

NASA CONTRACTOR
REPORT

NASA CR-61326

HANDBOOK FOR ESTIMATING TOXIC
FUEL HAZARDS

By R. K. Dumbauld, J. R. Bjorklund,
H. E. Cramer, and F. A. Record

GCA Corporation
GCA Technology Division
Bedford, Massachusetts

April 1970

Final Report

Prepared for

NASA-GEORGE C. MARSHALL SPACE FLIGHT CENTER
Marshall Space Flight Center, Alabama 35812

FACILITY FORM 602	N70-30506	
	(ACCESSION NUMBER)	(THRU)
	347	1
	(PAGES)	(CODE)
	CR-61326	20
	(NASA CR OR TMX OR AD NUMBER)	(CATEGORY)

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

1. Report No. CR-61326	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle HANDBOOK FOR ESTIMATING TOXIC FUEL HAZARDS		5. Report Date April 1970	
		6. Performing Organization Code	
7. Author(s) R. K. Dumbauld, J. R. Bjorklund, H. E. Cramer and F. A. Record		8. Performing Organization Report No.	
9. Performing Organization Name and Address GCA Corporation GCA Technology Division Bedford, Massachusetts		10. Work Unit No.	
		11. Contract or Grant No. NAS8-21453	
12. Sponsoring Agency Name and Address Aero-Astroynamics Laboratory George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		13. Type of Report and Period Covered Contractor, Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract The objective of the work under this contract was to prepare a Toxic Fuel Hazard Estimation Handbook that can be conveniently used, with readily-obtainable meteorological data, to predict concentration and dosage fields downwind from primary ground-level and elevated source emissions arising from operations at Cape Kennedy. The Handbook consists principally of (1) computer programs and instructions for the machine calculation of downwind concentration, dosage, and deposition fields, and (2) graphs, nomograms, and tables for the rapid manual estimation of ground-level concentration and dosage fields for selected sources and simplified atmospheric conditions. The Handbook also includes a description of the mathematical diffusion models used, procedures for obtaining requisite meteorological inputs for the diffusion models, and worked examples for selected release modes and meteorological regimes. Much of the development of the diffusion models for use in the Handbook and the formulation of procedures for the selection of meteorological model inputs were carried out concurrently under Contract NAS8-30503. Mr. Charles K. Hill of the Atmospheric Dynamics Branch of the Aero-Astroynamics Laboratory at Marshall Space Flight Center was the Contracting Officer's Representative. Mr. John W. Kaufman, Chief of the Atmospheric Dynamics Branch and Contracting Officer's Representative for Contract NAS8-30503, also assisted in planning the Handbook. Mr. William W. Vaughan, Chief of the Aerospace Environment Division, provided guidance throughout the entire program. The following professional staff members of the GCA Technology Division Environmental Sciences Laboratory made important contributions to this report: Dr. J. E. Faulkner, Mr. R. H. Huerta, Mr. R. C. Martin and Mr. R. N. Swanson.			
17. Key Words (Suggested by Author(s))		18. Distribution Statement FOR PUBLIC RELEASE: <i>W. D. Geissler</i> E: D. Geissler Director, Aero-Astroynamics Laboratory	
19. Security Classif. (of this report) UNCLASSIFIED	20. Security Classif. (of this page) UNCLASSIFIED	21. No. of Pages 496	22. Price*

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page No.</u>
1	INTRODUCTION	1
	1.1 Background	1
	1.2 Organization of the Handbook	1
2	GENERALIZED CONCENTRATION AND DOSAGE MODELS	3
	2.1 Generalized Concentration Model	3
	2.2 Generalized Dosage Model	6
	2.3 Subset of Equations for σ_y , σ_z and σ_x	7
	2.4 Model Formulas for Ground Deposition Caused by Precipitation Scavenging and Gravitational Settling	9
	2.5 Adaptation of the Generalized Models to Continuous Source Emission	11
3	THE KSC MULTI-LAYER DIFFUSION MODEL	13
	3.1 The Multi-Layer Concept	13
	3.2 Model 1	14
	3.3 Model 2	20
	3.4 Model 3	20
	3.5 Model 4	23
	3.6 Model 5	31
	3.7 Model 6	34
	3.8 Model 7	35
	3.9 Use of the Multi-Layer Construct for Cold Spills and Fuel Leaks in the Surface Layer	44
4	DESCRIPTION OF THE COMPUTER PROGRAM FOR THE KSC MULTI-LAYER DIFFUSION MODEL	45
	4.1 Organization of the Computer Program	45
	4.2 Meteorological Inputs	48
	4.3 Source Inputs	58

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page No.</u>
5	GRAPHICAL PROCEDURES FOR ESTIMATING GROUND-LEVEL CONCENTRATIONS AND DOSAGES	66
5.1	Selection of Stability Categories	66
5.2	Concentration and Dosage Fields from a Normal Launch	69
5.3	Box-Model Estimates of Concentration and Dosage for Normal and Abnormal Launches	96
5.4	Concentration Fields from Cold Spills and Leaks	101
	REFERENCES	132
 <u>Appendix</u>		
A	USER INSTRUCTIONS FOR THE KSC MULTI-LAYER DIFFUSION MODEL PROGRAM	A-1
A.1	Program Description	A-1
A.2	Program Input Sequence	A-5
A.3	Explanation of Program Inputs	A-5
A.4	Additional Remarks	A-23
A.5	Keypunch Instructions	A-23
A.6	Operator Instructions	A-23
A.7	Linkage for Subroutines in Computer Program for KSC Multi-Layer Diffusion Model	A-23
A.8	Linkage for Subroutines in Logic Sections 1 through 5	A-25
A.9	Data Field Configuration	A-25
B	LISTING OF THE COMPUTER PROGRAM FOR THE KSC MULTI-LAYER DIFFUSION MODEL	B-1
C	FLOW CHART FOR THE MULTI-LAYER DIFFUSION MODEL COMPUTER PROGRAM	C-1
D	COMPUTER OUTPUT FOR SAMPLE PROBLEM	D-1

TABLE OF CONTENTS (Continued)

<u>Appendix</u>	<u>Title</u>	<u>Page No.</u>
E	EXAMPLE CALCULATIONS EMPLOYING THE MULTI-LAYER DIFFUSION PROGRAM	E-1
	E. 1 Selection of Meteorological Input Parameters	E-2
	E. 2 Selection of Source Input Parameters	E-11
	E. 3 Concentration and Dosage Patterns for the Pre-Cold Front Situation	E-17
	E. 4 Concentration and Dosage Patterns for the Summertime Bermuda High Situation	E-53
	E. 5 Example Calculation of Ground-Level Deposition Due to Gravitational Settling	E-76
	E. 6 Example Calculation of a Change in Layer Structure and Deposition Due to Precipitation Scavenging	E-91
F	NOMOGRAMS FOR CALCULATING σ_A , σ_E AND p AND EXAMPLE CALCULATIONS	F-1
	F. 1 Nomograms for Calculating σ_A , σ_E and p	F-1
	F. 2 Example Calculations	F-1

LIST OF FIGURES

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
4-1	Block diagram of the computer program for the KSC multi-layer diffusion model	46
4-2	Dependence of σ_A at 18 meters on stability and wind speed at 18 meters	51
4-3	Dependence of σ_E at 18 meters on stability and wind speed at 18 meters	52
4-4	Seasonal variations in the time of transition	53
4-5	Dependence of p on stability and the wind speed at 18 meters	57
5-1	Normalized maximum concentration versus travel distance from a normal launch	70
5-2	Normalized maximum dosage versus travel distance from a normal launch	77
5-3	Nomogram for calculating normalized concentration for land trajectories	97
5-4	Nomogram for calculating normalized concentration for water trajectories	98
5-5	Nomogram for calculating normalized dosage for land trajectories	99
5-6	Nomogram for calculating normalized dosage for water trajectories	100
5-7	Two examples illustrating the use of Figure 5-4	102
5-8	Normalized axial ground-level concentration versus travel distance from a surface leak or cold spill	103
5-9	Normalized axial concentration versus travel distance from a leak at a height of 50 meters	110

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
4-1	Meteorological Input Parameters for Multi-Layer Construct	49
4-2	Meteorological Input Parameters for Cold Spill and Fuel Leak Calculations	59
4-3	Source Input Parameters for Normal and Abnormal Launch, Vehicle Destruct	60
4-4	Source Input Parameters for Cold Spill and Fuel Leak Calculations	65
5-1	Values of σ_A , σ_E and p for Stability and Wind Speed Classes	67
5-2	Key to Stability Categories	68
5-3	Meteorological Inputs for Each Stability Category	68
5-4	Residence Time of a Saturn V Vehicle Within the Surface Layer	81
5-5	Isopleth Widths of Normalized Concentration Versus Travel Distance from a Normal Launch	82
5-6	Isopleth Widths of Normalized Dosage Versus Travel Distance from a Normal Launch	89
5-7	Isopleth Widths of Normalized Ground-Level Concentration Versus Travel Distance from a Surface Spill or Leak	118
5-8	Isopleth Widths of normalized Concentration Versus Travel Distance from a Leak at a Height of 50 Meters	125

SECTION 1

INTRODUCTION

1.1 BACKGROUND

This handbook provides a complete documentation of the computerized and graphical procedures for estimating toxic fuel hazards at Kennedy Space Center that were developed under two concurrent contracts (Contracts Nos. NAS8-21453 and NAS8-30503). A detailed description of the generalized diffusion models and the meteorological data used to develop these procedures is given in the Final Report under Contract NAS8-30503 (Record, et al., 1970). The procedures outlined in this handbook for estimating toxic fuel hazards are applicable both to planning and research studies and to real-time operational problems. Because the methodology is new and the requisite input information with respect to source parameters and meteorological parameters is at present only partially complete, it is expected that the contents of the handbook will be revised as new information becomes available and experience is gained in the prediction of toxic fuel hazards.

1.2 ORGANIZATION OF THE HANDBOOK

The main body of the handbook contains five major topical sections. Section 2, following this Introduction, contains the generalized diffusion model equations used in the KSC multi-layer construct. This construct forms the basic framework for calculating concentration, dosage, and deposition fields associated with the emission of toxic materials from normal and abnormal launches, vehicle destructs, fuel leaks and spills, and other operations at Kennedy Space Center. Section 3 contains a description of the multi-layer construct and lists the mathematical formulas

for the various diffusion models used in the construct. The organization of the computer program for the multi-layer construct and the requisite meteorological and source inputs are outlined in Section 4. Graphical procedures for estimating ground-level concentrations and dosages for various release modes of toxic fuel materials are described in Section 5.

There are six appendices to the handbook. Appendix A contains the user's instructions for the computer program. A complete listing of the computer program is contained in Appendix B and the flow chart for the computer program is presented in Appendix C. Sample output of the program is shown in Appendix D. Appendix E contains completely worked example cases illustrating the application of the computer program to toxic fuel hazard problems. Appendix F explains the use of nomograms for estimating certain meteorological inputs to the computer program.

SECTION 2

GENERALIZED CONCENTRATION AND DOSAGE MODELS

The generalized concentration and dosage models given below are described in detail in Section 1 of the Final Report under Contract No. NAS8-30503 (Record, et al., 1970). The generalized models are presented here because they form the basis of the computerized multi-layer diffusion model, developed for use in estimating toxic fuel hazards at Kennedy Space Center, which is described in the following sections of this report. The form of the generalized models is similar to that of the Gaussian plume equations given by Pasquill (1962, p. 190). However, additional terms have been added to account for the effects of mesoscale factors, such as the depth of the surface mixing layer, vertical wind shear and precipitation scavenging. The equations also contain provision for variations in source dimensions, source emission time, and in meteorological structure along the downwind cloud trajectory. Subsets of equations are available for calculating the buoyant rise of material caused by the generation of heat during the emission process and surface deposition due to the gravitational settling of heavy particles or droplets.

The generalized models are given first for nearly instantaneous releases in which the cloud of toxic material is detached from the source after a few seconds or, at the most, a few minutes. This condition is typical of normal and abnormal launches, hot spills, and vehicle destruct situations. Adaptation of the generalized model to continuous source emission, which occurs with cold fuel spills and fuel leaks, is outlined at the end of this section.

2.1 GENERALIZED CONCENTRATION MODEL

The generalized concentration model is expressed as the product of five modular terms:

$$\text{Concentration} = \{\text{Peak Concentration Term}\} \times \{\text{Alongwind Term}\} \times \{\text{Lateral Term}\} \times \{\text{Vertical Term}\} \times \{\text{Depletion Term}\}$$

The mathematical formulas given below for the various terms are written according to conventional usage. Specifically, the concentration model is referred to a Cartesian coordinate system with the origin at $x = 0$, $y = 0$ and $z = H$, where H is the effective height of the source. The direction of x is along the mean azimuth wind direction, y is normal to the mean wind direction in the plane of the horizon, and z is directed vertically with $z = 0$ at ground level. The distribution of concentration along each of the three coordinate axes is assumed to be Gaussian. None of the above assumptions is required. The model equations are easily transformed to a polar coordinate system or other systems, and other distribution functions may be substituted for the Gaussian function.

The Peak Concentration Term refers to the concentration at the point $x = 0$, $y = 0$, $z = H$ and is defined by the expression

$$\frac{Q}{(2\pi)^{3/2} \sigma_x \sigma_y \sigma_z} \quad (2-1)$$

where

Q = source strength

σ_x = standard deviation of the alongwind concentration distribution

σ_y = standard deviation of the crosswind concentration distribution

σ_z = standard deviation of the vertical concentration distribution

The Alongwind Term is defined by the expression

$$\exp \left[-\frac{1}{2} \left(\frac{x - \bar{u}t}{\sigma_x} \right)^2 \right] \quad (2-2)$$

where

$\bar{u}$ = mean wind speed

t = time of cloud travel

The Lateral Term is defined by the expression

$$\exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right] \quad (2-3)$$

The Vertical Term is given by the expression

$$\begin{aligned} & \exp \left[-\frac{1}{2} \left(\frac{H-z}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{H+z}{\sigma_z} \right)^2 \right] + \sum_{i=1}^{\infty} \left\{ \exp \left[-\frac{1}{2} \left(\frac{2iH_m - H - z}{\sigma_z} \right)^2 \right] + \right. \\ & \left. \exp \left[-\frac{1}{2} \left(\frac{2iH_m - H + z}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{2iH_m + H - z}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{2iH_m + H + z}{\sigma_z} \right)^2 \right] \right\} \quad (2-4) \end{aligned}$$

where

H = effective source height

H_m = height of the top of the mixing layer

The multiple reflection terms following the summation sign stop the vertical cloud growth at the top of the mixing layer and change the form of the vertical concentration distribution from Gaussian to rectangular.

The Depletion Term refers to the loss of material by simple decay processes, precipitation scavenging, or gravitational settling. The form of the Depletion Term for each of these processes is:

$$(\text{Decay}) \quad \exp [-kt] \quad (2-5)$$

$$\begin{aligned} & \text{(Precipitation Scavenging)} \quad \exp [-\Lambda t] \quad (2-6) \\ & \text{(Gravitational Settling)} \end{aligned}$$

$$\exp \left[-\frac{1}{2} \left(\frac{H - (V_s x / \bar{u})}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{2H_m - H + (V_s x / \bar{u})}{\sigma_z} \right)^2 \right] \quad (2-7)$$

where

k = decay coefficient or fraction of material lost per unit time

t = time

Λ = washout coefficient or fraction of material removed by scavenging per unit time

V_s = settling velocity

When Equation (2-7) is used for the Depletion Term, the Vertical Term given by Equation (2-4) is set equal to unity. This causes the cloud axis to be inclined downward at the angle $\tan^{-1}(V_s / \bar{u})$ with respect to the horizon, following W. Schmidt's sedimentation hypothesis (see Pasquill, 1962, p. 226); material that deposits on the ground surface is retained and not reflected. The vertical growth of the cloud is stopped at the top of the mixing layer and reflected toward the ground by the second exponential term in Equation (2-7). The depletion by gravitational settling of material containing a size distribution is calculated by partitioning the distribution into various settling-velocity categories, solving Equation (2-7) for each settling velocity, and superposing the solutions.

2.2 GENERALIZED DOSAGE MODEL

The generalized dosage model is similar in form to the generalized concentration model and is defined by the product of four modular terms:

$$\begin{aligned} \text{Dosage} = & \{ \text{Peak Dosage Term} \} \times \{ \text{Lateral Term} \} \\ & \times \{ \text{Vertical Term} \} \times \{ \text{Depletion Term} \} \end{aligned}$$

The Peak Dosage Term is given by the expression

$$\frac{Q}{2\pi \bar{u} \sigma_y \sigma_z} \quad (2-8)$$

where

Q = source strength

$\bar{u}$ = mean wind speed

σ_y = standard deviation of the crosswind dosage distribution

σ_z = standard deviation of the vertical dosage distribution

The remaining terms in the generalized dosage model are defined in the same manner as the corresponding terms for the generalized concentration model which are given by Equations (2-3), (2-4), (2-5), (2-6) and (2-7).

2.3 SUBSET OF EQUATIONS FOR σ_y , σ_z and σ_x

The following subset of equations is used to define the distance dependence of the standard deviations of the crosswind, vertical and alongwind distributions in the generalized concentration and dosage models described above:

$$\sigma_y \{x\} = \left[\sigma_A'^2 \{ \tau \} x_r^2 \left(\frac{x+x_y}{x_r} \right)^{2\alpha} + \left(\frac{\Delta\theta'x}{4.3} \right)^2 \right]^{1/2} \quad (2-9)$$

where

$\sigma_A' \{ \tau \}$ = standard deviation of the azimuth wind angle in radians at height H for the release time τ

x_r = unit reference distance

x_y = virtual distance

$$= x_r \left(\frac{\sigma_{y0}}{\sigma_A' \{ \tau \} x_r} \right)^{1/\alpha}$$

- σ_{y0} = standard deviation of the crosswind distribution at the source
 α = lateral diffusion coefficient of the order of unity
 $\Delta\theta'$ = azimuth wind direction shear in radians within the layer containing the cloud

$$\sigma_z \{x\} = \sigma'_E x_r \left(\frac{x+x_z}{x_r} \right)^\beta \quad (2-10)$$

where

- σ'_E = standard deviation of the wind elevation angle in radians at height H

- x_z = virtual distance

$$= x_r \left(\frac{\sigma_{z0}}{\sigma'_E x_r} \right)^{1/\beta}$$

- σ_{z0} = standard deviation of the vertical distribution at the source

- β = vertical diffusion coefficient of the order of unity

$$\sigma_x \{x\} = \left[\left(\frac{L \{x\}}{4.3} \right)^2 + \sigma_{x0}^2 \right]^{1/2} \quad (2-11)$$

where

- $L \{x\}$ = alongwind cloud length when the center of the cloud is at distance x from the source

$$= \frac{0.28 (\Delta u) (x)}{\bar{u}}$$

- Δu = wind speed shear within the layer containing the cloud

- σ_{x0} = standard deviation of the alongwind distribution at the source

In Equation (2-9) above, σ'_A is expressed as a function of the release time τ .

Values of σ'_A for nearly instantaneous releases are difficult to measure directly,

but can be calculated from the following semi-empirical relationship (Cramer, et al., 1964):

$$\sigma_A' \{ \tau \} = \sigma_A' \{ \tau_0 \} \left(\frac{\tau}{\tau_0} \right)^{1/5} \quad (2-12)$$

where τ_0 is ≤ 10 minutes. The standard deviation of the wind elevation angle σ_E' is assumed independent of the release time τ because of the relatively narrow frequency range in the power spectrum of the vertical wind velocity component that contains significant amounts of turbulent energy. This assumption is generally valid at heights ≤ 100 meters above the ground surface. In the presence of large convective cells and at heights of the order of 1 kilometer, the assumption that σ_E' is independent of τ likely does not hold. However, the effect on the accuracy of ground-level concentration and dosage estimates is thought to be slight.

The source dimensions σ_{xo} , σ_{yo} , σ_{zo} in the above subset refer to a stabilized cloud or plume that has just reached equilibrium with ambient atmospheric conditions following the completion of the emission phase. These source dimensions are best estimated from direct measurements or observations. The virtual distances x_y , x_z are used to adjust the lateral and vertical terms of the generalized models for the initial source dimensions σ_{yo} and σ_{zo} . Two virtual distances are employed to facilitate the treatment of asymmetrical sources where $\sigma_{yo} \neq \sigma_{zo}$. The height of the stabilized cloud above ground level, when the emission mode is accompanied by the release of significant amounts of thermal energy, must be estimated from observations or by means of a mathematical formula for buoyant plume rise such as that given in Section 4.3 below.

2.4 MODEL FORMULAS FOR GROUND DEPOSITION CAUSED BY PRECIPITATION SCAVENGING AND GRAVITATIONAL SETTLING

The total amount of material deposited on the ground surface by precipitation scavenging, at some distance x , is given by the expression

$$\frac{\Lambda Q}{\sqrt{2\pi} \sigma_y \bar{u}} \left\{ \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right] \right\} \left\{ \exp \left[-\Lambda \left(\frac{x}{\bar{u}} - t_1 \right) \right] \right\} \quad (2-13)$$

where t_1 is the time at which the precipitation begins. The principal assumptions made in deriving the above expression are:

- The rate of precipitation is steady over an area that is large compared to the horizontal dimension of the cloud of toxic material
- The precipitation originates at a level above the top of the toxic cloud so that hydrometeors pass vertically through the entire cloud
- The time duration of the precipitation is sufficiently long so that the entire alongwind length of the toxic cloud passes over the point x

Engelmann (see Slade, 1968, pp. 208-221) discusses the general problem of calculating the amount of material removed by precipitation scavenging and recommends values of the coefficient Λ that may be combined with precipitation rates to obtain estimates of total surface deposition.

The total deposition due to the gravitational settling of heavy particles or droplets with settling velocity V_s , at a downwind distance x from the source and on the projection of the alongwind cloud axis on the ground plane, is given by the expression

$$\begin{aligned} \frac{Q}{\sqrt{2\pi} \sigma_y} \frac{d}{dx} \left\{ \frac{1}{\sqrt{2\pi} \sigma_z} \int_{-\infty}^0 \left\{ \exp \left[-\frac{1}{2} \left(\frac{H - (V_s x / \bar{u}) - z}{\sigma_z} \right)^2 \right] \right. \right. \\ \left. \left. + \exp \left[-\frac{1}{2} \left(\frac{2H_m - H + (V_s x / \bar{u}) - z}{\sigma_z} \right)^2 \right] \right\} dz \right\} \end{aligned} \quad (2-14)$$

After the integration and differentiation are performed, the above expression becomes

$$\begin{aligned} & \frac{Q}{2\pi \sigma_y} \left\{ \left[\frac{\beta H + \left(1 - \left(\frac{\beta x}{x+x_z}\right)\right) V_s (x+x_z)/\bar{u}}{\sigma_z (x+x_z)} \right] \exp \left[-\frac{1}{2} \left(\frac{H - (V_s x/\bar{u})}{\sigma_z} \right)^2 \right] \right. \\ & + \left[\frac{\beta (2H_m - H) - \left(1 - \left(\frac{\beta x}{x+x_z}\right)\right) V_s (x+x_z)/\bar{u}}{\sigma_z (x+x_z)} \right] \\ & \left. \exp \left[-\frac{1}{2} \left(\frac{2H_m - H + (V_s x/\bar{u})}{\sigma_z} \right)^2 \right] \right\} \end{aligned} \quad (2-15)$$

2.5 ADAPTATION OF THE GENERALIZED MODELS TO CONTINUOUS SOURCE EMISSION

The generalized concentration and dosage models respectively discussed in Sections 2.1 and 2.2 above are applicable to cases in which the source is nearly-instantaneous. Treatment of cold spills and fuel leaks that occur near ground level requires that these models be adapted for use in predicting concentrations downwind from continuous sources.

The generalized concentration model for continuous source emission is given by the product of four terms

$$\begin{aligned} \text{Concentration} &= \{\text{Peak Concentration}\} \times \{\text{Lateral Term}\} \\ &\times \{\text{Vertical Term}\} \times \{\text{Depletion Term}\} \end{aligned}$$

The Peak Concentration Term is given by the expression

$$\frac{Q}{2\pi \bar{u} \sigma_y \sigma_z} \quad (2-16)$$

where

Q = source strength in units of total mass released per unit time

$\bar{u}$ = mean wind speed at the effective source height

σ_y = standard deviation of the crosswind concentration distribution

σ_z = standard deviation of the vertical concentration distribution

The Lateral Term, Vertical Term and the subset of equations defining σ_y and σ_z are respectively given by Equations (2-3), (2-4), (2-9) and (2-10). The Depletion Term is given by Equations (2-5, (2-6) and (2-7), depending on the depletion mechanism. The expression for the Peak Concentration Term given by Equation (2-16) is very similar to the Peak Dosage Term in Equation (2-8) except for the definition of source strength and the mean wind speed.

SECTION 3

THE KSC MULTI-LAYER DIFFUSION MODEL

3.1 THE MULTI-LAYER CONCEPT

The meteorological structure at Kennedy Space Center between ground level and 5 kilometers, the top of the reference air volume for hazard estimation, is usually comprised of several layers with distinctive wind, temperature and humidity fields (Record, et al., 1970). A typical daytime vertical profile at KSC shows an easterly sea-breeze circulation in the surface layer, a transition zone, and a regime of westerly winds at the top of the reference volume. Large horizontal spatial variations in wind regimes also occur in the surface layer, usually as a consequence of the land-water interface.

If the generalized diffusion models described in Section 2 are to be of practical use in hazard estimation at KSC, a way must be found to adapt them to the vertical and horizontal variations in meteorological structure that typically occur in the reference air volume. The vertical stratification problem in the reference volume is handled by applying the models to individual layers in which the meteorological structure is reasonably homogenous. Layer boundaries are placed arbitrarily at the points of major discontinuities in the vertical profiles of wind, temperature, and humidity. For simplicity, it is assumed that there is no flux of material across layer boundaries due to turbulent mixing. Provision is made, however, for the flux of material across layer boundaries as a result of gravitational settling or precipitation scavenging.

Step changes in the meteorological structure of layers, at some arbitrary time or downwind distance from the point of release, are accommodated by stopping the transport and diffusion processes in the layers affected by the change in structure, calculating new sets of initial source and meteorological model input parameters, and re-starting the transport and diffusion process with the new inputs.

Two geometries are involved in the multi-layer concepts outlined above. The first is the layer geometry used with the Cartesian coordinate system of the generalized models in which the x-axis is along the mean wind direction in the layer. The second geometry refers to a basic reference grid for the area surrounding KSC that is referred to fixed spatial coordinates. Transformation equations that relate the two geometries are easily written.

The above concepts have been used to develop a multi-layer construct, based on the generalized diffusion models, for application to the toxic fuel hazard problem at KSC. Mathematical specifications for the various layer models used in the KSC multi-layer construct are given below. These specifications provide the foundation for the computer programs that constitute the principal methods for estimating toxic fuel hazards at KSC. The seven layer models first described refer principally to the transport, dispersal, and depletion of toxic material formed as the result of normal and abnormal launches, vehicle destruct, and hot fuel spills. The use of the multi-layer diffusion program for estimating concentration fields downwind from cold fuel spills and surface fuel leaks is described at the end of the section.

3.2 MODEL 1

In this layer model, the source extends vertically through the entire layer and turbulent mixing is occurring. It is assumed that the vertical distribution of toxic material is uniform with height and that the distributions of toxic material along the x- and y-layer coordinates are Gaussian.

3.2.1 Dosage Equation for Model 1

The dosage equation for Model 1 in the K^{th} layer is

$$D_K \{x_K, y_K, z_K\} = \frac{Q_K}{\sqrt{2\pi} \bar{u} \{z_K\} \sigma_{yK}} \left\{ \exp \left(\frac{-y_K^2}{2\sigma_{yK}^2} \right) \right\} \quad (3-1)$$

In the above expression

Q_K = source strength in units of mass per unit layer depth

The quantity $\bar{u} \{z_K\}$ in Equation (3-1) is the mean wind speed in meters per second at the height z_K for which the dosage is to be estimated. In the surface layer ($K = 1$), this term is defined as follows:

$$\bar{u} \{z_K, K=1\} = \bar{u}_R \left(\frac{z_K \{K=1\}}{z_R} \right)^p \quad (3-2)$$

where

$\bar{u}_R$ = mean wind speed measured at the reference height z_R

p = power-law exponent for the wind speed profile in the surface layer

$$= \log \left(\frac{\bar{u}_{TK} \{K=1\}}{\bar{u}_R} \right) / \log \left(\frac{z_{TK} \{K=1\}}{z_R} \right)$$

$\bar{u}_{TK} \{K=1\}$ = mean wind speed at the top of the surface layer $z_{TK} \{K=1\}$

For layers above the surface layer ($K > 1$),

$$\bar{u} \{z_K, K>1\} = \bar{u}_{BK} + \left(\frac{\bar{u}_{TK} - \bar{u}_{BK}}{z_{TK} - z_{BK}} \right) (z_K - z_{BK}) \quad (3-3)$$

where

$\bar{u}_{TK}$ = mean wind speed at the top of the layer z_{TK}

$\bar{u}_{BK}$ = mean wind speed at the base of the layer z_{BK}

The standard deviation of the crosswind dosage distribution

σ_{yK} is defined by the expression

$$\sigma_{yK} = \left\{ \left[\sigma'_{AK} \{ \tau_K \} x_r \left(\frac{x_K + x_{yK}}{x_r} \right)^{\alpha_K} \right]^2 + \left[\frac{\Delta \theta'_K x_K}{4.3} \right]^2 \right\}^{1/2} \quad (3-4)$$

where

$\sigma'_{AK} \{ \tau_K \}$ = mean layer standard deviation of the wind azimuth angle in radians for the cloud stabilization time τ_K

In the surface layer ($K = 1$),

$$\sigma'_{AK} \{ \tau_K, K=1 \} = \frac{\sigma'_{AR} \{ \tau_K \} \left[(z_{TK} \{ K=1 \})^{m+1} - (z_R)^{m+1} \right]}{(m+1) (z_{TK} \{ K=1 \} - z_R) (z_R)^m} \quad (3-5)$$

where

$\sigma'_{AR} \{ \tau_K \}$ = standard deviation of the wind azimuth angle in radians at height z_R and for the cloud stabilization time τ_K

$$= \sigma_{AR} \{ \tau_{oK} \} \left(\frac{\tau_K}{\tau_{oK}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{AR} \{ \tau_{oK} \}$ = standard deviation of the wind azimuth angle in degrees at height z_R and for the reference time period τ_{oK}

m = power-law exponent for the vertical profile of the standard deviation of the wind azimuth angle in the surface layer

$$= \log \left(\frac{\sigma'_{ATK} \{ \tau_K, K=1 \}}{\sigma'_{AR} \{ \tau_K \}} \right) / \log \left(\frac{z_{TK} \{ K=1 \}}{z_R} \right)$$

$$\sigma'_{ATK} \{ \tau_K, K=1 \} = \sigma_{ATK} \{ \tau_{oK}, K=1 \} \left(\frac{\tau_K}{\tau_{oK}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ATK} \{ \tau_{oK}, K=1 \}$ = standard deviation of the wind azimuth angle in degrees at the top of the surface layer z_{TK} for the reference time period τ_{oK}

For layers above the surface layer ($K > 1$),

$$\sigma'_{ATK} \{ \tau_K, K>1 \} = \left(\sigma'_{ATK} \{ \tau_K \} + \sigma'_{ABK} \{ \tau_K \} \right) / 2 \quad (3-6)$$

where

$$\sigma'_{ATK} \{ \tau_K \} = \sigma_{ATK} \{ \tau_{oK} \} \left(\frac{\tau_K}{\tau_{oK}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ATK} \{ \tau_{oK} \}$ = standard deviation of the wind azimuth angle in degrees at the top of the layer for the reference time period τ_{oK}

$$\sigma'_{ABK} \{ \tau_K \} = \sigma_{ABK} \{ \tau_{oK} \} \left(\frac{\tau_K}{\tau_{oK}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ABK} \{ \tau_{oK} \}$ = standard deviation of the wind azimuth angle in degrees at the base of the layer for the reference time period τ_{oK}

x_K = downwind distance from the source

y_K = crosswind distance from the axis of the cloud

x_{yK} = crosswind virtual distance

$$= x_r \left(\frac{\sigma_{yo} \{ K \}}{\sigma'_{AK} \{ \tau_K \} x_r} \right)^{1/\alpha_K}$$

$\sigma_{yo} \{ K \}$ = standard deviation of the lateral source dimension in the layer

α_K = lateral diffusion coefficient in the layer
 $\Delta\theta'_K$ = vertical wind direction shear in the layer

$$= (\theta_{TK} - \theta_{BK}) \left(\pi/180 \right)$$

θ_{TK} = mean wind direction in degrees at the top of the layer
 θ_{BK} = mean wind direction in degrees at the base of the layer

3.2.2 Concentration Equation for Model 1

The concentration equation for Model 1 in the K^{th} layer is given by the expression

$$\chi_K \{x_K, y_K, t\} = \frac{D_K \bar{u} \{z_K\}}{\sqrt{2\pi} \sigma_{xK}} \left\{ \exp \left[\frac{-(x_K - \bar{u}_K t)^2}{2\sigma_{xK}^2} \right] \right\} \quad (3-7)$$

where

$\bar{u}_K$ = mean cloud transport speed in the layer

$$\bar{u}_K \{K=1\} = \frac{\bar{u}_R \left[(z_{TK} \{K=1\})^{1+p} - (z_R)^{1+p} \right]}{(1+p) (z_{TK} \{K=1\} - z_R) (z_R)^p}$$

$$\bar{u}_K \{K>1\} = (\bar{u}_{TK} + \bar{u}_{BK}) / 2$$

t = time after cloud stabilization

σ_{xK} = standard deviation of the alongwind concentration distribution in the layer

$$= \left[\left(\frac{L \{x_K\}}{4.3} \right)^2 + \sigma_{xo}^2 \{K\} \right]^{1/2} \quad (3-8)$$

$L\{x_K\}$ = alongwind cloud length in the layer at distance x_K from the source

$$= \left\{ \begin{array}{ll} \frac{0.28 (\Delta \bar{u}_K) (x_K)}{\bar{u}_K} & ; \quad \Delta \bar{u}_K \geq 0 \\ 0 & ; \quad \Delta \bar{u}_K \leq 0 \end{array} \right\} \quad (3-9)$$

$\Delta \bar{u}_K$ = vertical wind speed shear in the layer

$\Delta \bar{u}_K \{K=1\}$ = $\bar{u}_{TK} \{K=1\} - \bar{u}_K$

$\Delta \bar{u}_K \{K>1\}$ = $\bar{u}_{TK} - \bar{u}_{BK}$

$\sigma_{xo} \{K\}$ = standard deviation of the alongwind source dimension in the layer

The above equation for $L\{x_K\}$ is based on results reported by Tyldesley and Wallington (1965) who analyzed ground-level concentration measurements made at distances of 5 to 120 kilometers downwind from instantaneous line-source releases.

The peak concentration χ_{PK} at distance x_K and at an arbitrary distance $y_K \neq 0$ from the cloud centerline is given by

$$\chi_{PK} \{x_K, y_K, t = x_K / \bar{u}_K\} = \frac{D_K \bar{u} \{z_K\}}{\sqrt{2\pi} \sigma_{xK}} \quad (3-10)$$

Similarly, the maximum peak concentration χ_{MPK} at distance x_K on the cloud centerline $y_K = 0$ is given by the equivalent expressions

$$x_{MPK} \left\{ x_K, y_K = 0, t = x_K / u_K \right\} = \frac{D_K \bar{u} \{z_K\}}{\sqrt{2\pi} \sigma_{xK}} \frac{1}{\{\text{LATERAL TERM}\}} \quad (3-11)$$

$$= \frac{Q_K}{2\pi \sigma_{yK} \sigma_{xK}} \quad (3-12)$$

3.3 MODEL 2

Layer model 2 refers to the same source configuration as Model 1 in which the source extends vertically through the entire depth of the layer and the distribution of toxic material is uniform with height. In Model 2, however, it is assumed that no turbulent mixing is occurring. Consequently, there is no dilution of the cloud due to turbulent expansion. The dosage and concentration equations for Model 2 are given by Equations (3-1) and (3-7), respectively, with the following substitutions:

$$\sigma_{yK} = \sigma_{yo} \{K\} \quad (3-13)$$

$$\sigma_{xK} = \sigma_{xo} \{K\} \quad (3-14)$$

3.4 MODEL 3

This layer model differs from Models 1 and 2 in that the vertical extent of the source is less than the depth of the layer. The model equation thus contains vertical expansion terms.

3.4.1 Dosage Equation for Model 3

The dosage equation for Model 3 in the K^{th} layer is given by the expression

$$\begin{aligned}
 D_K \{x_K, y_K, z_{BK} < z_K < z_{TK}\} &= \frac{Q_K}{2\pi \sigma_{yK} \sigma_{zK} \bar{u} \{z_K\}} \left\{ \exp \left[\frac{-y_K^2}{2\sigma_{yK}^2} \right] \right. \\
 &\left\{ \exp \left[\frac{-(H_K - z_K)^2}{2\sigma_{zK}^2} \right] + \exp \left[\frac{-(H_K - 2z_{BK} + z_K)^2}{2\sigma_{zK}^2} \right] \right. \\
 &+ \sum_{i=1}^{\infty} \left\{ \exp \left[\frac{-(2i(z_{TK} - z_{BK}) - (H_K - 2z_{BK} + z_K))^2}{2\sigma_{zK}^2} \right] \right. \\
 &\exp \left[\frac{-(2i(z_{TK} - z_{BK}) + (H_K - z_K))^2}{2\sigma_{zK}^2} \right] + \exp \left[\frac{-(2i(z_{TK} - z_{BK}) + (H_K - z_K))^2}{2\sigma_{zK}^2} \right] \\
 &\left. \left. \left. + \exp \left[\frac{-(2i(z_{TK} - z_{BK}) + (H_K - 2z_{BK} + z_K))^2}{2\sigma_{zK}^2} \right] \right\} \right\} \right\} \quad (3-15)
 \end{aligned}$$

where

Q_K = source strength or total mass of material in the layer

H_K = effective source height or height of the centroid of the stabilized cloud

σ_{zK} = standard deviation of the vertical dosage distribution in the layer

The remaining terms are the same as those in Equation (3-1) for Model 1.

The standard deviation of the vertical dosage distribution is defined by the expression

$$\sigma_{zK} = \sigma'_{EK} x_r \left(\frac{x_K + x_{zK}}{x_r} \right)^{\beta_K} \quad (3-16)$$

where

σ'_{EK} = mean standard deviation of the wind elevation angle in radians for the layer

x_{zK} = vertical virtual distance in the layer

β_K = vertical diffusion coefficient in the layer

In the surface layer ($K = 1$),

$$\sigma'_{EK} \{K=1\} = \frac{\sigma_{ER} \left[(z_{TK} \{K=1\})^{q+1} - (z_R)^{q+1} \right]}{(q+1)(z_{TK} \{K=1\} - z_R)(z_R)^q} \left(\frac{\pi}{180} \right) \quad (3-17)$$

where

σ_{ER} = standard deviation of the wind elevation angle in degrees at the height z_R

q = power-law exponent for the vertical profile of the standard deviation of the wind elevation angle in the surface layer

$$= \log \left(\frac{\sigma_{ETK} \{K=1\}}{\sigma_{ER}} \right) / \log \left(\frac{z_{TK} \{K=1\}}{z_R} \right)$$

$\sigma_{ETK} \{K=1\}$ = standard deviation of the wind elevation angle in degrees at the top of the surface layer

Above the surface layer ($K > 1$),

$$\sigma'_{EK} \{K>1\} = (\sigma_{ETK} + \sigma_{EBK}) \left(\pi/360 \right) \quad (3-18)$$

where

σ_{ETK} = standard deviation of the wind elevation angle in degrees
at the top of the layer

σ_{EBK} = standard deviation of the wind elevation angle in degrees
at the base of the layer

The vertical virtual distance x_{zK} is given by the expression

$$x_{zK} = x_r \left(\frac{\sigma_{zo} \{K\}}{\sigma_{EK} x_r} \right)^{1/\beta}$$

where

$\sigma_{zo} \{K\}$ = standard deviation of the source vertical dosage distribution

3.4.2 Concentration Equation for Model 3

The concentration equation for Model 3 is the same as that for Model 1 which is given by Equation (3-7) in Section 3.2.2. Equations (3-10) and (3-11) in Section 3.2.2 also give the peak concentration and maximum peak concentration for Model 3. The Model 1 formula for maximum peak concentration given by Equation (3-12) does not apply to Model 3 because no provision is made for the vertical terms.

3.5 MODEL 4

In this layer model, a simple step change in layer structure is assumed to occur at a predetermined time t^* subsequent to the generation of the cloud at the source. Model 4 is applied in the calculation of dosage and concentration fields after time t^* under the following assumptions:

- The boundary between adjacent layers is eliminated and the layers are replaced by a single layer L
- Turbulent mixing is occurring in layer L
- The cloud is fully adjusted to the new meteorological structure in layer L
- Reflection occurs at the upper and lower boundaries of L

Under these assumptions, the contribution to the dosage and concentration fields in layer L from the source in the K^{th} layer can be expressed as a simple box model formula. The total contribution to a receptor position in layer L is found by summing the contribution from all K layers.

3.5.1 Dosage Equation for Model 4

The dosage equation for Model 4 for the contribution from the cloud in the K^{th} layer to the receptor position in the layer L is

$$D_{LK} \{x_L, y_L, z_L\} = \frac{Q_K (z_{TK} - z_{BK})}{\sqrt{2\pi} \bar{u} \{z_L\} \sigma_{yLK} (z_{TL} - z_{BL})} \left\{ \exp \left[\frac{-y_L^2}{2\sigma_{yLK}^2} \right] \right\} \quad (3-19)$$

In the above expression

Q_K = source strength in units of mass per unit layer depth
(g m^{-1}) for the source in the layer K

In Model 4 the quantity $\bar{u}\{z_L\}$ is the mean wind speed in meters per second at the height z_L for which the dosage is to be estimated. If the layer L is the surface layer ($L = 1$), this term is defined by the expression

$$\bar{u}\{z_L, L=1\} = \bar{u}_{RL} \left(\frac{z_L\{L=1\}}{z_R} \right)^{p_L} \quad (3-20)$$

where

$\bar{u}_{RL}$ = mean wind speed at the reference height z_R in the new surface layer L

p_L = power-law exponent for the wind speed profile in the surface layer ($L = 1$)

$$= \log \left(\frac{\bar{u}_{TL}\{L=1\}}{\bar{u}_{RL}} \right) / \log \left(\frac{z_{TL}\{L=1\}}{z_R} \right)$$

$\bar{u}_{TL}\{L=1\}$ = mean wind at the top of the surface layer $z_{TL}\{L=1\}$

For layers above the surface layer ($L > 1$),

$$\bar{u}\{z_{LK}, L>1\} = \bar{u}_{BL} + \left(\frac{\bar{u}_{TL} - \bar{u}_{BL}}{z_{TL} - z_{BL}} \right) (z_L - z_{BL}) \quad (3-21)$$

where

$\bar{u}_{TL}$ = mean wind speed at the top of the layer z_{TL}

$\bar{u}_{BL}$ = mean wind speed at the base of the layer z_{BL}

The crosswind distance from the axis of the cloud to a receptor, y_L , is given by the expression

$$y_L = (y_j - y_{SK}) \sin \theta'_L - (x_j - x_{SK}) \cos \theta'_L \quad (3-22)$$

where

x_j, y_j = position of the receptor with respect to the origin of the reference coordinate system

x_{SK}, y_{SK} = coordinates of the cloud centroid in the K^{th} layer at time t^* with respect to the origin of the reference coordinate system

$$x_{SK} = x_i - x_K^* \sin \theta'_K$$

$$y_{SK} = y_i - x_K^* \cos \theta'_K$$

x_i, y_i = coordinates of the real source in the K^{th} layer with respect to the origin of the reference coordinate system

$$x_K^* = \bar{u}_K t^*$$

$$\theta'_L = (\theta_{TL} + \theta_{BL}) (\pi/360)$$

θ_{TL} = mean wind direction in degrees at the top of the layer z_{TL}

θ_{BL} = mean wind direction in degrees at the base of the layer z_{BL}

$$\theta'_K = (\theta_{TK} + \theta_{BK}) (\pi/360)$$

The standard deviation of the crosswind dosage distribution σ_{yLK} in the L^{th} layer is defined by the expression

$$\sigma_{yLK} = \left\{ \left[\sigma'_{AL} \tau_L \right] (x_L + x_{yKL}^*)^2 + \left[\frac{\Delta \theta'_L x_L}{4.3} \right]^2 \right\}^{1/2} \quad (3-23)$$

where

$\sigma'_{AL} \tau_L$ = mean layer standard deviation of the wind azimuth angle in radians for the effective cloud stabilization time τ_L

In the surface layer ($L = 1$),

$$\sigma'_{AL}\{\tau_L, L=1\} = \frac{\sigma'_{ARL}\{\tau_L\} \left[(z_{TL}\{L=1\})^{m_L+1} - (z_R)^{m_L+1} \right]}{(m_L+1) (z_{TL}\{L=1\} - z_R) (z_R)^{m_L}} \quad (3-24)$$

where

$\sigma'_{ARL}\{\tau_L\}$ = standard deviation of the wind azimuth angle in radians at height z_R and for time τ_L

$$= \sigma_{ARL}\{\tau_{oL}\} \left(\frac{\tau_L}{\tau_{oL}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ARL}\{\tau_{oL}\}$ = standard deviation of the wind azimuth angle in degrees at height z_R and for the reference time period τ_{oL}

m_L = power-law exponent for the vertical profile of the standard deviation of the wind azimuth angle in the surface layer $L = 1$

$$= \log \left(\frac{\sigma'_{ATL}\{\tau_L, L=1\}}{\sigma'_{ARL}\{\tau_L\}} \right) \bigg/ \log \left(\frac{z_{TL}\{L=1\}}{z_R} \right)$$

$$\sigma'_{ATL}\{\tau_L, L=1\} = \sigma_{ATL}\{\tau_{oL}, L=1\} \left(\frac{\tau_L}{\tau_{oL}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ATL}\{\tau_{oL}, L=1\}$ = standard deviation of the wind azimuth angle in degrees at the top of the surface layer z_{TL} for the reference time period τ_{oL}

For layers above the surface layer ($L > 1$),

$$\sigma'_{AL}\{\tau_L, L>1\} = \left(\sigma'_{ATL}\{\tau_L\} + \sigma'_{ABL}\{\tau_L\} \right) / 2 \quad (3-25)$$

where

$$\sigma'_{ATL} \{ \tau_L \} = \sigma_{ATL} \{ \tau_{oL} \} \left(\frac{\tau_L}{\tau_{oL}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ATL} \{ \tau_{oL} \}$ = standard deviation of the wind azimuth angle in degrees at the top of the layer for the reference time period τ_{oL}

$$\sigma'_{ABL} \{ \tau_L \} = \sigma_{ABL} \{ \tau_{oL} \} \left(\frac{\tau_L}{\tau_{oL}} \right)^{1/5} \left(\frac{\pi}{180} \right)$$

$\sigma_{ABL} \{ \tau_{oL} \}$ = standard deviation of the wind azimuth angle in degrees at the base of the layer for the reference time τ_{oL}

The wind direction shear in radians in the layer is given by the expression

$$\Delta \theta'_L = (\theta_{TL} - \theta_{BL}) \left(\frac{\pi}{180} \right)$$

The crosswind virtual distance in the L^{th} layer due to source (cloud) originating in the K^{th} layer is given by the equation

$$x^*_{yKL} = x_r \left(\frac{\sigma^*_{yKL}}{\sigma'_{AL} \{ \tau_L \} x_r} \right)^{1/\alpha_L}$$

where

σ^*_{yKL} = crosswind source dimension in layer L due to source (cloud) originating in the K^{th} layer

$$= \left\{ \left[(\sigma^*_{xK})^2 \sin^2 (\theta'_K - \theta'_L) \right] + \left[(\sigma^*_{yK})^2 \cos^2 (\theta'_K - \theta'_L) \right] \right\}^{1/2}$$

σ_{xK}^* = alongwind standard deviation of the dosage distribution in the K^{th} layer at time t^*

σ_{yK}^* = crosswind standard deviation of the dosage distribution in the K^{th} layer at time t^*

α_L = lateral diffusion coefficient in the layer

The downwind distance from the point where the change in layer structure occurs for the source (cloud) in the K^{th} layer to the point where the dosage is to be calculated, x_L , is given by the expression

$$x_L = -(x_j - x_{SK}) \sin \theta'_L - (y_j - y_{SK}) \cos \theta'_L \quad (3-26)$$

3.5.2 Concentration Equation for Model 4

The concentration equation for Model 4 is given by the expression

$$x_{LK} \{x_L, y_L, t\} = \frac{D_{LK} \bar{u} \{z_L\}}{\sqrt{2\pi} \sigma_{xLK}} \left\{ \exp \left[-\frac{(x_L - \bar{u}_L (t-t^*))^2}{2\sigma_{xLK}^2} \right] \right\} \quad (3-27)$$

where

$\bar{u}_L$ = mean wind speed in the layer

$$\bar{u}_L \{L=1\} = \frac{\bar{u}_{RL} \left[(z_{TL} \{L=1\})^{p_L+1} - (z_R)^{p_L+1} \right]}{(p_L+1) (z_{TL} \{L=1\} - z_R) (z_R)^{p_L}}$$

$$\bar{u}_L \{L>1\} = (\bar{u}_{TL} + \bar{u}_{BL}) / 2$$

σ_{xLK} = standard deviation of the cloud alongwind concentration distribution in layer

$$= \left[\left(\frac{L \{x_{LK}\}}{4.3} \right)^2 + (\sigma_{xKL}^*)^2 \right]^{1/2}$$

$L \{x_{LK}\}$ = alongwind length of cloud in layer at distance x_L

$$= \left\{ \begin{array}{ll} \frac{0.28 (\Delta \bar{u}_L)(x_L)}{\bar{u}_L} & ; \quad \Delta \bar{u}_L \geq 0 \\ 0 & ; \quad \Delta \bar{u}_L \leq 0 \end{array} \right\} \quad (3-28)$$

$\Delta \bar{u}_L$ = vertical wind speed shear in the layer

$$\Delta \bar{u}_L \{L=1\} = \bar{u}_{TL} \{L=1\} - \bar{u}_{RL}$$

$$\Delta \bar{u}_L \{L>1\} = \bar{u}_{TL} - \bar{u}_{BL}$$

σ_{xKL}^* = alongwind source dimension in layer L due to source (cloud) originating in the K^{th} layer

$$= \left\{ \left[(\sigma_{xK}^*)^2 \cos^2(\theta'_K - \theta'_L) \right] + \left[(\sigma_{yK}^*)^2 \sin^2(\theta'_K - \theta'_L) \right] \right\}^{1/2}$$

The peak concentration x_{PL} at distance x_L and at an arbitrary distance $y_L \neq 0$ from the cloud centerline is given by

$$x_{PL} \{x_L, y_L, t\} = x_L / \bar{u}_L \left\{ \frac{D_{LK} \bar{u} \{z_L\}}{\sqrt{2\pi} \sigma_{xLK}} \right\} \quad (3-29)$$

and the maximum peak concentration x_{MPL} at distance x_L on the centerline $y_L = 0$ by the expression

$$x_{MPL} \left\{ x_L, y_L = 0, t = x_L / \bar{u}_L \right\} = \frac{D_{LK} \bar{u} \{z_L\}}{\sqrt{2\pi} \sigma_{xLK}} \frac{1}{\{\text{LATERAL TERM}\}} \quad (3-30)$$

$$= \frac{Q_K}{2\pi \sigma_{yLK} \sigma_{xLK}}$$

3.6 MODEL 5

The use of Model 4 above does not permit estimation of the dosage and concentration fields in the transition period between the time t^* and the time at which material originating in the K^{th} layer becomes rectangularly distributed in the vertical throughout the layer L. Layer Model 5 contains vertical terms which permit estimation of the dosage and concentration fields in and after the transition period. The same assumptions applied in deriving Model 4 are used in deriving Model 5 with the exception that the cloud need not be fully adjusted to the new meteorological structure in layer L. However, the cloud in the K^{th} layer must be uniformly distributed in the vertical prior to time t^* .

3.6.1 Dosage Equation for Model 5

The dosage equation for Model 5 is given by the expression

$$\begin{aligned}
D_{LK} = & \frac{Q_K}{2\sqrt{2\pi} \bar{u} \{z_L\} \sigma_{yLK}} \left\{ \exp \left[-\left(\frac{y_L^2}{2\sigma_{yLK}^2} \right) \right] \right\} \\
& \left\{ \sum_{i=0}^{\infty} \left[\operatorname{erf} \left(\frac{2i(z_{TL} - z_{BL}) - z_{BK} + z_L}{\sqrt{2} \sigma_{zLK}} \right) + \operatorname{erf} \left(\frac{2i(z_{TL} - z_{BL}) + z_{TK} - z_L}{\sqrt{2} \sigma_{zLK}} \right) \right. \right. \\
& \quad \left. \left. + \operatorname{erf} \left(\frac{2i(z_{TL} - z_{BL}) + 2z_{BL} - z_{BK} - z_L}{\sqrt{2} \sigma_{zLK}} \right) + \operatorname{erf} \left(\frac{2i(z_{TL} - z_{BL}) - 2z_{BL} + z_{TK} + z_L}{\sqrt{2} \sigma_{zLK}} \right) \right] \right. \\
& \quad \left. + \sum_{i=1}^{\infty} \left[\operatorname{erf} \left(\frac{-2i(z_{TL} - z_{BL}) - z_{BK} + z_L}{\sqrt{2} \sigma_{zLK}} \right) + \operatorname{erf} \left(\frac{-2i(z_{TL} - z_{BL}) + z_{TK} - z_L}{\sqrt{2} \sigma_{zLK}} \right) \right. \right. \\
& \quad \left. \left. + \operatorname{erf} \left(\frac{-2i(z_{TL} - z_{BL}) + 2z_{BL} - z_{BK} - z_L}{\sqrt{2} \sigma_{zLK}} \right) + \operatorname{erf} \left(\frac{-2i(z_{TL} - z_{BL}) - 2z_{BL} + z_{TK} + z_L}{\sqrt{2} \sigma_{zLK}} \right) \right] \right\} \quad (3-31)
\end{aligned}$$

where

σ_{zLK} = standard deviation of the vertical dosage distribution in the layer for the source (cloud) originating in the K^{th} layer

The remaining terms are the same as those in Equation (3-19) for Model 4.

