{K} = \frac{1}{2}\left(\frac{d\sigma^2}{dt}\right) = \sigma\,\frac{d\sigma}{dt} \tag{4}$$

or

$$\hat{K} \cong \frac{\sigma^2}{nt} = G\sigma^{2-n/n}$$

where $\sigma^2 = Gt$ and G has dimension of m^2/sec. In order to account for vertical variation in turbulence intensity, Equation 4 is pre-multiplied by Az^K such that

$$\hat{K} = Az^K C\sigma^{2-n/n} \tag{5}$$

Equation 5 is assumed to be valid for $t < 20$ minutes. Individual values for A, K, C, σ, and n are given in Table 2 to be easily changed. When $t > 20$ minutes, a different set of relations is used to account for the decrease of turbulent intensity following decay of the thunderstorm to very unstable atmospheric conditions. The expressions are:

$$\begin{aligned} K_x &= D(\bar{u}t)^{\alpha}/(2t) \\ K_y &= E(\bar{u}t)^{\alpha}/(2t) \\ K_z &= Fu^* z_0 (z/z_0)^{\beta} \end{aligned} \tag{6}$$

where u is the translational velocity of the storm, t is time, $D = 0.004\ (1-.075\ \log_{10}z)$, $E = 0.0075\ (1-.075\ \log_{10}z)$, $\sigma = 7/4$, $F = 0.41$, $\beta = .45$, z_0 is the surface roughness, u^* is the friction velocity defined by $u^* = 1.2C_gU_g\ (\mathrm{Log}_{10}R_o - 1.8)$, with

* T. V. Crawford, Personnal Communication, 1977.

C_g being the geostrophic drag coefficient, U_g the eostrophic wind, and $R_o = U_g/z_o f$ where f is the coriolis parameter. The empirical constants appearing in Equation 6 were obtained from Ragland and Dennis[34] and Lettau[38] for unstable atmospheric conditions. The effect of topography is not included in the advective wind field analysis,* but is introduced through the diffusion coefficients by the surface roughness parameter, z_o.

Flux boundary conditions are important at z = 0 and z = H. Neglecting resuspension, the surface is assumed to act as an absorber of plutonium particles (whether in the form of rain or dry particulates). When the flux of vertical concentration is set to zero at the surface, the surface acts as a perfect reflector. In order to account for deposition velocities at the surface, the flux at the ground is expressed in terms of a deposition velocity, p (Calder[39]), such that

$$\lim_{z\to 0} [-F(z)] = p \lim_{z\to 0} [C(z)] \tag{7}$$

and

$$\lim_{z\to 0} [K_z \frac{\partial C}{\partial z} + (V_g - p)C(z)] = 0 \tag{8}$$

TABLE 2

Diffusion Coefficient Parameters

K	A	K	C	σ	n
K_x	0.10	0.20	0.16	t	1
K_y	0.10	0.20	3	t	1
K_z	0.60	0.20	$\frac{3600-t}{t}$	1	1

*Topographic effects on pollutant dispersion are discussed in Pepper and Baker[35] and Reynolds, et al.[40]

where v_g is the actual settling velocity. By expressing the flux at the surface in form

$$F = -(1-r)\ K_z \frac{\partial C}{\partial z} \tag{9}$$

where $0 < r < 1$ is the reflection coefficient, Equations 7 through 9 can be combined to give

$$pC \approx v_g C + \left(K_z \frac{\partial C}{\partial z}\right)_{z=0} \approx (1-r)\ K_z \left(\frac{\partial C}{\partial z}\right) \tag{10}$$

Thus, varying the value of r from 0 to 1 will simulate the effect of losses at the surface by deposition (Kao[41]).

The flux at the top of the cloud is set to transport 5 percent of the concentration within that layer to the stratosphere according to the mass balance of a rotating thunderstorm as suggested by Fujita[1]. Figure 5 shows the mass balance of a tornadic storm with 5 percent of the concentration eventually reaching the stratosphere. The remaining 95 percent of the concentration is assumed to be well mixed within the thunderstorm cell. The top of the anvil is assumed to act as a vertical lid. The 5 percent injected into the stratosphere could be advected and diffused globally as fallout with continual entrainment between the tropopause and the stratosphere (Crawford*). Because these dispersion conditions usually have long-term effects spread over very large regions, the 5 percent mass lost out the top of the anvil is considered to have negligible immediate effect on the population.

Scavenging of the plutonium particles may occur by rainout. Based on the work of Slinn[42], the sink term in Equation 1 is written as

$$S = -\ \psi C \tag{11}$$

where the removal rate, ψ, is obtained from the relation (for in-cloud and below-cloud scavenging)

$$\psi = \int_0^\infty dR N(r) \pi R^2 E(a,R) V_t(R) \tag{12}$$

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* T. V. Crawford, Personal Communication, 1977.

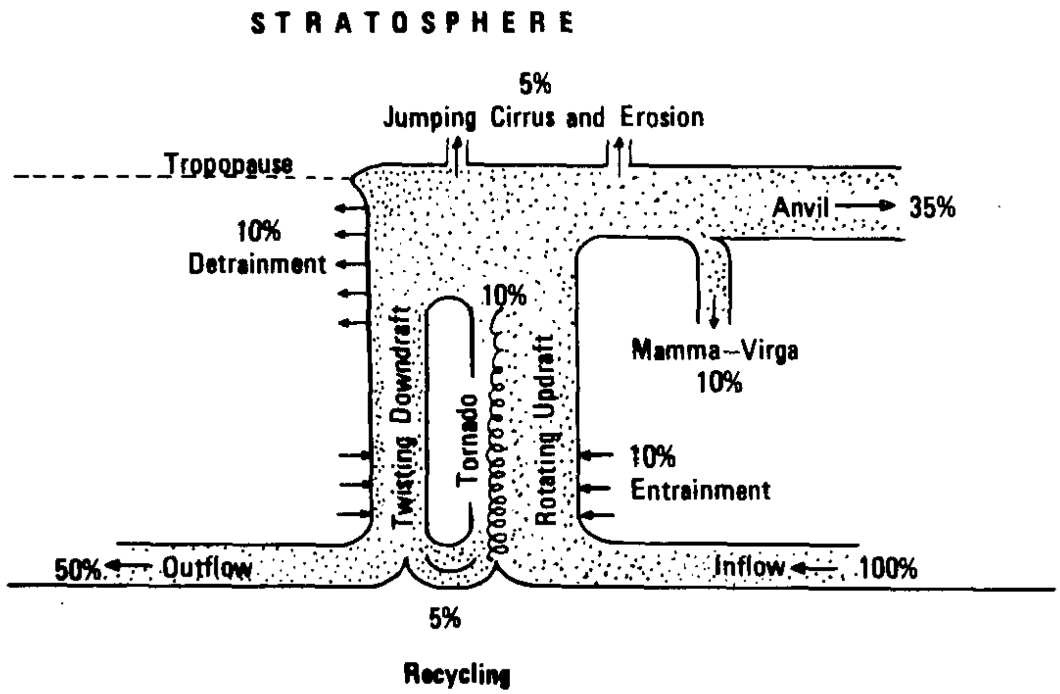


Figure 5. Mass Budget Within a Rotating Thunderstorm

with N(r) being the number distribution function for liquid hydrometers in a cloud, E(a,R) is the collision efficiency, $V_t(R)$ is the drop's terminal velocity, a is the particle radius and R is the droplet radius. In order to simplify the expression for the removal rate, Equation 12 is approximated by the empirical expression

$$\psi \simeq C_1 \frac{J_0}{R_m} E(a,R_m) \tag{13}$$

Where C_1 is an empirical constant which varies from 0.5 to 1.0, J_o is the rainfall rate, R_m is the mean droplet size, E is the collision efficiency (≡1), and a is the radius of the particulate. The relation for Ψ is obtained in part from work by Davis[9], Slinn[4], Dingle[44], and Hane[9]. In order to maintain mass conservation6, in the model, the amount of material scavenged in Equation 11 is added to the surface concentration on the ground (g/m^2).

IV. THE NUMERICAL MODEL

The model developed in this study is based on the solution of the three-dimensional time-dependent equation for pollutant transport as given by Equation 1. Since little is known about the physics of motion in tornadic storms, a great deal of empiricism must be used. In order to accommodate the numerous velocity and diffusion values which exist during the lifetime of a tornado, a numerical model has been developed.

Release of radioactive material into a tornadic storm begins as a small scale dispersion problem which quickly develops into a mesoscale problem. Mesoscale problems normally require solution of three-dimensional equations. In order to keep computer running times and storage to a minimum, mesh spacing intervals are usually increased. However, if the mesh spacing is larger than the dimensions of the pollutant cloud, the mesh spacing is too coarse to accurately resolve steep gradients. Hence, the mesh spacing must either be redefined or subgrid scale monitoring of the concentration be maintained. Although Lagrangian marker particles are very useful in visualizing concentration transport and diffusion, their use is time consuming since the particle sum must be calculated for each cell. A particle-in-cell approach was attempted based on the methods used by Sklarew[45] and Lange[46], but was found to be uneconomical and required excessive core storage.

In order to overcome the problems of numerical dispersion errors and mesh refinement inherent in most numerical schemes, a quasi-Lagrangian technique is coupled with a method which maintains subgrid scale resolution. To further reduce the core requirements needed to solve the three-dimensional equation of concentration transport (and winds), Equation 1 is split into a series of one-dimensional advection-diffusion equations such that

$$\frac{\partial C^*}{\partial t} + u\frac{\partial C}{\partial x} - \frac{\partial}{\partial x}(K_x \frac{\partial C}{\partial x}) = S_x \qquad (14)$$

$$\frac{\partial C^{**}}{\partial t} + v\frac{\partial C^*}{\partial y} - \frac{\partial}{\partial y}(K_y \frac{\partial C^*}{\partial y}) = S_y \qquad (15)$$

$$\frac{\partial C^{n+1}}{\partial t} + w\frac{\partial C^{**}}{\partial z} - \frac{\partial}{\partial z}(K_z \frac{\partial C^{**}}{\partial z}) = S_z \qquad (16)$$

This method involves splitting each individual one-dimensional equation into a Lagrangian advection part plus an Eulerian diffusion part. The method of second moments is used to maintain subgrid scale resolution of the concentration.

The method of second moments is a unique quasi-Lagrangian scheme initially developed by Egan and Mahoney[47] to accurately model the transport of urban pollutants. The method calculates the zeroth, first, and second moments of the concentration within a mesh and then advects and diffuses the concentration by conserving the moments. The moments correspond to the mean concentration, center of mass, and scaled distribution variance (moment of inertia), respectively, and are given by

$$C_m = \int_{-0.5}^{0.5} C(\S_m)d\S \qquad (17)$$

$$F_m = \int_{-0.5}^{0.5} C(\S_m)\S_m d\S/C_m \qquad (18)$$

$$R_m^2 = 12\int_{-0.5}^{0.5} C(\S_m)(\S_m - F_m)^2 d\S/C_m \qquad (19)$$

where subscript m denotes cell location in one-dimensional space, and $\S_m$ denotes the relative displacement of material within the m^{th} cell from the center of the cell. $\S_m$ varies from -0.5 to 0.5 corresponding to the left and right hand extreme boundaries of a cell. The length of the cell is non-dimensionalized by the grid element length (width or height, depending on the direction of the calculation). For simple rectangular concentration distributions (rectangular mesh geometry), the integrals are evaluated by summing the concentration distributions remaining and newly transported into each grid element for each time step. The advection of a single cell of concentration in two dimensions with the Courant numbers ($u\Delta T/\Delta s$) equal to 0.5 is shown in Figure 6. Simple advection tests in one dimension showed that a single cell of concentration could be advected accurately with time without numerical dispersion or computational damping errors. Further test cases with two- and three-dimensional advection of both single and multiple cells of concentration showed no numerical dispersion errors or minimal damping (Pepper and Long[48]). Similar tests with both finite difference and finite element techniques by Long and Pepper[49] showed either 1) severe spreading of the concentration due to computational damping, or 2) generation of wave packets of plus and minus concentration due to numerical dispersion. Since the dispersion of concentration within a tornadic storm is essentially one of advection, the second-moment technique appears to be applicable to the three-dimensional equation of concentration transport. The diffusion of concentration is of secondary importance during the early stages of dispersion within the storm cell; hence a simple, explicit centered difference scheme is used to approximate the second-order gradient transfer terms.

The downwind transfer of concentration by advection depends upon the value of the portioning parameter, P_m, where P_m is defined (Egan and Mahoney[47])

$$P_m = (F_m + \lambda + \frac{R_m}{2} - 0.5)/R_m \tag{20}$$

and λ is the Courant number. If $P_m < 0$, the concentration is not advected into the m + 1 cell. If $P_m > 0$, all of the concentration is advected into the downwind cell. For $0 < P_m < 1$, a fraction of the concentration P_mC_m is advected while $(1 - P_m)C_m$ remains behind. Figure 7 shows the scaling parameters involved in the advection of a rectangular concentration distribution in one dimension during one time step. The center of mass of the distribution is given at $-0.5 + P_mR_m/2$ relative to the center of the m + 1 cell and has a horizontal spread equal to P_mR_m in the new cell. The amount left in cell m has a center of mass at $(1 - R_m + P_mR_m)/2$ with a horizontal spread of $(1 - P_m)R_m$.

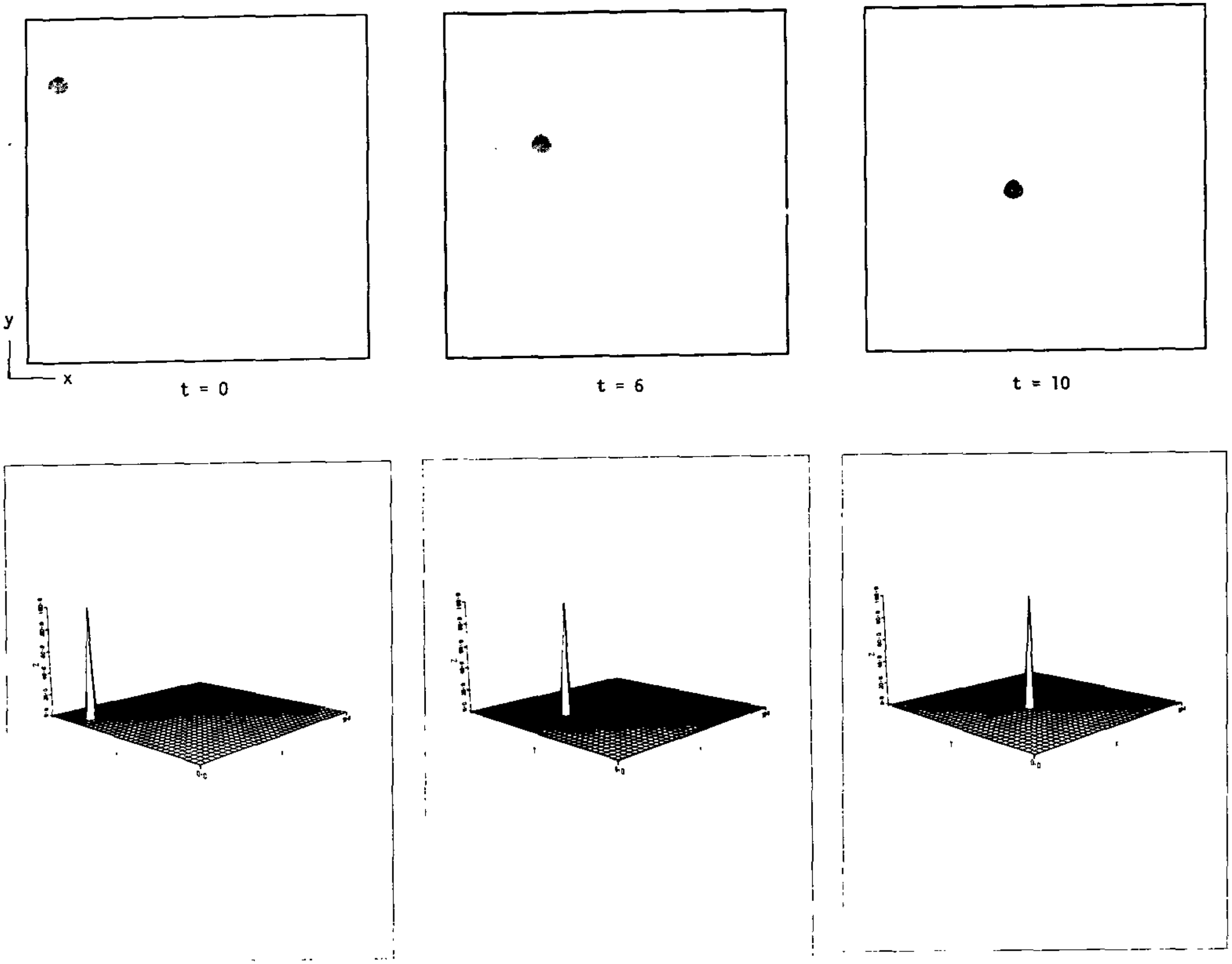


Figure 6. Advection of a Single Cell of Concentration in a Two Dimensional Plane

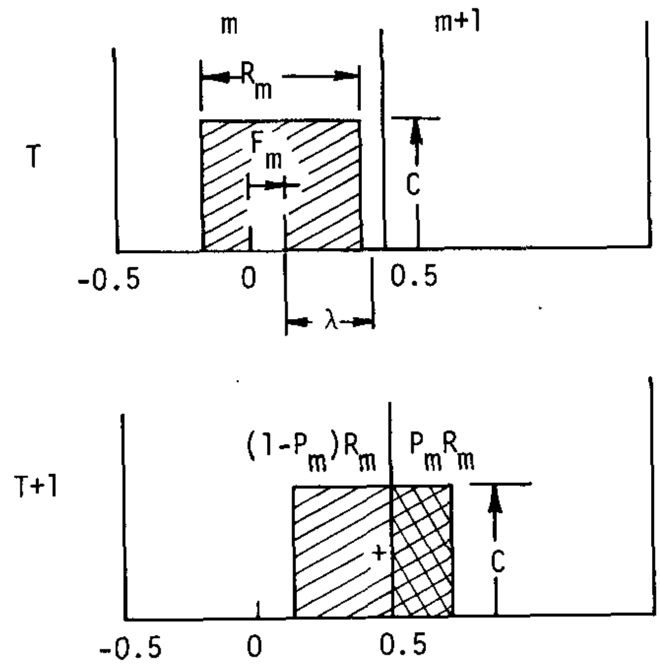


Figure 7. Transport of a Cell of Concentration by Advection During One Time Step Using the Method of Moments

Extension of the method of moments to two and three dimensions is straightforward as based on the rules for the one-dimensional example just discussed (Pepper and Baker[31]). Since the zeroth through second moments are generally evaluated from concentration distributions advected from several adjacent cells in multi-dimensional flow, the computational procedure determines which neighboring cells contribute to the moment calculations and then computes the new values for each cell. Thus the moment distributions are calculated using

$$C^{n+1} = \Sigma C_m \tag{21}$$

$$F^{n+1} = \frac{\Sigma C_m F_m}{C^{n+1}} \tag{22}$$

$$(R_i^{n+1})^2 = \frac{\Sigma\ C^n(\S i)R_i^{n^2}}{C_i^{n+1}} + 12\left[\frac{\Sigma\ C^n(\S i)F_i^{n^2}}{C_i^{n+1}} - \left(\frac{\Sigma\ C^n(\S i)F_i^n}{C_i^{n+1}}\right)^2\right] \tag{23}$$

where n + 1 denotes values at the new time step and m denotes cell location in the computational mesh. Equation 23 is obtained from the modified second-moment algorithms derived by Prahm and Pedersen[51].

The diffusion terms in Equation 1 are solved with a forward-in-time, centered-in-space difference technique modified to account for variable grid spacing. In this study, the horizontal mesh distance was equally spaced while the vertical mesh spacing was varied to account for regions where variables change rapidly with height. The concentration within a cell acted upon by vertical diffusion is calculated by the equation

$$C_k^{n+1} = (1 - \alpha_{k+1} - \alpha_{k-1})\ C_k^n + \alpha_{k+1}\ C_{k+1}^n + \alpha_{k-1}\ C_{k-1}^n \tag{24}$$

where k denotes concentration at the vertical level, k. The horizontal subscripts for x and y directions have been deleted. The values α_{k+1} and α_{k-1} are defined as

$$\alpha_{k+1} = \frac{\left(K_{z_k} + K_{z_{k-1}}\right)\Delta t}{\Delta z_k (\Delta z_k + \Delta z_{k+1})} \quad (25)$$

$$\alpha_{k-1} = \frac{\left(K_{z_k} + K_{z_{k-1}}\right)\Delta t}{\Delta z_k (\Delta z_k + \Delta k_{k-1})} \quad (26)$$

where the diffusion coefficients are evaluated at the center of the grid mesh and Δz_k denotes the depth of the k^{th} grid. At the top and bottom boundary cells, the α's are defined as

$$\left.\begin{aligned} \alpha_{k+1} &= (1 - r_{top})\, \alpha_{k-1} \\ \alpha_{k-1} &= (1 - r_{bottom})\, \alpha_{k+1} \end{aligned}\right\} \quad (27)$$

where r varies between 0 and 1 to account for absorption or loss of material from the grid network (Kao[41]). In order to maintain conservation of the zeroth, first, and second moment distribution following solution of the diffusion terms, the first and second moments are recalculated using the following general relations (for one-dimensional vertical diffusion):

$$\begin{aligned} F_k^{n+1} = \Big[C_k^n F_k^n (1 - \alpha_{k+1} - \alpha_{k-1}) + \alpha_{k+1} C_{k+1}^n + F_{k+1}^n \\ + \alpha_{k-1} C_{k-1}^n F_{k-1}^n \Big] \Big/ C_k^{n+1} \end{aligned} \quad (28)$$

$$\begin{aligned} (R_k^2)^{n+1} = \Big\{ C_k^n \left[(R^2)_k^n + 12(F_k^n - F_k^{n+1})^2 \right] (1 - \alpha_{k+1} - \alpha_{k-1}) \\ + \alpha_{k+1} C_{k+1}^n \left[(R^2)_{k+1}^n + 12(F_{k+1}^n + F_{k+1}^{n+1})^2 \right] \\ + \alpha_{k-1} C_{k-1}^n \Big[(R^2)_{k-1}^n \\ + 12(F_{k-1}^n - F_{k-1}^{n+1})^2 \Big] \Big\} \Big/ C_k^{n+1} \end{aligned} \quad (29)$$

Similar expressions are used for the horizontal and lateral moments as well.

In order to enhance resolution of the peak concentration and prevent inaccurate horizontal spread (due to computational damping), a slightly modified version of the second moment solution is used. Based on the technique developed by Pedersen and Prahm[51], a width correction procedure is used to check the lateral spread of concentration within each cell. If ${R_m}^{n+1}$ is greater than ${F_m}^{n+1} \pm 0.5$, then ${R_m}^{n+1} = \min |{F_m}^{n+1} \pm 0.5|$. This procedure reduces the small amounts of lateral dispersion errors produced when the concentration field is nonuniform and the flow field irregular. An example of the effect of width correction on the second-moment method under variable conditions is given by Pepper and Long[48].

The computational domain consists of 2640 cells, 30 cells in the longitudinal direction (x), 11 cells in the lateral direction (y), and 8 levels in the vertical direction (K). Equal mesh spacing is used inn the horizontal plane with $\Delta x = \Delta y = 2000$ m. The vertical mesh is given as

$$z_1 = 0$$

$$z_2 = 2 \text{ m}$$

$$z_3 = 350 \text{ m}$$

$$z_4 = 1000 \text{ m}$$

$$z_k = z_{k-1} + (H - z_k)/4$$

where the height of the anvil, H, used in this study is 15,000 m. The height of the cloud base above the ground is set to 1000 m, corresponding to z_4. The time step increment, Δt, is equal to 30 sec. This insures the stability criteria, $\lambda < \vec{U}\Delta t/\Delta s$, where $\vec{U}$ and Δs correspond to the particular direction of the velocity vector and grid interval. The translational velocity of the cloud center is prescribed according to the translational speeds of the tornado, given in Table 1.

The magnitudes of the values chosen for the initial distribution of concentration (Figure 3) are based on crude assumptions. A more realistic distribution may be achieved by incorporating the tornado model proposed by Fujita[6] into the existing model and calculating the uptake and injection of the concentration into the thunderstorm cell. Lack of a definitive severe storm model restricts calculation of the concentration once in the thunderstorm. However, additional work could conceivably provide insight into the initial dispersal patterns within the storm.

A modified second-moment technique is again used to advect the updraft and downdraft velocity distribution at the 1000 m level (Figure 4 and Figure 5). The horizontal distribution of vertical velocity is advected and diffused according to parameters established within the three-dimensional concentration code. Incorporation of particulate fall velocities with $v_g = 0.3$ m/sec is added to the vertical velocity field to account for the terminal fall velocity of 10-μ plutonium particles. Within the thunderstorm cell, the terminal velocity of particles ranging from 1 to 10-μ in radius is negligible compared to the updraft and downdraft velocities. If the rainout removal rate is large, particle deposition becomes negligible. Once the storm has passed and scavenging by rainout and washout is over, particulate deposition becomes more significant.

Rain is assumed to fall throughout the lifetime of the thunderstorm cell at a constant rate of 20 mm/hr. This assumption is obtained from the measured rainfall rates of tornadic storms analyzed by Fujita, et al.[52]. Heavier rainfall rates have the effect of increasing the depletion rate, resulting in deposition closer to the site. The 20 mm/hr rate is felt to be the average value over the entire storm area.

The concentration is readjusted for rainout scavenging after calculation of the advection and diffusion terms in Equation 1 by the relation

$$C_k^{n+1} = C_k^n \left[1 - C_1 \Delta t \frac{J_0}{R_m} E\ (a, R_m)\right] \tag{30}$$

where the horizontal indices for the x and y locations of concentration have been deleted. The value of C_1 is equal to 0.5, R_m is the mean droplet diameter of the hydrometers within the cloud and is arbitrarily set, and J_o is equal to 20 mm/hr. The values for C_1 and E are derived by Slinn[53] based on data obtained by Burtsev, et al.,[54] for removal rates in convective storms.

Updrafts markedly reduce the effects of rainout in the forward portions of the storm cell. Ψ is set equal to zero in those regions of the storm where vertical velocities are positive upwards. This allows the rainfall to occur in the trailing edges of the storm, corresponding to the rain core and downdraft regions observed in actual storms. In order for the model to maintain conservation of mass within the computational domain, the decrease in concentration in the upper levels of the thunderstorm cell due to rainout is counterbalanced by an equal increase in the surface concentration below the cloud.

Computer storage is moderate due to the peripheral subroutine used to generate the three-dimensional wind fields and contour displays. Optimization of the basic program would help reduce the core requirements. Simulation of pollutant dispersal over one hour (corresponding to a longitudinal distance of approximately 60 km from the point of initial breachment of the nuclear facility), requires about two minutes of computer time on an IBM-360/195.

Listings of the computer programs have been sent to Oak Ridge National Laboratory, Argonne National Laboratory, and the Nuclear Regulatory Commission. The program is written in FORTRAN IV language for use on an IBM-360/195 computer.

V. RESULTS

Numerous cases were simulated to determine the most likely dispersion patterns as well as potential radiological hazard to the people. The results shown in this study should be regarded as conservative estimates.

Output of the numerical model consists of concentration values specified within individual cell volumes. These values are appropriately adjusted within cell volume to correspond to the spatial dimensions of the cell. Since the amount of radioactive debris picked up by a tornado varies according to the structural damage sustained, a unit release of material has been used to specify the source term. Results are presented as isopleths of ground-level air concentration (ratio of concentration to source mass, X/Q, m^{-3}) and surface deposition (m^{-2}) at $t = 60$ minutes. Centerline ground-level values of air concentration (maximum values) are shown as a function of longitudinal distance along the trajectory of the storm. The isopleths are drawn with respect to distance from the point where the material is initially dispersed within the storm.

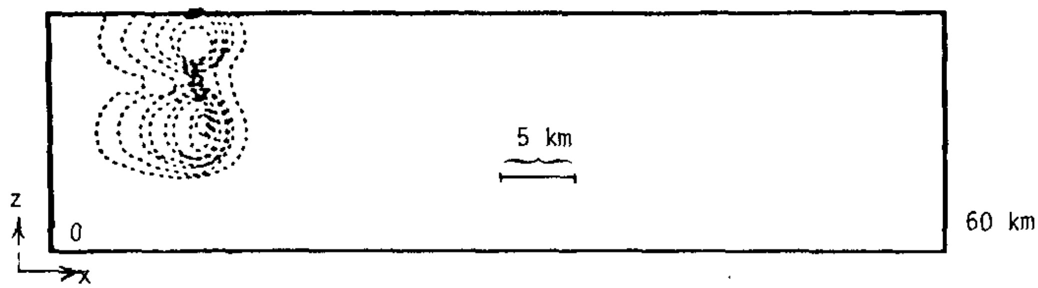
The convergence and divergence of the mesoscale wind field are not considered; therefore, the longitudinal wind transports the storm cell in a straight line. Since the direction of the tornadic storm is arbitrary, direction is independent of points of the compass. Similarly, since dispersion is a function of translational windspeed, the translational velocities are input into the model corresponding to each design-basis tornado. Lateral dispersion along the trajectory of the storm is due primarily to the horizontal extent of the downdraft region (and rotational wind field) in the rear of the storm with minor influence from horizontal diffusion. Scavenging acts to dilute the concentration in the cloud so that ground-level air concentrations are less than those obtained without scavenging.

The initial air concentration distribution (X/Q) is shown in Figure 8a in the x-z plane with the center of the plane passing through the axis of the tornado (t = 0). Figures 8b and 8c show air concentration (m^{-3}) isopleths for $\vec{U}$ = 13.4 m/sec in the x-z plane at t = 5 and 40 min, respectively. Figure 9 shows ground-level air concentration in the x-y plane at t = 40 min.

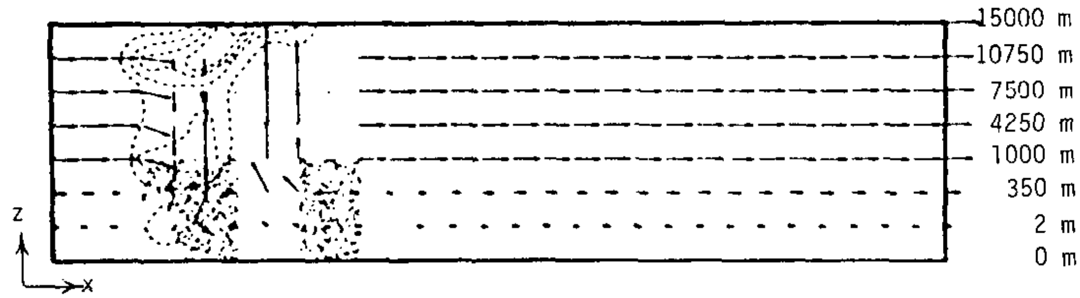
Ground-level centerline X/Q values are shown in Figures 10 and 11 for each specific translational velocity. The displacement of concentration as a function of translational velocity is evident. In all three cases, 90% of the peak air concentration has reached ground-level within one hour after initial dispersion within the cloud (20 min after uptake of the pollutant). The decrease of X/Q values beginning at X = 20 km in Figure 11 is due to the depletion of concentration from the cloud (except that part transported to the anvil region) and to nearly complete diffusion of the concentration below the cloud base to the ground.

Isopleths of air concentration at ground level for t = 60 min are shown in Figure 12 corresponding to storm translational velocities of $\vec{U}$ = 13.4, 19.2, and 25.0 m/sec, respectively. The irregularity in the isopleth contours is due primarily to the advection and diffusion of the concentration by the updraft/downdraft regions and rainout removal rate of the storm with time. The ground-level layer consists of unit cells with dimensions of 2000 m x 2000 m x 2 m. Figure 12 shows that as the translational velocty of the storm increases, the lateral spread of air concentration is stretched downwind. Higher peak concentrations appear less displaced to the right for the tornadic storm with a translational velocity of 13.4 m/sec than with the succeeding two velocities. However, once beyond the initial peak concentration area, downwind values of ground-level air concentration are less than values obtained for $\vec{U}$ = 19.2 and 25.0 m/sec. This is to be expected because the increase in advection causes the peak concentration values to be more displaced in the longitudinal direction. Similarly, the slower the translational velocity, the more effects turbulent diffusion, vertical advection, and rainout have to act on the airborne concentration.

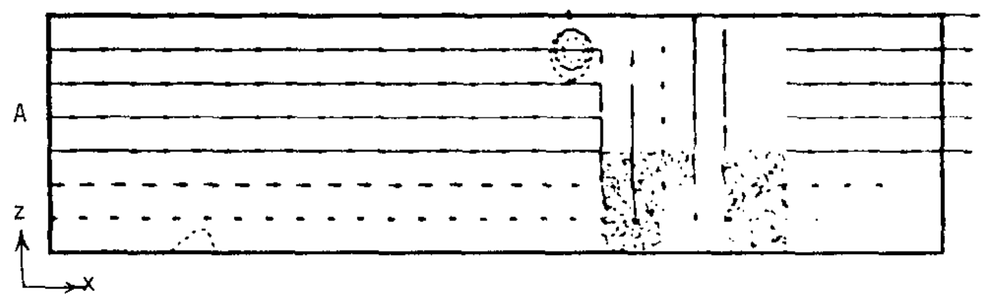
In test cases run without the influence of updrafts, downdrafts, and scavenging, the air concentration eventually reached ground after six hours, but was several orders of magnitude less in value. If the storm moves at 25 m/sec for six hours, deposition at the surface would begin approximately 540 km from the plant. However, studies made by Davis[8], Hane[9] and Jessup[10] indicate that it would be unlikely for the pollutant to remain entirely with-in a storm cell for several hours without vertical wind shear and scavenging bringing a fraction of the pollutant to the surface.



a. Initial skewed log-normal distribution



b. Air concentration at t = 5 min (particles represent rain)



c. Air concentration at t = 40 min

Figure 8. Air Concentration in the X-Z Plane (Center of Plane Passing Through Axis of Tornado)

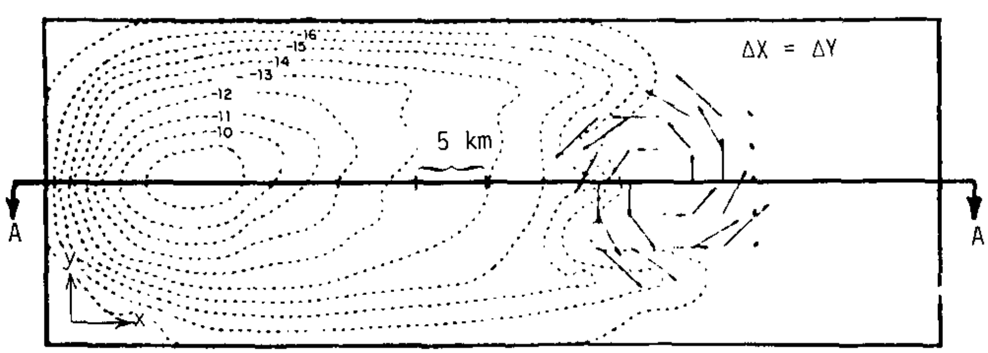


Figure 9. Ground Level Air Concentration in the X-Y Plane (T = 40 min) (Rotational Winds Represent Tornadic Storm)

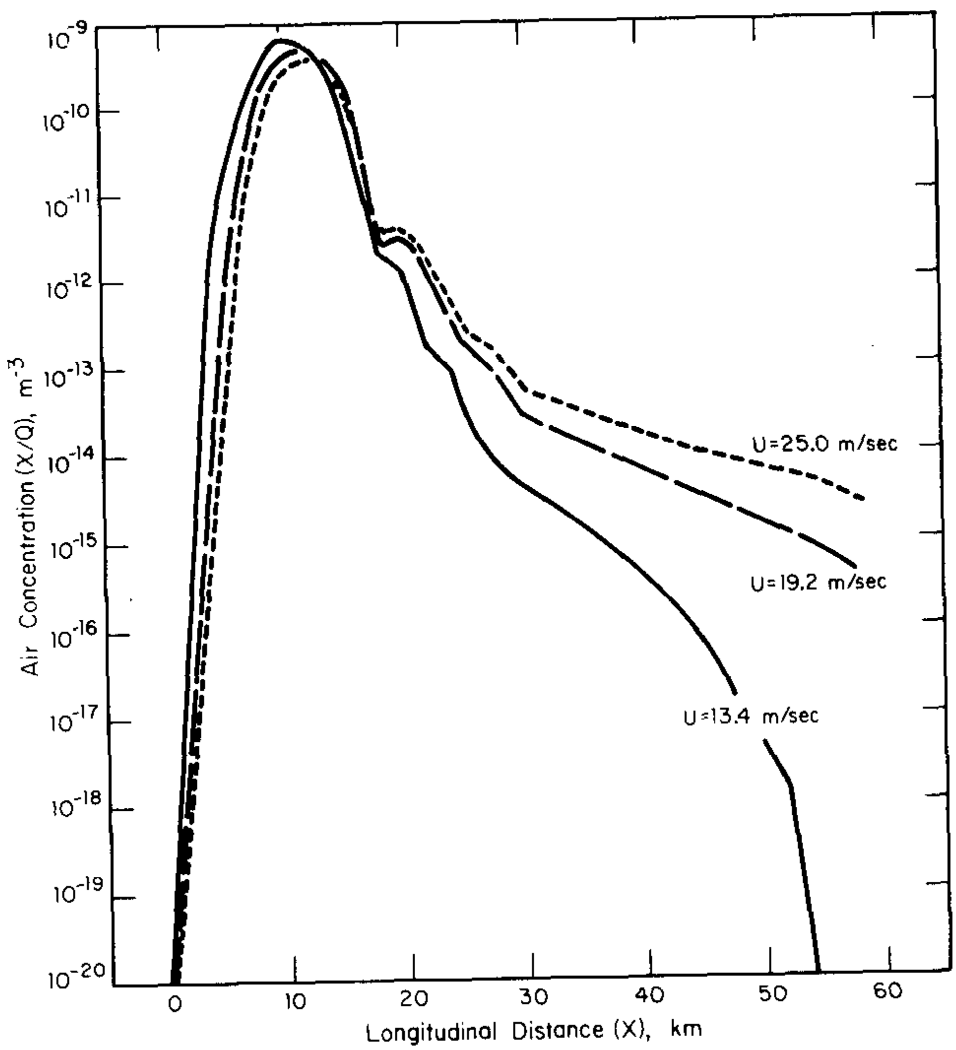


Figure 10. Maximum Ground-Level Centerline Air Concentration from Initialization Point in Storm