The standard deviation of the vertical dosage distribution is defined by the expression

$$\sigma_{zLK} = \sigma'_{EL} x_r \left(\frac{x_L}{x_r} \right)^{\beta_L} \quad (3-32)$$

where

σ'_{EL} = mean standard deviation of the wind elevation angle in radians for the layer

β_L = vertical diffusion coefficient in the layer

x_r = unit reference distance

In the surface layer ($L = 1$),

$$\sigma'_{EL}\{L=1\} = \frac{\sigma_{ERL} \left[(z_{TL}\{L=1\})^{q_L+1} - (z_R)^{q_L+1} \right]}{(q_L+1) (z_{TL}\{L=1\} - z_R) (z_R)^{q_L}} \left(\frac{\pi}{180} \right) \quad (3-33)$$

where

σ_{ERL} = standard deviation of the wind elevation angle in degrees at the reference height z_R

q_L = power-law exponent for the vertical profile of the standard deviation of the wind elevation angle in the surface layer

$$= \log \left(\frac{\sigma_{ETL}\{L=1\}}{\sigma_{ERL}} \right) \bigg/ \log \left(\frac{z_{TL}\{L=1\}}{z_R} \right)$$

$\sigma_{ETL}\{L=1\}$ = standard deviation of the wind elevation angle in degrees at the top of the layer z_{TL}

Above the surface layer ($L > 1$),

$$\sigma'_{EL}\{L>1\} = (\sigma_{ETL} + \sigma_{EBL}) \left(\pi/360 \right) \quad (3-34)$$

where

σ_{ETL} = standard deviation of the wind elevation angle in degrees at the top of layer z_{TL}

σ_{EBL} = standard deviation of the wind elevation angle in degrees at the base of the layer z_{BL}

The multiple reflection terms following the summation signs in Equation (3-31) simulate reflection of the cloud at the top and base of layer L .

3.6.2 Concentration Equation

The concentration equation for Model 5 is the same as that for Model 4 given by Equation (3-27). The peak concentration and maximum peak concentration respectively given by Equations (3-29) and (3-30) also apply to Model 5.

3.7 MODEL 6

This model is used to calculate the amount of material deposited on the surface by precipitation scavenging in the K^{th} layer. The assumptions made in deriving the model are stated in Section 2.4. The ground-level deposition WD_K due to precipitation scavenging, for the case in which the vertical distribution of toxic material in the layer is uniform with height (Models 1 and 2), is given by the expression

$$WD_K \left\{ x_K, y_K, z=0 \right\} = \frac{\Lambda Q_K (z_{TK} - z_{BK})}{\sqrt{2\pi} \sigma_{yK} \bar{u}_K} \left\{ \exp \left[-\frac{1}{2} \left(\frac{y_K}{\sigma_{yK}} \right)^2 \right] \right\} \quad (3-35)$$

$$\left\{ \exp \left[-\Lambda \left(\frac{x_K}{\bar{u}_K} - t_1 \right) \right] \right\}$$

where

t_1 = time precipitation begins

Λ = percent of material removed per unit time

For the case in which the vertical extent of the source is less than the depth of the layer (Model 3), the term $(z_{TK} - z_{BK})$ in Equation (3-35) is set equal to unity.

When changes in layer structure occur at time t^* , the ground deposition WD_L due to precipitation scavenging in the L^{th} layer is given by the expression

$$WD_L \{x_L, y_L, z=0\} = \frac{\Lambda Q_K (z_{TL} - z_{BL})}{\sqrt{2\pi} \sigma_{yLK} \bar{u}_L} \left\{ \exp \left[-\frac{1}{2} \left(\frac{y_L}{\sigma_{yLK}} \right)^2 \right] \right\} \quad (3-36)$$

$$\left\{ \exp \left[-\Lambda \left(\frac{x_L}{\bar{u}_L} + t^* - t_o \right) \right] \right\}$$

The above equations give the contribution to total deposition at the ground from precipitation scavenging in the K^{th} or L^{th} layer. Total ground deposition is obtained by summing the contributions from all layers through which precipitation is falling at points on the reference grid coordinate system. The height of the top of the uppermost layer through which precipitation is falling z_{lim} must be supplied as an input to the computer program. The height z_{lim} must correspond to the height of one of the layers selected for the dosage or concentration calculations.

The dosage or concentration at a point in space, assuming precipitation scavenging occurs, is obtained by multiplying the appropriate dosage or concentration equation by the exponential term in Equation (3-35) or (3-36) containing the coefficient Λ .

3.8 MODEL 7

This model is used to calculate the ground deposition due to gravitational settling. The basic source configuration is an area source of finite lateral extent and unit vertical extent. Other source configurations are treated by summing the deposition at the ground resulting from a number of basic sources

arranged to simulate the desired configuration. The model is essentially a tilted plume model in which the effects of wind shear are taken into account. The axis of a particle or droplet cloud of a given settling velocity intersects the ground plane at a distance from the source and at an angle from the mean surface wind direction that are proportional to the total angular wind shear and the residence time of the settling material in the layers between the source and the ground surface. In any layer the inclination of the cloud axis from the horizontal is given by $\tan^{-1} V_s / \bar{u}$, where V_s is the particle or droplet settling velocity and $\bar{u}$ is the mean transport wind speed in the layer. In all cases, material released in the K^{th} layer and dispersed upwards by turbulence is assumed to be reflected downwards at the interface of the K^{th} and $(K + 1)^{\text{th}}$ layers. The basic model is used to calculate the ground-level deposition pattern for a single value of the settling velocity. The total deposition pattern is obtained by summing the results for all settling velocities representative of the particle or droplet size distribution of the released material on a reference coordinate grid system.

In the computer program, provision is made for calculating deposition from a source which fills the layer in the vertical and for a source in which the vertical extent is less than the depth of the layer. These models are described below.

3.8.1 Gravitational Deposition Model for a Source that Extends Vertically through Entire Layer

Ground-level deposition by gravitational settling for a source that extends vertically through the entire layer and in which the material is uniformly distributed in the vertical is calculated from the following expression for an area source at height H_{nK}

$$DEP_{nK} = \frac{f_i Q_K T_K}{2\pi \sigma_{ynK} \zeta_K} \left\{ M_{nK} + N_{nK} \right\} \left\{ \exp \left[- \frac{1}{2} \left(\frac{y_s}{\sigma_{ynK}} \right)^2 \right] \right\} \quad (3-37)$$

where

- f_i = fraction of particles or droplets with settling velocity V_s
- Q_K = source emission rate in layer K
- T_K = source emission time in layer K
- ζ_K = number of elementary sources in layer K for simulating a uniform vertical distribution
- y_s = lateral distance from the deposition axis of particles or droplets with settling velocity V_s
 $= R_s \sin \phi_s$
- R_s = radial distance in the horizontal plane from the source to a receptor
- ϕ_s = angle between the axis of the ground-level deposition pattern and the radial connecting source and receptor for settling velocity V_s

The terms M_{nK} and N_{nK} are vertical terms that include provision for reflection from the boundary between the K^{th} and $(K+1)^{th}$ layers. These terms are defined by the expressions

$$M_{nK} = \left\{ \frac{\bar{\beta}_K H_{nK} + ((1-\bar{\beta}_K) V_s x_s / \bar{u}_{nK})}{\sigma'_{EnK}(x_s)^{1+\bar{\beta}_K}} \right\} \left\{ \exp \left[- \frac{1}{2} \left(\frac{H_{nK} - (V_s x_s / \bar{u}_{nK})}{\sigma'_{EnK}(x_s)^{\bar{\beta}_K}} \right)^2 \right] \right\} \quad (3-38)$$

$$N_{nK} = \left\{ \frac{\bar{\beta}_K (2z_{TK} - H_{nK}) - ((1-\bar{\beta}_K) V_s x_s / \bar{u}_{nK})}{\sigma'_{EnK}(x_s)^{1+\bar{\beta}_K}} \right\} \left\{ \exp \left[- \frac{1}{2} \left(\frac{2z_{TK} - H_{nK} + (V_s x_s / \bar{u}_{nK})}{\sigma'_{EnK}(x_s)^{\bar{\beta}_K}} \right)^2 \right] \right\} \quad (3-39)$$

where

$$x_s = R_s \cos \phi_s$$

$$\bar{u}_{nK} = \text{mean wind transport speed in the layer between } H_{nK} \text{ and the ground}$$

$$= \frac{\left(X_{nK}^2 + Y_{nK}^2 \right)^{1/2}}{H_{nK}} V_s$$

$$X_{nK} = \frac{\bar{u}_{HK}}{V_s b_K} \left\{ \sin \left[b_K (H_{nK} - z_{BK}) + S\theta'_{K-1} \right] - \sin(S\theta'_{K-1}) \right\} \\ + \sum_{i=1}^{K-1} \left\{ \frac{\bar{u}_i}{V_s b_i} \left[\sin(S\theta'_i) - \sin(S\theta'_{i-1}) \right] \right\}$$

$$Y_{nK} = \frac{\bar{u}_{HK}}{V_s b_K} \left\{ \cos \left[b_K (H_{nK} - z_{BL}) + S\theta'_{K-1} \right] - \cos(S\theta'_{K-1}) \right\} \\ + \sum_{i=1}^{K-1} \left\{ \frac{-\bar{u}_i}{V_s b_i} \left[\cos(S\theta'_i) - \cos(S\theta'_{i-1}) \right] \right\}$$

$$S\theta'_{K-1} = \sum_{i=1}^{K-1} \Delta\theta'_i$$

$$S\theta'_K = \sum_{i=1}^K \Delta\theta'_i$$

$$b_K = \frac{S\theta'_K - S\theta'_{K-1}}{z_{TK} - z_{BK}}$$

The quantity $\bar{u}_{HK}$ is the mean layer wind speed between the height H_K and the base of the K^{th} layer. The following expressions define the mean layer wind speeds in the surface layer ($K = 1$) and the layers above the surface layer ($K > 1$):

$$\bar{u}_{HK} \{K=1\} = \frac{\bar{u}_R \left[(H_{nK} \{K=1\})^{1+p} - (z_R)^{1+p} \right]}{(1+p) (H_{nK} \{K=1\} - z_R) (z_R)^p} \quad (3-40)$$

$$\bar{u}_{HK} \{K>1\} = \left[\left(\frac{\bar{u}_{TK} - \bar{u}_{BK}}{z_{TK} - z_{BK}} \right) \left(\frac{H_{nK} - z_{BK}}{2} \right) \right] + \left[\frac{\bar{u}_{BK}}{2} \right] \quad (3-41)$$

The mean standard deviation of the wind elevation angle in radians in the layer between H_{nK} and the base of the K^{th} layer is given by the expressions

$$\sigma'_{EnK} \{K=1\} = \frac{\sigma_{ER} \left[(H_{nK} \{K=1\})^{1+q} - (z_R)^{1+q} \right]}{(1+q) (H_{nK} \{K=1\} - z_R) (z_R)^q} \left(\frac{\pi}{180} \right) \quad (3-42)$$

$$\begin{aligned} \sigma'_{EnK} \{K>1\} = & \frac{1}{H_{nK}} \left\{ \left[\sigma'_{EnK} \{K=1\} \right] + \left[\sum_{i=2}^{K-1} \sigma'_{Ei} (z_{Ti} - z_{Bi}) \right] \right. \\ & \left. + \frac{\pi (H_{nK} - z_{BK})}{360} \left[\left(\frac{\sigma_{ETK} - \sigma_{EBK}}{z_{TK} - z_{BK}} \right) (H_{nK} - z_{BK}) + \sigma_{EBK} \right] \right\} \end{aligned} \quad (3-43)$$

The vertical diffusion coefficient in the layer between H_{nK} and the base of the K^{th} layer is given by the terms

$$\bar{\beta}_K \{K=1\} = \beta_K \quad (3-44)$$

$$\begin{aligned} \bar{\beta}_K \{K>1\} = \frac{1}{H_{nK}} & \left\{ \left[\sum_{i=1}^{K-1} \beta_i (z_{Ti} - z_{Bi}) \right] \right. \\ & \left. + \left[\beta_K (H_{nK} - z_{BK}) \right] \right\} \end{aligned} \quad (3-45)$$

The standard deviation of the crosswind distribution of material downwind from the source, σ_{ynK} , is given by the expression

$$\sigma_{ynK} = \left\{ \left[\sigma'_{AnK} \left(\frac{x_s + x_{yK}}{x_r} \right)^{\bar{\alpha}_K} \right]^2 + \left[\Delta Y_K \right]^2 \right\}^{1/2} \quad (3-46)$$

where

σ'_{AnK} = mean standard deviation of the wind azimuth angle in radians in the layer between H_{nK} and the ground

$$\sigma'_{AnK} \{K=1\} = \frac{\sigma_{AR} \left[(H_{nK} \{K=1\})^{1+m} - (z_R)^{1+m} \right]}{(1+m) (H_{nK} \{K=1\} - z_R) (z_R)^m} \quad \left(\frac{\pi}{180} \right)$$

$$\begin{aligned} \sigma'_{AnK} \{K>1\} = \frac{1}{H_{nK}} & \left\{ \left[\sigma'_{AnK} \{K=1\} \right] + \left[\sum_{i=2}^{K-1} \sigma'_{Ai} (z_{Ti} - z_{Bi}) \right] \right. \\ & \left. + \frac{\pi (H_{nK} - z_{BK})}{360} \left[\left(\frac{\sigma_{ATK} - \sigma_{BTK}}{z_{TK} - z_{BK}} \right) (H_{nK} - z_{BK}) + \sigma_{ABK} \right] \right\} \end{aligned}$$

x_{yK} = lateral virtual distance in the layer

$$= x_r \left(\frac{\sigma_{yo\{K\}}}{\sigma_{AnK} x_r} \right)^{1/\bar{\alpha}_K}$$

$$\Delta Y_K = \frac{\sigma'_{EnK} (x_s)^{\beta_K} Y_{nK}}{H_{nK}}$$

The mean lateral diffusion coefficient in the layer between H_{nK} and the surface is given by the terms

$$\bar{\alpha}_K\{K=1\} = \alpha_K \quad (3-47)$$

$$\begin{aligned} \bar{\alpha}_K\{K>1\} = \frac{1}{H_{nK}} & \left\{ \left[\sum_{i=1}^{K-1} \alpha_i (z_{Ti} - z_{Bi}) \right] \right. \\ & \left. + \left[\alpha_K (H_{nK} - z_{BK}) \right] \right\} \end{aligned} \quad (3-48)$$

The number of elementary sources ζ_K required to simulate a uniformly distributed source in the vertical is given by the expression

$$\zeta_K = (z_{TK} - z_{BK}) / \Delta h_K \quad (3-49)$$

where

Δh_K = vertical separation of elemental area sources in the K^{th} layer

$$= R \sigma'_{EH} \left(X_{HK}^2 + Y_{HK}^2 \right)^{1/2} \left(1 + \frac{V_s}{\bar{u}_{HK}} \right)^{1/2}$$

R = a constant value depending on the accuracy desired in simulating a vertical line source configuration. A value of R = 0.45 yields deposition estimates that are within 10 percent of the true value

$$\sigma'_{EH} = \sigma'_{EnK} \text{ with } H_{nK} = \frac{1}{3} (z_{TK} - z_{BK}) + z_{BK}$$

$$X_{HK} = X_{nK} \text{ with } H_{nK} = \frac{1}{3} (z_{TK} - z_{BK}) + z_{BK}$$

$$Y_{HK} = Y_{nK} \text{ with } H_{nK} = \frac{1}{3} (z_{TK} - z_{BK}) + z_{BK}$$

$$\bar{u}_{HK} = \bar{u}_{nK} \text{ with } H_{nK} = \frac{1}{3} (z_{TK} - z_{BK}) + z_{BK}$$

The angle between the axis of the ground-level deposition pattern and the radial connecting source and receptor for settling velocity V_s is defined by the expression

$$\phi_s = \left| \theta_1 - 180 + \Phi_s - \theta_R \right| \quad (0 < \theta_1 < 180) \quad (3-50)$$

$$\phi_s = \left| \theta_1 + 180 + \Phi_s - \theta_R \right| \quad (180 < \theta_1 < 360)$$

where

θ_1 = mean wind direction at the reference height z_R

θ_R = angle between north and a line connecting source and receptor

$$\Phi_s = \tan^{-1} \left(\frac{Y_{nK}}{X_{nK}} \right)$$

3.8.2 Gravitational Deposition Model for a Volume Source in the Kth Layer

For a volume source at height H_{SK} in the Kth layer, the ground-level deposition from gravitational settling is given by the expression

$$DEP_{SK} = \frac{f_i Q_{SK}}{2\pi \sigma_{ySK}} \left\{ M_{SK} + N_{SK} \right\} \left\{ \exp \left[-\frac{1}{2} \left(\frac{y_{SK}}{\sigma_{ySK}} \right)^2 \right] \right\} \quad (3-51)$$

where the subscript SK indicates that the parameters refer to a single source in the Kth layer. The subset of equations which define the SK subscripted parameters is the same as the subset defining the terms in Equation (3-37) except the following substitution is made for the term x appearing in Equations (3-38) and (3-39):

$$x_s = R_{SK} \cos \phi_{SK} + x_{zSK} \quad (3-52)$$

where

x_{zSK} = the vertical virtual distance for the volume source

$$= x_r \left(\frac{\sigma_{zo}\{SK\}}{\sigma'_{ESK} x_r} \right)^{1/\beta_K}$$

σ'_{ESK} = mean standard deviation of the wind elevation angle in the layer between H_{SK} and the ground

$\sigma_{zo}\{SK\}$ = vertical source dimension of the volume source

In using Equation (3-51), deposition patterns from all values of V_{SK} representative of the particle or droplet size distribution of the volume source are summed on a reference coordinate system to obtain the total deposition pattern.

3.9 USE OF THE MULTI-LAYER CONSTRUCT FOR COLD SPILLS AND FUEL LEAKS IN THE SURFACE LAYER

The multi-layer construct can be used, through adaptation of model inputs, to estimate concentration fields downwind from cold spills at the surface and fuel leaks near ground-level. As mentioned in Section 2.5 above, the concentration model for continuous source emission is similar in form to the dosage model for instantaneous sources. In the computer program, Model 3 described in Section 3.3 above can thus be used as a concentration model for surface spills and leaks if proper adjustments are made in values of the input parameters. The adjustments include the requirement that σ_A , σ_E and $\bar{u}$ be specified at source height. Also, the reference value of σ_A must be adjusted to an averaging time τ . The averaging time τ will usually be either the source emission time, or a period for which toxicity levels have been established. The requisite adjustments in meteorological and source input parameters when Model 3 is used to calculate concentration fields downwind from cold spills and fuel leaks are described in Sections 4.2.2 and 4.3.2 below.

SECTION 4

DESCRIPTION OF THE COMPUTER PROGRAM FOR THE KSC MULTI-LAYER DIFFUSION MODEL

The equations for the multi-layer construct given in Section 3 have been programmed for machine calculations. This section describes the general organization of the program as well as the meteorological and source inputs required for various types of toxic fuel hazard problems. As explained below, the primary emphasis has been placed on machine calculations of toxic fuel hazards arising from normal and abnormal launches and vehicle destructs in a reference volume that extends vertically from the earth's surface to a height of 5 kilometers and extends laterally to maximum distances of the order of 100 kilometers from Kennedy Space Center. At present, calculations of the hazard arising from cold surface spills and fuel leaks are made in the program by using the dosage form of the multi-layer model for a volume source. While this procedure gives the appropriate estimates of ground-level concentrations, certain alterations in the source and meteorological inputs are required. For future use, it would probably be desirable to modify the program so that the cold-spill and fuel-leak calculations can be made directly as a program option. There was not time to accomplish this under the present contract.

4.1 ORGANIZATION OF THE COMPUTER PROGRAM

The computer program for the KSC multi-layer diffusion model is written in FORTRAN V and has been run on the UNIVAC 1108 machine at the University of Utah Computer Center. The program contains 22 subroutines, including the main driver, and requires 33280₁₀ executable case locations.

Figure 4-1 shows in block diagram form the seven diffusion models and the five major logic sections of the computer program. Section 1 provides for

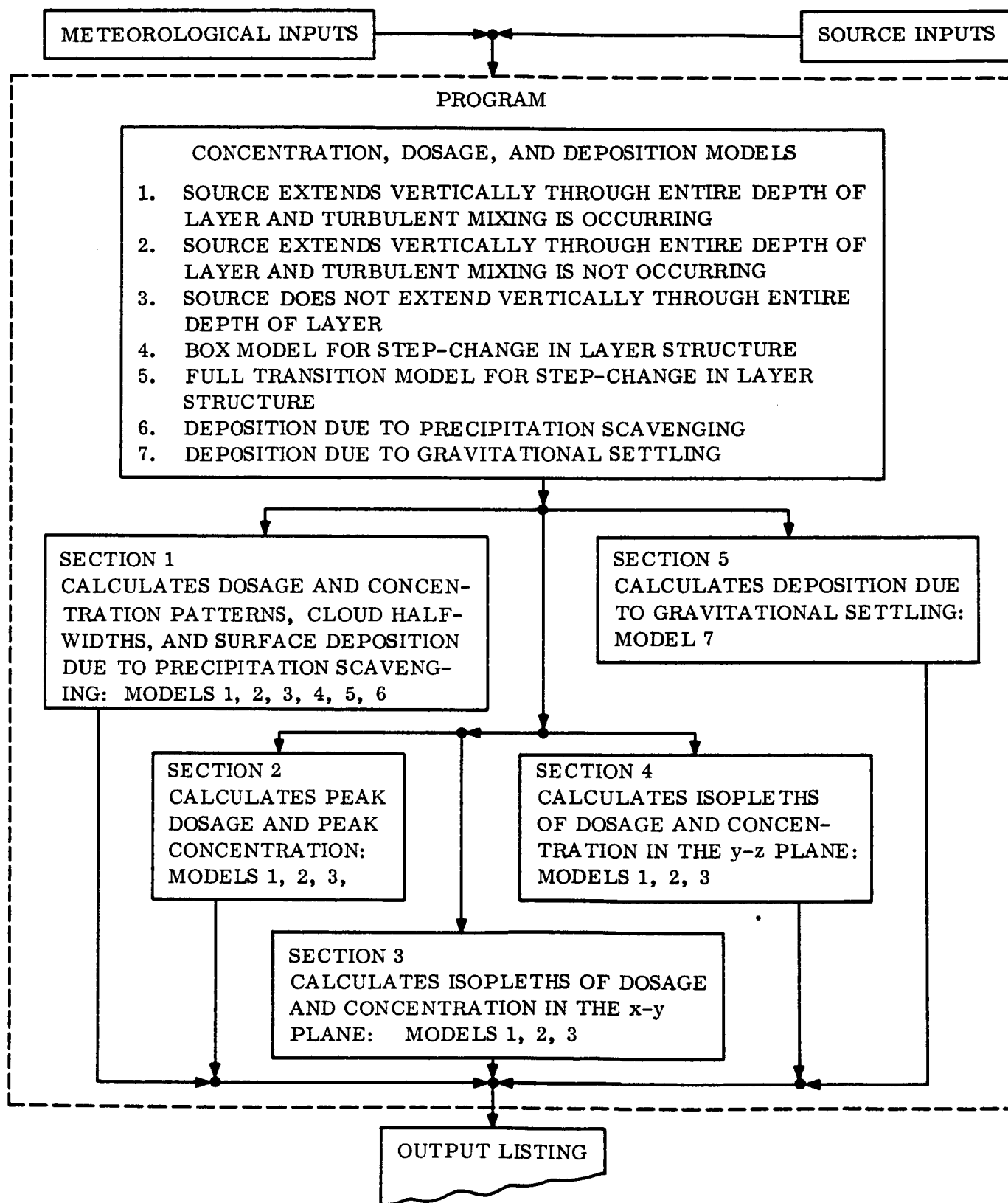


FIGURE 4-1. Block diagram of the computer program for the KSC multi-layer diffusion model.

calculations of concentration and dosage at selected points referenced to a three-dimensional coordinate system. The origin of this system can be located at any convenient point in the ground plane and either Cartesian or polar coordinates may be used. If Cartesian coordinates are employed, the positive y-axis is directed toward true north and the positive x-axis is directed toward east. In the polar coordinate system, north is 0 degrees and east is 90 degrees. The maximum number of receptor locations that can be specified in the ground plane is 10,000. Additionally, a maximum of 100 receptor locations may be specified along the vertical above each receptor point in the ground plane. Section 1 of the program also contains transformation equations that relate the cloud-layer geometry, which is referenced to the layer mean wind direction, to the ground-plane reference grid. As shown in Figure 4-1, Logic Section 1 uses Models 1 through 6 to calculate layer concentration and dosage patterns, surface deposition due to washout or precipitation scavenging, and cloud half-widths.

Section 2 of the computer program contains the logic for calculating maximum concentrations and peak dosages for Models 1, 2 and 3. The logic required to calculate concentration and dosage isopleths for Models 1, 2 and 3 is in Sections 3 and 4 of the program; Section 3 refers to isopleths in the x-y plane while Section 4 refers to isopleths in the y-z plane. Logic Sections 1 through 4 can be combined, if desired, in a single execution. The logic in Section 5 provides for calculations of surface deposition due to gravitational settling from Model 7. The deposition is calculated at the receptor locations specified for the ground-plane reference grid mentioned above.

A detailed explanation of the operation of the computer program is given in Appendix A and a complete program listing is given in Appendix B. The program flow chart is contained in Appendix C. A sample problem including input card formats and a listing of the program output is given in Appendix D. Appendix E contains example program calculations of toxic fuel hazards arising from normal launch, vehicle destruct, and a surface cold spill. Assembly time for the

program is 30 seconds and the maximum run time experienced for the example calculations described in Section 6 is 3.5 minutes.

4.2 METEOROLOGICAL INPUTS

4.2.1 Multi-Layer Construct

Meteorological inputs for the multi-layer construct are listed in Table 4-1. Selection of meteorological inputs begins with the assignment of layer boundaries based on the vertical profiles of wind, temperature, and humidity within this volume. The vertical profiles used to determine layer boundaries may be either observed or forecast, and should be representative of the structure within a reference volume. Except for the cold spill and fuel-leak problems, the reference volume at Kennedy Space Center extends to a height of 5 kilometers and extends horizontally to a maximum distance of about 100 kilometers. Spatial or temporal variations in structure within the volume may be accommodated by step changes in model inputs, as explained in Sections 3.5 and 3.6. Layer boundaries are assigned principally on the basis of KSC radiosonde, Jimsphere, and 150-meter tower data. Vertical profiles of wind speed, wind direction, temperature, and dewpoint are inspected for major discontinuities, and layer boundaries are assigned to isolate regions of different thermal stability and wind shear. It should be noted that the assignment of layer boundaries removes the necessity for specifying the depth of the mixing layer H_m as a separate model input. When a ground-based temperature inversion exists, the top of the surface layer is assumed to coincide with the top of the inversion. The procedure for subdividing the atmosphere into layers is illustrated in Appendix E of this report and in Section 3 of the Final Report under Contract No. NAS8-30503 (Record, et al., 1970). After the layer boundaries have been specified, values of wind speed, wind direction and potential temperature are assigned at the top and bottom of each layer, and at a reference height within the surface layer. The

TABLE 4-1
METEOROLOGICAL INPUT PARAMETERS FOR
MULTI-LAYER CONSTRUCT

Parameter	Definition
$\sigma_{AR} \{ \tau_{oR} \}$	Standard deviation of wind azimuth angle in degrees at z_R for reference time τ_{oR}
σ_{ER}	Standard deviation of wind elevation angle in degrees at z_R
$\bar{u}_R$	Mean wind speed at z_R
z_R	Reference height in surface layer
$\sigma_{ATK} \{ \tau_{oK} \}, \sigma_{ABK} \{ \tau_{oK} \}$	Standard deviation of wind azimuth angle in degrees at the top and base of the K^{th} layer for reference time τ_{oK}
$\sigma_{ETK}, \sigma_{EBK}$	Standard deviation of wind elevation angle in degrees at the top and base of the K^{th} layer
$\bar{u}_{TK}, \bar{u}_{BK}$	Mean wind speed at the top and base of the K^{th} layer
θ_{TK}, θ_{BK}	Mean azimuth wind direction in degrees at the top and base of the K^{th} layer
Θ_{TK}, Θ_{BK}	Potential temperature at the top and base of the K^{th} layer
z_{TK}, z_{BK}	Height of the top and base of the K^{th} layer
α_K	Lateral diffusion coefficient in the K^{th} layer
β_K	Vertical diffusion coefficient in the K^{th} layer
Λ	Washout coefficient
z_{lim}	Height interval through which precipitation falls
t_1	Time precipitation begins
t^*	Time at which change in layer structure occurs

potential temperatures are used to calculate the effective source height in the layer when heat is generated during the release mode. This calculation is performed outside the program.

Values of the turbulence parameters σ_A and σ_E must also be specified at the reference height z_R and at all layer boundaries. For general application at Cape Kennedy, z_R is assigned a value of 18 meters, corresponding to the lowest measurement height on the NASA 150-meter Meteorological Tower. The parameters $\sigma_{AR} \{\tau_{oR}\}$ and σ_{ER} are obtained from Figures 4-2 and 4-3, using the 18-meter mean wind speed and the temperature difference ΔT between 3 meters and 60 meters as predictors. In the absence of an observed ΔT , the following guidelines can be used to select an appropriate ΔT value. Under strong insolation, temperature differences of -2 to -1 degrees Celsius may be anticipated. Zero temperature differences occur during the morning and afternoon transition times and in the presence of overcast skies with moderate or strong winds. Estimates of the times of occurrence of the two diurnal transition periods throughout the year are given by the curves in Figure 4-4. Positive values of ΔT occur at night during periods of clear skies and light winds. According to Figures 4-2 and 4-3, $\sigma_{AR} \{\tau_{oR}\}$ and σ_{ER} are relatively insensitive to the magnitude of ΔT under stable conditions.

Model input values for $\sigma_A \{\tau_{oK}\}$ and σ_E at the top of the surface layer ($K = 1$) and, possibly, at the top of the $K = 2$ layer are obtained from the following expressions:

- Under all stability conditions

$$\sigma_{ATK} \{\tau_{oK}\} = \sigma_{AR} \{\tau_{oR}\} \left(\frac{z_{TK}}{z_R} \right)^{-p}, \quad K = 1 \quad (4-1)$$

$$\sigma_{ATK} \{\tau_{oK}\} = \sigma_{ARK} \{\tau_{oK}\} \left(\frac{z_{TK}}{z_{BK}} \right)^{-p}, \quad K = 2 \quad (4-2)$$

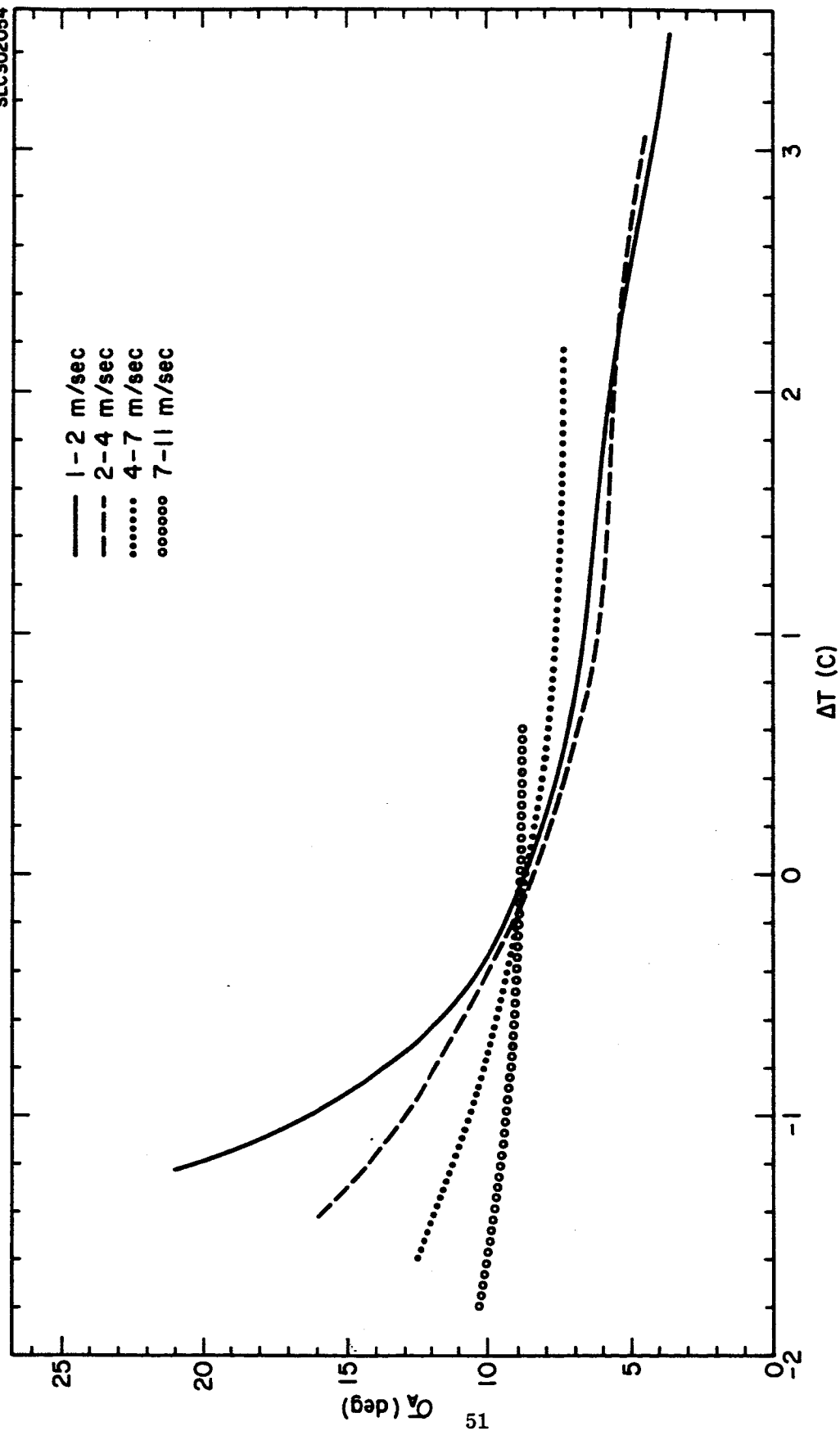


FIGURE 4-2. Dependence of Q_A at 18 meters on stability and wind speed at 18 meters.
 ΔT is the temperature at 60 meters minus the temperature at 3 meters.

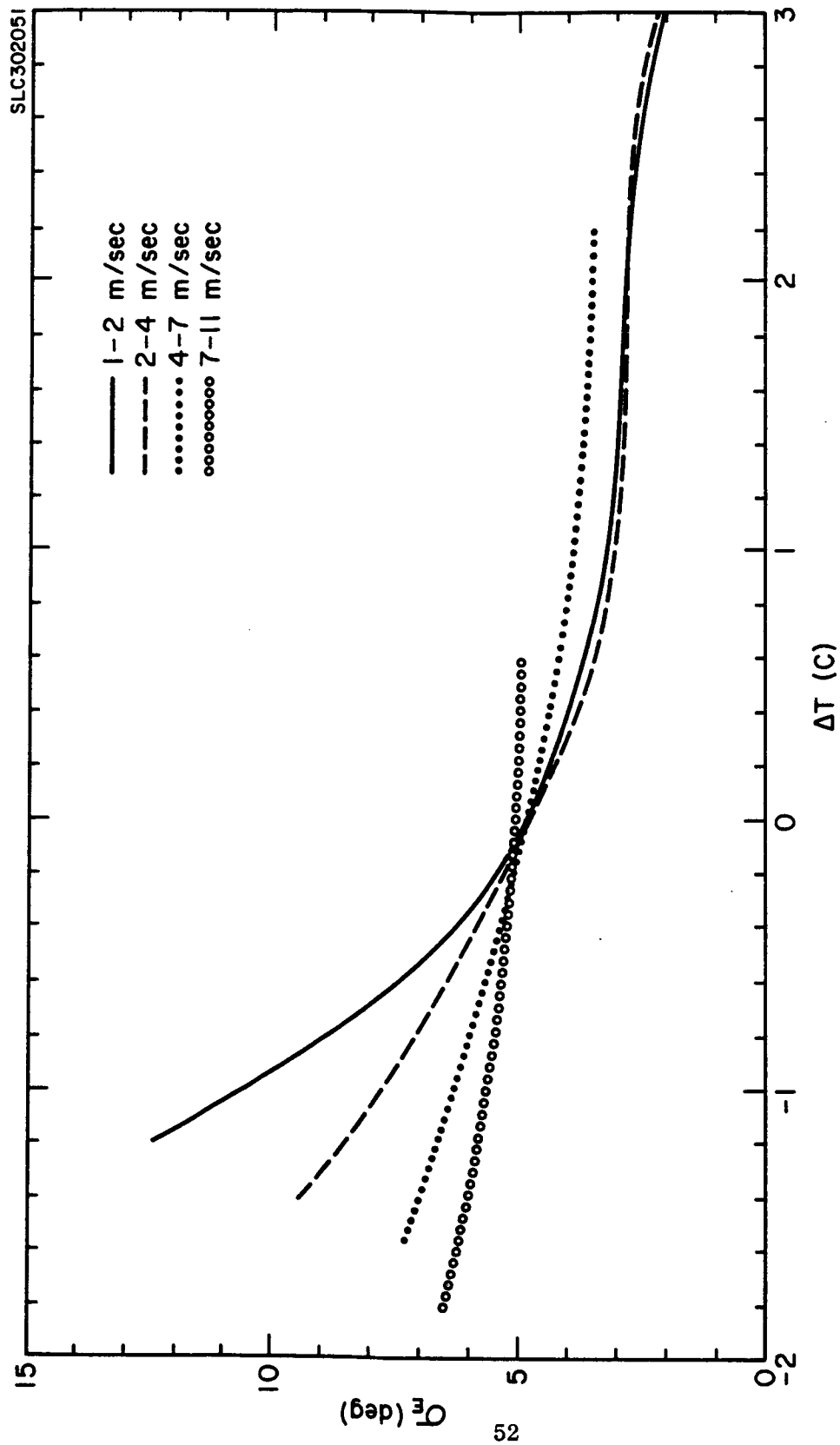


FIGURE 4-3. Dependence of Q_E at 18 meters on stability and wind speed at 18 meters.
 ΔT is the temperature at 60 meters minus the temperature at 3 meters.

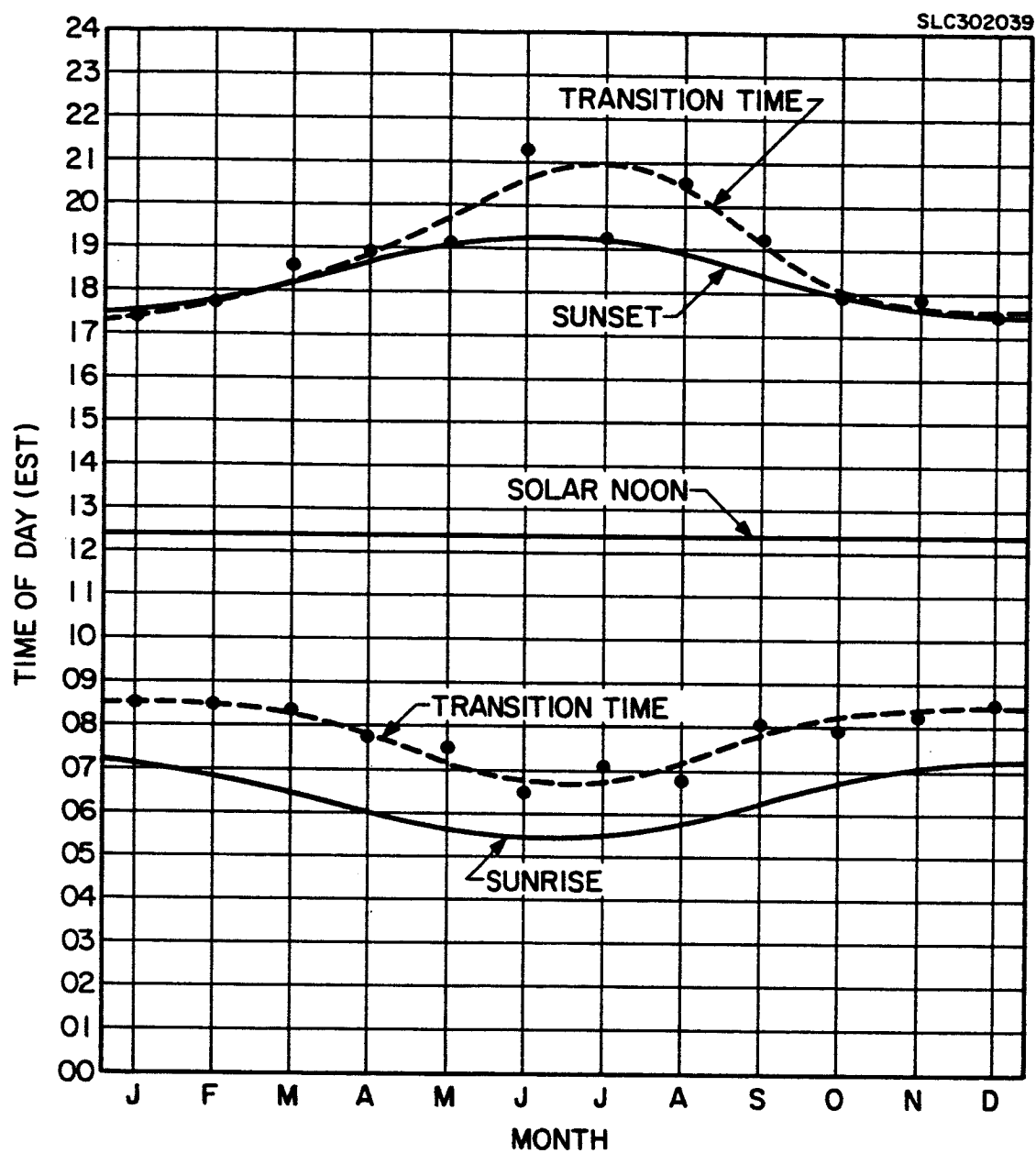


FIGURE 4-4. Seasonal variations in the time of transition from lapse to inversion (above) and from inversion to lapse (below) with respect to sunset and sunrise.

where $\sigma_{ARK}\{\tau_{oK}\}$ for $K = 2$ and $\sigma_{ATK}\{\tau_{oK}\}$ for $K = 1$ are equivalent

- Under unstable conditions

$$\sigma_{ETK} = \sigma_{ER} \left(\frac{z_{TK}}{z_R} \right)^{0.3-p}, \quad K = 1 \quad (4-3)$$

$$\sigma_{ETK} = \sigma_{EBK} \left(\frac{z_{TK}}{z_{BK}} \right)^{0.3-p}, \quad K = 2 \quad (4-4)$$

$$\text{where } \sigma_{EBK}\{K=2\} = \sigma_{ETK}\{K=1\}$$

- Under near-neutral and stable conditions

$$\sigma_{ETK} = \sigma_{ER} \left(\frac{z_{TK}}{z_R} \right)^{-p}, \quad K = 1 \quad (4-5)$$

$$\sigma_{ETK} = \sigma_{BTK} \left(\frac{z_{TK}}{z_{BK}} \right)^{-p}, \quad K = 2 \quad (4-6)$$

$$\text{where } \sigma_{EBK}\{K=2\} = \sigma_{ETK}\{K=1\}$$

In the above expressions, the quantity p is the exponent in the power-law relationship for the vertical profile of mean wind speed as defined by

$$\bar{u}_{TK} = \bar{u}_R \left(\frac{z_{TK}}{z_R} \right)^p, \quad K = 1 \quad (4-7)$$

$$\bar{u}_{TK} = \bar{u}_{BK} \left(\frac{z_{TK}}{z_{BK}} \right)^p, \quad K = 2 \quad (4-8)$$

The requisite turbulence inputs for layers $K = 1, K = 2$ may be calculated from the above expressions or by means of the nomograms given in Appendix F. For simplicity, the meteorological inputs for the reference height z_R are generally assumed to be representative of the base of the surface layer. However, values for some other height may be calculated from the power-law expressions for the layer $K = 1$ given above if desired. Above the surface layers, turbulent mixing is assumed negligible; σ_A and σ_E are consequently set equal to zero at the boundaries of layers in which no turbulent mixing is occurring. In the computer program, these zero inputs are interpreted as $\sigma_A = 0.5$ degrees and $\sigma_E = 0.1$ degrees. Also, in the program, wind speeds less than 0.1 meters per second, supplied as inputs to the program, or obtained through use of the power-law expression for the vertical profile of mean wind speed in the program, are interpreted as $\bar{u} = 0.1$ meters per second.

The diffusion coefficients α_K, β_K are set equal to unity for all releases.

Calculations of the effects of precipitation scavenging require specification of the washout coefficient Λ , the height interval through which precipitation falls z_{lim} , and the time after release at which the precipitation starts t_1 . Existing knowledge of Λ is summarized by Engelmann (see Slade, 1968, pp. 213-220). In the absence of reliable estimates of Λ , a value of $\Lambda = 10^{-3}$ is suggested for hazard calculations. This maximizes the rate of removal of material by precipitation scavenging and may therefore lead to overestimates of surface deposition resulting from this process.

4.2.2 Surface Cold Spill and Fuel Leak

As explained in Section 3.9, the dosage form of Model 3 is used in the computer program to calculate concentration fields downwind from

surface cold spills and fuel leaks that occur near ground level. The meteorological inputs given in Table 4-1, which refers only to the surface layer ($K = 1$), must be adapted for this purpose.

For correct application of Model 3 to cold spills and fuel leaks, values of σ_A , σ_E and $\bar{u}$ actually used in the program must apply at the height of release H . The mean wind speed $\bar{u}$ at release height H can be calculated from the power-law relationship

$$\bar{u}\{H\} = \bar{u}_R \left(\frac{H}{z_R} \right)^p \quad (4-9)$$

where the value of p is given by Figure 4-5. Appropriate values of σ_A and σ_E at H can be found from the following expressions:

- Under all stability conditions

$$\sigma_A\{\tau_o, H\} = \sigma_{AR}\{\tau_o\} \left(\frac{H}{z_R} \right)^{-p} \quad (4-10)$$

- Under unstable conditions

$$\sigma_E\{H\} = \sigma_{ER} \left(\frac{H}{z_R} \right)^{0.3-p} \quad (4-11)$$

- Under near-neutral and stable conditions

$$\sigma_E\{H\} = \sigma_{ER} \left(\frac{H}{z_R} \right)^{-p} \quad (4-12)$$

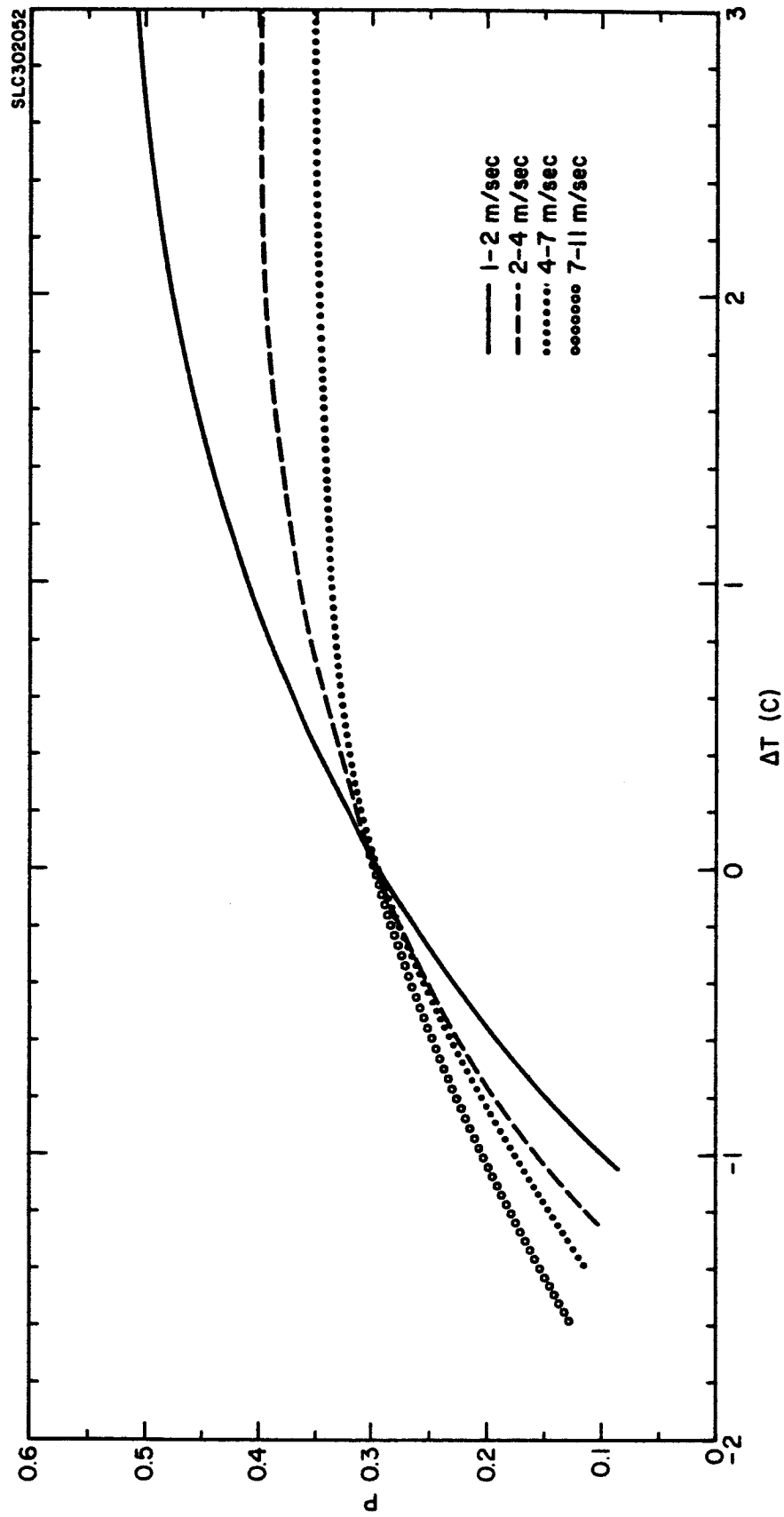


FIGURE 4-5. Dependence of p on stability and the wind speed at 18 meters. ΔT is the temperature at 60 meters minus the temperature at 3 meters.

The nomograms in Appendix F can also be used to calculate $\sigma_A\{\tau_o, H\}$, $\sigma_E\{H\}$, and $\bar{u}\{H\}$ from the values of these parameters at the reference height z_R .

Adaptation of the computer program meteorological inputs of Table 4-1 for the multi-layer construct to hazard calculations for surface cold spills and fuel leaks is shown in Table 4-2. Values used for meteorological parameters from Table 4-1 in these calculations are entered in the second column of Table 4-2. The asterisk superscript denotes that a substitute or dummy value is required for the cold spill and fuel leak applications.

4.3 SOURCE INPUTS

4.3.1 Normal and Abnormal Launch, Vehicle Destruct

Source input parameters to the multi-layer diffusion model program are listed in Table 4-3 for normal and abnormal launch and vehicle destruct. The units for the source strength Q_K in each layer depend on the source configuration and the layer model used. When the source fills the layer, Q_K is expressed in terms of the total mass per unit depth of the layer. For a volume source, Q_K is simply the total mass available for downwind transport and dispersion. When ground deposition due to gravitational settling is calculated (see Section 3.8) for a source that fills the layer, Q_K is given by the mass released per unit time. The vehicle residence time T_K in the layer is used to convert the source strength for this special case into the units required by Equation (3-37). For calculating ground deposition due to gravitational settling downwind from a single volume source in the layer, the source strength Q_{SK} is expressed in terms of total mass released.

TABLE 4-2
METEOROLOGICAL INPUT PARAMETERS FOR SURFACE COLD SPILL
AND FUEL LEAK HAZARD CALCULATIONS

PARAMETERS		DEFINITION
From Table 4-1	Substitution	
$\sigma_{AR}\{\tau_{OR}\}^*$	$\sigma_A\{\tau_o, H\}$	Standard deviation of wind azimuth angle in degrees at height of source H for reference time τ_o
σ_{ER}^*	$\sigma_E\{H\}$	Standard deviation of wind elevation angle in degrees at height of source H
z_R	z_R	Reference height of 18 meters
$\sigma_{ATK}\{\tau_{OK}\}^*,$ $\sigma_{ABK}\{\tau_{OK}\}^*$	$\sigma_A\{\tau_o, H\}$	
$\sigma_{ETK}^*, \sigma_{EBK}^*$	$\sigma_E\{H\}$	
$\bar{u}_{TK}^*, \bar{u}_{BK}^*$	$\bar{u}\{H\}$	Mean wind speed at height of source H
θ_{TK}, θ_{BK}	θ_{TK}, θ_{BK}	Mean wind direction at the top and base of the surface layer
z_{TK}, z_{BK}	$z_{TK}\{K=1\},$ $z_{BK}\{K=1\}$	Height above ground of the top and base of the surface layer
α_K		Lateral diffusion coefficient
β_K	1.0	Vertical diffusion coefficient

TABLE 4-3
SOURCE INPUT PARAMETERS FOR NORMAL AND ABNORMAL
LAUNCH, VEHICLE DESTRUCT

PARAMETER	DEFINITION
Q_K, Q_{SK}	Source strength expressed either as total mass of material in the K^{th} layer or as the total mass per meter of layer depth
H_K, H_{SK}	Effective height of source above ground
τ_K	Source emission time or cloud stabilization time
$\sigma_{xo}\{K\}$	Alongwind source dimension
$\sigma_{yo}\{K\}$	Crosswind source dimension
$\sigma_{zo}\{K\}$	Vertical source dimension
k	Decay coefficient
V_s	Settling velocity
f_i	Fraction of material with settling velocity V_s
T_K	Residence time of vehicle in layer K

Because of the large amounts of thermal energy that may be released during normal or abnormal launch, vehicle destruct, or hot spills, it is essential to have a satisfactory method of estimating the buoyant rise of material thus released. The following formula, after Briggs (see Record, et al., 1970), is recommended for use in estimating the buoyant cloud rise Δh :

$$\Delta h = 8.0 \left(\frac{Q'}{\Delta \Theta} \right)^{1/3} \quad (4-13)$$

where

Δh = cloud rise (meters)

Q' = energy released (kilocalories)

$\Delta \Theta$ = change in potential temperature over Δh

If the gradient of potential temperature with height is used instead of $\Delta \Theta$, the expression for Δh becomes

$$\Delta h = 4.76 \left(\frac{Q'}{\partial \Theta / \partial z} \right)^{1/4} \quad (4-14)$$

The effective height of the source H_K is thus given by

$$H_K = h + \Delta h \quad (4-15)$$

where h = height of source before the cloud is affected by buoyant rise.

Equation (4-14) fits cloud rise data from high-explosive detonations recently published by Church (1969). Susko, Kaufman, and Hill (1968) have shown that the plume rise formula for continuous sources given by Morton, Taylor, and Turner (1956) provide satisfactory estimates of the buoyant rise of exhaust plumes from statically fired rocket engines.

In Table 4-3, H_{SK} is the effective height above ground of a single volume source comprised of heavy particles or droplets and is used in the calculation of deposition at the ground due to gravitational settling (see Equation (3-51)). The height H_{SK} is also calculated from Equation (4-15) with H_{SK} substituted for H_K .

The time τ_K required for the cloud to become stabilized immediately following the emission process is dependent on the mode of release. In the case of a vehicle destruct or hot spill, τ_K is of the order of 100 seconds. For normal launches, the time required for cloud stabilization is approximately the same as the vehicle residence time in the layer.

The source dimensions σ_{x0} , σ_{y0} and σ_{z0} appearing in Table 4-3 also depend on the mode of release. Reliable source dimensions are probably best obtained from photographic measurements or observations of actual releases. Gifford (see Slade, 1968, pp. 103-105) discusses the quantitative use of plume observations to determine cloud dimensions. Under the assumptions that the distribution of material within the plume is Gaussian and the visible edge of the plume represents one-tenth of the axial concentration, the standard deviation of the concentration distribution is obtained by multiplying the observed plume dimension by the factor 1/4.3.

The use of Model 7 to calculate ground deposition due to gravitational settling requires that the distribution of settling velocities be specified. When the size distribution of the material is known, the distribution is partitioned into categories and the settling velocity is calculated for each category. Van der Hoven (see Slade, 1968, pp. 202-203) discusses the calculation of settling velocity and gives settling velocities for particles of density 2.5 and 5 grams per cubic centimeter. Johnson (1954, p. 230) presents a table of settling velocities for water droplets.

4.3.2 Surface Cold Spill and Fuel Leak

As mentioned previously, the dosage form of Model 3 is used to calculate concentration fields downwind from cold surface spills and fuel leaks

that occur near ground level. The source inputs listed in Table 4-2 must be adapted for this purpose for the source in the surface layer $K = 1$.

Since fuel leaks and evaporation from surface spills are semi-continuous sources, the source strength Q must be expressed in terms of mass per unit time. In the case of the surface spill, the release height is set equal to zero. For a fuel leak, the height at which the leak occurs is used.

For correct application of Model 3 to cold spills and fuel leaks, the source emission time τ must be adjusted for emission times greater than ten minutes. According to Hino (1968), and others, time-mean concentrations downwind from continuous sources are inversely proportional to the square root of the time τ , for values of τ ranging from about 10 to 60 minutes. For $\tau < 10$ minutes, a one-fifth power law is applicable (see Equation (2-12)). The computer program contains a routine that adjusts $\sigma_A\{\tau\}$ for source emission times less than 10 minutes according to the one-fifth power law, but has no provision for adjusting $\sigma_A\{\tau\}$ for source emission times greater than 10 minutes. Thus, when source emission times exceed 10 minutes, the following substitute value of τ must be used in the program:

$$\tau \text{ (input value)} = (\tau_0)^{-3/2} (\tau)^{5/2} \quad (4-16)$$

where τ_0 = reference time period between 10 and 60 minutes

τ = source emission time > 10 minutes for cold spills and fuel leaks

The use of Equation (4-16) to obtain the input value of τ causes the program to adjust $\sigma_A\{\tau\}$ according to the expression

$$\sigma_A'\{\tau\} = \sigma_A'\{\tau_0\} \left(\frac{\tau}{\tau_0} \right)^{1/2} \quad 10 \text{ min} < \tau < 60 \text{ min} \quad (4-17)$$

The source dimension σ_{yo} for surface spills can be obtained by dividing the crosswind dimension of the spill by 4.3. The vertical source dimension, σ_{zo} , is usually small. In the example hazard calculations in Section 5 and Appendix E, σ_{zo} has been arbitrarily set equal to 1 meter. The values of σ_{yo} and σ_{zo} in the case of a fuel leak are also likely to be small. In the absence of detailed observations, a value of 1 meter for both σ_{yo} and σ_{zo} is suggested for use in hazard calculations.

Adaptation of the computer program source inputs of Table 4-3 for the multi-layer construct to hazard calculations for surface cold spills and leaks is shown in Table 4-4. Values used for the source parameters from Table 4-3 in these calculations are entered in the second column of Table 4-4. The asterisk superscript denotes that a substitute value is required for the cold spill and fuel leak applications.

TABLE 4-4
SOURCE INPUT PARAMETERS FOR SURFACE COLD SPILL
AND FUEL LEAK HAZARD CALCULATIONS

PARAMETERS		DEFINITION
From Table 4-3	Substitution	
Q_K, Q_{SK}	Q	Source strength in terms of mass per unit time
H_K, H_{SK}	H	Release height
τ_K^*	τ	Source emission time
$\sigma_{xo}\{K\}$	σ_{xo}	Alongwind source dimension
$\sigma_{yo}\{K\}$	σ_{yo}	Crosswind source dimension
$\sigma_{zo}\{K\}$	σ_{zo}	Vertical source dimension
k	k	Decay coefficient

SECTION 5

GRAPHICAL PROCEDURES FOR ESTIMATING GROUND-LEVEL CONCENTRATIONS AND DOSAGES

Graphs and tables are given in this section for estimating ground-level concentrations and dosages resulting from normal and abnormal launches, vehicle destruct, fuel spills and fuel leaks. The estimates refer only to sources contained within the surface layer. The graphs give estimates of axial concentration and dosage as a function of travel distance, and the tables give the widths of selected isopleths. In addition, nomograms are presented that provide box-model estimates of axial concentration and dosage from quasi-instantaneous sources as a function of mixing depth for maximum travel distances of 100 kilometers. No allowance is made for depletion or for changes in atmospheric structure that may occur during cloud travel.

5.1 SELECTION OF STABILITY CATEGORIES

For convenience, atmospheric conditions within the surface layer at KSC are described by stability categories similar to those used by Gifford (1961), Pasquill (1961), and Turner (1969). In preparing the graphs and tables of Sections 5.2 and 5.4, seven stability categories were used based on an analysis of meteorological data collected at NASA's 150-meter Tower Facility (Record, et al., 1970). The first step in developing the stability categories for KSC was to abstract values of the meteorological parameters σ_A , σ_E and p from Figures 4-2, 4-3 and 4-5, respectively, for selected ΔT values and for the four wind speed classes. The results are shown in Table 5-1. The temperature differences ΔT in the column headings of the table refer to heights of 3 and 60 meters. The wind speed and ΔT classes in Table 5-1 were then combined into the seven stability categories shown in Table 5-2. Average values of σ_A , σ_E and p for each stability category, which are shown in Table 5-3, were used to calculate concentration and

TABLE 5-1
VALUES OF σ_A , σ_E AND p FOR SELECTED STABILITY AND WIND SPEED CLASSES

Wind Speed at 18m (m sec ⁻¹)	STABILITY CLASS				
	Very Unstable ($\Delta T = -1.4C$)	Slightly Unstable ($\Delta T = -0.8C$)	Near-Neutral or Transitional ($\Delta T = 0C$)	Slightly Stable ($\Delta T = 0.4C$)	Very Stable ($\Delta T = 2.0C$)
1-2	σ_A (deg) 25	14	8.5	7.5	5.5
	σ_E (deg) 15	9	5	4	3
	p 0.05	0.15	0.29	0.35	0.47
2-4	σ_A (deg) 16	12	8.5	7.5	5.5
	σ_E (deg) 9.5	7	5	4	3
	p 0.07	0.19	0.29	0.33	0.39
4-7	σ_A (deg) 12	10	8.5	8	7
	σ_E (deg) 7	6	5	4.5	3.5
	p 0.12	0.20	0.29	0.32	0.34
7-11	σ_A (deg) 10	9.5	8.5	8.5	--
	σ_E (deg) 6	5.5	5	5	--
	p 0.15	0.22	0.29	--	--

TABLE 5-2
KEY TO STABILITY CATEGORIES

Wind Speed at 18 m (m sec ⁻¹)	STABILITY CLASS				
	Very Unstable ($\Delta T = -1.4\text{C}$)	Slightly Unstable ($\Delta T = -0.8\text{C}$)	Near-Neutral or Transitional ($\Delta T = 0\text{C}$)	Slightly Stable ($\Delta T = 0.4\text{C}$)	Very Stable ($\Delta T = 2.0\text{C}$)
1-2	I	II	V	VI	VII
2-4	II	III	V	VI	VII
4-7	III	IV	V	V	VI
7-11	IV	V	V	V	--

TABLE 5-3
METEOROLOGICAL INPUTS FOR EACH STABILITY CATEGORY

	CATEGORY						
	I	II	III	IV	V	VI	VII
σ_A (deg)	25	15	12	10	8.5	7.5	5.5
σ_E (deg)	15	9	7	6	5	4	3
p	0.05	0.11	0.15	0.18	0.29	0.34	0.42

dosage fields. For fuel leaks and surface spills, 10-minute values of σ_A and σ_E at the 18-meter reference height were obtained from Table 5-3 and used as model inputs. For the normal launch, it was assumed that σ_A varied with height as z^{-P} . Wind speed was assumed to vary with height as z^P throughout the surface layer in all calculations.

5.2 CONCENTRATION AND DOSAGE FIELDS FROM A NORMAL LAUNCH

Figures 5-1 and 5-2 give the maximum normalized concentrations and dosages, respectively, from a normal launch, as a function of travel distance, for the seven stability categories. In this case, the source extends vertically through the entire surface mixing layer. The source strength has been assumed invariant with height and the initial cloud diameter has been assumed to be 1250 meters. The maximum concentration and dosage values thus apply to all heights within the mixing layer.

In the calculations, the 10-minute σ_A values were reduced by the one-fifth power-law to values appropriate for the time required for cloud stabilization, τ , in the surface layer. The values of τ were assumed equal to the residence time of the vehicle, in this case a Saturn V, in the layer, and were determined from Figure E-7 of Appendix E. The values of τ used for each mixing height are given in Table 5-4.

Tables 5-5 and 5-6, respectively, give the widths of selected normalized concentration and dosage isopleths.

To obtain actual concentration levels, the normalized values in Figure 5-1 and Table 5-5 are multiplied by Q , where Q is the amount of material released per meter of height. To obtain actual dosage levels, the normalized values in Figure 5-2 and Table 5-6 are multiplied by $Q/\bar{u}$, where Q is again the amount of material released per meter, and $\bar{u}$ is the wind speed at a height of 18 meters.

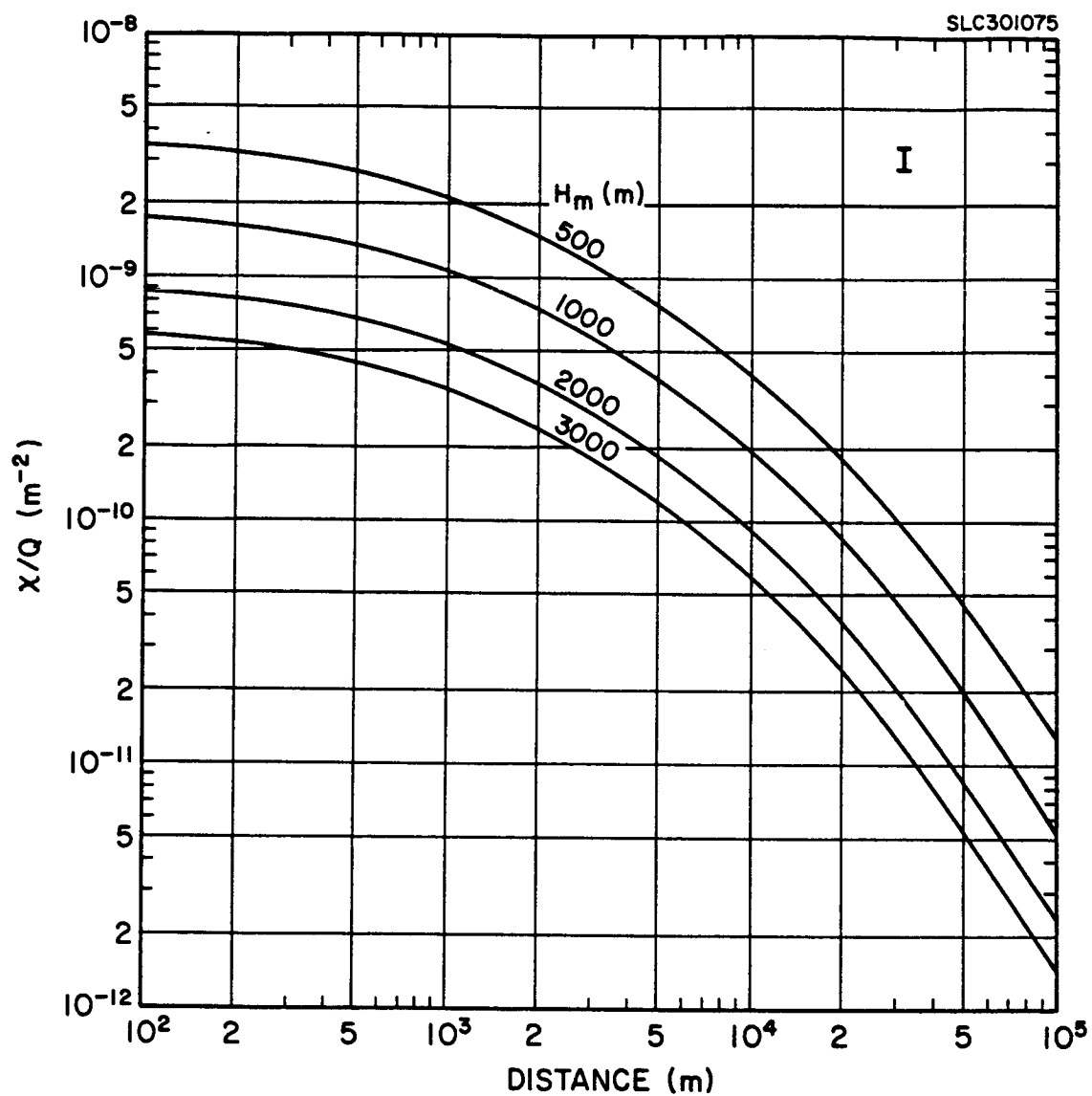


FIGURE 5-1. Normalized maximum concentration as a function of travel distance from a normal launch for Stability Category I. H_m is the depth of the surface mixing layer.

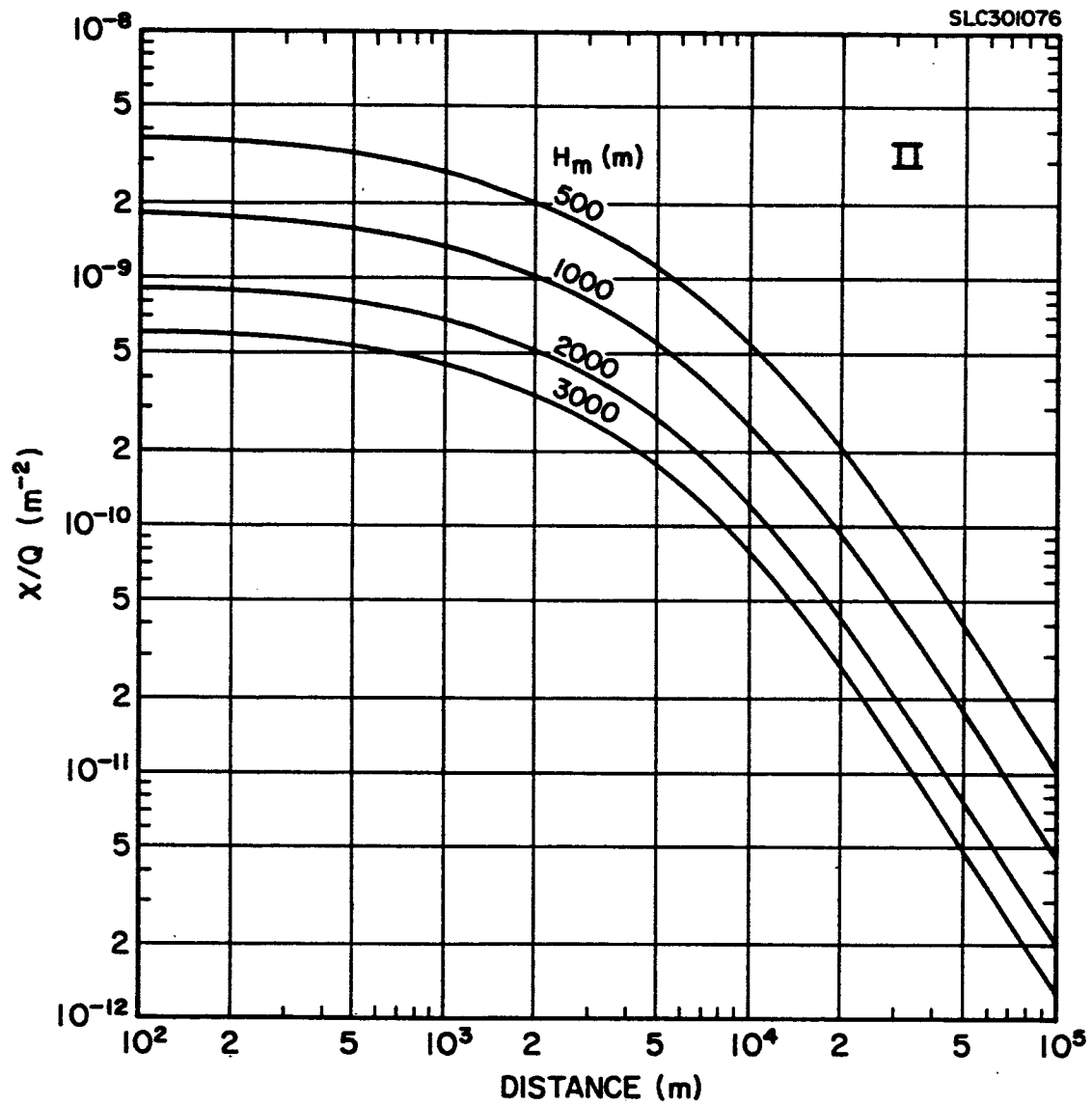


FIGURE 5-1. (Continued) Stability Category II

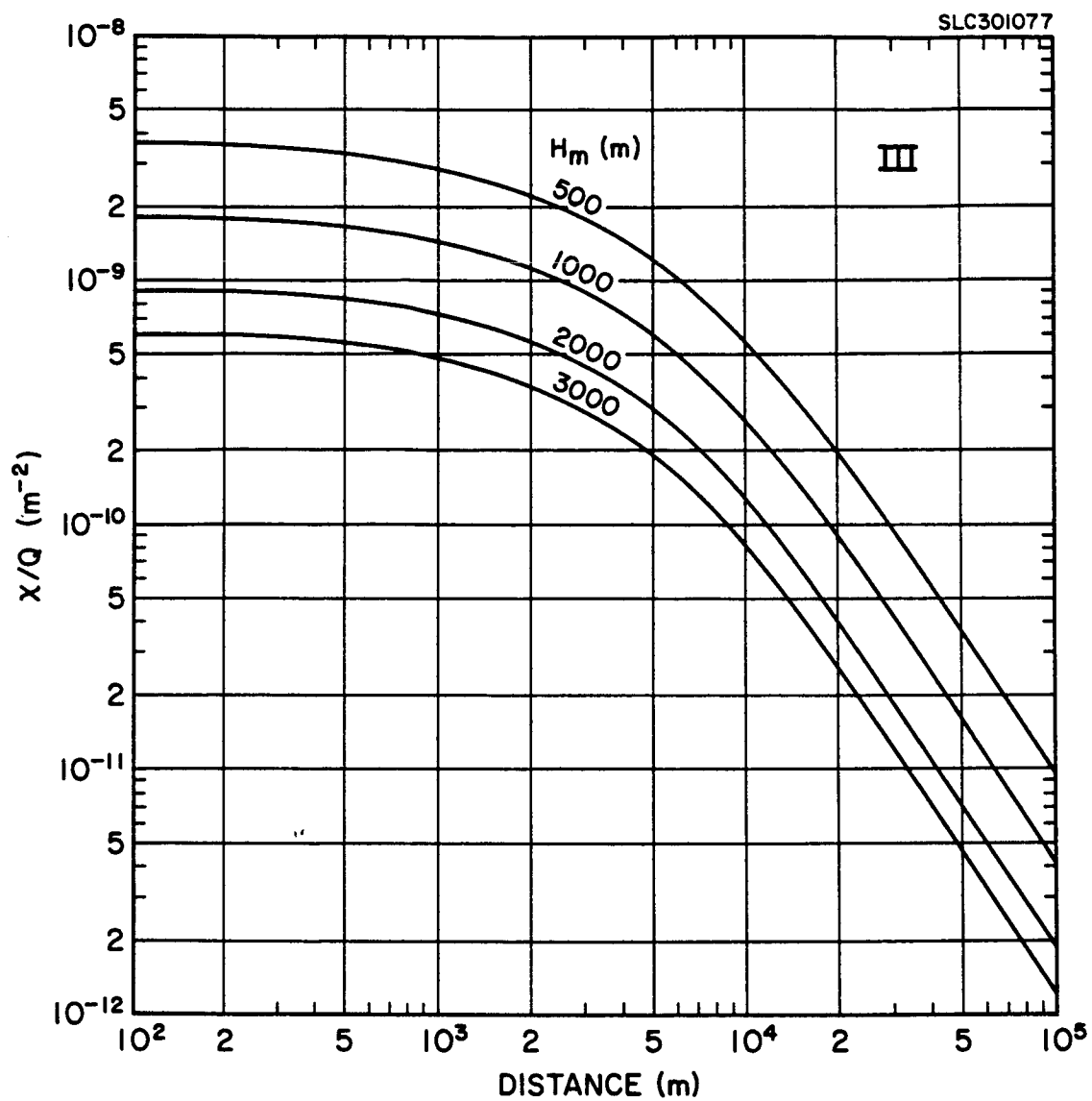


FIGURE 5-1. (Continued) Stability Category III

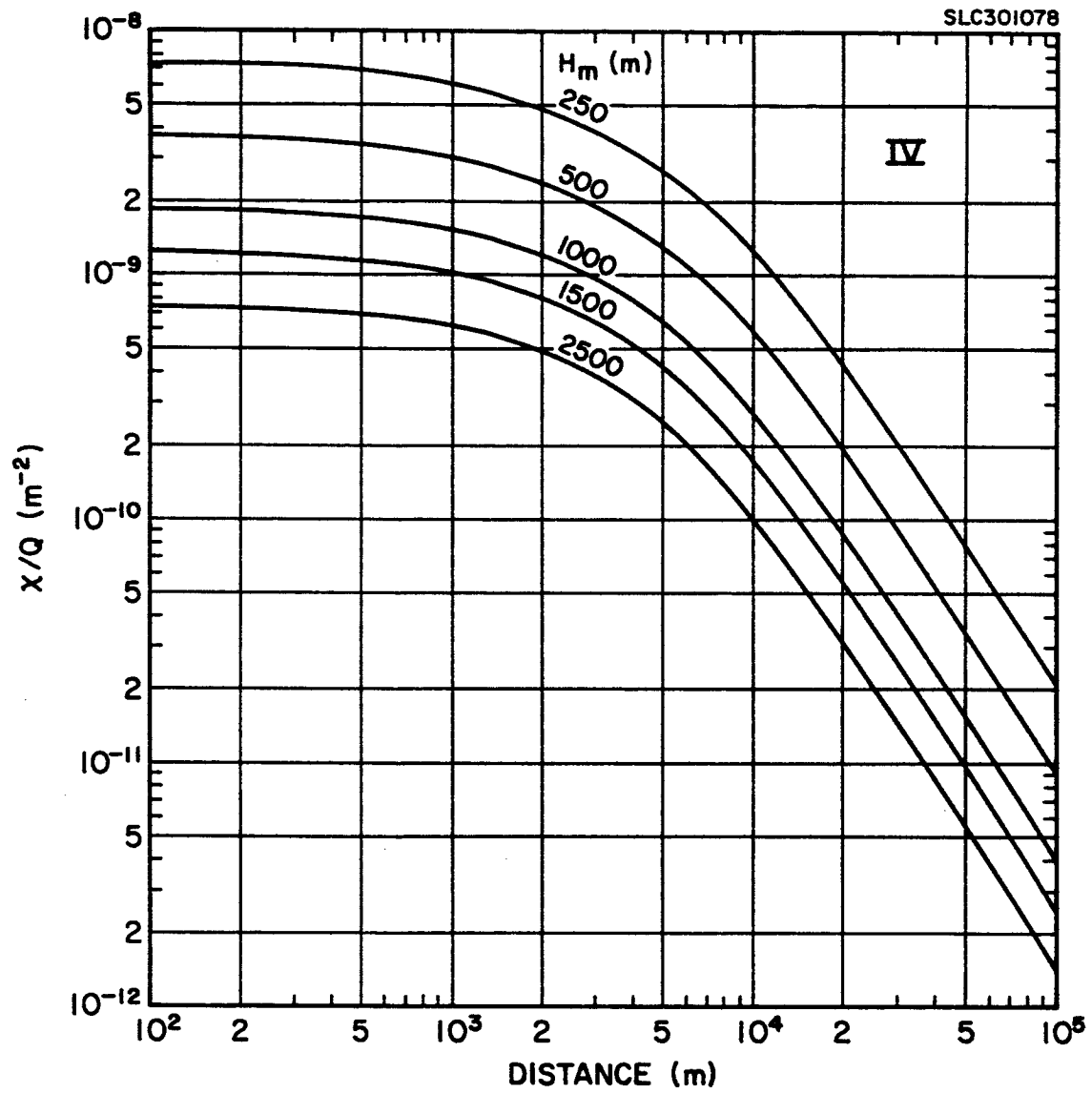


FIGURE 5-1. (Continued) Stability Category IV

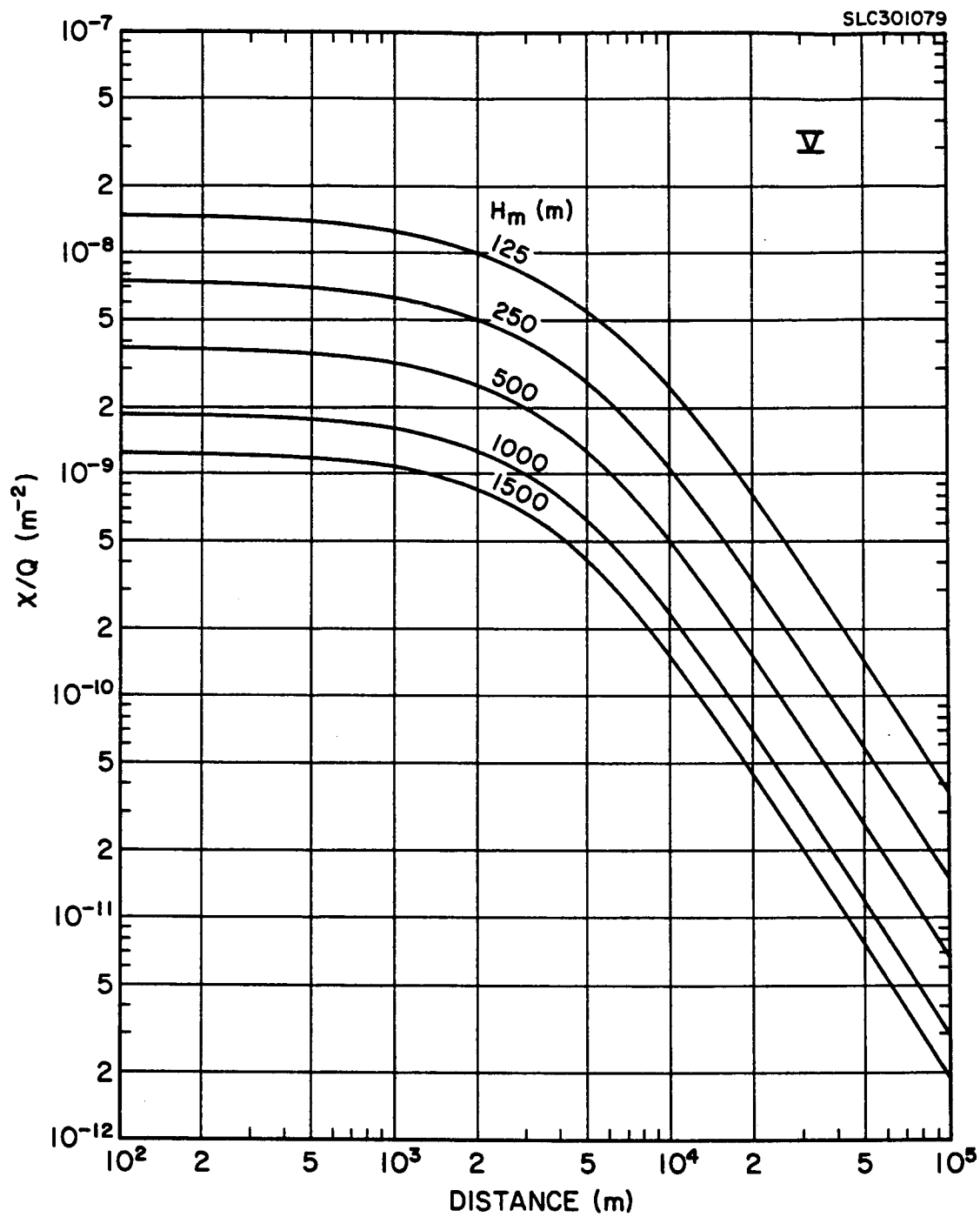


FIGURE 5-1. (Continued) Stability Category V

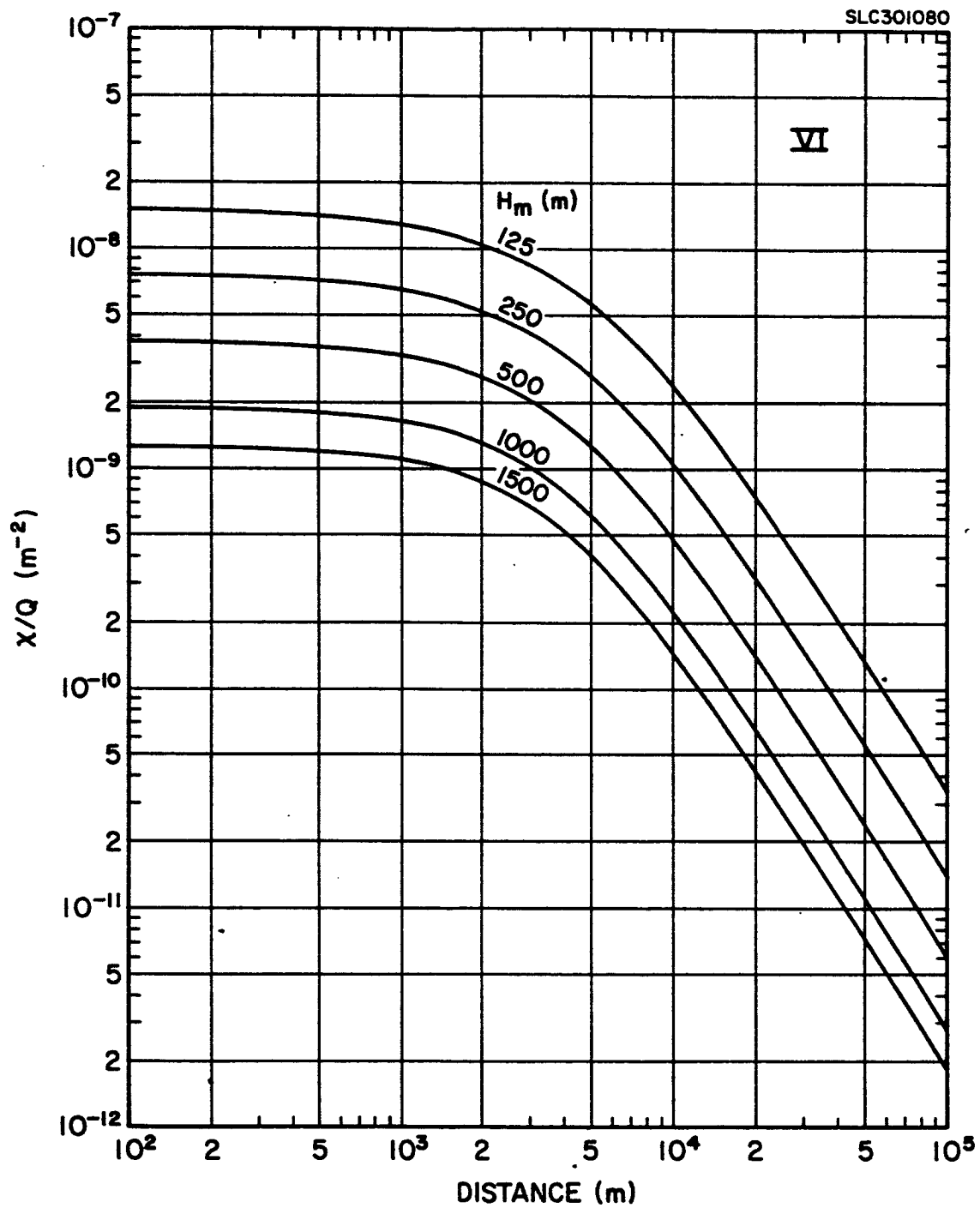


FIGURE 5-1. (Continued) Stability Category VI

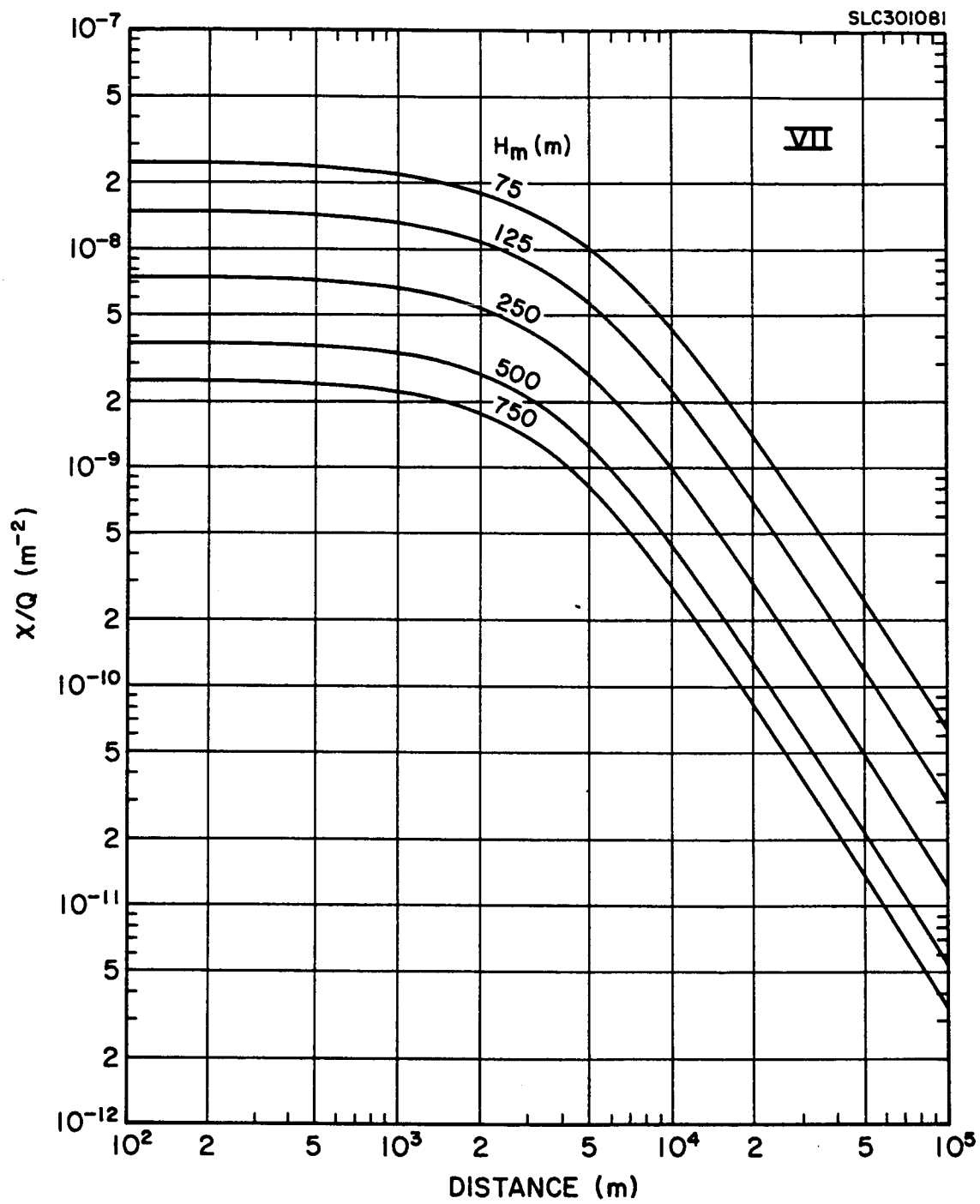


FIGURE 5-1. (Continued) Stability Category VII

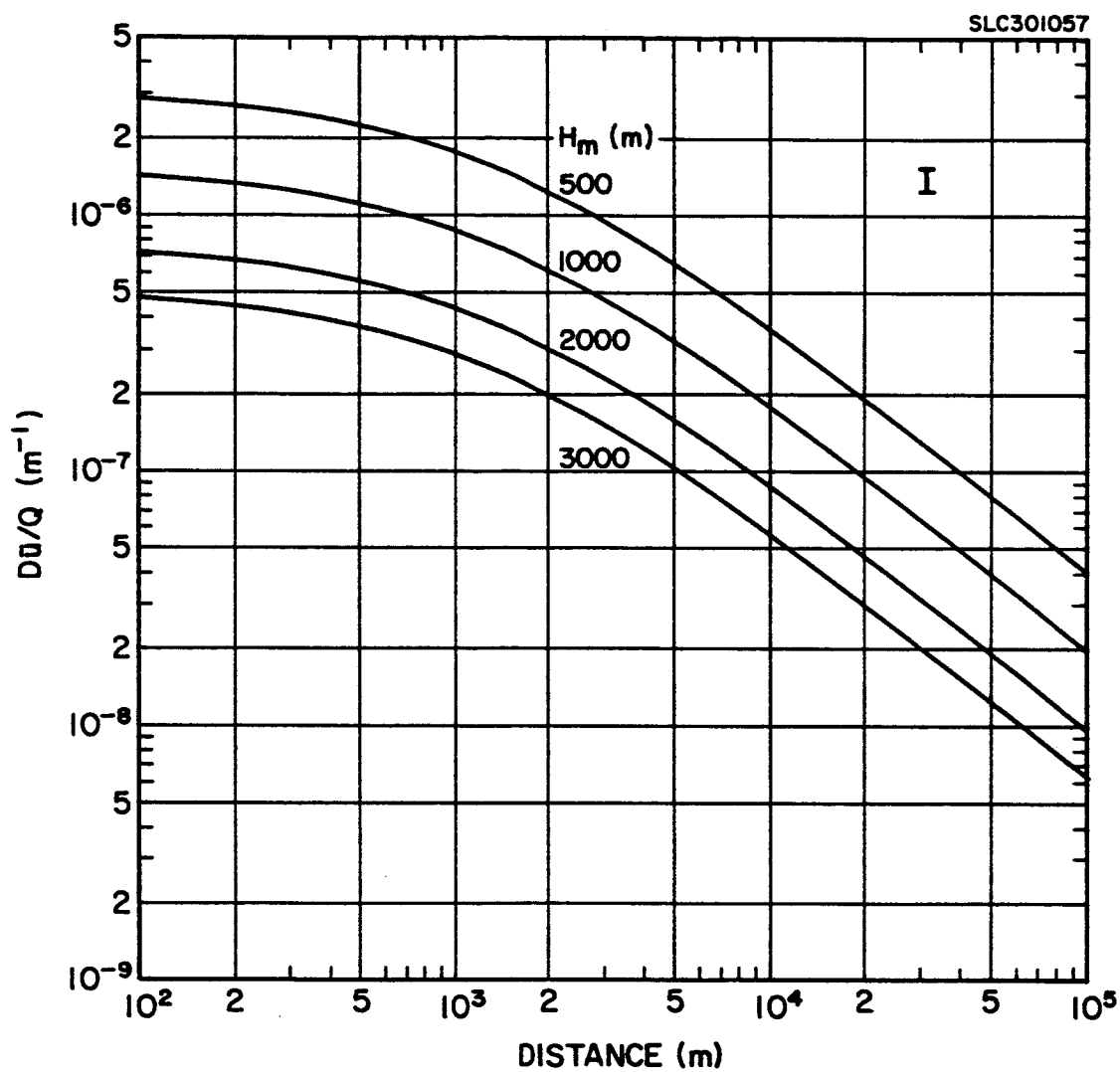


FIGURE 5-2. Normalized maximum dosage as a function of travel distance from a normal launch for Stability Category I. H_m is the depth of the surface mixing layer.

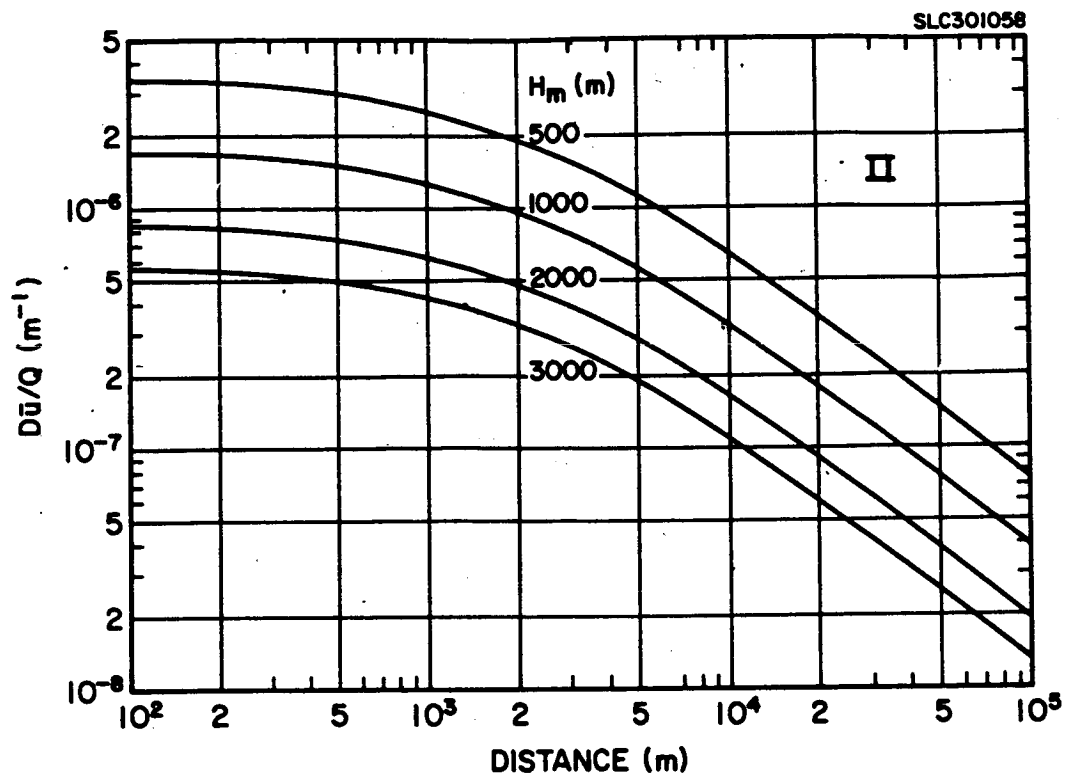


FIGURE 5-2. (Continued) Stability Category II

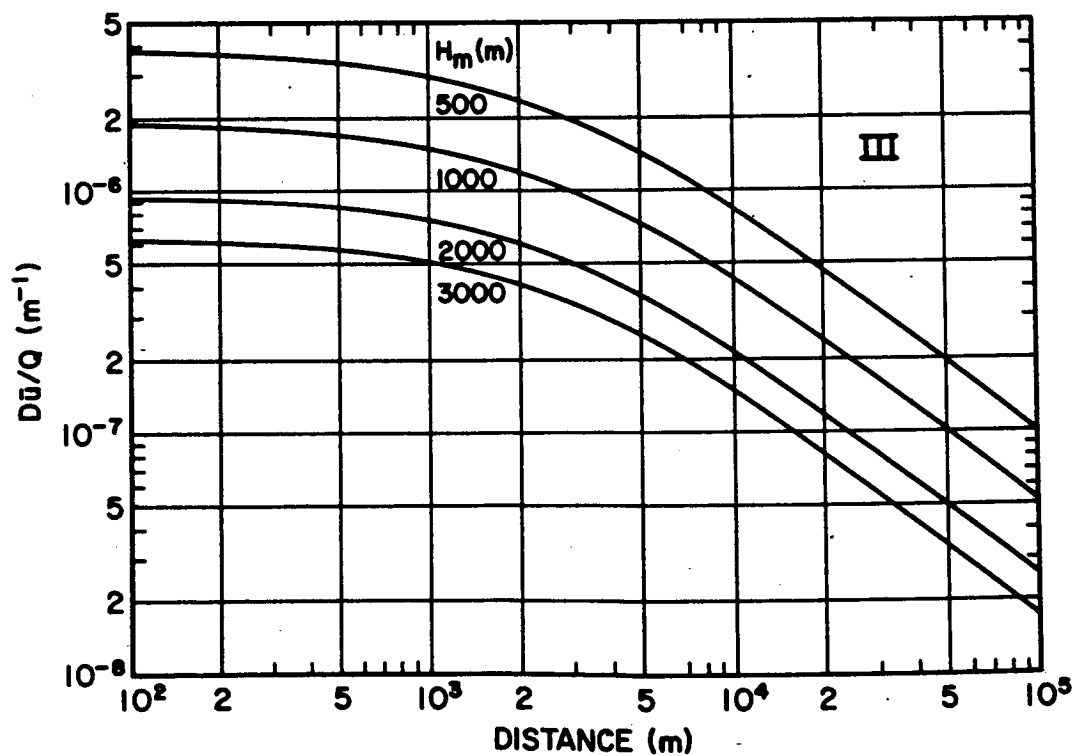


FIGURE 5-2. (Continued) Stability Category III

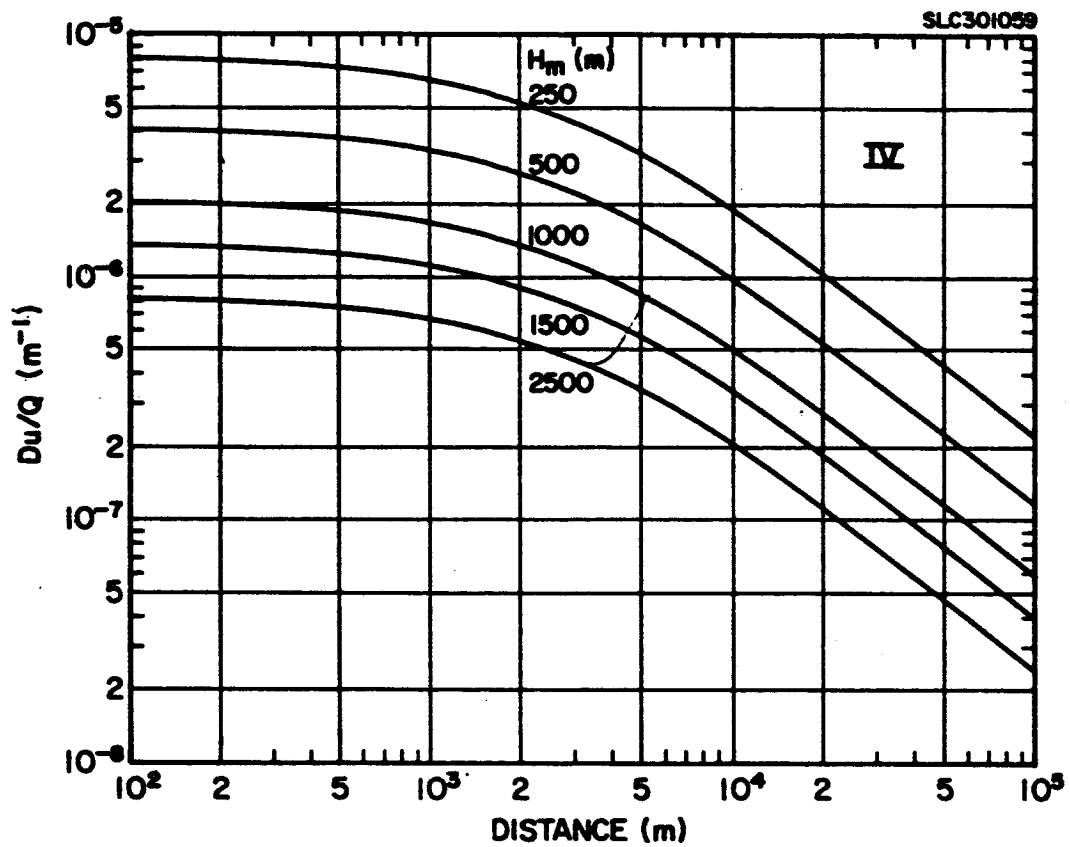


FIGURE 5-2. (Continued) Stability Category IV

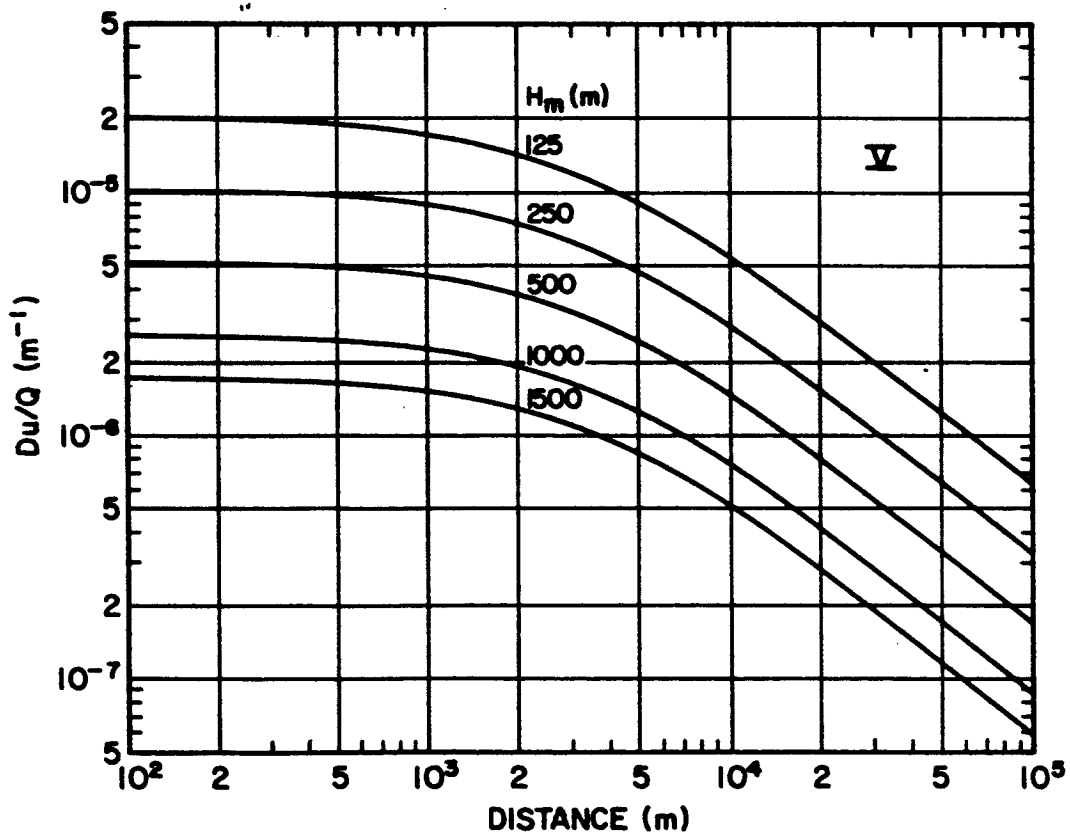


FIGURE 5-2. (Continued) Stability Category V

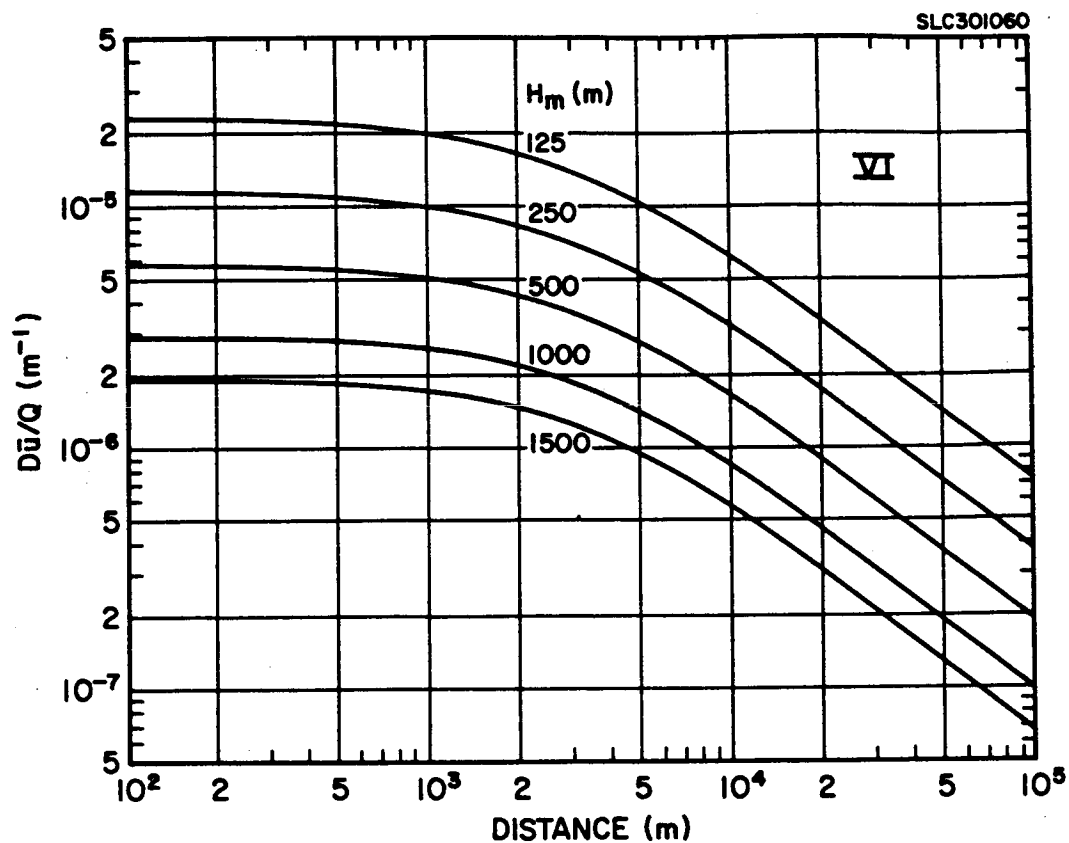


FIGURE 5-2. (Continued) Stability Category VI

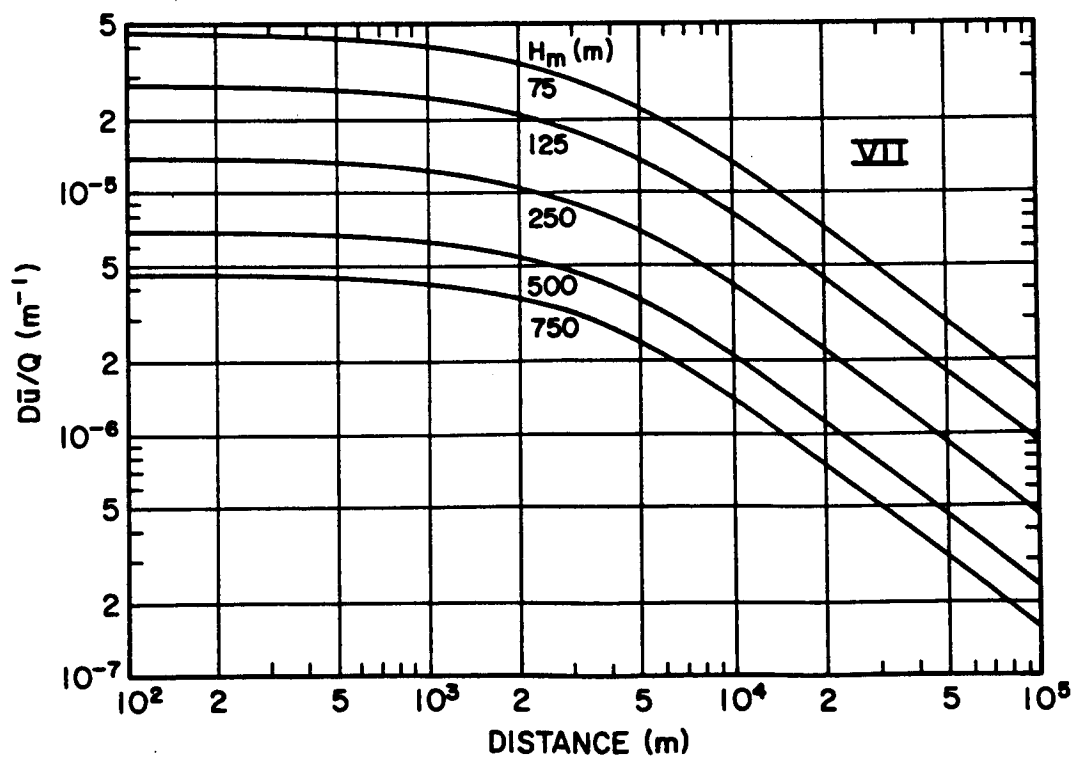


FIGURE 5-2. (Continued) Stability Category VII

TABLE 5-4
RESIDENCE TIME OF A SATURN V VEHICLE WITHIN THE
SURFACE LAYER

Depth of Surface Layer H_m (m)	75	125	250	500	750	1000	1500	2000	2500	3000
Residence Time or τ (sec)	13	15	18.5	22.5	25	27.5	33	37.5	42	44.5

TABLE 5-5

ISOPLATH WIDTHS IN KILOMETERS OF NORMALIZED CONCENTRATION VERSUS
TRAVEL DISTANCE DOWNWIND FROM A NORMAL LAUNCH

STABILITY CATEGORY I														
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$						
	10 ⁻⁹	5x10 ⁻¹⁰	10 ⁻¹⁰	10 ⁻¹¹	10 ⁻¹²	10 ⁻¹³		5x10 ⁻¹⁰	10 ⁻¹⁰	5x10 ⁻¹¹	10 ⁻¹¹	10 ⁻¹²	10 ⁻¹³	
	$H_m = 500 \text{ m}$							$H_m = 2000 \text{ m}$						
0.5	1.1	1.5	2.0	2.6	3.1	3.6	0.5	0.6	1.6	1.8	2.3	2.9	3.3	
1	1.3	1.7	2.5	3.3	3.9	4.4	1	0.4	1.9	2.2	2.9	3.6	4.2	
2	1.3	2.1	3.3	4.5	5.4	6.2	2	0	2.4	2.9	3.9	5.0	5.9	
4	0	2.6	4.8	6.9	8.4	9.7	4		3.0	4.1	5.9	7.7	9.2	
8		1.3	7.3	11.3	14.2	16.6	8		2.7	5.5	9.2	12.8	15.5	
10		0	8.3	13.3	17.0	19.9	10		0	5.8	10.7	15.2	18.6	
20			10.6	22.4	29.8	35.7	20			0	15.9	25.8	32.9	
40			0	35.2	52.0	64.6	40				14.2	41.9	57.6	
80				42.1	86.4	114.	80				0	58.7	97.5	
100				33.7	99.8	137.	100					59.9	114.	
$H_m = 3000 \text{ m}$														
0.5	0.6	1.1	1.8	2.5	3.0	3.4	0.5	0	1.4	1.7	2.2	2.8	3.3	
1	0.4	1.3	2.2	3.1	3.7	4.3	1		1.6	2.0	2.7	3.5	4.1	
2	0	1.3	2.9	4.2	5.2	6.0	2		2.0	2.6	3.7	4.9	5.8	
4		0	4.0	6.4	8.0	9.4	4		2.2	3.5	5.5	7.5	9.0	
8			5.5	10.3	13.4	16.0	8		0	4.1	8.5	12.3	15.2	
10			5.9	12.0	16.0	19.1	10			3.5	9.8	14.6	18.2	
20			0	19.4	27.8	34.1	20			0	13.3	24.5	32.0	
40				27.0	47.0	60.8	40				0	38.4	55.4	
80				0	73.6	105.	80					47.2	91.8	
100					82.2	125.	100					40.5	106.	