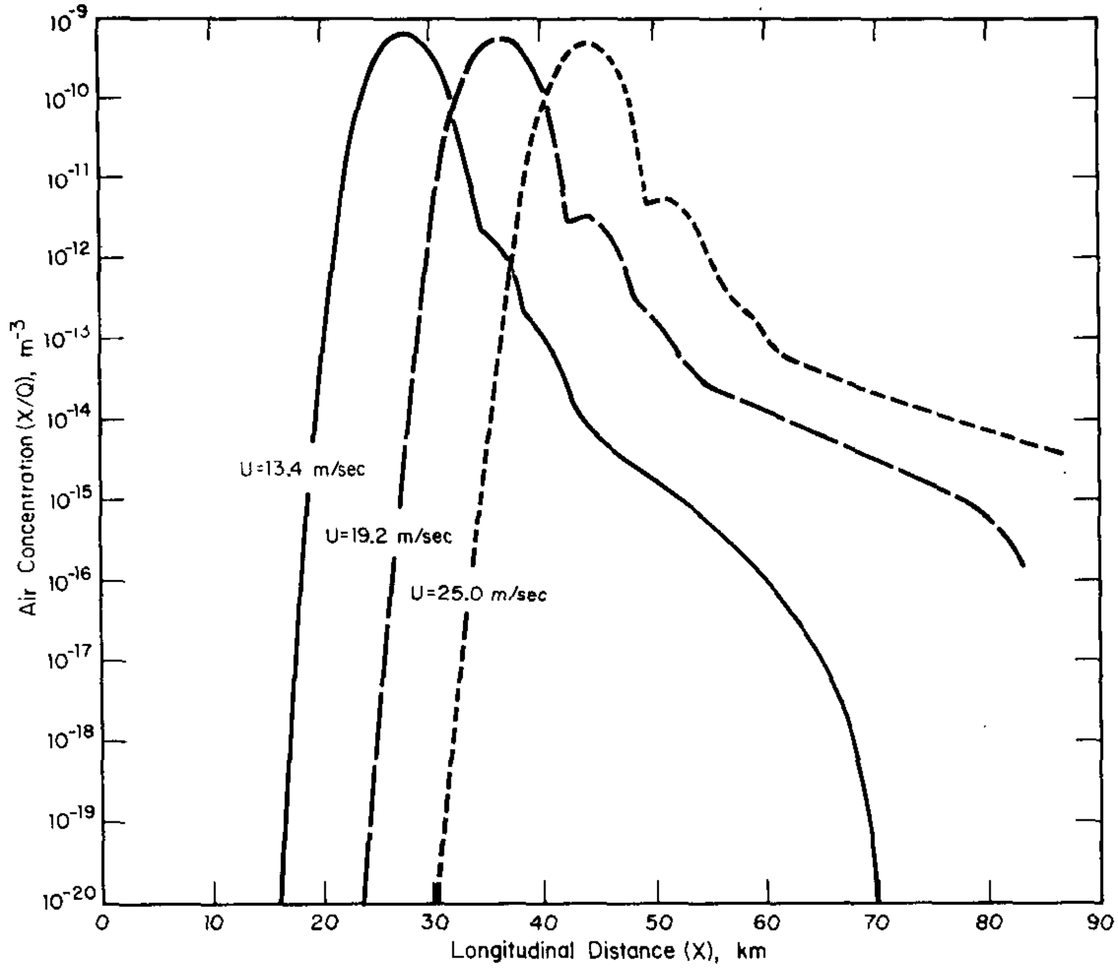
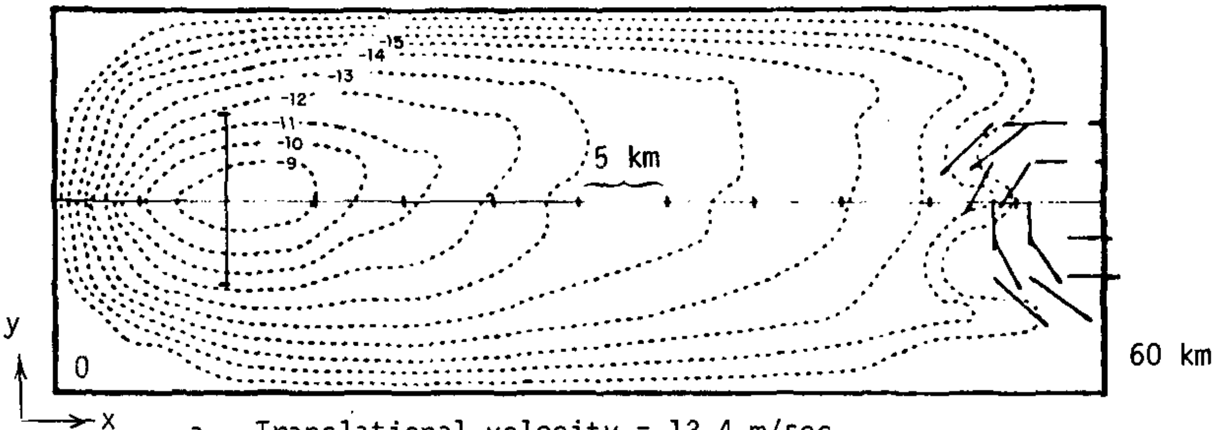
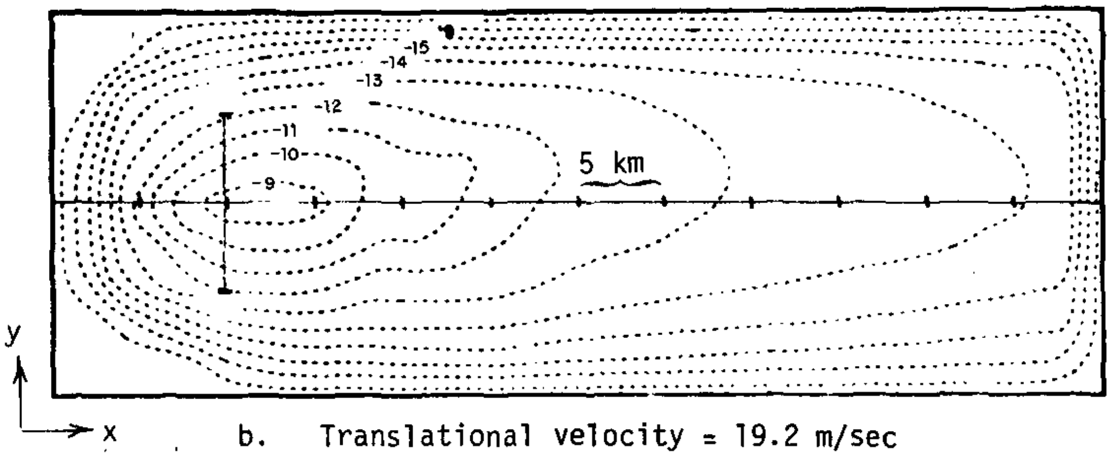


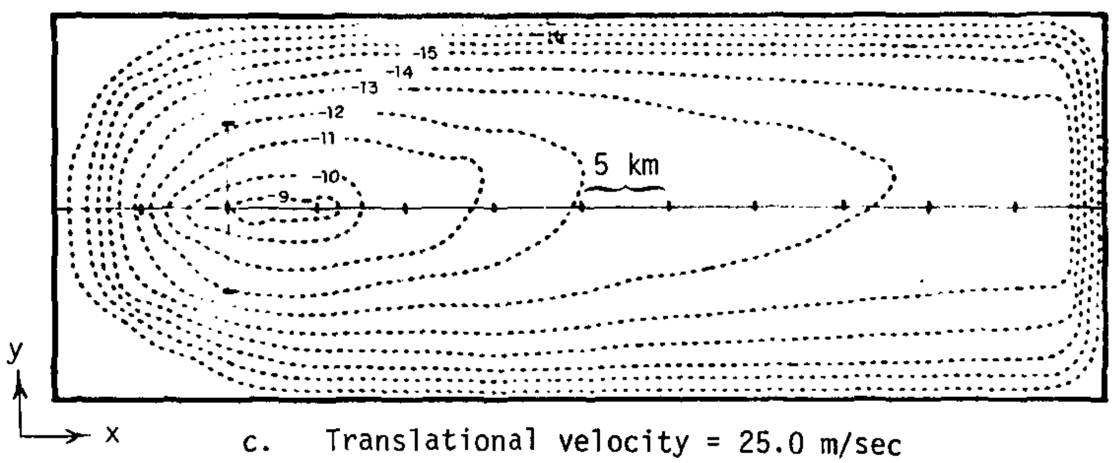
Figure 11. Maximum Ground-Level Centerline Air Concentration from Plant Site



a. Translational velocity = 13.4 m/sec
(rotational winds represent tornadic storms)



b. Translational velocity = 19.2 m/sec



c. Translational velocity = 25.0 m/sec

Figure 12. Ground-Level Air Concentration Isolog Plots (m^{-3}) in the X-Y Plane (T = 60 min)

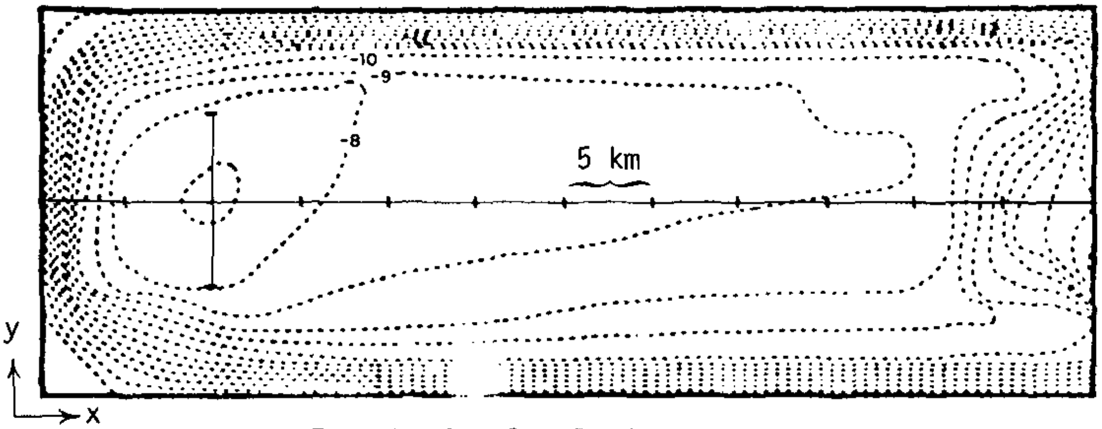
Ground-level raindrop depositions (m^{-2}) are shown in Figure 13 for $\vec{U}$ = 13.4, 19.2, and 25.0 m/sec, respectively. The effect of advection on air concentration is also evident on ground-level deposition: the highest peak values are obtained when $\vec{U}$ = 13.4 m/sec with the peak region being nearest to the initial dispersion point in the cloud; subsequent downwind values are less in value than the succeeding cases with $\vec{U}$ = 19.2 and 25.0 m/sec. The increase in translational velocity causes the region of peak concentration to be shifted along the direction of the storm.

Based on the test cases analyzed in this study, early deposition of concentration occurs within 10 to 20 min after the initial dispersion of concentration within the storm cell. The primary mechanisms for concentration reaching the surface come from the effect of the downdraft vertical velocity distribution and wet deposition. In all cases, 50% of the initial concentration, except that portion lifted into the anvil region of the cloud, is removed from the cloud within 15 min from the time of initial dispersion within the storm. The maximum ground-level concentration, in all cases occurs within about 35 min of ground-level injection.

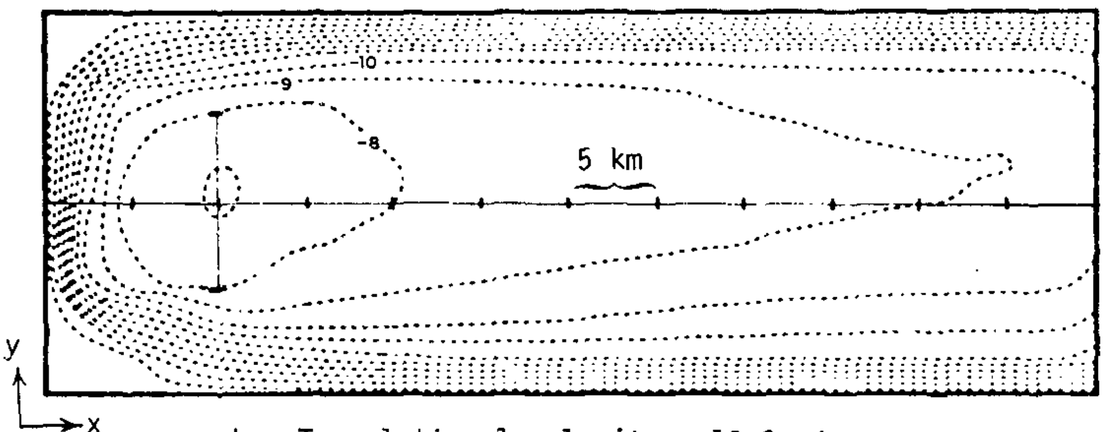
Maximum centerline air concentration values reveal that peak concentration at the surface occurs within 15 km from the point where the initial dispersion within the storm is established (Figure 11). The concentration is essentially removed from the lower and middle layers of the cloud within 50 km of the peak ground-level value.

The modified Gaussian puff tornado model developed by Pepper[7] was also used to calculate ground-level concentration and lateral spreading ($2\sigma_y$) of radioactive debris. Figure 14 shows the results of the Gaussian puff centerline values. The peak value occurs closer to the nuclear facility than that predicted by the numerical model. In these tests, the pollutant was diffused from a height of 6,500 m with an initial vertical distribution of 12,000 m (σz_o) and a lateral distribution of 5,000 m (σy_o). These initial standard deviations were chosen to represent the material being dispersed within the thunderstorm cell. Calculation of the turbulent diffusion parameters (standard deviations) were based on a turbulent energy dissipation rate equal to 1 m^2/sec^3. Such values of energy dissipation rates are typical of the atmosphere associated with severe storms (Agee[35], Frisch and Strauch[36]).

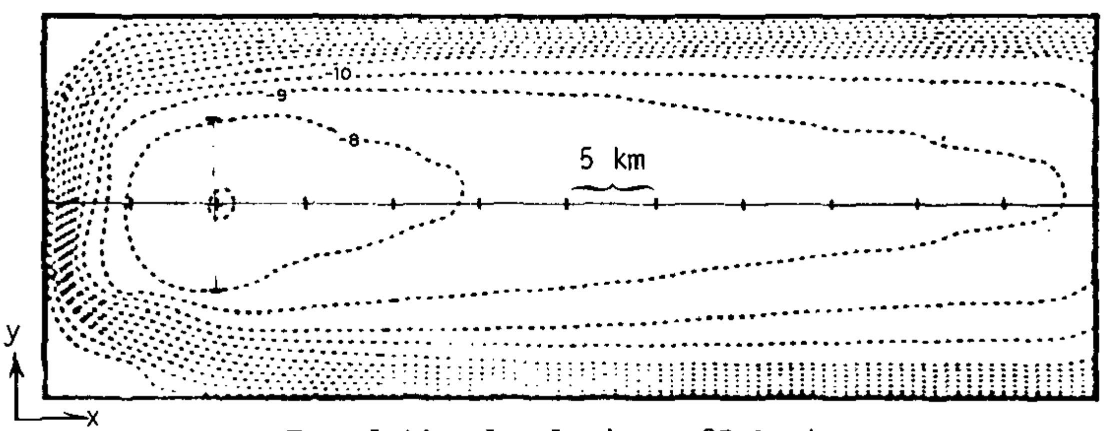
The Gaussian puff model predicts ground-level concentration values that are several orders of magnitude less than those predicted by the numerical model. Similarly, the lateral spread of concentration at ground-level (distances obtained at $\pm 2\sigma y$ from the center of the puff) is significantly greater than that predicted by the numerical model. These rather small values of ground-level concentration are due primarily to the initial height at which the



a. Translational velocity = 13.4 m/sec



b. Translational velocity = 19.2 m/sec



c. Translational velocity = 25.0 m/sec

Figure 13. Ground-Level Deposition Isolog Plots (m^{-2}) in the X-Y Plane (T = 60 min)

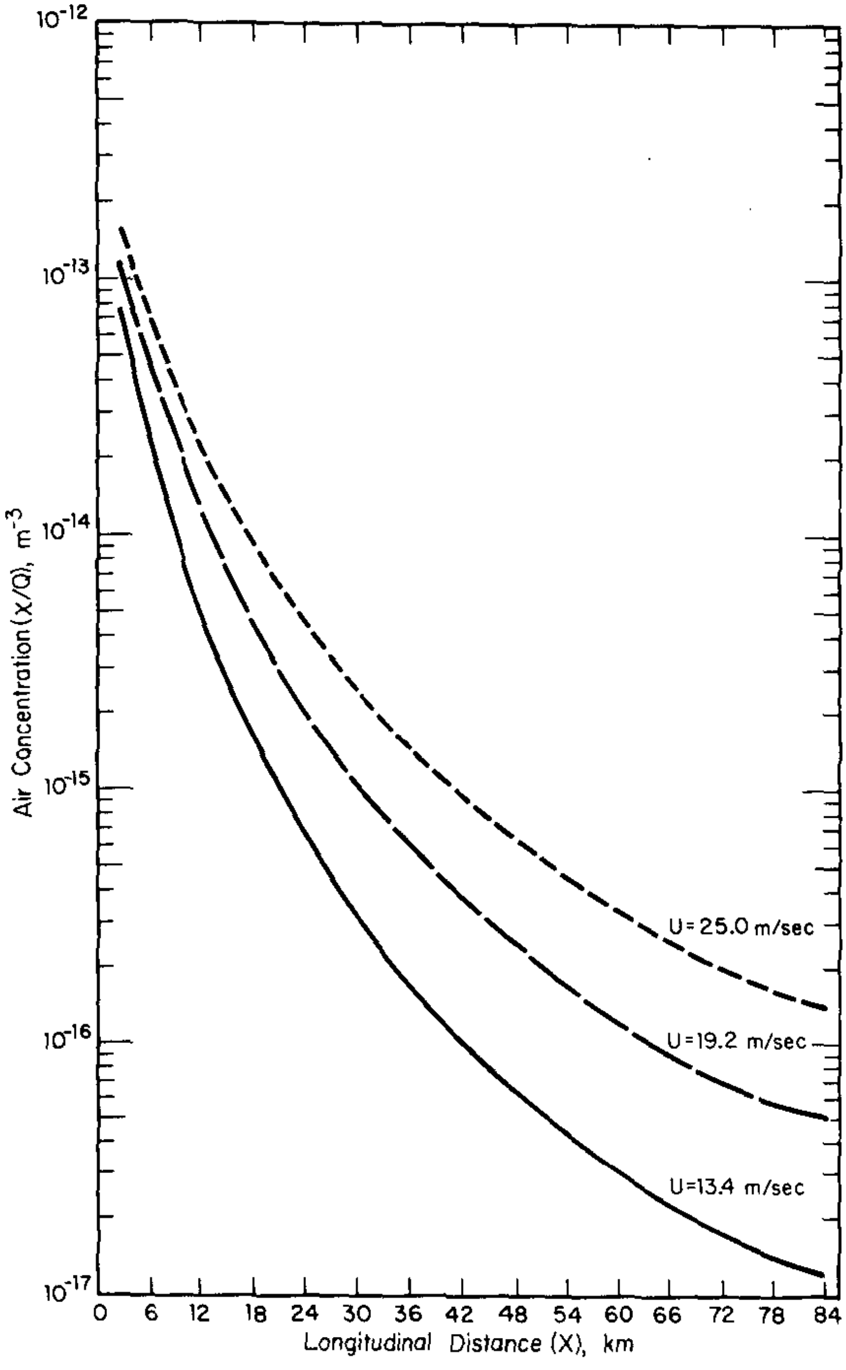


Figure 14. Maximum-Ground Level Centerline Air Concentration (m^{-3}) - Modified Gaussian Model

Gaussian model begins to diffuse the concentration, and to the high energy dissipation rate used to generate the diffusion parameters. A modified Gaussian model to include the effects of scavenging and topography (Kao[41]) was also developed and the results compared to the Gaussian puff model developed by Pepper[7]. Only slight improvement was obtained in accounting for more rapid diffusion to the ground.

Figure 15 shows concentric annuli from the initial cloud dispersion point with radii of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, and 40 miles in 22.5° sectors overlaid on the x-y grid network. Average air concentration and deposition values after 60 min are given in Tables 3 and 4 corresponding to sector-averaged ground-level values for each of the three translational velocities, respectively. Since the directional dependence of the storm has been eliminated, sector values for 180 to 360° are considered to be zero. The centerline trajectory of the storm lies between Sectors 4 and 5. Appropriate assignment of the centerline trajectory of the storm to a specific direction (N, NNE, E, etc.), would then give corresponding sector averages based on compass points.

VI. MODEL SENSITIVITY

A. Effect of Neglecting Diffusion

Most dispersion models neglect the effect of longitudinal diffusion since $u\ \partial c/\partial x$ is generally much larger than $\partial/\partial x\ (K_x \partial_c/\partial_x)$. In these cases where the source strength does not significantly vary with location, the lateral diffusion term is often neglected. The effect of neglecting horizontal dispersion generally increases as the wind velocity increases, with the transport becoming predominantly advection-oriented. When the winds are calm, diffusion becomes the dominant mechanism. However, in regions where the concentration gradients are very steep, horizontal diffusion cannot be neglected (when the concentration is undergoing rapid change).

Severe thunderstorms contain regions of intense updrafts and downdrafts and highly turbulent horizontal winds. Although the storm cell may be steered in a straight line, the storm cell fluid dynamics are very complex, with a continual cascade of turbulent energy from large- to small-scale eddies. It is reasonable to assume that the dispersion within the cloud is essentially advection-dominated. However, as the storm cell dissipates and the winds be come calm, lateral diffusion begins to spread the concentration in the horizontal plane. Tornadic storm cells have been observed to increase horizontally following dissipation of the tornado even though the intensity of the storm cell has decreased (Fujita, et al.[52]). Also, the decay of one storm cell has been known to be followed by generation of a new storm cell,

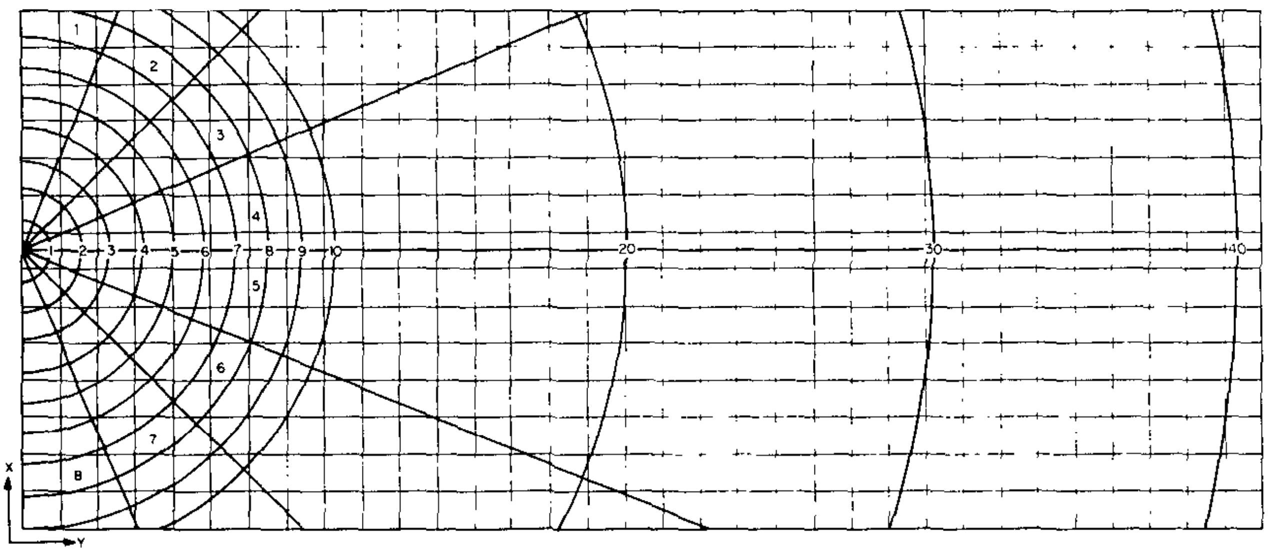


Figure 15. Concentric Annuli in 22.5° Sectors in the X-Y Plane

TABLE 3

Average Sector Air Concentration (m^{-3}) at Ground Level*

TRANS VEL = 13.4

Sector → 1	2	3	4	5	6	7	8	Radius, mile
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
0.0	7.3E-19	8.0E-18	2.4E-16	2.4E-16	4.7E-18	4.2E-19	0.0	2
0.0	7.1E-18	1.1E-15	3.5E-13	3.5E-13	1.2E-15	3.3E-18	0.0	3
0.0	4.0E-16	1.2E-14	7.7E-12	8.0E-12	1.3E-14	4.0E-16	6.7E-21	4
0.0	9.0E-17	2.0E-13	5.7E-11	5.8E-11	3.0E-13	1.7E-16	1.5E-20	5
0.0	5.6E-18	6.9E-14	1.4E-10	1.6E-10	9.4E-14	1.8E-16	0.0	6
0.0	0.0	9.5E-14	2.9E-10	3.4E-10	1.7E-13	7.6E-19	0.0	7
0.0	2.8E-20	3.2E-14	2.7E-10	3.5E-10	8.7E-14	6.5E-19	0.0	8
0.0	0.0	2.0E-15	1.6E-10	2.7E-10	2.3E-14	0.0	0.0	9
0.0	0.0	1.1E-15	8.5E-11	1.5E-10	1.8E-14	0.0	0.0	10
0.0	0.0	9.4E-17	1.2E-11	5.7E-11	2.4E-15	0.0	0.0	20
0.0	0.0	0.0	1.2E-14	4.0E-14	0.0	0.0	0.0	30
0.0	0.0	0.0	1.8E-17	1.1E-16	0.0	0.0	0.0	40

TRANS VEL = 19.2

Sector → 1	2	3	4	5	6	7	8	Radius, mile
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
0.0	1.1E-19	1.2E-18	2.2E-18	2.1E-18	8.1E-19	7.4E-20	0.0	2
0.0	1.1E-18	2.2E-16	5.8E-15	5.8E-15	2.3E-16	6.4E-19	0.0	3
0.0	9.4E-17	2.5E-15	1.1E-12	1.1E-12	2.7E-15	1.0E-16	2.1E-21	4
0.0	2.1E-17	1.3E-14	1.4E-11	1.4E-11	1.7E-14	4.6E-17	4.6E-21	5
0.0	1.4E-18	2.5E-14	4.1E-11	4.3E-11	2.8E-14	7.1E-17	0.0	6
0.0	0.0	4.6E-14	1.5E-10	1.6E-10	6.0E-14	3.0E-19	0.0	7
0.0	7.5E-21	2.2E-14	1.6E-10	2.0E-10	3.5E-14	4.5E-19	0.0	8
0.0	0.0	1.7E-15	1.6E-10	1.8E-10	9.0E-15	0.0	0.0	9
0.0	0.0	1.1E-15	9.9E-11	1.2E-10	7.5E-15	0.0	0.0	10
0.0	0.0	9.1E-17	4.0E-11	6.7E-11	1.1E-15	0.0	0.0	20
0.0	0.0	0.0	9.6E-14	2.3E-13	0.0	0.0	0.0	30
0.0	0.0	0.0	8.7E-15	1.8E-14	0.0	0.0	0.0	40

TRANS VEL = 25.0

Sector → 1	2	3	4	5	6	7	8	Radius, mile
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
0.0	2.0E-20	2.2E-19	4.6E-19	4.6E-19	2.0E-19	1.8E-20	0.0	2
0.0	1.9E-19	5.8E-17	9.3E-16	9.6E-16	6.6E-17	1.7E-19	0.0	3
0.0	2.4E-17	6.7E-16	2.0E-13	2.0E-13	7.7E-16	3.1E-17	8.5E-22	4
0.0	5.5E-18	4.7E-15	3.8E-12	3.8E-12	5.9E-15	1.5E-17	1.9E-21	5
0.0	5.1E-19	1.1E-14	1.2E-11	1.2E-11	1.4E-14	3.1E-17	0.0	6
0.0	0.0	2.5E-14	7.7E-11	7.7E-11	3.0E-14	1.3E-19	0.0	7
0.0	3.0E-21	1.3E-14	1.2E-10	1.2E-10	1.8E-14	3.2E-19	0.0	8
0.0	0.0	1.2E-15	1.2E-10	1.2E-10	5.1E-15	0.0	0.0	9
0.0	0.0	8.7E-16	8.2E-11	8.5E-11	4.2E-15	0.0	0.0	10
0.0	0.0	8.9E-17	4.9E-11	6.2E-11	7.1E-16	0.0	0.0	20
0.0	0.0	0.0	2.6E-13	4.8E-13	0.0	0.0	0.0	30
0.0	0.0	0.0	3.9E-14	6.5E-14	0.0	0.0	0.0	40

* Values followed by the letter E (for exponent), minus symbol, and two digits indicate the powers of 10 by which the number must be multiplied to obtain the correct value; for example, 7.3E-19 is 7.3×10^{-19}.

TABLE 4

Average Sector Deposition (m^{-2}) at Ground Level*

TRANS VEL = 13.4

Sector → 1	2	3	4	5	6	7	8	Radius, mile
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
0.0	2.9E-13	3.2E-12	1.1E-12	8.8E-13	9.1E-14	8.3E-15	0.0	2
0.0	4.4E-12	4.6E-11	4.0E-10	3.9E-10	3.7E-11	7.0E-14	0.0	3
2.5E-18	4.3E-11	5.5E-10	2.1E-09	2.1E-09	5.1E-10	3.3E-11	1.3E-16	4
5.5E-18	8.5E-12	1.0E-09	6.2E-09	6.3E-09	1.1E-09	1.7E-11	2.9E-16	5
0.0	2.7E-14	9.2E-10	1.1E-08	1.1E-08	1.2E-09	1.1E-11	2.7E-20	6
0.0	3.4E-17	7.3E-10	1.3E-08	1.7E-08	1.4E-09	2.1E-15	0.0	7
0.0	5.7E-17	1.6E-10	7.5E-09	1.4E-08	7.9E-10	3.3E-15	0.0	8
0.0	0.0	5.0E-11	2.9E-09	9.4E-09	5.8E-10	0.0	0.0	9
0.0	0.0	2.5E-11	1.3E-09	5.5E-09	3.6E-10	0.0	0.0	10
0.0	0.0	1.0E-12	4.3E-09	1.4E-08	3.0E-11	0.0	0.0	20
0.0	0.0	0.0	1.3E-09	3.5E-09	0.0	0.0	0.0	30
0.0	0.0	0.0	1.5E-10	5.9E-10	0.0	0.0	0.0	40

TRANS VEL = 19.2

Sector → 1	2	3	4	5	6	7	8	Radius, mile
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
0.0	1.8E-13	1.9E-12	6.2E-13	5.0E-13	4.0E-14	3.7E-15	0.0	2
0.0	2.6E-12	3.3E-11	3.0E-10	2.9E-10	2.7E-11	3.1E-14	0.0	3
4.1E-19	3.1E-11	4.0E-10	1.6E-09	1.6E-09	3.7E-10	2.4E-11	6.3E-17	4
9.1E-19	6.2E-12	7.6E-10	4.8E-09	4.9E-09	8.0E-10	1.2E-11	1.4E-16	5
0.0	7.9E-15	7.7E-10	9.7E-09	9.9E-09	9.3E-10	6.5E-12	0.0	6
0.0	3.9E-18	6.7E-10	1.2E-08	1.5E-08	1.1E-09	5.8E-16	0.0	7
0.0	1.3E-17	1.5E-10	7.9E-09	1.4E-08	4.9E-10	6.9E-16	0.0	8
0.0	0.0	3.5E-11	3.8E-09	9.5E-09	3.0E-10	0.0	0.0	9
0.0	0.0	1.8E-11	2.0E-09	5.4E-09	2.0E-10	0.0	0.0	10
0.0	0.0	8.1E-13	7.9E-09	1.8E-08	1.6E-11	0.0	0.0	20
0.0	0.0	0.0	1.9E-09	4.0E-09	0.0	0.0	0.0	30
0.0	0.0	0.0	6.4E-10	1.4E-09	0.0	0.0	0.0	40

TRANS VEL = 25.0

Sector → 1	2	3	4	5	6	7	8	Radius, mile
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1
0.0	1.5E-13	1.7E-12	4.3E-13	3.3E-13	1.8E-14	1.7E-15	0.0	2
0.0	2.3E-12	2.4E-11	2.1E-10	2.0E-10	1.9E-11	1.5E-14	0.0	3
3.1E-19	2.2E-11	2.8E-10	1.5E-09	1.3E-09	2.6E-10	1.7E-11	3.9E-17	4
6.7E-19	4.4E-12	6.3E-10	4.1E-09	4.2E-09	6.6E-10	9.1E-12	8.6E-17	5
0.0	3.6E-15	6.7E-10	8.2E-09	8.5E-09	7.6E-10	4.9E-12	0.0	6
0.0	9.9E-19	6.0E-10	1.1E-08	1.3E-08	8.3E-10	2.6E-16	0.0	7
0.0	4.1E-18	1.3E-10	7.7E-09	1.2E-08	3.4E-10	2.5E-16	0.0	8
0.0	0.0	2.5E-11	4.2E-09	9.0E-09	1.7E-10	0.0	0.0	9
0.0	0.0	1.3E-11	2.6E-09	5.6E-09	1.2E-10	0.0	0.0	10
0.0	0.0	6.1E-13	1.1E-08	2.0E-08	7.7E-12	0.0	0.0	20
0.0	0.0	0.0	3.2E-09	5.6E-09	0.0	0.0	0.0	30
0.0	0.0	0.0	8.9E-10	1.6E-09	0.0	0.0	0.0	40

* Values followed by the letter E (for exponent), minus symbol, and two digits indicate the powers of 10 by which the number must be multiplied to obtain the correct value; for example, 7.3E-19 is 7.3×10^{-19}.

with ingestion of the pollutant concentration possible in the new cell. If this were to occur, it is assumed that the dimensions of the new thunderstorm cell would define the lateral boundaries of the concentration. Within the thunderstorm cell, the concentration would be continually sheared and dispersed by the winds.

Vertical diffusion is quite sensitive to the atmospheric temperature gradient. Highly unstable conditions create a turbulent flow field which in turn causes the pollutant to be well-mixed in the atmosphere. As the atmosphere becomes stable, the turbulence becomes suppressed, the winds become calm, and the pollutant is generally confined near the surface of the earth under an inversion. Because the tornadic storm is associated with extremely unstable conditions (within the thunderstorm cell), the pollutant is assumed to be well-mixed throughout the vertical extent of the cell. Below the base of the thunderstorm, the atmosphere is also unstable, but to a much lesser extent. In test cases run with only horizontal advection and vertical diffusion, the pollutant began to diffuse below the base of the cloud after two hours, but failed to reach ground level even after six hours. Abnormally high values of k_z did not significantly decrease the amount of time for the pollutant to reach the ground. This indicated that the dominant mechanism of pollutant dispersion was the advection terms. Hence the only way the pollutant could reach the ground in a short length of time was by downdraft and in-cloud scavenging. However, if the storm cell were to quickly dissipate, the vertical diffusion would become more significant as the wind speeds decrease in intensity.

B. Effects of Wind Profiles

The variation of the wind speed with height and magnitude significantly influence the downwind spread and shear of the pollutant cloud. The greater the wind speed, the further the pollutant is advected before settling to the ground. If the wind velocity increases dramatically with height, the concentration becomes sheared and distributed more longitudinally in the direction of the shear. As the wind profile becomes flat and the speed drops, vertical diffusion acts to spread the concentration throughout the mixed layer.

C. Effects of Updrafts and Downdrafts

Significant updrafts and downdrafts of tens of meters per second are known to exist in severe storms. The design basis tornado used in this study is assumed to entrain radioactive particles ranging in size from 1-10 μ into its vortex and then to lift the particles to the base of the storm cell. Once the particles enter the storm cell, the action of the severe updrafts and downdrafts act to disperse the particles throughout the storm cell. The updrafts lift these small particles considerable distances, possibly out the top of the anvil and into the stratosphere. Downdrafts near the rear of the storm cause the pollutant to be dispersed below the storm cell. Test cases were run with and without the vertical wind vectors. Results showed that the concentration remained in the cloud over considerable lengths of time (hours) before turbulent diffusion brought the concentration to the ground. Inclusion of updrafts and downdrafts diluted the concentration in the vertical plane initially, but then began to bring the concentration to the ground much more rapidly.

D. In-Cloud Scavenging (Rainout)

Precipitation-scavenging field experiments by the Illinois State Water Survey and Batelle Northwest Laboratories have shown that scavenging by storms which are greater than 10,000-ft deep deposit a significant fraction of released tracer. However, in the study of dispersion within tornadic storms, the following factors must be considered:

- Is the particulate incorporated entirely into the rain?
- Are there motions in the rain area which are upward (creating scavenging by consideration processes)?
- Does the rain area extend over the entire thunderstorm cell as the tornado and severity of the thunderstorm decrease?

These questions can be answered more accurately when more data becomes available. The present model assumes the concentration is acted upon by rainout and washout scavenging, except for that concentration which is lifted into the anvil (top level of the model). In test cases run with and without rainout, inclusion of the rainout sink term in the governing equations significantly added to early deposition of the radioactive particulate on the ground. Coupling of this effect with the effect of downdraft velocities within the storm account for earlier deposition than with downdraft velocities alone. The magnitude of the rainfall rate and mean droplet diameter determine the rainout removal rate. Under actual conditions, the rainfall rates vary throughout the lifetime of the storm and are more intense in some areas than in others. This in turn ultimately affects the deposition patterns on the ground, creating areas of intense concentration beneath the storm.

Since the radioactive material is assumed to be totally entrained within the thunderstorm, scavenging by washout is less significant than rainout scavenging. Should part of the pollutant be thrown out of the vortex below the base of the thunderstorm, washout is likely to contribute to early deposition near the strike point.

E. Height of the Storm

Severe tornadoes are generally associated with large single-cell convective storms with anvil tops reaching as high as 15,000 m or more. A tornadic storm with a 15,000 m top is considered to be typical of storms observed in the vicinity of the Pennsylvania plant site. The heights to which the concentration is initially assumed to reach are critical to the dispersion pattern. The higher the concentration is initally transported, the longer it takes for the concentration to be deposited on the ground. For point sources released at varying heights under less severe atmospheric conditions, downwind ground-level concentrations reach peak levels at greater distances from the initial point of release than those emitted closer to the ground. Turbulent mixing distributes the concentration vertically so that by the time the concentration begins to reach the ground, it has been sufficiently diluted. Evidence of radar signals of tracers in convective clouds indicate that wide-level dispersion occurs almost immediately following injection. The heights to which the concentration is reached in this model is based on estimates made by Fujita* and Carson.** A compact distribution of concentration (puff) near the base of the thunderstorm cell, as used by Pepper[7], could cause the concentration to be more quickly deposited near a nuclear facility in higher amounts.

F. Effect of Topography (Surface Roughness Length)

The influence of topography on a velocity vector field is well known from elementary fluid dynamics. In regions where the terrain is irregular, the flow fields converge and diverge in an effort to conform to the boundary shape of the terrain. Atmospheric flow over hills and mountains creates upward motion and wake-recirculation regions which are downwind of high terrain features. Since the advection of the wind strongly governs the dispersion pattern of concentration in a severe storm, accurate prediction of the wind velocities should give a fairly accurate estimation of the dispersion pattern. In regions where the terrain is essentially flat, classical 'flat plate' boundary layer analysis is usually adequate for determining the wind velocities. When the terrain is irregular, however, the equations of fluid motion must be solved in order to account for the secondary

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* T. T. Fujita, Personal Communication, 1977.

** J. Carson, Personal Communication, 1977.

motions created by the terrain. The effect of topography (surrounding the Pennsylvania plant site) on advection has not been considered in this study. However, the model can be modified to account for terrain by using a grid network with variable mesh spacing (Pepper and Baker[31]). Provided the terrain features are known over the entire surface domain of calculation, and a mass-consistent wind field is generated (which requires reasonably good initial estimates of the three-dimensional flow field within the storm and its surrounding vicinity), the terrain influence on the deposition pattern can be taken into account. Neglect of the irregularity in terrain undoubtedly produces some degree of error in the calculations. As knowledge of the correlation between terrain feature and air flow patterns in severe storms improves, this effect can be more accurately modeled.

Topography also influences the degree of turbulence intensity which acts on the diffusion parameters in the atmosphere. Little is known about turbulent diffusion in severe storms, and even less about the effect of terrain on dispersion during severe storms. In order to account for the influence of terrain on the vertical diffusion coefficient, K_z, an empirical relation has been used which incorporates a surface roughness parameter, z_o. Turbulent diffusion below the base of the thunderstorm cell and near the surface is determined by an extrapolated surface layer of "lay of the wall" formulation which includes z_o. The higher the value of z_o, the more turbulent the diffusion near the surface. This empirical relation coupled with an additional relation for K_z above the surface layer allows the influence of surface roughness (or topography) to be propogated with height to the base of the thunderstorm cell. The intensity of turbulence within the thunderstorm cell is felt to be significantly greater than that below the cloud base. Hence the influence of terrain on dispersion within the thunderstorm cell is considered to be negligible.

VII. CONCLUSIONS

A three-dimensional numerical model is used to calculate the dispersion of small particles in a tornadic storm. The model is designed to allow various meteorological parameters to be updated as more precise information becomes available. The three-dimensional transient equation of concentration transport is solved by a quasi-Lagrangian method of second moments in an Eulerian mesh centered over the assumed trajectory of the storm.

The horizontal wind field varies with height over the one-hour period after the facility is breached. The updrafts and downdrafts associated with the tornadic storm are calculated from initial empirical estimates and then advected with the storm. The horizontal rotational wind field within the storm cell is also advected with the vertical velocity field. As the storm cell spreads horizontally, the wind field within the storm cell spreads accordingly.

Because of the lack of precise information regarding turbulence within severe storms, the turbulence diffusion coefficients are obtained from empirical estimates. These estimates are based on data measured within storms, theoretical equations appearing in the literature, and discussions with noted authorities on turbulence diffusion.

Scavenging is calculated as a sink term in the governing equation. Rainout scavenging acts on small particles within the cloud. However, limited knowledge of scavenging in severe storms necessitates the use of a simple general expression based on rainfall rates, droplet size, and 100% collision efficiency. Washout scavenging below the cloud base is not considered because of the high values of downdraft velocities associated with the storm. The effect of droplet evaporation is also neglected.

The effect of topography downwind of the plant is introduced through specification of roughness heights used in determining turbulent diffusion below the cloud. The effect of topography on advection is not considered.

The dispersion patterns and total time of uptake within the vortex have not been considered. However, the recent appearance of an engineering design-basis tornado model provides the three-dimensional wind patterns surrounding the vortex. Inclusion of this model with the dispersion model should allow the trajectories and dispersion patterns of material to be calculated immediately following ground-level uptake. In this study the pollutant is assumed to be dispersed throughout the thunderstorm cell in a skewed log-normal distribution with the maximum value centered on the axis of the tornado. The material is allowed to disperse for 20 min before rainout contributes to the deposition. About 35% of the material is assumed to be dispersed within the upper regions of the cloud, 15% within the middle section of the storm, and 50% within the lower layers and cloud base of the storm.

The updraft and downdraft vertical velocity distributions and wet deposition account for most of the material being deposited at the surface one hour after initial uptake of the material. Scavenging accounts for about 50% of the particle removal from the cloud within 15 min (following the initial 20 min).

In test cases without the inclusion of rainout and updrafts and downdrafts, the material diffuses to the ground after six hours following uptake into the cloud. Since the advection velocities dominate the dispersion of the pollutant, the effect of turbulent diffusion between the cloud base and the surface are not significant until the storm cell has traveled some distance. Although rainfall rates and droplet diameters vary during the life of the storm, a constant rainfall rate of 20 mm/hr and a mean droplet diameter of 1 mm were chosen as ensemble averages in order to simplify the complexity of input data. Once the pollutant is completely dispersed within the thunderstorm cell, capture of the particulates by rain drops begins immediately with 100 percent efficiency. The deposition of concentration at the surface consists primarily of plutonium particles suspended within waterdrops. As additional information on rainfall rates and velocities in tornadic storms becomes available, deposition will likely become highly nonuniform.

Ground-level air concentration begins to reach the surface within 5 min. Results show that ground-level concentrations begin occurring within 20 to 45 km from the plant site. Peak centerline concentrations occur within 15 km of the point of initial dispersion within the cloud. The concentration decreases significantly with distance after peak-ground level values are reached. The lateral spread of ground-level concentration is principally governed by the size of the thunderstorm cell directly overhead. Downdrafts and scavenging have more influence on bringing the concentration directly from the storm cell to the surface than turbulent diffusion. Shearing of the pollutant cloud occurs in the upper level of the storm cell. Concentration reaching the anvil portion of the cloud is advected at a faster velocity than concentration in the lower levels of the storm; 5% of the concentration is advected out of the anvil into the stratosphere.

Results obtained with a modified Gaussian puff model were considered to be low and showed the inflexibility of the analytical solution to account for the transient nature of the vertical wind field. Ground-level X/Q values were several orders of magnitude less than those obtained from the numerical method (within 20 km of the point of initial dispersion in the tornadic storm). Lateral spread of the concentration was significantly greater than that predicted by the three-dimensional numerical model.

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APPENDIX

```
1  //DWPA4336 JOB (8521-93,T4336,L010,C12,C7,CCCC,,1),                    101
1  //               'PEPPER :TCRNADO      ',MSGLEVEL=1                     102
1  /*SETUP        CORE=800K,GTIME=8,LINES=7K                               103
1  //STEP1 EXEC FORTHCLG,GTIME=03,MAP=NCMAP,SOURCE=NCSOURCE,               104
1  //            GOSIZE=800K,FSIZE=400K,                                   105
1  //            PLOT='SYSOUT=(J,,PLOT)',PLIB='SRL.NCAA.CENTUR'            106
1  //FORT.SYSIN DD DISP=SHR,DSN=T4336.EDIT.DATA(TORNADC)                   107
1  //              DD DISP=SHR,DSN=T4336.EDIT.DATA(TORNWIND)               108
1  //              DD DISP=SHR,DSN=T4336.EDIT.DATA(SECTOP)                 201
1  //              DD DISP=SHR,DSN=T4336.EDIT.DATA(SECSIT)                 202
1  //              DD DISP=SHR,DSN=T4336.EDIT.DATA(RANDCT)                 203
1  //              DD DISP=SHR,DSN=T4336.EDIT.DATA(VECTR)                  204
1  //              DD DISP=SHR,DSN=T4336.EDIT.DATA(ISCPTH)                 204
1  //GO.SYSIN DD *                                                         205
9         30        11         8        30.00     26.620      0.00         206
5     1.0      10.0      11.46     20.0      2.00                          207
5     1.0     2000.      2000.      1.0      1.0                           208
3    250.0     250.0      75.0     250.0    175.0                          301
3    .006      .011      .021      .029      .006                          302
3    .02       .038      .069      .058      .02                           303
3    .029      .056      .104      .147      .029                          304
3    .02       .038      .069      .058      .02                           305
3    .006      .011      .021      .029      .006                          306
3    .006      .011      .021      .029      .006                          307
3    .02       .038      .069      .058      .02                           308
3    .029      .056      .104      .147      .029                          401
3    .02       .038      .069      .058      .02                           402
3    .006      .011      .021      .029      .006                          403
8        -4.       -5.      -10.       -1.       10.        5.             404
7       -10.      -15.      -35.        1.       35.       15.             405
7       -15.      -35.     -100.        2.      100.       35.             406
7       -10.      -15.      -35.        1.       35.       15.             407
8        -4.       -5.      -10.       -1.       10.        5.             408
```

```
1  C*********** >>>>>>> THIS IS NAMED TERNACE  <<<<<<<< *******************
1  C      THREE DIMENSIONAL CONCENTRATION PROGRAM USING SECOND MOMENTS FOR
1  C      ADVECTION AND CENTERED DIFFERENCING FOR DIFFUSION
1  C
7        REAL KXX,KYY,KZZ
7        COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7        COMMON/MATRX1/U(30,11,8),V(30,11,8)  ,W(30,11,8 ),C(30,11,8) ,KXX(
6       $        8),KYY(         8),KZZ(         8)
7        COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WDN(8),UH( 9),WK
7        COMMON/KONTUR/NL,VMIN,STEP,LTLE(20),KMCD
7        COMMON/VCTR/TIME,CIN(30,11)
7        CALL GFRBO(9,'PEPPER:DISPERSION IN A TERNACE    $',100)
7        CALL ERRSET(209,566,-1,1)
7        NSTOP=121
7        NITER=0
7        CALL CLEAR(CIN,330)
7        CALL INIT
7        CALL INITU
7        CALL INITV
7        CALL INITW
7        DO 5 II=1,NSTOP
7        TIME=DT*NITER
7        IF(NITER.EQ.0)GO TO 8
7        CALL WINDS
7        CALL ADVEC
7        CALL DIFFUS
7        DO 3 I=1,30
7        DO 3 J=1,11
7        CIN(I,J)=CIN(I,J)+C(I,J,1)*DT
5      3 CONTINUE
7        IF(NITER.EQ.5)CALL PRINT1
5      8 IF(NITER/20.EQ.NITER/20.)CALL PRINT1
1  C     CALL PRINT2
7        IF(RR.GT.0.)CALL PRINT3
7        NITER=NITER+1
5      5 CONTINUE
7        CALL DONEPL(0)
7        STOP
7        END
7        SUBROUTINE INIT
7        REAL KXX,KYY,KZZ
7        COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7        COMMON/MATRX1/U(30,11,8),V(30,11,8)  ,W(30,11,8 ),C(30,11,8) ,KXX(
6       $        8),KYY(         8),KZZ(         8)
7        COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WDN(8),UH( 9),WK
7        COMMON/VAR2/RTX(30,11,8) ,RTY(30,11,8) ,FTX(30,11,8) ,FTY(30,11,
6       $ 8),RTZ(30,11,8) ,FTZ(30,11,8)
7        COMMON/VCTR/TIME,CIN(30,11)
7        COMMON/KONTUR/NL,VMIN,STEP,LTLE(20),KMCD
7        COMMON/DELTS/                  FRACX,FRACY
7        COMMON/DELTZ/DELTAZ( 8),FRACZ( 8)
7        COMMON/CVELTY/VX,VY
7        DIMENSION CL(8,11),CN(8)
7        READ(5,103)IN,JM,KN,DT,VX,VY
7        INN=IN-1
7        JMM=JM-1
7        KNN=KN-1
7        READ(5,110)ZO,PS,PHC,RR,TS,CELL,DX,DY,P1,P2
7        READ(5,104)(CN(K),K=4,KN)
7        N1=IN+JM
7        N2=3*KN+4*KN*IN*JM
7        N3=6*KN*IN*JM
7        CALL CLEAR(X,N1)
7        HLID=15000.
7        DO 20 I=1,INN
4     20 X(I+1)=X(I)+DX*P1
7        DO 23 J=1,JMM
4     23 Y(J+1)=Y(J)+DY*P2
7        DO 6 K= 5,KN
5      6 Z(K)=Z(K-1)+(HLID-Z(4))/(KN-4)
```

```
7        DO 4  K=1,KNN
5      4 DELTAZ(K)=Z(K+1)-Z(K)
7        DELTAZ(KN)=Z(KN)-Z(KNN)
7        PRINT 100,IN,DX,VX,VY
3    100 FORMAT(5X,I4,5X,'DX=DY=',F7.2,5X,'VX=',F6.2,5X,'VY=',F6.2)
7        PRINT 101,ZO,PS    ,RHC,RR,TS,CELL
3    101 FORMAT( /,1X,'ZC=',F4.1,'M',2X,'PARTICLE SIZE=',F4.1,'ML',2X,
6       $'DENSITY=',F5.2,'GM/CC',2X,'RAINFALL=',F4.1,'MM/HR',2X,'STORM TIME
6       $=',F4.1,'HR',2X,'NC. CELLS=',F3.0,/ )
7        CALL CLEAR(U,N2)
7        CALL CLEAR(RTX,N3)
7        READ(5,102)((CL(I,J),I=3,7),J=4,8)
7        DO 10 K=4,KNN
7        DO 10 J=4,8
7        DO 10 I=3,7
4     10 C(I,J,K)=CN(K)*CL(I,J)
7        READ(5,102)((CL(I,J),I=3,7),J=4,8)
7        K=KN
7        DO 12 J=4,8
7        DC 12 I=3,7
4     12 C(I,J,K)=CN(K)*CL(I,J)
7        DO 11 K=4,KN
7        DO 11 J=4,8
7        DO 11 I=3,7
7        IF(C(I,J,K).EQ.0.)GO TO 11
7        RTX(I,J,K)=1.0
7        RTY(I,J,K)=1.0
7        RTZ(I,J,K)=1.0
4     11 CONTINUE
3    110 FORMAT(5F10.4)
3    102 FORMAT(5F10.4)
3    103 FORMAT(3I10,3F1C.2)
3    104 FORMAT(5F10.0)
7        RETURN
7        END
7        SUBROUTINE PRINTL
7        COMMON/VB/ZO,DX,PLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7        COMMON/MATRX1/U(30,11,8),V(30,11,8)  ,W(3C,11,8 ),C(30,11,8) ,KXX(
6       $      8),KYY(       8),KZZ(      8)
7        DIMENSION DUMY(30,11),LS(30,11),DUM1(30,11),DUM2(30,11)
7        COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WCN(8),UH( 9),WK
7        COMMON/VCTR/TIME,CIN(30,11)
7        COMMON/CVELTY/VX,VY
7        DUMM=VX*.02
7        DO 6 I=1,IN
7        DO 6 J=1,JM
7        DUM1(I,J)=U(I,J,4)*.02
7        IF(DUM1(I,J).EQ.DUMM)DUM1(I,J)=0.
5      6 DUM2(I,J)=V(I,J,4)*.02
7        CALL VECTR(DUM1,DUM2,IN,JM,DUMY)
7        SUM=0.0
7        DO 8 K=1,KN
7        DO 8 I=1,IN
7        DO 8 J=1,JM
5      8 SUM=SUM+  C(I,J,K)
7        K=1
7        FLAG=0.
7        DO 9  I=1,IN
7        DO 9  J=1,JM
7        JJ=JM-J+1
7        DUMY(I,JJ)=  C(I,J,K)/(DX*DY*Z(2)*1CCC.)
7        IF(DUMY(I,JJ).GT.0.)FLAG=1.
7        LS(I,J)=  C(I,J,K)
5      9 CONTINUE
7        IF(FLAG.EQ.0.)GC TC 1
7        PRINT 2
5      2 FORMAT(1H1,50X,'AIR CCNCENTRATION',/ )
7        WRITE(6,101)
7        WRITE(6,102)K,TIME,SUM
7        WRITE(6,107) (I,I=1,30)
7        DO 5 J=1,JM
7        JJ=JM-J+1
```

```
5      5 WRITE(6,103)    (  LS(I,JJ),I=1,30)                                   1802
7        PRINT 12                                                              1703
4     12 FORMAT(1H1,50X,'INTEGRATED GROUNDLEVEL CONCENTRATION',/ )             1704
7        WRITE(6,101)                                                          1705
7        WRITE(6,102)K,TIME,SUM                                                1706
7        DO 15 I=1,IN                                                          1708
7        II=IN-I+1                                                             1801
4     15 WRITE(6,104)    ( CIN(II,J),J=1,11)                                   1802
7        CALL ISOLOG(DUMY,IN,JM,DUM1,DUM2)                                     1803
7        DO 3  I=1,IN                                                          1804
7        DO 3  J=1,JM                                                          1805
5      3 DUMY(I,J)=C(I,J,1)/(DX*DY*Z(2)*1000.)                                 1806
7        IF(NITER.EQ.120)CALL SECTOR(DUMY,IN,JM)                               1807
7        IF(NITER.EQ.120)CALL SECSIT(DUMY,IN,JM,VX)                            1808
5      1 CONTINUE                                                              1901
7        CALL PRINT2                                                           1902
3    101 FORMAT( /,T46,'X-Y PLANE',/ )                                         1903
3    102 FORMAT(20X,'K=',I5,10X,'TIME=',F10.2,10X,'SUM=',1PE10.3)              1904
3    103 FORMAT(30(I4))                                                        1905
3    104 FORMAT(1X,1P11E11.3)                                                  1905
3    107 FORMAT( /,1X,30(I3,1X),/ )                                            1906
7        RETURN                                                                1907
7        END                                                                   1908
7        SUBROUTINE PRINT2                                                     2001
7        COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS       2002
7        COMMON/MATRX1/U(30,11,8),V(30,11,8)   ,W(30,11,8 ),C(30,11,8) ,KXX(   2003
6      $        8),KYY(         8),KZZ(         8)                             2004
7        COMMON/VCTR/TIME,CIN(30,11)                                           2005
7        COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WDN(8),UF( 9),WK                   2006
7        DIMENSION ZPT(30),LS(30,8),DUMY(30,8),W1(30,8),DUM1(30,8),UN(30,8)    2007
7        J=6                                                                   2008
7        N1=IN*KN                                                              2101
7        DO 4  I=1,IN                                                          2102
7        DO 4  K=1,KN                                                          2103
7        W1(I,K)=W(I,J,K)*.01                                                  2104
7        UN(I,K)=U(I,J,K)*.01                                                  2105
7        DUMY(I,K)=  C(I,J,K)                                                  2106
5      4 LS(I,K)=  C(I,J,K)+SIGN(0.5,  C(I,J,K))                               2107
7        CALL VECTR(UN,W1,IN,KN,DUM1)                                          2108
7        IY=1                                                                  2201
7        DO 7 K=1,3                                                            2202
7        DO 7 I=2,IN                                                           2203
7        FLAG=0.                                                               2204
7        IF(W1(I,K).LT.-.005)FLAG=1.                                           2205
7        IF(FLAG.EQ.1.)CALL RANDOT(FLOAT(I),FLOAT(K),IN,KN,IY)                 2206
7        IF(FLAG.EQ.1..AND.K.EQ.2)CALL RANDOT(FLOAT(I),FLOAT(I),IN,KN,IY)      2207
7        IF(UN(I,4).EQ.0..AND.UN(I,2).LT..01.AND.W1(I-1,4).GT.0.)              2208
6       $CALL RANDOT(FLOAT(I),FLOAT(K),IN,KN,IY)                               2301
7        IY=IY+2                                                               2302
5      7 CONTINUE                                                              2303
7        CALL RECON                                                            2304
7        CALL ISOPTH(DUMY,IN,KN,DUM1,0.,0.5)                                   2305
7        DO 40 I=1,IN                                                          2306
7        ZPT(I)= DUMY(I,1)/(DX*DY*Z(2)*1000.)                                  2307
4     40 IF(ZPT(I).LE.0.)ZPT(I)=1.00E-20                                       2308
7        CALL YLGPLT(X,ZPT,30)                                                 2401
3    101 FORMAT(//,46X,'X-Z PLANE IN J DIRECTION',/ )                          2402
3    102 FORMAT(30X,'TIME= ',F10.2)                                            2403
3    103 FORMAT(30(I4))                                                        2404
3    107 FORMAT( /,1X,30(I3,1X),/ )                                            2405
7        RETURN                                                                2406
7        END                                                                   2407
7        SUBROUTINE PRINT3                                                     2408
7        COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS       2501
7        COMMON/MATRX1/U(30,11,8),V(30,11,8)   ,W(30,11,8 ),C(30,11,8) ,KXX(   2502
6      $        8),KYY(         8),KZZ(         8)                             2503
7        DIMENSION DUMY(30,11),LS(30,11),XX(30,11),DUM1(30,11),DUM2(30,11)     2504
7        COMMON/CVELTY/VX,VY                                                   2505
7        COMMON/VCTR/TIME,CIN(30,11)                                           2506
7        N2=IN*JM                                                              2507
7        IF(NITER.EQ.0)CALL CLEAR(XX,N2)                                       2508
```

```
7         FLAG=0.
7         IF(NITER.EQ.0)GO TO 4
7         PSI=2.0E-04* RR**.8
7         KNNN=6
7         DO 12 K=3,KNNN
7         DO 12 I=1,IN
7         DO 12 J=1,JM
7         XX(I,J )  = XX(I,J ) +  C(I,J,K)*PSI*DT
7         IF(XX(I,J ).GT.0.)FLAG=1.
4      12 CONTINUE
5       4 DO 2 J=1,JM
7         DO 2 I=1,IN
7         JJ=JM-J+1
5       2 DUMY(I,JJ)=XX(I,J)/(DX*DY*1000.)
7         DO 9 J=1,JM
7         DO 9 I=1,IN
7         LS(I,J)=XX(I,J) +SIGN(0.5,XX(I,J))
5       9 CONTINUE
7         IF(FLAG.EQ.0.)GO TO 111
7         IF(NITER/20.NE.NITER/20.)GO TO 1
7         PRINT 10
4      10 FORMAT(// ,40X,'GROUND LEVEL DEPOSITION BY RAINOUT',//)
7         WRITE(6,101)
7         WRITE(6,102)TIME
7         WRITE(6,107) (I,I=1,30)
7         DO 5 J=1,JM
7         JJ=JM-J+1
5       5 WRITE(6,103)(LS(I,JJ),I=1,30)
3     111 IF(FLAG.EQ.0.)PRINT 108
7         IF(FLAG.EQ.0.)GO TO 1
7         CALL RECON
7         CALL ISOLOG(DUMY,IN,JM,DUM1,DUM2)
7         DO 3  I=1,IN
7         DO 3   J=1,JM
5       3 DUMY(I,J)=XX(I,J)/(DX*DY*1000.)
7         IF(NITER.EQ.120)CALL SECTOR(DUMY,IN,JM)
7         IF(NITER.EQ.120)CALL SECSIT(DUMY,IN,JM,VX)
5       1 CONTINUE
3     101 FORMAT( /,T40,'X-Y PLANE FOR Z=0',/ )
3     102 FORMAT(40X,'TIME=',F10.2)
3     103 FORMAT(30(I4))
3     107 FORMAT( /,1X,30(I3,1X),/ )
3     108 FORMAT(40X,' **** NO CONCENTRATION AT THE GROUND **** ')
7         RETURN
7         END
7         SUBROUTINE EDDY
7         REAL KXX,KYY,KZZ,L1,KM,KT
7         COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7         COMMON/MATRX1/U(30,11,8),V(30,11,8)  ,W(30,11,8 ),C(30,11,8) ,KXX(
6        $      8),KYY(        8),KZZ(        8)
7         COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WCN(8),UH( 5),WK
7         COMMON/CVELTY/VX,VY
7         COMMON/VCTR/TIME,CIN(30,11)
7         DO 4 K=2,KN
7         IF(TIME.GT. 600)GO TO 2
7         KZZ(K)=.60*Z(K)**.60*(3600.-TIME)/3600.
7         KYY(K)=.10*Z(K)**.20*3.*TIME*TIME/10000.
7         KXX(K)=.20*Z(K)**.20*.16*TIME
7         GO TO 4
5       2 UBAR=1.25*VX
7         BETA=.45
7         UG=VX
7         F=1.0E-04
7         RO=UG/(ZO*F)
7         USTAR=1.2*.16*UG/(ALOG10(RO)-1.8)
7         A=1.-.075*ALOG10(Z(K))
7         EP=7./4.
7         KYY(K)=(A*(UBAR*TIME)**EP)/(2.*TIME)*.0075
7         KZZ(K)=.41*USTAR*ZO*(Z(K)/ZO)**BETA
7         IF(K.LT.4)KYY(K)=10.*KZZ(K)
7         KXX(K)=KYY(K)
```

```
5      4 CONTINUE
7        IF(NITEP.GT.1)GC TC 3
7        PRINT 100
7        DO 5 KK=1,KN
7        K=KN-KK+1
5      5 WRITE(6,35)Z(K),KZZ(K),KXX(K),KYY(K),U(15,6,K),WK
5      3 CONTINUE
4     35 FORMAT(2X,6F10.2)
3    100 FORMAT(//,T8,'Z',T18,'KZ',T28,'KX',T38,'KY',T48,'U',T58,'WK')
8         RETURN
8         END
7        BLOCK DATA
7        COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WDN(8),UH( 9),WK
7        DATA WDN/0.0,1.C, 8.00, 10.0, 14.25, 9.0, 4.0,0.0/
7        DATA WU/0.0,1.0,8.00,10.0,17.50,18.C,8.C,C.C/
7        DATA Z/0., 2. ,350.,1C00.,0.0,C.0,0.0,0.0/
7        DATA UH/-4.0,-5.0,-6.0,-8.0,-10.0,-8.0,-7.0,-6.0,-4.0/
7        END
7        SUBROUTINE WINDS
7        REAL KXX,KYY,KZZ
7        COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7        COMMON/MATRX1/U(30,11,8),V(3C,11,8)   ,W(3C,11,8 ),C(30,11,8) ,KXX(
6       $        8),KYY(        8),KZZ(         8)
7        COMMON/VARV/CV(30,11),FVX(30,11),RVX(30,11),FVY(30,11),RVY(3C,11)
7        COMMON/VARU/CU(30,11),FUX(30,11),RUX(30,11),FUY(30,11),RUY(3C,11)
7        COMMON/VARI/CT(30,11),FWX(3C,11),RWX(3C,11),FWY(30,11),RWY(3C,11)
7        COMMON/DIM/X(30),Y(11),Z( 8),WU(8),WDN(8),UH( 9),WK
7        COMMON/DELTS/                          FRACX,FRACY
7        COMMON/CVELTY/VX,VY
7        N4=KN*IN*JM*2
7        DO 8 I=1,IN
7        DO 8 J=1,JM
7        DO 8 K=4,KNN
5      8 U(I,J,K)=0.
7        CALL CLEAR(V,N4)
7        CALL LONGTU(DX,DY,IN,JM,INN,JMM,DT,NITER)
7        CALL LATERV(DX,DY,IN,JM,INN,JMM,DT,NITER)
7        CALL UPDOWN(DX,DY,IN,JM,INN,JMM,DT,NITER)
7        DO 9 I=1,IN
7        DO 9 J=1,JM
7        DO 9 K=2,KNN
7        WK=-.16
7        IF(CT(I,J).LE.0.)SET=CT(I,J)*WDN(K)/5C.
7        IF(CT(I,J).GT.0.)SET=CT(I,J)*WU(K)/50.
5      9 W(I,J,K)=SET+WK
7        IF(NITER.GT.1)GC TO 1
7        DO 4 J=1,JM
7        DO 2 K=2,3
7        DO 2 I=1,IN
7        U(I,J,K)=2.2*Z(K)**.18
5      2 V(I,J,K)=0.0
7        DO 4 I=2,10
7        U(I,J,3)=UH(I-1)
5      4 U(I,J,2)=.30*U(I,J,3)
7        GO TO 7
5      1 DO 6 J=1,JM
7        DO 6 K=2,3
7        DO 5 I=2,IN
5      5 U(I,J,K)=U(I-1,J,K)+(U(I,J,K)-U(I-1,J,K))*(DX-VX*DT)/DX
5      6 V(I,J,K)=0.0
5      7 DO 3 K=4,KN
7        DO 3 J=1,JM
7        DO 3 I=1,IN
7        U(I,J,K)=CU(I,J)
7        IF(CU(I,J).EQ.0..AND.CV(I,J).EQ.0.)U(I,J,K)=VX
7        IF(CU(I,7).LT.0..AND.CV(I,6).EQ.0.)U(I,6,K)=0.
7        IF(K.EQ.KN)U(I,J,K)=1.25*VX
5      3 V(I,J,K)=CV(I,J)
7        CALL EDDY
7        RETURN
7        END
```

```
7          SUBROUTINE DIFFUS                                                    4307
7          REAL KZZ,KZZK,KZZP,KZZM,KXX,KYY,KXXK,KYYK                            4308
7          COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS       4401
7          COMMON/MATRX1/U(30,11,8),V(30,11,8)   ,W(30,11,8 ),C(30,11,8) ,KXX(   4402
6         $          8),KYY(          8),KZZ(          8)                       4403
7          COMMON/DIM/X(30),Y(11),Z( 8),WL(8),WDN(8),UH( 9),WK                  4404
7          COMMON/CALGOR/O    (30,11,8) ,FXA   (30,11,8) ,FYA   (30,11,8) ,FZA  4405
6         1(30,11,8) ,RXA   (30,11,8) ,RYA   (30,11,8) ,RZA   (30,11,8)         4406
7          COMMON/DELTS/                          FRACX,FRACY                   4407
7          COMMON/DELTZ/DELTAZ( 8),FRACZ( 8)                                    4408
7          COMMON/VAR2/RTX(30,11,8) ,RTY(30,11,8) ,FTX(30,11,8) ,FTY(30,11,     4501
6         $ 8),RTZ(30,11,8) ,FTZ(30,11,8)                                       4502
7          CALL SCAVEG                                                          4503
7          DO 10 K=1,KN                                                         4504
7          DO 10 J=1,JM                                                         4505
7          DO 10 I=1,IN                                                         4506
7          O(I,J,K)=C(I,J,K)                                                    4507
7          RXA(I,J,K)=RTX(I,J,K)                                                4508
7          RYA(I,J,K)=RTY(I,J,K)                                                4601
7          RZA(I,J,K)=RTZ(I,J,K)                                                4602
7          FXA(I,J,K)=FTX(I,J,K)                                                4603
7          FYA(I,J,K)=FTY(I,J,K)                                                4604
7          FZA(I,J,K)=FTZ(I,J,K)                                                4605
4       10 CONTINUE                                                             4606
7          RB=1.0                                                               4607
7          RT=0.95                                                              4608
7          DO 6 I=2,INN                                                         4701
7          DO 6 J=2,JMM                                                         4702
7          DO 6 K=1,KNN                                                         4703
7          KXXK=KXX(      K)                                                    4704
7          KYYK=KYY(      K)                                                    4705
7          AXM=KXXK*DT/(DX*DX)                                                  4706
7          AXP=AXM                                                              4707
7          AYM=KYYK*DT/(DY*DY)                                                  4708
7          AYP=AYM                                                              4801
7          IF(K.EQ.1)GO TO 8                                                    4802
7          IF(K.EQ.KNN)GO TO 9                                                  4803
7          DZP=Z(K+2)-Z(K)                                                      4804
7          DZ=Z(K+1)-Z(K-1)                                                     4805
7          KZZP=KZZ(K+1)                                                        4806
7          KZZK=KZZ(K)                                                          4807
7          KZZM=KZZ(K-1)                                                        4808
7          AKM=AKP                                                              4901
7          AKP=(KZZK+KZZP)*DT/(DZ*DZP)                                          4902
7          DIF=1.-AXP-AXM-AYP-AYM-AKP-AKM                                       4903
7          IF(DIF.LT.0.)PRINT 100                                               4904
7          C(I,J,K)=O(I,J,K)*DIF+AXP*O(I+1,J,K)+AXM*                            4905
6         $O(I-1,J,K)+AYP*C(I,J+1,K)+AYM*C(I,J-1,K)+AKP*C(I,J,K+1)+AKM*         4906
6         $O(I,J,K-1)                                                           4907
7          IF(C(I,J,K).LT.1.E-10)GO TO 30                                       4908
7          FTX(I,J,K)=(O(I,J,K)*FXA(I,J,K)*DIF+AXP*C(I+1,J,K)*FXA(I+1,J,K)      5001
6         $+AXM*O(I-1,J,K)*FXA(I-1,J,K)+AYP*C(I,J+1,K)*FXA(I,J+1,K)+AYM*        5002
6         $C(I,J-1,K)*FXA(I,J-1,K)+AKP*C(I,J,K+1)*FXA(I,J,K+1)+AKM*O(I,J,       5003
6         $K-1)*FXA(I,J,K-1))/C(I,J,K)                                          5004
7          FTY(I,J,K)=(O(I,J,K)*FYA(I,J,K)*DIF+AXP*O(I+1,J,K)*FYA(I+1,J,K)      5005
6         $+AXM*O(I-1,J,K)*FYA(I-1,J,K)+AYP*C(I,J+1,K)*FYA(I,J+1,K)+AYM*        5006
6         $C(I,J-1,K)*FYA(I,J-1,K)+AKP*C(I,J,K+1)*FYA(I,J,K+1)+AKM*C(I,J,       5007
6         $K-1)*FYA(I,J,K-1))/C(I,J,K)                                          5008
7          FTZ(I,J,K)=(O(I,J,K)*FZA(I,J,K)*DIF+AXP*C(I+1,J,K)*FZA(I+1,J,K)      5101
6         $+AXM*O(I-1,J,K)*FZA(I-1,J,K)+AYP*O(I,J+1,K)*FZA(I,J+1,K)+AYM*        5102
6         $C(I,J-1,K)*FZA(I,J-1,K)+AKP*C(I,J,K+1)*FZA(I,J,K+1)+AKM*C(I,J,       5103
6         $K-1)*FZA(I,J,K-1))/C(I,J,K)                                          5104
7          GO TO 6                                                              5105
4        8 DZP=Z(2)-Z(1)                                                        5106
7          DZ=Z(3)-Z(1)                                                         5107
7          KZZP=KZZ(2)                                                          5108
7          KZZK=KZZ(1)                                                          5201
7          AKP=(KZZK+KZZP)*DT/(DZ*DZP)                                          5202
7          DIF=1.-AKP*(2.-RB)-AXP-AXM-AYP-AYM                                   5203
7          IF(DIF.LT.0.)PRINT 101                                               5204
7          C(I,J,K)=O(I,J,K)*DIF+AXP*O(I+1,J,K)                                 5205
```

```
6          $+AXM*O(I-1,J,K)+AYP*O(I,J+1,K)+AYM*C(I,J-1,K)+AKP*O(I,J,K+1)
7           IF(C(I,J,K).LT.1.E-10)GO TO 30
7           FTX(I,J,K)=(O(I,J,K)*FXA(I,J,K)*DIF+AXP*O(I+1,J,K)*FXA(I+1,J,K)
6          $+AXM*C(I-1,J,K)*FXA(I-1,J,K)+AYP*C(I,J+1,K)*FXA(I,J+1,K)+AYM*