TABLE 5-5 (Continued)

STABILITY CATEGORY II														
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$						
	10 ⁻⁹	5x10 ⁻¹⁰	10 ⁻¹⁰	10 ⁻¹¹	10 ⁻¹²	10 ⁻¹³		5x10 ⁻¹⁰	10 ⁻¹⁰	5x10 ⁻¹¹	10 ⁻¹¹	10 ⁻¹²	10 ⁻¹³	
$H_m = 500 \text{ m}$													$H_m = 2000 \text{ m}$	
0.5	1.0	1.3	1.8	2.3	2.8	3.1	0.5	0.7	1.4	1.6	2.0	2.5	2.9	
1	1.1	1.5	2.1	2.7	3.2	3.6	1	0.6	1.6	1.8	2.3	2.9	3.3	
2	1.3	1.8	2.6	3.4	4.1	4.7	2	0.3	1.9	2.2	2.9	3.7	4.3	
4	1.2	2.2	3.5	4.9	5.9	6.8	4	0	2.4	3.0	4.0	5.2	6.1	
8	0	2.2	5.2	7.6	9.4	10.9	8		2.6	4.0	6.0	8.1	9.8	
10		1.5	5.8	8.9	11.1	13.0	10		2.1	4.2	6.9	9.5	11.5	
20		0	7.0	14.2	18.8	22.5	20		0	0	9.6	15.4	19.6	
40			0	21.1	31.7	39.6	40				7.0	24.1	33.4	
80				21.8	51.2	69.0	80				0	32.2	55.5	
100				10.2	58.5	82.1	100					31.7	64.6	
$H_m = 1000 \text{ m}$													$H_m = 3000 \text{ m}$	
0.5	0.7	1.0	1.6	2.2	2.6	3.0	0.5	0.2	1.3	1.5	1.9	2.4	2.8	
1	0.6	1.1	1.8	2.5	3.0	3.5	1	0	1.4	1.7	2.2	2.8	3.3	
2	0.3	1.3	2.2	3.2	3.9	4.5	2		1.6	2.0	2.7	3.5	4.2	
4	0	1.2	3.0	4.4	5.5	6.4	4		1.9	2.6	3.8	5.0	6.0	
8		0	4.0	6.8	8.7	10.3	8		1.1	3.2	5.5	7.7	9.5	
10			4.3	7.9	10.3	12.2	10		0	3.0	6.2	9.0	11.1	
20			0	12.0	17.1	20.9	20			0	8.0	14.4	18.7	
40				15.4	27.9	36.3	40				0	21.7	31.6	
80				0	42.2	62.0	80					24.9	51.4	
100					46.3	73.1	100					19.0	59.1	

TABLE 5-5 (Continued)

STABILITY CATEGORY III															
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$							
	10 ⁻⁹	5x10 ⁻¹⁰	10 ⁻¹⁰	10 ⁻¹¹	10 ⁻¹²	10 ⁻¹³		5x10 ⁻¹⁰	10 ⁻¹⁰	5x10 ⁻¹¹	10 ⁻¹¹	10 ⁻¹²	10 ⁻¹³		
														$H_m = 2000 \text{ m}$	
0.5	1.0	1.3	1.7	2.3	2.7	3.0	0.5	0.7	1.3	1.6	1.9	2.4	2.8		
1	1.1	1.4	1.9	2.5	3.0	3.4	1	0.7	1.5	1.7	2.2	2.7	3.1		
2	1.2	1.6	2.4	3.1	3.7	4.2	2	0.5	1.7	2.0	2.6	3.3	3.8		
4	1.2	2.0	3.1	4.3	5.2	5.9	4	0	2.1	2.6	3.5	4.5	5.3		
8	0	2.1	4.5	6.5	8.1	9.4	8		2.3	3.4	5.1	6.9	8.2		
10		1.5	5.0	7.6	9.5	11.0	10		1.9	3.5	5.8	8.0	9.7		
20		0	5.8	11.9	15.8	18.9	20		0	0	7.9	12.8	16.2		
40			0	17.4	26.4	33.1	40				4.9	19.7	27.5		
80				16.4	43.3	57.5	80				0	25.9	45.5		
100				0	48.2	68.4	100					24.9	52.8		
$H_m = 1000 \text{ m}$															
0.5	0.7	1.0	1.6	2.0	2.5	2.9	0.5	0.3	1.2	1.4	1.9	2.3	2.7		
1	0.7	1.1	1.7	2.3	2.8	3.2	1	0	1.3	1.6	2.0	2.6	3.0		
2	0.5	1.2	2.0	2.9	3.5	4.0	2		1.5	1.8	2.5	3.1	3.7		
4	0	1.2	2.7	3.9	4.8	5.6	4		1.7	2.3	3.3	4.3	5.1		
8		0	3.5	5.8	7.4	8.8	8		1.2	2.7	4.7	6.5	7.9		
10			3.7	6.7	8.7	10.3	10		0	2.6	5.2	7.5	9.3		
20			0	10.0	14.2	17.5	20			0	6.5	11.9	15.4		
40				12.4	23.1	30.2	40				0	17.7	25.9		
80				0	34.5	51.3	80					19.7	41.9		
100					37.6	60.4	100					13.8	48.2		
$H_m = 3000 \text{ m}$															
0.5	0.7	1.0	1.6	2.0	2.5	2.9	0.5	0.3	1.2	1.4	1.9	2.3	2.7		
1	0.7	1.1	1.7	2.3	2.8	3.2	1	0	1.3	1.6	2.0	2.6	3.0		
2	0.5	1.2	2.0	2.9	3.5	4.0	2		1.5	1.8	2.5	3.1	3.7		
4	0	1.2	2.7	3.9	4.8	5.6	4		1.7	2.3	3.3	4.3	5.1		
8		0	3.5	5.8	7.4	8.8	8		1.2	2.7	4.7	6.5	7.9		
10			3.7	6.7	8.7	10.3	10		0	2.6	5.2	7.5	9.3		
20			0	10.0	14.2	17.5	20			0	6.5	11.9	15.4		
40				12.4	23.1	30.2	40				0	17.7	25.9		
80				0	34.5	51.3	80					19.7	41.9		
100					37.6	60.4	100					13.8	48.2		

TABLE 5-5 (Continued)

STABILITY CATEGORY IV														
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$						
	5×10^{-9}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}		10^{-9}	5×10^{-10}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	
$H_m = 250 \text{ m}$														
0.5	0.5	1.3	1.9	2.3	2.7	3.1	0.5	0.7	1.0	1.5	2.1	2.5	2.8	
1	0.4	1.4	2.1	2.6	3.0	3.4	1	0.7	1.1	1.7	2.2	2.7	3.1	
2	0	1.6	2.5	3.1	3.7	4.1	2	0.6	1.2	1.9	2.7	3.3	3.7	
4		1.9	3.3	4.3	5.1	5.8	4	0	1.2	2.5	3.6	4.4	5.1	
8		2.1	4.9	6.6	7.9	9.1	8		0	3.2	5.3	6.7	7.9	
10		1.7	5.5	7.6	9.3	10.7	10			3.3	6.0	7.8	9.3	
20		0	7.8	12.4	15.7	18.4	20			0	8.9	12.8	15.7	
40			6.0	19.4	26.7	32.5	40				10.9	20.7	27.1	
80			0	26.1	44.5	57.3	80				0	30.7	46.0	
100				25.9	51.8	68.5	100					33.3	54.2	
$H_m = 500 \text{ m}$														
0.5	0	1.0	1.7	2.2	2.6	2.9	0.5	0.3	0.8	1.4	2.0	2.4	2.8	
1		1.1	1.9	2.4	2.9	3.3	1	0.2	0.8	1.5	2.1	2.6	3.0	
2		1.2	2.2	2.9	3.5	3.9	2	0	0.8	1.8	2.5	3.1	3.6	
4		1.2	2.9	3.9	4.7	5.4	4		0.4	2.2	3.4	4.2	5.0	
8		0	4.1	5.9	7.3	8.5	8		0	2.6	4.9	6.4	7.6	
10			4.5	6.8	8.5	10.0	10			2.5	5.6	7.4	8.9	
20			5.1	10.7	14.2	17.0	20			0	7.9	12.0	15.0	
40			0	15.4	23.7	29.7	40				7.5	18.9	25.7	
80				13.7	37.7	51.6	80				0	26.3	43.0	
100				0	42.9	61.3	100					27.1	50.2	
$H_m = 1500 \text{ m}$														
0.5	0	1.0	1.7	2.2	2.6	2.9	0.5	0.3	0.8	1.4	2.0	2.4	2.8	
1		1.1	1.9	2.4	2.9	3.3	1	0.2	0.8	1.5	2.1	2.6	3.0	
2		1.2	2.2	2.9	3.5	3.9	2	0	0.8	1.8	2.5	3.1	3.6	
4		1.2	2.9	3.9	4.7	5.4	4		0.4	2.2	3.4	4.2	5.0	
8		0	4.1	5.9	7.3	8.5	8		0	2.6	4.9	6.4	7.6	
10			4.5	6.8	8.5	10.0	10			2.5	5.6	7.4	8.9	
20			5.1	10.7	14.2	17.0	20			0	7.9	12.0	15.0	
40			0	15.4	23.7	29.7	40				7.5	18.9	25.7	
80				13.7	37.7	51.6	80				0	26.3	43.0	
100				0	42.9	61.3	100					27.1	50.2	

TABLE 5-5 (Continued)

STABILITY CATEGORY V													
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$					
	$H_m = 125 \text{ m}$							$H_m = 500 \text{ m}$					
	5×10^{-9}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}		10^{-9}	5×10^{-10}	10^{-10}	10^{-11}	10^{-12}	10^{-13}
0.5	0.9	1.5	2.0	2.4	2.8	3.1	0.5	1.0	1.2	1.7	2.1	2.5	2.9
1	0.9	1.6	2.2	2.6	3.0	3.4	1	1.0	1.3	1.8	2.3	2.7	3.1
2	1.0	1.8	2.6	3.1	3.6	4.1	2	1.1	1.5	2.0	2.7	3.2	3.6
4	0.9	2.3	3.4	4.2	4.9	5.5	4	1.1	1.7	2.6	3.5	4.2	4.9
8	0	3.0	5.0	6.5	7.6	8.6	8	0	1.5	3.5	5.2	6.4	7.5
10		3.1	5.8	7.5	9.0	10.2	10		0.5	3.8	5.9	7.5	8.7
20		0	8.5	12.3	15.2	17.6	20		0	3.6	9.1	12.3	14.9
40			10.3	19.9	26.2	31.2	40			0	12.6	20.4	25.9
80			0	29.5	44.5	55.6	80				5.3	31.9	44.8
100				31.9	52.4	66.8	100				0	35.8	53.1
$H_m = 250 \text{ m}$													
0.5	0.5	1.2	1.8	2.3	2.6	3.0	0.5	0.7	1.0	1.5	2.0	2.4	2.7
1	0.5	1.3	2.0	2.5	2.9	3.2	1	0.7	1.0	1.6	2.1	2.6	2.9
2	0.2	1.5	2.3	2.9	3.4	3.8	2	0.6	1.1	1.8	2.5	3.0	3.4
4	0	1.8	3.0	3.9	4.6	5.2	4	0	1.0	2.2	3.2	3.9	4.5
8		1.7	4.3	5.8	7.0	8.0	8		0	2.7	4.6	5.9	6.9
10		1.0	4.8	6.7	8.2	9.4	10			2.7	5.2	6.8	8.1
20		0	6.3	10.7	13.7	16.2	20			0	7.5	11.0	13.7
40			0	16.3	23.2	28.5	40				8.2	17.7	23.6
80				20.2	38.1	50.0	80				0	25.4	39.9
100				17.9	44.1	59.7	100					26.9	46.7

TABLE 5-5 (Continued)

STABILITY CATEGORY VI														
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$						
	5×10^{-9}	10^{-8}	10^{-10}	10^{-11}	10^{-12}	10^{-13}		10^{-9}	5×10^{-10}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	
0.5	0.9	1.4	2.0	2.4	2.7	3.1	0.5	1.0	1.2	1.6	2.1	2.5	2.8	
1	0.9	1.5	2.1	2.6	3.0	3.3	1	1.0	1.3	1.7	2.3	2.7	3.0	
2	1.0	1.8	2.5	3.0	3.5	3.9	2	1.1	1.4	2.0	2.6	3.1	3.5	
4	0.9	2.2	3.3	4.0	4.7	5.3	4	1.0	1.6	2.5	3.4	4.0	4.6	
8	0	2.8	4.8	6.1	7.2	8.2	8	0	1.4	3.3	4.9	6.1	7.1	
10		2.9	5.4	7.1	8.5	9.7	10		0	3.6	5.6	7.1	8.3	
20		0	8.0	11.6	14.4	16.7	20			3.2	8.6	11.7	14.2	
40			9.3	18.7	24.7	29.6	40			0	11.7	19.3	24.7	
80			0	27.3	42.0	52.7	80				0	30.1	42.7	
100				29.4	49.4	63.3	100					33.7	50.5	
$H_m = 250 \text{ m}$														
0.5	0.5	1.2	1.8	2.2	2.6	2.9	0.5	0.7	1.0	1.5	2.0	2.4	2.7	
1	0.5	1.3	1.9	2.4	2.8	3.2	1	0.7	1.0	1.5	2.1	2.5	2.9	
2	0.2	1.4	2.2	2.8	3.3	3.7	2	0.6	1.1	1.7	2.4	2.9	3.3	
4	0	1.7	2.9	3.7	4.4	4.9	4	0	1.0	2.1	3.0	3.7	4.3	
8		1.6	4.0	5.5	6.6	7.6	8		0	2.5	4.3	5.6	6.6	
10		0.8	4.5	6.4	7.8	9.0	10			2.5	4.9	6.5	7.7	
20		0	5.9	10.1	13.0	15.4	20			0	7.1	10.5	13.1	
40			0	15.3	22.0	27.0	40				7.5	16.8	22.6	
80				18.3	36.0	47.5	80				0	23.9	38.1	
100				15.3	41.5	56.7	100					25.1	44.7	

TABLE 5-5 (Continued)

STABILITY CATEGORY VII														
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$						
	5×10^{-9}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}		5×10^{-9}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	
0.5	1.1	1.6	2.0	2.4	2.8	3.1	0.5	0.5	1.2	1.8	2.2	2.6	2.9	
1	1.1	1.6	2.2	2.6	3.0	3.3	1	0.5	1.3	1.9	2.3	2.7	3.0	
2	1.2	1.9	2.5	3.0	3.4	3.8	2	0.3	1.4	2.1	2.7	3.1	3.5	
4	1.4	2.4	3.3	4.0	4.6	5.1	4	0	1.6	2.7	3.4	4.0	4.6	
8	1.1	3.2	4.8	6.1	7.1	8.0	8		1.4	3.7	5.1	6.1	7.0	
10	0	3.5	5.6	7.1	8.3	9.4	10		0.2	4.1	5.9	7.2	8.3	
20		3.2	8.6	11.7	14.2	16.3	20		0	5.3	9.3	12.1	14.3	
40		0	11.9	19.5	24.9	29.3	40			0	14.0	20.4	25.3	
80			2.9	30.5	43.0	52.6	80				16.0	33.4	44.5	
100			0	34.2	51.0	63.5	100				11.8	38.4	53.1	
$H_m = 125 \text{ m}$														
0.5	0.9	1.4	1.9	2.3	2.7	3.0	0.5	0	1.0	1.6	2.1	2.4	2.8	
1	0.9	1.5	2.0	2.5	2.9	3.2	1		1.0	1.7	2.2	2.6	2.9	
2	1.0	1.7	2.3	2.9	3.3	3.7	2		1.0	1.9	2.4	2.9	3.3	
4	0.9	2.0	3.0	3.7	4.3	4.9	4		1.0	2.3	3.1	3.8	4.3	
8	0	2.5	4.4	5.6	6.6	7.5	8		0	3.0	4.5	5.7	6.6	
10		2.6	5.0	6.5	7.8	8.9	10			3.3	5.2	6.6	7.7	
20		0	7.2	10.7	13.3	15.4	20			2.6	8.0	11.0	13.3	
40			8.0	17.1	22.9	27.5	40			0	10.7	18.1	23.3	
80			0	24.7	38.8	48.9	80				0	28.0	40.3	
100				26.1	45.5	58.8	100					31.2	47.7	

TABLE 5-6

ISOPLETH WIDTHS IN KILOMETERS OF NORMALIZED DOSAGE VERSUS
TRAVEL DISTANCE DOWNWIND FROM A NORMAL LAUNCH

STABILITY CATEGORY I													
Distance (km)	Dū/Q						Distance (km)	Dū/Q					
	H _m = 500 m							H _m = 2000 m					
	10 ⁻⁶	5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹		5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹	
0.5	1.0	1.4	2.0	2.2	2.6	2.7	0.5	0.4	1.5	1.7	2.2	2.4	
1	1.1	1.6	2.4	2.7	3.2	3.4	1	0	1.7	2.1	2.8	3.0	
2	1.0	1.9	3.2	3.6	4.4	4.7	2		2.2	2.8	3.8	4.2	
4	0	2.2	4.6	5.3	6.7	7.2	4		2.7	3.8	5.7	6.3	
8		0	6.9	8.4	11.0	12.0	8		1.6	5.1	9.0	10.2	
10			7.8	9.7	13.1	14.3	10		0	5.4	10.5	12.0	
20			10.6	15.1	22.4	24.8	20			0	16.7	20.0	
40			0	21.0	38.3	43.6	40				24.5	32.7	
80				5.9	63.3	75.6	80				23.3	48.6	
100				0	73.3	89.6	100				0	52.6	
H _m = 1000 m													
0.5	0.4	1.0	1.7	2.0	2.4	2.6	0.5	0	1.3	1.6	2.1	2.3	
1	0	1.1	2.1	2.4	3.0	3.2	1		1.5	1.9	2.6	2.9	
2		1.0	2.7	3.2	4.1	4.4	2		1.7	2.4	3.6	4.0	
4		0	3.8	4.6	6.2	6.8	4		1.6	3.2	5.3	6.0	
8			5.1	6.9	10.0	11.1	8		0	3.5	8.3	9.6	
10			5.4	7.9	11.8	13.1	10			2.8	9.5	11.2	
20			0	10.6	19.7	22.5	20			0	14.4	18.3	
40				0	32.1	38.5	40				18.0	28.4	
80					48.1	63.6	80				0	36.0	
100					52.3	73.7	100					32.9	

TABLE 5-6 (Continued)

STABILITY CATEGORY II												
Distance (km)	D $\bar{u}$ /Q					Distance (km)	D $\bar{u}$ /Q					
	10 ⁻⁶	5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸		5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹	
	H _m = 500 m						H _m = 2000 m					
0.5	1.0	1.3	1.8	2.0	2.3	2.5	0.6	1.4	1.6	2.0	2.2	
1	1.1	1.4	2.0	2.3	2.7	2.8	0.6	1.5	1.8	2.3	2.5	
2	1.2	1.7	2.6	2.8	3.4	3.6	0	1.8	2.2	2.9	3.1	
4	1.1	2.2	3.5	4.0	4.9	5.2		2.4	3.0	4.0	4.4	
8	0	2.5	5.3	6.1	7.7	8.2		3.0	4.2	6.2	6.9	
10		2.3	6.0	7.1	9.0	9.7		3.1	4.7	7.2	8.1	
20		0	9.1	11.4	15.3	16.8		0	6.1	11.8	13.5	
40			12.2	17.8	26.6	29.6			0	19.0	22.8	
80			0	24.3	45.7	52.3				27.9	37.4	
100				24.4	54.0	62.6				30.2	43.2	
H _m = 1000 m							H _m = 3000 m					
0.5	0.6	1.0	1.6	1.8	2.2	2.3	0	1.2	1.5	1.9	2.1	
1	0.6	1.1	1.8	2.0	2.5	2.7		1.4	1.6	2.2	2.4	
2	0	1.2	2.2	2.5	3.1	3.4		1.6	2.0	2.7	3.0	
4		1.2	3.0	3.5	4.4	4.8		1.9	2.6	3.8	4.2	
8		0	4.2	5.2	6.9	7.6		1.9	3.5	5.8	6.5	
10			4.7	6.0	8.1	8.9		1.4	3.8	6.7	7.6	
20			6.1	9.0	13.6	15.1		0	3.5	10.6	12.5	
40			0	12.2	22.9	26.2			0	16.2	20.6	
80				0	37.5	45.1				20.5	32.1	
100					43.3	53.3				18.8	36.0	

TABLE 5-6 (Continued)

STABILITY CATEGORY III												
Distance (km)	Dū/Q						Distance (km)	Dū/Q				
	H _m = 500 m							H _m = 2000 m				
	10 ⁻⁶	5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹		5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹
0.5	1.0	1.3	1.8	1.9	2.3	2.4	0.5	0.7	1.4	1.6	1.9	2.1
1	1.1	1.4	2.0	2.1	2.5	2.7	1	0.7	1.5	1.7	2.2	2.3
2	1.2	1.7	2.4	2.6	3.1	3.3	2	0.6	1.7	2.0	2.6	2.8
4	1.3	2.1	3.2	3.6	4.3	4.6	4	0	2.2	2.7	3.6	3.9
8	0.2	2.6	4.8	5.4	6.7	7.2	8		2.9	3.9	5.4	6.0
10	0	2.7	5.5	6.3	7.9	8.5	10		3.2	4.4	6.3	7.0
20		0	8.5	10.2	13.4	14.6	20		2.7	6.1	10.4	11.7
40			12.3	16.4	23.4	25.8	40		0	5.9	17.1	20.0
80			11.5	24.3	40.6	45.9	80			0	26.5	33.6
100			0	26.3	48.3	55.2	100				29.7	39.2
H _m = 3000 m												
0.5	0.7	1.0	1.6	1.7	2.1	2.2	0.5	0.3	1.2	1.4	1.9	2.0
1	0.7	1.1	1.7	1.9	2.3	2.5	1	0.1	1.3	1.6	2.1	2.2
2	0.6	1.2	2.1	2.3	2.9	3.1	2	0	1.5	1.9	2.5	2.7
4	0	1.3	2.7	3.1	3.9	4.2	4		1.9	2.4	3.4	3.7
8		0.5	3.9	4.7	6.1	6.6	8		2.2	3.3	5.0	5.6
10		0	4.4	5.4	7.1	7.7	10		2.2	3.7	5.8	6.6
20			6.2	8.3	11.9	13.1	20		0	4.5	9.4	10.9
40			5.8	12.1	20.3	22.9	40			0	14.9	18.2
80			0	11.9	33.9	39.8	80				21.3	29.4
100				2.5	39.6	47.4	100				22.4	33.8

TABLE 5-6 (Continued)

STABILITY CATEGORY IV													
Distance (km)	D $\bar{u}$ /Q						Distance (km)	D $\bar{u}$ /Q					
	H $_m$ = 250 m							H $_m$ = 1000 m					
	5x10 ⁻⁶	10 ⁻⁶	5x10 ⁻⁷	10 ⁻⁷	10 ⁻⁸	5x10 ⁻⁹		10 ⁻⁶	5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹
0.5	0.6	1.3	1.5	1.9	2.4	2.4	0.5	0.7	1.0	1.5	1.7	2.1	2.2
1	0.5	1.4	1.6	2.1	2.6	2.7	1	0.7	1.1	1.7	1.9	2.3	2.4
2	0.3	1.6	1.9	2.5	3.2	3.3	2	0.7	1.2	2.0	2.2	2.7	2.9
4	0	2.1	2.5	3.4	4.4	4.6	4	0	1.4	2.6	2.9	3.7	3.9
8		2.7	3.6	5.1	6.8	7.2	8		1.2	3.7	4.4	5.6	6.0
10		2.8	4.0	6.0	8.0	8.5	10		0.4	4.2	5.0	6.5	7.1
20		1.5	5.5	9.7	13.7	14.7	20		0	6.1	7.9	11.0	12.1
40		0	3.8	15.9	24.3	26.3	40			7.0	11.9	18.9	21.2
80			0	24.2	43.4	47.7	80			0	14.2	32.0	37.1
100				26.8	52.2	57.8	100				11.8	37.6	44.3
0.5	H $_m$ = 500 m						0.5	H $_m$ = 1500 m					
	0	1.0	1.3	1.7	2.2	2.3		0.4	0.9	1.4	1.6	2.0	2.1
	1	1.1	1.4	1.9	2.4	2.6		0.3	0.9	1.5	1.8	2.2	2.3
	2	1.2	1.6	2.3	2.9	3.1		0	0.9	1.8	2.1	2.6	2.8
	4	1.4	2.0	3.0	4.0	4.3			0.9	2.3	2.7	3.5	3.7
	8	1.2	2.6	4.4	6.2	6.6			0	3.2	4.0	5.3	5.7
	10	0	2.8	5.1	7.3	7.8				3.6	4.5	6.1	6.7
	20		1.7	8.0	12.4	13.4				4.7	6.9	10.2	11.4
	40		0	12.1	21.7	23.8				0	9.4	17.3	19.7
	80			14.1	37.9	42.5					0	28.4	34.0
	100			11.2	45.2	51.2						32.8	40.2

TABLE 5-6 (Continued)

STABILITY CATEGORY V																				
Distance (km)	D $\bar{u}$ /Q						Distance (km)	D $\bar{u}$ /Q						Distance (km)	D $\bar{u}$ /Q					
	10 ⁻⁵	5x10 ⁻⁶	10 ⁻⁶	10 ⁻⁷	10 ⁻⁸	5x10 ⁻⁹		10 ⁻⁶	5x10 ⁻⁷	10 ⁻⁷	5x10 ⁻⁸	10 ⁻⁸	5x10 ⁻⁹							
	H _m = 125 m							H _m = 500 m							H _m = 1000 m					
0.5	0.1	1.0	1.5	2.1	2.5	2.6	0.5	1.1	1.3	1.7	1.9	2.2	2.3	1.1	1.3	1.7	1.9	2.2		
1	0.7	1.1	1.7	2.2	2.7	2.8	1	1.2	1.4	1.9	2.0	2.4	2.5	1.2	1.4	1.9	2.0	2.4		
2	0.7	1.2	1.9	2.6	3.2	3.4	2	1.3	1.6	2.2	2.4	2.8	2.9	1.3	1.6	2.2	2.4	2.8		
4	0.3	1.4	2.5	3.6	4.4	4.6	4	1.6	2.0	2.8	3.1	3.7	3.9	1.6	2.0	2.8	3.1	3.7		
8	0	1.3	3.6	5.5	6.8	7.2	8	1.8	2.8	4.2	4.7	5.7	6.0	1.8	2.8	4.2	4.7	5.7		
10		0.8	4.1	6.4	8.0	8.4	10	1.8	3.1	4.9	5.5	6.7	7.1	1.8	3.1	4.9	5.5	6.7		
20		0	6.1	10.8	14.0	14.8	20	0	3.6	7.9	9.1	11.5	12.3	0	3.6	7.9	9.1	11.5		
40			7.3	18.5	25.1	26.8	40		0	12.5	15.2	20.3	22.1		0	12.5	15.2	20.3		
80			0	31.5	45.9	49.4	80			17.6	24.7	36.0	40.0			17.6	24.7	36.0		
100				37.0	55.6	60.1	100			18.3	28.2	43.2	48.3			18.3	28.2	43.2		
H _m = 250 m																				
0.5	0	0.7	1.3	1.9	2.3	2.4	0.5	0.8	1.1	1.6	1.7	2.1	2.2	0.8	1.1	1.6	1.7	2.1		
1		0.7	1.4	2.1	2.5	2.7	1	0.9	1.2	1.7	1.8	2.2	2.3	0.9	1.2	1.7	1.8	2.2		
2		0.7	1.6	2.4	3.0	3.1	2	0.9	1.3	1.9	2.1	2.5	2.7	0.9	1.3	1.9	2.1	2.5		
4		0.4	2.1	3.2	4.0	4.2	4	0.9	1.5	2.5	2.8	3.4	3.6	0.9	1.5	2.5	2.8	3.4		
8		0	2.8	4.8	6.2	6.6	8	0	1.8	3.6	4.1	5.1	5.5	0	1.8	3.6	4.1	5.1		
10			3.1	5.6	7.3	7.8	10		1.8	4.1	4.8	6.0	6.5		1.8	4.1	4.8	6.0		
20			3.6	9.3	12.7	13.5	20		0	6.3	7.7	10.3	11.2		0	6.3	7.7	10.3		
40			0	15.6	22.7	24.5	40			8.8	12.3	17.9	19.9			8.8	12.3	17.9		
80				25.1	41.0	44.6	80			4.7	17.5	31.0	35.3			4.7	17.5	31.0		
100				28.7	49.5	54.2	100			0	18.3	36.8	42.4			0	18.3	36.8		

TABLE 5-6 (Continued)

STABILITY CATEGORY VI														
Distance (km)	D $\bar{u}$ /Q						Distance (km)	D $\bar{u}$ /Q						
	$H_m = 125\text{ m}$							$H_m = 500\text{ m}$						
10^{-5}	5×10^{-6}	10^{-6}	10^{-7}	10^{-8}	5×10^{-9}		5×10^{-6}	10^{-6}	5×10^{-7}	10^{-7}	10^{-8}	5×10^{-9}		
0.5	0.8	1.1	1.6	2.1	2.5	2.6	0.5	0.3	1.1	1.3	1.7	2.2	2.3	
1	0.8	1.1	1.7	2.2	2.7	2.8	1	0.1	1.2	1.4	1.9	2.3	2.5	
2	0.8	1.3	1.9	2.6	3.1	3.3	2	0	1.3	1.6	2.1	2.7	2.8	
4	0.7	1.5	2.5	3.5	4.2	4.4	4		1.6	2.0	2.8	3.6	3.8	
8	0	1.6	3.6	5.3	6.5	6.9	8		2.0	2.8	4.1	5.5	5.8	
10		1.4	4.1	6.2	7.7	8.1	10		2.0	3.1	4.8	6.4	6.9	
20		0	6.2	10.5	13.5	14.2	20		0	4.1	7.8	11.2	12.0	
40			8.1	18.2	24.4	25.9	40			0	12.6	19.9	21.6	
80			0	31.2	44.6	47.9	80				18.6	35.5	39.2	
100				36.9	54.2	58.4	100				20.0	42.7	47.4	
0.5 1 2 4 8 10 20 40 80 100	$H_m = 250\text{ m}$						0.5 1 2 4 8 10 20 40 80 100	$H_m = 1000\text{ m}$						
	$H_m = 250\text{ m}$							$H_m = 1000\text{ m}$						
														0.2
0.1	0.8	1.4	2.0	2.5	2.6	1		0.9	1.2	1.7	2.2	2.3		
0	0.8	1.6	2.4	2.9	3.1	2		1.0	1.3	1.9	2.5	2.6		
	0.7	2.1	3.1	3.9	4.1	4		1.0	1.6	2.4	3.3	3.5		
	0	2.9	4.7	6.0	6.3	8		0.4	2.0	3.5	5.0	5.3		
		3.2	5.5	7.1	7.5	10		0	2.0	4.1	5.8	6.3		
		4.1	9.2	12.3	13.1	20			0	6.4	10.0	10.9		
		0	15.5	22.1	23.7	40				9.3	17.7	19.5		
			25.3	40.0	43.5	80				8.7	30.9	34.9		
			29.2	48.4	52.9	100				0	36.8	42.0		

TABLE 5-6 (Continued)

STABILITY CATEGORY VII															
Distance (km)	Dū/Q					Distance (km)	Dū/Q								
	10 ⁻⁵	5x10 ⁻⁶	10 ⁻⁶	10 ⁻⁷	10 ⁻⁸		10 ⁻⁵	5x10 ⁻⁶	10 ⁻⁶	10 ⁻⁷	10 ⁻⁸				
H _m = 75 m										H _m = 250 m					
0.5	1.1	1.3	1.7	2.1	2.5	2.6	0.5	0.5	0.8	1.4	1.9	2.3	2.4		
1	1.1	1.4	1.8	2.3	2.7	2.8	1	0.4	0.9	1.5	2.0	2.4	2.6		
2	1.2	1.5	2.1	2.7	3.1	3.3	2	0.3	0.9	1.6	2.3	2.8	2.9		
4	1.4	1.9	2.7	3.5	4.2	4.4	4	0	1.0	2.0	3.0	3.7	3.9		
8	1.6	2.6	4.0	5.4	6.5	6.8	8		0	2.9	4.5	5.7	6.0		
10	1.5	2.8	4.6	6.3	7.7	8.0	10			3.3	5.3	6.7	7.1		
20	0	3.2	7.4	10.9	13.5	14.2	20			4.5	8.9	11.8	12.5		
40		0	11.6	19.3	24.7	26.1	40			3.8	15.3	21.4	22.9		
80			15.9	34.3	45.8	48.7	80			0	25.7	39.0	42.2		
100			16.1	41.1	55.8	59.6	100				30.0	47.3	51.4		
0.5	H _m = 125 m						H _m = 500 m								
	0.9	1.1	1.6	2.0	2.4		2.5	0	0.5	1.2	1.8			2.2	2.3
	0.9	1.2	1.7	2.2	2.6		2.7	1	0.4	1.2	1.8			2.3	2.4
	0.9	1.3	1.9	2.5	3.0		3.1	2	0.3	1.3	2.1			2.6	2.7
	1.0	1.6	2.4	3.3	4.0		4.1	4	0	1.6	2.7			3.4	3.6
	0	1.9	3.5	5.0	6.1		6.4	8		2.2	4.0			5.2	5.5
		1.9	4.1	5.9	7.2		7.6	10		2.3	4.7			6.2	6.6
		0	6.3	10.1	12.8		13.5	20		1.8	7.7			10.8	11.6
			9.1	17.7	23.3		24.7	40		0	12.8			19.5	21.1
			7.5	30.8	42.9		45.9	80			19.9			35.1	38.5
			0	36.6	52.2		56.1	100			22.2			42.3	46.7

5.3 BOX-MODEL ESTIMATES OF CONCENTRATION AND DOSAGE FOR NORMAL AND ABNORMAL LAUNCHES

The four nomograms given in Figures 5-3 through 5-6 can be used to calculate the normalized peak concentration and dosage for downwind distances exceeding 10 kilometers. In constructing the nomograms it was assumed that:

- The effective height of release and source dimensions may be neglected
- There is complete vertical mixing throughout the surface layer
- The alongwind concentration distribution and the crosswind concentration and dosage distributions are Gaussian with standard deviations that are proportional to the downwind distance
- Wind direction shear in the mixing layer is 20 degrees over land and 10 degrees over water

Under these assumptions, the expressions for normalized concentration and dosage can be written

$$x/Q = \left(2\pi H_m \sigma_x \sigma_y \right)^{-1} \quad (5-1)$$

$$D\bar{u}/Q = \left(\sqrt{2\pi} H_m \sigma_y \right)^{-1} \quad (5-2)$$

where

- Q = total amount of material released in the surface layer
- H_m = depth of the mixing layer (meters)
- σ_x = alongwind standard deviation (meters)
- σ_y = crosswind standard deviation (meters)

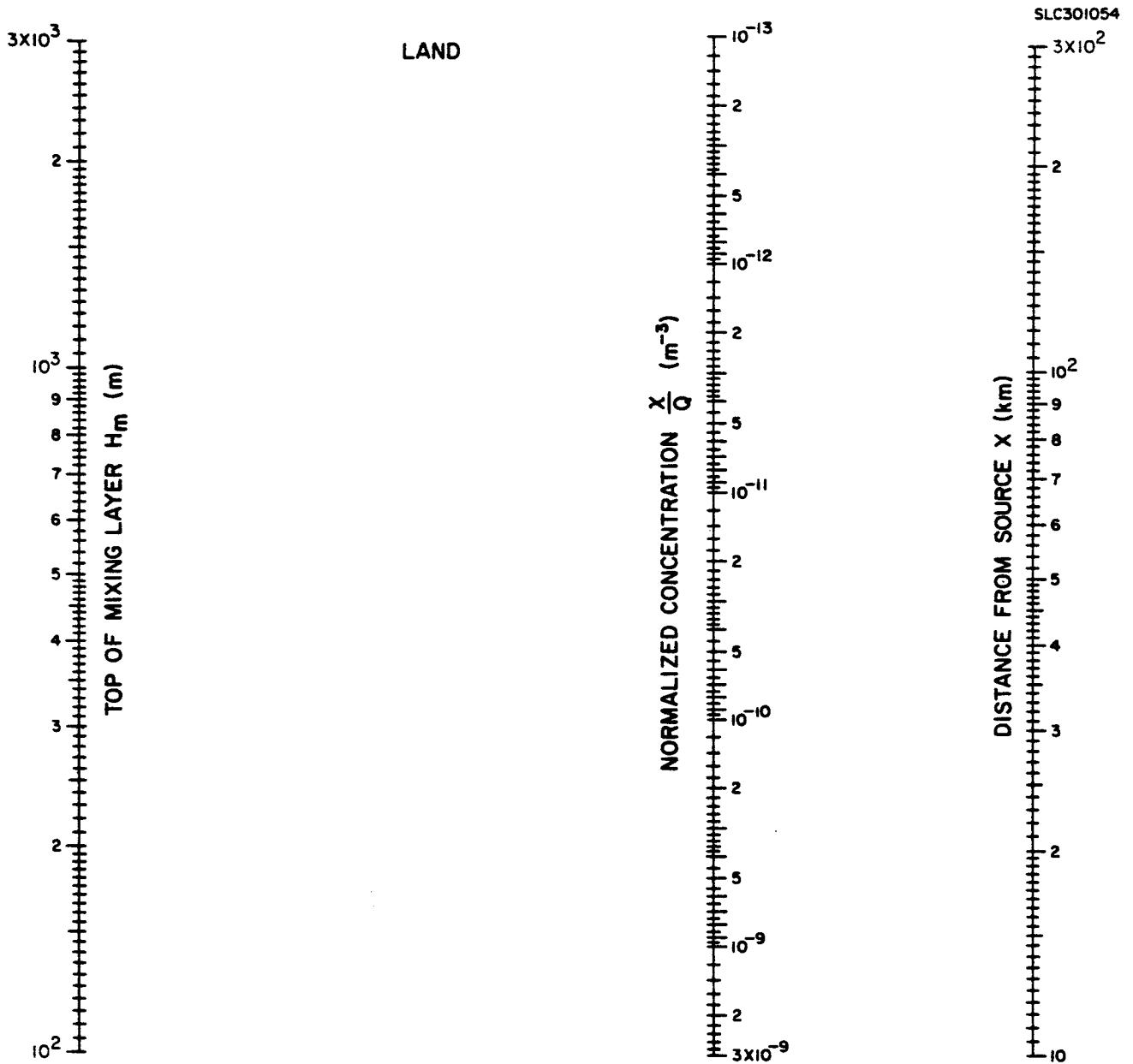


FIGURE 5-3. Nomogram for calculating normalized concentration for land trajectories at travel distances greater than 10 kilometers.

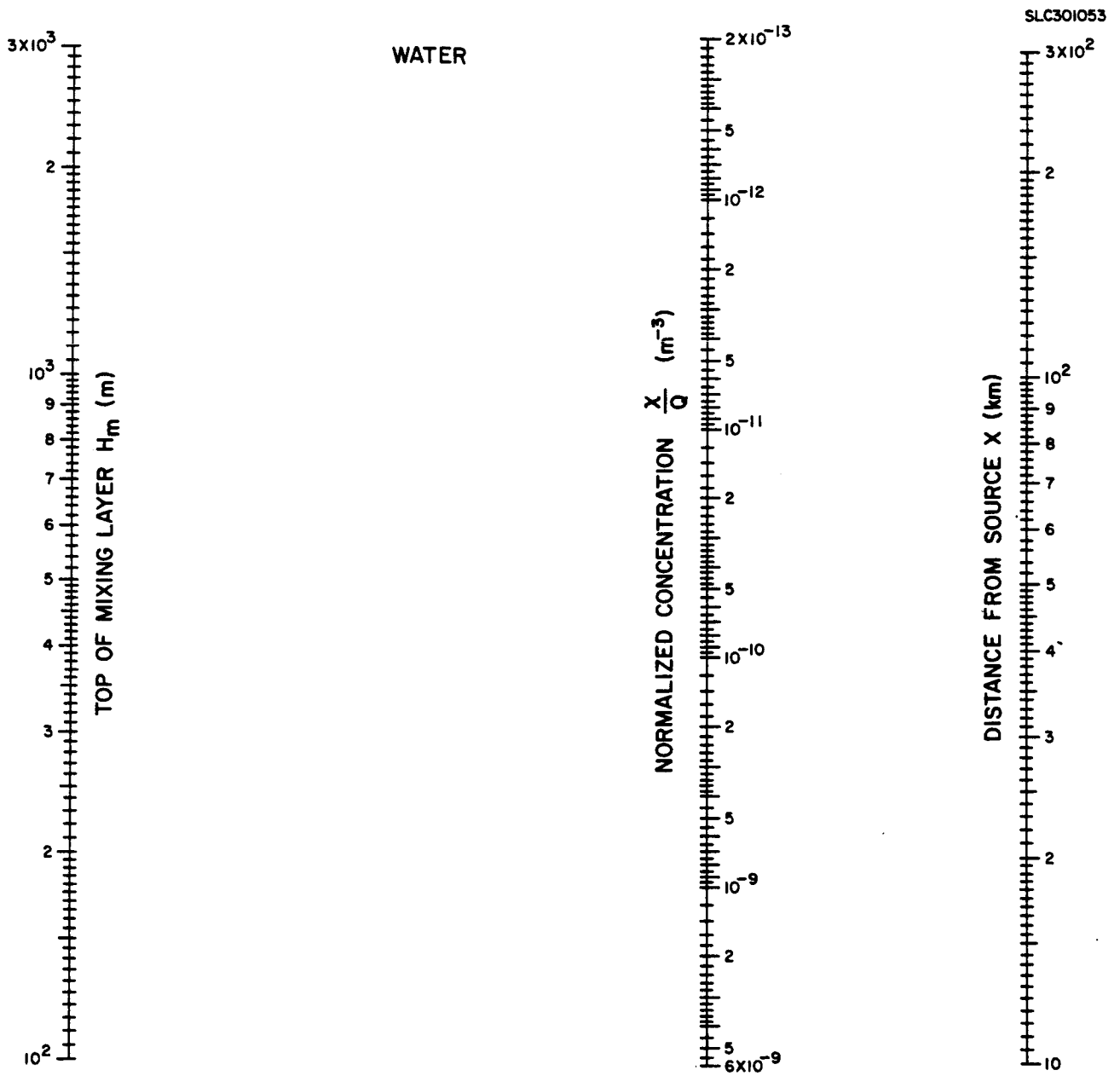


FIGURE 5-4. Nomogram for calculating normalized concentration for water trajectories at travel distances greater than 10 kilometers.

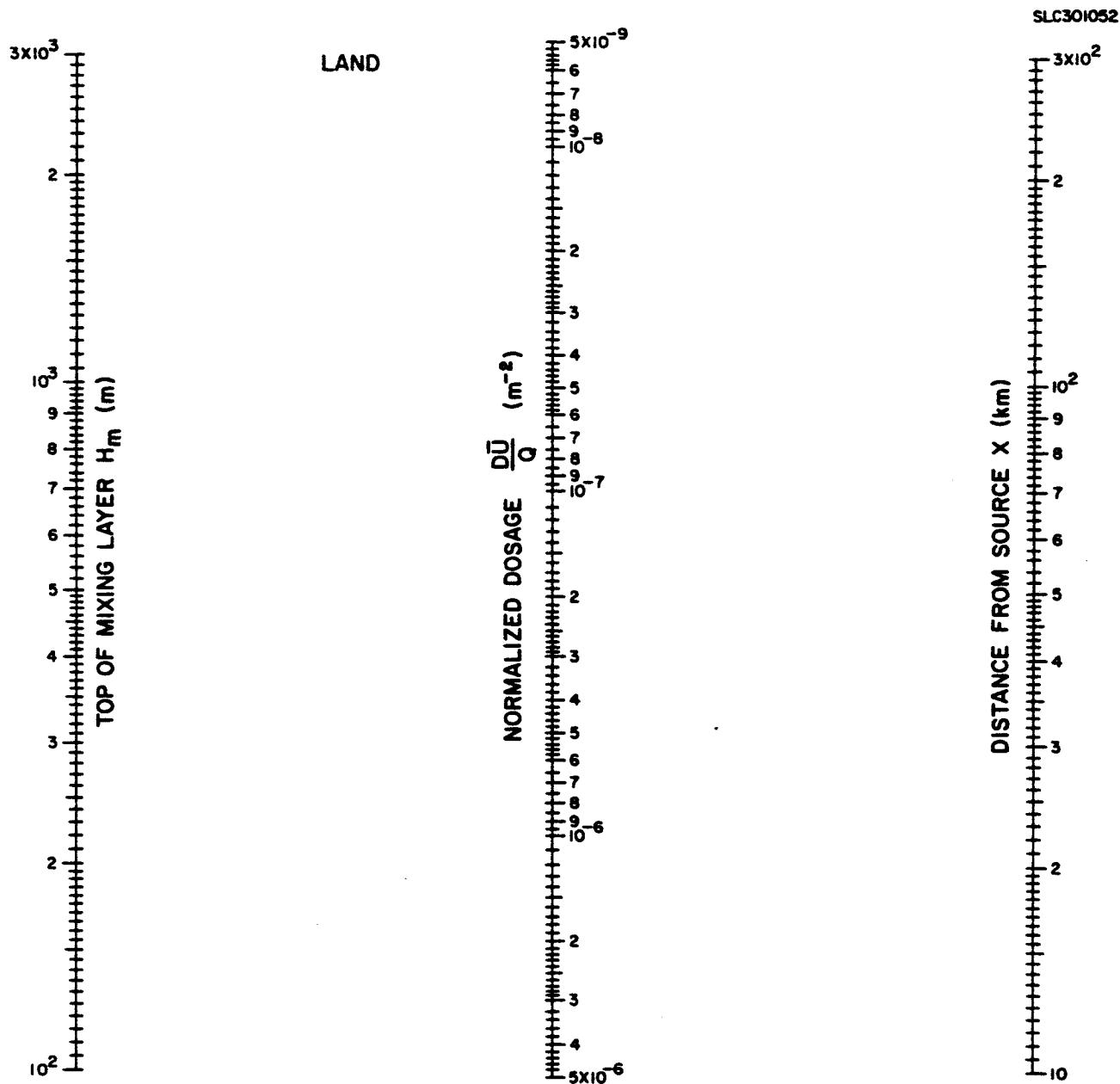


FIGURE 5-5. Nomogram for calculating normalized dosage for land trajectories at travel distances greater than 10 kilometers.