6          $O(I,J-1,K)*FXA(I,J-1,K)+AKP*C(I,J,K+1)*FXA(I,J,K+1))/C(I,J,K)
7           FTY(I,J,K)=(O(I,J,K)*FYA(I,J,K)*DIF+AXP*O(I+1,J,K)*FYA(I+1,J,K)
6          $+AXM*O(I-1,J,K)*FYA(I-1,J,K)+AYP*C(I,J+1,K)*FYA(I,J+1,K)+AYM*
6          $O(I,J-1,K)*FYA(I,J-1,K)+AKP*C(I,J,K+1)*FYA(I,J,K+1))/C(I,J,K)
7           FTZ(I,J,K)=(O(I,J,K)*FZA(I,J,K)*DIF+AXP*C(I+1,J,K)*FZA(I+1,J,K)
6          $+AXM*O(I-1,J,K)*FZA(I-1,J,K)+AYP*O(I,J+1,K)*FZA(I,J+1,K)+AYM*
6          $O(I,J-1,K)*FZA(I,J-1,K)+AKP*C(I,J,K+1)*FZA(I,J,K+1))/C(I,J,K)
7           GO TO 6
5         9 AKM=AKP
7           DIF=1.-AKM*(2.-RT)-AXP-AXM-AYP-AYM
7           IF(DIF.LT.O.)PRINT 102
7           C(I,J,K)=O(I,J,K)*DIF+AXP*O(I+1,J,K)
6          $+AXM*O(I-1,J,K)+AYP*O(I,J+1,K)+AYM*C(I,J-1,K)+AKM*O(I,J,K-1)
7           IF(C(I,J,K).LT.1.E-10)GO TO 30
7           FTX(I,J,K)=(O(I,J,K)*FXA(I,J,K)*DIF+AXP*O(I+1,J,K)*FXA(I+1,J,K)
6          $+AXM*O(I-1,J,K)*FXA(I-1,J,K)+AYP*C(I,J+1,K)*FXA(I,J+1,K)+AYM*
6          $O(I,J-1,K)*FXA(I,J-1,K)+AKM*C(I,J,K-1)*FXA(I,J,K-1))/C(I,J,K)
7           FTY(I,J,K)=(O(I,J,K)*FYA(I,J,K)*DIF+AXP*O(I+1,J,K)*FYA(I+1,J,K)
6          $+AXM*O(I-1,J,K)*FYA(I-1,J,K)+AYP*C(I,J+1,K)*FYA(I,J+1,K)+AYM*
6          $O(I,J-1,K)*FYA(I,J-1,K)+AKM*O(I,J,K-1)*FYA(I,J,K-1))/C(I,J,K)
7           FTZ(I,J,K)=(O(I,J,K)*FZA(I,J,K)*DIF+AXP*C(I+1,J,K)*FZA(I+1,J,K)
6          $+AXM*O(I-1,J,K)*FZA(I-1,J,K)+AYP*O(I,J+1,K)*FZA(I,J+1,K)+AYM*
6          $C(I,J-1,K)*FZA(I,J-1,K)+AKM*O(I,J,K-1)*FZA(I,J,K-1))/C(I,J,K)
7           GO TO 6
4        30 FTX(I,J,K)=0.0
7           FTY(I,J,K)=0.0
7           FTZ(I,J,K)=0.0
7           C(I,J,K)=0.0
5         6 CONTINUE
7           DO 39 I=2,INN
7           DO 39 J=2,JMM
7           DO 39 K=1,KNN
7           IF(C(I,J,K).LT.1.E-10)GO TO 50
7           KXXK=KXX(     K)
7           KYYK=KYY(     K)
7           AXM=KXXK*DT/(DX*DX)
7           AXP=AXM
7           AYM=KYYK*DT/(DY*DY)
7           AYP=AYM
7           GO TO 40
4        50 RTX(I,J,K)=0.0
7           RTY(I,J,K)=0.0
7           RTZ(I,J,K)=0.0
7           GO TO 39
4        40 RX1=RXA(I,J,K)
7           RX2=RXA(I+1,J,K)
7           RX3=RXA(I-1,J,K)
7           RX4=RXA(I,J+1,K)
7           RX5=RXA(I,J-1,K)
7           SX1=RX1*RX1+12.*(FXA(I,J,K)-FTX(I,J,K))**2
7           SX2=RX2*RX2+12.*(FXA(I+1,J,K)-FTX(I+1,J,K))**2
7           SX3=RX3*RX3+12.*(FXA(I-1,J,K)-FTX(I-1,J,K))**2
7           SX4=RX4*RX4+12.*(FXA(I,J+1,K)-FTX(I,J+1,K))**2
7           SX5=RX5*RX5+12.*(FXA(I,J-1,K)-FTX(I,J-1,K))**2
7           RY1=RYA(I,J,K)
7           RY2=RYA(I+1,J,K)
7           RY3=RYA(I-1,J,K)
7           RY4=RYA(I,J+1,K)
7           RY5=RYA(I,J-1,K)
7           SY1=RY1*RY1+12.*(FYA(I,J,K)-FTY(I,J,K))**2
7           SY2=RY2*RY2+12.*(FYA(I+1,J,K)-FTY(I+1,J,K))**2
7           SY3=RY3*RY3+12.*(FYA(I-1,J,K)-FTY(I-1,J,K))**2
7           SY4=RY4*RY4+12.*(FYA(I,J+1,K)-FTY(I,J+1,K))**2
7           SY5=RY5*RY5+12.*(FYA(I,J-1,K)-FTY(I,J-1,K))**2
7           RZ1=RZA(I,J,K)
7           RZ2=RZA(I+1,J,K)
7           RZ3=RZA(I-1,J,K)
```

```
7        RZ4=RZA(I,J+1,K)
7        RZ5=RZA(I,J-1,K)
7        SZ1=RZ1*RZ1+12.*(FZA(I,J,K)-FTZ(I,J,K))**2
7        SZ2=RZ2*RZ2+12.*(FZA(I+1,J,K)-FTZ(I+1,J,K))**2
7        SZ3=RZ3*RZ3+12.*(FZA(I-1,J,K)-FTZ(I-1,J,K))**2
7        SZ4=RZ4*RZ4+12.*(FZA(I,J+1,K)-FTZ(I,J+1,K))**2
7        SZ5=RZ5*RZ5+12.*(FZA(I,J-1,K)-FTZ(I,J-1,K))**2
7        IF(K.EQ.1)GO TO 41
7        IF(K.EQ.KNN)GO TO 42
7        DZP=Z(K+2)-Z(K)
7        DZ=Z(K+1)-Z(K-1)
7        KZZP=KZZ(     K+1)
7        KZZK=KZZ(     K)
7        KZZM=KZZ(     K-1)
7        AKM=AKP
7        AKP=(KZZP+KZZK)*DT/(DZ*DZP)
7        RX6=RXA(I,J,K+1)
7        RX7=RXA(I,J,K-1)
7        SX6=RX6*RX6+12.*(FXA(I,J,K+1)-FTX(I,J,K+1))**2
7        SX7=RX7*RX7+12.*(FXA(I,J,K-1)-FTX(I,J,K-1))**2
7        RY6=RYA(I,J,K+1)
7        RY7=RYA(I,J,K-1)
7        SY6=RY6*RY6+12.*(FYA(I,J,K+1)-FTY(I,J,K+1))**2
7        SY7=RY7*RY7+12.*(FYA(I,J,K-1)-FTY(I,J,K-1))**2
7        RZ6=RZA(I,J,K+1)
7        RZ7=RZA(I,J,K-1)
7        SZ6=RZ6*RZ6+12.*(FZA(I,J,K+1)-FTZ(I,J,K+1))**2
7        SZ7=RZ7*RZ7+12.*(FZA(I,J,K-1)-FTZ(I,J,K-1))**2
7        DIF=1.-AXP-AXM-AYP-AYM-AKP-AKM
7        RTX(I,J,K)=(D(I,J,K)*SX1*DIF+C(I+1,J,K)*AXP*SX2+D(I-1,J,K)*AXM
6       $*SX3+C(I,J+1,K)*AYP*SX4+D(I,J-1,K)*AYM*SX5+C(I,J,K+1)*AKP*SX6+
6       $D(I,J,K-1)*AKM*SX7)/C(I,J,K)
7        RTY(I,J,K)=(D(I,J,K)*SY1*DIF+D(I+1,J,K)*AXP*SY2+D(I-1,J,K)*AXM
6       $*SY3+D(I,J+1,K)*AYP*SY4+D(I,J-1,K)*AYM*SY5+C(I,J,K+1)*AKP*SY6+
6       $D(I,J,K-1)*AKM*SY7)/C(I,J,K)
7        RTZ(I,J,K)=(D(I,J,K)*SZ1*DIF+C(I+1,J,K)*AXP*SZ2+D(I-1,J,K)*AXM
6       $*SZ3+D(I,J+1,K)*AYP*SZ4+D(I,J-1,K)*AYM*SZ5+D(I,J,K+1)*AKP*SZ6+
6       $D(I,J,K-1)*AKM*SZ7)/C(I,J,K)
7        GO TO 43
4     41 DZP=Z(2)-Z(1)
7        DZ=Z(3)-Z(1)
7        KZZP=KZZ(2)
7        KZZK=KZZ(1)
7        AKP=(KZZP+KZZK)*DT/(DZ*DZP)
7        DIF=1.-AKP*(2.-RB)-AXP-AXM-AYP-AYM
7        RX6=RXA(I,J,K+1)
7        SX6=RX6*RX6+12.*(FXA(I,J,K+1)-FTX(I,J,K+1))**2
7        RY6=RYA(I,J,K+1)
7        SY6=RY6*RY6+12.*(FYA(I,J,K+1)-FTY(I,J,K+1))**2
7        RZ6=RZA(I,J,K+1)
7        SZ6=RZ6*RZ6+12.*(FZA(I,J,K+1)-FTZ(I,J,K+1))**2
7        RTX(I,J,K)=(D(I,J,K)*SX1*DIF+D(I+1,J,K)*AXP*SX2+D(I-1,J,K)*AXM
6       $*SX3+D(I,J+1,K)*AYP*SX4+D(I,J-1,K)*AYM*SX5+C(I,J,K+1)*AKP*SX6)
6       $/C(I,J,K)
7        RTY(I,J,K)=(D(I,J,K)*SY1*DIF+C(I+1,J,K)*AXP*SY2+D(I-1,J,K)*AXM
6       $*SY3+D(I,J+1,K)*AYP*SY4+D(I,J-1,K)*AYM*SY5+C(I,J,K+1)*AKP*SY6)
6       $/C(I,J,K)
7        RTZ(I,J,K)=(D(I,J,K)*SZ1*DIF+D(I+1,J,K)*AXP*SZ2+D(I-1,J,K)*AXM
6       $*SZ3+D(I,J+1,K)*AYP*SZ4+D(I,J-1,K)*AYM*SZ5+C(I,J,K+1)*AKP*SZ6)
6       $/C(I,J,K)
7        GO TO 43
4     42 AKM=AKP
7        DIF=1.-AKM*(2.-RT)-AXP-AXM-AYP-AYM
7        RX7=RXA(I,J,K-1)
7        SX7=RX7*RX7+12.*(FXA(I,J,K-1)-FTX(I,J,K-1))**2
7        RY7=RYA(I,J,K-1)
7        SY7=RY7*RY7+12.*(FYA(I,J,K-1)-FTY(I,J,K-1))**2
7        RZ7=RZA(I,J,K-1)
7        SZ7=RZ7*RZ7+12.*(FZA(I,J,K-1)-FTZ(I,J,K-1))**2
7        RTX(I,J,K)=(D(I,J,K)*SX1*DIF+D(I+1,J,K)*AXP*SX2+D(I-1,J,K)*AXM
6       $*SX3+D(I,J+1,K)*AYP*SX4+D(I,J-1,K)*AYM*SX5+C(I,J,K-1)*AKM*SX7)
```

```
6         $/C(I,J,K)
7          RTY(I,J,K)=(D(I,J,K)*SY1*DIF+C(I+1,J,K)*AXP*SY2+D(I-1,J,K)*AXM
6         $*SY3+D(I,J+1,K)*AYP*SY4+D(I,J-1,K)*AYM*SY5+C(I,J,K-1)*AKM*SY7)
6         $/C(I,J,K)
7          RTZ(I,J,K)=(D(I,J,K)*SZ1*DIF+C(I+1,J,K)*AXP*SZ2+D(I-1,J,K)*AXM
6         $*SZ3+D(I,J+1,K)*AYP*SZ4+D(I,J-1,K)*AYM*SZ5+C(I,J,K-1)*AKM*SZ7)
6         $/C(I,J,K)
4       43 RTZ(I,J,K)=SQRT(RTZ(I,J,K))
7          RTX(I,J,K)=SQRT(RTX(I,J,K))
7          RTY(I,J,K)=SQRT(RTY(I,J,K))
4       39 CONTINUE
3      100 FORMAT(10X,'DIF FOR 0<Z<KN IS <0')
3      101 FORMAT(10X,'DIF FOR Z=1 IS <0')
3      102 FORMAT(10X,'DIF FOR Z=KN IS <0')
7          RETURN
7          END
7          SUBROUTINE ADVEC
7          COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7          COMMON/MATRX1/U(30,11,8),V(30,11,8)  ,W(30,11,8 ),C(30,11,8) ,KXX(
6         $      8),KYY(       8),KZZ(       8)
7          COMMON/CALGOR/D    (30,11,8) ,FXA  (30,11,8) ,FYA  (30,11,8) ,FZA
6         1(30,11,8) ,RXA  (30,11,8) ,RYA  (30,11,8) ,RZA  (30,11,8)
7          COMMON/SQFXYZ/F2XA(30,11,8),F2YA(30,11,8),F2ZA(30,11,8)
7          COMMON/VAR2/RTX(30,11,8) ,RTY(30,11,8) ,FTX(30,11,8) ,FTY(30,11,
6         $ 8),RTZ(30,11,8) ,FTZ(30,11,8)
7          COMMON/DELTS/                          FRACX,FRACY
7          COMMON/DELTZ/DELTAZ( 8),FRACZ( 8)
7          N5=7*KN*IN*JM
7          N6=3*KN*IN*JM
7          CALL CLEAR(D,N5)
7          CALL CLEAR(F2XA,N6)
1   C
1   C      CALCULATE SIGMAS, PX, PY, AND PZ
1   C
7          FRACX=DT/DX
7          FRACY=DT/DY
7          DO 3 K=1,KN
5        3 FRACZ(K)=     DT/DELTAZ(K)
1   C      CALL SCAVEG
7          DO 500 K= 1,KN
7          DO 500 I= 2,INN
7          DO 500 J= 2,JMM
7          IF(C(I,J,K).LT.1.E-10 ) GOTO 500
7          SIGMAX=U(I,J,K)*FRACX
7          SIGMAY=V(I,J,K)*FRACY
7          SIGMAZ=W(I,J,K)*FRACZ(K)
7          IF(SIGMAX.NE.0.)SIGNX=SIGMAX/ABS(SIGMAX)
7          IF(SIGMAX.EQ.0.)SIGNX=1.
7          IF(SIGMAY.EQ.0.)SIGNY=1.
7          IF(SIGMAY.NE.0.)SIGNY=SIGMAY/ABS(SIGMAY)
7          IF(SIGMAZ.EQ.0.)SIGNZ=1.
7          IF(SIGMAZ.NE.0.)SIGNZ=SIGMAZ/ABS(SIGMAZ)
7          IF (SIGMAX.GT.0.) GOTO 100
7          PX=(-2.*(FTX(I,J,K)+SIGMAX)+RTX(I,J,K)-1.)/(2.*RTX(I,J,K))
7          GOTO 110
3      100 PX=(2.*(FTX(I,J,K) +SIGMAX)+RTX(I,J,K)-1.)/(2.*RTX(I,J,K))
3      110 IF(SIGMAY.GT.0.) GC TC 120
7          PY=(-2.*(FTY(I,J,K) +SIGMAY)+RTY(I,J,K)-1.)/(2.*RTY(I,J,K))
7          GOTO 130
3      120 PY=(2.*(FTY(I,J,K) +SIGMAY)+RTY(I,J,K)-1.)/(2.*RTY(I,J,K))
3      130 IF(SIGMAZ.GT.0.)GC TO 140
7          PZ=(-2.*(FTZ(I,J,K) +SIGMAZ)+RTZ(I,J,K)-1.)/(2.*RTZ(I,J,K))
7          GOTO 145
3      140 PZ=(2.*(FTZ(I,J,K) +SIGMAZ)+FTZ(I,J,K)-1.)/(2.*RTZ(I,J,K))
3      145 CONTINUE
1   C
1   C
1   C                    NORMAL CONDITIONS
1   C
1   C      IF PX,PY,PZ < 0 OR PX,PY,PZ > 1 MODIFICATIONS ARE MADE
1   C
```

```
7        NCOUNT=0
7        IF(P  X.GE.0.0001.AND.P  X.LE.0.9999) GO TO 150
7        NCOUNT=1
7        IF(P  X.LT.0.0001) P  X=0.0
7        IF(P  X.GT.0.9999) P  X=1.0
3    150 IF(P  Y.GE.0.0001.AND.P  Y.LE.0.9999) GO TO 160
7        NCOUNT=1
7        IF(P  Y.LT.0.0001) P  Y=0.0
7        IF(P  Y.GT.0.9999) P  Y=1.0
3    160 IF(PZ  .GE.0.0001.AND.PZ  .LE.0.9999) GO TO 170
7        NCOUNT=1
7        IF(PZ  .LT.0.0001) PZ  =0.0
7        IF(PZ  .GT.0.9999) PZ  =1.0
3    170 CONTINUE
7        IF(SIGMAX.GT.0.0) I1=I+1
7        IF(SIGMAX.EQ.0.) I1 = I
7        IF(SIGMAX.LT.0.0) I1=I-1
7        IF(SIGMAY.GT.0.0) J1=J+1
7        IF(SIGMAY.EQ.0.) J1 = J
7        IF(SIGMAY.LT.0.0) J1=J-1
7        IF(SIGMAZ.GT.0.0) K1=K+1
7        IF(SIGMAZ.EQ.0.) K1 = K
7        IF(SIGMAZ.LT.0.0) K1=K-1
1   C
7        C1=C(I,J,K)    *P  X*(1.0-P  Y)*(1.0-PZ)
7        C2=C(I,J,K)    *(1.0-P  X)*PY*(1.0-PZ)
7        C3=C(I,J,K)*PX*PY*(1.0-PZ)
7        C4=C(I,J,K)*(1.0-PX)*(1.0-PY)*(1.0-PZ)
7        C5=C(I,J,K)*PX*(1.0-PY)*PZ
7        C6=C(I,J,K)*PY*(1.0-PX)*PZ
7        C7=C(I,J,K)*PX*PY*PZ
7        C8=C(I,J,K)*(1.0-PX)*(1.0-PY)*PZ
1   C
7        F1X  =(PX*RTX(I,J,K)-1.0)/2.0*SIGNX
7        F2X  =(1.0-RTX(I,J,K)*(1.0-PX))/2.0*SIGNX
1   C
7        R1X  =(PX*RTX(I,J,K))**2
7        R2X  =((1.0-PX)*RTX(I,J,K))**2
1   C
7        F1Y  =(PY*RTY(I,J,K)-1.0)/2.0*SIGNY
7        F2Y  =(1.0-RTY(I,J,K)*(1.0-PY))/2.0*SIGNY
1   C
1   C
7        R1Y  =(PY*RTY(I,J,K))**2
7        R2Y  =((1.0-PY)*RTY(I,J,K))**2
1   C
7        F1Z  =(PZ*RTZ(I,J,K)-1.0)/2.0*SIGNZ
7        F2Z  =(1.0-RTZ(I,J,K)*(1.0-PZ))/2.0*SIGNZ
1   C
7        R1Z  =(PZ*RTZ(I,J,K))**2
7        R2Z  =((1.0-PZ)*RTZ(I,J,K))**2
1   C
7        O   (I1,J,K)=O   (I1,J,K)+C1
7        O   (I,J1,K)=O   (I,J1,K)+C2
7        O   (I1,J1,K)=O   (I1,J1,K)+C3
7        O   (I,J,K)=O   (I,J,K)+C4
1   C
7        FXA  (I1,J,K)=FXA  (I1,J,K)+F1X*C1
7        FXA  (I,J1,K)=FXA  (I,J1,K)+F2X*C2
7        FXA  (I1,J1,K)=FXA  (I1,J1,K)+F1X   *C3
7        FXA  (I,J,K)=FXA  (I,J,K)+F2X   *C4
1   C
7        F2XA  (I1,J,K)=F2XA  (I1,J,K)+F1X   *F1X   *C1
7        F2XA  (I,J1,K)=F2XA  (I,J1,K)+F2X   *F2X   *C2
7        F2XA  (I1,J1,K)=F2XA  (I1,J1,K)+F1X   *F1X   *C3
7        F2XA  (I,J,K) = F2XA  (I,J,K)+F2X  *F2X   *C4
1   C
7        RXA  (I1,J,K )=RXA  (I1,J,K )+R1X*C1
7        RXA  (I,J1,K )=RXA  (I,J1,K )+R2X*C2
7        RXA  (I1,J1,K )=RXA  (I1,J1,K )+R1X*C3
7        RXA  (I,J,K )=RXA  (I,J,K )+R2X*C4
1   C
```

```
7        FYA  (I1,J,K)=FYA  (I1,J,K)+F2Y*C1
7        FYA  (I,J1,K)=FYA  (I,J1,K)+F1Y*C2
7        FYA  (I1,J1,K)=FYA  (I1,J1,K)+F1Y  *C3
7        FYA  (I,J,K)=FYA  (I,J,K)+F2Y  *C4
1   C
7        F2YA  (I1,J,K)=F2YA  (I1,J,K)+F2Y  *F2Y  *C1
7        F2YA  (I,J1,K)=F2YA  (I,J1,K)+F1Y  *F1Y  *C2
7        F2YA  (I1,J1,K)=F2YA  (I1,J1,K)+F1Y  *F1Y  *C3
7        F2YA  (I,J,K)=F2YA  (I,J,K)+F2Y*F2Y *C4
1   C
7        RYA  (I1,J,K )=RYA  (I1,J,K )+R2Y*C1
7        RYA  (I,J1,K )=RYA  (I,J1,K )+R1Y*C2
7        RYA  (I1,J1,K )=RYA  (I1,J1,K )+R1Y*C3
7        RYA  (I,J,K )=RYA  (I,J,K )+R2Y*C4
1   C
7        FZA  (I1,J,K)=FZA  (I1,J,K)+F2Z*C1
7        FZA  (I,J1,K)=FZA  (I,J1,K)+F2Z*C2
7        FZA  (I1,J1,K)=FZA  (I1,J1,K)+F2Z  *C3
7        FZA  (I,J,K)=FZA  (I,J,K)+F2Z  *C4
1   C
7        F2ZA  (I1,J,K)=F2ZA  (I1,J,K)+F2Z  *F2Z  *C1
7        F2ZA  (I,J1,K)=F2ZA  (I,J1,K)+F2Z  *F2Z  *C2
7        F2ZA  (I1,J1,K)=F2ZA  (I1,J1,K)+F2Z  *F2Z  *C3
7        F2ZA  (I,J,K)=F2ZA  (I,J,K)+F2Z*F2Z *C4
1   C
7        RZA  (I1,J,K )=RZA  (I1,J,K )+R2Z*C1
7        RZA  (I,J1,K )=RZA  (I,J1,K )+R2Z*C2
7        RZA  (I1,J1,K )=RZA  (I1,J1,K )+R2Z*C3
7        RZA  (I,J,K )=RZA  (I,J,K )+R2Z*C4
1   C
7        IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GC TC 489
7        IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GC TC 489
7        O   (I1,J,K1)=O    (I1,J,K1)+C5
7        O   (I,J1,K1)=O    (I,J1,K1)+C6
7        O   (I1,J1,K1)=O   (I1,J1,K1)+C7
7        O   (I,J,K1)=O    (I,J,K1)+C8
7        FXA  (I1,J,K1)=FXA  (I1,J,K1)+F1X*C5
7        FXA  (I,J1,K1)=FXA  (I,J1,K1)+F2X*C6
7        FXA  (I1,J1,K1)=FXA  (I1,J1,K1)+F1X*C7
7        FXA  (I,J,K1)=FXA  (I,J,K1)+F2X*C8
1   C
7        F2XA  (I1,J,K1)=F2XA  (I1,J,K1)+F1X*F1X  *C5
7        F2XA  (I,J1,K1)=F2XA  (I,J1,K1)+F2X*F2X  *C6
7        F2XA  (I1,J1,K1)=F2XA  (I1,J1,K1)+F1X*F1X  *C7
7        F2XA  (I,J,K1)= F2XA  (I,J,K1)+F2X*F2X  *C8
1   C
7        RXA  (I1,J,K1)=RXA  (I1,J,K1)+R1X*C5
7        RXA  (I,J1,K1)=RXA  (I,J1,K1)+R2X*C6
7        RXA  (I1,J1,K1)=RXA  (I1,J1,K1)+R1X*C7
7        RXA  (I,J,K1)=RXA  (I,J,K1)+R2X*C8
1   C
7        FYA  (I1,J,K1)=FYA  (I1,J,K1)+F2Y*C5
7        FYA  (I,J1,K1)=FYA  (I,J1,K1)+F1Y*C6
7        FYA  (I1,J1,K1)=FYA  (I1,J1,K1)+F1Y*C7
7        FYA  (I,J,K1)=FYA  (I,J,K1)+F2Y*C8
1   C
7        F2YA  (I1,J,K1)=F2YA  (I1,J,K1)+F2Y*F2Y  *C5
7        F2YA  (I,J1,K1)=F2YA  (I,J1,K1)+F1Y*F1Y  *C6
7        F2YA  (I1,J1,K1)=F2YA  (I1,J1,K1)+F1Y*F1Y  *C7
7        F2YA  (I,J,K1)=F2YA  (I,J,K1)+F2Y*F2Y*C8
1   C
7        RYA  (I1,J,K1)=RYA  (I1,J,K1)+R2Y*C5
7        RYA  (I,J1,K1)=RYA  (I,J1,K1)+R1Y*C6
7        RYA  (I1,J1,K1)=RYA  (I1,J1,K1)+R1Y*C7
7        RYA  (I,J,K1)=RYA  (I,J,K1)+R2Y*C8
1   C
7        FZA  (I1,J,K1)=FZA  (I1,J,K1)+F1Z*C5
7        FZA  (I,J1,K1)=FZA  (I,J1,K1)+F1Z*C6
7        FZA  (I1,J1,K1)=FZA  (I1,J1,K1)+F1Z*C7
7        FZA  (I,J,K1)=FZA  (I,J,K1)+F1Z*C8
1   C
```

```
7        F2ZA  (I1,J,K1)=F2ZA  (I1,J,K1)+F1Z*F1Z  *C5                      9702
7        F2ZA  (I,J1,K1)=F2ZA  (I,J1,K1)+F1Z*F1Z  *C6                      9703
7        F2ZA  (I1,J1,K1)=F2ZA  (I1,J1,K1)+F1Z*F1Z  *C7                    9704
7        F2ZA  (I,J,K1)=F2ZA  (I,J,K1)+F1Z*F1Z*C8                          9705
1   C                                                                      9706
7        RZA  (I1,J,K1)=RZA  (I1,J,K1)+R1Z*C5                              9707
7        RZA  (I,J1,K1)=RZA  (I,J1,K1)+R1Z*C6                              9708
7        RZA  (I1,J1,K1)=RZA  (I1,J1,K1)+R1Z*C7                            9801
7        RZA  (I,J,K1)=RZA  (I,J,K1)+R1Z*C8                                9802
1   C                                                                      9803
3    489 IF(NCOUNT.EQ.0) GO TO 500                                         9804
7        SIGMX = SIGMAX+FTX(I,J,K)                                         9805
7        SIGMY = SIGMAY + FTY(I,J,K)                                       9806
7        SIGMZ = SIGMAZ + FTZ(I,J,K)                                       9807
7        IF(PX  .GT.0.0001) GO TO 490                                      9808
1   C                                                                      9901
7        FXA  (I1,J,K)=FXA  (I1,J,K)-C1    * F1X                           9902
7        F2XA  (I1,J,K)=F2XA  (I1,J,K)-C1* F1X  *F1X                       9903
7        FXA  (I,J1,K)=FXA  (I,J1,K)-C2    *(F2X   - SIGMX)                9904
7        F2XA  (I,J1,K)=F2XA  (I,J1,K)-C2 *(F2X  *F2X  -SIGMX*SIGMX)       9905
7        FXA  (I1,J1,K)=FXA  (I1,J1,K)-C3* F1X                             9906
7        F2XA  (I1,J1,K)=F2XA  (I1,J1,K)-C3* F1X  *F1X                     9907
7        FXA  (I,J,K)=FXA  (I,J,K)-C4   *(F2X   - SIGMX)                   9908
7        F2XA  (I,J,K)=F2XA  (I,J,K)-C4  *(F2X  *F2X  -SIGMX*SIGMX)        10001
1   C                                                                      10002
7        IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GO TO 492                           10003
7        IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GO TO 492                            10004
7        FXA  (I1,J,K1)=FXA  (I1,J,K1)-C5  * F1X                           10005
7        F2XA  (I1,J,K1)=F2XA  (I1,J,K1)-C5*F1X *F1X                       10006
7        FXA  (I,J1,K1)=FXA  (I,J1,K1)-C6  *(F2X   - SIGMX)                10007
7        F2XA  (I,J1,K1)=F2XA  (I,J1,K1)-C6*(F2X *F2X  -SIGMX*SIGMX)       10008
7        FXA  (I1,J1,K1)=FXA  (I1,J1,K1)-C7*F1X                            10101
7        F2XA  (I1,J1,K1)=F2XA  (I1,J1,K1)-C7*F1X *F1X                     10102
7        FXA  (I,J,K1)=FXA  (I,J,K1)-C8* (F2X   - SIGMX)                   10103
7        F2XA  (I,J,K1)=F2XA  (I,J,K1)-C8*(F2X  *F2X  -SIGMX*SIGMX)        10104
7        GO TO 492                                                         10105
3    490 IF(PX  .LT.0.9999)GO TO 492                                       10106
7        FXA  (I1,J,K)=FXA  (I1,J,K)-C1   *(F1X  -SIGMX +1.*SIGNX)         10107
7        F2XA  (I1,J,K)=F2XA  (I1,J,K)-C1*(F1X*F1X-(SIGMX-1.*SIGNX)**2)    10108
7        FXA  (I,J1,K)=FXA  (I,J1,K)-C2     * F2X                          10201
7        F2XA  (I,J1,K)=F2XA  (I,J1,K)-C2* F2X  *F2X                       10202
7        FXA  (I1,J1,K)=FXA  (I1,J1,K)-C3     *(F1X   - SIGMX +1.*SIGNX)   10203
7        F2XA  (I1,J1,K)=F2XA  (I1,J1,K)-C3*(F1X*F1X-(SIGMX-1.*SIGNX)**2)  10204
7        FXA  (I,J,K)=FXA  (I,J,K)-C4     * F2X                            10205
7        F2XA  (I,J,K)=F2XA  (I,J,K)-C4* F2X  *F2X                         10206
1   C                                                                      10207
7        IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GO TO 492                           10208
7        IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GO TO 492                            10301
7        FXA  (I1,J,K1)=FXA  (I1,J,K1)-C5 *(F1X  -SIGMX +1.*SIGNX)         10302
7        F2XA  (I1,J,K1)=F2XA  (I1,J,K1)-C5*(F1X*F1X-(SIGMX-1.*SIGNX)**2)  10303
7        FXA  (I,J1,K1)=FXA  (I,J1,K1)-C6  * F2X                           10304
7        F2XA  (I,J1,K1)=F2XA  (I,J1,K1)-C6*F2X *F2X                       10305
7        FXA  (I1,J1,K1)=FXA  (I1,J1,K1)-C7  *(F1X   - SIGMX +1.*SIGNX)    10306
7        F2XA  (I1,J1,K1)=F2XA  (I1,J1,K1)-C7*(F1X*F1X-(SIGMX-1.*SIGNX)**2) 10307
7        FXA  (I,J,K1)=FXA  (I,J,K1)-C8  * F2X                             10308
7        F2XA  (I,J,K1)=F2XA  (I,J,K1)-C8*F2X*F2X                          10401
3    492 IF(PY  .GE.0.0001) GO TO 494                                      10402
7        FYA  (I1,J,K)=FYA  (I1,J,K)-C1   *(F2Y  -SIGMY)                   10403
7        F2YA  (I1,J,K)=F2YA  (I1,J,K)-C1*(F2Y*F2Y- SIGMY   *SIGMY)        10404
7        FYA  (I,J1,K)=FYA  (I,J1,K)-C2     * F1Y                          10405
7        F2YA  (I,J1,K)=F2YA  (I,J1,K)-C2* F1Y  *F1Y                       10406
7        FYA  (I1,J1,K)=FYA  (I1,J1,K)-C3     * F1Y                        10407
7        F2YA  (I1,J1,K)=F2YA  (I1,J1,K)-C3* F1Y*F1Y                       10408
7        FYA  (I,J,K)=FYA  (I,J,K)-C4*(F2Y-SIGMY)                          10501
7        F2YA  (I,J,K)=F2YA  (I,J,K)-C4*(F2Y  *F2Y-SIGMY*SIGMY)            10502
1   C                                                                      10503
7        IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GO TO 496                           10504
7        IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GO TO 496                            10505
7        FYA  (I1,J,K1)=FYA  (I1,J,K1)-C5 *(F2Y  -SIGMY)                   10506
7        F2YA  (I1,J,K1)=F2YA  (I1,J,K1)-C5*(F2Y*F2Y- SIGMY   *SIGMY)      10507
7        FYA  (I,J1,K1)=FYA  (I,J1,K1)-C6  * F1Y                           10508
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7         F2YA  (I,J1,K1)=F2YA  (I,J1,K1)-C6*F1Y *F1Y
7         FYA  (I1,J1,K1)=FYA  (I1,J1,K1)-C7  * F1Y
7         F2YA  (I1,J1,K1)=F2YA  (I1,J1,K1)-C7* F1Y*F1Y
7         FYA  (I,J,K1)=FYA  (I,J,K1)-C8  *(F2Y-SIGMY)
7         F2YA  (I,J,K1)=F2YA  (I,J,K1)-C8*(F2Y*F2Y-SIGMY*SIGMY)
7         GO TO 496
3     494 IF(PY  .LT.0.9999)GO TO 496
7         FYA  (I1,J,K)=FYA  (I1,J,K)-C1    * F2Y
7         F2YA  (I1,J,K)=F2YA  (I1,J,K)-C1* F2Y  *F2Y
7         FYA  (I,J1,K)=FYA  (I,J1,K)-C2    *(F1Y -SIGMY+1.*SIGNY)
7         F2YA  (I,J1,K)=F2YA  (I,J1,K)-C2 *(F1Y*F1Y-(SIGMY-1.*SIGNY)**2)
7         FYA  (I1,J1,K)=FYA  (I1,J1,K)-C3*(F1Y-SIGMY+1.*SIGNY)
7         F2YA  (I1,J1,K)=F2YA  (I1,J1,K)-C3*(F1Y*F1Y-(SIGMY-1.*SIGNY)**2)
7         FYA  (I,J,K)=FYA  (I,J,K)-C4    * F2Y
7         F2YA  (I,J,K)=F2YA  (I,J,K)-C4  * F2Y  *F2Y
1   C
7         IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GO TO 496
7         IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GO TO 496
7         FYA  (I1,J,K1)=FYA  (I1,J,K1)-C5  * F2Y
7         F2YA  (I1,J,K1)=F2YA  (I1,J,K1)-C5*F2Y *F2Y
7         FYA  (I,J1,K1)=FYA  (I,J1,K1)-C6  *(F1Y -SIGMY+1.*SIGNY)
7         F2YA  (I,J1,K1)=F2YA  (I,J1,K1)-C6*(F1Y*F1Y-(SIGMY-1.*SIGNY)**2)
7         FYA  (I1,J1,K1)=FYA  (I1,J1,K1)-C7*(F1Y-SIGMY+1.*SIGNY)
7         F2YA  (I1,J1,K1)=F2YA(I1,J1,K1)-C7*(F1Y*F1Y-(SIGMY-1.*SIGNY)**2)
7         FYA  (I,J,K1)=FYA  (I,J,K1)-C8*  F2Y
7         F2YA  (I,J,K1)=F2YA  (I,J,K1)-C8* F2Y  *F2Y
3     496 IF(PZ  .GE.0.0001) GO TO 498
7         FZA  (I1,J,K)=FZA  (I1,J,K)-C1   *(F2Z  -SIGMZ)
7         F2ZA  (I1,J,K)=F2ZA  (I1,J,K)-C1*(F2Z*F2Z- SIGMZ   *SIGMZ)
7         FZA  (I,J1,K)=FZA  (I,J1,K)-C2 *(F2Z-SIGMZ)
7         F2ZA  (I,J1,K)=F2ZA  (I,J1,K)-C2*(F2Z  *F2Z-SIGMZ*SIGMZ)
7         FZA  (I1,J1,K)=FZA  (I1,J1,K)-C3 *(F2Z-SIGMZ)
7         F2ZA  (I1,J1,K)=F2ZA  (I1,J1,K)-C3*(F2Z*F2Z-SIGMZ*SIGMZ)
7         FZA  (I,J,K)=FZA  (I,J,K)-C4*(F2Z-SIGMZ)
7         F2ZA  (I,J,K)=F2ZA  (I,J,K)-C4*(F2Z  *F2Z-SIGMZ*SIGMZ)
1   C
7         IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GO TO 500
7         IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GO TO 500
7         FZA  (I1,J,K1)=FZA  (I1,J,K1)-C5 * F1Z
7         F2ZA  (I1,J,K1)=F2ZA  (I1,J,K1)-C5* F1Z*F1Z
7         FZA  (I,J1,K1)=FZA  (I,J1,K1)-C6  * F1Z
7         F2ZA  (I,J1,K1)=F2ZA  (I,J1,K1)-C6*F1Z *F1Z
7         FZA  (I1,J1,K1)=FZA  (I1,J1,K1)-C7  * F1Z
7         F2ZA  (I1,J1,K1)=F2ZA  (I1,J1,K1)-C7* F1Z*F1Z
7         FZA  (I,J,K1)=FZA  (I,J,K1)-C8  * F1Z
7         F2ZA  (I,J,K1)=F2ZA  (I,J,K1)-C8* F1Z*F1Z
7         GO TO 500
3     498 IF(PZ  .LT.0.9999)GO TO 500
7         FZA  (I1,J,K)=FZA  (I1,J,K)-C1    * F2Z
7         F2ZA  (I1,J,K)=F2ZA  (I1,J,K)-C1* F2Z  *F2Z
7         FZA  (I,J1,K)=FZA  (I,J1,K)-C2    * F2Z
7         F2ZA  (I,J1,K)=F2ZA  (I,J1,K)-C2 * F2Z*F2Z
7         FZA  (I1,J1,K)=FZA  (I1,J1,K)-C3* F2Z
7         F2ZA  (I1,J1,K)=F2ZA  (I1,J1,K)-C3* F2Z*F2Z
7         FZA  (I,J,K)=FZA  (I,J,K)-C4    * F2Z
7         F2ZA  (I,J,K)=F2ZA  (I,J,K)-C4  * F2Z  *F2Z
1   C
7         IF(SIGMAZ.GT.0.0.AND.K1.GT.KN)GO TO 500
7         IF(SIGMAZ.LT.0.0.AND.K1.LT.1)GO TO 500
7         FZA  (I1,J,K1)=FZA  (I1,J,K1)-C5  *(F1Z-SIGMZ+1.*SIGNZ)
7         F2ZA  (I1,J,K1)=F2ZA(I1,J,K1)-C5*(F1Z*F1Z-(SIGMZ-1.*SIGNZ)**2)
7         FZA  (I,J1,K1)=FZA  (I,J1,K1)-C6  *(F1Z -SIGMZ+1.*SIGNZ)
7         F2ZA  (I,J1,K1)=F2ZA  (I,J1,K1)-C6*(F1Z*F1Z-(SIGMZ-1.*SIGNZ)**2)
7         FZA  (I1,J1,K1)=FZA  (I1,J1,K1)-C7*(F1Z-SIGMZ+1.*SIGNZ)
7         F2ZA  (I1,J1,K1)=F2ZA(I1,J1,K1)-C7*(F1Z*F1Z-(SIGMZ-1.*SIGNZ)**2)
7         FZA  (I,J,K1)=FZA  (I,J,K1)-C8*(F1Z-SIGMZ+1.*SIGNZ)
7         F2ZA  (I,J,K1)=F2ZA  (I,J,K1)-C8*(F1Z*F1Z-(SIGMZ-1.*SIGNZ)**2)
3     500 CONTINUE
1   C
1   C                COUPLINGS BETWEEN BORDER AND BULK
1   C
```

```
7         DO 560 K=1,KN
7         DO 550 I=1,IN
7         DO 550 J=1,JM
7         SIGMAX =U(I,J,K)*FRACX
7         SIGMAY =V(I,J,K)*FRACY
7         SIGMAZ =W(I,J,K)*FRACZ(K)
7         IF(SIGMAZ.NE.0.)SIGNZ=SIGMAZ/ABS(SIGMAZ)
7         IF(SIGMAZ.EQ.0.)SIGNZ=1.
7         IF(SIGMAX.NE.0.)SIGNX=SIGMAX/ABS(SIGMAX)
7         IF(SIGMAX.EQ.0.)SIGNX=1.
7         IF(SIGMAY.EQ.0.)SIGNY=1.
7         IF(SIGMAY.NE.0.)SIGNY=SIGMAY/ABS(SIGMAY)
7         K1 = K+1
7         I1 = I+1
7         J1 = J + 1
7         IF(SIGMAZ.LT.0.) K1 = K-1
7         IF(SIGMAX.LT.0.) I1 = I-1
7         IF(SIGMAY.LT.0.) J1 = J-1
7         IF(I.EQ.1.OR.I.EQ.IN) GO TO 557
7         IF(J.EQ.1.OR.J.EQ.JM) GO TO 558
7         GO TO 550
3     557 IF(J.EQ.1.OR.J.EQ.JM)GO TO 550
7         IF(I1.LE.1.OR.I1.GE.IN)GO TO 550
7         GO TO 559
3     558 IF(J1.LE.1.OR.J1.GE.JM)GO TO 550
3     559 C1=C(I,J,K) *ABS(SIGMAX)*(1.-ABS(SIGMAY))*(1.-ABS(SIGMAZ))
7         C2=C(I,J,K) *ABS(SIGMAY)*(1.-ABS(SIGMAX))*(1.-ABS(SIGMAZ))
7         C3=C(I,J,K) *ABS(SIGMAX)*ABS(SIGMAY)*(1.-ABS(SIGMAZ))
7         C4=C(I,J,K) *(1.-ABS(SIGMAX))*(1.-ABS(SIGMAY))*(1.-ABS(SIGMAZ))
7         C5=C(I,J,K) *ABS(SIGMAX)*(1.-ABS(SIGMAY))*ABS(SIGMAZ)
7         C6=C(I,J,K) *ABS(SIGMAY)*(1.-ABS(SIGMAX))*ABS(SIGMAZ)
7         C7=C(I,J,K) *ABS(SIGMAX)*ABS(SIGMAY)*ABS(SIGMAZ)
7         C8=C(I,J,K) *(1.-ABS(SIGMAX))*(1.-ABS(SIGMAY))*ABS(SIGMAZ)
1   C
4       4 O    (I1,J,K )=O    (I1,J,K )+C1
7         O    (I,J1,K )=O    (I,J1,K )+C2
7         O    (I1,J1,K )=O    (I1,J1,K )+C3
7         O    (I,J,K )=O    (I,J,K )+C4
1   C
7         FXA  (I1,J,K )=FXA  (I1,J,K )+(SIGMAX/2.-.5*SIGNX)*C1
7         FXA  (I,J1,K )=FXA  (I,J1,K )+(SIGMAX/2.)*C2
7         FXA  (I1,J1,K )=FXA  (I1,J1,K )+(SIGMAX/2.-.5*SIGNX)*C3
7         FXA  (I,J,K )=FXA  (I,J,K )+(SIGMAX/2.)*C4
1   C
7         F2XA  (I1,J,K )=F2XA  (I1,J,K )+(SIGMAX/2.-.5*SIGNX)**2*C1
7         F2XA  (I,J1,K )=F2XA  (I,J1,K )+(SIGMAX**2/4.)*C2
7         F2XA  (I1,J1,K )=F2XA  (I1,J1,K )+(SIGMAX/2.-.5*SIGNX)**2*C3
7         F2XA  (I,J,K )=F2XA  (I,J,K )+(SIGMAX**2/4.)*C4
1   C
7         RXA  (I1,J,K )=RXA  (I1,J,K )+ABS(SIGMAX)**2*C1
7         RXA  (I,J1,K )=RXA  (I,J1,K )+(1.-ABS(SIGMAX))**2*C2
7         RXA  (I1,J1,K )=RXA  (I1,J1,K )+ABS(SIGMAX)**2*C3
7         RXA  (I,J,K )=RXA  (I,J,K )+(1.-ABS(SIGMAX))**2*C4
1   C
7         FYA  (I1,J,K )=FYA  (I1,J,K )+(SIGMAY/2.)*C1
7         FYA  (I,J1,K )=FYA  (I,J1,K )+(SIGMAY/2.-.5*SIGNY)*C2
7         FYA  (I1,J1,K )=FYA  (I1,J1,K )+(SIGMAY/2.-.5*SIGNY)*C3
7         FYA  (I,J,K )=FYA  (I,J,K )+(SIGMAY/2.)*C4
1   C
7         F2YA  (I1,J,K )=F2YA  (I1,J,K )+(SIGMAY**2/4.)*C1
7         F2YA  (I,J1,K )=F2YA  (I,J1,K )+(SIGMAY/2.-.5*SIGNY)**2*C2
7         F2YA  (I1,J1,K )=F2YA  (I1,J1,K )+(SIGMAY/2.-.5*SIGNY)**2*C3
7         F2YA  (I,J,K )=F2YA  (I,J,K )+(SIGMAY**2/4.)*C4
1   C
7         RYA  (I1,J,K )=RYA  (I1,J,K )+(1.-ABS(SIGMAY))**2*C1
7         RYA  (I,J1,K )=RYA  (I,J1,K )+ABS(SIGMAY)**2*C2
7         RYA  (I1,J1,K )=RYA  (I1,J1,K )+ABS(SIGMAY)**2*C3
7         RYA  (I,J,K )=RYA  (I,J,K )+(1.-ABS(SIGMAY))**2*C4
1   C
7         FZA  (I1,J,K )=FZA  (I1,J,K )+(SIGMAZ/2.)*C1
7         FZA  (I,J1,K )=FZA  (I,J1,K )+(SIGMAZ/2.)*C2
7         FZA  (I1,J1,K )=FZA  (I1,J1,K )+(SIGMAZ/2.)*C3
7         FZA  (I,J,K )=FZA  (I,J,K )+(SIGMAZ/2.)*C4
```

```
1  C
7        F2ZA  (I1,J,K )=F2ZA  (I1,J,K )+(SIGMAZ**2/4.)*C1
7        F2ZA  (I,J1,K )=F2ZA  (I,J1,K )+(SIGMAZ**2/4.)*C2
7        F2ZA  (I1,J1,K )=F2ZA  (I1,J1,K )+(SIGMAZ**2/4.)*C3
7        F2ZA  (I,J,K )=F2ZA  (I,J,K )+(SIGMAZ**2/4.)*C4
1  C
7        RZA  (I1,J,K )=RZA  (I1,J,K )+(1.-ABS(SIGMAZ))**2*C1
7        RZA  (I,J1,K )=RZA  (I,J1,K )+(1.-ABS(SIGMAZ))**2*C2
7        RZA  (I1,J1,K )=RZA  (I1,J1,K )+(1.-ABS(SIGMAZ))**2*C3
7        RZA  (I,J,K )=RZA  (I,J,K )+(1.-ABS(SIGMAZ))**2*C4
1  C
7        IF(K1.LT.1)GO TO 550
7        IF(K1.GT.KN)GO TO 550
7        U   (I1,J,K1)=U   (I1,J,K1)+C5
7        U   (I,J1,K1)=U   (I,J1,K1)+C6
7        U   (I1,J1,K1)=U   (I1,J1,K1)+C7
7        U   (I,J,K1)=U   (I,J,K1)+C8
1  C
7        FXA  (I1,J,K1)=FXA  (I1,J,K1)+(SIGMAX/2.-.5*SIGNX)*C5
7        FXA  (I,J1,K1)=FXA  (I,J1,K1)+(SIGMAX/2.)*C6
7        FXA  (I1,J1,K1)=FXA  (I1,J1,K1)+(SIGMAX/2.-.5*SIGNX)*C7
7        FXA  (I,J,K1)=FXA  (I,J,K1)+(SIGMAX/2.)*C8
1  C
7        F2XA  (I1,J,K1)=F2XA  (I1,J,K1)+(SIGMAX/2.-.5*SIGNX)**2*C5
7        F2XA  (I,J1,K1)=F2XA  (I,J1,K1)+(SIGMAX**2/4.)*C6
7        F2XA  (I1,J1,K1)=F2XA  (I1,J1,K1)+(SIGMAX/2.-.5*SIGNX)**2*C7
7        F2XA  (I,J,K1)=F2XA  (I,J,K1)+(SIGMAX**2/4.)*C8
1  C
7        RXA  (I1,J,K1)=RXA  (I1,J,K1)+ABS(SIGMAX)**2*C5
7        RXA  (I,J1,K1)=RXA  (I,J1,K1)+(1.-ABS(SIGMAX))**2*C6
7        RXA  (I1,J1,K1)=RXA  (I1,J1,K1)+ABS(SIGMAX)**2*C7
7        RXA  (I,J,K1)=RXA  (I,J,K1)+(1.-ABS(SIGMAX))**2*C8
1  C
7        FYA  (I1,J,K1)=FYA  (I1,J,K1)+(SIGMAY/2.)*C5
7        FYA  (I,J1,K1)=FYA  (I,J1,K1)+(SIGMAY/2.-.5*SIGNY)*C6
7        FYA  (I1,J1,K1)=FYA  (I1,J1,K1)+(SIGMAY/2.-.5*SIGNY)*C7
7        FYA  (I,J,K1)=FYA  (I,J,K1)+(SIGMAY/2.)*C8
1  C
7        F2YA  (I1,J,K1)=F2YA  (I1,J,K1)+(SIGMAY**2/4.)*C5
7        F2YA  (I,J1,K1)=F2YA  (I,J1,K1)+(SIGMAY/2.-.5*SIGNY)**2*C6
7        F2YA  (I1,J1,K1)=F2YA  (I1,J1,K1)+(SIGMAY/2.-.5*SIGNY)**2*C7
7        F2YA  (I,J,K1)=F2YA  (I,J,K1)+(SIGMAY**2/4.)*C8
1  C
7        RYA  (I1,J,K1)=RYA  (I1,J,K1)+(1.-ABS(SIGMAY))**2*C5
7        RYA  (I,J1,K1)=RYA  (I,J1,K1)+ABS(SIGMAY)**2*C6
7        RYA  (I1,J1,K1)=RYA  (I1,J1,K1)+ABS(SIGMAY)**2*C7
7        RYA  (I,J,K1)=RYA  (I,J,K1)+(1.-ABS(SIGMAY))**2*C8
1  C
7        FZA  (I1,J,K1)=FZA  (I1,J,K1)+(SIGMAZ/2.-.5*SIGNZ)*C5
7        FZA  (I,J1,K1)=FZA  (I,J1,K1)+(SIGMAZ/2.-.5*SIGNZ)*C6
7        FZA  (I1,J1,K1)=FZA  (I1,J1,K1)+(SIGMAZ/2.-.5*SIGNZ)*C7
7        FZA  (I,J,K1)=FZA  (I,J,K1)+(SIGMAZ/2.-.5*SIGNZ)*C8
1  C
7        F2ZA  (I1,J,K1)=F2ZA  (I1,J,K1)+(SIGMAZ/2.-.5*SIGNZ)**2*C5
7        F2ZA  (I,J1,K1)=F2ZA  (I,J1,K1)+(SIGMAZ /2.-.5*SIGNZ)**2*C6
7        F2ZA  (I1,J1,K1)=F2ZA  (I1,J1,K1)+(SIGMAZ/2.-.5*SIGNZ)**2*C7
7        F2ZA  (I,J,K1)=F2ZA  (I,J,K1)+(SIGMAZ/2.-.5*SIGNZ)**2*C8
1  C
7        RZA  (I1,J,K1)=RZA  (I1,J,K1)+     ABS(SIGMAZ) **2*C5
7        RZA  (I,J1,K1)=RZA  (I,J1,K1)+     ABS(SIGMAZ) **2*C6
7        RZA  (I1,J1,K1)=RZA  (I1,J1,K1)+     ABS(SIGMAZ) **2*C7
7        RZA  (I,J,K1)=RZA  (I,J,K1)+     ABS(SIGMAZ) **2*C8
3    550 CONTINUE
1  C
1  C              THE PLANE CORNERS ARE NOW TREATED:
1  C
7        DO 560 I=1,IN,INN
7        DO 560 J=1,JM,JMM
7        SIGMAX=U(I,J,K )*FRACX
7        SIGMAY=V(I,J,K )*FRACY
7        IF(SIGMAX.NE.0.)SIGNX=SIGMAX/ABS(SIGMAX)
```

```
7         IF(SIGMAX.EQ.0.)SIGNX=1.
7         IF(SIGMAY.EQ.0.)SIGNY=1.
7         IF(SIGMAY.NE.0.)SIGNY=SIGMAY/ABS(SIGMAY)
7         I1 = I+1
7         J1 = J+1
7         IF(SIGMAX.LT.0.) I1 = I-1
7         IF(SIGMAY.LT.0.) J1 = J-1
8          IF(I1.NE.2.AND.I1.NE.INN ) GO TO 560
8          IF(J1.NE.2.AND.J1.NE.JMM ) GO TO 560
1   C
7         C3=C(I,J,K )*ABS(SIGMAX)*ABS(SIGMAY)*(1.-ABS(SIGMAZ))
7         C7=C(I,J,K )*ABS(SIGMAX)*ABS(SIGMAY)*ABS(SIGMAZ)
7         O    (I1,J1,K )=O    (I1,J1,K )+C3
7         FYA  (I1,J1,K )=FYA  (I1,J1,K )+(SIGMAY/2.-.5*SIGNY)*C3
7         F2YA  (I1,J1,K )=F2YA  (I1,J1,K )+(SIGMAY/2.-.5*SIGNY)**2*C3
7         RYA  (I1,J1,K )=RYA  (I1,J1,K )+ABS(SIGMAY)**2*C3
7         FXA  (I1,J1,K )=FXA  (I1,J1,K )+(SIGMAX/2.-.5*SIGNX)*C3
7         F2XA  (I1,J1,K )=F2XA  (I1,J1,K )+(SIGMAX/2.-.5*SIGNX)**2*C3
7         RXA  (I1,J1,K )=RXA  (I1,J1,K )+ABS(SIGMAX)**2*C3
7         FZA  (I1,J1,K )=FZA  (I1,J1,K )+(SIGMAZ/2.)*C3
7         F2ZA  (I1,J1,K )=F2ZA  (I1,J1,K )+(SIGMAZ**2/4.)*C3
7         RZA  (I1,J1,K )=RZA  (I1,J1,K )+(1.-ABS(SIGMAZ))**2*C3
1   C
7         IF(K1.LT.1.OR.K1.GT.KN)GO TO 560
7         O    (I1,J1,K1)=O    (I1,J1,K1)+C7
7         FXA  (I1,J1,K1)=FXA  (I1,J1,K1)+(SIGMAX/2.-.5*SIGNX)*C7
7         F2XA  (I1,J1,K1)=F2XA  (I1,J1,K1)+(SIGMAX/2.-.5*SIGNX)**2*C7
7         RXA  (I1,J1,K1)=RXA  (I1,J1,K1)+ABS(SIGMAX)**2*C7
7         FYA  (I1,J1,K1)=FYA  (I1,J1,K1)+(SIGMAY/2.-.5*SIGNY)*C7
7         F2YA  (I1,J1,K1)=F2YA  (I1,J1,K1)+(SIGMAY/2.-.5*SIGNY)**2*C7
7         RYA  (I1,J1,K1)=RYA  (I1,J1,K1)+ABS(SIGMAY)**2*C7
7         FZA  (I1,J1,K1)=FZA  (I1,J1,K1)+(SIGMAZ/2.-.5*SIGNZ)*C7
7         F2ZA  (I1,J1,K1)=F2ZA  (I1,J1,K1)+(SIGMAZ/2.-.5*SIGNZ)**2*C7
7         RZA  (I1,J1,K1)=RZA  (I1,J1,K1)+ABS(SIGMAZ)**2*C7
3     560 CONTINUE
1   C
1   C               VALUES AT NEXT TIME STEP ARE CALCULATED
1   C
7         DO 600 K=1,KN
7         DO 600 I=1,IN
7         DO 600 J=1,JM
7         C(I,J,K)=O    (I,J,K)
7         IF(C(I,J,K).LT.0.)C(I,J,K)=0.0
7         CTREPL = O(I,J,K)
7         IF(CTREPL.LT.1.0E-10) GO TO 599
7         FTX(I,J,K)=FXA  (I,J,K)/CTREPL
7         FX = FTX(I,J,K)
7         RXMAX = ABS(FX-0.5)*2.
7         RXMIN = ABS(FX+0.5)*2.
7         IF(RXMIN.GT.RXMAX) RXMIN=RXMAX
7         HA=RXA  (I,J,K)/CTREPL+12.*(-FX*FX+F2XA  (I,J,K)/CTREPL)
7         RTX(I,J,K)=SQRT(ABS(HA))
7         IF(RTX(I,J,K).GT.RXMIN)RTX(I,J,K)=RXMIN
1   C
7         FTY(I,J,K)=FYA  (I,J,K)/CTREPL
7         FY = FTY(I,J,K)
7         RYMAX = ABS(FY-0.5)*2.
7         RYMIN = ABS(FY+0.5)*2.
7         IF(RYMIN.GT.RYMAX) RYMIN = RYMAX
7         HB=RYA  (I,J,K)/CTREPL+12.*(-FY*FY+F2YA  (I,J,K)/CTREPL)
7         RTY(I,J,K)=SQRT(ABS(HB))
7         IF(RTY(I,J,K).GT.RYMIN)RTY(I,J,K)=RYMIN
1   C
7         FTZ(I,J,K)=FZA  (I,J,K)/CTREPL
7         FZ = FTZ(I,J,K)
7         RZMAX = ABS(FZ-0.5)*2.
7         RZMIN = ABS(FZ+0.5)*2.
7         IF(RZMIN.GT.RZMAX) RZMIN = RZMAX
7         HC=RZA  (I,J,K)/CTREPL+12.*(-FZ*FZ+F2ZA  (I,J,K)/CTREPL)
7         RTZ(I,J,K)=SQRT(ABS(HC))
7         IF(RTZ(I,J,K).GT.RZMIN)RTZ(I,J,K)=RZMIN
7         GO TO 600
```

```
3     599 FTX(I,J,K)=0.
7         FTY(I,J,K)=0.
7         FTZ(I,J,K)=0.
7         RTX(I,J,K)=0.
7         RTY(I,J,K)=0.
7         RTZ(I,J,K)=0.
3     600 CONTINUE
7         RETURN
7         END
7         SUBROUTINE INITW
7         COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7         COMMON/VAR1/CT(30,11),FWX(30,11),RWX(30,11),FWY(30,11),RWY(30,11)
7         COMMON/CALGO1/F    (30,11),FXW   (30,11),FYW   (30,11),RXW   (30,11),
6        1RYW   (30,11),F2WX   (30,11),F2WY   (30,11)
7         COMMON/CVELTY/VX,VY
7         N1=IN*JM*5
7         CALL CLEAR(CT,N1)
7         DO 3 J=4,8
5       3 READ(5,100)(CT(I,J),I=2,7)
7         DO 1 J=4,8
7         DO 1 I=2,7
7         IF(CT(I,J).EQ.0.)GO TO 1
7         RWX(I,J)=1.
7         RWY(I,J)=1.
5       1 CONTINUE
3     100 FORMAT(6F10.0)
7         RETURN
7         END
7         SUBROUTINE UPDOWN(DX,DY,IN,JM,INN,JMM,DT,NITER)
7         COMMON/VAR1/CT(30,11),FWX(30,11),RWX(30,11),FWY(30,11),RWY(30,11)
7         COMMON/CALGO1/F    (30,11),FXW   (30,11),FYW   (30,11),RXW   (30,11),
6        1RYW   (30,11),F2WX   (30,11),F2WY   (30,11)
7         COMMON/CVELTY/VX,VY
7         N2=7*IN*JM
7         CALL CLEAR(F,N2)
1     C
1     C
1     C   CALCULATE SIGMAS, PX, AND PY
1     C
7         DO 501 I= 2,INN
7         DO 500 J= 2,JMM
7         IF(CT(I,J).EQ.0.0E-00 ) GOTO 500
7         SIGMAX= VX      *CT     /DX
7         SIGMAY= VY      *DT     /DY
7         IF(SIGMAX.EQ.0.) GO TO 90
7         SIGNX=SIGMAX/ABS(SIGMAX)
7         GO TO 92
4      90 SIGNX = 1.
4      92 IF(SIGMAY.EQ.0.) GO TO 94
7         SIGNY = SIGMAY/ABS(SIGMAY)
7         GO TO 96
4      94 SIGNY=1.
4      96 CONTINUE
7         IF (SIGMAX.GT.0.) GOTO 100
7         PIJX=(-2.*(FWX(I,J)+SIGMAX)+RWX(I,J)-1.0)/(2.0*RWX(I,J))
7         GOTO 110
3     100 PIJX=(2.0*(FWX(I,J)+SIGMAX)+RWX(I,J)-1.)/(2.0*RWX(I,J))
3     110 IF(SIGMAY.GT.0.) GO TO 120
7         PIJY=(-2.0*(FWY(I,J)+SIGMAY)+RWY(I,J)-1.0)/ (2.0*RWY(I,J))
7         GOTO 130
3     120 PIJY=(2.0*(FWY(I,J)+SIGMAY)+RWY(I,J)-1.0)/(2.0*RWY(I,J))
3     130 CONTINUE
1     C
1     C
1     C             NORMAL CONDITIONS
1     C
1     C             IF PX,PY<0 OR PX,PY>1 MODIFICATIONS ARE MADE
1     C
7         NCOUNT=0
7         IF(PIJX.GE.0.0001.AND.PIJX.LE.0.9999) GO TO 150
7         NCOUNT=1
```

```
7         IF(PIJX.LT.0.0001) PIJX=0.0                                    15007
7         IF(PIJX.GT.0.9999) PIJX=1.0                                    15008
3     150 IF(PIJY.GE.0.0001.AND.PIJY.LE.0.9999) GO TO 160                15101
7         NCOUNT=1                                                       15102
7         IF(PIJY.LT.0.0001) PIJY=0.0                                    15103
7         IF(PIJY.GT.0.9999) PIJY=1.0                                    15104
3     160 CONTINUE                                                       15105
7         IF(SIGMAX.GT.0.0) I1=I+1                                       15106
7         IF(SIGMAX.EQ.0.) I1 = I                                        15107
7         IF(SIGMAX.LT.0.0) I1=I-1                                       15108
7         IF(SIGMAY.GT.0.0) J1=J+1                                       15201
7         IF(SIGMAY.EQ.0.) J1 = J                                        15202
7         IF(SIGMAY.LT.0.0) J1=J-1                                       15203
1   C                                                                    15204
7         C1     =CT(I,J)*PIJX*(1.0-PIJY)                                15205
7         C2     =CT(I,J)*(1.0-PIJX)*PIJY                                15206
7         C3     =CT(I,J)*PIJX*PIJY                                      15207
7         C4     =CT(I,J)*(1.0-PIJX)*(1.-PIJY)                           15208
1   C                                                                    15301
7         F    (I1,J)=F    (I1,J)+C1                                     15302
7         F    (I,J1)=F    (I,J1)+C2                                     15303
7         F    (I1,J1)=F    (I1,J1)+C3                                   15304
7         F    ( I,J) =F    (I,J)+C4                                     15305
1   C                                                                    15306
1   C                                                                    15307
7         F1X  =(PIJX*RWX(I,J)-1.0)/2.0*SIGNX                            15308
7         F1Y  =(1.0-RWY(I,J)*(1.0-PIJY))/2.0*SIGNY                      15401
7         F2X  =(1.0-RWX(I,J)*(1.0-PIJX))/2.0*SIGNX                      15402
7         F2Y  =(PIJY*RWY(I,J)-1.0)/2.0*SIGNY                            15403
1   C                                                                    15404
7         FXW  (I1,J)=FXW  (I1,J)+F1X  *C1                               15405
7         FYW  (I1,J)=FYW  (I1,J)+F1Y  *C1                               15406
7         FXW  (I,J1)=FXW  (I,J1)+F2X  *C2                               15407
7         FYW  (I,J1) = FYW  (I,J1) + F2Y  *C2                           15408
7         FXW  (I1,J1) = FXW  (I1,J1) + F1X  *C3                         15501
7         FYW  (I1,J1) = FYW  (I1,J1) + F2Y  *C3                         15502
7         FXW  (I,J) = FXW  (I,J) + F2X  *C4                             15503
7         FYW  (I,J) = FYW  (I,J) + F1Y  *C4                             15504
1   C                                                                    15505
7         F2WX  (I1,J) = F2WX  (I1,J) + F1X  *F1X  *C1                   15506
7         F2WY  (I1,J) = F2WY  (I1,J) + F1Y  *F1Y  *C1                   15507
7         F2WX  (I,J1) = F2WX  (I,J1) + F2X  *F2X  *C2                   15508
7         F2WY  (I,J1) = F2WY  (I,J1) + F2Y  *F2Y  *C2                   15601
7         F2WX  (I1,J1) = F2WX  (I1,J1) + F1X  *F1X  *C3                 15602
7         F2WY  (I1,J1) = F2WY  (I1,J1) + F2Y  *F2Y  *C3                 15603
7         F2WX  (I,J)   = F2WX  (I,J)+ F2X  *F2X  *C4                    15604
7         F2WY  (I,J)= F2WY  (I,J)+F1Y  *F1Y  *C4                        15605
1   C                                                                    15606
1   C                                                                    15607
7         R1X  =(PIJX*RWX(I,J))**2                                       15608
7         R1Y  =((1.0-PIJY)*RWY(I,J))**2                                 15701
7         R2X  =((1.0-PIJX)*RWX(I,J))**2                                 15702
7         R2Y  =(PIJY*RWY(I,J))**2                                       15703
1   C                                                                    15704
7         RXW  (I1,J)=RXW  (I1,J)+ R1X  * C1                             15705
7         RYW  (I1,J)=RYW  (I1,J)+ R1Y  * C1                             15706
7         RXW  (I,J1)=RXW  (I,J1)+ R2X  * C2                             15707
7         RYW  (I,J1)=RYW  (I,J1)+ R2Y  * C2                             15708
7         RXW  (I1,J1)=RXW  (I1,J1)+R1X  *C3                             15801
7         RYW  (I1,J1)=RYW  (I1,J1)+R2Y  *C3                             15802
7         RXW  (I,J) = RXW  (I,J)+ R2X  *C4                              15803
7         RYW  (I,J)=RYW  (I,J)+R1Y   *C4                                15804
1   C                                                                    15805
1   C                                                                    15806
1   C                                                                    15807
7         IF(NCOUNT.EQ.0) GO TO 500                                      15808
7         SIGMX = SIGMAX+FWX(I,J)                                        15901
7         SIGMY = SIGMAY + FWY(I,J)                                      15902
7         IF(PIJX.GT.0.0001) GO TO 490                                   15903
1   C                                                                    15904
```

```
7          FXW  (I1,J) = FXW  (I1,J) - C1     * F1X
7          F2WX  (I1,J)=F2WX  (I1,J)-C1     * F1X  *F1X
7          FXW  (I,J1) = FXW  (I,J1) - C2     *(F2X   - SIGMX)
7          F2WX  (I,J1)= F2WX  (I,J1)-C2     *(F2X  *F2X  -SIGMX*SIGMX)
7          FXW  (I1,J1)=FXW  (I1,J1)-C3     * F1X
7          F2WX  (I1,J1)=F2WX  (I1,J1)-C3     * F1X  *F1X
7          FXW  (I,J)= FXW  (I,J) - C4     *(F2X   - SIGMX)
7          F2WX  (I,J) = F2WX  (I,J)-C4     *(F2X  *F2X  -SIGMX*SIGMX)
1    C
7          GO TO 492
3      490 IF(PIJX.LT.0.9999)GO TO 492
7          FXW  (I1,J) = FXW  (I1,J)- C1     *(F1X  -SIGMX +1.*SIGNX)
1    C
7          F2WX  (I1,J)=F2WX  (I1,J)-C1     *(F1X  *F1X  -(SIGMX -1.
6         1*SIGNX)**2)
7          FXW  (I,J1) = FXW  (I,J1) - C2     * F2X
7          F2WX  (I,J1)=F2WX  (I,J1)-C2     * F2X  *F2X
1    C
7          FXW  (I1,J1) = FXW  (I1,J1) - C3     *(F1X   - SIGMX +1.*SIGNX)
7          F2WX  (I1,J1)=F2WX  (I1,J1)-C3     *(F1X  *F1X  -(SIGMX -1.
6         1*SIGNX)**2)
7          FXW  (I,J) = FXW  (I,J) - C4     * F2X
7          F2WX  (I,J)=F2WX  (I,J)-C4     * F2X  *F2X
3      492 IF(PIJY.GE.0.0001) GO TO 494
1    C
7          FYW  (I1,J) = FYW  (I1,J) - C1     *(F1Y   - SIGMY)
7          F2WY  (I1,J) = F2WY  (I1,J) - C1     *(F1Y  *F1Y  -SIGMY*SIGMY)
7          FYW  (I,J1) = FYW  (I,J1) - C2     * F2Y
7          F2WY  (I,J1) = F2WY  (I,J1) - C2     * F2Y  *F2Y
7          FYW  (I1,J1) = FYW  (I1,J1) - C3     * F2Y
7          F2WY  (I1,J1) = F2WY  (I1,J1) - C3     * F2Y  *F2Y
7          FYW  (I,J)=FYW  (I,J)-C4     *(F1Y  -SIGMY)
7          F2WY  (I,J)=F2WY  (I,J)-C4     *(F1Y  *F1Y  -SIGMY*SIGMY)
7          GO TO 500
3      494 IF(PIJY.LT.0.9999)GO TO 500
7          FYW  (I1,J) = FYW  (I1,J) - C1     * F1Y
7          F2WY  (I1,J)=F2WY  (I1,J)-C1     *(F1Y  *F1Y  )
7          FYW  (I,J1) = FYW  (I,J1) - C2     *(F2Y   - SIGMY +1.*SIGNY)
7          F2WY  (I,J1)=F2WY  (I,J1)-C2     *(F2Y  *F2Y  -(SIGMY -1.
6         1*SIGNY)**2)
1    C
7          FYW  (I1,J1)=FYW  (I1,J1)-C3     *(F2Y  -SIGMY +1.*SIGNY)
7          F2WY  (I1,J1)=F2WY  (I1,J1)-C3     *(F2Y  *F2Y  -(SIGMY -1.
6         1*SIGNY)**2)
7          FYW  (I,J) = FYW  (I,J) - C4     * F1Y
7          F2WY  (I,J)=F2WY  (I,J)-C4     * F1Y  *F1Y
3      500 CONTINUE
3      501 CONTINUE
1    C
1    C                  COUPLING BETWEEN BORDER AND BULK
1    C
7          DO 551 I=1,IN
7          DO 550 J=1,JM
7          IF(I.EQ.1.OR.I.EQ.IN) GO TO 557
7          IF(J.EQ.1.OR.J.EQ.JM) GO TO 558
7          GO TO 550
3      557 IF(J.EQ.1.OR.J.EQ.JM) GO TO 550
7          SIGMAX = VX      *DT     /DX
7          SIGMAY = VY      *DT     /DY
7          IF(SIGMAX.EQ.0.) GO TO 552
7          SIGNX = SIGMAX/ABS(SIGMAX)
7          GO TO 554
3      552 SIGNX = 1.
3      554 IF(SIGMAY.EQ.0.) GO TO 553
7          SIGNY = SIGMAY/ABS(SIGMAY)
7          GO TO 556
3      553 SIGNY = 1.
3      556 I1 = I+1
7          J1 = J + 1
7          IF(SIGMAX.LT.0.) I1 = I-1
7          IF(SIGMAY.LT.0.) J1 = J-1
7          IF(I1.LE.1.OR.I1.GE.IN) GO TO 550
```

```
7          GO TO 559
3      558 IF(I.LE.1.OR.I.GE.IN) GO TO 550
7          SIGMAX= VX      *DT     /DX
7          SIGMAY = VY      *DT     /DY
7          IF(SIGMAX.EQ.0.) GO TO 5520
7          SIGNX= SIGMAX/ABS(SIGMAX)
7          GO TO 5540
2     5520 SIGNX = 1.
2     5540 IF(SIGMAY.EQ.0.) GO TO 5530
7          SIGNY = SIGMAY/ABS(SIGMAY)
7          GO TO 5560
2     5530 SIGNY = 1.
2     5560 I1 = I  + 1
7          J1 = J+1
7          IF(SIGMAX.LT.0.)I1=I-1
7          IF(SIGMAY.LT.0.) J1 = J-1
7          IF(J1.LE.1.OR.J1.GE.JM) GO TO 550
3      559 C1 = CT(I,J)*ABS(SIGMAX)*(1.-ABS(SIGMAY))
7          C2 = CT(I,J)*ABS(SIGMAY)*(1.-ABS(SIGMAX))
7          C3 = CT(I,J)*ABS(SIGMAX)*ABS(SIGMAY)
7          C4 = CT(I,J)*(1.-ABS(SIGMAX))*(1.-ABS(SIGMAY))
1   C
7          F    (I1,J) = F    (I1,J) + C1
7          F    (I,J1) = F    (I,J1) + C2
7          F    (I1,J1) = F    (I1,J1) + C3
7          F    (I,J) = F    (I,J) + C4
1   C
7          FXW  (I1,J) = FXW  (I1,J) + (SIGMAX/2.-0.5*SIGNX)*C1
7          FYW  (I1,J) = FYW  (I1,J) +(SIGMAY/2.)*C1
7          FXW  (I,J1) = FXW  (I,J1) +(SIGMAX/2.)*C2
7          FYW  (I,J1) = FYW  (I,J1) + (SIGMAY/2.-0.5*SIGNY)*C2
7          FXW  (I1,J1) = FXW  (I1,J1) + (SIGMAX/2.-0.5*SIGNX)*C3
7          FYW  (I1,J1) = FYW  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)*C3
7          FXW  (I,J) = FXW  (I,J) +(SIGMAX/2.)*C4
7          FYW  (I,J) = FYW  (I,J) +(SIGMAY/2.)*C4
1   C
7          F2WX  (I1,J) = F2WX  (I1,J) + (SIGMAX/2.-0.5*SIGNX)**2*C1
7          F2WY  (I1,J) = F2WY  (I1,J) + (SIGMAY**2/4.)*C1
7          F2WX  (I,J1) = F2WX  (I,J1) +(SIGMAX**2/4.)*C2
7          F2WY  (I,J1) = F2WY  (I,J1) + (SIGMAY/2.-0.5*SIGNY)**2*C2
7          F2WX  (I1,J1) = F2WX  (I1,J1) + (SIGMAX/2.-0.5*SIGNX)**2*C3
7          F2WY  (I1,J1) = F2WY  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)**2*C3
7          F2WX  (I,J) = F2WX  (I,J) +(SIGMAX**2/4.)*C4
7          F2WY  (I,J) = F2WY  (I,J) +(SIGMAY**2/4.)*C4
1   C
7          RXW  (I1,J) = RXW  (I1,J) + ABS(SIGMAX)**2*C1
7          RYW  (I1,J) = RYW  (I1,J) + (1.-ABS(SIGMAY))**2*C1
7          RXW  (I,J1) = RXW  (I,J1) + (1.-ABS(SIGMAX))**2*C2
7          RYW  (I,J1) = RYW  (I,J1) + ABS(SIGMAY)**2*C2
7          RXW  (I1,J1) = RXW  (I1,J1) + ABS(SIGMAX)**2*C3
7          RYW  (I1,J1) = RYW  (I1,J1) + ABS(SIGMAY)**2*C3
7          RXW  (I,J) = RXW  (I,J) + (1.-ABS(SIGMAX))**2*C4
7          RYW  (I,J) = RYW  (I,J) + (1.-ABS(SIGMAY))**2*C4
3      550 CONTINUE
3      551 CONTINUE
1   C
1   C               THE FOUR CORNERS ARE NOW TREATED:
1   C
7          DO 561 I=1,IN,INN
7          DO 560 J=1,JM,JMM
7          SIGMAX = VX      *DT     /DX
7          SIGMAY = VY      *DT     /DY
7          IF(SIGMAX.EQ.0.) GO TO 562
7          SIGNX = ABS(SIGMAX)/SIGMAX
7          GO TO 564
3      562 SIGNX = 1.
3      564 IF(SIGMAY.EQ.0.) GO TO 563
7          SIGNY = ABS(SIGMAY)/SIGMAY
7          GO TO 566
3      563 SIGNY = 1.
3      566 I1 = I+1
7          J1 = J+1
```

```
7          IF(SIGMAX.LT.0.) I1 = I-1
7          IF(SIGMAY.LT.0.) J1 = J-1
8           IF(I1.NE.2.AND.I1.NE.INN ) GC TC 560
8           IF(J1.NE.2.AND.J1.NE.JMM ) GC TC 560
1    C
7          C3 = CT(I,J)*ABS(SIGMAX)*ABS(SIGMAY)
7          F    (I1,J1) = F    (I1,J1) + C3
7          FXW  (I1,J1) = FXW  (I1,J1) + (SIGMAX/2.-C.5*SIGNX)*C3
7          FYW  (I1,J1) = FYW  (I1,J1) + (SIGMAY/2.-C.5*SIGNY)*C3
7          F2WX  (I1,J1) = F2WX  (I1,J1) + (SIGMAX/2.-C.5*SIGNX)**2*C3
7          F2WY  (I1,J1) = F2WY  (I1,J1) + (SIGMAY/2.-C.5*SIGNY)**2*C3
7          RXW  (I1,J1) = RXW  (I1,J1) + ABS(SIGMAX)**2*C3
7          RYW  (I1,J1) = RYW  (I1,J1) + ABS(SIGMAY)**2*C3
3      560 CONTINUE
3      561 CCNTINUE
1    C
1    C               VALUES AT NEXT TIME STEP ARE CALCULATED
1    C
7          DC 601 I=1,IN
7          DO 600 J=1,JM
7          CT(I,J) = F    (I,J)
7          CTREPL = F    (I,J)
7          IF(CTREPL.EQ.0.0E-00) GO TO 599
7          FWX(I,J) = FXW  (I,J)/CTREPL
7          FWY(I,J) = FYW  (I,J)/CTREPL
1    C
1    C     WIDTH CORRECTICN
1    C
7          FX = FWX(I,J)
7          FY = FWY(I,J)
7          RXMAX = ABS(FX-0.5)*2.
7          RXMIN = ABS(FX+C.5)*2.
7          IF(RXMIN.GT.RXMAX                 )RXMIN=RXMAX
7          RYMAX = ABS(FY-0.5)*2.
7          RYMIN = ABS(FY+0.5)*2.
7          IF(RYMIN.GT.RYMAX                 )RYMIN=RYMAX
7          HA=RXW  (I,J)/CTREPL+12.*(-FX*FX+F2WX  (I,J)/CTREPL)
19                   RWX(I,J)=SQRT(ABS(HA))
7          HB=RYW  (I,J)/CTREPL+12.*(-FY*FY+F2WY  (I,J)/CTREPL)
19                   RWY(I,J)=SQRT(ABS(HB))
7          IF(RWX(I,J).GT.RXMIN                    )RWX(I,J)=RXMIN
7          IF(RWY(I,J).GT.RYMIN                    )RWY(I,J)=RYMIN
7          GO TO 600
3      599 FWX(I,J) = 0.
7          FWY(I,J) = 0.
7          RWX(I,J) = 0.
7          RWY(I,J) = 0.
3      600 CCNTINUE
3      601 CONTINUE
7          RETURN
7          END
7          SUBROUTINE SCAVEG
7          COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7          COMMON/MATRX1/U(30,11,8),V(30,11,8)   ,W(30,11,8 ),C(30,11,8) ,KXX(
6         $        8),KYY(        8),KZZ(        8)
1    C
1    C               THIS RCUTINE CALCULATES OVERALL WASHOUT SCAVENGING
1    C
7          PSI= 2.0E-04*(RR**.8)
7          KNNN=KNN-1
7          DO 1 K=3,KNNN
7          DO 1 I=2,INN
7          DO 1 J=2,JMM
7          IF(C(I,J,K).LT.1.0E-10)GO TC 1
7          C(I,J,K)=C(I,J,K)*(1.-PSI*DT)
5        1 CCNTINUE
7          RETURN
7          END
```

```
7        SUBROUTINE INITV
7        COMMON/VB/ZO,DX,HLID,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7        COMMON/VARV/CV(30,11),FVX(30,11),RVX(30,11),FVY(30,11),RVY(3C,11)
7        COMMON/CALGOV/FV  (30,11),FXV  (30,11),FYV  (30,11),RXV  (3C,11),
6       1RYV  (30,11),F2VX  (30,11),F2VY  (3C,11)
7        COMMUN/CVELTY/VX,VY
7        N1=IN*JM*5
7        N2=IN*JM*7
7        CALL CLEAR(CV,N1)
7        CALL CLEAR(FV,N2)
7        DO 3 J=4,8
7        DO 3 I=3,7
5      3 CV(I,J)=(FLOAT(I)-5.)*5.0
7        DO 1 J=4,8
7        DO 1 I=3,7
7        IF(CV(I,J).EQ.0.)GC TC 1
7        RVX(I,J)=1.
7        RVY(I,J)=1.
5      1 CONTINUE
7        RETURN
7        END
7        SUBROUTINE LATERV(DX,DY,IN,JM,INN,JMM,DT,NITER)
7        COMMON/VARV/CV(3C,11),FVX(30,11),RVX(30,11),FVY(30,11),RVY(3C,11)
7        COMMON/CALGOV/FV  (30,11),FXV  (30,11),FYV  (30,11),RXV  (30,11),
6       1RYV  (30,11),F2VX  (30,11),F2VY  (30,11)
7        COMMJN/CVELTY/VX,VY
7        N2=7*IN*JM
7        CALL CLEAR(FV,N2)
1   C
1   C
1   C    CALCULATE SIGMAS, PX, AND PY
1   C
7        DO 501 I= 2,INN
7        DO 500 J= 2,JMM
7        IF(CV(I,J).EQ.0.0E-00 ) GOTO 500
7        SIGMAX= VX      *DT     /DX
7        SIGMAY= VY      *DT     /DY
7        IF(SIGMAX.EQ.0.) GO TC 90
7        SIGNX=SIGMAX/ABS(SIGMAX)
7        GO TO 92
4     90 SIGNX = 1.
4     92 IF(SIGMAY.EQ.0.) GC TC 94
7        SIGNY = SIGMAY/ABS(SIGMAY)
7        GO TO 96
4     94 SIGNY=1.
4     96 CONTINUE
7        IF (SIGMAX.GT.0.) GOTC 100
7        PIJX=(-2.*(FVX(I,J)+SIGMAX)+RVX(I,J)-1.0)/(2.C*RVX(I,J))
7        GOTO 110
3    100 PIJX=(2.0*(FVX(I,J)+SIGMAX)+RVX(I,J)-1.)/(2.0*RVX(I,J))
3    110 IF(SIGMAY.GT.0.) GO TC 120
7        PIJY=(-2.0*(FVY(I,J)+SIGMAY)+FVY(I,J)-1.0)/ (2.0*RVY(I,J))
7        GOTO 130
3    120 PIJY=(2.0*(FVY(I,J)+SIGMAY)+RVY(I,J)-1.0)/(2.0*RVY(I,J))
3    130 CONTINUE
1   C
1   C
1   C               NORMAL CCNDITIONS
1   C
1   C               IFVPX,PY<C OR PX,PY>1 MODIFICATICNS ARE MADE
1   C
7        NCOUNT=0
7        IF(PIJX.GE.0.0001.AND.PIJX.LE.0.9999) GC TC 15C
7        NCOUNT=1