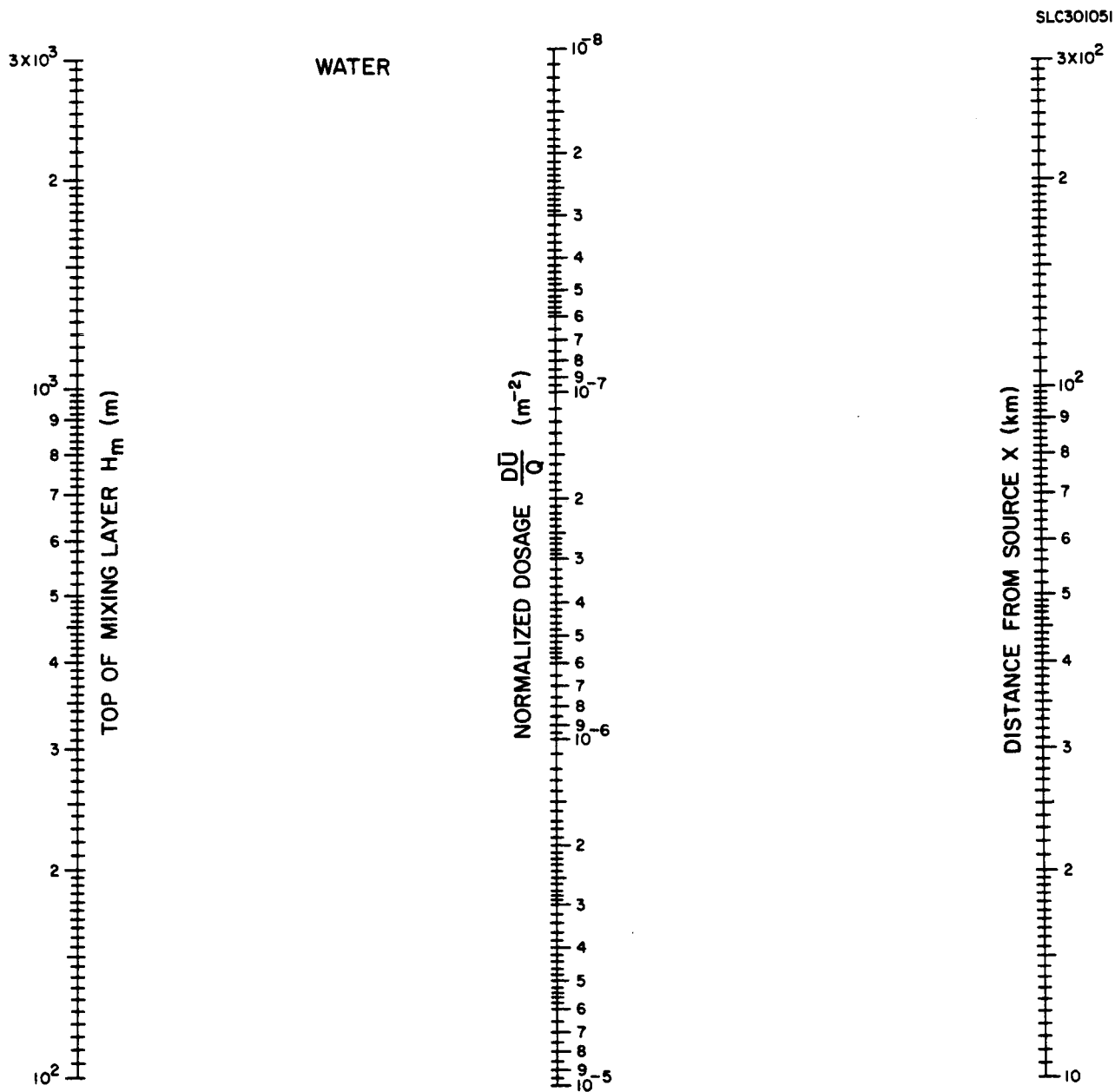


FIGURE 5-6. Nomogram for calculating normalized dosage for water trajectories at travel distances greater than 10 kilometers.

The crosswind and alongwind cloud dimensions are given by the following relationships:

$$\text{Over a land surface} \quad \sigma_x = 0.0651 x \quad \sigma_y = 0.0811 x$$

$$\text{Over a water surface} \quad \sigma_x = 0.0651 x \quad \sigma_y = 0.0406 x$$

where x is the downwind distance in meters. Figures 5-3 and 5-4 are used to calculate normalized concentration for land and water trajectories, respectively. Figures 5-5 and 5-6 are used to calculate normalized dosage for overland and overwater trajectories, respectively. In each case, the nomograms can also be used to calculate the distance at which the concentration or dosage drops to some specified level. Examples of the use of the nomograms are given in Figure 5-7.

5.4 CONCENTRATION FIELDS FROM COLD SPILLS AND LEAKS

Figure 5-8 shows the normalized axial ground-level ($z=2m$) concentration resulting from either a cold spill 50 meters in diameter or a surface leak as a function of travel distance. Separate plots are given for each of the seven stability categories, and individual curves have been drawn on each plot for several mixing depths. Differences between the concentration fields from the two release modes are significant only at distances less than 0.5 kilometers. Over these short distances, the values predicted for the cold spill are indicated by dashed lines. Estimates of actual concentration are obtained by multiplying the ordinate values by $Q/\bar{u}$, where Q is the quantity of material released per second and $\bar{u}$ is the wind speed at a height of 18 meters in meters per second.

Figure 5-9 shows similar plots of normalized axial concentration downwind from a leak at a height of 50 meters. At short travel distances, the axial concentrations at ground level ($z=2m$) are indicated by dashed lines and the axial concentrations at a height of 50 meters by the solid curves.

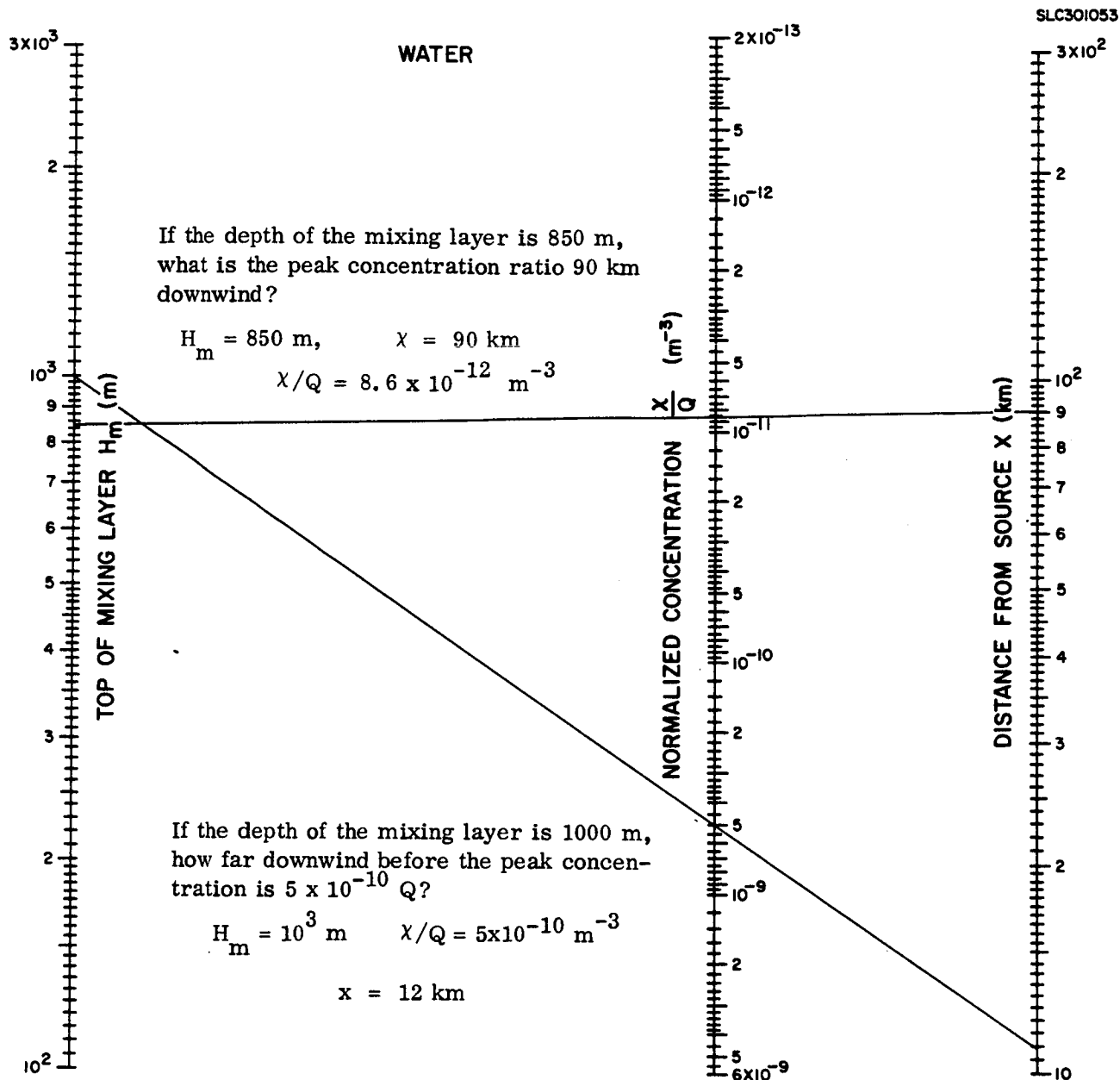


FIGURE 5-7. Two examples illustrating the use of Figure 5-4.

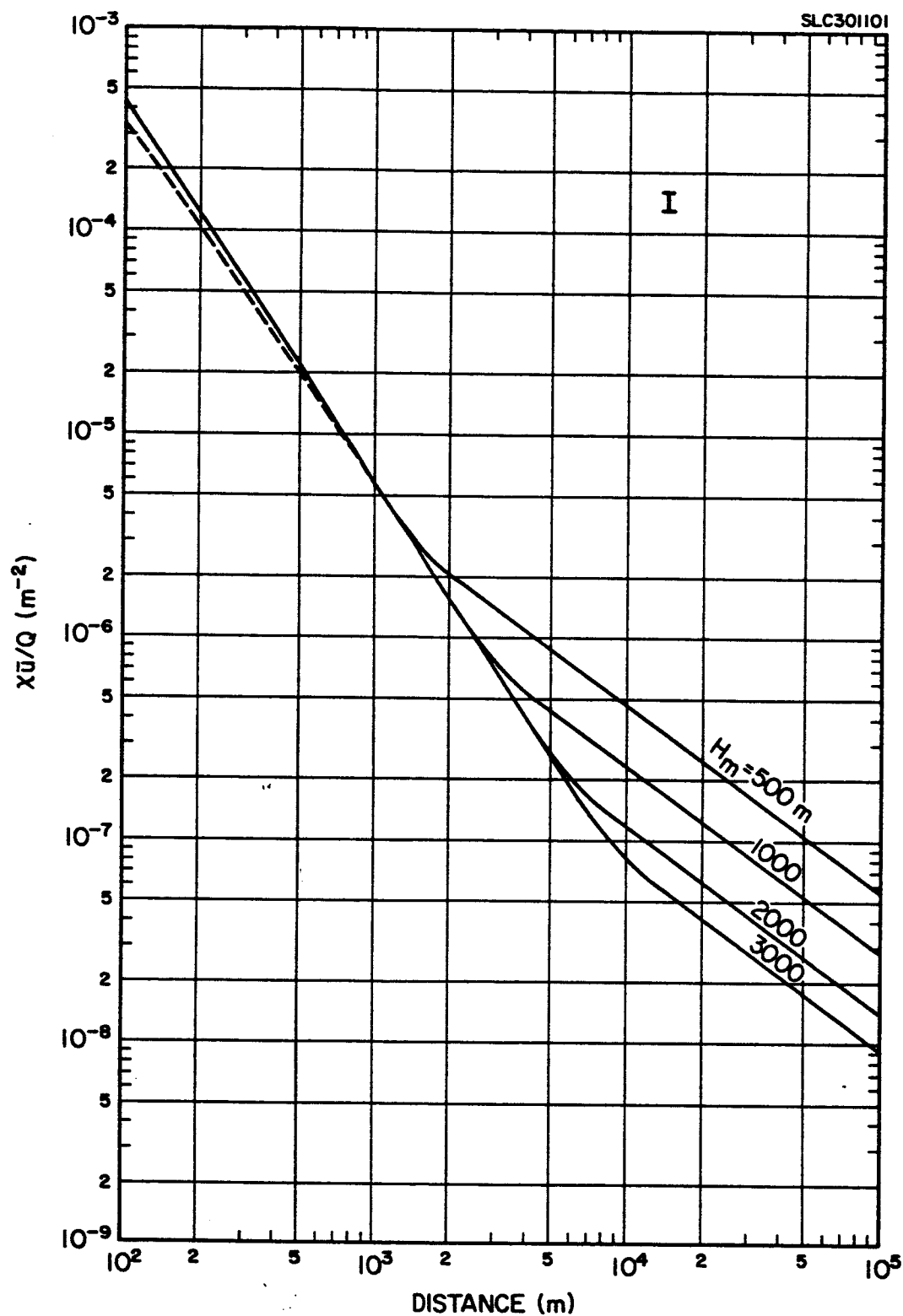


FIGURE 5-3. Normalized axial ground-level concentration versus travel distance from a surface leak or cold spill for Stability Category I. Dashed curve shows predicted values at short distances from a surface spill. H_m is depth of mixing layer.

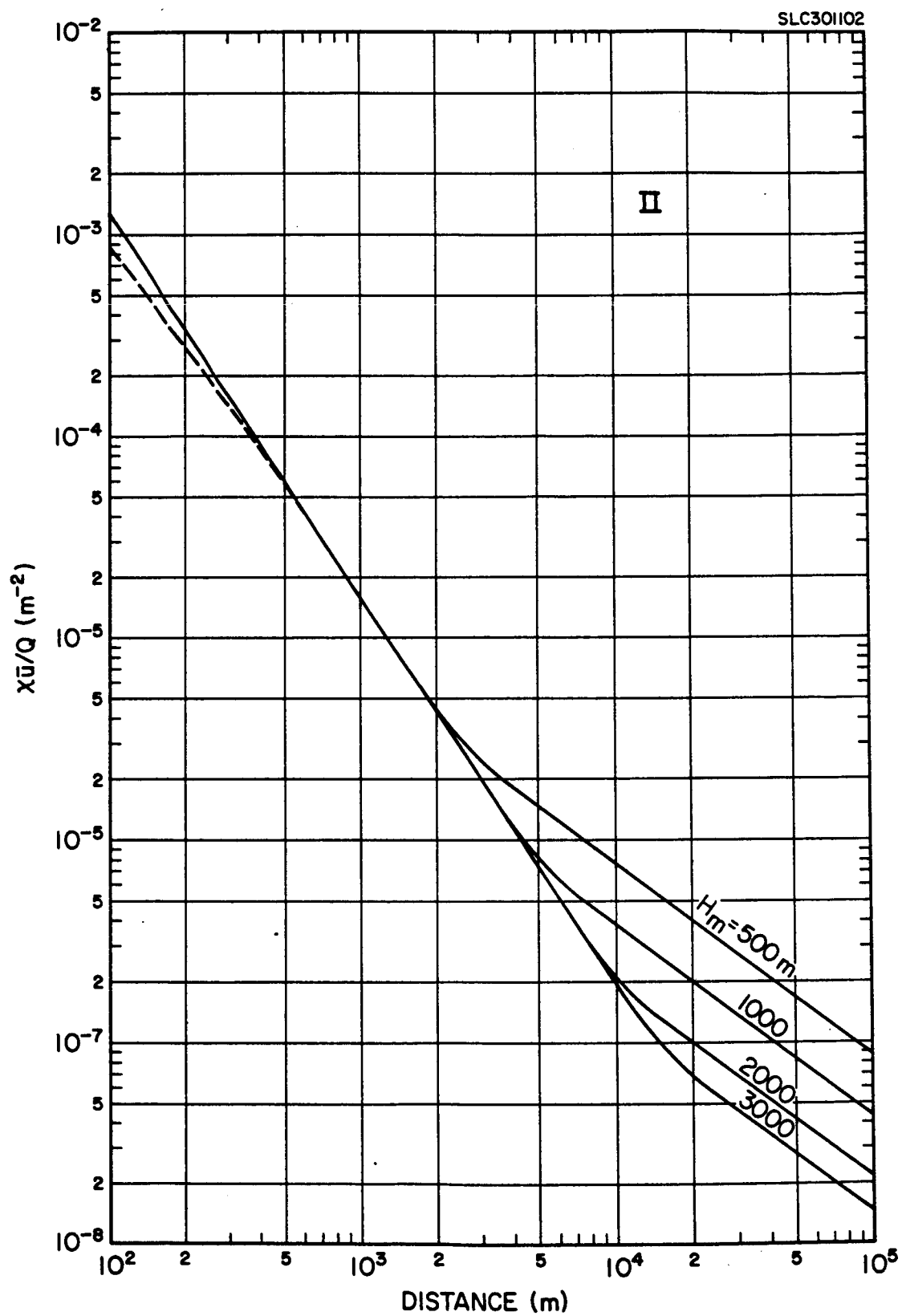


FIGURE 5-8. (Continued) Stability Category II

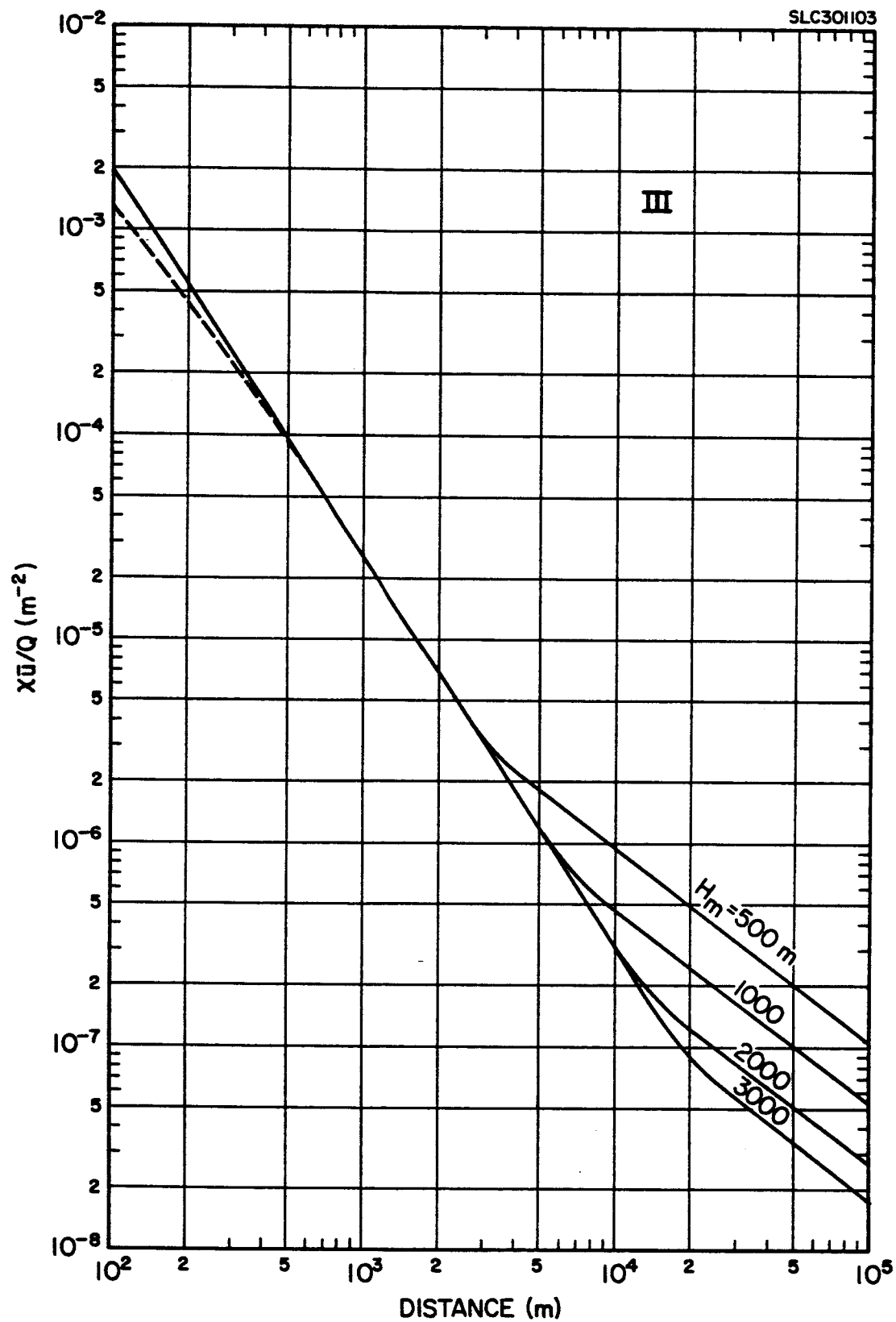


FIGURE 5-8. (Continued) Stability Category III.

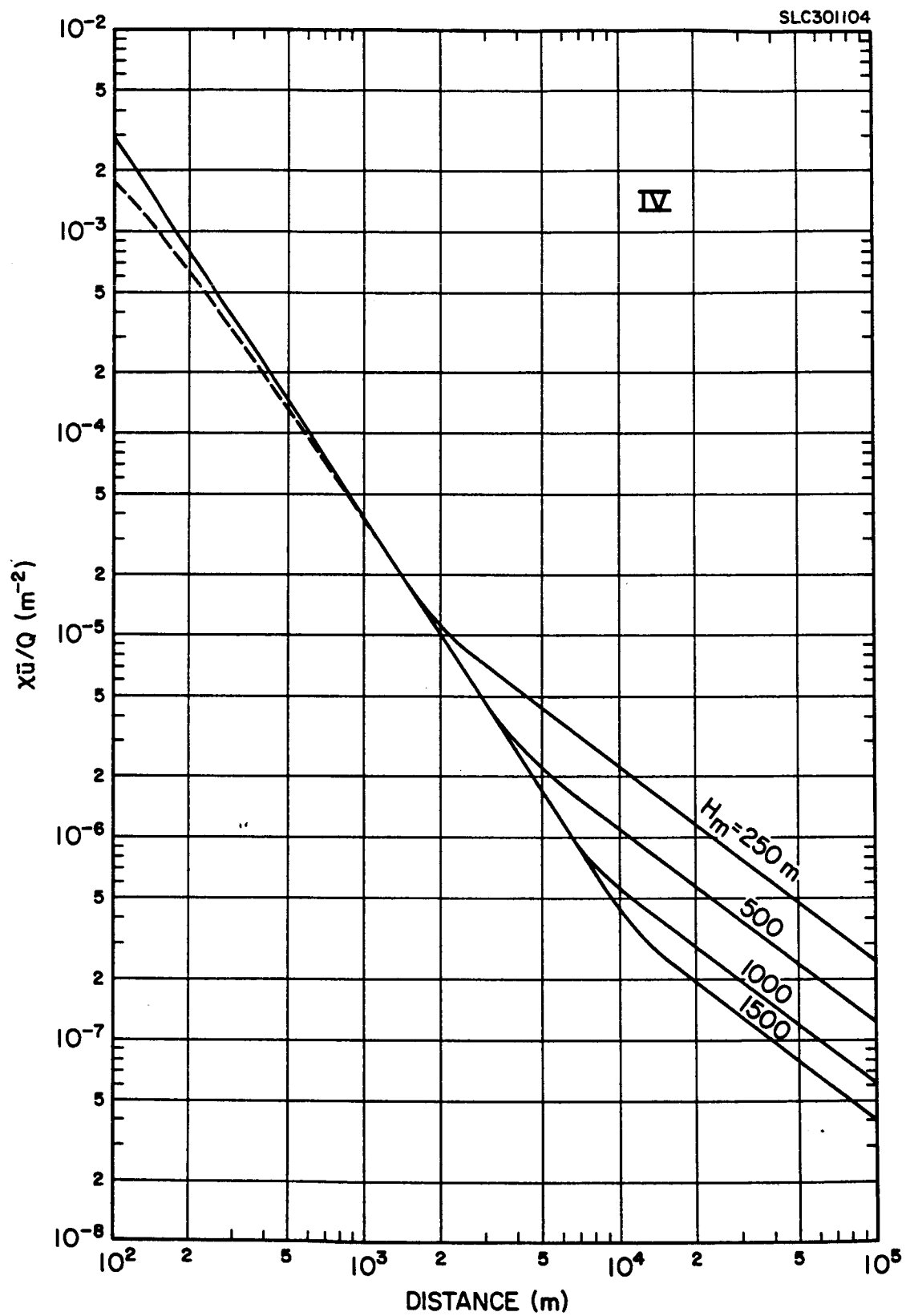


FIGURE 5-8. (Continued) Stability Category IV.

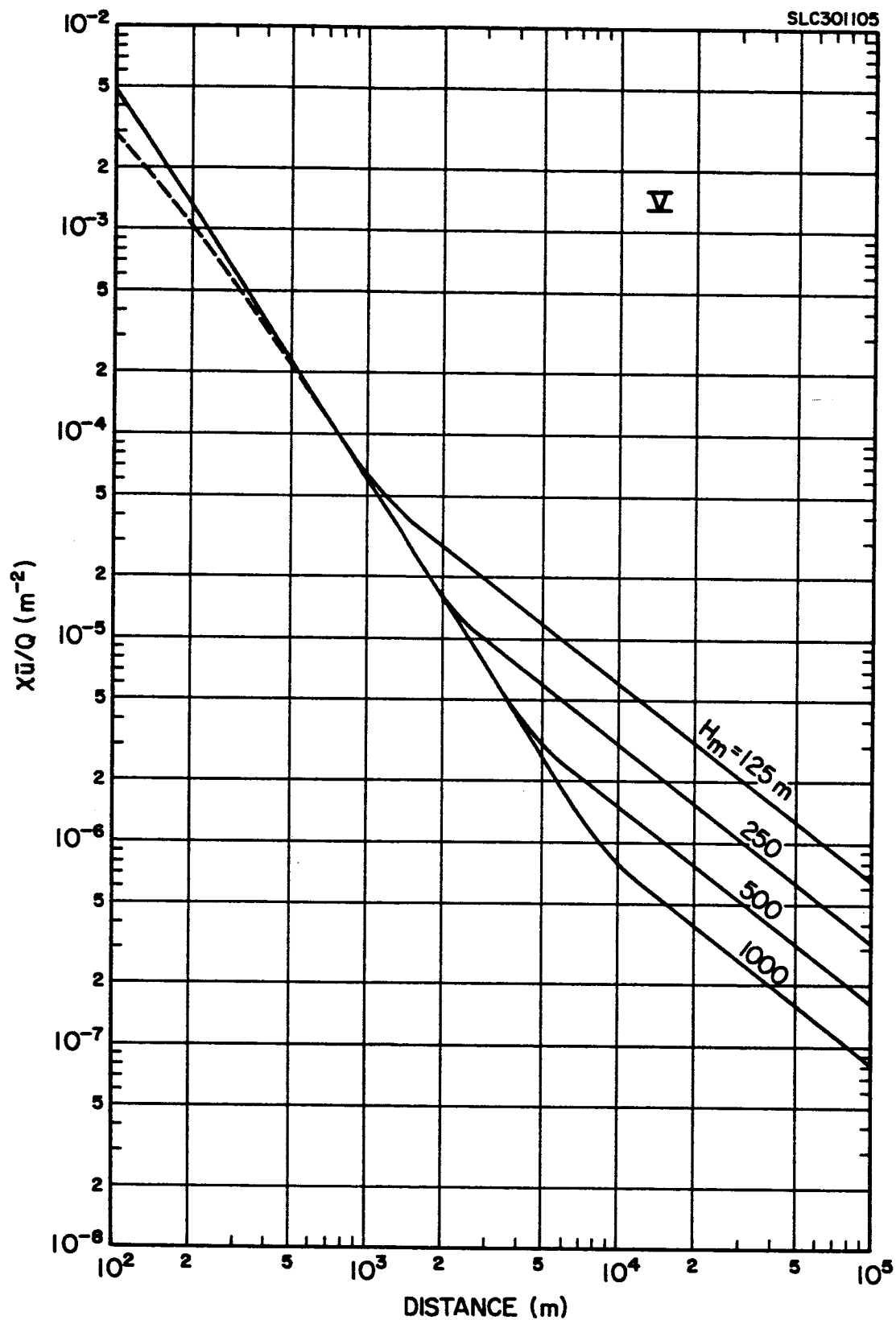


FIGURE 5-8. (Continued) Stability Category V.

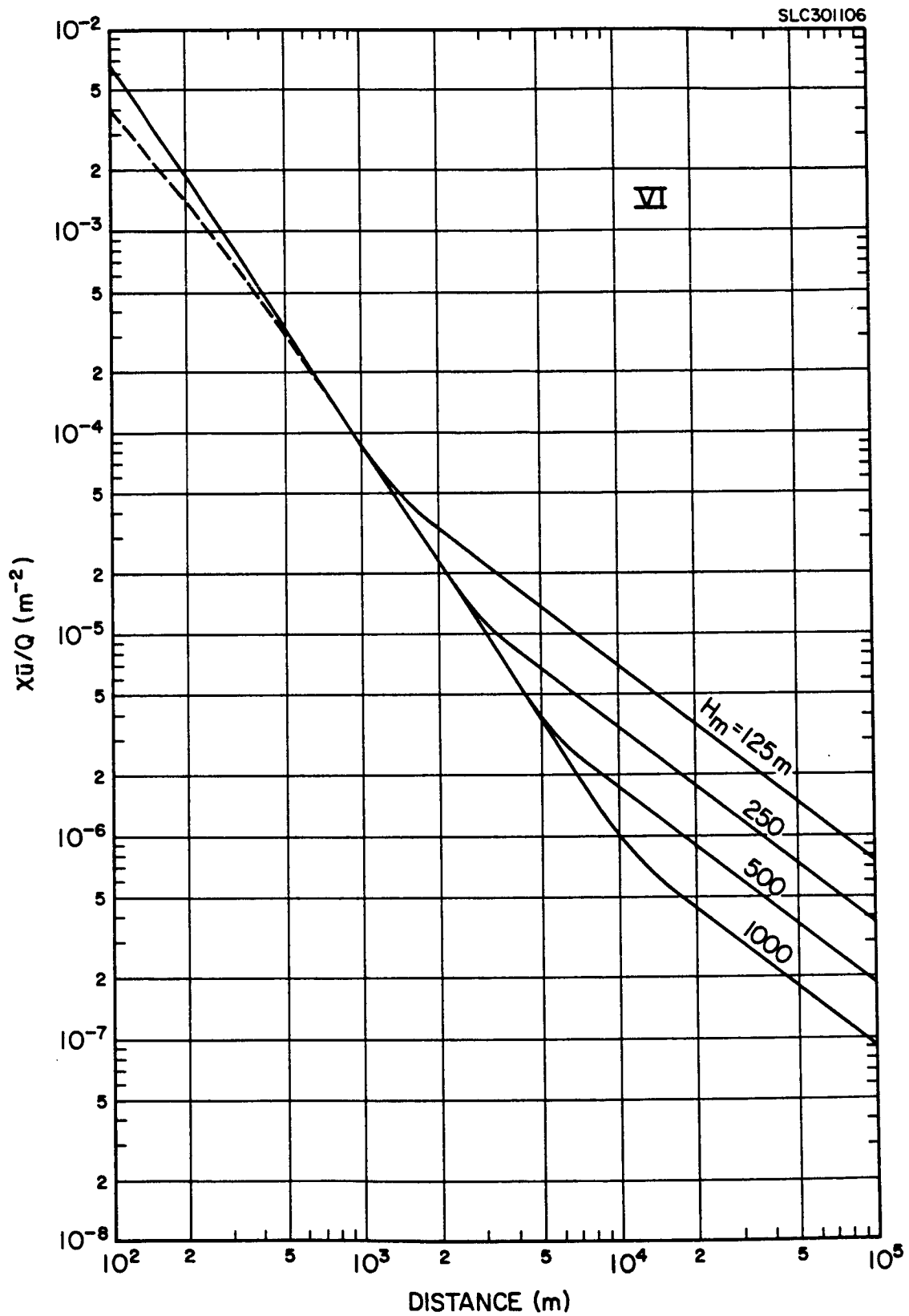


FIGURE 5-8. (Continued) Stability Category VI.

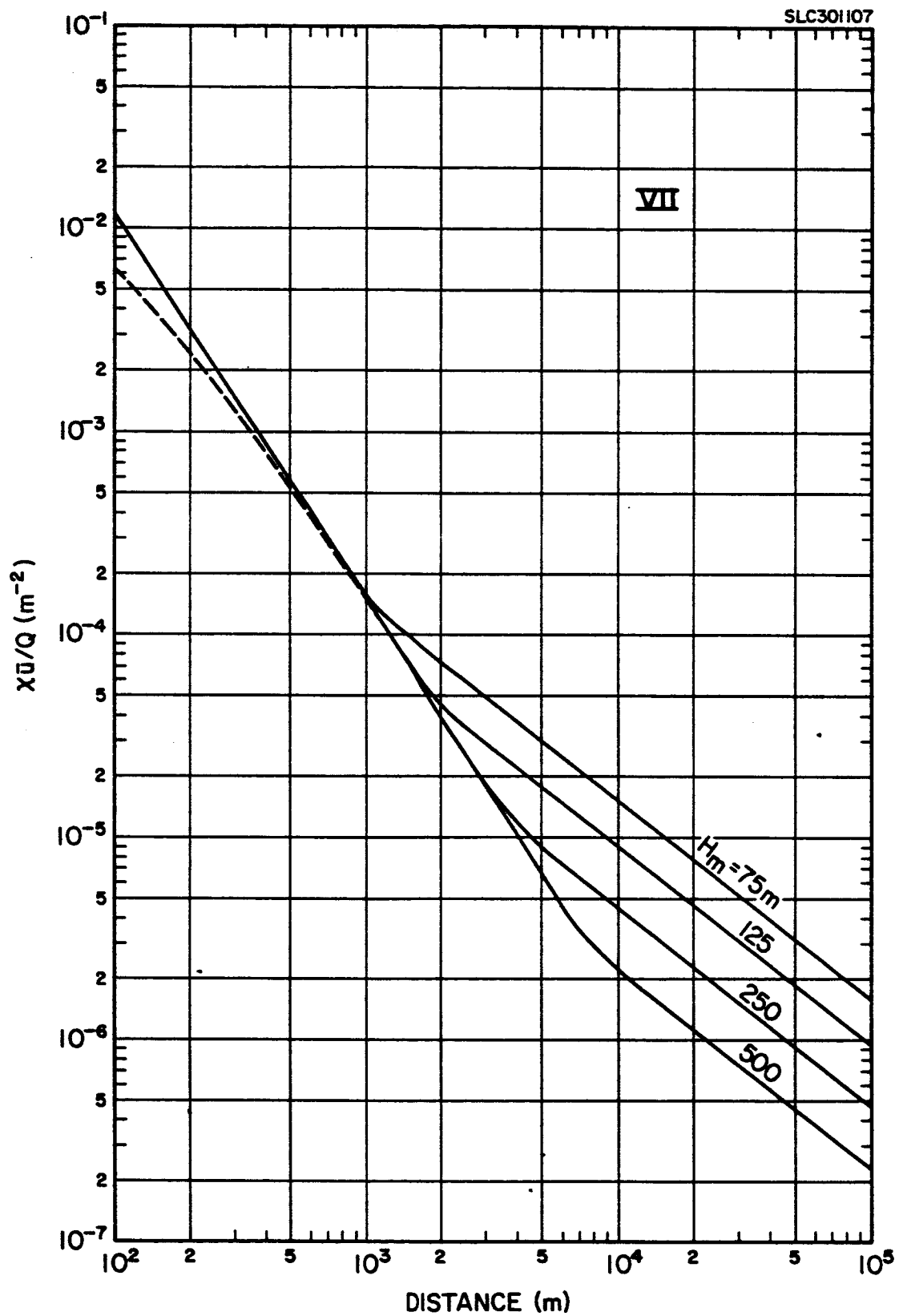


FIGURE 5-8. (Continued) Stability Category VII.

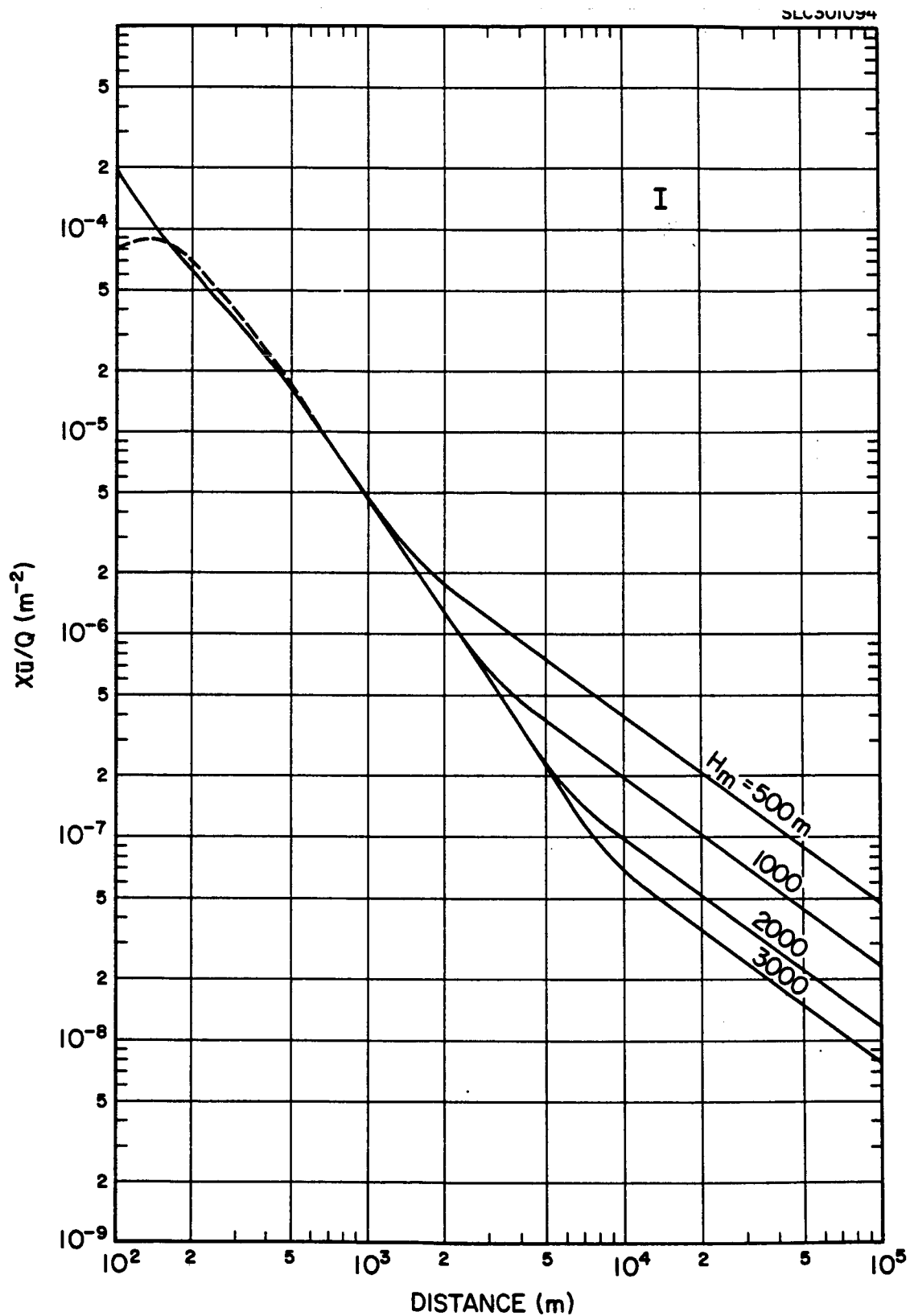


FIGURE 5-9. Normalized axial concentration versus travel distance from a leak at a height of 50 meters for Stability Category I. At short distances, solid curve shows predicted values at a height of 50 meters and the dashed curve shows predicted values at ground level. H_m is depth of mixing layer.

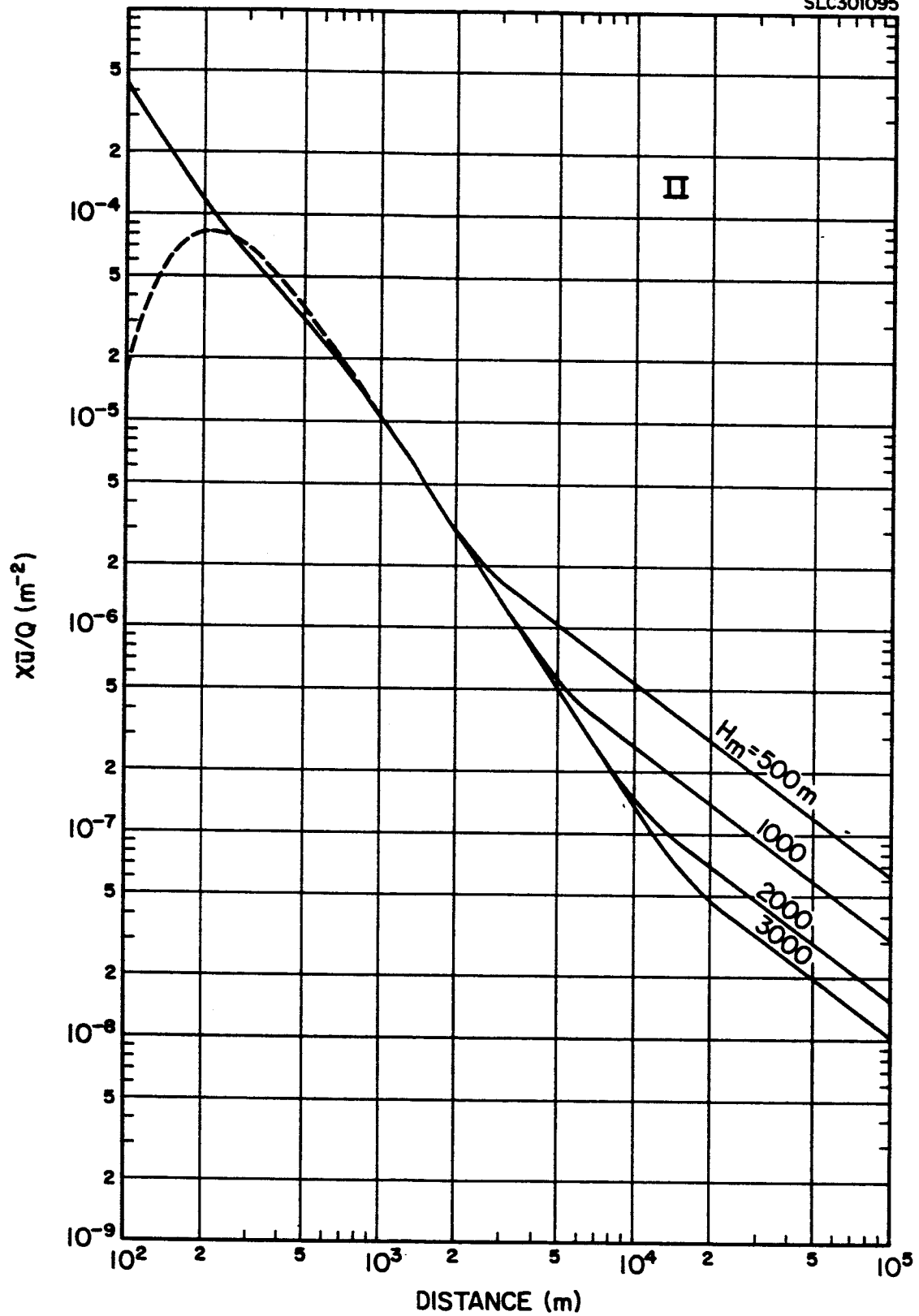


FIGURE 5-9. (Continued) Stability Category II.

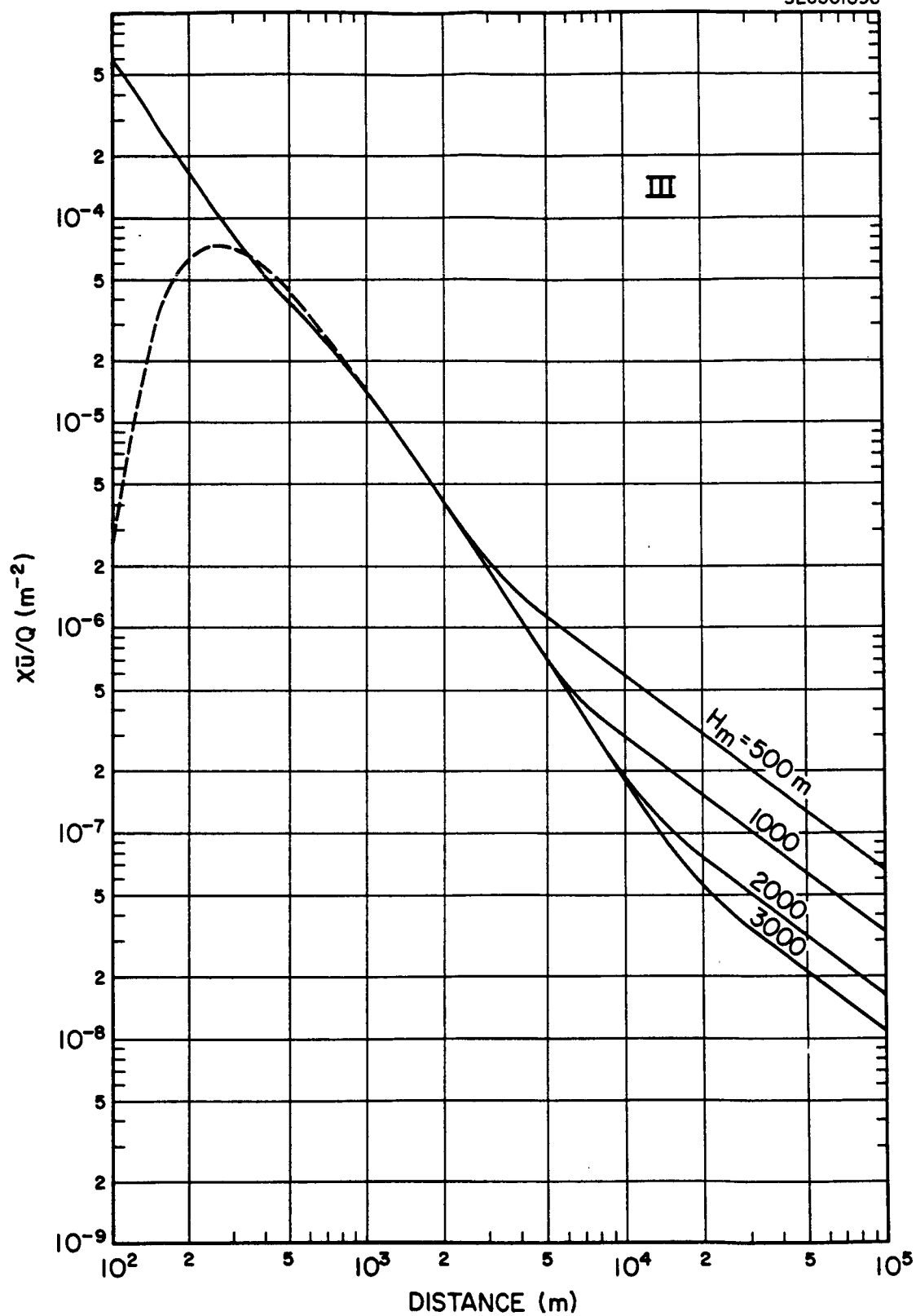


FIGURE 5-9. (Continued) Stability Category III.

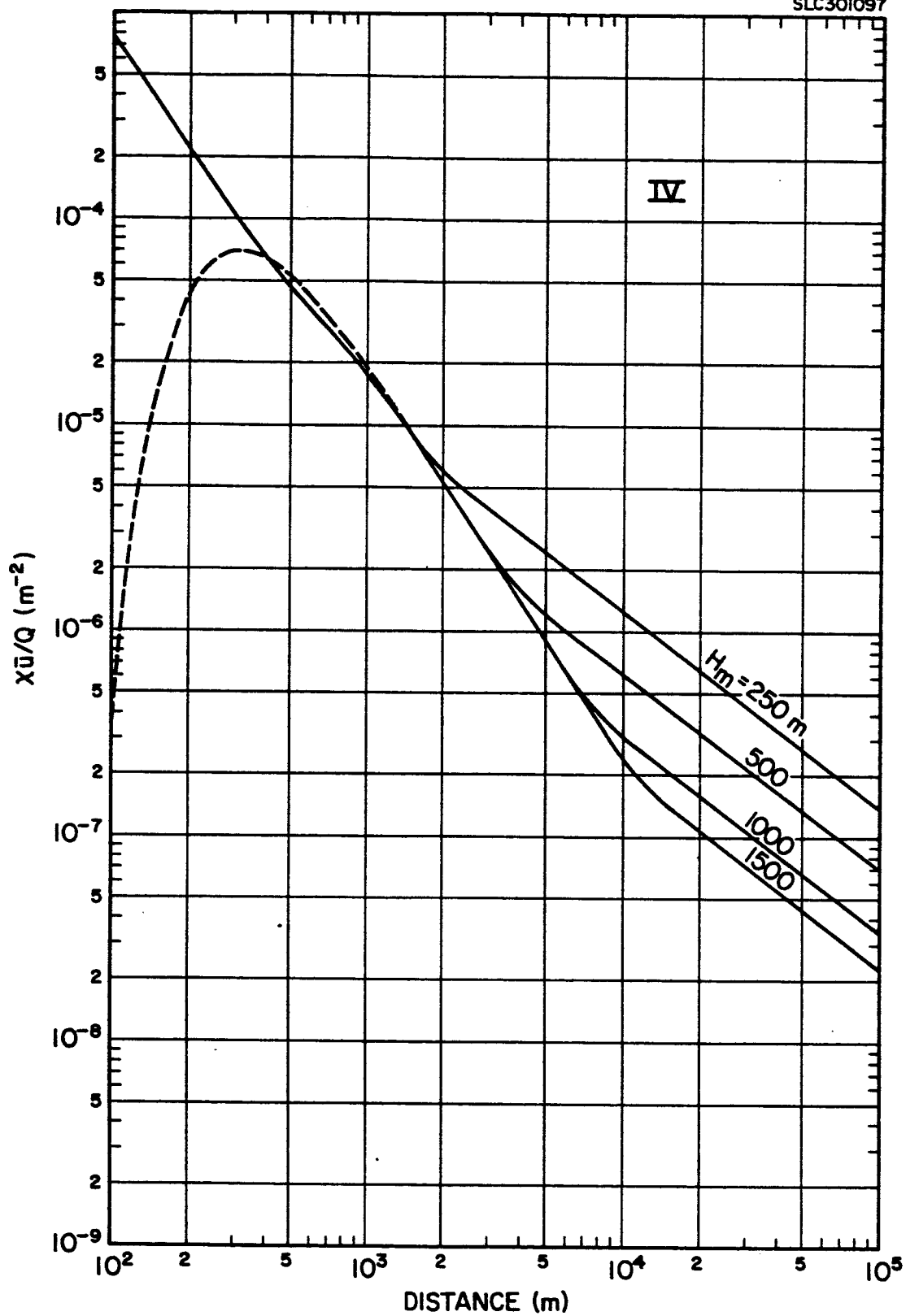


FIGURE 5-9. (Continued) Stability Category IV.

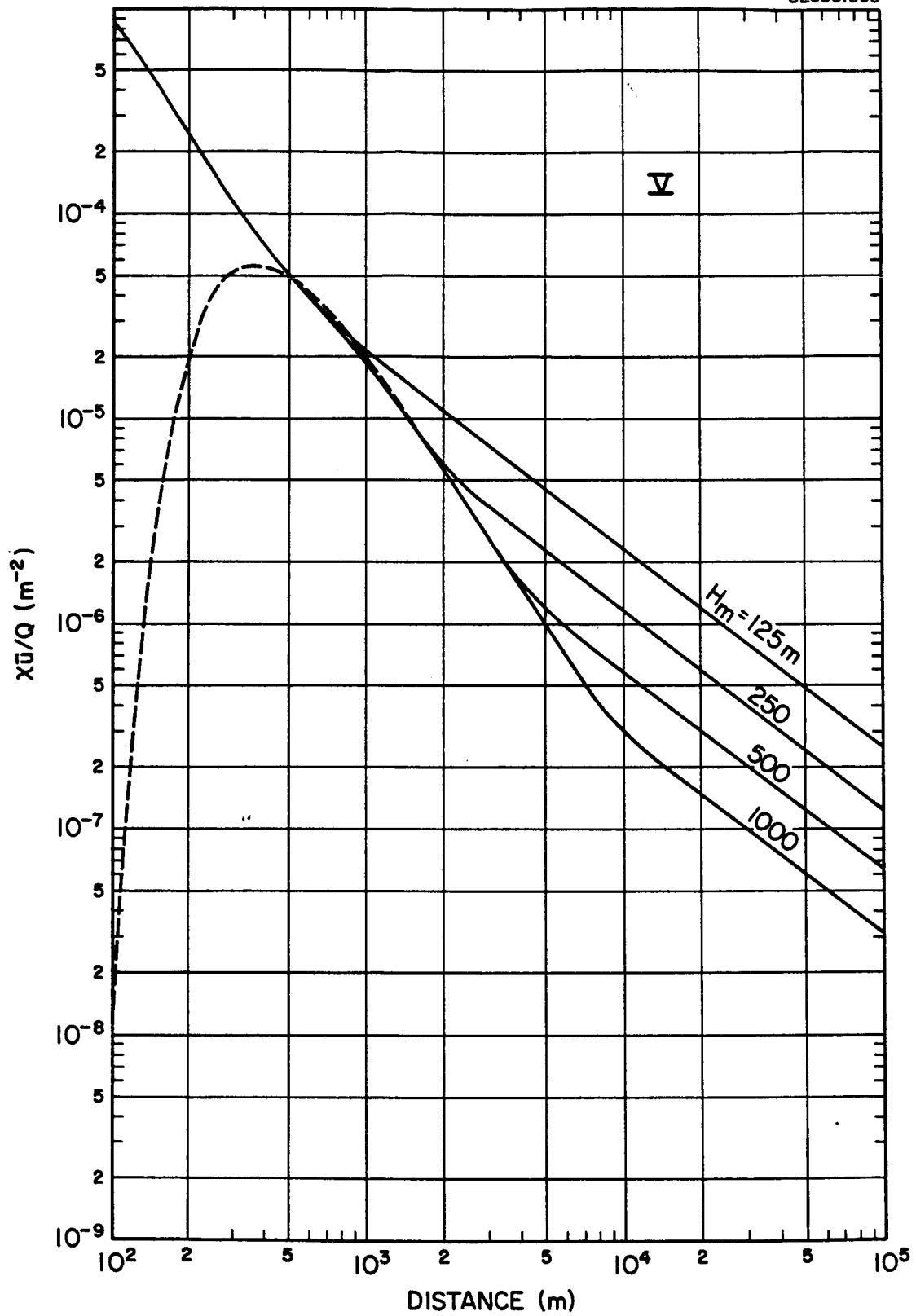


FIGURE 5-9. (Continued) Stability Category V.