7        IF(PIJX.LT.0.0001) PIJX=0.0
7        IF(PIJX.GT.0.9999) PIJX=1.0
3    150 IF(PIJY.GE.0.COC1.AND.PIJY.LE.C.9995) GC TC 160
7        NCOUNT=1
7        IF(PIJY.LT.0.0001) PIJY=0.0
7        IF(PIJY.GT.0.9999) PIJY=1.0
3    160 CONTINUE
```

```
7         IF(SIGMAX.GT.0.0) I1=I+1
7         IF(SIGMAX.EQ.0.) I1 = I
7         IF(SIGMAX.LT.0.0) I1=I-1
7         IF(SIGMAY.GT.0.0) J1=J+1
7         IF(SIGMAY.EQ.0.) J1 = J
7         IF(SIGMAY.LT.0.0) J1=J-1
1   C
7         C1      =CV(I,J)*PIJX*(1.0-PIJY)
7         C2      =CV(I,J)*(1.0-PIJX)*PIJY
7         C3      =CV(I,J)*PIJX*PIJY
7         C4      =CV(I,J)*(1.0-PIJX)*(1.-PIJY)
1   C
7         FV  (I1,J)=FV  (I1,J)+C1
7         FV  (I,J1)=FV  (I,J1)+C2
7         FV  (I1,J1)=FV  (I1,J1)+C3
7         FV  ( I,J) =FV  (I,J)+C4
1   C
1   C
7         F1X  =(PIJX*RVX(I,J)-1.0)/2.0*SIGNX
7         F1Y  =(1.0-RVY(I,J)*(1.0-PIJY))/2.0*SIGNY
7         F2X  =(1.0-RVX(I,J)*(1.0-PIJX))/2.0*SIGNX
7         F2Y  =(PIJY*RVY(I,J)-1.0)/2.0*SIGNY
1   C
7         FXV  (I1,J)=FXV  (I1,J)+F1X  *C1
7         FYV  (I1,J)=FYV  (I1,J)+F1Y  *C1
7         FXV  (I,J1)=FXV  (I,J1)+F2X  *C2
7         FYV  (I,J1) = FYV  (I,J1) + F2Y  *C2
7         FXV  (I1,J1) = FXV  (I1,J1) + F1X  *C3
7         FYV  (I1,J1) = FYV  (I1,J1) + F2Y  *C3
7         FXV  (I,J) = FXV  (I,J) + F2X  *C4
7         FYV  (I,J) = FYV  (I,J) + F1Y  *C4
1   C
7         F2VX  (I1,J) = F2VX  (I1,J) + F1X  *F1X  *C1
7         F2VY  (I1,J) = F2VY  (I1,J) + F1Y  *F1Y  *C1
7         F2VX  (I,J1) = F2VX  (I,J1) + F2X  *F2X  *C2
7         F2VY  (I,J1) = F2VY  (I,J1) + F2Y  *F2Y  *C2
7         F2VX  (I1,J1) = F2VX  (I1,J1) + F1X  *F1X  *C3
7         F2VY  (I1,J1) = F2VY  (I1,J1) + F2Y  *F2Y  *C3
7         F2VX  (I,J)   = F2VX  (I,J)+ F2X  *F2X  *C4
7         F2VY  (I,J)= F2VY  (I,J)+F1Y  *F1Y  *C4
1   C
1   C
7         R1X  =(PIJX*RVX(I,J))**2
7         R1Y  =((1.0-PIJY)*RVY(I,J))**2
7         R2X  =((1.0-PIJX)*RVX(I,J))**2
7         R2Y  =(PIJY*RVY(I,J))**2
1   C
7         RXV  (I1,J)=RXV  (I1,J)+ R1X  * C1
7         RYV  (I1,J)=RYV  (I1,J)+ R1Y  * C1
7         RXV  (I,J1)=RXV  (I,J1)+ R2X  * C2
7         RYV  (I,J1)=RYV  (I,J1)+ R2Y  * C2
7         RXV  (I1,J1)=RXV  (I1,J1)+R1X  *C3
7         RYV  (I1,J1)=RYV  (I1,J1)+R2Y  *C3
7         RXV  (I,J) = RXV  (I,J)+ R2X  *C4
7         RYV  (I,J)=RYV  (I,J)+R1Y    *C4
1   C
1   C
1   C
7         IF(NCOUNT.EQ.0) GO TO 500
7         SIGMX = SIGMAX+FVX(I,J)
7         SIGMY = SIGMAY + FVY(I,J)
7         IF(PIJX.GT.0.0001) GO TO 490
1   C
7         FXV  (I1,J) = FXV  (I1,J) - C1     * F1X
7         F2VX  (I1,J)=F2VX  (I1,J)-C1     * F1X  *F1X
7         FXV  (I,J1) = FXV  (I,J1) - C2     *(F2X   - SIGMX)
7         F2VX  (I,J1)= F2VX  (I,J1)-C2     *(F2X  *F2X  -SIGMX*SIGMX)
7         FXV  (I1,J1)=FXV  (I1,J1)-C3     * F1X
7         F2VX  (I1,J1)=F2VX  (I1,J1)-C3     * F1X  *F1X
7         FXV  (I,J)= FXV  (I,J) - C4     *(F2X   - SIGMX)
7         F2VX  (I,J) = F2VX  (I,J)-C4     *(F2X  *F2X  -SIGMX*SIGMX)
1   C
7         GO TO 492
```

```
3    490 IF(PIJX.LT.0.9999)GC TO 492
7        FXV  (I1,J) = FXV  (I1,J)- C1     *(F1X  -SIGMX +1.*SIGNX)
1   C
7        F2VX  (I1,J)=F2VX  (I1,J)-C1     *(F1X  *F1X  -(SIGMX -1.
6       1*SIGNX)**2)
7        FXV  (I,J1) = FXV  (I,J1) - C2     * F2X
7        F2VX  (I,J1)=F2VX  (I,J1)-C2     * F2X  *F2X
1   C
7        FXV  (I1,J1) = FXV  (I1,J1) - C3     *(F1X   - SIGMX +1.*SIGNX)
7        F2VX  (I1,J1)=F2VX  (I1,J1)-C3     *(F1X  *F1X  -(SIGMX -1.
6       1*SIGNX)**2)
7        FXV  (I,J) = FXV  (I,J) - C4     * F2X
7        F2VX  (I,J)=F2VX  (I,J)-C4     * F2X  *F2X
3    492 IF(PIJY.GE.0.0001) GC TO 494
1   C
7        FYV  (I1,J) = FYV  (I1,J) - C1     *(F1Y   - SIGMY)
7        F2VY  (I1,J) = F2VY  (I1,J) - C1     *(F1Y  *F1Y  -SIGMY*SIGMY)
7        FYV  (I,J1) = FYV  (I,J1) - C2     * F2Y
7        F2VY  (I,J1) = F2VY  (I,J1) - C2     * F2Y  *F2Y
7        FYV  (I1,J1) = FYV  (I1,J1) - C3     * F2Y
7        F2VY  (I1,J1) = F2VY  (I1,J1) - C3     * F2Y  *F2Y
7        FYV  (I,J)=FYV  (I,J)-C4     *(F1Y  -SIGMY)
7        F2VY  (I,J)=F2VY  (I,J)-C4     *(F1Y  *F1Y  -SIGMY*SIGMY)
7        GO TO 500
3    494 IF(PIJY.LT.0.9999)GC TO 500
7        FYV  (I1,J) = FYV  (I1,J) - C1     * F1Y
7        F2VY  (I1,J)=F2VY  (I1,J)-C1     *(F1Y  *F1Y  )
7        FYV  (I,J1) = FYV  (I,J1) - C2     *(F2Y   - SIGMY +1.*SIGNY)
7        F2VY  (I,J1)=F2VY  (I,J1)-C2     *(F2Y  *F2Y  -(SIGMY -1.
6       1*SIGNY)**2)
1   C
7        FYV  (I1,J1)=FYV  (I1,J1)-C3     *(F2Y  -SIGMY +1.*SIGNY)
7        F2VY  (I1,J1)=F2VY  (I1,J1)-C3     *(F2Y  *F2Y  -(SIGMY -1.
6       1*SIGNY)**2)
7        FYV  (I,J) = FYV  (I,J) - C4     * F1Y
7        F2VY  (I,J)=F2VY  (I,J)-C4     * F1Y  *F1Y
3    500 CONTINUE
3    501 CONTINUE
1   C
1   C                    COUPLING BETWEEN BORDER AND BULK
1   C
7        DO 551 I=1,IN
7        DO 550 J=1,JM
7        IF(I.EQ.1.OR.I.EQ.IN) GO TO 557
7        IF(J.EQ.1.OR.J.EQ.JM) GO TO 558
7        GO TO 550
3    557 IF(J.EQ.1.OR.J.EQ.JM) GO TO 550
7        SIGMAX = VX      *DT     /DX
7        SIGMAY = VY      *DT     /DY
7        IF(SIGMAX.EQ.0.) GO TC 552
7        SIGNX = SIGMAX/ABS(SIGMAX)
7        GO TO 554
3    552 SIGNX = 1.
3    554 IF(SIGMAY.EQ.0.) GC TO 553
7        SIGNY = SIGMAY/ABS(SIGMAY)
7        GO TO 556
3    553 SIGNY = 1.
3    556 I1 = I+1
7        J1 = J + 1
7        IF(SIGMAX.LT.0.) I1 = I-1
7        IF(SIGMAY.LT.0.) J1 = J-1
7        IF(I1.LE.1.OR.I1.GE.IN) GO TO 550
7        GO TO 559
3    558 IF(I.LE.1.OR.I.GE.IN) GO TO 550
7        SIGMAX= VX      *DT     /DX
7        SIGMAY = VY      *DT     /DY
7        IF(SIGMAX.EQ.0.) GC TC 5520
7        SIGNX= SIGMAX/ABS(SIGMAX)
7        GO TO 5540
2   5520 SIGNX = 1.
2   5540 IF(SIGMAY.EQ.0.) GC TC 5530
7        SIGNY = SIGMAY/ABS(SIGMAY)
```

```
7          GO TO 5560
2    5530  SIGNY = 1.
2    5560  I1 = I  + 1
7          J1 = J+1
7          IF(SIGMAX.LT.0.)I1=I-1
7          IF(SIGMAY.LT.0.) J1 = J-1
7          IF(J1.LE.1.OR.J1.GE.JM) GO TC 550
3     559  C1 = CV(I,J)*ABS(SIGMAX)*(1.-ABS(SIGMAY))
7          C2 = CV(I,J)*ABS(SIGMAY)*(1.-ABS(SIGMAX))
7          C3 = CV(I,J)*ABS(SIGMAX)*ABS(SIGMAY)
7          C4 = CV(I,J)*(1.-ABS(SIGMAX))*(1.-ABS(SIGMAY))
1   C
7          FV  (I1,J) = FV  (I1,J) + C1
7          FV  (I,J1) = FV  (I,J1) + C2
7          FV  (I1,J1) = FV  (I1,J1) + C3
7          FV  (I,J) = FV  (I,J) + C4
1   C
7          FXV  (I1,J) = FXV  (I1,J) + (SIGMAX/2.-C.5*SIGNX)*C1
7          FYV  (I1,J) = FYV  (I1,J) +(SIGMAY/2.)*C1
7          FXV  (I,J1) = FXV  (I,J1) +(SIGMAX/2.)*C2
7          FYV  (I,J1) = FYV  (I,J1) + (SIGMAY/2.-C.5*SIGNY)*C2
7          FXV  (I1,J1) = FXV  (I1,J1) + (SIGMAX/2.-C.5*SIGNX)*C3
7          FYV  (I1,J1) = FYV  (I1,J1) + (SIGMAY/2.-C.5*SIGNY)*C3
7          FXV  (I,J) = FXV  (I,J) +(SIGMAX/2.)*C4
7          FYV  (I,J) = FYV  (I,J) +(SIGMAY/2.)*C4
1   C
7          F2VX  (I1,J) = F2VX  (I1,J) + (SIGMAX/2.-C.5*SIGNX)**2*C1
7          F2VY  (I1,J) = F2VY  (I1,J) + (SIGMAY**2/4.)*C1
7          F2VX  (I,J1) = F2VX  (I,J1) +(SIGMAX**2/4.)*C2
7          F2VY  (I,J1) = F2VY  (I,J1) + (SIGMAY/2.-C.5*SIGNY)**2*C2
7          F2VX  (I1,J1) = F2VX  (I1,J1) + (SIGMAX/2.-C.5*SIGNX)**2*C3
7          F2VY  (I1,J1) = F2VY  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)**2*C3
7          F2VX  (I,J) = F2VX  (I,J) +(SIGMAX**2/4.)*C4
7          F2VY  (I,J) = F2VY  (I,J) +(SIGMAY**2/4.)*C4
1   C
7          RXV  (I1,J) = RXV  (I1,J) + ABS(SIGMAX)**2*C1
7          RYV  (I1,J) = RYV  (I1,J) + (1.-ABS(SIGMAY))**2*C1
7          RXV  (I,J1) = RXV  (I,J1) + (1.-ABS(SIGMAX))**2*C2
7          RYV  (I,J1) = RYV  (I,J1) + ABS(SIGMAY)**2*C2
7          RXV  (I1,J1) = RXV  (I1,J1) + ABS(SIGMAX)**2*C3
7          RYV  (I1,J1) = RYV  (I1,J1) + ABS(SIGMAY)**2*C3
7          RXV  (I,J) = RXV  (I,J) + (1.-ABS(SIGMAX))**2*C4
7          RYV  (I,J) = RYV  (I,J) + (1.-ABS(SIGMAY))**2*C4
3     550  CONTINUE
3     551  CONTINUE
1   C
1   C                THE FOUR CORNERS ARE NOW TREATED:
1   C
7          DO 561 I=1,IN,INN
7          DO 560 J=1,JM,JMM
7          SIGMAX = VX     *CT    /DX
7          SIGMAY = VY     *CT    /DY
7          IF(SIGMAX.EQ.0.) GC TC 562
7          SIGNX = ABS(SIGMAX)/SIGMAX
7          GO TO 564
3     562  SIGNX = 1.
3     564  IF(SIGMAY.EQ.0.) GC TO 563
7          SIGNY = ABS(SIGMAY)/SIGMAY
7          GO TO 566
3     563  SIGNY = 1.
3     566  I1 = I+1
7          J1 = J+1
7          IF(SIGMAX.LT.0.) I1 = I-1
7          IF(SIGMAY.LT.0.) J1 = J-1
8           IF(I1.NE.2.AND.I1.NE.INN ) GC TC 560
8           IF(J1.NE.2.AND.J1.NE.JMM ) GC TO 560
1   C
7          C3 = CV(I,J)*ABS(SIGMAX)*ABS(SIGMAY)
7          FV  (I1,J1) = FV  (I1,J1) + C3
7          FXV  (I1,J1) = FXV  (I1,J1) + (SIGMAX/2.-C.5*SIGNX)*C3
7          FYV  (I1,J1) = FYV  (I1,J1) + (SIGMAY/2.-C.5*SIGNY)*C3
7          F2VX  (I1,J1) = F2VX  (I1,J1) + (SIGMAX/2.-C.5*SIGNX)**2*C3
```

```
7          F2VY  (I1,J1) = F2VY  (I1,J1) + (SIGMAY/2.-C.5*SIGNY)**2*C3
7          RXV  (I1,J1) = RXV  (I1,J1) + ABS(SIGMAX)**2*C3
7          RYV  (I1,J1) = RYV  (I1,J1) + ABS(SIGMAY)**2*C3
3     560 CONTINUE
3     561 CONTINUE
1   C
1   C                VALUES AT NEXT TIME STEP ARE CALCULATED
1   C
7          DO 601 I=1,IN
7          DO 600 J=1,JM
7          CV(I,J) = FV  (I,J)
7          CTREPL = FV  (I,J)
7          IF(CTREPL.EQ.0.0E-00) GO TO 599
7          FVX(I,J) = FXV  (I,J)/CTREPL
7          FVY(I,J) = FYV  (I,J)/CTREPL
1   C
1   C      WIDTH CORRECTION
1   C
7          FX = FVX(I,J)
7          FY = FVY(I,J)
7          RXMAX = ABS(FX-C.5)*2.
7          RXMIN = ABS(FX+C.5)*2.
7          IF(RXMIN.GT.RXMAX                    )RXMIN=RXMAX
7          RYMAX = ABS(FY-C.5)*2.
7          RYMIN = ABS(FY+C.5)*2.
7          IF(RYMIN.GT.RYMAX                    )RYMIN=RYMAX
7          HA=RXV  (I,J)/CTREPL+12.*(-FX*FX+F2VX  (I,J)/CTREPL)
19                  RVX(I,J)=SQRT(ABS(HA))
7          HB=RYV  (I,J)/CTREPL+12.*(-FY*FY+F2VY  (I,J)/CTREPL)
19                  RVY(I,J)=SQRT(ABS(HB))
7          IF(RVX(I,J).GT.RXMIN                 )RVX(I,J)=RXMIN
7          IF(RVY(I,J).GT.RYMIN                 )RVY(I,J)=RYMIN
7          GO TO 600
3     599 FVX(I,J) = 0.
7          FVY(I,J) = 0.
7          RVX(I,J) = 0.
7          RVY(I,J) = 0.
3     600 CONTINUE
3     601 CONTINUE
7          RETURN
7          END
7          SUBROUTINE INITC
7          COMMON/VB/ZO,DX,HLED,IN,JM,KN,INN,JMM,KNN,DY, DT,NITER,ZP,RR,PS
7          COMMON/VARU/CU(30,11),FUX(30,11),RUX(30,11),FUY(30,11),RUY(3C,11)
7          COMMON/CALGOU/FU  (30,11),FXU  (30,11),FYU  (30,11),RXU  (30,11),
6         1RYU  (30,11),F2UX  (30,11),F2UY  (3C,11)
7          COMMON/CVELTY/VX,VY
7          N1=IN*JM*5
7          N2=IN*JM*7
7          CALL CLEAR(CU,N1)
7          CALL CLEAR(FU,N2)
7          DO 3 J=4,8
7          DO 3 I=3,7
5       3 CU(I,J)=(6.-FLOAT(J))*5.0
7          DO 1 J=4,8
7          DO 1 I=3,7
7          IF(CU(I,J).EQ.0.)GC TC 1
7          RUX(I,J)=1.
7          RUY(I,J)=1.
5       1 CONTINUE
7          RETURN
7          END
7          SUBROUTINE LONGTU(CX,DY,IN,JM,INN,JMM,DT,NITER)
7          COMMON/VARU/CU(30,11),FUX(30,11),RUX(30,11),FUY(30,11),RUY(3C,11)
7          COMMON/CALGOU/FU  (30,11),FXU  (30,11),FYU  (30,11),RXU  (30,11),
6         1RYU  (30,11),F2UX  (3C,11),F2UY  (3C,11)
7          COMMON/CVELTY/VX,VY
7          N2=7*IN*JM
7          CALL CLEAR(FU,N2)
1   C
1   C
1   C      CALCULATE SIGMAS, PX, AND PY
```

```
1   C
7         DO 501 I= 2,INN
7         DO 500 J= 2,JMM
7         IF(CU(I,J).EQ.0.0E-00 ) GOTO 500
7         SIGMAX= VX      *DT     /DX
7         SIGMAY= VY      *DT     /DY
7         IF(SIGMAX.EQ.0.) GO TO 90
7         SIGNX=SIGMAX/ABS(SIGMAX)
7         GO TO 92
4      90 SIGNX = 1.
4      92 IF(SIGMAY.EQ.0.) GO TO 94
7         SIGNY = SIGMAY/ABS(SIGMAY)
7         GO TO 96
4      94 SIGNY=1.
4      96 CONTINUE
7         IF (SIGMAX.GT.0.) GOTO 100
7         PIJX=(-2.*(FUX(I,J)+SIGMAX)+RUX(I,J)-1.0)/(2.0*RUX(I,J))
7         GOTO 110
3     100 PIJX=(2.0*(FUX(I,J)+SIGMAX)+RUX(I,J)-1.)/(2.0*RUX(I,J))
3     110 IF(SIGMAY.GT.0.) GO TO 120
7         PIJY=(-2.0*(FUY(I,J)+SIGMAY)+RUY(I,J)-1.0)/ (2.0*RUY(I,J))
7         GOTO 130
3     120 PIJY=(2.0*(FUY(I,J)+SIGMAY)+RUY(I,J)-1.0)/(2.0*RUY(I,J))
3     130 CONTINUE
1   C
1   C
1   C                 NORMAL CONDITIONS
1   C
1   C                 IFUPX,PY<C CR PX,PY>1 MODIFICATIONS ARE MADE
1   C
7         NCOUNT=0
7         IF(PIJX.GE.0.0001.AND.PIJX.LE.0.9999) GO TO 150
7         NCOUNT=1
7         IF(PIJX.LT.0.0001) PIJX=0.0
7         IF(PIJX.GT.0.9999) PIJX=1.0
3     150 IF(PIJY.GE.0.0001.AND.PIJY.LE.0.9999) GO TO 160
7         NCOUNT=1
7         IF(PIJY.LT.0.0001) PIJY=0.0
7         IF(PIJY.GT.0.9999) PIJY=1.0
3     160 CONTINUE
7         IF(SIGMAX.GT.0.0) I1=I+1
7         IF(SIGMAX.EQ.0.) I1 = I
7         IF(SIGMAX.LT.0.0) I1=I-1
7         IF(SIGMAY.GT.0.0) J1=J+1
7         IF(SIGMAY.EQ.0.) J1 = J
7         IF(SIGMAY.LT.0.0) J1=J-1
1   C
7         C1     =CU(I,J)*PIJX*(1.0-PIJY)
7         C2     =CU(I,J)*(1.0-PIJX)*PIJY
7         C3     =CU(I,J)*PIJX*PIJY
7         C4     =CU(I,J)*(1.0-PIJX)*(1.-PIJY)
1   C
7         FU  (I1,J)=FU  (I1,J)+C1
7         FU  (I,J1)=FU  (I,J1)+C2
7         FU  (I1,J1)=FU  (I1,J1)+C3
7         FU  ( I,J) =FU  (I,J)+C4
1   C
1   C
7         F1X  =(PIJX*RUX(I,J)-1.0)/2.0*SIGNX
7         F1Y  =(1.0-RUY(I,J)*(1.0-PIJY))/2.0*SIGNY
7         F2X  =(1.0-RUX(I,J)*(1.0-PIJX))/2.0*SIGNX
7         F2Y  =(PIJY*RUY(I,J)-1.0)/2.0*SIGNY
1   C
7         FXU  (I1,J)=FXU  (I1,J)+F1X  *C1
7         FYU  (I1,J)=FYU  (I1,J)+F1Y  *C1
7         FXU  (I,J1)=FXU  (I,J1)+F2X  *C2
7         FYU  (I,J1) = FYU  (I,J1) + F2Y  *C2
7         FXU  (I1,J1) = FXU  (I1,J1) + F1X  *C3
7         FYU  (I1,J1) = FYU  (I1,J1) + F2Y  *C3
7         FXU  (I,J) = FXU  (I,J) + F2X  *C4
7         FYU  (I,J) = FYU  (I,J) + F1Y  *C4
1   C
```

```
7        F2UX  (I1,J) = F2UX  (I1,J) + F1X  *F1X  *C1
7        F2UY  (I1,J) = F2UY  (I1,J) + F1Y  *F1Y  *C1
7        F2UX  (I,J1) = F2UX  (I,J1) + F2X  *F2X  *C2
7        F2UY  (I,J1) = F2UY  (I,J1) + F2Y  *F2Y  *C2
7        F2UX  (I1,J1) = F2UX  (I1,J1) + F1X  *F1X  *C3
7        F2UY  (I1,J1) = F2UY  (I1,J1) + F2Y  *F2Y  *C3
7        F2UX  (I,J)   = F2UX  (I,J)+ F2X  *F2X  *C4
7        F2UY  (I,J)= F2UY  (I,J)+F1Y  *F1Y  *C4
1  C
1  C
7        R1X  =(PIJX*RUX(I,J))**2
7        R1Y  =((1.0-PIJY)*RUY(I,J))**2
7        R2X  =((1.0-PIJX)*RUX(I,J))**2
7        R2Y  =(PIJY*RUY(I,J))**2
1  C
7        RXU  (I1,J)=RXU  (I1,J)+ R1X  * C1
7        RYU  (I1,J)=RYU  (I1,J)+ R1Y  * C1
7        RXU  (I,J1)=RXU  (I,J1)+ R2X  * C2
7        RYU  (I,J1)=RYU  (I,J1)+ R2Y  * C2
7        RXU  (I1,J1)=RXU  (I1,J1)+R1X  *C3
7        RYU  (I1,J1)=RYU  (I1,J1)+R2Y  *C3
7        RXU  (I,J) = RXU  (I,J)+ R2X  *C4
7        RYU  (I,J)=RYU  (I,J)+R1Y   *C4
1  C
1  C
1  C
7        IF(NCOUNT.EQ.0) GO TO 500
7        SIGMX = SIGMAX+FUX(I,J)
7        SIGMY = SIGMAY + FUY(I,J)
7        IF(PIJX.GT.0.0001) GO TO 490
1  C
7        FXU  (I1,J) = FXU  (I1,J) - C1    * F1X
7        F2UX  (I1,J)=F2UX  (I1,J)-C1    * F1X  *F1X
7        FXU  (I,J1) = FXU  (I,J1) - C2    *(F2X   - SIGMX)
7        F2UX  (I,J1)= F2UX  (I,J1)-C2    *(F2X  *F2X  -SIGMX*SIGMX)
7        FXU  (I1,J1)=FXU  (I1,J1)-C3    * F1X
7        F2UX  (I1,J1)=F2UX  (I1,J1)-C3    * F1X  *F1X
7        FXU  (I,J)= FXU  (I,J) - C4    *(F2X   - SIGMX)
7        F2UX  (I,J) = F2UX  (I,J)-C4    *(F2X  *F2X  -SIGMX*SIGMX)
1  C
7        GO TO 492
3    490 IF(PIJX.LT.0.9999)GO TO 492
7        FXU  (I1,J) = FXU  (I1,J)- C1    *(F1X  -SIGMX +1.*SIGNX)
1  C
7        F2UX  (I1,J)=F2UX  (I1,J)-C1    *(F1X  *F1X  -(SIGMX -1.
6       1*SIGNX)**2)
7        FXU  (I,J1) = FXU  (I,J1) - C2    * F2X
7        F2UX  (I,J1)=F2UX  (I,J1)-C2    * F2X  *F2X
1  C
7        FXU  (I1,J1) = FXU  (I1,J1) - C3    *(F1X   - SIGMX +1.*SIGNX)
7        F2UX  (I1,J1)=F2UX  (I1,J1)-C3    *(F1X  *F1X  -(SIGMX -1.
6       1*SIGNX)**2)
7        FXU  (I,J) = FXU  (I,J) - C4    * F2X
7        F2UX  (I,J)=F2UX  (I,J)-C4    * F2X  *F2X
3    492 IF(PIJY.GE.0.0001) GO TO 494
1  C
7        FYU  (I1,J) = FYU  (I1,J) - C1    *(F1Y   - SIGMY)
7        F2UY  (I1,J) = F2UY  (I1,J) - C1    *(F1Y  *F1Y  -SIGMY*SIGMY)
7        FYU  (I,J1) = FYU  (I,J1) - C2    * F2Y
7        F2UY  (I,J1) = F2UY  (I,J1) - C2    * F2Y  *F2Y
7        FYU  (I1,J1) = FYU  (I1,J1) - C3    * F2Y
7        F2UY  (I1,J1) = F2UY  (I1,J1) - C3    * F2Y  *F2Y
7        FYU  (I,J)=FYU  (I,J)-C4    *(F1Y  -SIGMY)
7        F2UY  (I,J)=F2UY  (I,J)-C4    *(F1Y  *F1Y  -SIGMY*SIGMY)
7        GO TO 500
3    494 IF(PIJY.LT.0.9999)GO TO 500
7        FYU  (I1,J) = FYU  (I1,J) - C1    * F1Y
7        F2UY  (I1,J)=F2UY  (I1,J)-C1    *(F1Y  *F1Y   )
7        FYU  (I,J1) = FYU  (I,J1) - C2    *(F2Y   - SIGMY +1.*SIGNY)
7        F2UY  (I,J1)=F2UY  (I,J1)-C2    *(F2Y  *F2Y  -(SIGMY -1.
6       1*SIGNY)**2)
```

```
1  C
7        FYU  (I1,J1)=FYU  (I1,J1)-C3    *(F2Y  -SIGMY +1.*SIGNY)
7        F2UY  (I1,J1)=F2UY  (I1,J1)-C3    *(F2Y  *F2Y  -(SIGMY -1.
6       1*SIGNY)**2)
7        FYU  (I,J) = FYU  (I,J) - C4    * F1Y
7        F2UY  (I,J)=F2UY  (I,J)-C4    * F1Y  *F1Y
3    500 CONTINUE
3    501 CONTINUE
1  C
1  C                 COUPLING BETWEEN BORDER AND BULK
1  C
7        DO 551 I=1,IN
7        DO 550 J=1,JM
7        IF(I.EQ.1.OR.I.EQ.IN) GO TO 557
7        IF(J.EQ.1.OR.J.EQ.JM) GO TO 558
7        GO TO 550
3    557 IF(J.EQ.1.OR.J.EQ.JM) GO TO 550
7        SIGMAX = VX      *DT     /DX
7        SIGMAY = VY      *DT     /DY
7        IF(SIGMAX.EQ.0.) GO TO 552
7        SIGNX = SIGMAX/ABS(SIGMAX)
7        GO TO 554
3    552 SIGNX = 1.
3    554 IF(SIGMAY.EQ.0.) GO TO 553
7        SIGNY = SIGMAY/ABS(SIGMAY)
7        GO TO 556
3    553 SIGNY = 1.
3    556 I1 = I+1
7        J1 = J + 1
7        IF(SIGMAX.LT.0.) I1 = I-1
7        IF(SIGMAY.LT.0.) J1 = J-1
7        IF(I1.LE.1.OR.I1.GE.IN) GO TO 550
7        GO TO 559
3    558 IF(I.LE.1.OR.I.GE.IN) GO TO 550
7        SIGMAX= VX      *DT     /DX
7        SIGMAY = VY      *DT     /DY
7        IF(SIGMAX.EQ.0.) GO TO 5520
7        SIGNX= SIGMAX/ABS(SIGMAX)
7        GO TO 5540
2   5520 SIGNX = 1.
2   5540 IF(SIGMAY.EQ.0.) GO TO 5530
7        SIGNY = SIGMAY/ABS(SIGMAY)
7        GO TO 5560
2   5530 SIGNY = 1.
2   5560 I1 = I  + 1
7        J1 = J+1
7        IF(SIGMAX.LT.0.)I1=I-1
7        IF(SIGMAY.LT.0.) J1 = J-1
7        IF(J1.LE.1.OR.J1.GE.JM) GO TO 550
3    559 C1 = CU(I,J)*ABS(SIGMAX)*(1.-ABS(SIGMAY))
7        C2 = CU(I,J)*ABS(SIGMAY)*(1.-ABS(SIGMAX))
7        C3 = CU(I,J)*ABS(SIGMAX)*ABS(SIGMAY)
7        C4 = CU(I,J)*(1.-ABS(SIGMAX))*(1.-ABS(SIGMAY))
1  C
7        FU  (I1,J) = FU  (I1,J) + C1
7        FU  (I,J1) = FU  (I,J1) + C2
7        FU  (I1,J1) = FU  (I1,J1) + C3
7        FU  (I,J) = FU  (I,J) + C4
1  C
7        FXU  (I1,J) = FXU  (I1,J) + (SIGMAX/2.-0.5*SIGNX)*C1
7        FYU  (I1,J) = FYU  (I1,J) +(SIGMAY/2.)*C1
7        FXU  (I,J1) = FXU  (I,J1) +(SIGMAX/2.)*C2
7        FYU  (I,J1) = FYU  (I,J1) + (SIGMAY/2.-0.5*SIGNY)*C2
7        FXU  (I1,J1) = FXU  (I1,J1) + (SIGMAX/2.-0.5*SIGNX)*C3
7        FYU  (I1,J1) = FYU  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)*C3
7        FXU  (I,J) = FXU  (I,J) +(SIGMAX/2.)*C4
7        FYU  (I,J) = FYU  (I,J) +(SIGMAY/2.)*C4
1  C
7        F2UX  (I1,J) = F2UX  (I1,J) + (SIGMAX/2.-0.5*SIGNX)**2*C1
7        F2UY  (I1,J) = F2UY  (I1,J) + (SIGMAY**2/4.)*C1
7        F2UX  (I,J1) = F2UX  (I,J1) +(SIGMAX**2/4.)*C2
7        F2UY  (I,J1) = F2UY  (I,J1) + (SIGMAY/2.-0.5*SIGNY)**2*C2
7        F2UX  (I1,J1) = F2UX  (I1,J1) + (SIGMAX/2.-0.5*SIGNX)**2*C3
```

```
7          F2UY  (I1,J1) = F2UY  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)**2*C3
7          F2UX  (I,J) = F2UX  (I,J) +(SIGMAX**2/4.)*C4
7          F2UY  (I,J) = F2UY  (I,J) +(SIGMAY**2/4.)*C4
1   C
7          RXU  (I1,J) = RXU  (I1,J) + ABS(SIGMAX)**2*C1
7          RYU  (I1,J) = RYU  (I1,J) + (1.-ABS(SIGMAY))**2*C1
7          RXU  (I,J1) = RXU  (I,J1) + (1.-ABS(SIGMAX))**2*C2
7          RYU  (I,J1) = RYU  (I,J1) + ABS(SIGMAY)**2*C2
7          RXU  (I1,J1) = RXU  (I1,J1) + ABS(SIGMAX)**2*C3
7          RYU  (I1,J1) = RYU  (I1,J1) + ABS(SIGMAY)**2*C3
7          RXU  (I,J) = RXU  (I,J) + (1.-ABS(SIGMAX))**2*C4
7          RYU  (I,J) = RYU  (I,J) + (1.-ABS(SIGMAY))**2*C4
3      550 CONTINUE
3      551 CONTINUE
1   C
1   C                THE FOUR CORNERS ARE NOW TREATED:
1   C
7          DO 561 I=1,IN,INN
7          DO 560 J=1,JM,JMM
7          SIGMAX = VX      *DT     /DX
7          SIGMAY = VY      *DT     /DY
7          IF(SIGMAX.EQ.0.) GO TO 562
7          SIGNX = ABS(SIGMAX)/SIGMAX
7          GO TO 564
3      562 SIGNX = 1.
3      564 IF(SIGMAY.EQ.0.) GO TO 563
7          SIGNY = ABS(SIGMAY)/SIGMAY
7          GO TO 566
3      563 SIGNY = 1.
3      566 I1 = I+1
7          J1 = J+1
7          IF(SIGMAX.LT.0.) I1 = I-1
7          IF(SIGMAY.LT.0.) J1 = J-1
8           IF(I1.NE.2.AND.I1.NE.INN ) GO TO 560
8           IF(J1.NE.2.AND.J1.NE.JMM ) GO TO 560
1   C
7          C3 = CU(I,J)*ABS(SIGMAX)*ABS(SIGMAY)
7          FU  (I1,J1) = FU  (I1,J1) + C3
7          FXU  (I1,J1) = FXU  (I1,J1) + (SIGMAX/2.-0.5*SIGNX)*C3
7          FYU  (I1,J1) = FYU  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)*C3
7          F2UX  (I1,J1) = F2UX  (I1,J1) + (SIGMAX/2.-0.5*SIGNX)**2*C3
7          F2UY  (I1,J1) = F2UY  (I1,J1) + (SIGMAY/2.-0.5*SIGNY)**2*C3
7          RXU  (I1,J1) = RXU  (I1,J1) + ABS(SIGMAX)**2*C3
7          RYU  (I1,J1) = RYU  (I1,J1) + ABS(SIGMAY)**2*C3
3      560 CONTINUE
3      561 CONTINUE
1   C
1   C                VALUES AT NEXT TIME STEP ARE CALCULATED
1   C
7          DO 601 I=1,IN
7          DO 600 J=1,JM
7          CU(I,J) = FU  (I,J)
7          CTREPL = FU  (I,J)
7          IF(CTREPL.EQ.0.0E-00) GO TO 599
7          FUX(I,J) = FXU  (I,J)/CTREPL
7          FUY(I,J) = FYU  (I,J)/CTREPL
1   C
1   C      WIDTH CORRECTION
1   C
7          FX = FUX(I,J)
7          FY = FUY(I,J)
7          RXMAX = ABS(FX-0.5)*2.
7          RXMIN = ABS(FX+0.5)*2.
7          IF(RXMIN.GT.RXMAX                    )RXMIN=RXMAX
7          RYMAX = ABS(FY-0.5)*2.
7          RYMIN = ABS(FY+0.5)*2.
7          IF(RYMIN.GT.RYMAX                    )RYMIN=RYMAX
7          HA=RXU  (I,J)/CTREPL+12.*(-FX*FX+F2UX  (I,J)/CTREPL)
19                   RUX(I,J)=SQRT(ABS(HA))
7          HB=RYU  (I,J)/CTREPL+12.*(-FY*FY+F2UY  (I,J)/CTREPL)
19                   RUY(I,J)=SQRT(ABS(HB))
```

```
7          IF(RUX(I,J).GT.RXMIN                  )RUX(I,J)=RXMIN             81.8
7          IF(RUY(I,J).GT.RYMIN                  )RUY(I,J)=RYMIN             82.1
7          GO TO 600                                                         82.2
3      599 FUX(I,J) = 0.                                                     82.3
7          FUY(I,J) = 0.                                                     82.4
7          RUX(I,J) = 0.                                                     82.5
7          RUY(I,J) = 0.                                                     82.6
3      600 CONTINUE                                                          82.7
3      601 CONTINUE                                                          82.8
7          RETURN                                                            83.1
7          END                                                               83.2
```

```
7          SUBROUTINE VECTR(X,Y,M,N,VVMG)
7          DIMENSION X(M,N),Y(M,N),VVMG(M,N)
7          COMMON /VCTR/ TIME
7          DATA PMIN/0.15/,PDIF/.85/
7          CNTINT=1.0
7          VMIN = 1.E10
7          VMAX =-1.E10
7          DO 10I = 1,M
7          DO 10J = 1,N
7          IF(ABS(X(I,J)) .LT. 1.E-15) GOTO 1
7          X2X=X(I,J)*X(I,J)
7          GOTO 2
1    1     CONTINUE
7          X2X=0.0
1    2     CONTINUE
7          IF(ABS(Y(I,J)) .LT. 1.E-15) GOTO 3
7          Y2Y=Y(I,J)*Y(I,J)
7          GOTO 4
1    3     CONTINUE
7          Y2Y=0.0
1    4     CONTINUE
7          VVMG(I,J) = SQRT(X2X+Y2Y)
7          IF(VMIN.GT.VVMG(I,J)) VMIN = VVMG(I,J)
7          IF(VMAX.LT.VVMG(I,J)) VMAX = VVMG(I,J)
2     10   CONTINUE
7          VDIF=VMAX-VMIN
7          IF(VDIF.EQ.0.0) VDIF=VMAX
7          XIN=M
7          YJM=N
7          XPHYS=0.75
7          YPHYS=0.75
7          CALL AXESS(XIN,YJM,ITITLE,XAXIS,YAXIS)
7          XSTP=FLOAT(M)-1.
7          YSTP=FLOAT(N)-1.
7          XMAX=FLOAT(M)
7          YMAX=FLOAT(N)
7          CALL PHYSOR(XPHYS,YPHYS)
7          CALL TITLE(' ',ITITLE,0,0,0,0,XAXIS,YAXIS)
7          CALL GRAF( 1.,XSTP,XMAX,1.,YSTP,YMAX  )
7          DO 30 J = 1,N                                               SR
7          Y1 = FLOAT( J )
7          DO 30 I = 1,M                                               SR
7          IF(VVMG(I,J).EQ.0.) GO TO 30
7          X1 = FLOAT( I )
7          PLEN = (PMIN+PDIF*(VVMG(I,J)-VMIN)/VDIF)/VVMG(I,J)
7          X2 =  X1 + PLEN*X(I,J)                                      SR
7          Y2 = Y1 + PLEN*Y(I,J)
7          XPO1  =   XPOSN(   X1,Y1   )
7          YPO1  =   YPOSN(   X1,Y1   )
7          XPO2  =   XPOSN(   X2,Y2   )
7          YPO2  =   YPOSN(   X2,Y2   )
7          DX=XPO1-XPO2
7          DY=YPO1-YPO2
7          DP=SQRT(DX*DX+DY*DY)
7          IF(DP.LE.0.03) GOTO 5
7          CALL VECTOR(  XPO1,YPO1,XPO2,YPO2,0121 )
7          GOTO 30
2     5    CONTINUE
7          CALL VECTOR(  XPO1,YPO1,XPO2,YPO2,0000 )
2     30   CONTINUE
7          CALL ENDGR(0)
7          RETURN
7          END                                                         SR
```

```
8          SUBROUTINE RANDOT (X,Y,M,N,IY)
8          XIN = M
8          YJM = N
8          XPHYS=0.75
8          YPHYS=0.75
8          CALL AXESS (XIN,YJM,ITITLE,XAXIS,YAXIS)
8          XSTP=FLOAT(M)-1.
8          YSTP=FLOAT(N)-1.
8          XMAX=FLOAT(M)
8          YMAX=FLOAT(N)
8          CALL PHYSOR(XPHYS,YPHYS)
8          CALL TITLE(' ',ITITLE,0,0,C,C,XAXIS,YAXIS)
8          CALL GRAF(1.,XSTP,XMAX,1.,YSTP,YMAX)
8          DO 1 I=1,30
8          DX= RANDU (IY)
8          DY= RANDU (IY)
8          XI = X+DX
8          YJ = Y+DY
8          CALL HEIGHT (0.04)
8          CALL RLMESS ('.',1,XI,YJ)
2     1    CONTINUE
8          CALL ENDGR(0)
8          RETURN
8          END
```

```
7         SUBROUTINE SECSIT(P,IN,JM,VX)
1   C