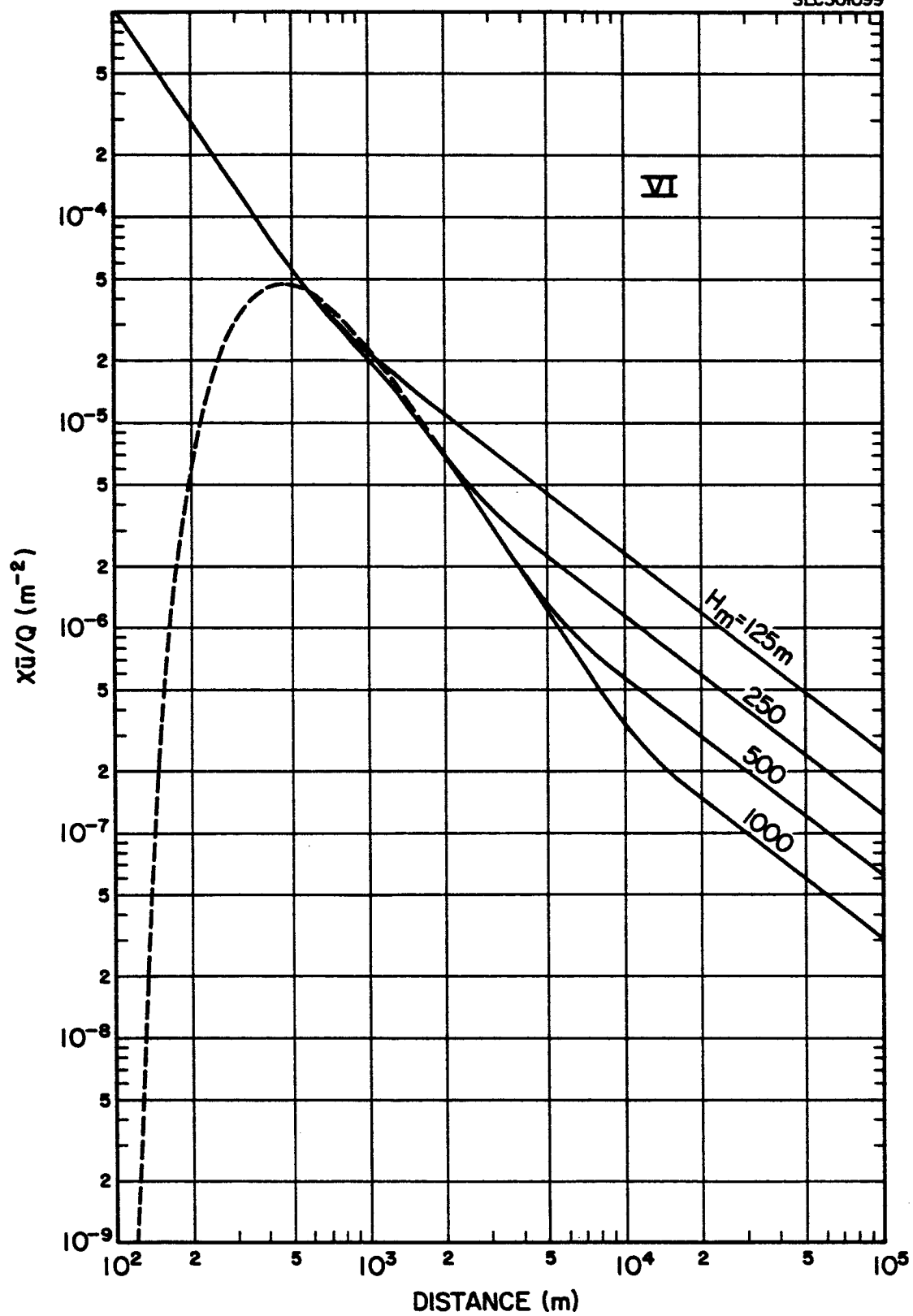


FIGURE 5-9. (Continued) Stability Category VI.

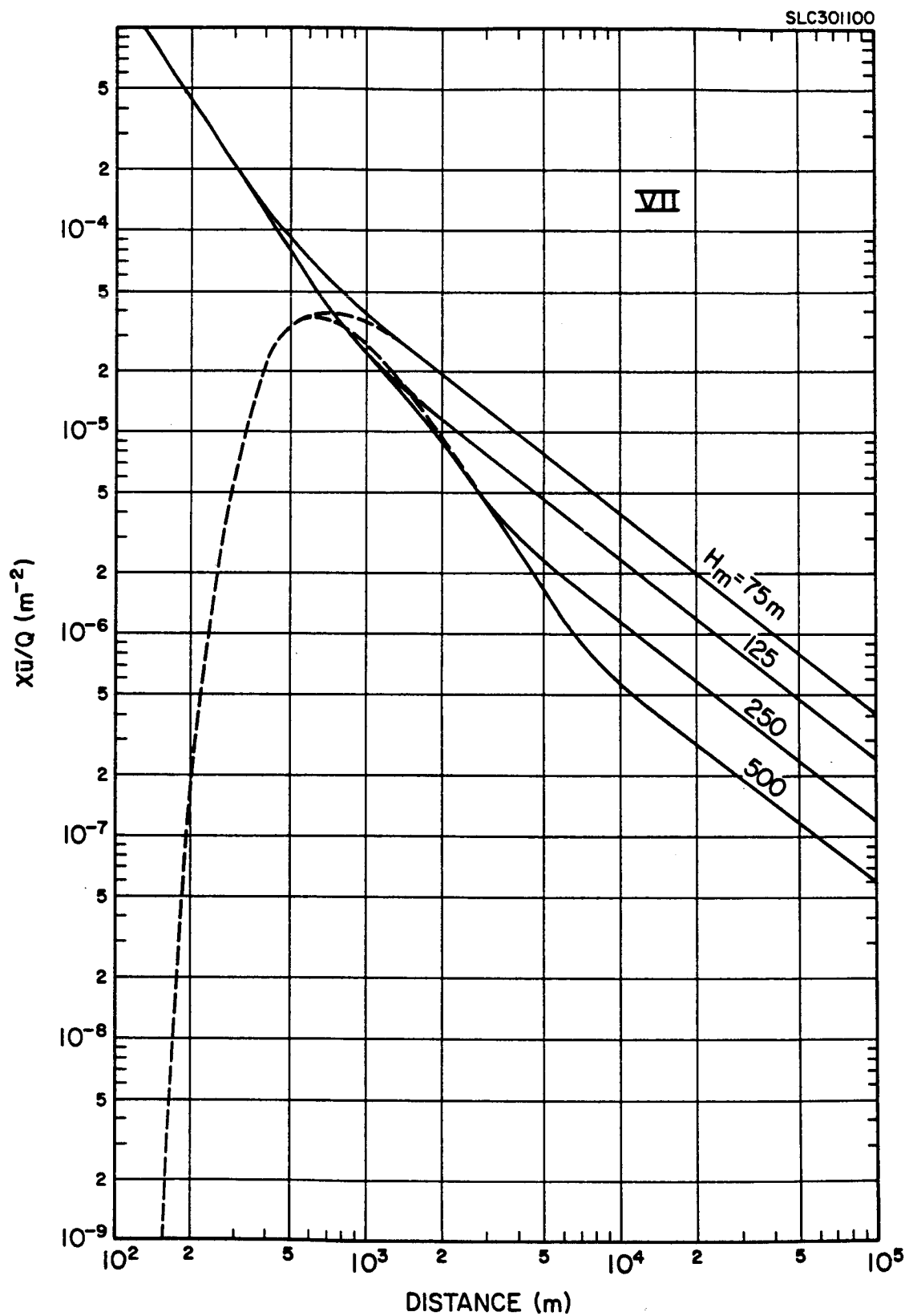


FIGURE 5-9. (Continued) Stability Category VII.

Table 5-7 gives the widths at ground level of selected normalized concentration isopleths at a number of downwind distances from either a surface spill or a surface leak. Table 5-8 gives the isopleth widths downwind from a leak at a height of 50 meters. At distances greater than 0.5 kilometers isopleth widths are not dependent on the height of release. Actual concentrations associated with each isopleth width are obtained by multiplying the column headings by $Q/\bar{u}$.

The axial concentrations and isopleth widths given in Figures 5-8 and 5-9 and Tables 5-7 and 5-8 are for a source emission or an averaging time of 10 minutes. According to Hino (1968) and others, time mean concentrations downwind from continuous elevated sources are inversely proportional to the square root of the averaging time t for values of t ranging from about 10 to 60 minutes. For $t < 10$ minutes, a minus one-fifth power-law describes the variation of ground-level concentration with time. These relationships may be used with values from Figures 5-8 and 5-9 to calculate concentrations for source emission times or averaging times different from 10 minutes. Isopleth widths from Tables 5-7 and 5-8 may be adjusted to other release times by assuming the width proportional to $t^{1/2}$ for t between 10 and 60 minutes, and proportional to $t^{1/5}$ for $t < 10$ minutes.

TABLE 5-7
ISOPLETH WIDTHS IN KILOMETERS OF NORMALIZED GROUND-LEVEL CONCENTRATION
VERSUS TRAVEL DISTANCE FROM A SURFACE SPILL OR LEAK

STABILITY CATEGORY I												
Distance (km)	$\chi \bar{u}/Q$				Distance (km)	$\chi \bar{u}/Q$						
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		
$H_m = 500 \text{ m}$												
0.5	0.6	0.7	0.9	1.0	0.5	0.6	0.7	0.9	1.0	0.9	0.9	1.0
1	0.9	1.1	1.4	1.7	1	0.9	1.1	1.4	1.7	1.5	1.5	1.7
2	1.1	1.5	2.2	2.9	2	0.8	1.3	2.1	2.8	2.3	2.3	2.8
4	0.6	2.1	3.6	5.1	4	0	0	2.8	4.5	3.4	3.4	4.5
8	0	1.6	5.9	8.9	8			2.7	7.2	4.6	4.6	7.2
10		0	6.7	10.7	10			2.1	8.5	5.0	5.0	8.5
20			9.7	18.4	20			0	13.8	4.7	4.7	13.8
40			10.0	31.1	40				21.1	0	0	21.1
80			0	51.1	80				27.0			27.0
100				59.4	100				26.0			26.0
$H_m = 1000 \text{ m}$												
0.5	0.6	0.7	0.9	1.0	0.5	0.6	0.7	0.9	1.0	0.9	0.9	1.0
1	0.9	1.1	1.4	1.7	1	0.9	1.1	1.4	1.7	1.5	1.5	1.7
2	0.8	1.3	2.1	2.8	2	0.8	1.3	2.1	2.8	2.3	2.3	2.8
4	0	0.7	3.1	4.7	4	0	0	2.8	4.5	3.4	3.4	4.5
8		0	4.5	8.1	8			1.5	6.9	4.0	4.0	6.9
10			5.0	9.6	10			0	7.9	3.8	3.8	7.9
20			4.7	16.3	20				12.2	0	0	12.2
40			0	26.6	40				17.1			17.1
80				40.9	80				13.3			13.3
100				45.8	100				0			0
$H_m = 3000 \text{ m}$												
0.5	0.6	0.7	0.9	1.0	0.5	0.6	0.7	0.9	1.0	0.9	0.9	1.0
1	0.9	1.1	1.4	1.7	1	0.9	1.1	1.4	1.7	1.5	1.5	1.7
2	0.8	1.3	2.1	2.8	2	0.8	1.3	2.1	2.8	2.3	2.3	2.8
4	0	0.7	3.1	4.7	4	0	0	2.8	4.5	3.4	3.4	4.5
8		0	4.5	8.1	8			1.5	6.9	4.0	4.0	6.9
10			5.0	9.6	10			0	7.9	3.8	3.8	7.9
20			4.7	16.3	20				12.2	0	0	12.2
40			0	26.6	40				17.1			17.1
80				40.9	80				13.3			13.3
100				45.8	100				0			0

TABLE 5-7 (Continued)

STABILITY CATEGORY II												
Distance (km)	$X \bar{u}/Q$					Distance (km)	$X \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 500 \text{ m}$												
0.5	0.5	0.5	0.6	0.7	0.7	0.5	0.5	0.5	0.6	0.7	0.7	0.7
1	0.8	0.8	1.0	1.1	1.2	1	0.8	0.8	1.0	1.1	1.2	1.2
2	1.0	1.2	1.6	1.8	2.1	2	1.0	1.2	1.6	1.8	2.1	2.1
4	1.2	1.8	2.7	3.0	3.6	4	0.6	1.5	2.5	2.8	3.5	3.5
8	0	2.4	4.6	5.2	6.5	8	0	0	3.2	4.1	5.6	5.6
10		2.5	5.4	6.2	7.8	10			3.2	4.5	6.5	6.5
20		0	8.5	10.4	13.8	20			0.3	6.0	10.9	10.9
40			11.8	16.5	24.0	40			0	2.8	17.7	17.7
80			7.6	23.4	41.0	80				0	26.5	26.5
100			0	24.6	48.4	100					29.1	29.1
$H_m = 1000 \text{ m}$												
0.5	0.5	0.5	0.6	0.7	0.7	0.5	0.5	0.5	0.6	0.7	0.7	0.7
1	0.8	0.8	1.0	1.1	1.2	1	0.8	0.8	1.0	1.1	1.2	1.2
2	1.0	1.2	1.6	1.8	2.1	2	1.0	1.2	1.6	1.8	2.1	2.1
4	0.6	1.5	2.5	2.8	3.5	4	0.6	1.5	2.5	2.8	3.5	3.5
8	0	0	3.8	4.6	6.0	8	0	0	3.2	4.1	5.6	5.6
10			4.4	5.4	7.2	10			3.1	4.4	6.5	6.5
20			6.0	8.5	12.4	20			0	3.9	9.9	9.9
40			2.9	11.8	21.1	40				0	15.4	15.4
80			0	7.6	34.5	80					20.4	20.4
100				0	39.9	100					20.2	20.2
$H_m = 3000 \text{ m}$												
0.5	0.5	0.5	0.6	0.7	0.7	0.5	0.5	0.5	0.6	0.7	0.7	0.7
1	0.8	0.8	1.0	1.1	1.2	1	0.8	0.8	1.0	1.1	1.2	1.2
2	1.0	1.2	1.6	1.8	2.1	2	1.0	1.2	1.6	1.8	2.1	2.1
4	0.6	1.5	2.5	2.8	3.5	4	0.6	1.5	2.5	2.8	3.5	3.5
8	0	0	3.8	4.6	6.0	8	0	0	3.2	4.1	5.6	5.6
10			4.4	5.4	7.2	10			3.1	4.4	6.5	6.5
20			6.0	8.5	12.4	20			0	3.9	9.9	9.9
40			2.9	11.8	21.1	40				0	15.4	15.4
80			0	7.6	34.5	80					20.4	20.4
100				0	39.9	100					20.2	20.2

TABLE 5-7 (Continued)

STABILITY CATEGORY III												
Distance (km)	$X \bar{u}/Q$				Distance (km)	$X \bar{u}/Q$						
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}			
$H_m = 500 \text{ m}$					$H_m = 2000 \text{ m}$							
0.5	0.5	0.5	0.6	0.7	0.5	0.5	0.6	0.6	0.7			
1	0.7	0.8	0.9	1.1	1	0.7	0.8	0.9	1.1			
2	1.0	1.2	1.5	1.9	2	1.0	1.2	1.5	1.9			
4	1.3	1.7	2.5	3.3	4	1.1	1.6	2.4	3.2			
8	1.1	2.5	4.2	5.8	8	0	0	3.3	5.3			
10	0	2.7	5.0	7.1	10			3.5	6.1			
20		0	8.1	12.6	20			2.9	10.1			
40			11.9	22.2	40			0	16.8			
80			12.5	38.4	80				26.1			
100			7.3	45.6	100				29.3			
$H_m = 1000 \text{ m}$					$H_m = 3000 \text{ m}$							
0.5	0.5	0.5	0.6	0.7	0.5	0.5	0.6	0.6	0.7			
1	0.7	0.8	0.9	1.1	1	0.7	0.8	0.9	1.1			
2	1.0	1.2	1.5	1.9	2	1.0	1.2	1.5	1.9			
4	1.1	1.6	2.4	3.2	4	1.1	1.6	2.4	3.2			
8	0	1.1	3.6	5.4	8	0	0	3.3	5.3			
10		0	4.1	6.5	10			3.5	6.1			
20			6.1	11.4	20			0	9.4			
40			6.1	19.7	40				14.8			
80			0	32.8	80			0	21.2			
100				38.3	100				22.3			

TABLE 5-7 (Continued)

STABILITY CATEGORY IV												
Distance (km)	$\chi \bar{u}/Q$					Distance (km)	$\chi \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
0.5	0.4	0.5	0.5	0.5	0.6	0.5	0.4	0.5	0.5	0.5	0.6	
1	0.7	0.7	0.9	0.9	1.0	1	0.7	0.7	0.9	0.9	1.0	
2	1.0	1.2	1.4	1.5	1.8	2	1.0	1.1	1.4	1.5	1.7	
4	1.6	2.0	2.5	2.8	3.2	4	1.2	1.6	2.3	2.5	3.0	
8	2.5	3.2	4.5	4.9	5.8	8	0	1.5	3.5	4.0	5.1	
10	2.7	3.7	5.3	5.9	7.1	10	2.2	1.0	4.0	4.7	6.1	
20	2.2	5.4	9.2	10.4	12.8	20	0	0	6.0	7.8	10.8	
40	0	4.7	15.3	18.0	23.1	40			7.1	11.9	18.8	
80		0	23.5	30.0	41.3	80			0	14.3	31.8	
100			26.2	34.9	49.6	100				12.1	37.3	
$H_m = 500 \text{ m}$												
0.5	0.4	0.5	0.5	0.5	0.6	0.5	0.4	0.5	0.5	0.5	0.6	
1	0.7	0.7	0.9	0.9	1.0	1	0.7	0.7	0.9	0.9	1.0	
2	1.0	1.1	1.4	1.5	1.7	2	1.0	1.1	1.4	1.5	1.7	
4	1.3	1.7	2.3	2.6	3.0	4	1.3	1.7	2.3	2.5	3.0	
8	1.4	2.5	4.0	4.5	5.4	8	1.4	2.5	3.4	3.9	5.0	
10	1.0	2.7	4.7	5.3	6.6	10	1.0	2.7	3.7	4.5	5.9	
20	0	2.2	7.8	9.2	11.8	20	0	2.2	4.7	6.8	10.1	
40		0	11.9	15.3	21.1	40		0	0	9.4	17.3	
80			14.3	23.5	36.8	80				0.1	28.4	
100			12.2	26.1	43.9	100					32.8	
$H_m = 1500 \text{ m}$												
0.5	0.4	0.5	0.5	0.5	0.6	0.5	0.4	0.5	0.5	0.5	0.6	
1	0.7	0.7	0.9	0.9	1.0	1	0.7	0.7	0.9	0.9	1.0	
2	1.0	1.1	1.4	1.5	1.7	2	1.0	1.1	1.4	1.5	1.7	
4	1.3	1.7	2.3	2.6	3.0	4	1.21	1.6	2.3	2.5	3.0	
8	1.4	2.5	4.0	4.5	5.4	8	0	1.3	3.4	3.9	5.0	
10	1.0	2.7	4.7	5.3	6.6	10		0	3.7	4.5	5.9	
20	0	2.2	7.8	9.2	11.8	20			4.7	6.8	10.1	
40		0	11.9	15.3	21.1	40			0	9.4	17.3	
80			14.3	23.5	36.8	80				0.1	28.4	
100			12.2	26.1	43.9	100					32.8	

TABLE 5-7 (Continued)

STABILITY CATEGORY V												
Distance (km)	$\chi \bar{u}/Q$					Distance (km)	$\chi \bar{u}/Q$					
	$H_m = 125 \text{ m}$						$H_m = 500 \text{ m}$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
0.5	0.4	0.4	0.5	0.5	0.6	0.5	0.4	0.4	0.5	0.5	0.6	
1	0.7	0.7	0.8	0.9	1.0	1	0.7	0.7	0.8	0.9	1.0	
2	1.1	1.2	1.5	1.6	1.7	2	1.0	1.1	1.4	1.5	1.7	
4	1.9	2.2	2.7	2.8	3.2	4	1.4	1.7	2.3	2.5	2.9	
8	3.3	3.8	4.8	5.2	5.9	8	1.8	2.6	3.9	4.4	5.3	
10	3.8	4.5	5.8	6.2	7.2	10	1.8	3.0	4.7	5.3	6.4	
20	5.9	7.5	10.3	11.3	13.3	20	0	3.7	7.9	9.2	11.6	
40	7.4	11.7	18.1	20.2	24.5	40		0	12.7	15.6	20.9	
80	0	14.9	30.9	45.6	44.8	80			17.8	25.2	37.0	
100		13.7	36.4	42.5	54.2	100			18.4	28.7	44.2	
$H_m = 250 \text{ m}$												
0.5	0.4	0.4	0.5	0.5	0.6	0.5	0.4	0.4	0.5	0.5	0.6	
1	0.7	0.7	0.8	0.9	1.0	1	0.7	0.7	0.8	0.9	1.0	
2	1.0	1.2	1.4	1.5	1.7	2	1.0	1.1	1.4	1.5	1.7	
4	1.7	1.9	2.5	2.6	3.0	4	1.4	1.7	2.3	2.5	2.9	
8	2.6	3.3	4.4	4.8	5.6	8	0.7	2.0	3.6	4.0	5.0	
10	3.0	3.8	5.3	5.8	6.8	10	0	1.9	4.1	4.7	6.0	
20	3.7	5.9	9.2	10.3	12.5	20		0	6.5	7.9	10.6	
40	0	7.4	15.6	18.1	22.7	40			8.9	12.7	18.8	
80		0	25.2	30.8	41.0	80			0.9	17.8	32.4	
100			28.8	36.3	49.5	100			0	18.3	38.3	
$H_m = 1000 \text{ m}$												
0.5	0.4	0.4	0.5	0.5	0.6	0.5	0.4	0.4	0.5	0.5	0.6	
1	0.7	0.7	0.8	0.9	1.0	1	0.7	0.7	0.8	0.9	1.0	
2	1.0	1.2	1.4	1.5	1.7	2	1.0	1.1	1.4	1.5	1.7	
4	1.7	1.9	2.5	2.6	3.0	4	1.4	1.7	2.3	2.5	2.9	
8	2.6	3.3	4.4	4.8	5.6	8	0.7	2.0	3.6	4.0	5.0	
10	3.0	3.8	5.3	5.8	6.8	10	0	1.9	4.1	4.7	6.0	
20	3.7	5.9	9.2	10.3	12.5	20		0	6.5	7.9	10.6	
40	0	7.4	15.6	18.1	22.7	40			8.9	12.7	18.8	
80		0	25.2	30.8	41.0	80			0.9	17.8	32.4	
100			28.8	36.3	49.5	100			0	18.3	38.3	

TABLE 5-7 (Continued)

STABILITY CATEGORY VI												
Distance (km)	$X \bar{u}/Q$					Distance (km)	$X \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 125 \text{ m}$												
0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5
1	0.7	0.7	0.8	0.8	0.9	1	0.7	0.7	0.8	0.8	0.8	0.9
2	1.1	1.2	1.4	1.5	1.7	2	1.0	1.2	1.4	1.5	1.5	1.6
4	1.9	2.1	2.6	2.7	3.1	4	1.5	1.8	2.3	2.5	2.5	2.9
8	3.3	3.7	4.7	5.0	5.7	8	1.9	2.7	3.9	4.3	4.3	5.1
10	3.8	4.5	5.7	6.1	7.0	10	2.0	3.1	4.6	5.2	5.2	6.2
20	6.1	7.5	10.2	11.1	13.0	20	0	4.1	7.9	9.1	9.1	11.4
40	8.2	12.0	18.0	20.0	24.0	40		0	13.0	15.6	15.6	20.6
80	0	16.4	31.0	35.5	44.1	80			19.0	25.6	25.6	36.7
100		16.4	36.6	42.4	53.6	100			20.3	29.5	29.5	44.1
$H_m = 250 \text{ m}$												
0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5
1	0.7	0.7	0.8	0.8	0.9	1	0.7	0.7	0.8	0.8	0.8	0.9
2	1.0	1.2	1.4	1.5	1.6	2	1.0	1.2	1.4	1.5	1.5	1.6
4	1.7	1.9	2.4	2.6	2.9	4	1.5	1.8	2.3	2.5	2.5	2.9
8	2.7	3.2	4.3	4.7	5.4	8	1.5	2.3	3.7	4.1	4.1	5.0
10	3.1	3.8	5.2	5.6	6.6	10	0.4	2.3	4.2	4.8	4.8	5.9
20	4.1	6.1	9.1	10.1	12.2	20	0	0	6.6	7.9	7.9	10.4
40	0	8.2	15.7	17.9	22.4	40			9.5	12.9	12.9	18.6
80		0	25.7	30.9	40.6	80			7.8	18.9	18.9	32.4
100			29.6	36.5	49.0	100			0	20.2	20.2	38.5
$H_m = 1000 \text{ m}$												
0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5
1	0.7	0.7	0.8	0.8	0.9	1	0.7	0.7	0.8	0.8	0.8	0.9
2	1.0	1.2	1.4	1.5	1.6	2	1.0	1.2	1.4	1.5	1.5	1.6
4	1.7	1.9	2.4	2.6	2.9	4	1.5	1.8	2.3	2.5	2.5	2.9
8	2.7	3.2	4.3	4.7	5.4	8	1.5	2.3	3.7	4.1	4.1	5.0
10	3.1	3.8	5.2	5.6	6.6	10	0.4	2.3	4.2	4.8	4.8	5.9
20	4.1	6.1	9.1	10.1	12.2	20	0	0	6.6	7.9	7.9	10.4
40	0	8.2	15.7	17.9	22.4	40			9.5	12.9	12.9	18.6
80		0	25.7	30.9	40.6	80			7.8	18.9	18.9	32.4
100			29.6	36.5	49.0	100			0	20.2	20.2	38.5

TABLE 5-7 (Continued)

STABILITY CATEGORY VII												
Distance (km)	$X \bar{u}/Q$					Distance (km)	$X \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 75 \text{ m}$						$H_m = 250 \text{ m}$						
0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.5	
1	0.6	0.7	0.8	0.8	0.9	1	0.6	0.7	0.8	0.8	0.9	
2	1.1	1.2	1.4	1.4	1.6	2	1.0	1.1	1.3	1.4	1.5	
4	2.0	2.2	2.5	2.7	3.0	4	1.6	1.9	2.3	2.4	2.8	
8	3.5	3.9	4.7	5.0	5.6	8	2.7	3.2	4.1	4.4	5.2	
10	4.2	4.7	5.7	6.1	6.9	10	3.1	3.8	5.0	5.4	6.3	
20	7.2	8.3	10.5	11.3	13.0	20	4.6	6.2	8.9	9.8	11.7	
40	11.6	14.2	19.0	20.7	24.3	40	3.7	9.1	15.5	17.6	21.6	
80	16.2	23.1	34.0	37.7	45.2	80	0	7.7	26.1	30.8	39.7	
100	16.7	26.3	40.8	45.6	55.2	100	0	0	30.4	36.6	48.1	
$H_m = 125 \text{ m}$						$H_m = 500 \text{ m}$						
0.5	0.4	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.5	
1	0.6	0.7	0.8	0.8	0.9	1	0.6	0.7	0.8	0.8	0.9	
2	1.0	1.1	1.3	1.4	1.6	2	1.0	1.1	1.3	1.4	1.5	
4	1.8	2.0	2.4	2.6	2.9	4	1.6	1.8	2.2	2.4	2.7	
8	3.2	3.6	4.5	4.8	5.4	8	2.1	2.7	3.8	4.1	4.9	
10	3.8	4.3	5.4	5.8	6.6	10	2.3	3.1	4.5	5.0	5.9	
20	6.2	7.5	9.8	10.7	12.4	20	1.8	4.5	7.8	8.9	10.9	
40	9.1	12.3	17.6	19.5	23.2	40	0	3.7	13.1	15.5	20.0	
80	7.9	18.2	30.9	34.9	42.9	80	0	0	20.3	26.1	36.1	
100	0	19.5	36.7	42.0	52.3	100	0	0	22.5	30.4	43.5	

TABLE 5-8

ISOPLETH WIDTHS IN KILOMETERS OF NORMALIZED CONCENTRATION VERSUS
TRAVEL DISTANCE FROM A LEAK AT A HEIGHT OF 50 METERS

STABILITY CATEGORY I													
Distance (km)	$\chi \bar{u}/Q$					Distance (km)	$\chi \bar{u}/Q$						
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		
													$H_m = 500 \text{ m}$
0.5	0.6	0.7	0.8	0.9	1.0	0.5	0.6	0.7	0.8	0.9	1.0		
1	0.8	1.0	1.3	1.4	1.6	1	0.8	1.0	1.3	1.4	1.6		
2	0.9	1.4	2.1	2.3	2.8	2	0.6	1.2	2.0	2.2	2.7		
4	0	1.8	3.5	4.0	5.0	4	0	0	2.6	3.3	4.4		
8		0	5.6	6.7	8.7	8			2.0	4.2	7.0		
10			6.4	7.8	10.4	10			0	4.5	8.2		
20			8.8	12.3	17.9	20				2.2	13.2		
40			6.2	17.3	30.1	40				0	19.6		
80			0	14.6	48.9	80					22.6		
100				0	56.5	100					18.7		
$H_m = 1000 \text{ m}$													
0.5	0.6	0.7	0.8	0.9	1.0	0.5	0.6	0.7	0.8	0.9	1.0		
1	0.8	1.0	1.3	1.4	1.6		0.8	1.0	1.3	1.4	1.6		
2	0.6	1.2	2.0	2.2	2.7		0.6	1.2	2.0	2.2	2.7		
4	0	0	2.9	3.5	4.6		0	0	2.6	3.3	4.4		
8			4.2	5.6	7.9				0	3.6	6.6		
10			4.5	6.4	9.4					3.1	7.5		
20			2.2	8.8	15.7					0	11.5		
40			0	6.2	25.4						15.2		
80				0	38.1						0		
100					42.1								
$H_m = 3000 \text{ m}$													
0.5	0.6	0.7	0.8	0.9	1.0	0.5	0.6	0.7	0.8	0.9	1.0		
1	0.8	1.0	1.3	1.4	1.6	1	0.8	1.0	1.3	1.4	1.6		
2	0.6	1.2	2.0	2.2	2.7	2	0.6	1.2	2.0	2.2	2.7		
4	0	0	2.9	3.5	4.6	4	0	0	2.6	3.3	4.4		
8			4.2	5.6	7.9	8			0	3.6	6.6		
10			4.5	6.4	9.4	10				3.1	7.5		
20			2.2	8.8	15.7	20				0	11.5		
40			0	6.2	25.4	40					15.2		
80				0	38.1	80					0		
100					42.1	100							

TABLE 5-8 (Continued)

STABILITY CATEGORY II												
Distance (km)	$\chi \bar{u}/Q$					Distance (km)	$\chi \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 500 \text{ m}$						$H_m = 2000 \text{ m}$						
0.5	0.4	0.5	0.6	0.6	0.7	0.5	0.4	0.5	0.6	0.6	0.7	
1	0.7	0.8	0.9	1.0	1.2	1	0.7	0.8	0.9	1.0	1.2	
2	0.9	1.1	1.5	1.7	2.0	2	0.9	1.1	1.5	1.7	2.0	
4	0.8	1.5	2.5	2.9	3.5	4	0	1.1	2.3	2.6	3.3	
8	0	1.6	4.2	4.9	6.2	8		0	2.6	3.7	5.3	
10		1.1	4.9	5.8	7.5	10			2.3	3.9	6.1	
20		0	7.3	9.4	13.1	20			0	4.2	10.0	
40			8.6	14.3	22.6	40				0	15.7	
80			0	17.3	37.8	80					21.3	
100				15.1	44.2	100					21.5	
$H_m = 1000 \text{ m}$						$H_m = 3000 \text{ m}$						
0.5	0.4	0.5	0.6	0.6	0.7	0.5	0.4	0.5	0.6	0.6	0.7	
1	0.7	0.8	0.9	1.0	1.2	1	0.7	0.8	0.9	1.0	1.2	
2	0.9	1.1	1.5	1.7	2.0	2	0.9	1.1	1.5	1.7	2.0	
4	0	1.1	2.3	2.7	3.3	4	0	1.1	2.3	2.6	3.3	
8		0	3.3	4.2	5.7	8		0	2.6	3.6	5.3	
10			3.7	4.9	6.8	10			2.1	3.8	6.0	
20			4.2	7.3	11.7	20			0	0	8.9	
40			0	8.5	19.4	40					13.0	
80				0	30.7	80					12.9	
100					34.8	100					5.2	

TABLE 5-8 (Continued)

STABILITY CATEGORY III													
Distance (km)	$\chi \bar{u}/Q$						Distance (km)	$\chi \bar{u}/Q$					
	$H_m = 500 \text{ m}$							$H_m = 2000 \text{ m}$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}			10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
0.5	0.4	0.4	0.5	0.5	0.6	0.5 1 2 4 8 10 20 40 80 100	0.5	0.4	0.4	0.5	0.5	0.6	
1	0.6	0.7	0.8	0.9	1.0		1	0.6	0.7	0.8	0.9	1.0	
2	0.9	1.1	1.4	1.5	1.8		2	0.9	1.1	1.4	1.5	1.8	
4	0.8	1.4	2.3	2.5	3.1		4	0.5	1.3	2.2	2.4	3.0	
8	0	1.6	3.8	4.4	5.5		8	0	0	2.8	3.6	4.9	
10		1.3	4.4	5.2	6.6		10			2.7	3.8	5.7	
20		0	6.7	8.6	11.8		20			0	4.1	9.1	
40			8.3	13.2	20.5		40				0	14.4	
80			0	16.7	34.6		80					20.1	
100				15.4	40.6		100					20.8	
0.5 1 2 4 8 10 20 40 80 100	$H_m = 1000 \text{ m}$						0.5 1 2 4 8 10 20 40 80 100	$H_m = 3000 \text{ m}$					
	0.4	0.4	0.5	0.5	0.6	0.4		0.4	0.5	0.5	0.6		
	0.6	0.7	0.8	0.9	1.0	0.6		0.7	0.8	0.9	1.0		
	0.9	1.1	1.4	1.5	1.8	0.9		1.1	1.4	1.5	1.8		
	0.5	1.3	2.2	2.4	3.0	0.5		1.3	2.2	2.4	3.0		
	0	0	3.0	3.8	5.1	0		0	2.8	3.6	4.9		
			3.4	4.4	6.1				2.7	3.8	5.7		
			4.1	6.7	10.5				0	1.9	8.3		
			0	8.3	17.7					0	12.1		
				0	28.3						13.1		
					32.3						8.7		

TABLE 5-8 (Continued)

STABILITY CATEGORY IV												
Distance (km)	$X \bar{u}/Q$					Distance (km)	$X \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 250 \text{ m}$												
0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.5	
1	0.6	0.6	0.8	0.8	0.9	1	0.6	0.6	0.8	0.8	0.9	
2	0.9	1.0	1.3	1.4	1.7	2	0.8	1.0	1.3	1.4	1.6	
4	1.3	1.7	2.3	2.6	3.0	4	0.7	1.3	2.0	2.3	2.8	
8	1.6	2.6	4.0	4.5	5.5	8	0	0	2.9	3.5	4.7	
10	1.4	2.9	4.8	5.4	6.6	10			3.2	4.1	5.6	
20	0	3.0	8.0	9.4	12.0	20			4.0	6.3	9.8	
40		0	12.5	15.7	21.4	40			0	8.1	16.6	
80			16.2	24.7	37.6	80				0	26.8	
100			15.5	27.8	44.9	100					30.7	
$H_m = 500 \text{ m}$												
0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.5	
1	0.6	0.6	0.8	0.8	0.9	1	0.6	0.6	0.8	0.8	0.9	
2	0.8	1.0	1.3	1.4	1.6	2	0.8	1.0	1.3	1.4	1.6	
4	0.9	1.4	2.1	2.3	2.8	4	0.7	1.3	2.0	2.3	2.8	
8	0	1.6	3.5	4.0	5.1	8	0	0	2.8	3.4	4.6	
10		1.4	4.1	4.8	6.1	10			2.9	3.8	5.4	
20		0	6.3	8.0	10.9	20			1.5	5.1	9.0	
40			8.1	12.5	19.2	40			0	3.4	14.9	
80			0	16.2	32.7	80				0	22.7	
100				15.4	38.4	100					25.1	
$H_m = 1500 \text{ m}$												
0.5	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.5	0.5	
1	0.6	0.6	0.8	0.8	0.9	1	0.6	0.6	0.8	0.8	0.9	
2	0.8	1.0	1.3	1.4	1.6	2	0.8	1.0	1.3	1.4	1.6	
4	0.9	1.4	2.1	2.3	2.8	4	0.7	1.3	2.0	2.3	2.8	
8	0	1.6	3.5	4.0	5.1	8	0	0	2.8	3.4	4.6	
10		1.4	4.1	4.8	6.1	10			2.9	3.8	5.4	
20		0	6.3	8.0	10.9	20			1.5	5.1	9.0	
40			8.1	12.5	19.2	40			0	3.4	14.9	
80			0	16.2	32.7	80				0	22.7	
100				15.4	38.4	100					25.1	

TABLE 5-8 (Continued)

STABILITY CATEGORY V												
Distance (km)	$\chi \bar{u}/Q$					Distance (km)	$\chi \bar{a}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 125 \text{ m}$												
0.5	0.3	0.3	0.4	0.4	0.5	0.5	0.3	0.3	0.4	0.4	0.5	
1	0.6	0.6	0.7	0.8	0.9	1	0.5	0.6	0.7	0.8	0.9	
2	0.9	1.1	1.3	1.4	1.6	2	0.8	1.0	1.2	1.3	1.5	
4	1.6	1.8	2.4	2.6	3.0	4	0.8	1.3	2.0	2.2	2.7	
8	2.4	3.1	4.2	4.6	5.5	8	0	1.4	3.2	3.8	4.7	
10	2.7	3.6	5.1	5.6	6.6	10		1.2	3.8	4.5	5.7	
20	2.5	5.3	8.8	9.9	12.2	20		0	5.8	7.5	10.3	
40	0	5.2	14.7	17.3	22.1	40			7.2	11.6	18.0	
80		0	23.0	29.1	39.7	80			0	14.4	30.7	
100			25.8	33.9	47.8	100				13.0	36.1	
$H_m = 250 \text{ m}$												
0.5	0.3	0.3	0.4	0.4	0.5	0.5	0.3	0.3	0.4	0.4	0.5	
1	0.5	0.6	0.7	0.8	0.9	1	0.5	0.6	0.7	0.8	0.9	
2	0.8	1.0	1.2	1.3	1.5	2	0.8	1.0	1.2	1.3	1.5	
4	1.2	1.6	2.2	2.4	2.8	4	0.8	1.3	2.0	2.2	2.7	
8	1.4	2.4	3.8	4.2	5.1	8	0	0	2.8	3.4	4.4	
10	1.2	2.6	4.5	5.1	6.2	10			3.0	3.8	5.3	
20	0	2.5	7.5	8.8	11.3	20			3.6	5.8	9.2	
40		0	11.6	14.7	20.2	40			0	7.2	15.5	
80			14.5	22.9	35.5	80				0	25.0	
100			13.1	25.7	42.3	100					28.5	
$H_m = 1000 \text{ m}$												
0.5	0.3	0.3	0.4	0.4	0.5	0.5	0.3	0.3	0.4	0.4	0.5	
1	0.5	0.6	0.7	0.8	0.9	1	0.5	0.6	0.7	0.8	0.9	
2	0.8	1.0	1.2	1.3	1.5	2	0.8	1.0	1.2	1.3	1.5	
4	1.2	1.6	2.2	2.4	2.8	4	0.8	1.3	2.0	2.2	2.7	
8	1.4	2.4	3.8	4.2	5.1	8	0	0	2.8	3.4	4.4	
10	1.2	2.6	4.5	5.1	6.2	10			3.0	3.8	5.3	
20	0	2.5	7.5	8.8	11.3	20			3.6	5.8	9.2	
40		0	11.6	14.7	20.2	40			0	7.2	15.5	
80			14.5	22.9	35.5	80				0	25.0	
100			13.1	25.7	42.3	100					28.5	

TABLE 5-8 (Continued)

STABILITY CATEGORY VI												
Distance (km)	$\chi \bar{u}/Q$					Distance	$\chi \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 125 \text{ m}$												
0.5	0.3	0.3	0.4	0.4	0.4	0.5	0.3	0.3	0.4	0.4	0.4	0.4
1	0.5	0.6	0.7	0.7	0.8	1	0.5	0.6	0.7	0.7	0.8	0.8
2	0.9	1.0	1.3	1.3	1.5	2	0.8	0.9	1.2	1.3	1.5	1.5
4	1.5	1.8	2.3	2.4	2.8	4	0.9	1.3	1.9	2.2	2.6	2.6
8	2.3	2.9	4.0	4.4	5.2	8	0	1.4	3.1	3.6	4.6	4.6
10	2.5	3.4	4.9	5.4	6.4	10		1.1	3.6	4.3	5.5	5.5
20	2.3	5.0	8.5	9.6	11.7	20		0	5.6	7.2	9.9	9.9
40	0	4.8	14.2	16.7	21.4	40			6.8	11.1	17.4	17.4
80		0	22.1	28.1	38.4	80			0	13.7	29.6	29.6
100			24.7	32.8	46.3	100				12.0	34.8	34.8
$H_m = 250 \text{ m}$												
0.5	0.3	0.3	0.4	0.4	0.4	0.5	0.3	0.3	0.4	0.4	0.4	0.4
1	0.5	0.6	0.7	0.7	0.8	1	0.5	0.6	0.7	0.7	0.8	0.8
2	0.8	0.9	1.2	1.3	1.5	2	0.8	0.9	1.2	1.3	1.5	1.5
4	1.2	1.5	2.1	2.3	2.7	4	0.9	1.3	1.9	2.2	2.6	2.6
8	1.4	2.3	3.6	4.0	4.9	8	0	0.4	2.8	3.4	4.4	4.4
10	1.1	2.5	4.3	4.9	6.0	10		0	3.0	3.8	5.1	5.1
20	0	2.3	7.2	8.4	10.8	20			3.4	5.6	8.8	8.8
40		0	11.1	14.2	19.5	40			0	6.8	15.0	15.0
80			13.7	22.0	34.3	80				0	24.1	24.1
100			12.1	24.6	40.9	100					27.4	27.4
$H_m = 1000 \text{ m}$												
0.5	0.3	0.3	0.4	0.4	0.4	0.5	0.3	0.3	0.4	0.4	0.4	0.4
1	0.5	0.6	0.7	0.7	0.8	1	0.5	0.6	0.7	0.7	0.8	0.8
2	0.8	0.9	1.2	1.3	1.5	2	0.8	0.9	1.2	1.3	1.5	1.5
4	1.2	1.5	2.1	2.3	2.7	4	0.9	1.3	1.9	2.2	2.6	2.6
8	1.4	2.3	3.6	4.0	4.9	8	0	0.4	2.8	3.4	4.4	4.4
10	1.1	2.5	4.3	4.9	6.0	10		0	3.0	3.8	5.1	5.1
20	0	2.3	7.2	8.4	10.8	20			3.4	5.6	8.8	8.8
40		0	11.1	14.2	19.5	40			0	6.8	15.0	15.0
80			13.7	22.0	34.3	80				0	24.1	24.1
100			12.1	24.6	40.9	100					27.4	27.4

TABLE 5-8 (Continued)

STABILITY CATEGORY VII												
Distance (km)	$X \bar{u}/Q$					Distance (km)	$X \bar{u}/Q$					
	10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}		10^{-6}	5×10^{-7}	10^{-7}	5×10^{-8}	10^{-8}	
$H_m = 75 \text{ m}$						$H_m = 250 \text{ m}$						
0.5	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.3	0.3	0.3	0.4	
1	0.5	0.6	0.6	0.7	0.8	1	0.5	0.5	0.6	0.7	0.8	
2	0.9	1.0	1.2	1.3	1.4	2	0.8	0.9	1.1	1.2	1.4	
4	1.6	1.8	2.2	2.4	2.7	4	1.1	1.4	1.9	2.1	2.5	
8	2.6	3.1	4.0	4.4	5.1	8	1.2	2.1	3.3	3.7	4.6	
10	3.0	3.7	4.9	5.3	6.2	10	1.0	2.3	4.0	4.5	5.5	
20	4.2	5.9	8.7	9.6	11.5	20	0	2.0	6.7	7.9	10.1	
40	1.2	8.3	15.1	17.2	21.3	40	0	0	10.4	13.3	18.3	
80	0	3.0	25.1	30.0	39.0	80			12.6	20.7	32.4	
100		0	29.1	35.6	47.2	100			10.7	23.0	38.7	
$H_m = 125 \text{ m}$						$H_m = 500 \text{ m}$						
0.5	0.3	0.3	0.3	0.3	0.4	0.5	0.3	0.3	0.3	0.3	0.4	
1	0.5	0.5	0.6	0.7	0.8	1	0.5	0.5	0.6	0.7	0.8	
2	0.8	0.9	1.1	1.2	1.4	2	0.8	0.9	1.1	1.2	1.4	
4	1.4	1.6	2.1	2.3	2.6	4	1.0	1.3	1.9	2.1	2.4	
8	2.1	2.7	3.7	4.1	4.9	8	0	1.3	2.9	3.4	4.2	
10	2.3	3.2	4.5	5.0	5.9	10		1.0	3.4	4.0	5.1	
20	2.1	4.7	7.9	8.9	11.0	20		0	5.2	6.7	9.2	
40	0	4.3	13.3	15.7	20.1	40			6.2	10.4	16.3	
80		0	20.7	26.4	36.3	80			0	12.5	27.9	
100			23.1	30.8	43.8	100				10.6	32.8	

REFERENCES

- Adelfang, S. I., E. V. Ashburn, and A. Court, 1968: A study of Jimsphere wind profiles related to space vehicle design and operations, Final Report No. LR21588 under Contract No. NAS8-20747, Lockheed California Co., Lockheed Aircraft Corporation, Burbank, Calif., 101 pp.
- Church, H. W., 1969: Cloud rise from high-explosives detonations, Research Report No. SC-RR-68-903, Sandia Laboratories, Albuquerque, New Mexico, 24 pp.
- Cramer, H. E., G. M. DeSanto, R. K. Dumbauld, P. Morgenstern, and R. N. Swanson, 1964: Meteorological prediction techniques and data system, Final Report, Contract No. DA-42-007-CML-552, U. S. Army Dugway Proving Ground, Dugway, Utah.
- Gifford, F. A., 1961: Uses of routine meteorological observations for estimating atmospheric dispersion, Nuclear Safety, 2, 4, 47-51.
- Hage, K. D., N. E. Bowne, and G. R. Hilst, 1965: Preliminary estimates of environmental exposure for fuel and exhaust products. NASA Report CR-61056, Travelers Research Center, Inc., under Contract No. NAS8-11450.
- Hino, M., 1968: Maximum ground-level concentration and sampling time, Atmos. Environ., 2, 149-165.
- Johnson, J. E., 1954: Physical Meteorology, John Wiley and Sons, Inc., New York.
- Morton, B. R., G. I. Taylor, and J. S. Turner, 1956: Turbulent gravitational convection from maintained and instantaneous sources, Proc. Roy. Soc. (London), Ser. A, 234, 1-23.
- Pasquill, F., 1961: The estimation of the dispersion of windborne material, Meteorol. Mag., 90, 1063, 33-49.
- Pasquill, F., 1962: Atmospheric Diffusion, D. Van Nostrand Company, Ltd., London, p. 190.
- Record, F. A., R. N. Swanson, H. E. Cramer, and R. K. Dumbauld, 1970: Analysis of lower atmospheric data for diffusion studies, NASA Report _____, GCA Technology Division under Contract No. NAS8-30503.

REFERENCES (Continued)

- Slade, D. H. (Editor), 1968: Meteorology and Atomic Energy, prepared by Air Resources Laboratories, ESSA, for U. S. Atomic Energy Commission, 445 pp.
- Susko, M., J. W. Kaufman, and K. Hill, 1968: Rise rate and growth of static test vehicle engine exhaust clouds, NASA TM X-53782, Aero-Astroynamics Research Review No. 7, George C. Marshall Space Flight Center, NASA, Marshall Space Flight Center, Alabama.
- Turner, D. B., 1969: Workbook of Atmospheric Dispersion Estimates, Air Resources Laboratories, ESSA, 84 pp.
- Tyldesley, J. B. and C. E. Wallington, 1965: The effect of wind shear and vertical diffusion on horizontal dispersion, Quart. J. Roy. Met. Soc., Vol. 91, pp. 158-174.