1   C     CALCULATION OF SECTOR AVERAGE CONCENTRATION FROM PT. OF RELEASE
1   C
7         COMMON/SEC/A(16,5)
7         DIMENSION P(IN,JM)
7         CALL CLEAR(A,80)
7         IF(VX.GE.2.0.AND.VX.LT.7.0)CALL SECSI6(P,IN,JM)
7         IF(VX.GE.7.0.AND.VX.LE.10.0)CALL SECSI3(P,IN,JM)
7         IF(VX.GT.10.0.AND.VX.LE.12.5)CALL SECSI5(P,IN,JM)
7         IF(VX.GT.12.5.AND.VX.LE.15.C)GO TC 1
7         IF(VX.GT.15.0.AND.VX.LE.17.C)CALL SECSI4(P,IN,JM)
7         IF(VX.GT.17.0.AND.VX.LE.20.C)CALL SECSI1(P,IN,JM)
7         IF(VX.GT.20.0.AND.VX.LE.24.0)CALL SECSI7(P,IN,JM)
7         IF(VX.GT.24.0.AND.VX.LE.27.0)CALL SECSI2(P,IN,JM)
1   C     IF(VX.GT.27.0.AND.VX.LE.31.0)CALL SECSI8(P,IN,JM)
7         IF(VX.EQ.0.)RETURN
7         GO TO 100
5       1 A(3,2)=P(1,11)+P(2,11)+P(3,11)+.7*P(4,11)+.3*P(5,11)+0.05*P(6,11)
6        $+.9*P(1,10)+.6*P(2,10)+.25*P(3,10)+.1*P(1,9)
7         A(6,2)=P(1,1)+P(2,1)+P(3,1)+.7*P(4,1)+.3*P(5,1)+.05*P(6,1)+.9*P(1,
6        $2)+.6*P(2,2)+.25*P(3,2)+.1*P(1,3)
7         A(4,2)=.95*P(6,11)+P(7,11)+.1*P(1,10)+.4*P(2,10)+.75*P(3,10)+.3*
6        $P(4,11)+.7*P(5,11)+.2*P(8,11)+.4*P(8,10)+.6*P(8,9)+.8*P(8,8)+.9*
6        $P(8,7)+.9*P(1,9)
7         SUM=0.
7         DO 4 I=1,7
7         DO 4 J=7,8
5       4 SUM=SUM+P(I,J)
7         SUM1=0.
7         DO 5 I=1,8
5       5 SUM1=SUM1+.5*P(I,6)
7         SUM2=0.
7         DO 6 I=2,7
5       6 SUM2=SUM2+P(I,9)
7         A(4,2)=A(4,2)+SUM+SUM1+SUM2
7         A(5,2)=.95*P(6,1)+P(7,1)+.1*P(1,2)+.4*P(2,2)+.75*P(3,2)+.3*P(4,1)
6        $+.7*P(5,1)+.2*P(8,1)+.4*P(8,2)+.6*P(8,3)+.8*P(8,4)+.9*P(8,5)+
6        $.9*P(1,3)
7         SUM=0.
7         DO 7 I=1,7
7         DO 7 J=4,5
5       7 SUM=SUM+P(I,J)
7         SUM2=0.
7         DO 9 I=2,7
5       9 SUM2=SUM2+P(I,3)
7         A(5,2)=A(5,2)+SUM+SUM1+SUM2
7         A(4,3)=.8*P(8,11)+.6*P(8,10)+.4*P(8,9)+.2*P(8,8)+.1*P(8,7)+.6*
6        $P(16,11)+.9*P(16,10)+P(16,9)+P(16,8)+P(16,7)+.1*P(17,9)+.15*
6        $P(17,8)+.20*P(17,7)+.1*P(17,6)
7         SUM=0.
7         DO 10 I=9,15
7         DO 10 J=7,11
4      10 SUM=SUM+P(I,J)
7         SUM1=0.
7         DO 11 I=9,16
4      11 SUM1=SUM1+P(I,6)*.5
7         A(4,3)=A(4,3)+SUM+SUM1
7         A(5,3)=.8*P(8,1)+.6*P(8,2)+.4*P(8,3)+.2*P(8,4)+.1*P(8,5)+.6*
6        $P(16,1)+.9*P(16,2)+P(16,3)+P(16,4)+P(16,5)+.1*P(17,3)+.15*P(17,4)
6        $+.20*P(17,5)+.1*P(17,6)
7         SUM=0.
7         DO 12 I=9,15
7         DO 12 J=1,5
4      12 SUM=SUM+P(I,J)
7         A(5,3)=A(5,3)+SUM+SUM1
7         A(4,4)=.4*P(17,6)+.4*P(16,11)+.1*P(16,10)+.9*P(17,9)+.85*P(17,8)+
6        $.8*P(17,7)+.8*P(24,11)+.95*P(24,10)+P(24,9)+P(24,8)+P(24,7)+.05*
6        $P(25,10)+.1*P(25,9)+.2*P(25,8)+.25*P(25,7)+.15*P(25,6)
7         SUM=0.
7         DO 14 I=18,23
7         DO 14 J=7,11
```

```
4        14 SUM=SUM+P(I,J)
7           SUM1=0.
7           DO 15 I=18,24
4        15 SUM1=SUM1+.5*P(I,6)
7           A(4,4)=A(4,4)+SUM+SUM1
7           A(5,4)=.4*P(17,6)+.4*P(16,1)+.1*P(16,2)+.5*P(17,3)+.65*P(17,4)+
6          $.8*P(17,5)+.8*P(24,1)+.95*P(24,2)+P(24,3)+P(24,4)+P(24,5)+.05*
6          $P(25,2)+.1*P(25,3)+.2*P(25,4)+.25*P(25,5)+.15*P(25,6)
7           SUM=0.
7           DO 16 I=18,23
7           DO 16 J=1,5
4        16 SUM=SUM+P(I,J)
7           A(5,4)=A(5,4)+SUM+SUM1
7           A(4,5)=.35*P(25,6)+.2*P(24,11)+.05*P(24,10)+.95*P(25,10)+.9*P(25,
6          $9)+.8*P(25,8)+.75*P(25,7)
7           SUM=0.
7           DO 17 I=26,30
7           DO 17 J=7,11
4        17 SUM=SUM+P(I,J)
7           SUM1=0.
7           DO 18 I=26,30
4        18 SUM1=SUM1+.5*P(I,6)
7           A(4,5)=A(4,5)+SUM+SUM1
7           A(5,5)=.35*P(25,6)+.2*P(24,1)+.05*P(24,2)+.95*P(25,2)+.9*P(25,3)
6          $+.8*P(25,4)+.75*P(25,5)
7           SUM=0.
7           DO 19 I=26,30
7           DO 19 J=1,5
4        19 SUM=SUM+P(I,J)
7           A(5,5)=A(5,5)+SUM+SUM1
3       100 PRINT 105,VX
7           PRINT 104
7           PRINT 101,(I,I=1,16)
7           DO 41 J=1,5
4        41 WRITE(6,102)(A(I,J),I=1,16)
3       101 FORMAT(1X,16(I6,2X))
3       102 FORMAT(2X,16(1PE8.1))
1   C       DO 42 J=1,5
1   C    42 WRITE(7,103)(A(I,J),I=1,8)
1   C       DO 43 J=1,5
1   C    43 WRITE(7,103)(A(I,J),I=9,16)
3       103 FORMAT(8(1PE10.3))
3       104 FORMAT(1H0,10X,'SECTOR VALUES FROM SITE IN 10 MI INCREMENTS',//)
3       105 FORMAT(1H0,5X,'TRANSLATIONAL VELOCITY = ',F5.1,//)
7           RETURN
7           END
7           SUBROUTINE SECS11(P,IN,JM)
7           COMMON/SEC/A(16,5)
7           DIMENSION P(IN,JM)
7           A(3,2)=.25*P(1,11)+.05*P(2,11)
7           A(6,2)=.25*P(1,1)+.05*P(2,1)
7           A(4,2)=.75*P(1,11)+.95*P(2,11)+P(3,11)+.45*P(4,6)+.5*P(4,7)+.8*
6          $P(4,8)+.6*P(4,9)+.45*P(4,10)+.15*P(4,11)
7           SUM=0.
7           DO 20 I=1,3
7           DO 20 J=7,10
4        20 SUM=SUM+P(I,J)
7           SUM1=0.
7           DO 21 I=1,3
4        21 SUM1=SUM1+P(I,6)*.5
7           A(4,2)=A(4,2)+SUM+SUM1
7           A(5,2)=.75*P(1,1)+.95*P(2,1)+P(3,1)+.45*P(4,6)+.9*P(4,5)+.8*P(4,4)
6          $+.6*P(4,3)+.45*P(4,2)+.15*P(4,1)
7           SUM=0.
7           DO 22 I=1,3
7           DO 22 J=2,5
4        22 SUM=SUM+P(I,J)
7           A(5,2)=A(5,2)+SUM+SUM1
7           A(4,3)=.05*P(4,6)+.1*P(4,7)+.2*P(4,8)+.4*P(4,9)+.55*P(4,10)+.85*
6          $P(4,11)+.7*P(12,11)+.9*P(12,10)+P(12,9)+P(12,8)+P(12,7)+.05*P(13,
6          $9)+.1*P(13,8)+.15*P(13,7)+.1*P(13,6)
7           SUM=0.
```

```
7        DO 23 I=5,11
7        DO 23 J=7,11
4     23 SUM=SUM+P(I,J)
7        SUM1=0.
7        DO 24 I=5,12
4     24 SUM1=SUM1+P(I,6)*.5
7        A(4,3)=A(4,3)+SUM+SUM1
7        A(5,3)=.05*P(4,6)+.1*P(4,5)+.2*P(4,4)+.4*P(4,3)+.55*P(4,2)+.85*
6       $P(4,1)+.7*P(12,1)+.9*P(12,2)+P(12,3)+P(12,4)+P(12,5)+.05*P(13,3)
6       $+.1*P(13,4)+.15*P(13,5)+.1*P(13,6)
7        SUM=0.
7        DO 25 I=5,11
7        DO 25 J=1,5
4     25 SUM=SUM+P(I,J)
7        A(5,3)=A(5,3)+SUM+SUM1
7        A(4,4)=.4*P(13,6)+.95*P(13,9)+.9*P(13,8)+.85*P(13,7)+.3*P(12,11)
6       $+.1*P(12,10)+.85*P(20,11)+.95*P(20,10)+.05*P(21,10)+P(20,9)+.1*
6       $P(21,9)+P(20,8)+.15*P(21,8)+P(20,7)+.2*P(21,7)+.1*P(21,6)
7        SUM=0.
7        DO 26 I=14,19
7        DO 26 J=7,11
4     26 SUM=SUM+P(I,J)
7        SUM1=0.
7        DO 27 I=14,20
4     27 SUM1=SUM1+P(I,6)*.5
7        A(4,4)=A(4,4)+SUM+SUM1
7        A(4,5)=.4*P(13,6)+.95*P(13,3)+.9*P(13,4)+.85*P(13,5)+.3*P(12,1)
6       $+.1*P(12,2)+.85*P(20,1)+.05*P(20,2)+.05*P(21,2)+P(20,3)+.1*P(21,3)
6       $+P(20,4)+.15*P(21,4)+P(20,5)+.2*P(21,5)+.1*P(21,6)
7        SUM=0.
7        DO 28 I=14,19
7        DO 28 J=1,5
4     28 SUM=SUM+P(I,J)
7        A(4,5)=A(4,5)+SUM+SUM1
7        A(5,4)=.4*P(21,6)+.15*P(20,11)+.05*P(20,10)+.95*P(21,10)+.9*P(21,9
6       $)+.85*P(21,8)+.8*P(21,7)+P(21,11)+.25*P(29,6)+.5*P(29,7)+.48*P(29,
6       $8)+.45*P(29,9)+.40*P(29,10)+.35*P(29,11)
7        SUM=0.
7        DO 29 I=22,28
7        DO 29 J=7,11
4     29 SUM=SUM+P(I,J)
7        SUM1=0.
7        DO 30 I=22,28
4     30 SUM1=SUM1+P(I,6)*.5
7        A(5,4)=A(5,4)+SUM+SUM1
7        A(5,5)=.4*P(21,6)+.15*P(20,1)+.05*P(20,2)+.95*P(21,2)+.9*P(21,3)
6       $+.85*P(21,4)+.8*P(21,5)+P(21,1)+.25*P(29,6)+.5*P(29,5)+.48*P(29,4)
6       $+.45*P(29,3)+.40*P(29,2)+.35*P(29,1)
7        SUM=0.
7        DO 31 I=22,28
7        DO 31 J=1,5
4     31 SUM=SUM+P(I,J)
7        A(5,5)=A(5,5)+SUM+SUM1
7        RETURN
7        END
7        SUBROUTINE SECS12(P,IN,JM)
7        COMMON/SEC/A(16,5)
7        DIMENSION P(IN,JM)
7        A(4,2)=.45*P(1,6)+.8*P(1,7)+.7*P(1,8)+.55*P(1,9)+.4*P(1,10)+.1*
6       $P(1,11)
7        A(5,2)=.45*P(1,6)+.8*P(1,5)+.7*P(1,4)+.55*P(1,3)+.4*P(1,2)+.1*
6       $P(1,1)
7        A(4,3)=.05*P(1,6)+.2*P(1,7)+.3*P(1,8)+.45*P(1,9)+.6*P(1,10)+.9*
6       $P(1,11)+.1*P(10,6)+.15*P(10,7)+.1*P(10,8)+.05*P(10,9)+.95*P(9,10
6       $)+.65*P(9,11)+P(9,9)+P(9,8)+P(9,7)
7        SUM=0.
7        DO 32 I=2,8
7        DO 32 J=7,11
4     32 SUM=SUM+P(I,J)
7        SUM1=0.
7        DO 33 I=2,9
```

```
4      33 SUM1=SUM1+P(I,6)*.5
7         A(4,3)=A(4,3)+SUM+SUM1
7         A(5,3)=.05*P(1,6)+.2*P(1,5)+.3*P(1,4)+.45*P(1,3)+.6*P(1,2)+.9*P(1,
6        $1)+.1*P(10,6)+.15*P(10,5)+.1*P(10,4)+.05*P(10,3)+.95*P(9,2)+.65*
6        $P(9,1)+P(9,3)+P(9,4)+P(9,5)
7         SUM=0.
7         DO 34 I=2,8
7         DO 34 J=1,5
4      34 SUM=SUM+P(I,J)
7         A(5,3)=A(5,3)+SUM+SUM1
7         A(4,4)=.4*P(10,6)+.85*P(10,7)+.9*P(10,8)+.95*P(10,9)+.05*P(9,10)
6        $+.45*P(9,11)+P(17,7)+P(17,8)+P(17,9)+.95*P(17,10)+.75*P(17,11)+
6        $.05*P(18,9)+.1*P(18,8)+.2*P(18,7)+.1*P(18,6)
7         SUM=0.
7         DO 35 I=11,16
7         DO 35 J=7,11
4      35 SUM=SUM+P(I,J)
7         SUM1=0.
7         DO 36 I=11,17
4      36 SUM1=SUM1+P(I,6)*.5
7         A(4,4)=A(4,4)+SUM+SUM1
7         A(4,5)=.4*P(10,6)+.85*P(10,5)+.9*P(10,4)+.95*P(10,3)+.05*P(9,2)+
6        $.45*P(9,1)+P(17,5)+P(17,4)+P(17,3)+.95*P(17,2)+.75*P(17,1)+.05*
6        $P(18,3)+.1*P(18,4)+.2*P(18,5)+.1*P(18,6)
7         SUM=0.
7         DO 37 I=11,16
7         DO 37 J=1,5
4      37 SUM=SUM+P(I,J)
7         A(4,5)=A(4,5)+SUM+SUM1
7         A(5,4)=.4*P(18,6)+.8*P(18,7)+.9*P(18,8)+.95*P(18,9)+.05*P(17,10)+
6        $.25*P(17,11)+.5*P(26,7)+.48*P(26,8)+.45*P(26,9)+.40*P(26,10)+.35
6        $*P(26,11)+.25*P(26,6)
7         SUM=0.
7         DO 38 I=19,25
7         DO 38 J=7,11
4      38 SUM=SUM+P(I,J)
7         SUM1=0.
7         DO 39 I=19,25
4      39 SUM1=SUM1+P(I,6)*.5
7         A(5,4)=A(5,4)+SUM+SUM1
7         A(5,5)=.4*P(18,6)+.8*P(18,5)+.9*P(18,4)+.95*P(18,3)+.05*P(17,2)+
6        $.25*P(17,1)+.5*P(26,5)+.48*P(26,4)+.45*P(26,3)+.40*P(26,2)+.35*
6        $P(26,1)+.25*P(26,6)
7         SUM=0.
7         DO 40 I=19,25
7         DO 40 J=1,5
4      40 SUM=SUM+P(I,J)
7         A(5,5)=A(5,5)+SUM+SUM1
7         RETURN
7         END
7         SUBROUTINE SECS13(G,IN,JM)
7         COMMON/SEC/A(16,5)
7         DIMENSION G(IN,JM),P(11,30)
1   C
1   C     VX=8.04 M/SEC
1   C
7         DO 1 I=1,IN
7         DO 1 J=1,JM
5       1 P(J,I)=G(I,J)
7         A(2,1)=0.5*P(11,1)
7         A(7,1)=0.5*P(1,1)
7         A(3,1)=0.5*P(11,1)+.8*P(11,2)+P(10,1)+P(10,2)+.6*P(10,3)+P(9,1)
6        C +.9*P(9,2)+.5*P(9,3)+.33*P(8,1)+.1*P(8,2)
7         A(6,1)=0.5*P(1,1)+.8*P(1,2)+P(2,1)+P(2,2)+.6*P(2,3)+P(3,1)+.9*P(3,
6        C2)+.5*P(3,3)+.33*P(4,1)+.1*P(4,2)
7         A(4,1)=.07*P(9,2)+.5*P(9,3)+.1*P(9,4)+.6*P(8,1)+.93*P(8,2)+P(8,3)+
6        C.3*P(8,4)+P(7,1)+P(7,2)+P(7,3)+.5*P(7,4)+.5*(P(6,1)+P(6,2)+P(6,3))
6        C+.25*P(6,4)
7         A(5,1)=.07*P(3,2)+.5*P(3,3)+.1*P(3,4)+.6*P(4,1)+.93*P(4,2)+P(4,3)+
6        C.3*P(4,4)+P(5,1)+P(5,2)+P(5,3)+.5*P(5,4)+.5*(P(6,1)+P(6,2)+P(6,3))
6        C+.25*P(6,4)
7         A(3,2)=.12*P(11,2)+.95*P(11,3)+P(11,4)+P(11,5)+P(11,6)+.9*P(11,7)+
6        C.5*P(11,8)+.1*P(11,9)+.5*P(10,3)+P(10,4)+.8*P(10,5)+.3*P(10,6)+.05
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6         C*P(10,7)+.2*P(9,4)
7          A(6,2)=.12*P(1,2)+.95*P(1,3)+P(1,4)+P(1,5)+P(1,6)+.9*P(1,7)+.5*P(1
6         C,8)+.1*P(1,9)+.5*P(2,3)+P(2,4)+.8*P(2,5)+.3*P(2,6)+.05*P(2,7)+.2*P
6         C(3,4)
7          A(4,2)=.1*P(11,7)+.5*P(11,8)+.9*P(11,9)+P(11,10)+.5*P(11,11)+.2*P(
6         C10,5)+.7*P(10,6)+.95*P(10,7)+P(10,8)+P(10,9)+P(10,  10)+.8*P(10,11
6         C)+.8*P(9,4)+P(9,5)+P(9,6)+P(9,7)+P(9,8)+P(9,9)+P(9,10)+P(9,11)+.1*
6         CP(9,12)+.7*P(8,4)+P(8,5)+P(8,6)+P(8,7)+P(8,8)+P(8,9)+P(8,10)+P(8,1
6         C1)+.2*P(8,12)+.5*P(7,4)+P(7,5)+P(7,6)+P(7,7)+P(7,8)+P(7,9)+P(7,10)
6         C+P(7,11)+.3*P(7,12)+.2*P(6,4)+.5*(P(6,5)+P(6,6)+P(6,7)+P(6,8)+P(6,
6         C9)+P(6,10)+P(6,11))+.2*P(6,12)
7          A(5,2)=.1*P(1,7)+.5*P(1,8)+.9*P(1,9)+P(1,10)+.5*P(1,11)+.2*P(2,5)
6         C+.7*P(2,6)+.95*P(2,7)+P(2,8)+P(2,9)+P(2,10)+.8*P(2,11)+.8*P(3,4)+
6         CP(3,5)+P(3,6)+P(3,7)+P(3,8)+P(3,9)+P(3,10)+P(3,11)+.1*P(3,12)+.7*
6         CP(4,4)+P(4,5)+P(4,6)+P(4,7)+P(4,8)+P(4,9)+P(4,10)+P(4,11)+.2*P(4,1
6         C2)+.5*P(5,4)+P(5,5)+P(5,6)+P(5,7)+P(5,8)+P(5,9)+P(5,10)+P(5,11)+.3
6         C*P(5,12)+.2*P(6,4)+.5*(P(6,5)+P(6,6)+P(6,7)+P(6,8)+P(6,9 )+P(6,10)
6         C+P(6,11))+.2*P(6,12)
7          A(4,3)=.5*P(11,11)+P(11,12)+P(11,13)+P(11,14)+P(11,15)+P(11,16)
6         C+P(11,17)+P(11,18)+.9*P(11,19)+.2*P(10,11)+P(10,12)+P(7,13)+P(7,14
6         C)+P(7,15)+P(7,16)+P(7,17)+P(7,18)+P(7,19)+.7*P(7,20)+.3*P(6,12)+.5
6         C*(P(6,13)+P(6,14)+P(6,15)+P(6,16)+P(6,17)+P(6,18)+P(6,19))+.4*P(6,
6         C20)
7          A(5,3)=.5*P(1,11)+P(1,12)+P(1,13)+P(1,14)+P(1,15)+P(1,16)+P(1,17)+
6         C P(1,18)+.9*P(1,19)+.2*P(2,11)+P(2,12)+P(2,13)+P(2,14)+P(2,15)+
6         C P(2,16)+P(2,17)+P(2,18)+P(2,19)+.1*P(2,20)+.9*P(3,12)+P(3,13)+
6         C P(3,14)+P(3,15)+P(3,16)+P(3,17)+P(3,18)+P(3,19)+.3*P(3,20)+.8*P(4
6         C ,12)+P(4,13)+P(4,14)+P(4,15)+P(4,16)+P(4,17)+P(4,18)+P(4,19)+.5*
6         CP(4,20)+.7*P(5,12)+P(5,13)+P(5,14)+P(5,15)+P(5,16)+P(5,17)+P(5,18)
6         C+P(5,19)+.7*P(5,20)+.3*P(6,12)+.5*(P(6,13)+P(6,14)+P(6,15)+P(6,16)
6         C+P(6,17)+P(6,18)+P(6,19))+.4*P(6,20)
7          A(4,4)=.1*P(11,19)+P(11,20)+P(11,21)+P(11,22)+P(11,23)+P(11,24)+
6         CP(11,25)+P(11,26)+P(11,27)+.2*P(11,28)+.9*P(10,20)+P(10,21)+P(10,
6         C22)+P(10,23)+P(10,24)+P(10,25)+P(10,26)+P(10,27)+.4*P(10,28)+.7*
6         CP(9,20)+P(9,21)+P(9,22)+P(9,23)+P(9,24) +P(9,25)+P(9,26)+P(9,27)+
6         C.7*P(9,28)+.5*P(8,20)+P(8,21)+P(8,22)+P(8,23)+P(8,24)+P(8,25)+P(8,
6         C26)+P(8,27)+.7*P(8,28)+.3*P(7,20)+P(7,21)+P(7,22)+P(7,23)+P(7,24)+
6         CP(7,25)+P(7,26)+P(7,27)+.8*P(7,28)+.1*P(6,20)+.5*(P(6,21)+P(6,22)+
6         CP(6,23)+P(6,24)+P(6,25)+P(6,26)+P(6,27))+.4*P(6,28)
7          A(5,4)=.1*P(1,19)+P(1,20)+P(1,21)+P(1,22)+P(1,23)+P(1,24)+P(1,25)+
6         CP(1,26)+P(1,27)+.2*P(1,28)+.9*P(2,20)+P(2,21)+P(2,22)+P(2,23)+P(2,
6         C24)+P(2,25)+P(2,26)+P(2,27)+.4*P(2,28)+.7*P(3,20)+P(3,21)+P(3,22)+
6         CP(3,23)+P(3,24)+P(3,25)+P(3,26)+P(3,27)+.3*P(3,28)+.5*P(4,20)+P(4,
6         C21)+P(4,22)+P(4,23)+P(4,24)+P(4,25)+P(4,26)+P(4,27)+.7*P(4,28)+.3*
6         CP(5,20)+P(5,21)+P(5,22)+P(5,23)+P(5,24)+P(5,25)+P(5,26)+P(5,27)+.8
6         C*P(5,28)+.1*P(6,20)+.5*(P(6,21)+P(6,22)+P(6,23)+P(6,24)+P(6,25)+
6         CP(6,26)+P(6,27))+.4*P(6,28)
7          A(4,5)=.8*P(11,28)+P(11,29)+P(11,30)+.6*P(10,28)+P(10,29)+P(10,30)
6         C+.3*P(9,28)+P(9,29)+P(9,30)+.3*P(8,28)+P(8,29)+P(8,30)+.2*P(7,28)+
6         CP(7,29)+P(7,30)+.1*P(6,28)+.5*(P(6,29)+P(6,30))
7          A(5,5)=.8*P(1,28)+P(1,29)+P(1,30)+.6*P(2,28)+P(2,29)+P(2,30)+.3*
6         CP(3,28)+P(3,29)+P(3,30)+.3*P(4,28)+P(4,29)+P(4,30)+.2*P(5,28)+P(5,
6         C29)+P(5,30)+.1*P(6,28)+.5*(P(6,29)+P(6,30))
7          RETURN
7          END
7          SUBROUTINE SECSI4(G,IN,JM)
7          COMMON/SEC/A(16,5)
7          DIMENSION G(IN,JM),P(11,30)
1   C
1   C      VX=16.5 M/SEC
1   C
7          DO 1 I=1,IN
7          DO 1 J=1,JM
5        1 P(J,I)=G(I,J)
7          A(3,2)=P(11,1)+.75*P(11,2)+.25*P(11,3)+.15*P(10,1)
7          A(6,2)=P(1,1)+.75*P(1,2)+.25*P(1,3)+.15*P(2,1)
7          A(4,2)=.25*P(11,2)+.75*P(11,3)+P(11,4)+.9*P(11,5)+.85*P(10,1)+
6         CP(10,2)+P(10,3)+P(10,4)+P(10,5)+.2*P(10,6)+P(9,1)+P(9,2)+P(9,3)+
6         CP(9,4)+P(9,5)+.5*P(9,6)+P(8,1)+P(8,2)+P(8,3)+P(8,4)+P(8,5)+.75*P(8
6         C,6)+P(7,1)+P(7,2)+P(7,3)+P(7,4)+P(7,5)+.8*P(7,6)+.5*(P(6,1)+P(6,2)
6         C+P(6,3)+P(6,4)+P(6,5))+.4*P(6,6)
7          A(5,2)=.25*P(1,2)+.75*P(1,3)+P(1,4)+.9*P(1,5)+.85*P(2,1)+P(2,2)+
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6        CP(2,3)+P(2,4)+P(2,5)+.2*P(2,6)+P(3,1)+P(3,2)+P(3,3)+P(3,4)+P(3,5)+
6        C.5*P(3,6)+P(4,1)+P(4,2)+P(4,3)+P(4,4)+P(4,5)+.7*P(4,6)+P(5,1)+P(5,
6        C2)+P(5,3)+P(5,4)+P(5,5)+.8*P(5,6)+.5*(P(6,1)+P(6,2)+P(6,3)+P(6,4)+
6        CP(6,5))+.4*P(6,6)
7         A(4,3)=.1*P(11,5)+P(11,6)+P(11,7)+P(11,8)+P(11,9)+P(11,10)+P(11,11
6        C)+P(11,12)+P(11,13)+.3*P(11,14)+.8*P(10,6)+P(10,7)+P(10,8)+P(10,9)
6        C+P(10,10)+P(10,11)+P(10,12)+P(10,13)+.6*P(10,14)+.5*P(9,6)+P(9,7)+
6        CP(9,8)+P(9,9)+P(9,10)+P(9,11)+P(9,12)+P(9,13)+.85*P(9,14)+.25*P(8,
6        C6)+P(8,7)+P(8,8)+P(8,9)+P(8,10)+P(8,11)+P(8,12)+P(8,13)+P(8,14)+.2
6        C*P(7,6)+P(7,7)+P(7,8)+P(7,9)+P(7,10)+P(7,11)+P(7,12)+P(7,13)+P(7,1
6        C4)+.15*P(7,15)+.1*P(6,6)+.5*(P(6,7)+P(6,8)+P(6,9)+P(6,10)+P(6,11)+
6        CP(6,12)+P(6,13)+P(6,14))+.1*P(6,15)
7         A(5,3)=.1*P(1,5)+P(1,6)+P(1,7)+P(1,8)+P(1,9)+P(1,10)+P(1,11)+P(1,1
6        C2)+P(1,13)+.3*P(1,14)+.8*P(2,6)+P(2,7)+P(2,8)+P(2,9)+P(2,10)+P(2,1
6        C1)+P(2,12)+P(2,13)+.6*P(2,14)+.5*P(3,6)+P(3,7)+P(3,8)+P(3,9)+P(3,1
6        C0)+P(3,11)+P(3,12)+P(3,13)+.85*P(3,14)+.25*P(4,6)+P(4,7)+P(4,8)+
6        CP(4,9)+P(4,10)+P(4,11)+P(4,12)+P(4,13)+P(4,14)+.2*P(5,6)+P(5,7)+
6        CP(5,8)+P(5,9)+P(5,10)+P(5,11)+P(5,12)+P(5,13)+P(5,14)+.15*P(5,15)+
6        C.1*P(6,6)+.5*(P(6,7)+P(6,8)+P(6,9)+P(6,10)+P(6,11)+P(6,12)+P(6,13)
6        C+P(6,14))+.1*P(6,15)
7         A(4,4)=.7*P(11,14)+P(11,15)+P(11,16)+P(11,17)+P(11,18)+P(11,19)+
6        CP(11,20)+P(11,21)+.75*P(11,22)+.4*P(10,14)+P(10,15)+P(10,16)+P(10,
6        C17)+P(10,18)+P(10,19)+P(10,20)+P(10,21)+.9*P(10,22)+.15*P(9,14)+
6        CP(9,15)+P(9,16)+P(9,17)+P(9,18)+P(9,19)+P(9,20)+P(9,21)+P(9,22)+
6        CP(8,15)+P(8,16)+P(8,17)+P(8,18)+P(8,19)+P(8,20)+P(8,21)+P(8,22)+
6        C.1*P(8,23)+.85*P(7,15)+P(7,16)+P(7,17)+P(7,18)+P(7,19)+P(7,20)+
6        CP(7,21)+P(7,22)+.2*P(7,23)+.4*P(6,15)+.5*(P(6,16)+P(6,17)+P(6,18)+
6        CP(6,19)+P(6,20)+P(6,21)+P(6,22))+.1*P(6,23)
7         A(5,4)=.7*P(1,14)+P(1,15)+P(1,16)+P(1,17)+P(1,18)+P(1,19)+P(1,20)+
6        CP(1,21)+.75*P(1,22)+.4*P(2,14)+P(2,15)+P(2,16)+P(2,17)+P(2,18)+
6        CP(2,19)+P(2,20)+P(2,21)+.9*P(2,22)+.15*P(3,14)+P(3,15)+P(3,16)+
6        CP(3,17)+P(3,18)+P(3,19)+P(3,20)+P(3,21)+P(3,22)+P(4,15)+P(4,16)+
6        CP(4,17)+P(4,18)+P(4,19)+P(4,20)+P(4,21)+P(4,22)+.1*P(4,23)+.85*
6        CP(5,15)+P(5,16)+P(5,17)+P(5,18)+P(5,19)+P(5,20)+P(5,21)+P(5,22)+.2
6        C*P(5,23)+.4*P(6,15)+.5*(P(6,16)+P(6,17)+P(6,18)+P(6,19)+P(6,20)+
6        CP(6,21)+P(6,22))+.1*P(6,23)
7         A(4,5)=.25*P(11,22)+P(11,23)+P(11,24)+P(11,25)+P(11,26)+P(11,27)+
6        CP(11,28)+P(11,29)+P(11,30)+.1*P(10,22)+P(10,23)+P(10,24)+P(10,25)+
6        CP(10,26)+P(10,27)+P(10,28)+P(10,29)+P(10,30)+P(9,23)+P(9,24)+P(9,2
6        C5)+P(9,26)+P(9,27)+P(9,28)+P(9,29)+P(9,30)+.9*P(8,23)+P(8,24)+
6        CP(8,25)+P(8,26)+P(8,27)+P(8,28)+P(8,29)+P(8,30)+.8*P(7,23)+P(7,24)
6        C+P(7,25)+P(7,26)+P(7,27)+P(7,28)+P(7,29)+P(7,30)+.4*P(6,23)+.5*(
6        CP(6,24)+P(6,25)+P(6,26)+P(6,27)+P(6,28)+P(6,29)+P(6,30))
7         A(5,5)=.25*P(1,22)+P(1,23)+P(1,24)+P(1,25)+P(1,26)+P(1,27)+P(1,28)
6        C+P(1,29)+P(1,30)+.1*P(2,22)+P(2,23)+P(2,24)+P(2,25)+P(2,26)+P(2,27
6        C)+P(2,28)+P(2,29)+P(2,30)+P(3,23)+P(3,24)+P(3,25)+P(3,26)+P(3,27)+
6        CP(3,28)+P(3,29)+P(3,30)+.9*P(4,23)+P(4,24)+P(4,25)+P(4,26)+P(4,27)
6        C+P(4,28)+P(4,29)+P(4,30)+.8*P(5,23)+P(5,24)+P(5,25)+P(5,26)+P(5,27
6        C)+P(5,28)+P(5,29)+P(5,30)+.4*P(6,23)+.5*(P(6,24)+P(6,25)+P(6,26)+
6        CP(6,27)+P(6,28)+P(6,29)+P(6,30))
7         RETURN
7         END
7         SUBROUTINE SECSIS(G,IN,JM)
7         COMMON/SEC/A(16,5)
7         DIMENSION G(IN,JM),P(11,30)
1   C
1   C     VELOCITY IS 11.60 M/SEC
1   C
7         DO 1 I=1,IN
7         DO 1 J=1,JM
5       1 P(J,I)=G(I,J)
7         A(3,1)=.1*P(10,1)+.25*P(9,1)
7         A(6,1)=.1*P(2,1)+.25*P(3,1)
7         A(4,1)=.3*P(9,1)+.5*P(8,1)+P(7,1)+.5*P(6,1)
7         A(5,1)=.3*P(3,1)+.5*P(4,1)+P(5,1)+.5*P(6,1)
7         A(3,2)=P(11,1)+P(11,2)+P(11,3)+P(11,4)+.75*P(11,5)+.25*P(11,6)+.9*
6        CP(10,1)+.9*P(10,2)+.6*P(10,3)+.2*P(10,4)+.2*P(9,1)+.1*P(9,2)
7         A(6,2)=P(1,1)+P(1,2)+P(1,3)+P(1,4)+.75*P(1,5)+.25*P(1,6)+.9*P(2,1)
6        C+.9*P(2,2)+.6*P(2,3)+.2*P(2,4)+.2*P(3,1)+.1*P(3,2)
7         A(4,2)=.25*P(11,5)+.75*P(11,6)+P(11,7)+P(11,8)*.9+.1*P(10,2)+.4*
6        CP(10,3)+.8*P(10,4)+P(10,5)+P(10,6)+P(10,7)+P(10,8)+.2*P(10,9)+.25*
6        CP(9,1)+.9*P(9,2)+P(9,3)+P(9,4)+P(9,5)+P(9,6)+P(9,7)+P(9,8)+.6*P(9,
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6        C9)+.1*P(8,1)+P(8,2)+P(8,3)+P(8,4)+P(8,5)+P(8,6)+P(8,7)+P(8,8)+.8*
6        CP(8,9)+P(7,2)+P(7,3)+P(7,4)+P(7,5)+P(7,6)+P(7,7)+P(7,8)+.9*P(7,9)+
6        C.5*(P(6,2)+P(6,3)+P(6,4)+P(6,5)+P(6,6)+P(6,7)+P(6,8)+P(6,9))
7         A(5,2)=.25*P(1,5)+.75*P(1,6)+P(1,7)+.9*P(1,8)+.1*P(2,2)+.4*P(2,3)+
6        C.8*P(2,4)+P(2,5)+P(2,6)+P(2,7)+P(2,8)+.2*P(2,9)+.25*P(3,1)+.9*P(3,
6        C2)+P(3,3)+P(3,4)+P(3,5)+P(3,6)+P(3,7)+P(3,8)+.6*P(3,9)+.1*P(4,1)+
6        CP(4,2)+P(4,3)+P(4,4)+P(4,5)+P(4,6)+P(4,7)+P(4,8)+.8*P(4,9)+P(5,2)+
6        CP(5,3)+P(5,4)+P(5,5)+P(5,6)+P(5,7)+P(5,8)+.9*P(5,9)+.5*(P(6,2)+P(6
6        C,3)+P(6,4)+P(6,5)+P(6,6)+P(6,7)+P(6,8)+P(6,9))
7         A(4,3)=.1*P(11,8)+.95*P(11,9)+P(11,10)+P(11,12)+P(11,13)+P(11,14)+
6        CP(11,15)+P(11,16)+.4*P(11,17)+.7*P(10,9)+P(10,10)+P(10,11)+P(10,12
6        C)+P(10,13)+P(10,14)+P(10,15)+P(10,16)+.7*P(10,17)+.4*P(9,9)+P(9,10
6        C)+P(9,11)+P(9,12)+P(9,13)+P(9,14)+P(9,15)+P(9,16)+.85*P(9,17)+.15*
6        CP(8,9)+P(8,10)+P(8,11)+P(8,12)+P(8,13)+P(8,14)+P(8,15)+P(8,16)+P(8
6        C,17)+.1*P(7,9)+P(7,10)+P(7,11)+P(7,12)+P(7,13)+P(7,14)+P(7,15)+P(7
6        C,16)+P(7,17)+.1*P(7,18)+.5*(P(6,10)+P(6,11)+P(6,12)+P(6,13)+P(6,14
6        C)+P(6,15)+P(6,16)+P(6,17))+.1*P(6,18)
7         A(5,3)=.1*P(1,8)+.95*P(1,9)+P(1,10)+P(1,11)+P(1,12)+P(1,13)+P(1,14
6        C)+P(1,15)+P(1,16)+.4*P(1,17)+.7*P(2,9)+P(2,10)+P(2,11)+P(2,12)+
6        CP(2,13)+P(2,14)+P(2,15)+P(2,16)+.7*P(2,17)+.4*P(3,9)+P(3,10)+P(3,1
6        C1)+P(3,12)+P(3,13)+P(3,14)+P(3,15)+P(3,16)+.85*P(3,17)+.15*P(4,9)+
6        CP(4,10)+P(4,11)+P(4,12)+P(4,13)+P(4,14)+P(4,15)+P(4,16)+P(4,17)+.1
6        C*P(5,9)+P(5,10)+P(5,11)+P(5,12)+P(5,13)+P(5,14)+P(5,15)+P(5,16)+
6        CP(5,17)+.1*P(5,18)+.5*(P(6,10)+P(6,11)+P(6,12)+P(6,13)+P(6,14)+P(6
6        C,15)+P(6,16)+P(6,17))+.1*P(6,18)
7         A(4,4)=.6*P(11,17)+P(11,18)+P(11,19)+P(11,20)+P(11,21)+P(11,22)+
6        CP(11,23)+P(11,24)+.8*P(11,25)+.3*P(10,17)+P(10,18)+P(10,19)+P(10,2
6        C0)+P(10,21)+P(10,22)+P(10,23)+P(10,24)+.95*P(10,25)+.15*P(9,17)+
6        CP(9,18)+P(9,19)+P(9,20)+P(9,21)+P(9,22)+P(9,23)+P(9,24)+P(9,25)+
6        C.05*P(9,26)+P(8,18)+P(8,19)+P(8,20)+P(8,21)+P(8,22)+P(8,23)+P(8,24
6        C)+P(8,25)+.15*P(8,26)+.9*P(7,18)+P(7,19)+P(7,20)+P(7,21)+P(7,22)+
6        CP(7,23)+P(7,24)+P(7,25)+.2*P(7,26)+.4*P(6,18)+.5*(P(6,19)+P(6,20)+
6        CP(6,21)+P(6,22)+P(6,23)+P(6,24)+P(6,25))+P(6,26)*.1
7         A(5,4)=.6*P(1,17)+P(1,18)+P(1,19)+P(1,20)+P(1,21)+P(1,22)+P(1,23)+
6        CP(1,24)+.8*P(1,25)+.3*P(2,17)+P(2,18)+P(2,19)+P(2,20)+P(2,21)+P(2,
6        C22)+P(2,23)+P(2,24)+.95*P(2,25)+.15*P(3,17)+P(3,18)+P(3,19)+P(3,20
6        C)+P(3,21)+P(3,22)+P(3,23)+P(3,24)+P(3,25)+.05*P(3,26)+P(4,18)+P(4,
6        C19)+P(4,20)+P(4,21)+P(4,22)+P(4,23)+P(4,24)+P(4,25)+.15*P(4,26)+
6        C.9*P(5,18)+P(5,19)+P(5,20)+P(5,21)+P(5,22)+P(5,23)+P(5,24)+P(5,25)
6        C+P(5,26)*.2+.4*P(6,18)+.5*(P(6,19)+P(6,20)+P(6,21)+P(6,22)+P(6,23)
6        C+P(6,24)+P(6,25))+.1*P(6,26)
7         A(4,5)=.2*P(11,25)+P(11,26)+P(11,27)+P(11,28)+P(11,29)+P(11,30)+
6        C.05*P(10,25)+P(10,26)+P(10,27)+P(10,28)+P(10,29)+P(10,30)+.95*P(9,
6        C26)+P(9,27)+P(9,28)+P(9,29)+P(9,30)+.85*P(8,26)+P(8,27)+P(8,28)+
6        CP(8,29)+P(8,30)+.8*P(7,26)+P(7,27)+P(7,28)+P(7,29)+P(7,30)+.4*P(6,
6        C26)+.5*(P(6,27)+P(6,28)+P(6,29)+P(6,30))
7         A(5,5)=.2*P(1,25)+P(1,26)+P(1,27)+P(1,28)+P(1,29)+P(1,30)+.05*P(2,
6        C25)+P(2,26)+P(2,27)+P(2,28)+P(2,29)+P(2,30)+.95*P(3,26)+P(3,27)+
6        CP(3,28)+P(3,29)+P(3,30)+.85*P(4,26)+P(4,27)+P(4,28)+P(4,29)+P(4,30
6        C)+.8*P(5,26)+P(5,27)+P(5,28)+P(5,29)+P(5,30)+.4*P(6,26)+.5*(P(6,27
6        C)+P(6,28)+P(6,29)+P(6,30))
7         RETURN
7         END
7         SUBROUTINE SECS16(G,IN,JM)
7         COMMON/SEC/A(16,5)
7         DIMENSION G(IN,JM),P(11,30)
1    C
1    C    VELOCITY IS 4.00  M/SEC
1    C
7         DO 1 I=1,IN
7         DO 1 J=1,JM
5       1 P(J,I)=G(I,J)
7         A(2,1)=P(11,1)+P(11,2)+.5*P(11,3)+P(10,1)+.5*P(10,2)+.5*P(9,1)
7         A(7,1)=P(1,1)+P(1,2)+.5*P(1,3)+P(2,1)+.5*P(2,2)+.5*P(3,1)
7         A(3,1)=.5*P(11,3)+.88*P(11,4)+.12*P(11,5)+.5*P(10,2)+P(10,4)+.6*
6        CP(10,5)+.5*P(9,1)+P(9,2)+P(9,3)+.94*P(9,4)+.6*P(9,5)+P(8,1)+.75*
6        CP(8,2)+.4*P(8,3)+.1*P(8,4)+.3*P(7,1)
7         A(6,1)=.5*P(1,3)+.88*P(1,4)+.12*P(1,5)+.5*P(2,2)+P(2,3)+P(2,4)+.6*
6        CP(2,5)+.5*P(3,1)+P(3,2)+P(3,3)+.94*P(3,4)+.6*P(3,5)+P(4,1)+.75*
6        CP(4,2)+.4*P(4,3)+.1*P(4,4)+.3*P(5,1)
7         A(4,1)=.1*P(9,4)+.4*P(9,5)+.2*P(9,6)+.25*P(8,2)+.6*P(8,3)+.9*P(8,4
6        C)+P(8,5)+.35*P(8,6)+.75*P(7,1)+P(7,2)+P(7,3)+P(7,4)+P(7,5)+.6*P(7,
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6          C6)+.5*P(6,1)+.5*(P(6,2)+P(6,3)+P(6,4)+P(6,5))+.3*P(6,6)
7           A(5,1)=.1*P(3,4)+.4*P(3,5)+.2*P(3,6)+.25*P(4,2)+.6*P(4,3)+.9*P(4,4
6          C)+P(4,5)+.35*P(4,6)+.75*P(5,1)+P(5,2)+P(5,3)+P(5,4)+P(5,5)+.6*P(5,
6          C6)+.5*P(6,1)+.5*(P(6,2)+P(6,3)+P(6,4)+P(6,5))+.3*P(6,6)
7           A(3,2)=.12*P(11,4)+P(11,5)+P(11,6)+P(11,7)+.9*P(11,8)+.5*P(11,9)+
6          C.15*P(11,10)+.4*P(10,5)+P(10,6)+.8*P(10,7)+.4*P(10,8)+.1*P(10,9)+
6          C.25*P(9,6)
7           A(6,2)=.12*P(1,4)+P(1,5)+P(1,6)+P(1,7)+.9*P(1,8)+.5*P(1,9)+.15*P(1
6          C,10)+.4*P(2,5)+P(2,6)+.8*P(2,7)+.4*P(2,8)+.1*P(2,9)+.25*P(3,6)
7           A(4,2)=.1*P(11,9)+.5*P(11,10)+.8*P(11,11)+P(11,12)+.5*P(11,13)+.25
6          C*P(10,7)+.66*P(10,8)+.9*P(10,9)+P(10,10)+P(10,11)+P(10,12)+.8*P(10
6          C,13)+.66*P(9,6)+P(9,7)+P(9,8)+P(9,9)+P(9,10)+P(9,11)+P(9,12)+P(9,1
6          C3)+.25*P(9,14)+.5*P(8,6)+P(8,7)+P(8,8)+P(8,9)+P(8,10)+P(8,11)+
6          CP(8,12)+P(8,13)+.33*P(8,14)+.33*P(7,6)+P(7,7)+P(7,8)+P(7,9)+P(7,10
6          C)+P(7,11)+P(7,12)+P(7,13)+.5*P(7,14)+.2*P(6,6)+.5*(P(6,7)+P(6,8)+
6          CP(6,9)+P(6,10)+P(6,11)+P(6,12)+P(6,13))+.25*P(6,14)
7           A(5,2)=.1*P(1,9)+.5*P(1,10)+.8*P(1,11)+P(1,12)+.5*P(1,13)+.25*
6          CP(2,7)+.66*P(2,8)+.9*P(2,9)+P(2,10)+P(2,11)+P(2,12)+.8*P(2,13)+.66
6          C*P(3,6)+P(3,7)+P(3,8)+P(3,9)+P(3,10)+P(3,11)+P(3,12)+P(3,13)+.25*
6          CP(3,14)+.5*P(4,6)+P(4,7)+P(4,8)+P(4,9)+P(4,10)+P(4,11)+P(4,12)+