TABLE OF CONTENTS

<u>Appendix</u>	<u>Title</u>	<u>Page No.</u>
A	USER INSTRUCTIONS FOR THE KSC MULTI-LAYER DIFFUSION MODEL PROGRAM	A-1
	A. 1 Program Description	A-1
	A. 2 Program Input Sequence	A-5
	A. 3 Explanation of Program Inputs	A-5
	A. 4 Additional Remarks	A-23
	A. 5 Keypunch Instructions	A-23
	A. 6 Operator Instructions	A-23
	A. 7 Linkage for Subroutines in Computer Program for KSC Multi-Layer Diffusion Model	A-23
	A. 8 Linkage for Subroutines in Logic Sections 1 through 5	A-25
	A. 9 Data Field Configuration	A-25
B	LISTING OF THE COMPUTER PROGRAM FOR THE KSC MULTI-LAYER DIFFUSION MODEL	B-1
C	FLOW CHART FOR THE MULTI-LAYER DIFFUSION MODEL COMPUTER PROGRAM	C-1
D	COMPUTER OUTPUT FOR SAMPLE PROBLEM	D-1
E	EXAMPLE CALCULATIONS EMPLOYING THE MULTI-LAYER DIFFUSION PROGRAM	E-1
	E. 1 Selection of Meteorological Input Parameters	E-2
	E. 2 Selection of Source Input Parameters	E-11
	E. 3 Concentration and Dosage Patterns for the Pre-Cold Front Situation	E-17
	E. 4 Concentration and Dosage Patterns for the Summertime Bermuda High Situation	E-53
	E. 5 Example Calculation of Ground-Level Deposition Due to Gravitational Settling	E-76
	E. 6 Example Calculation of a Change in Layer Structure and Deposition Due to Precipitation Scavenging	E-91

TABLE OF CONTENTS (Continued)

<u>Appendix</u>	<u>Title</u>	<u>Page No.</u>
F	NOMOGRAMS FOR CALCULATING σ_A , σ_E AND p AND EXAMPLE CALCULATIONS	F-1
F.1	Nomograms for Calculating σ_A , σ_E and p	F-1
F.2	Example Calculations	F-1

LIST OF FIGURES (Continued)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
A-1	Diagram of linkage between subroutines of computer program	A-24
A-2	Diagram of linkage between subroutines used in Logic Sections of computer program	A-26
A-3	Data field configuration	A-28
D-1	Sample problem input	D-4
D-2	Partial listing of computer output for sample problem	D-6
E-1	Surface map for 0000 GMT, 28 November 1966	E-3
E-2	700-mb map for 0000 GMT, 28 November 1966	E-3
E-3	Vertical profiles for 2315 GMT, 27 November 1966	E-4
E-4	Surface map for 0600 GMT, 12 May 1967	E-8
E-5	700-mb map for 0000 GMT, 12 May 1967	E-8
E-6	Vertical profiles for 0515 GMT, 12 May 1967	E-9
E-7	Altitude of the SATURN AS-504 as a function of flight time	E-14
E-8	Assumed distribution of mass in the cloud resulting from a vehicle destruct	E-15
E-9	Increase in height and width of plume from Apollo 10 as a function of elapsed time	E-16
E-10	Maximum ground-level concentration for a normal launch, 2315 GMT, 27 November 1966	E-23
E-11	Maximum ground-level dosage for a normal launch, 2315 GMT, 27 November 1966	E-24

LIST OF FIGURES (Continued)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
E-12	Ground-level concentration isopleths for a normal launch, 2315 GMT, 27 November 1966	E-25
E-13	Ground-level dosage isopleths for a normal launch, 2315 GMT, 27 November 1966	E-26
E-14	Concentration isopleths at a height of 853 meters for a normal launch, 2315 GMT, 27 November 1966	E-27
E-15	Dosage isopleths at a height of 853 meters for a normal launch, 2315 GMT, 27 November 1966	E-28
E-16	Concentration isopleths at a height of 1829 meters for a normal launch, 2315 GMT, 27 November 1966	E-29
E-17	Dosage isopleths at a height of 1829 meters for a normal launch, 2315 GMT, 27 November 1966	E-30
E-18	Concentration isopleths at a height of 3048 meters for a normal launch, 2315 GMT, 27 November 1966	E-31
E-19	Dosage isopleths at a height of 3048 meters for a normal launch, 2315 GMT, 27 November 1966	E-32
E-20	Maximum ground-level concentration for a vehicle destruct on pad, 2315 GMT, 27 November 1966	E-33
E-21	Maximum ground-level dosage for a vehicle destruct on pad, 2315 GMT, 27 November 1966	E-34
E-22	Ground-level concentration isopleths for a vehicle destruct on pad, 2315 GMT, 27 November 1966	E-36
E-23	Ground-level dosage isopleths for a vehicle destruct on pad, 2315 GMT, 27 November 1966	E-37
E-24	Concentration isopleths at a height of 853 meters for a vehicle destruct on pad, 2315 GMT, 27 November 1966	E-38

LIST OF FIGURES (Continued)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
E-25	Dosage isopleths at a height of 853 meters for a vehicle destruct on pad, 2315 GMT, 27 November 1966	E-39
E-26	Maximum ground-level concentration for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-42
E-27	Maximum ground-level dosage for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-43
E-28	Ground-level concentration isopleths for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-44
E-29	Ground-level dosage isopleths for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-45
E-30	Concentration isopleths at a height of 853 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-46
E-31	Dosage isopleths at a height of 853 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-47
E-32	Concentration isopleths at a height of 1829 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-48
E-33	Dosage isopleths at a height of 1829 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966	E-49
E-34	Ground-level concentration isopleths for a large surface spill, 2315 GMT, 27 November 1966	E-52
E-35	Maximum ground-level concentration for a normal launch, 0515 GMT, 12 May 1967	E-60
E-36	Maximum ground-level dosage for a normal launch, 0515 GMT, 12 May 1967	E-61

LIST OF FIGURES (Continued)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
E-37	Ground-level concentration isopleths for a normal launch, 0515 GMT, 12 May 1967	E-62
E-38	Ground-level dosage isopleths for a normal launch, 0515 GMT, 12 May 1967	E-63
E-39	Concentration isopleths at a height of 1067 meters for a normal launch, 0515 GMT, 12 May 1967	E-64
E-40	Dosage isopleths at a height of 1067 meters for a normal launch, 0515 GMT, 12 May 1967	E-65
E-41	Concentration isopleths at a height of 1615 meters for a normal launch, 0515 GMT, 12 May 1967	E-66
E-42	Dosage isopleths at a height of 1615 meters for a normal launch, 0515 GMT, 12 May 1967	E-67
E-43	Concentration isopleths at a height of 3048 meters for a normal launch, 0515 GMT, 12 May 1967	E-68
E-44	Dosage isopleths at a height of 3048 meters for a normal launch, 0515 GMT, 12 May 1967	E-69
E-45	Maximum ground-level concentration for a vehicle destruct on pad, 0515 GMT, 12 May 1967	E-70
E-46	Maximum ground-level dosage for a vehicle destruct on pad, 0515 GMT, 12 May 1967	E-71
E-47	Ground-level concentration isopleths for a vehicle destruct on pad, 0515 GMT, 12 May 1967	E-72
E-48	Ground-level dosage isopleths for a vehicle destruct on pad, 0515 GMT, 12 May 1967	E-73
E-49	Concentration isopleths at a height of 1067 meters for a vehicle destruct on pad, 0515 GMT, 12 May 1967	E-74

LIST OF FIGURES (Continued)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
E-50	Dosage isopleths at a height of 1067 meters for a vehicle destruct on pad, 0515 GMT, 12 May 1967	E-75
E-51	Maximum ground-level concentration for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-77
E-52	Maximum ground-level dosage for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-78
E-53	Ground-level concentration isopleths for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-79
E-54	Ground-level dosage isopleths for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-80
E-55	Concentration isopleths at a height of 1067 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-81
E-56	Dosage isopleths at a height of 1067 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-82
E-57	Concentration isopleths at a height of 1615 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-83
E-58	Dosage isopleths at a height of 1615 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967	E-84
E-59	Ground-level concentration isopleths for a large surface spill, 0515 GMT, 12 May 1967	E-87
E-60	Isopleths of ground-level deposition due to gravitational settling for a normal launch	E-90
E-61	Ground-level dosage isopleths for a normal launch with a change in layer structure and precipitation scavenging	E-95
E-62	Ground-level deposition isopleths for a normal launch with a change in layer structure and precipitation scavenging	E-96

LIST OF FIGURES (Continued)

<u>Figure No.</u>	<u>Title</u>	<u>Page No.</u>
F-1	Nomogram for calculating ratios or products	F-4
F-2	Nomogram for calculating the wind-profile exponent p	F-5
F-3	Nomogram for calculating σ_E under unstable thermal stratification	F-6
F-4	Use of Figure F-1 to calculate σ_A and σ_E	F-7
F-5	Use of Figure F-2 to calculate p	F-8
F-6	Use of Figure F-3 to calculate σ_E	F-9

LIST OF TABLES

<u>Table No.</u>	<u>Title</u>	<u>Page No.</u>
A-1	Card Input Information	A-6
D-1	Program Inputs for Sample Problem	D-2
E-1	Meteorological Model Inputs for 2315 GMT, 27 November 1966	E-6
E-2	Meteorological Model Inputs for 0515 GMT, 12 May 1967	E-10
E-3	Assumed Median Particle Diameters, Fraction of Material with Settling Velocity V_s , and V_s	E-18
E-4	Program Inputs for Pre-Cold Front Situation and Normal Launch	E-19
E-5	Program Inputs for Pre-Cold Front Situation and Destruct at Surface	E-21
E-6	Program Inputs for Pre-Cold Front Situation and Destruct Aloft	E-40
E-7	Program Inputs for Pre-Cold Front Situation and Cold Spill	E-50
E-8	Program Inputs for Summertime Bermuda High Situation and Normal Launch	E-54
E-9	Program Inputs for Summertime Bermuda High Situation and Destruct at Surface	E-56
E-10	Program Inputs for Summertime Bermuda High Situation and Destruct Aloft	E-58
E-11	Program Inputs for Summertime Bermuda High Situation and Cold Spill	E-85
E-12	Program Inputs for Pre-Cold Front Situation and Normal Launch with Gravitational Settling	E-88
E-13	Program Inputs for Pre-Cold Front Situation and Normal Launch with a Change in Layer Structure and Precipitation Scavenging	E-92

APPENDIX A
USER INSTRUCTIONS FOR THE KSC MULTI-LAYER
DIFFUSION MODEL PROGRAM

A.1 PROGRAM DESCRIPTION

The KSC Multi-Layer Diffusion Model Program consists of 22 sub-routines, including the main driver program. The program is written in ASA FORTRAN V and should execute under most high level FORTRAN compilers when the appropriate monitor control cards are used. The program requires 33820₁₀ locations of executable core. The size of the program can be reduced either by decreasing the size of common storage, or by using segmentation techniques. A diagram of the program linkage is given in Section A.7. The program consists of five major logic sections. A block diagram of these sections is given in Figure 4-1. The subroutine linkage of each logic section is shown in Section A.8. Sections 1 through 4 can be performed in any combination, or as a single case. Section 5 is performed as a single case and any number of cases can be processed by the program.

A.1.1 Logic Section 1

Section 1 calculates dosage and concentration at grid points on a three-dimensional reference coordinate system using either polar or rectangular coordinates. For rectangular coordinates, north is the positive y-axis and east is the positive x-axis. For polar coordinates, north is 0 degrees and east is 90 degrees. Options in this section include the calculation of dosage and concentration with cloud depletion by precipitation scavenging (washout) and simple time-dependent decay. Surface deposition due to precipitation scavenging can also be calculated. Provision is additionally made for calculating crosswind

distances from the cloud axis to dosage or concentration isopleths of interest (cloud half-widths). This section uses subroutines READER, WASHT, TESTR, BREAK, ISO, PEAK, EL, LATER, ALONGD, VERT, SIGMA, COORD, as well as the main driver program.

Subroutine READER reads and converts most of the program input data. All program input instructions reference logical tape 5 (card reader).

Subroutine WASHT calculates ground-level patterns of deposition due to precipitation scavenging, when this option is selected.

Subroutine TESTR defines the new layer structure if the structure is changed at time t^* .

Subroutine BREAK is the main calculation routine for this section and includes Models 1 through 6 as shown in Figure 4-1.

Subroutine ISO evaluates the error function $\text{ERF}(X)$ used in calculation of Models 4 and 5.

Subroutine PEAK calculates the peak terms for dosage and concentration in Models 1, 2 and 3.

Subroutine ACH has entry points EL, LATER AND ALONGD; EL evaluates the term $L\{x_K\}$ as given by Equation (3-9); LATER evaluates the lateral term in y in Equations (3-1), (3-15) and (3-19); ALONGD calculates the alongwind term in Equation (3-7).

Subroutine VERT calculates the vertical and vertical reflection terms for Model 3 as given by Equation (3-15).

Subroutine SIGMA calculates the various standard deviations for the dosage and concentration distributions, as given by Equations (3-4), (3-8), (3-13), (3-14), (3-16), (3-23), and (3-32).

Subroutine COORD performs all coordinate transformations. The layer models are written with reference to a cloud or plume coordinate system where the x-axis is oriented along the mean wind direction, the y-axis is perpendicular to the x-axis in the crosswind direction, and the z-axis is directed vertically. The subroutine COORD relates the cloud coordinate system to the fixed reference coordinate system used to locate source and receptor locations. The fixed reference system may be in either polar or rectangular coordinates.

A. 1. 2 Logic Section 2

Section 2 calculates peak dosage and maximum peak concentration along the cloud axis for Models 1, 2 and 3. Options include the calculation of dosage and concentration in the presence of cloud depletion by precipitation scavenging or simple decay. This section uses subroutines CENTRL, EL, ALONGD, PEAK, VERT and SIGMA, as well as the main driver program.

Subroutine CENTRL performs the main calculations and controls all output. All program outputs reference logical tape 6 (printer). All other subroutines of this section have the same functions as described above.

A. 1. 3 Logic Section 3

Section 3 calculates isopleths of dosage and concentration in the horizontal plane, about the cloud alongwind axis, for Models 1, 2 and 3. Options include the calculation of dosage and concentration with cloud depletion by precipitation scavenging and decay. This section uses subroutines ISOXY, EL, ALONGD, PEAK, VERT, SIGMA, as well as the main driver program.

Subroutine ISOXY performs the main calculations for Section 3 and controls all output. The functions of all other subroutines in this section have been outlined above. Section 3 is applicable only to Models 1, 2 and 3 as defined in Figure 4-1, and the various options that can be used with these models.

A. 1. 4 Logic Section 4

Section 4 calculates isopleths of dosage and concentration in the y-z plane at selected points on the alongwind cloud axis for Models 1, 2 and 3. Options include calculations of dosage and concentration isopleths with cloud depletion by precipitation scavenging and simple decay. This section uses subroutines ISOYZ, EL, ALONGD, PEAK, VERT, SIGMA, as well as the main driver routine.

Subroutine ISOYZ performs the main calculations for Section 4 and controls the output. The functions of all other subroutines in this section have been described above.

A. 1. 5 Logic Section 5

Section 5 of the program calculates deposition on the ground due to gravitational settling. This section uses subroutines DEPOS, SGP, COORD, as well as the main driver routine.

Subroutine DEPOS assembles the necessary logic for calculating the deposition and outputs all calculations.

Subroutine SGP consists of the entry points SGP, UBARS, DEPSO and BETAK, where SGP evaluates the mathematical equations in Section 3.8 of the main body of the report.

A.2 PROGRAM INPUT SEQUENCE

The card input information required for the computer program is listed in Table A-1. The information categories in the table are defined as follows:

CARD UNIT NO.	-	Sequence number of the card group
FORTTRAN	-	Fortran Symbolic notation defining the program input
MODEL	-	Notation used in models corresponding to FORTTRAN notation
UNITS	-	Dimensional units of input parameters
FORMAT	-	FORTTRAN format specification
CARD COLUMNS	-	Card column number in which input information is punched
LIMITS	-	Numerical limits on input values

A.3 EXPLANATION OF PROGRAM INPUTS

A.3.1 Card Unit No. 1

The first input card, Card Unit No. 1, gives the DATE of the run and is printed at the head of the listing.

A.3.2 Card Unit No. 2

Card Unit No. 2 gives the number (NP) of times the program is to be executed. All following cards are repeated NP times.

TABLE A-1
CARD INPUT INFORMATION

CARD UNIT NO.	FORTRAN	MODEL	UNITS	FORMAT	CARD COLUMNS	LIMITS
1	DATE			2A6	1-12	
2	NP			I2	1-2	
3	IA TESTNO			A1 12A6	1 2-73	IA='A'
4	ISKIP			40I2	1-80	
5	NXS NYS NZS NDI NCI NDXR NVS NBK NVB			I3 I3 I3 I3 I3 I3 I3 I3 I3	1-3 4-6 7-9 10-12 13-15 16-18 19-21 22-24 25-27	≤ 100 ≤ 100 ≤ 21 ≤ 10 ≤ 10 ≤ 100 ≤ 20 ≤ 10 ≤ 20
6	XX(I) I=1, NXS	x_j	meters	8F10.0	1-80	
7	YY(I) I=1, NYS	y_j	meters or degrees	8F10.0	1-80	If degrees $0.0 \leq YY$ < 360.0
8	Z(I) I=1, NZS	z_k	meters	8F10.0	1-80	$Z_1 > 0.0$

TABLE A-1 (Continued)

CARD UNIT NO.	FORTTRAN	MODEL	UNITS	FORMAT	CARD COLUMNS	LIMITS
9	DELX(I)	x_i	meters	F10.0	$\left\{ \begin{array}{l} 1-10 \\ 21-30 \\ 41-50 \\ 61-70 \end{array} \right.$	If degrees $0.0 \leq \text{DELY} < 360.0$
	DELY(I) I=1, NNZ (NNZ= NZZ-1)	y_i	meters	F10.0	$\left\{ \begin{array}{l} 11-20 \\ 31-40 \\ 51-60 \\ 71-80 \end{array} \right.$	
10	Q(I) I=1, NNZ	Q_K	Depends on model (See Sec- tion 3)	6E12.6	1-72	
11	UBARK(I) I=1, NNZ	u_{TK}	meters seconds ⁻¹	8F10.0	1-80	> 0.0
12	SIGAK(I) I=1, NNZ	$\sigma_{A_{TK}} \{ \tau_{oK} \}$	degrees	8F10.0	1-80	> 0.0
13	SIGYO(I) I=1, NNZ	$\sigma_{yo} \{ K \}$	meters	8F10.0	1-80	
14	SIGEK(I) I=1, NNZ	$\sigma_{E_{TK}} \{ \tau_{oK} \}$	degrees	8F10.0	1-80	
15	ALPHA(I) I=1, NNZ	α_K		8F10.0	1-80	
16	BETA(I) I=1, NNZ	β_K		8F10.0	1-80	
17	SIGZO(I) I=1, NNZ	$\sigma_{zo} \{ K \}$	meters	8F10.0	1-80	
18	SIGXO(I) I=1, NNZ	$\sigma_{xo} \{ K \}$	meters	8F10.0	1-80	

TABLE A-1 (Continued)

CARD UNIT NO.	FORTTRAN	MODEL	UNITS	FORMAT	CARD COLUMNS	LIMITS
19	ZRK	Z_R	meters	F10.0	1-10	> 0.0
	SIGARK	$\sigma_{AR} \{ \tau_{oK} \}$	degrees	F10.0	11-20	
	SIGERK	$\sigma_{ER} \{ \tau_{oK} \}$	degrees	F10.0	21-30	
	UBARRK	$\bar{u}_R$	meters ₋₁ seconds ⁻¹	F10.0	31-40	
	DELPHI		degrees	F10.0	41-50	≤ 180.0
20	THE TAK(I) I=1, (NZS*2)	$\theta_{BK} \& \theta_{TK}$	degrees	8F10.0	1-80	$0.0 \leq \theta_K$ < 360.0
21	TAUK(I) I=1, NNZ	τ_K	seconds	8F10.0	1-80	
22	TAUOK(I) I=1, NNZ	τ_{oK}	seconds	8F0.0	1-80	
23	T(I) I=1, NNZ	t or T_K	seconds	8F10.0	1-80	
24	H(I) I=1, NNZ	H_K	meters	8F10.0	1-80	
(The A sequence of cards is read only if ISKIP(1) $\neq$ 2)						
25-A	IZMOD(I) I=1, NNZ		N/A	20I2	1-20	=1, 2 or 3
26-A	NPT(I) I=1, NNZ		N/A	20I2	1-20	NNZ + $\sum_{i=1}^{NNZ} NPT_i$ ≤ 100

TABLE A-1 (Continued)

CARD UNIT NO.	FORTRAN	MODEL	UNITS	FORMAT	CARD COLUMNS	LIMITS
27-A	DECAY	k	seconds ⁻¹	F10.0	21-30	
	ZLIM	Z_{lim}	meters	F10.0	31-40	
	TIM1	t_1	seconds	F10.0	41-50	
	LAMBDA		seconds ⁻¹	F10.0	51-60	
28-A	DXR(I) I=1, NDXR	x_K	meters	8F10.0	1-80	
29-A	IFLAG(I) I=1, NDXR		N/A	40I2	1-80	
30-A	DI(I) I=1, NDI	$D_K \{x_K, y_K, K\}$	grams seconds meters ⁻³	6E12.6	1-72	
31-A	CI(I) I=1, NCI	$\chi_K \{x_K, y_K, t_K\}$	grams meters ⁻³	6E12.6	1-72	
(If ISKIP(13) = 0, 32-A through 45-A are not read)						
32-A	UBARL(I) I=1, NBK	$\bar{u}_{TL}$	meters seconds ⁻¹	8F10.0	1-80	
33-A	SIGAL(I) I=1, NBK	$\sigma_{ATL} \{ \tau_{oL} \}$	degrees	8F10.0	1-80	
34-A	SIGYO(I) I=NNZ+1, NNZ+NBK	$\sigma_{yo} \{L\}$	meters	8F10.0	1-80	
35-A	SIGEL(I) I=1, NBK	$\sigma_{ETL} \{ \tau_{oL} \}$	degrees	8F10.0	1-80	
36-A	ALPHA(I) I=NNZ+1, NNZ+NBK	α_L		8F10.0	1-80	

TABLE A-1 (Continued)

CARD UNIT NO.	FORTRAN	MODEL	UNITS	FORMAT	CARD COLUMNS	LIMITS
37-A	BETA(I) I=NNZ+1, NNZ+NBK	β_L		8F10.0	1-80	
38-A	SIGZO(I) I=NNZ+1, NNZ+NBK	$\sigma_{zo}\{L\}$	meters	8F10.0	1-80	
39-A	SIGXO(I) I=NNZ+1, NNZ+NBK	$\sigma_{xo}\{L\}$	meters	8F10.0	1-80	
40-A	ZRL SIGARL SIGERL UBARRL	Z_{RL} $\sigma_{AR}\{\tau_{oL}\}$ $\sigma_{ER}\{\tau_{oL}\}$ $\bar{u}_{RL}$	meters degrees degrees meters seconds ⁻¹	F10.0 F10.0 F10.0 F10.0	1-10 11-20 21-30 31-40	> 0.0
41-A	THETAL(I) I=1, (NBK*2)	$\theta_{BL} \& \theta_{TL}$	degrees	8F10.0	1-80	$0.0 \leq \theta_L' < 360.0$
42-A	TAUL(I) I=1, NBK	τ_L	seconds	8F10.0	1-80	
43-A	TAUOL(I) I=1, NBK	τ_{oL}	seconds	8F10.0	1-80	
44-A	TAST(I) I=1, NBK	t*	seconds	8F10.0	1-80	
45-A	JBOT(I) JTOP(I) I=1, NBK	K K + N	N/A N/A	 2012	 { 1-2, 5-6, 9-10----- -----37-38 3-4, 7-8, 11-12-----	

TABLE A-1 (Continued)

CARD UNIT NO.	FORTRAN	MODEL	UNITS	FORMAT	CARD COLUMNS	LIMITS
(If ISKIP(1) $\neq$ 2, Card Units 25-B through 30-B are not read)						
25-B	VS(I) I=1, NVS	V_s	meters seconds ⁻¹	8F10.0	1-80	$VS_i \leq 10.0$
26-B	PERC(I) I=1, NVS	f_i		8F10.0	1-80	
27-B	ACCUR	R		F10.0	1-10	
(If ISKIP(3) = 0, Card Units 28-B through 30-B are not read)						
28-B	VB(I) I=1, NVB	V_{SK}	meters seconds ⁻¹	8F10.0	1-80	
29-B	PERCB(I) I=1, NVB	f_i		8F10.0	1-80	
30-B	HB	H_{SK}	meters	F10.0	1-10	

A.3.3 Card Unit No. 3

Card Unit No. 3 contains the literal A in column 1 as an indicator for the start of a new case. Also, this card contains the title (TESTNO) of the case to be executed.

A.3.4 Card Unit No. 4

Card Unit No. 4 contains the following program model and logic options (ISKIP):

a. If ISKIP(1) equals 2, the Gravitational Deposition model (Model 7 in Figure 4-1) is executed. If ISKIP(1) is not equal to 2, all other models can be executed.

b. ISKIP(2) is the coordinate system control. If ISKIP(2) equals 0, XX, YY, DELX, DELY are assumed to be in rectangular coordinates. If ISKIP(2) equals 1, they are assumed to be in polar coordinates where XX and DELX are radial distances, and YY and DELY are positive angles measured clockwise from north or 0 degrees. ISKIP(2) affects all models except those for peak dosage, peak concentration and isopleths. These routines automatically use polar coordinates ($DXR, \pi \pm \theta_K$)

c. ISKIP(3) has a dual function. For all models except gravitational deposition, ISKIP(3) controls the calculation of the lateral term in Equation (3-1). If ISKIP(3) is set to 0, the lateral term is not calculated. If ISKIP(3) is set to 1, the lateral term is calculated. In the gravitational deposition model, the occurrence of a vehicle destruct in layer NNZ is indicated by setting ISKIP(3) = 1.

d. ISKIP(4) controls the calculation of the vertical term in the dosage equation for Model 3, which is given by the exponential term in Equation (3-15); and, also, the peak dosage, maximum peak concentration, and isopleth calculations. If ISKIP(4) is set to 0, the vertical term is not calculated. If ISKIP(4) is set to 1, the vertical term is calculated.

e. ISKIP(5) controls the calculation of the vertical reflection term in Equation (3-15); and, also, the peak dosage, peak concentration, and isopleth calculations. If ISKIP(5) is set to 0, this term is not calculated. If ISKIP(5) is set to 1, the vertical reflection term is calculated.

f. ISKIP(6) controls the calculation of the alongwind term in Equation (3-7) and the isopleth calculations. If ISKIP(6) is set to 0, the alongwind term is not calculated. If ISKIP(6) is set to 1, the alongwind term is calculated.

g. ISKIP(7) controls the calculation of dosage and concentration in Models 1 through 6 shown in Figure 4-1. Also, ISKIP(7) controls the calculation of cloud half-widths. If ISKIP(7) is set to 0, dosages, concentrations, and cloud half-widths are not calculated. If ISKIP(7) is set to 1, dosage and concentration are calculated, but half-widths are not. If ISKIP(7) is set to 2, only cloud half-widths are calculated. If ISKIP(7) is set to 3, dosage, concentration and cloud half-widths are calculated.

h. ISKIP(8) controls the calculations of peak dosage and maximum peak concentration. If ISKIP(8) is set to 0, peak dosages and maximum peak concentrations are not calculated. If ISKIP(8) is set to 1, only peak dosages are calculated. If ISKIP(8) is set to 2, only maximum peak concentrations are calculated. If ISKIP(8) is set to 3, both peak dosages and maximum peak concentrations are calculated.

i. ISKIP(9) controls the calculations of dosage and concentration isopleths in the horizontal or x-y plane. If ISKIP(9) is set to 0, no horizontal isopleths are calculated. If ISKIP(9) is set to 1, only dosage isopleths at ground-level are calculated. If ISKIP(9) is set equal to 2, only dosage isopleths calculated at layer boundaries are calculated. If ISKIP(9) is set to 3, only dosage isopleths at all specified heights are calculated. If ISKIP(9) is set to 4, only concentration isopleths at ground level are calculated. If ISKIP(9) is set to 5, concentration isopleths only are calculated at all specified heights. If ISKIP(9) is set to 7, 8, or 9, both dosage and concentration isopleths are calculated, respectively, at ground level, layer boundaries, or at all specified heights.

j. ISKIP(10) controls the calculations of dosage and concentration isopleths in the vertical or y-z plane. If ISKIP(10) is set to 0, no isopleths are calculated. If ISKIP(10) is set to 1, only dosage isopleths are calculated. If ISKIP(10) is set to 2, only concentration isopleths are calculated. If ISKIP(10) is set to 3, both dosage and concentration isopleths are calculated. Vertical isopleths are calculated only at radial distances DXR at which the corresponding element in the array IFLAG is set to 1.

k. ISKIP(11) controls the calculation of dosage and concentration with simple decay. If ISKIP(11) is set to 0, the decay term is not calculated. If ISKIP(11) is set to 1, the decay term is calculated for Models 1 through 6 shown in Figure 4-1.

l. ISKIP(12) controls the calculation of the deposition due to precipitation scavenging, as well as dosage and concentration with cloud depletion by precipitation scavenging. If ISKIP(12) is set to 0, deposition is not calculated. If ISKIP(12) is set to 1, the maximum possible deposition is calculated. If ISKIP(12) is set to 2, deposition due to precipitation scavenging is calculated from Equation (3-35).

m. ISKIP(13) controls Models 5 and 6 in Figure 4-1 for changes in layer structure. If ISKIP(13) is set to 0, the layer structure is assumed not to change. If ISKIP(13) is set to 1, the layer structure is assumed to change at time t^* , and the Box Model is used. If ISKIP(13) is set to 2, the Full Transition Model is used. Also, the geometry of structural change is identified by the arrays JBOT and JTOP.

ISKIP(14) through ISKIP(20) are not used at present.

A.3.5 Card Unit No. 5

Card Unit No. 5 contains the following input information:

- NXS - Number of x coordinates input for all calculations in Logic Sections 1 and 5 of the program (see Figure 4-1)
- NYS - Number of y coordinates input for all calculations in Logic Sections 1 and 5 of the program (see Figure 4-1)
- NZS - Number of initial layer boundaries
- NDI - Number of dosage values for which isopleths are to be calculated in the horizontal and vertical planes
- NCI - Number of concentration values for which isopleths are to be calculated in the horizontal and vertical planes
- NDXR - Number of radial distances input for all calculations in Logic Sections 2, 3 and 4 of the program
- NVS - Number of settling velocities used to calculate ground deposition for all layers except the layer in which a destruct occurs

- NBK - Number of new layers in structure-change Models 4 and 5 (see Figure 4-1)
- NVB - Number of particle settling velocities used to calculate ground deposition from vehicle destruct for layer in which the destruct occurs

A.3.6 Card Units Nos. 6 through 10

Card Units Nos. 6 through 10 contain the following information:

- XX - (Card Unit No. 6) - Receptor coordinates x_j relative to the fixed reference grid
- YY - (Card Unit No. 7) - Receptor coordinates y_j relative to the fixed reference grid
- Z - (Card Unit No. 8) - Layer boundary heights
- DELX, DELY - (Card Unit No. 9) - Coordinates of the source in the layers relative to the fixed reference grid
- Q - (Card Unit No. 10) - Source strength in the layer

A.3.7 Card Units Nos. 11 through 22

Card Units Nos. 11 through 22 apply to Models 1, 2, 3, 6 and 7 shown in Figure 4-1.

Card Units Nos. 11 through 18 contain the following information:

- UBARK - (Card Unit No. 11) - Mean wind speed at the top of the layer

- SIGAK - (Card Unit No. 12) - Standard deviation of wind azimuth angle for reference time τ_{OK} at the top of the layer
- SIGYO - (Card Unit No. 13) - Standard deviation of the crosswind concentration distribution of the source in the layer (lateral source dimension)
- SIGEK - (Card Unit No. 14) - Standard deviation of wind elevation angle at the top of the layer
- ALPHA - (Card Unit No. 15) - Lateral diffusion coefficient in the layer
- BETA - (Card Unit No. 16) - Vertical diffusion coefficient in the layer
- SIGZO - (Card Unit No. 17) - Standard deviation of the vertical concentration distribution of the source in the layer (vertical source dimension)
- SIGXO - (Card Unit No. 18) - Standard deviation of the alongwind concentration distribution of the source in the layer (alongwind source dimension)

Card Unit No. 19 contains the following information:

- ZRK - Reference height in the surface layer
- SIGARK - Standard deviation of azimuth wind angle at the reference height ZRK
- SIGERK - Standard deviation of the wind elevation angle at the reference height ZRK
- UBARRK - Mean wind speed at the reference height ZRK
- DELPHI - Angular sector, centered on alongwind cloud axis, in which concentrations and dosages are calculated

Card Units Nos. 20 through 22 contain the following information:

- THE TAK - (Card Unit No. 20) - Mean wind direction at the base and top of the layer
- TAU K - (Card Unit No. 21) - Time required for cloud stabilization in the layer (source emission time)
- TAU OK - (Card Unit No. 22) - Reference time for standard deviation of wind azimuth angle SIGARK at the reference height ZRK in the surface layer

A.3.8 Card Units Nos. 23 and 24

Card Units Nos. 23 and 24 contain the following information:

- T - (Card Unit No. 23) - Time required for cloud stabilization for Models 1, 2, 3, 4, 5 and 6; residence time of vehicle in the layer for Model 7 (see Figure 4-1)
- H - (Card Unit No. 24) - Effective source height in the layer

A.3.9 Card Units Nos. 25A through 45A

If ISKIP(1) is not equal to 2 (gravitational model is not being used), Card Units Nos. 25A through 31A will be read. If ISKIP(1) is equal to 2, Card Units Nos. 25A through 45A will not be read.

The following information is contained on Card Units Nos. 25A and 26A:

- IZMOD - (Card Unit No. 25A) - Model number used in the layer (Model No. 1, 2, or 3 as shown in Figure 4-1)
- NPT - (Card Unit No. 26A) - Contains number of heights in each layer (NPT) at which concentration or dosage calculations are to be made; calculations are automatically made in the program at all layer boundary heights

Card Unit No. 27A contains the following information:

- DECAY - Decay coefficient in the concentration and dosage equations
- ZLIM - Maximum height at which precipitation occurs (must be height of the top of layer)
- TIM1 - Time after launch at which precipitation begins
- LAMBDA - Washout coefficient

Card Units Nos. 28A through 31A contain the following information:

- DXR - (Card Unit No. 28A) - Radial distances at which peak dosage, maximum peak concentration, concentration and dosage isopleths (in the x-y and y-z planes) and cloud half-widths are to be calculated
- IFLAG - (Card Unit No. 29A) - Flag used to indicate radial distances DXR at which concentration and dosage isopleths in the y-z plane are to be calculated. If IFLAG is set to 0, the corresponding radial distance DXR is ignored and no isopleths are calculated. If IFLAG is set to 1, isopleths are calculated at the corresponding radial distance DXR

- DI - (Card Unit No. 30A) - Values of the dosage for which isopleths are to be calculated
- CI - (Card Unit No. 31A) - Values of the concentration for which isopleths are to be calculated

Card Units Nos. 32A through 39A contain the following information:

(NOTE: If ISKIP(13) equals 1 or 2, indicating a change in layer structure, Card Units Nos. 32A through 45A will be read. If ISKIP(13) equals 0, Card Units Nos. 32A through 45A will not be read.)

- UBARL - (Card Unit No. 32A) - Mean wind speed at the top of new Layers L formed as a result of a change in layer structure
- SIGAL - (Card Unit No. 33A) - Standard deviation of the azimuth wind angle at the top of Layer L
- SIGYO_L - (Card Unit No. 34A) - Standard deviation of lateral concentration distribution for new source in Layer L (lateral source dimension)
- SIGEL - (Card Unit No. 35A) - Standard deviation of the wind elevation angle at the top of Layer L
- ALPHA_L - (Card Unit No. 36A) - Lateral diffusion coefficient in Layer L
- BETA_L - (Card Unit No. 37A) - Vertical diffusion coefficient in Layer L
- SIGZO_L - (Card Unit No. 38A) - Standard deviation of vertical concentration distribution for new source in Layer L (vertical source dimension)
- SIGXO_L - (Card Unit No. 39A) - Standard deviation of alongwind concentration distribution for new source Layer L (alongwind source dimension)

Card Unit No. 49A contains the following information:

- ZRL - Reference height in new surface Layer L
- SIGARL - Standard deviation of wind azimuth angle at reference height ZRL if L equals 1; if L is not equal to 1, SIGARL refers to the base of first new Layer L above the surface Layer K=1
- SIGERL - Standard deviation of wind elevation angle at reference height ZRL if L equals 1; if L does not equal 1, SIGERL refers to base of first new Layer L above the surface Layer K=1
- UBARRL - Mean wind speed at reference height ZRL if L equals 1; if L is not equal to 1, UBARRL is mean wind speed at base of first new Layer L above the surface Layer K=1

Card Units Nos. 41A through 45A contain the following information:

- THE TAL - (Card Unit No. 41A) - Mean wind direction at the base and top of each new layer
- TAUL - (Card Unit No. 42A) - Cloud stabilization time in the new Layer L
- TAUOL - (Card Unit No. 43A) - Reference time period for SIGARL
- TAST - (Card Unit No. 44A) - Time after launch at which change in layer structure occurs
- JBOT, JTOP - (Card Unit No. 45A) - The K number of the original layer at the base of each new layer (JBOT) and at the top of each new layer (JTOP); new layers are formed from layers existing prior to time TAST

A.3.10 Card Units Nos. 25B through 30B

Card Units Nos. 25B through 30B contain the following information required for use with Model 7 (see Figure 4-1):

(NOTE: If ISKIP(1) is not equal to 2, Model 7 is not used and Card Units Nos. 25B through 30B are not read.)

- VS - (Card Unit No. 25B) - Settling velocity assigned to each particle or droplet size category
- PERC - (Card Unit No. 26B) - Fraction of material with settling velocity V_s
- ACCUR - (Card Unit No. 27B) - Accuracy constant in line source simulation used in Model 7. A value of 0.45 for ACCUR ensures that the calculated ground deposition is within 10 percent of the deposition expected from a vertical line source; if ACCUR is set to 0.32, the calculated ground deposition is within 5 percent of the deposition expected from a vertical line source

(NOTE: If ISKIP(3) equals 1 and ISKIP(1) equals 2, a vehicle destruct is assumed to have occurred in the top K layer and Card Units Nos. 28B through 30B are read.)

- VB - (Card Unit No. 28B) - Settling velocity assigned each particle or droplet size category assigned to material from vehicle destruct in the top K layer
- PERCB - (Card Unit No. 29B) - Fraction of material with settling velocity VB
- HB - (Card Unit No. 30B) - Effective height of vehicle destruct material above the surface

A.4 ADDITIONAL REMARKS

The sequence of input cards described in Section A.3, starting with Card Unit No. 3, will be read NP times or until an end-of-file is met. The order and number of cards read depends on ISKIP(1), ISKIP(3) and ISKIP(13).

Peak dosage, maximum peak concentration, and isopleths are not calculated for Models 4, 5, 6 and 7 shown in Figure 4-1. Hence, when ISKIP(8) $\neq$ 0, ISKIP(9) $\neq$ 0, or ISKIP(10) $\neq$ 0, all calculations refer to Models 1, 2 or 3.

Logic Sections 1 through 4 in Figure 4-1 may be processed in any combination as a multi-layer problem. Logic Section 5 in Figure 4-1 must be processed as a single multi-layer problem. Any number of problems can be processed in an execution of the computer program.

A.5 KEYPUNCH INSTRUCTIONS

The decimal in all F-type format statements can appear anywhere in the ten digit field. If the decimal is deleted, the number is right justified in the field. All I formats are right justified in the field (see Figure A-3).

A.6 OPERATOR INSTRUCTIONS

There are no special operator instructions.

A.7 LINKAGE FOR SUBROUTINES IN COMPUTER PROGRAM FOR KSC MULTI-LAYER DIFFUSION MODEL

The physical linkage for the computer program subroutines is shown in Figure A-1. Each connector represents a communication link between the subroutines.

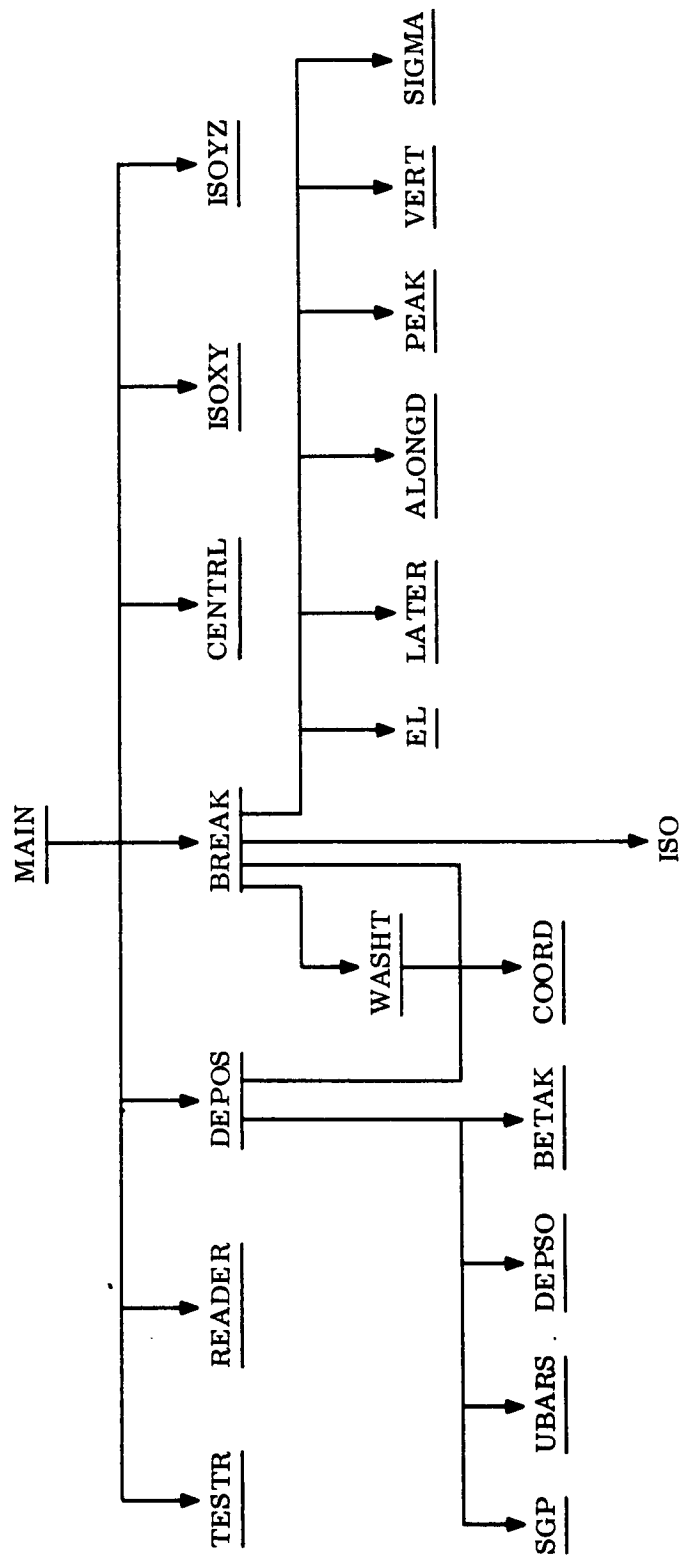


FIGURE A-1. Diagram of linkage between subroutines of computer program for KSC multi-layer diffusion model.

A.8 LINKAGE FOR SUBROUTINES IN LOGIC SECTIONS 1 THROUGH 5

The linkage for subroutines used in Logic Sections 1 through 5 of the computer program for the KSC multi-layer diffusion model is shown in Figure A-2. Each connector represents a communication link between the subroutines.

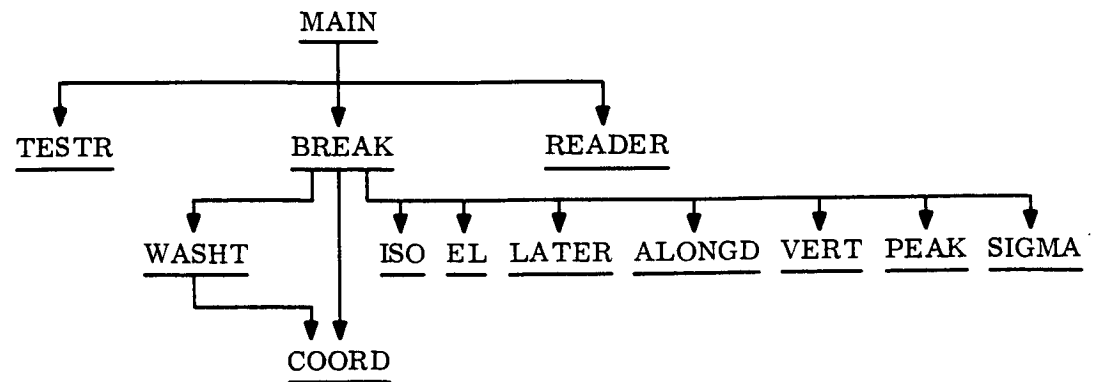
A.9 DATA FIELD CONFIGURATION

The data field configuration of each input parameter as it appears in the read sequence for the KSC multi-layer diffusion model program is shown in Figure A-3. The format symbols in the figure are defined as follows:

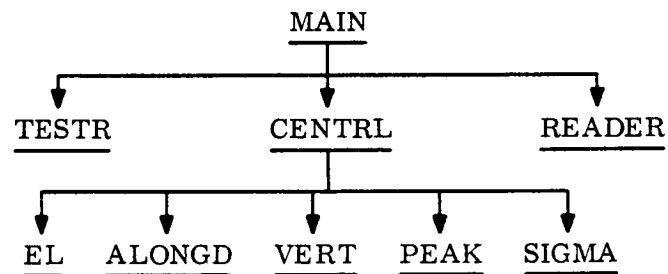
- A - Alphanumeric
- I - Integer
- X - Real
- E - Exponential

also, in Figure A-3, the parameter configurations are identified by the Card Unit No. and the FORTRAN name of the parameter.

SECTION 1 LINKAGE



SECTION 2 LINKAGE



SECTION 3 LINKAGE

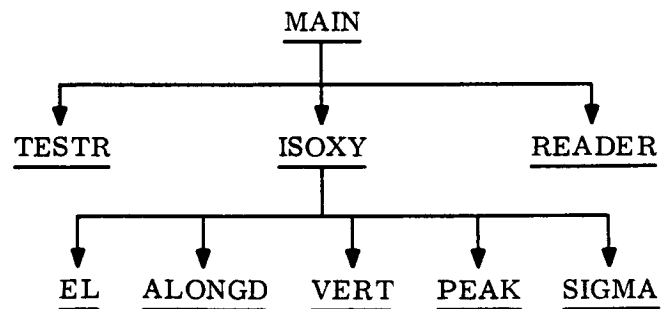
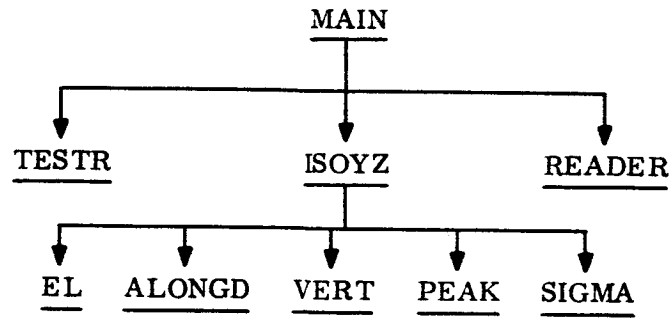


FIGURE A-2. Diagram of linkage between subroutines used in Logic Sections of computer program for KSC multi-layer diffusion model.

SECTION 4 LINKAGE



SECTION 5 LINKAGE

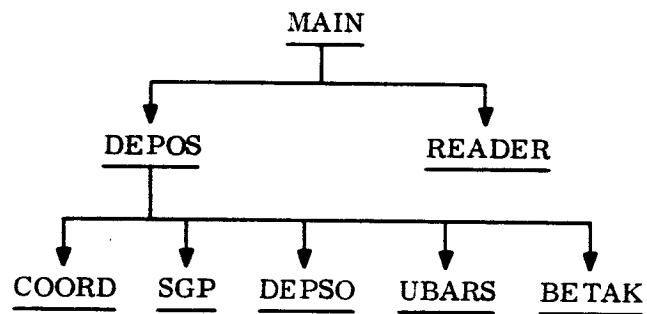


FIGURE A-2. (Continued)

FIGURE A-3. Data field configuration.

[illegible]

FIGURE A-3. (Continued)

REQUESTED BY		DEPARTMENT		JOB NO. & CODE		DATE	PAGE	OF
1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27
28	29	30	31	32	33	34	35	36
37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54
55	56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81
82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99
100	101	102	103	104	105	106	107	108
109	110	111	112	113	114	115	116	117
118	119	120	121	122	123	124	125	126
127	128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143	144
145	146	147	148	149	150	151	152	153
154	155	156	157	158	159	160	161	162
163	164	165	166	167	168	169	170	171
172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189
190	191	192	193	194	195	196	197	198
199	200	201	202	203	204	205	206	207
208	209	210	211	212	213	214	215	216
217	218	219	220	221	222	223	224	225
226	227	228	229	230	231	232	233	234
235	236	237	238	239	240	241	242	243
244	245	246	247	248	249	250	251	252
253	254	255	256	257	258	259	260	261
262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279
280	281	282	283	284	285	286	287	288
289	290	291	292	293	294	295	296	297
298	299	300	301	302	303	304	305	306
307	308	309	310	311	312	313	314	315
316	317	318	319	320	321	322	323	324
325	326	327	328	329	330	331	332	333
334	335	336	337	338	339	340	341	342
343	344	345	346	347	348	349	350	351
352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369
370	371	372	373	374	375	376	377	378
379	380	381	382	383	384	385	386	387
388	389	390	391	392	393	394	395	396
397	398	399	400	401	402	403	404	405
406	407	408	409	410	411	412	413	414
415	416	417	418	419	420	421	422	423
424	425	426	427	428	429	430	431	432
433	434	435	436	437	438	439	440	441
442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459
460	461	462	463	464	465	466	467	468
469	470	471	472	473	474	475	476	477
478	479	480	481	482	483	484	485	486
487	488	489	490	491	492	493	494	495
496	497	498	499	500	501	502	503	504
505	506	507	508	509	510	511	512	513
514	515	516	517	518	519	520	521	522
523	524	525	526	527	528	529	530	531
532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549
550	551	552	553	554	555	556	557	558
559	560	561	562	563	564	565	566	567
568	569	570	571	572	573	574	575	576
577	578	579	580	581	582	583	584	585
586	587	588	589	590	591	592	593	594
595	596	597	598	599	600	601	602	603
604	605	606	607	608	609	610	611	612
613	614	615	616	617	618	619	620	621
622	623	624	625	626	627	628	629	630
631	632	633	634	635	636	637	638	639
640	641	642	643	644	645	646	647	648
649	650	651	652	653	654	655	656	657
658	659	660	661	662	663	664	665	666
667	668	669	670	671	672	673	674	675
676	677	678	679	680	681	682	683	684
685	686	687	688	689	690	691	692	693
694	695	696	697	698	699	700	701	702
703	704	705	706	707	708	709	710	711
712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729
730	731	732	733	734	735	736	737	738
739	740	741	742	743	744	745	746	747
748	749	750	751	752	753	754	755	756
757	758	759	760	761	762	763	764	765
766	767	768	769	770	771	772	773	774
775	776	777	778	779	780	781	782	783
784	785	786	787	788	789	790	791	792
793	794	795	796	797	798	799	800	801
802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819
820	821	822	823	824	825	826	827	828
829	830	831	832	833	834	835	836	837
838	839	840	841	842	843	844	845	846
847	848	849	850	851	852	853	854	855
856	857	858	859	860	861	862	863	864
865	866	867	868	869	870	871	872	873
874	875	876	877	878	879	880	881	882
883	884	885	886	887	888	889	890	891
892	893	894	895	896	897	898	899	900
901	902	903	904	905	906	907	908	909
910	911	912	913	914	915	916	917	918
919	920	921	922	923	924	925	926	927
928	929	930	931	932	933	934	935	936
937	938	939	940	941	942	943	944	945
946	947	948	949	950	951	952	953	954
955	956	957	958	959	960	961	962	963
964	965	966	967	968	969	970	971	972
973	974	975	976	977	978	979	980	981
982	983	984	985	986	987	988	989	990
991	992	993	994	995	996	997	998	999
1000	1001	1002	1003	1004	1005	1006	1007	1008
1009	1010	1011	1012	1013	1014	1015	1016	1017
1018	1019	1020	1021	1022	1023	1024	1025	1026
1027	1028	1029	1030	1031	1032	1033	1034	1035
1036	1037	1038	1039	1040	1041	1042	1043	1044
1045	1046	1047	1048	1049	1050	1051	1052	1053
1054	1055	1056	1057	1058	1059	1060	1061	1062
1063	1064	1065	1066	1067	1068	1069	1070	1071
1072	1073	1074	1075	1076	1077	1078	1079	1080
1081	1082	1083	1084	1085	1086	1087	1088	1089
1090	1091	1092	1093	1094	1095	1096	1097	1098
1099	1100	1101	1102	1103	1104	1105	1106	1107
1108	1109	1110	1111	1112	1113	1114	1115	1116
1117	1118	1119	1120	1121	1122	1123	1124	1125
1126	1127	1128	1129	1130	1131	1132	1133	1134
1135	1136	1137	1138	1139	1140	1141	1142	1143
1144	1145	1146	1147	1148	1149	1150	1151	1152
1153	1154	1155	1156	1157	1158	1159	1160	1161
1162	1163	1164	1165	1166	1167	1168	1169	1170
1171	1172	1173	1174	1175	1176	1177	1178	1179
1180	1181	1182	1183	1184	1185	1186	1187	1188
1189	1190	1191	1192	1193	1194	1195	1196	1197
1198	1199	1200	1201	1202	1203	1204	1205	1206
1207	1208	1209	1210	1211	1212	1213	1214	1215
1216	1217	1218	1219	1220	1221	1222	1223	1224
1225	1226	1227	1228	1229	1230	1231	1232	1233
1234	1235	1236	1237	12				

FIGURE A-3. (Continued)

[illegible]

FIGURE A-3. (Continued)

REQUESTED BY	DEPARTMENT	JOB NO. & CODE	DATE	PAGE	OF
18-SIGXØ	SIGARK	SIGERK	UBARRK	DELPHI	
19-ZRK	SIGARK	SIGERK	UBARRK	DELPHI	
20-THETAK					
21-TAUK					
22-TAUKØK					
23-T					

FIGURE A-3. (Continued)

[illegible]

FIGURE A-3. (Continued)

[illegible]

FIGURE A-3. (Continued)

[illegible]

FIGURE A-3. (Continued)

REQUESTED BY		DEPARTMENT		JOB NO. & CODE		DATE		PAGE	
1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130
131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170
171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190
191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220
221	222	223	224	225	226	227	228	229	230
231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250
251	252	253	254	255	256	257	258	259	260
261	262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280
281	282	283	284	285	286	287	288	289	290
291	292	293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308	309	310
311	312	313	314	315	316	317	318	319	320
321	322	323	324	325	326	327	328	329	330
331	332	333	334	335	336	337	338	339	340
341	342	343	344	345	346	347	348	349	350
351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370
371	372	373	374	375	376	377	378	379	380
381	382	383	384	385	386	387	388	389	390
391	392	393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408	409	410
411	412	413	414	415	416	417	418	419	420
421	422	423	424	425					

FIGURE A-3. (Continued)

[illegible]

APPENDIX B

Appendix B contains a complete listing of the present configuration of the computer program for the KSC Multi-Layer Diffusion Model. The program is written in FORTRAN V and has been assembled and executed on a UNIVAC 1108 computer under the EXEC II Monitor.