6          CP(4,13)+.33*P(4,14)+.33*P(5,6)+P(5,7)+P(5,8)+P(5,9)+P(5,10)+P(5,11
6          C)+P(5,12)+P(5,13)+.5*P(5,14)+.2*P(6,6)+.5*(P(6,7)+P(6,8)+P(6,9)+
6          CP(6,10)+P(6,11)+P(6,12)+P(6,13))+.25*P(6,14)
7           A(4,3)=.4*P(11,13)+P(11,14)+P(11,15)+P(11,16)+P(11,17)+P(11,18)+
6          CP(11,19)+P(11,20)+P(11,21)+.2*P(10,13)+P(10,14)+P(10,15)+P(10,16)+
6          CP(10,17)+P(10,18)+P(10,19)+P(10,20)+P(10,21)+.25*P(10,22)+.75*P(9,
6          C14)+P(9,15)+P(9,16)+P(9,17)+P(9,18)+P(9,19)+P(9,20)+P(9,21)+.4*
6          CP(9,22)+.66*P(8,14)+P(8,15)+P(8,16)+P(8,17)+P(8,18)+P(8,19)+P(8,20
6          C)+P(8,21)+.66*P(8,22)+.6*P(7,14)+P(7,15)+P(7,16)+P(7,17)+P(7,18)+
6          CP(7,19)+P(7,20)+P(7,21)+.75*P(7,22)+.25*P(6,14)+.5*(P(6,15)+P(6,16
6          C)+P(6,17)+P(6,18)+P(6,19)+P(6,20)+P(6,21))+.33*P(6,22)
7           A(5,3)=.4*P(1,13)+P(1,14)+P(1,15)+P(1,16)+P(1,17)+P(1,18)+P(1,19)+
6          CP(1,20)+P(1,21)+.2*P(2,13)+P(2,14)+P(2,15)+P(2,16)+P(2,17)+P(2,18)
6          C+P(2,19)+P(2,20)+P(2,21)+.25*P(2,22)+.75*P(3,14)+P(3,15)+P(3,16)+
6          CP(3,17)+P(3,18)+P(3,19)+P(3,20)+P(3,21)+.4*P(3,22)+.66*P(4,14)+
6          CP(4,14)+P(4,15)+P(4,16)+P(4,17)+P(4,18)+P(4,19)+P(4,20)+P(4,21)+
6          C.66*P(4,22)+.6*P(5,14)+P(5,15)+P(5,16)+P(5,17)+P(5,18)+P(5,19)+
6          CP(5,20)+P(5,21)+.75*P(5,22)+.25*P(6,14)+.5*(P(6,15)+P(6,16)+P(6,17
6          C)+P(6,18)+P(6,19)+P(6,20)+P(6,21))+P(6,22)*.33
7           A(4,4)=.1*P(11,21)+P(11,22)+P(11,23)+P(11,24)+P(11,25)+P(11,26)+P(
6          C11,27)+P(11,28)+P(11,29)+.33*P(11,30)+.75*P(10,22)+P(10,23)+P(10,2
6          C4)+P(10,25)+P(10,26)+P(10,27)+P(10,28)+P(10,29)+.5*P(10,30)+.6*P(9
6          C,22)+P(9,23)+P(9,24)+P(9,25)+P(9,26)+P(9,27)+P(9,29)+P(9,30)*.66+
6          C.34*P(8,22)+P(8,23)+P(8,24)+P(8,25)+P(8,26)+P(8,27)+P(8,28)+P(8,29
6          C)+.75*P(8,30)+.25*P(7,22)+P(7,23)+P(7,24)+P(7,25)+P(7,26)+P(7,27)+
6          CP(7,28)+P(7,29)+.8*P(7,30)+.15*P(6,22)+.5*(P(6,23)+P(6,24)+P(6,25)
6          C+P(6,26)+P(6,27)+P(6,28)+P(6,29))+.4*P(6,30)
7           A(5,4)=.1*P(1,21)+P(1,22)+P(1,23)+P(1,24)+P(1,25)+P(1,26)+P(1,27)+
6          CP(1,28)+P(1,29)+.33*P(1,30)+.75*P(2,22)+P(2,23)+P(2,24)+P(2,25)+
6          CP(2,26)+P(2,27)+P(2,28)+P(2,29)+.5*P(2,30)+.6*P(3,22)+P(3,23)+P(3,
6          C24)+P(3,25)+P(3,26)+P(3,27)+P(3,28)+P(3,29)+.66*P(3,30)+.34*P(4,22
6          C)+P(4,23)+P(4,24)+P(4,25)+P(4,26)+P(4,27)+P(4,28)+P(4,29)+.75*P(4,
6          C30)+.25*P(5,22)+P(5,23)+P(5,24)+P(5,25)+P(5,26)+P(5,27)+P(5,28)+
6          CP(5,29)+.8*P(5,30)+.15*P(6,22)+.5*(P(6,23)+P(6,24)+P(6,25)+P(6,26)
6          C+P(6,27)+P(6,28)+P(6,29))+.1*P(6,30)
7           A(4,5)=.67*P(11,30)+.5*P(10,30)+.34*P(9,30)+.25*P(8,30)+.2*P(7,30)
6          C+.1*P(6,30)
7           A(5,5)=.67*P(1,30)+.5*P(2,30)+.34*P(3,30)+.25*P(4,30)+.2*P(5,30)+
6          C.1*P(6,30)
7           RETURN
7           END
7           SUBROUTINE SECSI7(G,IN,JM)
7           COMMON/SEC/A(16,5)
7           DIMENSION G(IN,JM),P(11,30)
1   C
1   C       VX=22.0 M/SEC
1   C
7           DO 1 I=1,IN
7           DO 1 J=1,JM
5        1 P(J,I)=G(I,J)
7           A(4,2)=P(11,1)+.4*P(11,2)+P(10,1)+.75*P(10,2)+P(9,1)+P(9,2)+P(8,1)   2
6          C+P(8,2)+.2*P(8,3)+P(7,1)+P(7,2)+.25*P(7,3)+.5*P(6,1)+.5*P(6,2)+.2*
```

```
6         CP(6,3)
7          A(5,2)=P(1,1)+.4*P(1,2)+P(2,1)+.75*P(2,2)+P(3,1)+P(3,2)+P(4,1)+P(4
6         C,2)+.2*P(4,3)+P(5,1)+P(5,2)+.25*P(5,3)+.5*(P(6,1)+P(6,2))+.2*P(6,3
6         C)
7          A(4,3)=.6*P(11,2)+P(11,3)+P(11,4)+P(11,5)+P(11,6)+P(11,7)+P(11,8)+
6         CP(11,9)+P(11,10)*.9+.25*P(10,2)+P(10,3)+P(10,4)+P(10,5)+P(10,6)+
6         CP(10,7)+P(10,8)+P(10,9)+P(10,10)+.1*P(10,11)+P(9,3)+P(9,4)+P(9,5)+
6         CP(9,6)+P(9,7)+P(9,8)+P(9,9)+P(9,10)+.3*P(9,11)+.8*P(8,3)+P(8,4)+
6         CP(8,5)+P(8,6)+P(8,7)+P(8,8)+P(8,9)+P(8,10)+.5*P(8,11)+.75*P(7,3)+
6         CP(7,4)+P(7,5)+P(7,6)+P(7,7)+P(7,8)+P(7,9)+P(7,10)+.65*P(7,11)+.3*
6         CP(6,3)+.5*(P(6,4)+P(6,5)+P(6,6)+P(6,7)+P(6,9)+P(6,10))+.3*P(6,11)
7          A(5,3)=.6*P(1,2)+P(1,3)+P(1,4)+P(1,5)+P(1,6)+P(1,7)+P(1,8)+P(1,9)+
6         C.9*P(1,10)+.25*P(2,2)+P(2,3)+P(2,4)+P(2,5)+P(2,6)+P(2,7)+P(2,8)+
6         CP(2,9)+P(2,10)+.1*P(2,11)+P(3,3)+P(3,4)+P(3,5)+P(3,6)+P(3,7)+P(3,8
6         C)+P(3,9)+P(3,10)+.3*P(3,11)+.8*P(4,3)+P(4,4)+P(4,5)+P(4,6)+P(4,7)+
6         CP(4,8)+P(4,9)+P(4,10)+.5*P(4,11)+.75*P(5,3)+P(5,4)+P(5,5)+P(5,6)+
6         CP(5,7)+P(5,8)+P(5,9)+P(5,10)+.65*P(5,11)+.3*P(6,3)+.5*(P(6,4)+P(6,
6         C5)+P(6,6)+P(6,7)+P(6,8)+P(6,9)+P(6,10))+.3*P(6,11)
7          A(4,4)=.1*P(11,10)+P(11,11)+P(11,12)+P(11,13)+P(11,14)+P(11,15)+
6         CP(11,16)+P(11,17)+P(11,18)+.2*P(11,19)+.9*P(10,11)+P(10,12)+P(10,1
6         C3)+P(10,14)+P(10,15)+P(10,16)+P(10,17)+P(10,18)+.4*P(10,19)+.7*
6         CP(9,11)+P(9,12)+P(9,13)+P(9,14)+P(9,15)+P(9,16)+P(9,17)+P(9,18)+.6
6         C*P(9,19)+.5*P(8,11)+P(8,12)+P(8,13)+P(8,14)+P(8,15)+P(8,16)+P(8,17
6         C)+P(8,18)+.7*P(8,19)+.35*P(7,11)+P(7,12)+P(7,13)+P(7,14)+P(7,15)+
6         CP(7,16)+P(7,17)+P(7,18)+.8*P(7,19)+.2*P(6,11)+.5*(P(6,12)+P(6,13)+
6         CP(6,14)+P(6,15)+P(6,16)+P(6,17)+P(6,18))+.1*P(6,19)
7          A(5,4)=.1*P(1,10)+P(1,11)+P(1,12)+P(1,13)+P(1,14)+P(1,15)+P(1,16)+
6         CP(1,17)+P(1,18)+P(1,19)*.2+.9*P(2,11)+P(2,12)+P(2,13)+P(2,14)+P(2,
6         C15)+P(2,16)+P(2,17)+P(2,18)+.4*P(2,19)+.7*P(3,11)+P(3,12)+P(3,13)+
6         CP(3,14)+P(3,15)+P(3,16)+P(3,17)+P(3,18)+.6*P(3,19)+.5*P(4,11)+P(4,
6         C12)+P(4,13)+P(4,14)+P(4,15)+P(4,16)+P(4,17)+P(4,18)+.7*P(4,19)+.35
6         C*P(5,11)+P(5,12)+P(5,13)+P(5,14)+P(5,15)+P(5,16)+P(5,17)+P(5,18)+
6         C.8*P(5,19)+.2*P(6,11)+.5*(P(6,12)+P(6,13)+P(6,14)+P(6,15)+P(6,16)+
6         CP(6,17)+P(6,18))+.1*P(6,19)
7          A(4,5)=.8*P(11,19)+P(11,20)+P(11,21)+P(11,22)+P(11,23)+P(11,24)+
6         CP(11,25)+P(11,26)+.8*P(11,27)+.8*P(10,19)+P(10,20)+P(10,21)+P(10,2
6         C2)+P(10,23)+P(10,24)+P(10,25)+P(10,26)+.85*P(10,27)+.4*P(9,19)+
6         CP(9,20)+P(9,21)+P(9,22)+P(9,23)+P(9,24)+P(9,25)+P(9,26)+.9*P(9,27)
6         C+.3*P(8,19)+P(8,20)+P(8,21)+P(8,22)+P(8,23)+P(8,24)+P(8,25)+P(8,26
6         C)+.95*P(8,27)+.2*P(7,19)+P(7,20)+P(7,21)+P(7,22)+P(7,23)+P(7,24)+
6         CP(7,25)+P(7,26)+.95*P(7,27)+.4*P(6,19)+.5*(P(6,20)+P(6,21)+P(6,22)
6         C+P(6,23)+P(6,24)+P(6,25)+P(6,26)+P(6,27))
7          A(5,5)=.8*P(1,19)+P(1,20)+P(1,21)+P(1,22)+P(1,23)+P(1,24)+P(1,25)+
6         CP(1,26)+.8*P(1,27)+.6*P(2,19)+P(2,20)+P(2,21)+P(2,22)+P(2,23)+P(2,
6         C24)+P(2,25)+P(2,26)+.85*P(2,27)+.4*P(3,19)+P(3,20)+P(3,21)+P(3,22)
6         C+P(3,23)+P(3,24)+P(3,25)+P(3,26)+.9*P(3,27)+.3*P(4,19)+P(4,20)+
6         CP(4,21)+P(4,22)+P(4,23)+P(4,24)+P(4,25)+P(4,26)+.95*P(4,27)+.2*
6         CP(5,19)+P(5,20)+P(5,21)+P(5,22)+P(5,23)+P(5,24)+P(5,25)+P(5,26)+
6         C.95*P(5,27)+.4*P(6,19)+.5*(P(6,20)+P(6,21)+P(6,22)+P(6,23)+P(6,24)
6         C+P(6,25)+P(6,26)+P(6,27))
7          RETURN
7          END
7          SUBROUTINE SECS18(P,IN,JM)
7          COMMON/SEC/A(16,5)
7          DIMENSION P(IN,JM)
7          A(4,3)=P(1,11)+P(2,11)+P(3,11)+P(4,11)+P(5,11)+.3*P(6,11)+P(1,10)+
6         *P(2,10)+P(3,10)+P(4,10)+P(5,10)+.5*P(6,10)+P(1,9)+P(2,9)+P(3,9)+
6         *P(4,9)+P(5,9)+.8*P(6,9)+P(1,8)+P(2,8)+P(3,8)+P(4,8)+P(5,8)+
6         *.9*P(6,8)+P(1,7)+P(2,7)+P(3,7)+P(4,7)+P(5,7)+P(6,7)+.1*P(7,7)+
6         *.5*P(1,6)+.5*P(2,6)+.5*P(3,6)+.5*P(4,6)+.5*P(5,6)+.5*P(6,6)+
6         *.1*P(7,6)
7          A(5,3)=.5*P(1,6)+.5*P(2,6)+.5*P(3,6)+.5*P(4,6)+.5*P(5,6)+.5*P(6,6)
6         *+.1*P(7,6)+P(1,5)+P(2,5)+P(3,5)+P(4,5)+P(5,5)+P(6,5)+.1*P(7,5)+
6         *P(1,4)+P(2,4)+P(3,4)+P(4,4)+P(5,4)+.9*P(6,4)+P(1,3)+P(2,3)+P(3,3)+
6         *P(4,3)+P(5,3)+.8*P(6,3)+P(1,2)+P(2,2)+P(3,2)+P(4,2)+P(5,2)+
6         *.5*P(6,2)+P(1,1)+P(2,1)+P(3,1)+P(4,1)+P(5,1)+.3*P(6,1)
7          A(4,4)=.7*P(6,11)+P(7,11)+P(8,11)+P(9,11)+P(10,11)+P(11,11)+
6         *P(12,11)+P(13,11)+.7*P(14,11)+.5*P(6,10)+P(7,10)+P(8,10)+P(9,10)+
6         *P(10,10)+P(11,10)+P(12,10)+P(13,10)+.8*P(14,10)+.2*P(6,9)+P(7,9)+
6         *P(8,9)+P(9,9)+P(10,9)+P(11,9)+P(12,9)+P(13,9)+P(14,9)+.1*P(6,8)+
6         *P(7,8)+P(8,8)+P(9,8)+P(10,8)+P(11,8)+P(12,8)+P(13,8)+P(14,8)+
6         *.1*P(15,8)+.9*P(7,7)+P(8,7)+P(9,7)+P(10,7)+P(11,7)+P(12,7)+P(13,7)
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6        *+P(14,7)+.1*P(15,7)+.4*P(7,6)+.5*P(8,6)+.5*P(9,6)+.5*P(10,6)+
6        *.5*P(11,6)+.5*P(12,6)+.5*P(13,6)+.5*P(14,6)+.1*P(15,6)
7         A(5,4)=.4*P(7,6)+.5*P(8,6)+.5*P(9,6)+.5*P(10,6)+.5*P(11,6)+
6        *.5*P(12,6)+.5*P(13,6)+.5*P(14,6)+.1*P(15,6)+.9*P(7,5)+P(8,5)+
6        *P(10,5)+P(11,5)+P(12,5)+P(13,5)+P(14,5)+.1*P(15,5)+P(13,1)+
6        *.9*P(7,4)+P(8,4)+P(9,4)+P(10,4)+P(11,4)+P(12,4)+P(13,4)+P(14,4)+
6        *.1*P(15,4)+.2*P(6,3)+P(7,3)+P(8,3)+P(9,3)+P(10,3)+P(11,3)+P(12,3)+
6        *P(13,3)+P(14,3)+.5*P(6,2)+P(7,2)+P(8,2)+P(9,2)+P(10,2)+P(11,2)+
6        *P(12,2)+P(13,2)+.8*P(14,2)+.3*P(6,1)+P(7,1)+P(8,1)+P(9,1)+P(10,1)+
6        *P(11,1)+P(12,1)+P(13,1)+.7*P(14,1)+P(9,5)
7         A(4,5)=.3*P(14,11)+P(15,11)+P(16,11)+P(17,11)+P(18,11)+P(19,11)+
6        *P(20,11)+P(21,11)+P(22,11)+.2*P(23,11)+.2*P(14,10)+P(15,10)+
6        *P(16,10)+P(17,10)+P(18,10)+P(19,10)+P(20,10)+P(21,10)+P(22,10)+
6        *.3*P(23,10)+P(15,9)+P(16,9)+P(17,9)+P(18,9)+P(19,9)+P(20,9)+
6        *P(21,9)+P(22,9)+.3*P(23,9)+.9*P(15,8)+P(16,8)+P(17,8)+P(18,8)+
6        *P(19,8)+P(20,8)+P(21,8)+P(22,8)+.3*P(23,8)+.8*P(15,7)+P(16,7)+
6        *P(17,7)+P(18,7)+P(19,7)+P(20,7)+P(21,7)+P(22,7)+.4*P(23,7)+
6        *.4*P(15,6)+.5*P(16,6)+.5*P(17,6)+.5*P(18,6)+.5*P(19,6)+.5*P(20,6)+
6        *.5*P(21,6)+.5*P(22,6)+.2*P(23,6)
7         A(5,5)=.4*P(15,6)+.5*P(16,6)+.5*P(17,6)+.5*P(18,6)+.5*P(19,6)+
6        *.5*P(20,6)+.5*P(21,6)+.5*P(22,6)+.2*P(23,6)+.8*P(15,5)+P(16,5)+
6        *P(17,5)+P(18,5)+P(19,5)+P(20,5)+P(21,5)+P(22,5)+.4*P(23,5)+
6        *.9*P(15,4)+P(16,4)+P(17,4)+P(18,4)+P(19,4)+P(20,4)+P(21,4)+P(22,4)
6        *+.3*P(23,4)+P(15,3)+P(16,3)+P(17,3)+P(18,3)+P(19,3)+P(20,3)+
6        *P(21,3)+P(22,3)+.3*P(23,3)+.2*P(14,2)+P(15,2)+P(16,2)+P(17,2)+
6        *P(18,2)+P(19,2)+P(20,2)+P(21,2)+P(22,2)+.3*P(23,2)+.3*P(14,1)+
6        *P(15,1)+P(16,1)+P(17,1)+P(18,1)+P(19,1)+P(20,1)+P(21,1)+P(22,1)+
6        *.2*P(23,1)
7         RETURN
7         END
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7          SUBROUTINE SECTCR(P,IN,JM)
1   C      CALCULATION OF SECTOR-AVERAGE GM-SEC/M**3 AND GM/M**2
1   C
7          DIMENSION  A(16,13),P(IN,JM)
7          G=1./16.
7          CALL CLEAR( A,208)
1   C
1   C      FIRST 22.5
1   C
7          A(1,1)=(.8*P(1,6   )+P(1,7   ))*G
7          A(1,2)=(5.2*P(1,7   )+P(1,8   ))*G
7          A(1,3)=7.2*P(1,8   )*G
7          A(1,4)=(11.7*P(1,9   )+2.8*P(1,8   )+P(2,9   ))*G
7          A(1,5)=(12.3*P(1,10   )+4.2*P(2,10   )+4.4*P(1,9   )+2.2*P(2,9   ))*G
7          A(1,6)=(4.3*P(1,10   )+8.2*P(1,11   )+3.0*P(2,11   )+5.2*P(2,10 ))*G
7          A(1,7)=(8.2*P(1,11   )+11.3*P(2,11   )+.4*P(3,11   ))*G
1   C
1   C      SECOND 22.5
1   C
7          A(2,1)=(P(1,6   )+.6*P(1,7   ))*G
7          A(2,2)=(6.1*P(1,7   )+.3*P(2,7   ))*G
7          A(2,3)=(.2*P(1,7   )+2.7*P(1,8   )+5.1*P(2,8   )+1.7*P(2,7   ))*G
7          A(2,4)=(9.1*P(2,8   )+4.3*P(2,9   )+1.8*P(3,8   ))*G
7          A(2,5)=(7.2*P(2,9   )+2.4*P(2,10   )+10.8*P(3,9   )+.4*P(3,8   ))*G
7          A(2,6)=(11.9*P(3,10   )+3.4*P(2,10   )+3.5*P(3,9   )+2.*P(4,9   )+
6         $1.7*P(4,10   ))*G
7          A(2,7)=(11.1*P(3,11 )+3.4*P(3,10 )+8.9*P(4,10 )+2.7*P(4,11 ))*G
7          A(2,8)=(12.8*P(4,11   )+3.2*P(3,11   )+5.9*P(5,11   )+1.2*P(5,10   )
6         $+.6*P(4,10   ))*G
7          A(2,9)=(6.9*P(5,11   )+.7*P(6,11   ))*G
7          A(2,10)=.3*P(6,11   )*G
1   C
1   C      SIXTH 22.5
1   C
7          A(6,1)=(1.9*P(1,6   )+.1*P(1,5   ))*G
7          A(6,2)=(2.*P(1,5   )+.5*P(1,6   )+3.3*P(2,5   ))*G
7          A(6,4)=(1.2*P(2,4   )+8.*P(3,4   )+5.8*P(3,5   ))*G
7          A(6,3)=(6.4*P(2,5   )+.5*P(2,4   )+.6*P(3,5   ))*G
7          A(6,5)=(5.5*P(3,4 )+2.*P(3,3 )+P(4,3 )+9.7*P(4,4 )+.9*P(4,5 ))*G
7          A(6,6)=(9.8*P(4,3   )+5.2*P(4,4   )+3.9*P(5,4   )+.5*P(5,3   ))*G
7          A(6,7)=(2.6*P(4,3   )+2.4*P(4,2   )+13.8*P(5,3   )+3.8*P(5,2   )+4.3*
6         $P(5,4   )+1.2*P(6,4   )+.8*P(6,3   ))*G
7          A(6,8)=(10.5*P(5,2   )+1.1*P(5,1   )+5.2*P(6,2   )+1.3*P(5,3   )+13.1*
6         $P(6,3   )+1.1*P(6,4   )+.2*P(7,3   ))*G
7          A(6,9)=(1.5*P(5,1   )+8.2*P(6,1   )+10.2*P(6,2   )+1.8*P(6,3   )+9.*
6         $P(7,3   )+4.9*P(7,2   ))*G
7          A(6,10)=(5.7*P(6,1   )+9.7*P(7,1   )+10.5*P(7,2   )+2.5*P(7,3   )+3.6*
6         $P(8,2   )+3.*P(8,3   ))*G
7          A(6,11)=(6.2*P(7,1   )+12.2*P(8,2   )+13.6*P(9,2   )+6.1*P(10,2   )+
6         $.8*P(11,2   )+14.6*P(11,1   )+8.1*P(12,1   )+2.*P(13,1   )+.3*P(9,3   )
6         $)*G+P(8,1   )+P(9,1   )+P(10,1   )
1   C
1   C      FOURTH 22.5
1   C
7          A(4,1)=2.*P(1,6   )*G
7          A(4,2)=(1.6*P(1,6   )+4.7*P(2,6   )+.2*P(2,7   ))*G
7          A(4,3)=(3.3*P(2,6   )+1.8*P(2,7   )+1.9*P(3,7   )+3.1*P(3,6   ))*G
7          A(4,4)=(4.9*P(3,6   )+6.9*P(3,7   )+2.4*P(4,7   )+2.2*P(4,6   ))*G
7          A(4,5)=(5.8*P(4,6   )+1.7*P(5,6   )+12.6*P(4,7   )+.2*P(4,8   )+.6*
6         $P(5,7   ))*G
7          A(4,6)=(.2*P(4,7   )+.6*P(4,8   )+6.*P(5,6   )+13.4*P(5,7   )+3.2*
6         $P(5,8   ))*G
7          A(4,7)=(.3*P(5,6   )+2.6*P(5,7   )+3.3*P(5,8   )+5.4*P(6,8   )+11.2*
6         $P(6,7   )+6.2*P(6,6   ))*G
7          A(4,8)=(4.8*P(6,7   )+1.8*P(6,6   )+7.8*P(6,8   )+5.4*P(7,8   )+.2*
6         $P(7,9   )+8.5*P(7,7   )+5.*P(7,6   ))*G
7          A(4,9)=(3.*P(7,6   )+7.5*P(7,7   )+10.6*P(7,8   )+3.2*P(7,9   )+2.7*
6         $P(8,8   )+5.6*P(8,7   )+3.6*P(8,6   ))*G
7          A(4,10)=(4.4*P(8,6   )+10.4*P(8,7   )+13.*P(8,8   )+7.2*P(8,9   )+.5*
6         $P(7,9   )+.4*P(9,9   )+2.9*P(9,7   )+2.*P(9,6   ))*G
7          A(4,11)=(.3*P(8,8   )+3.8*P(8,9   )+15.7*P(9,9   )+2.4*P(9,10   )+9.9*
```

```
6        $P(10,10  )+15.2*P(11,10  )+1.4*P(11,11  )+7.9*P(12,11  )+14.*P(13,
6        $11  )+15.6*P(9,8  )+13.2*P(9,7  )+6.*P(9,6  )+4.6*P(16,11  )+9.*
6        $P(16,10  )+12.4*P(16,9  )+15.*P(16,8  )+.3*P(17,6  )+.2*P(17,7  )
6        $+8.*P(10,6  )+8.*P(11,6  )+8.*P(12,6  )+8.*P(13,6  )+8.*P(14,6  )
6        $+8.*P(15,6  )+8.*P(16,6  ))*G+P(14,11  )+P(15,11  )+P(12,10  )+
6        $P(13,10  )+P(14,10  )+P(15,10  )+P(10,9  )+P(11,9  )+P(12,9  )+
6        $P(13,9  )+P(14,9  )+P(15,9  )+P(10,8  )+P(11,8  )+P(12,8  )+P(13,
6        $8  )+P(14,8  )+P(15,8  )+P(10,7  )+P(11,7  )+P(12,7  )+P(13,7  )
6        $+P(14,7  )+P(15,7  )+P(16,7  )
7         A(4,12)=(2.*P(25,8  )+3.*P(25,7  )+1.8*P(25,6  )+11.4*P(16,11  )+
6        $7.*P(16,10  )+3.6*P(16,9  )+P(16,8  )+7.7*P(17,6  )+15.8*P(17,7  )
6        $+11.2*P(24,11  )+14.*P(24,10  )+15.7*P(24,9  )+.1*P(25,9  ))*G
7         SUM=0.0
7         DO 1 I=17,23
7         DO 1 J=9,11
5       1 SUM=SUM+P(I,J  )
7         DO 2 I=18,24
5       2 SUM =SUM +P(I,8  )+P(I,7  )+.5*P(I,6  )
7         A(4,12)=A(4,12)+SUM+P(17,8)
7         A(4,13)=(4.8*P(24,11  )+2.*P(24,10  )+.3*P(24,9  )+15.9*P(25,9)
6        $+14.*P(25,8  )+13.*P(25,7  )+6.2*P(25,6  ))*G
7         SUM=0.0
7         DO 3 I=26,IN
5       3 SUM=SUM+.5*P(I,6  )
7         DO 4 I=26,IN
7         DO 4 J=7,JM
5       4 SUM=SUM+P(I,J  )
7         SUM=SUM+P(25,10  )+P(25,11  )
7         A(4,13)=A(4,13)+SUM
1   C
1   C     EIGHTH 22.5
1   C
7         A(8,1)=(.8*P(1,6  )+P(1,5  ))*G
7         A(8,2)=(5.2*P(1,5  )+P(1,4  ))*G
7         A(8,3)=7.2*P(1,4  )*G
7         A(8,4)=(11.7*P(1,3  )+2.8*P(1,4  )+P(2,3  ))*G
7         A(8,5)=(12.3*P(1,2  )+4.2*P(2,2  )+4.4*P(1,3  )+2.2*P(2,3  ))*G
7         A(8,6)=( 4.3*P(1,2  )+8.2*P(1,1  )+3.0*P(2,1  )+5.2*P(2,2  ))*
6        $G
7         A(8,7)=(8.2*P(1,1   )+11.3*P(2,1   )+.4*P(3,1   ))*G
1   C
1   C     SEVENTH 22.5
1   C
7         A(7,1)=(P(1,6  )+.6*P(1,5  ))*G
7         A(7,2)=(6.1*P(1,5  )+.3*P(2,5  ))*G
7         A(7,3)=(.2*P(1,5  )+2.7*P(1,4  )+5.1*P(2,4  )+1.7*P(2,5  ))*G
7         A(7,4)=(9.1*P(2,4  )+4.3*P(2,3  )+1.8*P(3,4  ))*G
7         A(7,5)=(7.2*P(2,3)+2.4*P(2,2)+10.8*P(3,3)+.4*P(3,4))*G
7         A(7,6)=(11.9*P(3,2)+3.4*P(2,2)+3.5*P(3,3)+2.*P(4,3)+
6        $1.7*P(4,2))*G
7         A(7,7)=(11.1*P(3,1)+3.4*P(3,2)+8.9*P(4,2)+2.7*P(4,1))*G
7         A(7,8)=(12.8*P(4,1)+3.2*P(3,1)+5.9*P(5,1)+1.2*P(5,2)+.6*P(4,2))*G
7         A(7,9)=(6.9*P(5,1)+.7*P(6,1))*G
7         A(7,10)=.3*P(6,1)*G
1   C
1   C     THIRD 22.5
1   C
7         A(3,1)=(1.9*P(1,6  )+.1*P(1,7  ))*G
7         A(3,2)=(2.*P(1,7  )+.5*P(1,6  )+3.3*P(2,7  ))*G
7         A(3,4)=(1.2*P(2,8  )+8.*P(3,8  )+5.8*P(3,7  ))*G
7         A(3,3)=(6.4*P(2,7  )+.5*P(2,8  )+.6*P(3,7  ))*G
7         A(3,5)=(5.5*P(3,8 )+2.*P(3,9 )+P(4,9 )+9.7*P(4,8 )+.9*P(4,7 ))*G
7         A(3,6)=(9.8*P(4,9  )+5.2*P(4,8  )+3.9*P(5,8  )+.5*P(5,9  ))*G
7         A(3,7)=(2.6*P(4,9  )+2.4*P(4,10  )+13.8*P(5,9  )+3.8*P(5,10  )+4.
6        $3*P(5,8  )+1.2*P(6,8  )+.8*P(6,9  ))*G
7         A(3,8)=(10.5*P(5,10  )+1.1*P(5,11  )+5.2*P(6,10  )+1.3*P(5,9  )+13
6        $.1*P(6,9  )+1.1*P(6,8  )+.2*P(7,9  ))*G
7         A(3,9)=(1.5*P(5,11  )+8.2*P(6,11  )+10.2*P(6,10  )+1.8*P(6,9  )+
6        $9.*P(7,9  )+4.9*P(7,10  ))*G
7         A(3,10)=(5.7*P(6,11  )+9.7*P(7,11  )+10.5*P(7,10  )+2.5*P(7,9  )+3
6        $.6*P(8,10  )+3.*P(8,9  ))*G
7         A(3,11)=(6.2*P(7,11  )+12.2*P(8,10  )+13.6*P(9,10  )+6.1*P(10,10
6        $)+ .8*P(11,10  )+14.6*P(11,11  )+8.1*P(12,11  )+2.*P(13,11  )+.3*
```

```
6        $P(9,9  ))*G+P(8,11  )+P(9,11  )+P(10,11  )
1  C
1  C      FIFTH 22.5
1  C
7         A(5,1)=2.*P(1,6  )*G
7         A(5,2)=(1.6*P(1,6  )+4.7*P(2,6  )+.2*P(2,5  ))*G
7         A(5,3)=(3.3*P(2,6  )+1.8*P(2,5  )+1.9*P(3,5  )+3.1*P(3,6  ))*G
7         A(5,4)=(4.9*P(3,6  )+6.9*P(3,5  )+2.4*P(4,5  )+2.2*P(4,6  ))*G
7         A(5,5)=(5.8*P(4,6  )+1.7*P(5,6  )+12.6*P(4,5  )+.2*P(4,4  )+.6*
6        $P(5,5  ))*G
7         A(5,6)=(.2*P(4,5  )+.6*P(4,4  )+6.*P(5,6  )+13.4*P(5,5  )+3.2*
6        $P(5,4  ))*G
7         A(5,7)=(.3*P(5,6  )+2.6*P(5,5  )+3.3*P(5,4  )+5.4*P(6,4  )+11.2*
6        $P(6,5  )+6.2*P(6,6  ))*G
7         A(5,8)=(4.8*P(6,5  )+1.8*P(6,6  )+7.8*P(6,4  )+5.4*P(7,4  )+.2*
6        $P(7,3  )+8.5*P(7,5  )+5.*P(7,6  ))*G
7         A(5,9)=(3.*P(7,6  )+7.5*P(7,5  )+10.6*P(7,4  )+3.2*P(7,3  )+2.7*
6        $P(8,4  )+5.6*P(8,5  )+3.6*P(8,6  ))*G
7         A(5,10)=(4.4*P(8,6  )+10.4*P(8,5  )+13.*P(8,4  )+7.2*P(8,3  )+.5*
6        $P(7,3  )+.4*P(9,4  )+2.8*P(9,5  )+2.*P(9,6  ))*G
7         A(5,11)=(.3*P(8,4  )+3.8*P(8,3  )+15.7*P(9,3  )+2.4*P(9,2  )+9.9*
6        $P(10,2  )+15.2*P(11,2  )+1.4*P(11,1  )+7.9*P(12,1  )+14.*P(13,1)
6        $+15.6*P(9,4  )+13.2*P(9,5  )+6.*P(9,6  )+4.6*P(16,1  )+9.*
6        $P(16,2  )+12.4*P(16,3  )+15.*P(16,4  )+.3*P(17,6  )+.2*P(17,5  )
6        $+8.*P(10,6  )+8.*P(11,6  )+8.*P(12,6  )+8.*P(13,6  )+8.*P(14,6  )
6        $+8.*P(15,6  )+8.*P(16,6  ))*G+P(14,1  )+P(15,1  )+P(12,2  )+
6        $P(13,2  )+P(14,2  )+P(15,2  )+P(10,3  )+P(11,3  )+P(12,3  )+
6        $P(13,3  )+P(14,3  )+P(15,3  )+P(10,4  )+P(11,4  )+P(12,4  )+P(13,
6        $4  )+P(14,4  )+P(15,4  )+P(10,5  )+P(11,5  )+P(12,5  )+P(13,5  )
6        $+P(14,5  )+P(15,5  )+P(16,5  )
7         A(5,12)=(2.*P(25,4  )+3.*P(25,5  )+1.8*P(25,6  )+11.4*P(16,1  )+
6        $7.*P(16,2  )+3.6*P(16,3  )+P(16,4  )+7.7*P(17,6  )+15.8*P(17,5  )
6        $+11.2*P(24,1  )+14.*P(24,2  )+15.7*P(24,3  )+.1*P(25,3  ))*G
7         SUM=0.0
7         DO 5 I=17,23
7         DO 5 J=1,3
5       5 SUM=SUM+P(I,J  )
7         DO 6 I=18,24
5       6 SUM =SUM +P(I,4  )+P(I,5  )+.5*P(I,6  )
7         A(5,12)=A(5,12)+SUM+P(17,4)
7         A(5,13)=(4.8*P(24,1  )+2.*P(24,2  )+.3*P(24,3  )+15.9*P(25,3)
6        $+14.*P(25,4  )+13.*P(25,5  )+6.2*P(25,6  ))*G
7         SUM=0.0
7         DO 7 I=26,IN
5       7 SUM=SUM+.5*P(I,6  )
7         DO 8 I=26,IN
7         DO 8 J=1,5
5       8 SUM=SUM+P(I,J  )
7         SUM=SUM+P(25,2  )+P(25,1  )
7         A(5,13)=A(5,13)+SUM
1  C
1  C      PRINT SECTOR AVERAGES
1  C
7         PRINT 100,(I,I=1,16)
7         DO 9 J=1,13
5       9 WRITE(6,101)(A(I,J),I=1,16)
3     100 FORMAT(1X,16(I6,2X))
3     101 FORMAT(2X,16(1PE8.1))
1  C      DO 10 J=1,13
1  C   10 WRITE(7,102)(A(I,J),I=1,8)
1  C      DO 11 J=1,13
1  C   11 WRITE(7,102)(A(I,J),I=9,16)
3     102 FORMAT(8(1PE10.3))
7         RETURN
7         END
```

```
7        SUBROUTINE ISOPTH(C,IN,JM,WK,DELTX,FMT)
1   C    THIS IS THE MAIN PROGRAM FOR USING THE NCAA CONTOUR PROGRAM
1   C    (CONSIDERABLY SIMPLIFIES PLOT SETUP).
1   C    INPUT PARAMETERS FOR ISOPTH WHICH IS THE NORMAL CALL FOR CONTOURING
1   C ANY FIELD THAT IS SPACED EVENLY IN THE X AND Y DIRECTIONS BUT DX NOT
1   C NECESARILY EQUAL TO DY. THE COORD. (1,1) IS LOCATED IN
1   C THE LOWER LEFT HAND CORNER OF THE PLOT.
1   C
1   C     PARAMETERS ARE:
1   C
1   C DELTX    CONTOUR INTERVAL. IF SET = TO 0.0 THEN CONTOUR INTERVAL
1   C          IS TAKEN AS MAX VALUE OF THE ARRAY,C WHOSE DIMENTIONS ARE
1   C          IN BY JM, MINUS THE MINIMUM VALUE OF THE ARRAY DIVIDED BY
1   C          8, THUS WILL BE ASSURED OF GETTING 7 CONTOURS
1   C
1   C C        THIS IS THE ARRAY TO BE CONTOURED. WHOSE DIMENTIONS ARE:
1   C IN BY JM  THE ARRAY DIMENTIONS
1   C
1   C FMT      CONTOUR LABEL WHICH DEFINES THE FORMAT AS FOLLOWS:
1   C          FMT> 0.0 IMPLIES USE OF F FIELD/ FMT=7.2 MEANS F7.2
1   C          FMT<1.0 IMPLIES USE OF E FIELD. A VALUE OF -10.3 MEANS E10.3
1   C          0.< OR = FMT< OR = 1.0 IMPLIES INTEGER FORMAT.
1   C
1   C WK       IS A WORKSPACE ARRAY DIMENTIONED (AT LEAST IN BY JM) USED BY
1   C          THE CONTOURING PROGRAM SO THAT THE ORIGINAL VALUES OF C ARE
1   C          MAINTAINED.
1   C
1   C        IF THE FIELD C HAS VERY LARGE GRADIENTS (SAY SEVERAL ORDERS OF
1   C        MAGNITUDE) THEN MAY ONLY WANT TO CONTOUR EVEN POWERS OF TEN
1   C        THIS SITUATION IS ACCOMPLISED BY CALLING ISOLOG WHOSE CALL IS
1   C
1   C        CALL ISOLOG(C,IN,JM,WK1,WK2)
1   C
1   C        THE ARRAYS ARE THE SAME, EXCEPT NEED TWO WORKSPACES, WK1 AND
1   C        WK2 BOTH OF WHOSE DIMENTIONS ARE IN BY JM. FMT IS AUTOMATICALLY
1   C        SET TO 0.5, WHICH MEANS AN INTEGER CONTOUR LABEL.
1   C
1   C        IF NEED TO CHANGE GRID ARRAY (THAT IS THE DIMENTIONS OF C AND
1   C        THE WORK SPACE(S)) THEN MUST CALL RECON (NO ARGUMENTS) THUS:
1   C
1   C      CALL RECON
1   C
7        DELTA=DELTX
7        DIMENSION WK(IN,JM), C(IN,JM)
7        VMAX = 1.E-10
7        VMN  = 1.E+10
7        DO 6 I = 1,IN
7        DO 6 J = 1,JM
7        IF(VMAX .LT. C(I,J) ) VMAX = C(I,J)
7        IF(VMN  .GT. C(I,J) ) VMN  = C(I,J)
2     6  CONTINUE
7        XIN=IN
7        YJM=JM
7        XPHYS=0.75
7        YPHYS=0.75
7        CALL AXESS(XIN,YJM,ITITLE,XAXIS,YAXIS)                          **
7        IF(DELTA.LE.0.0) DELTA=WLDCRD(C,IN,JM)
7        XSTEP=FLOAT(IN-1)                                               **
7        YSTEP=FLOAT(JM-1)                                               **
7        ITT=ITITLE                                                      **
7        XXS=XAXIS                                                       *
7        YXS=YAXIS                                                       *
7        CALL PHYSOR(XPHYS,YPHYS)
7        CALL TITLE(' ',ITT   ,0,0,0,0,XXS   ,YXS   )
7        CALL GRAPH(0.,XSTEP,0.,YSTEP)
7        CALL FRAME
7        CALL HEIGHT(0.10)
7        ALENG=XMESS('MIN ',4)
7        CALL MESSAG(  'MIN ',4,0.,-.45)
7        CALL REALNO(  VMN,105,ALENG,-0.45)
7        X1=4.00                                                         *
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```
7          ALENG=XMESS('XXXX',4)
7          CALL MESSAG('Z',1,X1+ALENG,-0.45)
7          ALENG=XMESS('MAX ',4)
7          CALL MESSAG(  'MAX ',4,6.0,-0.45)
7          CALL REALNO(  VMAX,105,6.0+ALENG,-0.45)
7          CALL DASH
1    C     CALL CONLAB(0.10,FMT ,0.,0.,0.,C.,1.C)
7          CALL CONTUR(C,IN,JM,WK,IN, JM,DELTA)
7          CALL RESET('DASH')
7          CALL ENDPL(0)
7          RETURN
8           END
7          FUNCTION WLDCRD(ARRAY,L,M)
7          DIMENSION ARRAY(L,M)
7          ARMAX=-1.E+50
7          ARMIN=+1.E+50
7          DO  1 I = 1,L
7          DO  1 J = 1,M
7          IF(ARMAX.LT.ARRAY(I,J)) ARMAX=ARRAY(I,J)
7          IF(ARMIN.GT.ARRAY(I,J)) ARMIN=ARRAY(I,J)
2     1    CONTINUE
7          IF(ARMAX.EQ.ARMIN) GOTO 2
7          WLDCRD=(ARMAX-ARMIN)/10.
7          RETURN
2     2    CONTINUE
7          WLDCRD=1.
7          RETURN
7          END
7          FUNCTION ISOLOG(C,II,JJ,WK1,WK2)
1    C     PROGRAM TO TO PLOT LOG CONTOURS OF DATA PASSED IN C(II,JJ)
1    C     IF THERE ARE ZERO VALUES OR NEG VALUES IN C THEY WILL BE SET
1    C     TO THE MIN VALUE GREATER THAN ZERO IN DUMY, DUMY WILL BE CONTURED
1    C     WITH CONTOUR INTERVAL OF 1.0 (THUS POWERS OF TEN)
7          DIMENSION C(II,JJ), WK1(II,JJ),WK2(II,JJ)
7          CMIN=1.E+50
7          DO 3 I=1,II
7          DO 3 J=1,JJ
7          IF(C(I,J)  .LE.C.0) GOTO 3
7          IF(C(I,J)  .LT.CMIN) CMIN=C(I,J)
1     3    CONTINUE
7          IF(CMIN.LE.0.0) CMIN=1.0
7          CMIN=ALOG10(CMIN)
7          DO 2 I = 1,II
7          DO 2 J = 1,JJ
7          WK1(I,J) =  CMIN
7          IF(C(I,J)  .LE.C.C) GOTO 2
7          WK1(I,J) =ALOG10(C(I,J))
1     2    CONTINUE
7          CALL ISOPTH(WK1,II,JJ,WK2,1.C,C.5)
7          RETURN
7          END
7          SUBROUTINE AXESS(XIN,YJM,ITITLE,XAXIS,YAXIS)                 **
7          XAXIS=7.0
7          YAXIS=7.0
7          ITITLE=1
7          RAT=YJM/XIN
7          IF(RAT-1.) 1,2,3
1     1    CONTINUE
1    C     RAT < 1.0 OR XAXIS > YAXIS
7          ITITLE=-1
7          XAXIS=9.5
2     6    CONTINUE
7          YAXIS=RAT*XAXIS
7          IF(YAXIS-7.0) 2,2,4
1     4    CONTINUE
1    C     RAT TOO BIG FOR XAXIS TO = 7.0
7          XAXIS=XAXIS-0.5
7          GOTO 6
2     2    IF(XAXIS.LT.0.5) XAXIS=0.5
7          IF(YAXIS.LT.0.5) YAXIS=0.5
7          RETURN
2     3    CONTINUE
7          YAXIS=RAT*XAXIS
7          IF(YAXIS-9.5) 2,2,5
1     5    CONTINUE
7          XAXIS=XAXIS-0.5
7          GOTO 3
7          END
```