BT FOR MODEL
UNIVAC 110R FOR-RAH V LEVEL 2706 0918 F5010P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:34:49

MAIN PROGRAM

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 001613
0002 *DATA 001127
0003 *BLANK 000000
0004 *PARAM 033754
0005 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 READER
0006 DEPOS
0007 TESTR
0010 AHEAD
0011 SIGNA
0012 CENTRL
0013 ISOXY
0014 ISOYZ
0015 HRDUF
0016 MI015
0017 MI028
0020 *SDUS
0021 SRT
0022 NEXP68
0023 NSTOP5

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000751	100L	0001	000006	1156	0001	00020	1236	0001	000040	1346	000054	1436
0001	000070	1526	0001	000172	1736	0001	000052	2L	0001	000140	2026	000150	2066
0001	000171	2156	0001	000201	2216	0001	000264	2476	0001	000403	3026	001024	405L
0001	001115	410L	0001	001123	420L	0001	001127	430L	0001	001271	440L	000247	5L
0001	000744	5176	0001	001146	520L	0001	000772	5226	0001	001346	522L	001401	524L
0001	001427	525L	0001	001542	527L	0001	001536	528L	0001	001567	535L	001673	540L
0001	001072	5466	0001	001577	540L	0001	001133	5746	0001	001603	580L	001300	600L
0001	001212	6206	0001	001231	6256	0001	001256	6336	0001	001333	6526	001343	6636
0001	000307	706L	0001	001402	708L	0001	001550	7276	0001	001607	777L	000321	80L
0001	000015	800F	0000	000016	8016	0000	000017	802F	0000	000020	806F	000025	807F
0001	000343	82L	0001	000355	84L	0001	000364	90L	0000	000027	900F	000035	901F
0000	000045	902F	0000	000050	903F	0000	000056	904F	0000	000063	905F	000203	906F
0000	000216	907F	0000	000223	908F	0000	000230	909F	0000	000272	910F	000335	911F
0000	000350	912F	0000	000363	913F	0000	000374	914F	0000	000447	915F	000443	916F
0000	000534	917F	0000	000510	918F	0000	000617	919F	0001	000477	92L	000623	920F
0000	000721	917F	0000	000776	922F	0000	001032	923F	0000	001067	924F	000834	93L
0001	000844	94L	0001	000831	94L	0001	000656	97L	0001	000726	98L	000816	ACCUR
0003	R 007102	ALONG	0003	R 00226	ALPHA	0004	R 001023	ALPHA	0004	R 001170	ANG	0003	R 000264
0004	R 000657	BETA	0003	R 007774	CI	0003	R 001522	CON	0004	R 000342	DATE	0004	R 000000
													DECAY

MULTILAYER DIFFUSION MODEL OCA CORP BJORNLUND

DATE 121269 PAGE 5

0004 R C2524 DELPHI	0003 R C00484 DELTHP	0003 R 001010 DELU	0003 R 000606 DELX	0003 R 000644 DELY
0004 R C00345 DEP	0004 R C01335 DEPN	0003 R 007762 DI	0000 R 000006 DIFF	0003 R 001386 DOS
0004 R C00373 DTHK	0003 R C07246 DTR	0004 R 000126 ERFX	0003 R 000036 H	0004 R 000267 HS
0003 I 010014 I	0000 I C00004 IA	0003 I 010080 IBUT	0000 I 000002 IERR	0003 I 007436 IFLAG
0004 I C00344 II	0003 I C10036 IIA	0003 I 000000 ISKIP	0003 I 007402 ITAG	0003 I 010047 ITOP
0003 I C00740 IZMOD	0000 I C00000 IB	0003 I 010018 J	0004 I 000014 JAST	0004 I 000041 JP
0004 I C00134 JTOP	0000 I 000003 JXJ	0003 I 000008 K	0003 I 010016 KA	0000 I 000010 KTK
0003 R 010012 L	0003 R 010110 LAM3DA	0003 R 006426 LAT	0004 I 000326 LB2	0004 I 000272 LBR
0004 R 000312 LB3	0000 I 000316 LB4	0000 I 000011 LSP	0000 I 000007 M	0004 R 000272 MPR
0000 I 000012 M	0003 I 010028 MRC	0003 I 010053 NCI	0003 I 010042 NCI	0003 I 010044 NDR
0003 I 010046 NNY	0000 I 000001 PP	0003 I 000744 NPT	0004 I 000321 NVB	0004 I 000320 NVS
0004 I 010334 NXCI	0003 I 010037 NXS	0003 I 010040 NYS	0003 I 010001 N2S	0003 R 004262 PEAKC
0003 R 010444 PEAKD	0004 R 000172 PERC	0004 R 000493 PERCB	0003 R 002342 PLT	0004 R 000270 PPAR
0003 R C00132 Q	0004 R C00271 QPR	0003 R 010045 RAC	0003 R 033860 SIGAK	0004 R 000013 SIGAL
0004 R C02122 SIGAN	0003 R C00360 SIGAP	0003 R 033331 SIGARK	0004 R 000000 SIGARL	0003 R 023604 SIGEK
0004 R C00025 SIGEL	0004 R C24784 SIGENK	0003 R 000880 SIGEP	0003 R 033632 SIGERK	0004 R 000042 SIGERL
0003 R 010010 SIGH	0003 R 010107 SIGIKK	0003 R 000914 SIGKD	0003 R 010007 SIGY	0004 R 024758 SIGYK
0003 R C00322 SIGHD	0003 R 010006 SIGI2	0003 R 000912 SIGZO	0004 R 001167 SSBAR	0003 R 010011 SSBZP
0003 R 010017 STOI	0003 R 010020 STOI2	0003 R 010021 STC3	0003 R 007412 T	0003 R 010023 TAST
0003 R 033704 TALA	0004 R 000070 TALL	0003 R 033730 TADOK	0004 R 000102 TAUOL	0003 I 007746 TESTNO
0003 R 010013 T	0003 R 000702 T-ETA	0003 R 033634 THETAK	0004 R 000044 THETAL	0003 I 010111 THH1
0003 R 010112 TIPE	0003 R 010022 TPD	0003 R 000910 UBARK	0003 R 033834 UBARK	0004 R 000001 UBARL
0004 R 000513 UBARN	0003 R 033633 ULARK	0004 R 000943 UBARL	0004 R 025347 UBARK	0004 R 025433 UBARZL
0004 R 000217 VS	0003 R C04872 VER	0003 R 000736 VREF	0004 R 000146 VS	0003 R 010114 WASHOU
0003 R 010081 XAST	0004 R 000812 XBARX	0003 R 001212 YR	0003 R 002032 YX	0000 R 000013 Y
0004 R 000346 YBARV	0000 R 000014 YS	0003 R 002176 YY	0003 R 000074 Z	0003 R 010113 ZLIK
0003 R 033630 ZRK	0004 R 000037 ZRL	0003 R 001046 ZZL		

1

00100	10	C	MAIN 20
00100	20	C	MAIN 30
00100	30	C	MAIN 40
00100	40	C	MAIN 50
00100	50	C	MAIN 60
00100	60	C	MAIN 70
00100	70	C	MAIN 80
00100	80	C	MAIN 90
00100	90	C	MAIN 100
00100	100	C	MAIN 110
00100	110	C	MAIN 120
00100	120	C	MAIN 130
00100	130	C	MAIN 140
00100	140	C	MAIN 150
00100	150	C	MAIN 160
00100	160	C	MAIN 170
00100	170	C	MAIN 180
00100	180	C	MAIN 190
00100	190	C	MAIN 200
00100	200	C	MAIN 210
00100	210	C	MAIN 220
00100	220	C	MAIN 230
00100	230	C	MAIN 240
00100	240	C	MAIN 250
00100	250	C	MAIN 260
00100	260	C	MAIN 270
00100	270	C	MAIN 280

***** MULTILAYER DIFFUSION MODEL *****

ISYIP = PROGRAM CONTROL OPTIONS
H = EFFECTIVE RELEASE HEIGHT IN LAYER (METERS)
Z = BOUNDARY HEIGHTS OF LAYER (METERS)
Q = SOURCE STRENGTH IN LAYER (MASS/HEIGHT)
UBAR = CALCULATED TRANSPORT SPEED IN LAYER
ALPHA = LATERAL POWER LAW EXPANSION COEFFICIENT
BETA = VERTICAL POWER LAW EXPANSION COEFFICIENT
SIGO = STANDARD DEVIATION OF THE LATERAL SOURCE DIMENSION (METER)
SIGAP = CALCULATED LATERAL DIFFUSION COEFFICIENT IN LAYER
SIGSD = STANDARD DEVIATION OF THE ALONG WIND SOURCE DIMENSION (METERS)
DELTHP = CALCULATED WIND DIRECTION SHEAR IN LAYER
SIGSD = STANDARD DEVIATION OF THE VERTICAL SOURCE DIMENSION (METERS)
SIGEP = CALCULATED VERTICAL DIFFUSION COEFFICIENT
DELX = X COORDINATE OF SOURCE IN LAYER RELATIVE TO ORIGIN OF FIXED GRID SYSTEM (METERS)
DELY = Y COORDINATE OF SOURCE IN LAYER RELATIVE TO ORIGIN OF FIXED GRID SYSTEM (METERS)
THETA = CALCULATED MEAN WIND DIRECTION IN LAYER
IZMOD = MODEL TO USE IN LAYER (1,2 OR 3)
NPT = NUMBER OF CALCULATION HEIGHTS ZZL DESIRED IN LAYER

00100 280 C DELU = CALCULATED WIND SPEED SHEAR MAIN 29
 00100 290 C ZTL = CALCULATION HEIGHTS IN LAYER MAIN 300
 00100 300 C AR = CLOUD HALF WIDTHS MAIN 310
 00100 310 C DQS = CALCULATED VALUE OF DOSAGE MAIN 320
 00100 320 C CON = CALCULATED VALUE OF CONCENTRATION MAIN 330
 00100 330 C PEAKD = PART OF DOSAGE EQUATION MAIN 340
 00100 340 C AX = X COORDINATE OF RECEPTOR RELATIVE TO FIXED GRID SYSTEM MAIN 350
 00100 350 C (POSITIVE X AXIS EAST 90 DEGREES) METERS, RECTANGULAR OR POLAR) MAIN 360
 00100 360 C YY = Y COORDINATE OF RECEPTOR RELATIVE TO FIXED GRID SYSTEM MAIN 370
 00100 370 C (POSITIVE Y AXIS NORTH 0 DEGREES) METERS OR DEGREES, RECTANGULAR MAIN 380
 00100 380 C POLAR) MAIN 390
 00100 390 C PLT = CALCULATED VALUES OF DOSAGE AND CONCENTRATION ISOPLETHS MAIN 400
 00100 400 C LAT = LATERAL TERM OF DOSAGE EQUATION MAIN 410
 00100 410 C VEA = VERTICAL TERM OF DOSAGE EQUATION MAIN 420
 00100 420 C VREF = REFLECTION TERM OF DOSAGE EQUATION MAIN 430
 00100 430 C ALONGH = ALONG WIND TERM OF CONCENTRATION EQUATION MAIN 440
 00100 440 C DXR = RADIAL DISTANCES FOR MAXIMUM PEAK DOSAGE AND CONCENTRATION MAIN 450
 00100 450 C Y = AND ISOPLETH AND CLOUD HALF-DEPTH CALCULATIONS MAIN 460
 00100 460 C Y = TIME AFTER CLOUD STABILIZATION EXCEPT IN GRAVITATIONAL MAIN 470
 00100 470 C DEPOSITION MODEL SOURCE EMISSION TIME IN LAYER (SECONDS) MAIN 480
 00100 480 C IFLAG = FLAG TO INDICATE AT WHICH DISTANCES DIR VERTICAL ISOPLETHS MAIN 490
 00100 490 C ARE TO BE CALCULATED MAIN 500
 00100 500 C IFLAG = FLAG TO INDICATE WHICH RECEPTOR COORDINATES ARE OUTSIDE MAIN 510
 00100 510 C OF CALCULATION SECTOR DELPHI MAIN 520
 00100 520 C TESTNO = CASE TITLE MAIN 530
 00100 530 C DI = DOSAGE ISOPLETH VALUES OF INTEREST MAIN 540
 00100 540 C CI = CONCENTRATION ISOPLETH VALUES OF INTEREST MAIN 550
 00100 550 C SIGZ = CALCULATED STANDARD DEVIATION OF THE VERTICAL DOSAGE MAIN 560
 00100 560 C DISTRIBUTION MAIN 570
 00100 570 C SIGY = CALCULATED STANDARD DEVIATION OF THE LATERAL DOSAGE MAIN 580
 00100 580 C DISTRIBUTION MAIN 590
 00100 590 C SIGX = CALCULATED STANDARD DEVIATION OF THE ALONG WIND DOSAGE MAIN 600
 00100 600 C DISTRIBUTION MAIN 610
 00100 610 C SQRPZ = SQUARE ROOT TWO PI MAIN 620
 00100 620 C L = LENGTH OF CLOUD IN ALONG WIND DIRECTION MAIN 630
 00100 630 C TH = $\text{THETA} \times \pi / 180$ MAIN 640
 00100 640 C I = INDEX OF X COORDINATES MAIN 650
 00100 650 C J = INDEX OF Y COORDINATES MAIN 660
 00100 660 C KK = INDEX OF LAYERS MAIN 670
 00100 670 C K = INDEX LAYER CALCULATION HEIGHTS Z2L MAIN 680
 00100 680 C STD1 = TEMP STORAGE MAIN 690
 00100 690 C STD2 = TEMP STORAGE MAIN 700
 00100 700 C STD3 = TEMP STORAGE MAIN 710
 00100 710 C TRD = HALF CALCULATION SECTOR DELPHI MAIN 720
 00100 720 C TAST = TIME OF LAYER STRUCTURE CHANGE (SECONDS) MAIN 730
 00100 730 C NBK = NO OF DISTINCT GROUPS OF LAYERS THAT FORM INTO ONE AT TIME TAST. MAIN 740
 00100 740 C ILK = INDEX OF NEW LAYERS AFTER TIME TAST MAIN 750
 00100 750 C NXS = NO OF X COORDINATES MAIN 760
 00100 760 C NYS = NO OF Y COORDINATES MAIN 770
 00100 770 C NZS = NO OF LAYER BOUNDARIES MAIN 780
 00100 780 C NDI = NO OF DOSAGE ISOPLETHS MAIN 790
 00100 790 C NCI = NO OF CONCENTRATION ISOPLETHS MAIN 800
 00100 800 C PDXR = NO OF RADIAL DISTANCES DIR ALONG CLOUD AXIS MAIN 810
 00100 810 C RAD = $\pi / 180$ MAIN 820
 00100 820 C NZS-1 NO OF LAYERS MAIN 830
 00100 830 C NZS = TOP OF NEW LAYER AFTER TAST IN TERMS OF OLD LAYER STRUCTURE MAIN 840
 00100 840 C ITOP = TOP OF NEW LAYER AFTER TAST IN TERMS OF OLD LAYER MAIN 850
 00100 850 C IBDT = BOTTOM OF NEW LAYER AFTER TAST IN TERMS OF OLD LAYER MAIN 860

00100	840	C	STRUCTURE (JTOP AND JBOT INDEXES)	MAIN 870
00100	870	C	KAST = CALCULATE DISTANCE TO TAST	MAIN 880
00100	880	C	SIGAK = SIGA OF NEW LAYER STRUCTURE	MAIN 890
00100	890	C	LAMBDA = WASHOUT COEFFICIENT	MAIN 900
00100	900	C	TIME1 = TIME OF START OF RAIN (SECONDS)	MAIN 910
00100	910	C	TIME2 = TIME RAIN STOPS (SECONDS)	MAIN 920
00100	920	C	ZLIM = MAXIMUM HEIGHT OF WASHOUT	MAIN 930
00100	930	C	WASHOU = CALCULATE WASHOUT AT GROUND	MAIN 940
00100	940	C	UBARK = WIND SPEED AT TOP OF LAYER (METERS/SEC)	MAIN 950
00100	950	C	SIGAK = SIGAP AT TOP OF LAYER (DEGREES)	MAIN 960
00100	960	C	SIGK = SIGEP AT TOP OF LAYER (DEGREES)	MAIN 970
00100	970	C	ZRK = REFERENCE HEIGHT IN SURFACE LAYER (METERS)	MAIN 980
00100	980	C	SIGARK = SIGAP AT ZRK (DEGREES)	MAIN 990
00100	990	C	SIGERK = SIGEP AT ZRK (DEGREES)	MAIN1000
00100	1000	C	UBARRK = WIND SPEED AT ZRK (METERS/SEC)	MAIN1010
00100	1010	C	THETAK = WIND DIRECTION AT LAYER BOUNDARIES (DEGREES)	MAIN1020
00100	1020	C	TAK = TIME IN SECONDS REQUIRED FOR LATERAL CLOUD STABILIZATION	MAIN1030
00100	1030	C	TAUK = SAMPLING PERIOD IN SECONDS AT THE TOP OF THE LAYER	MAIN1040
00100	1040	C	DECAY = DECAY COEFFICIENT IN DUSAGE EQUATION	MAIN1050
00100	1050	C	UBARL = WIND SPEED AT TOP OF NEW LAYER AFTER TAST (DEGREES)	MAIN1060
00100	1060	C	SIGAL = SIGAP AT TOP OF NEW LAYER AFTER TAST (DEGREES)	MAIN1070
00100	1070	C	SIGEL = SIGEP AT TOP OF NEW LAYER AFTER TAST (DEGREES)	MAIN1080
00100	1080	C	ZRL = REFERENCE HEIGHT IN SURFACE LAYER OF NEW STRUCTURE (METERS)	MAIN1090
00100	1090	C	SIGARL = SIGAP AT ZRL IF FIRST LAYER INCLUDES OLD SURFACE LAYER	MAIN1100
00100	1100	C	ELSE EQUALS SIGAP AT BOTTOM OF FIRST NEW LAYER (DEGREES)	MAIN1110
00100	1110	C	SIGERL = SIGEP AT ZRL IF FIRST LAYER INCLUDES OLD SURFACE LAYER	MAIN1120
00100	1120	C	ELSE EQUALS SIGEP AT BOTTOM OF FIRST NEW LAYER (DEGREES)	MAIN1130
00100	1130	C	UBARL = WIND SPEED AT ZRL IF FIRST LAYER INCLUDES OLD SURFACE LAYER	MAIN1140
00100	1140	C	ELSE EQUALS WIND SPEED AT BOTTOM OF FIRST NEW LAYER (METERS/SEC)	MAIN1150
00100	1150	C	THETAL = WIND DIRECTION AT BOUNDARIES OF NEW LAYER STRUCTURE (DEGREES)	MAIN1160
00100	1160	C	TAUL = TIME IN SECONDS FOR LATERAL CLOUD STABILIZATION IN NEW LAYER STRUCTURE	MAIN1170
00100	1170	C	TAUOL = TIME IN SECONDS OF SAMPLING PERIOD AT TOP OF NEW LAYER	MAIN1180
00100	1180	C	JBOT = INPUT LAYER NUMBER OF BOTTOM OF NEW LAYER STRUCTURE	MAIN1190
00100	1190	C	RELATIVE TO OLD	MAIN1200
00100	1200	C	JTOP = INPUT LAYER NUMBER OF TOP OF NEW LAYER STRUCTURE	MAIN1210
00100	1210	C	RELATIVE TO OLD	MAIN1220
00100	1220	C	VS = SETTLING VELOCITY IN GRAVITATIONAL DEPOSITION MODEL	MAIN1230
00100	1230	C	PERC = FREQUENCY OF VS	MAIN1240
00100	1240	C	ACCUR = DESIRED ACCURACY COEFFICIENT (.45) INSURES THAT GROUND DEPOSITION FROM WXCI POINT SOURCES IN THE LAYER VARIES LESS THAN TEN PERCENT FROM DEPOSITION EXPECTED FROM A VERTICAL LINE SOURCE IN THE LAYER, FOR (.32) REDUCED TO FIVE PERCENT	MAIN1250
00100	1250	C	VB = SETTLING VELOCITIES FROM A BURST OR DESTRUCT IN LAYER NNZ	MAIN1260
00100	1260	C	PERCB = FREQUENCY OF VB	MAIN1270
00100	1270	C	HB = HEIGHT OF BURST (METERS)	MAIN1280
00100	1280	C	PPWR = CALCULATED WIND SPEED POWER LAW EXPONENT	MAIN1290
00100	1290	C	QPPWR = CALCULATED SIGEP POWER LAW EXPONENT	MAIN1300
00100	1300	C	HPWR = CALCULATED SIGAP POWER LAW EXPONENT	MAIN1310
00100	1310	C	DTWK = WIND ANGLE SHEAR	MAIN1320
00100	1320	C	NVS = NUMBER OF SETTLING VELOCITIES VS	MAIN1330
00100	1330	C	NVB = NUMBER OF SETTLING VELOCITIES VB	MAIN1340
00100	1340	C	LBI = PRINTED INFORMATION =L02,LB0,L94	MAIN1350
00100	1350	C	DATE = RUN DATE	MAIN1360
00100	1360	C	II = IDEAL ON VS AND VB	MAIN1370
00100	1370	C	DEP = TEMP STORAGE	MAIN1380
00100	1380	C		MAIN1390
00100	1390	C		MAIN1400
00100	1400	C		MAIN1410
00100	1410	C		MAIN1420
00100	1420	C		MAIN1430
00100	1430	C		MAIN1440

```

MULTILAYER DIFF. SIG. MODEL 6CA CORP BJORKLUND
DATE 121269 PAGE 8

C 1489 YBARY = CALCULATED COORDINATE OF POINT ON CLOUD AXIS OF VS AT MAIN1450
C 1490 INTERSECTION WITH GROUND (DEPOSITION) MAIN1461
C 1491 XBARA = CALCULATED COORDINATE OF POINT ON CLOUD AXIS OF VS AT MAIN1470
C 1492 INTERSECTION WITH GROUND (DEPOSITION) MAIN1480
C 1493 UBARNK = CALCULATED WIND SPEED (DEPOSITION) MAIN1490
C 1494 BETANK = CALCULATED BETA (DEPOSITION) MAIN1500
C 1495 ALPHNK = CALCULATED ALPHA (DEPOSITION) MAIN1510
C 1496 SGBAR = TEMP STORAGE MAIN1520
C 1497 ANG = ANGLE TO POINT XBARAYBARY (DEPOSITION) MAIN1530
C 1498 NACI = NUMBER OF POINT SOURCES IN LAYER (DEPOSITION) MAIN1540
C 1499 DEPN = CALCULATED VALUE OF GRAVITATIONAL DEPOSITION MAIN1550
C 1500 SIGYNK = SIGY OF NEW LAYER STRUCTURE IN CALCULATION OF DOSAGE AND MAIN1560
C 1501 CONCENTRATION MAIN1570
C 1502 SIGENK = CALCULATED SIGEP (DEPOSITION) MAIN1580
C 1503 SIGANK = CALCULATED SIGAP (DEPOSITION) MAIN1590
C 1504
C 1505 NOTE ALL REFERENCES TO GROUND REFER TO SOME SLIGHT DISTANCE ABOVE MAIN1600
C 1506 THE GROUND AS A STARTING PLANE FOR ALL MODELS MAIN1610
C 1507
C 1508 COMMON/PARAMT/ISKIP(30),H(30),Z(30),Q(30),UBAR(30),ALPHA(30), MAIN1620
C 1509 BETA(30),SIGY(30),SIGAP(30),SIGX(30),DELYNP(30),SIGZ(30), MAIN1630
C 1510 ZSIGEP(30),DELY(30),DELY(30),THETA(30),IZMOD(20),NPT(20),DELU(30), MAIN1640
C 1511 SZL(100),XR(100),DOSE(100),CON(100),PEAKD(100),XX(100),YY(100), MAIN1650
C 1512 4PLT(2,100,10),PEAKC(100),LAT(100),VER(100),VREF(100),ALONGW(100), MAIN1660
C 1513 5DRX(100),T(20),IFLAG(100),ITAG(100),TESTNO(12),DI(10),C(10),SIGZ, MAIN1670
C 1514 6SIGY,SIGX,SQRZP,LTH,I,J,KK,STOI,STO2,STO3,TRD,TAST(10),NBK,ILK, MAIN1680
C 1515 7NKS,NYS,NZS,NOI,NCI,NOXR,RAD,NHZ,IPOP,ISOT,XAST(30), MAIN1690
C 1516 8SIGYNK,LAMBDA,TIM,TIM2,ZLIM,ASHDU(100,100),UBARK(20),SIGAK(20), MAIN1700
C 1517 9SIGEK(20),ZRK,SIGARK,SIGERK,UBARRK,THETA(40),TAUK(20),TAUK(20), MAIN1710
C 1518 COMMON/PARAMS/DECAT,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF, MAIN1720
C 1519 13IGERL,UBARRL,THETA(20),TAUL(10),TAUL(10),JBOT(10),ERX(4), MAIN1730
C 1520 2JTOP(10),VS(20),PERC(20),ACCUR,VB(20),PERC(20),HB,PPWR,JPWR, MAIN1740
C 1521 3PPWR,ADTHK(21),NVS,NVSLB(14),LBZ(4),LB3(4),LB4(4),DATE(2),I,DEP, MAIN1750
C 1522 4YBARY(100),XBARK,UBARK(100),BETANK(100),ALPHNK(100),SGBAR, MAIN1760
C 1523 5ANG(100),NACI,DEPN(100,100),SIGYNK,SIGENK(100),SIGANK(100), MAIN1770
C 1524 6UELPHI,UBARZK(100),UBARZL(100) MAIN1780
C 1525 REAL MPWR,L,LAT,LAMBDA MAIN1790
C 1526 INTEGER TESTNO MAIN1800
C 1527 DATA LB1/24HX IS RADIAL DISTANCE /LB2/24HY IS ANGLE IN DEGREES MAIN1810
C 1528 DATA LB1/24HX IS LATERAL DISTANCE /LB4/24HY IS LINEAR DISTANCE MAIN1820
C 1529 1 /LB3/24HY IS INPUT SECTION *** MAIN1830
C 1530 2 / MAIN1840
C 1531 READ (5,800) (DATE(I),I=1,2) MAIN1850
C 1532 WRITE (6,900) (DATE(I),I=1,2) MAIN1860
C 1533 READ (5,802) NP MAIN1870
C 1534 IERR = 0 MAIN1880
C 1535 EXECUTE PROGRAM NP TIMES MAIN1890
C 1536 DO 700 JXJ=1,NP MAIN1900
C 1537 IF (IERR.EQ.1) GO TO 2 MAIN1910
C 1538 READ (5,807) IA,(TESTNO(I),I=1,12) MAIN1920
C 1539 2 CONTINUE MAIN1930
C 1540 READ (5,801) (ISKIP(I),I=1,30) MAIN1940
C 1541 READ (5,802) NXS,NYS,NZS,NOI,NCI,NOXR,NVS,NBK,NVB MAIN1950
C 1542 WRITE (6,901) (TESTNO(I),I=1,12) MAIN1960
C 1543 IF (ISKIP(12).EQ.0) WRITE (6,902) LB4,LB3 MAIN1970
C 1544 IF (ISKIP(12).EQ.1) WRITE (6,902) LB1,LB2 MAIN1980
C 1545
C 1546
C 1547
C 1548
C 1549
C 1550
C 1551
C 1552
C 1553
C 1554
C 1555
C 1556
C 1557
C 1558
C 1559
C 1560
C 1561
C 1562
C 1563
C 1564
C 1565
C 1566
C 1567
C 1568
C 1569
C 1570
C 1571
C 1572
C 1573
C 1574
C 1575
C 1576
C 1577
C 1578
C 1579
C 1580
C 1581
C 1582
C 1583
C 1584
C 1585
C 1586
C 1587
C 1588
C 1589
C 1590
C 1591
C 1592
C 1593
C 1594
C 1595
C 1596
C 1597
C 1598
C 1599
C 1600
C 1601
C 1602
C 1603
C 1604
C 1605
C 1606
C 1607
C 1608
C 1609
C 1610
C 1611
C 1612
C 1613
C 1614
C 1615
C 1616
C 1617
C 1618
C 1619
C 1620
C 1621
C 1622

```

```

00225 2020 100Z = NZS-1
00226 2030 SQRTP = SQRT(16.2831853072)
00227 2040 RAD = 3.1415926536/180.0
00228 2050 TERR = 0
00229 2060
00230 2070 READ MODEL PARAMETERS
00231 2080 CALL READER(ITER, NP, JXJ)
00232 2090 IF (ITER.EQ. 1) GO TO 700
00233 2100 IF (ITER.EQ. 2) GO TO 777
00234 2110 IF (ITER(1).NE. 2) GO TO 5
00235 2120 EXECUTE GRAVITATIONAL DEPOSITION MODEL
00236 2130 CALL DEPOS(NP)
00237 2140 GO TO 700
00238 2150 5 CONTINUE
00239 2160 IF (DELPHI.GT. 180.0) DELPHI = 180.0
00240 2170 CALCULATE HEIGHTS ZZL(K) AND WIND SPEED UBARZK(KK) AT ZZL(K).
00241 2180 K = 0
00242 2190 DO 90 KK=1,NMZ
00243 2200 DIFF = (Z(KK+1)-Z(KK))/FLOAT(NPT(KK)+1)
00244 2210 M = 1
00245 2220 K = K+1
00246 2230 ZZL(K) = Z(KK)
00247 2240 GO TO 80
00248 2250 70 K = K+1
00249 2260 ZZL(K) = ZZL(K-1)+DIFF
00250 2270 M = M+1
00251 2280 80 CONTINUE
00252 2290 IF (KK.EQ. 1) GO TO 82
00253 2300 UBARZK(K) = UBARZK(K-1)+((UBARK(KK)-UBARK(KK-1))/(Z(KK)-Z(KK-1)))
00254 2310 1(ZZL(K)-Z(KK))
00255 2320 GO TO 84
00256 2330 UBARZK(K) = UBARZK(K-1)+((UBARK(KK)-UBARK(KK-1))/(Z(KK)-Z(KK-1)))
00257 2340 84 CONTINUE
00258 2350 IF (M.EQ. NPT(KK)+1) GO TO 90
00259 2360 GO TO 70
00260 2370 90 CONTINUE
00261 2380 KTK = K
00262 2390 TRD = .5*DELPHI/RAD
00263 2400 K = 0
00264 2410 ILK = 1
00265 2420 DO 600 KK=1,NMZ
00266 2430 TH = RAD*THETA(KK)
00267 2440 *** LIST INPUT PARAMETERS ***
00268 2450 LSP = KK*2-1
00269 2460 WRITE (6,903) KK
00270 2470 WRITE (6,904)
00271 2480 IF (KK.NE. 1) GO TO 92
00272 2490 WRITE (6,905) Q(KK),Z(KK),Z(KK),UBARK(KK),SIGAK(KK),TAUK(KK),SIGAK(KK),
00273 2500 1,ALPHA(KK),SIGO(KK),Z(KK),UBARK(KK),THETA(LSP),THETA(LSP+1),
00274 2510 2,SIGAK(KK),SIGAK(KK),BETA(KK),SIGO(KK),SIGO(KK),DELTA(KK),DELTA(KK),
00275 2520 3,DELPHI,12MOD(KK),TIMI,ZLPH,LANHDA,SIGD(KK)
00276 2530 GO TO 93
00277 2540 92 CONTINUE
00278 2550 WRITE (6,918) Q(KK),TAUK(KK),TAUK(KK),SIGAK(KK),ALPHA(KK),SIGO(KK),
00279 2560 1K),Z(KK),UBARK(KK),THETA(LSP),THETA(LSP+1),SIGAK(KK),BETA(KK),
00280 2570 2,SIGAK(KK),SIGAK(KK),M(KK),DELTA(KK),DELTA(KK),DELPHI,12MOD(KK),TIMI,
00281 2580 3,ZLPH,LANHDA,SIGD(KK)
00282 2590 93 IF (KK.NE. NMZ) GO TO 94
00283 2600
00284 2610
00285 2620
00286 2630
00287 2640
00288 2650
00289 2660
00290 2670
00291 2680
00292 2690
00293 2700
00294 2710
00295 2720
00296 2730
00297 2740
00298 2750
00299 2760
00300 2770
00301 2780
00302 2790
00303 2800
00304 2810
00305 2820
00306 2830
00307 2840
00308 2850
00309 2860
00310 2870
00311 2880
00312 2890
00313 2900
00314 2910
00315 2920
00316 2930
00317 2940
00318 2950
00319 2960
00320 2970
00321 2980
00322 2990
00323 3000
00324 3010
00325 3020
00326 3030
00327 3040
00328 3050
00329 3060
00330 3070
00331 3080
00332 3090
00333 3100
00334 3110
00335 3120
00336 3130
00337 3140
00338 3150
00339 3160
00340 3170
00341 3180
00342 3190
00343 3200
00344 3210
00345 3220
00346 3230
00347 3240
00348 3250
00349 3260
00350 3270
00351 3280
00352 3290
00353 3300
00354 3310
00355 3320
00356 3330
00357 3340
00358 3350
00359 3360
00360 3370
00361 3380
00362 3390
00363 3400
00364 3410
00365 3420
00366 3430
00367 3440
00368 3450
00369 3460
00370 3470
00371 3480
00372 3490
00373 3500
00374 3510
00375 3520
00376 3530
00377 3540
00378 3550
00379 3560
00380 3570
00381 3580
00382 3590
00383 3600
00384 3610
00385 3620
00386 3630
00387 3640
00388 3650
00389 3660
00390 3670
00391 3680
00392 3690
00393 3700
00394 3710
00395 3720
00396 3730
00397 3740
00398 3750
00399 3760
00400 3770
00401 3780
00402 3790
00403 3800
00404 3810
00405 3820
00406 3830
00407 3840
00408 3850
00409 3860
00410 3870
00411 3880
00412 3890
00413 3900
00414 3910
00415 3920
00416 3930
00417 3940
00418 3950
00419 3960
00420 3970
00421 3980
00422 3990
00423 4000
00424 4010
00425 4020
00426 4030
00427 4040
00428 4050
00429 4060
00430 4070
00431 4080
00432 4090
00433 4100
00434 4110
00435 4120
00436 4130
00437 4140
00438 4150
00439 4160
00440 4170
00441 4180
00442 4190
00443 4200
00444 4210
00445 4220
00446 4230
00447 4240
00448 4250
00449 4260
00450 4270
00451 4280
00452 4290
00453 4300
00454 4310
00455 4320
00456 4330
00457 4340
00458 4350
00459 4360
00460 4370
00461 4380
00462 4390
00463 4400
00464 4410
00465 4420
00466 4430
00467 4440
00468 4450
00469 4460
00470 4470
00471 4480
00472 4490
00473 4500
00474 4510
00475 4520
00476 4530
00477 4540
00478 4550
00479 4560
00480 4570
00481 4580
00482 4590
00483 4600
00484 4610
00485 4620
00486 4630
00487 4640
00488 4650
00489 4660
00490 4670
00491 4680
00492 4690
00493 4700
00494 4710
00495 4720
00496 4730
00497 4740
00498 4750
00499 4760
00500 4770
00501 4780
00502 4790
00503 4800
00504 4810
00505 4820
00506 4830
00507 4840
00508 4850
00509 4860
00510 4870
00511 4880
00512 4890
00513 4900
00514 4910
00515 4920
00516 4930
00517 4940
00518 4950
00519 4960
00520 4970
00521 4980
00522 4990
00523 5000
00524 5010
00525 5020
00526 5030
00527 5040
00528 5050
00529 5060
00530 5070
00531 5080
00532 5090
00533 5100
00534 5110
00535 5120
00536 5130
00537 5140
00538 5150
00539 5160
00540 5170
00541 5180
00542 5190
00543 5200
00544 5210
00545 5220
00546 5230
00547 5240
00548 5250
00549 5260
00550 5270
00551 5280
00552 5290
00553 5300
00554 5310
00555 5320
00556 5330
00557 5340
00558 5350
00559 5360
00560 5370
00561 5380
00562 5390
00563 5400
00564 5410
00565 5420
00566 5430
00567 5440
00568 5450
00569 5460
00570 5470
00571 5480
00572 5490
00573 5500
00574 5510
00575 5520
00576 5530
00577 5540
00578 5550
00579 5560
00580 5570
00581 5580
00582 5590
00583 5600
00584 5610
00585 5620
00586 5630
00587 5640
00588 5650
00589 5660
00590 5670
00591 5680
00592 5690
00593 5700
00594 5710
00595 5720
00596 5730
00597 5740
00598 5750
00599 5760
00600 5770
00601 5780
00602 5790
00603 5800
00604 5810
00605 5820
00606 5830
00607 5840
00608 5850
00609 5860
00610 5870
00611 5880
00612 5890
00613 5900
00614 5910
00615 5920
00616 5930
00617 5940
00618 5950
00619 5960
00620 5970
00621 5980
00622 5990
00623 6000
00624 6010
00625 6020
00626 6030
00627 6040
00628 6050
00629 6060
00630 6070
00631 6080
00632 6090
00633 6100
00634 6110
00635 6120
00636 6130
00637 6140
00638 6150
00639 6160
00640 6170
00641 6180
00642 6190
00643 6200
00644 6210
00645 6220
00646 6230
00647 6240
00648 6250
00649 6260
00650 6270
00651 6280
00652 6290
00653 6300
00654 6310
00655 6320
00656 6330
00657 6340
00658 6350
00659 6360
00660 6370
00661 6380
00662 6390
00663 6400
00664 6410
00665 6420
00666 6430
00667 6440
00668 6450
00669 6460
00670 6470
00671 6480
00672 6490
00673 6500
00674 6510
00675 6520
00676 6530
00677 6540
00678 6550
00679 6560
00680 6570
00681 6580
00682 6590
00683 6600
00684 6610
00685 6620
00686 6630
00687 6640
00688 6650
00689 6660
00690 6670
00691 6680
00692 6690
00693 6700
00694 6710
00695 6720
00696 6730
00697 6740
00698 6750
00699 6760
00700 6770
00701 6780
00702 6790
00703 6800
00704 6810
00705 6820
00706 6830
00707 6840
00708 6850
00709 6860
00710 6870
00711 6880
00712 6890
00713 6900
00714 6910
00715 6920
00716 6930
00717 6940
00718 6950
00719 6960
00720 6970
00721 6980
00722 6990
00723 7000
00724 7010
00725 7020
00726 7030
00727 7040
00728 7050
00729 7060
00730 7070
00731 7080
00732 7090
00733 7100
00734 7110
00735 7120
00736 7130
00737 7140
00738 7150
00739 7160
00740 7170
00741 7180
00742 7190
00743 7200
00744 7210
00745 7220
00746 7230
00747 7240
00748 7250
00749 7260
00750 7270
00751 7280
00752 7290
00753 7300
00754 7310
00755 7320
00756 7330
00757 7340
00758 7350
00759 7360
00760 7370
00761 7380
00762 7390
00763 7400
00764 7410
00765 7420
00766 7430
00767 7440
00768 7450
00769 7460
00770 7470
00771 7480
00772 7490
00773 7500
00774 7510
00775 7520
00776 7530
00777 7540
00778 7550
00779 7560
00780 7570
00781 7580
00782 7590
00783 7600
00784 7610
00785 7620
00786 7630
00787 7640
00788 7650
00789 7660
00790 7670
00791 7680
00792 7690
00793 7700
00794 7710
00795 7720
00796 7730
00797 7740
00798 7750
00799 7760
00800 7770
00801 7780
00802 7790
00803 7800
00804 7810
00805 7820
00806 7830
00807 7840
00808 7850
00809 7860
00810 7870
00811 7880
00812 7890
00813 7900
00814 7910
00815 7920
00816 7930
00817 7940
00818 7950
00819 7960
00820 7970
00821 7980
00822 7990
00823 8000
00824 8010
00825 8020
00826 8030
00827 8040
00828 8050
00829 8060
00830 8070
00831 8080
00832 8090
00833 8100
00834 8110
00835 8120
00836 8130
00837 8140
00838 8150
00839 8160
00840 8170
00841 8180
00842 8190
00843 8200
00844 8210
00845 8220
00846 8230
00847 8240
00848 8250
00849 8260
00850 8270
00851 8280
00852 8290
00853 8300
00854 8310
00855 8320
00856 8330
00857 8340
00858 8350
00859 8360
00860 8370
00861 8380
00862 8390
00863 8400
00864 8410
00865 8420
00866 8430
00867 8440
00868 8450
00869 8460
00870 8470
00871 8480
00872 8490
00873 8500
00874 8510
00875 8520
00876 8530
00877 8540
00878 8550
00879 8560
00880 8570
00881 8580
00882 8590
00883 8600
00884 8610
00885 8620
00886 8630
00887 8640
00888 8650
00889 8660
00890 8670
00891 8680
00892 8690
00893 8700
00894 8710
00895 8720
00896 8730
00897 8740
00898 8750
00899 8760
00900 8770
00901 8780
00902 8790
00903 8800
00904 8810
00905 8820
00906 8830
00907 8840
00908 8850
00909 8860
00910 8870
00911 8880
00912 8890
00913 8900
00914 8910
00915 8920
00916 8930
00917 8940
00918 8950
00919 8960
00920 8970
00921 8980
00922 8990
00923 9000
00924 9010
00925 9020
00926 9030
00927 9040
00928 9050
00929 9060
00930 9070
00931 9080
00932 9090
00933 9100
00934 9110
00935 9120
00936 9130
00937 9140
00938 9150
00939 9160
00940 9170
00941 9180
00942 9190
00943 9200
00944 9210
00945 9220
00946 9230
00947 9240
00948 9250
00949 9260
00950 9270
00951 9280
00952 9290
00953 9300
00954 9310
00955 9320
00956 9330
00957 9340
00958 9350
00959 9360
00960 9370
00961 9380
00962 9390
00963 9400
00964 9410
00965 9420
00966 9430
00967 9440
00968 9450
00969 9460
00970 9470
00971 9480
00972 9490
00973 9500
00974 9510
00975 9520
00976 9530
00977 9540
00978 9550
00979 9560
00980 9570
00981 9580
00982 9590
00983 9600
00984 9610
00985 9620
00986 9630
00987 9640
00988 9650
00989 9660
00990 9670
00991 9680
00992 9690
00993 9700
00994 9710
00995 9720
00996 9730
00997 9740
00998 9750
00999 9760
01000 9770
01001 9780
01002 9790
01003 9800
01004 9810
01005 9820
01006 9830
01007 9840
01008 9850
01009 9860
01010 9870
01011 9880
01012 9890
01013 9900
01014 9910
01015 9920
01016 9930
01017 9940
01018 9950
01019 9960
01020 9970
01021 9980
01022 9990
01023 10000
01024 10010
01025 10020
01026 10030
01027 10040
01028 10050
01029 10060
01030 10070
01031 10080
01032 10090
01033 10100
01034 10110
01035 10120
01036 10130
01037 10140
01038 10150
01039 10160
01040 10170
01041 10180
01042 10190
01043 10200
01044 10210
01045 10220
01046 10230
01047 10240
01048 10250
01049 10260
01050 10270
01051 10280
01052 10290
01053 10300
01054 10310
01055 10320
01056 10330
01057 10340
01058 10350
01059 10360
01060 10370
01061 10380
01062 10390
01063 10400
01064 10410
01065 10420
01066 10430
01067 10440
01068 10450
01069 10460
01070 10470
01071 10480
01072 10490
01073 10500
01074 10510
01075 10520
01076 10530
01077 10540
01078 10550
01079 10560
01080 10570
01081 10580
01082 10590
01083 10600
01084 10610
01085 10620
01086 10630
01087 10640
01088 10650
01089 10660
01090 10670
01091 10680
01092 10690
01093 10700
01094 10710
01095 10720
01096 10730
01097 10740
01098 10750
01099 10760
01100 10770
01101 10780
01102 10790
01103 10800
01104 10810
01105 10820
01106 10830
01107 10840
01108 10850
01109 10860
01110 10870
01111 10880
01112 10890
01113 10900
01114 10910
01115 10920
01116 10930
01117 10940
01118 10950
01119 10960
01120 10970
01121 10980
01122 10990
01123 11000
01124 11010
01125 11020
01126 11030
01127 11040
01128 11050
01129 11060
01130 11070
01131 11080
01132 11090
01133 11100
01134 11110
01135 11120
01136 11130
01137 11140
01138 11150
01139 11160
01140 11170
01141 11180
01142 11190
01143 11200
01144 11210
01145 11220
01146 11230
01147 11240
01148 11250
01149 11260
01150 11270
01151 11280
01152 11290
01153 11300
01154 11310
01155 11320
01156 11330
01157 11340
01158 11350
01159 11360
01160 11370
01161 11380
01162 11390
01163 11400
01164 11410
01165 11420
01166 11430
01167 11440
01168 11450
01169 11460
01170 11470
01171 11480
01172 11490
01173 11500
01174 11510
01175 11520
01176 11530
01177 11540
01178 11550
01179 11560
01180 11570
01181 11580
01182 11590
01183 11600
01184 11610
01185 11620
01186 11630
01187 11640
01188 11650
01189 11660
01190 11670
01191 11680
01192 11690
01193 11700
01194 11710
01195 11720
01196 11730
01197 11740
01198 11750
01199 11760
01200 11770
01201 11780
01202 11790
01203 11800
01204 11810
01205 11820
01206 11830
01207 11840
01208 11850
01209 11860
01210 11870
01211 11880
01212 11890
01213 11900
01214 11910
01215 11920
01216 11930
01217 11940
01218 11950
01219 11960
01220 11970
01221 11980
01222 11990
01223 12000
01224 12010
01225 12020
01226 12030
01227 12040
01228 12050
01229 12060
01230 12070
01231 12080
01232 12090
01233 12100
01234 12110
01235 12120
01236 12130
01237 12140
01238 12150
01239 12160
01240 12170
01241 12180
01242 12190
01243 12200
01244 12210
01245 12220
01246 12230
```

MULTILAYER DIFFUSION MODEL GCA CORP BUCKLUND

```

00407 2600
00412 2610
00413 2620
00415 2630
00417 2640
00420 2650
00420 2660
00420 2670
00432 2680
00443 2690
00444 2700
00444 2710
00444 2720
00462 2730
00463 2740
00463 2750
00473 2760
00475 2770
00475 2780
00505 2790
00504 2800
00507 2810
00511 2820
00511 2830
00513 2840
00514 2850
00516 2860
00521 2870
00524 2880
00525 2890
00526 2900
00526 2910
00526 2920
00530 2930
00532 2940
00535 2950
00540 2960
00543 2970
00545 2980
00550 2990
00552 3000
00552 3010
00564 3020
00565 3030
00570 3040
00572 3050
00573 3060
00574 3070
00603 3080
00605 3090
00607 3100
00611 3110
00613 3120
00616 3130
00617 3140
00622 3150
00632 3160
00635 3170

      WRITE (6,919) Z(NK+1)
96 CONTINUE
      IF (ISKIP(13) .EQ. 0) DR=KK .NE. JBOT(ILK)) GO TO 97
      IF (JBOT(1) .NE. KK) GO TO 96
      LSP = ILK*2-1
      WRITE (6,920) ZRL,UBARRL,SIGARL,TAUOL(ILK),TAUL(ILK),SIGAL(ILK),
      1ALPHAINNZ+ILK),SIGCINNZ+ILK),UBARL(ILK),THETAL(LSP),THETAL(LSP+1),
      2SIGELR,SIGEL(ILK),BETA(NNZ+ILK),SIGZO(NNZ+ILK),SIGZO(NNZ+ILK)
      GO TO 97
96 CONTINUE
      WRITE (6,921) TAUOL(ILK),TAUL(ILK),SIGAL(ILK),ALPHAINNZ+ILK),
      1SIGCINNZ+ILK),UBARL(ILK),THETAL(LSP),THETAL(LSP+1),SIGEL(ILK),
      2BETAINNZ+ILK),SIGZO(NNZ+ILK),SIGZO(NNZ+ILK)
97 CONTINUE
      WRITE (6,922) UBAP(KK),THETA(KK),DELTHPI(KK),DELU(KK),SIGAP(KK),
      1SIGEPI(KK)
      IF (ISKIP(13) .EQ. 0) DR=KK .NE. JBOT(ILK)) GO TO 98
      WRITE (6,923) UBAPINNZ+ILK),THETA(NNZ+ILK),DELTHP(NNZ+ILK),
      1DELU(NNZ+ILK),SIGAP(NNZ+ILK),SIGEPI(NNZ+ILK)
98 CONTINUE
      CALL TESTR(KTR)
      WRITE (6,917)
      IF (ISKIP(7) .EQ. 0) DR,ISKIP(7) .EQ. 2) GO TO 600
      *** GENERAL GRID PATTERN CALCULATION SECTION ***
      H = 0
      100 M = M+1
      K = K+1
      DO 520 I=1,NXS
      DO 310 J=1,NYS
      M = 1
      CALL BREAK(K,M,XX(1),YY(J))
310 CONTINUE
      *****OUTPUT SECTION *****
      IF (1 .NE. 1) GO TO 405
      WRITE (6,906) ZZLIN
405 WRITE (6,907) XX(1)
      IF (ISKIP(11) .EQ. 1) WRITE (6,924)
      IF (ISKIP(13) .NE. 0) AND KK .LE. 1307) AND KK .LE. 1707) GO TO 430
      DO 420 J=1,NYS
      IF (ITAG(J) .EQ. 9) GO TO 410
      WRITE (6,908) YY(J),DOOS(J),PEAKC(J),CON(J),VER(J),VREF(J),ALONGW(
      1),LAT(LJ)
      GO TO 420
410 WRITE (6,909) YY(J)
420 ITAG(J) = 9
      GO TO 520
430 DO 433 J=1,NYS
      WRITE (6,911) YY(J),DOOS(J),CON(J)
433 CONTINUE
520 CONTINUE
      WRITE (6,917)
      IF (ISKIP(12) .EQ. 0) GO TO 440
      IF (KK .NE. NHZ) OR (M-1 .LT. NPT(KK)) GO TO 440
      WRITE (6,913)
      DO 435 I=1,NXS
      WRITE (6,916) XX(1),YY(J),WASHOU(I,J),J=1,NYS
      DO 435 J=1,NYS
      WASHOU(I,J) = 0.0

```

```

00436 3180 MAIN3280
00441 3190 MAIN3290
00443 3200 MAIN3300
00443 3210 MAIN3330
00444 3220 MAIN3340
00444 3230 MAIN3350
00444 3240 MAIN3360
00447 3250 MAIN3370
00447 3260 MAIN3380
00451 3270 MAIN3390
00453 3280 MAIN3400
00455 3290 MAIN3410
00456 3300 MAIN3420
00461 3310 MAIN3430
00462 3320 MAIN3440
00465 3330 MAIN3450
00467 3340 MAIN3460
00470 3350 MAIN3470
00471 3360 MAIN3480
00472 3370 MAIN3490
00474 3380 MAIN3500
00475 3390 MAIN3510
00476 3400 MAIN3520
00477 3410 MAIN3530
00701 3420 MAIN3540
00703 3430 MAIN3550
00705 3440 MAIN3560
00706 3450 MAIN3570
00710 3460 MAIN3580
00712 3470 MAIN3590
00713 3480 MAIN3600
00715 3490 MAIN3610
00717 3500 MAIN3620
00723 3510 MAIN3630
00724 3520 MAIN3640
00734 3530 MAIN3650
00734 3540 MAIN3660
00740 3550 MAIN3670
00741 3560 MAIN3680
00743 3570 MAIN3690
00744 3580 MAIN3700
00744 3590 MAIN3710
00744 3600 MAIN3720
00745 3610 MAIN3730
00747 3620 MAIN3740
00750 3630 MAIN3750
00751 3640 MAIN3760
00753 3650 MAIN3770
00754 3660 MAIN3780
00754 3670 MAIN3790
00755 3680 MAIN3800
00755 3690 MAIN3810
00757 3700 MAIN3820
00760 3710 MAIN3830
00761 3720 MAIN3840
00762 3730 MAIN3850
00763 3740 MAIN3860
00764 3750 MAIN3870
00765 3760

435 CONTINUE
WRITE (4,917)
440 CONTINUE
C
IF (M-1) .GE. NPT(KK1) GO TO 600
GO TO 100
400 CONTINUE
***** CALCULATE CLOUD HALF WIDTHS *****
IF (ISKIP(7) .NE. 2) AND (ISKIP(7) .NE. 3) GO TO 535
WRITE (4,914)
ILK = 1
DO 530 KK1,NNZ
CALL TESTTRK(KK1)
DO 525 I=1,DXR
IF (ISKIP(13) .NE. 0) AND (KK .GE. 1807) AND (KK .LE. 1707) GO TO 522
CALL SIGMADXR(I),0,0)
XR(I) = SIGY*2.15
522 GO TO 525
524 IF (DXR(I) .LT. XAST(KK1)) GO TO 522
CALL SIGMADXR(KK1),0,0)
CALL SIGMADXR(I),KK,0)
XR(I) = SIGYHK*2.15
525 CONTINUE
IF (THETA(KK) .LT. 180.0) Y = THETA(KK)+180.0
IF (THETA(KK) .GE. 180.0) Y = THETA(KK)-180.0
WRITE (4,903) KK
IF (ISKIP(13) .NE. 0) AND (KK .GE. 1807) AND (KK .LE. 1707) GO TO 527
GO TO 528
527 IF (THETA(NNZ+ILK-1) .GE. 180.0) YS = THETA(NNZ+ILK-1)+180.0
IF (THETA(NNZ+ILK-1) .LT. 180.0) YS = THETA(NNZ+ILK-1)-180.0
WRITE (4,912) YS,XAST(KK)
528 CONTINUE
WRITE (4,918) Y,DXR(I),XR(I),I=1,NCRR)
530 CONTINUE
535 CONTINUE
***** CALCULATE CENTER LINE CONCENTRATION AND/OR DOSAGE *****
IF (ISKIP(8) .EQ. 0) GO TO 540
CALL CENTRL
540 CONTINUE
C
***** ISOPLETH SECTION *****
IF (ISKIP(9) .EQ. 0) GO TO 560
CALL ISOPXY
570 CONTINUE
***** CALCULATE ISOPLETHS YZ PLANE *****
IF (ISKIP(10) .EQ. 0) GO TO 580
CALL ISOPYZ
580 CONTINUE
***** LOOP FOR NEXT TEST *****
700 CONTINUE
770 CONTINUE
800 FORMAT (A46)
801 FORMAT (4012)
802 FORMAT (1013)
804 FORMAT (276.2,4F10.0,2F6.2/814,516)
807 FORMAT (A12,26)
900 FORMAT (18H) ***** RUN DATE ,2A6.6H *****

```


MULTI-LAYER DIFFUSION MODEL GCA CORP WORKLOAD

```

01013 4340 2/1X, CPM, SIGAP = F10.5, 9M, SIGEP = F10.5, MAIN4460
01014 4350 923 FORMAT (10, 4) CALCULATED INPUT PARAMETERS FOR LAYER CHANGE MODELS: MAIN4470
01015 4360 1 0000 USAR = F10.5, 9M, THETA = F10.5, 10M, DELTHP = F10.5, 1X, 0M, GENMAIN4480
01016 4370 2LU = F10.5, 9M, SIGAP = F10.5, 9M, SIGEP = F10.5, MAIN4490
01017 4380 924 FORMAT (10, 4) DECAY IS INCLUDED IN DOSAGE AND CONCENTRATION 0) MAIN4500
01018 4390 STOP MAIN4510
01019 4400 END MAIN4520

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 DIAGNOSTIC MESSAGE(S)

31 FOR BREAK

UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5018P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:34:53

SUBROUTINE BREAK ENTRY POINT 001035

STORAGE USED (BLOCK, NAME, LENGTH)

```

0001 *CODE 001076
0000 *DATA 000057
0002 *BLANK 000000
0003 *PARAM 033754
0004 *PARAMS 028577

```

EXTERNAL REFERENCES (BLOCK, NAME)

```

0005 COORD
0006 EL
0007 SIGMA
0010 PEAK
0011 VERT
0012 LATER
0013 ALONGD
0014 ISO
0015 TASHT
0016 EXP
0017 NERR35

```

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

```

0001 000051 125L 0001 000166 127L 0001 000214 135L 0001 000235 140L 0001 000383 150L
0001 000242 152G 0001 000451 160L 0001 000454 165L 0001 000413 160L
0001 000424 185L 0001 000745 195L 0001 000742 200L 0001 000849 214G 0001 000849 214G
0001 000764 310L 0001 001017 340L 0001 001007 340L 0001 000264 350L 0001 000264 350L
0003 R 000226 ALPHA 0004 R 001023 ALPHAK 0004 R 001170 ANG 0004 R 000003 ASP 0003 R 007102 ALONGA
0004 R 000487 BETANK 0003 R 000774 CI 0003 R 001522 CON 0004 R 000404 DELX 0004 R 000000 DECAY
0004 R 028266 DELPHI 0003 R 000484 DELTHP 0003 R 001010 DELU 0003 R 000404 DELY 0004 R 000000 DELTA
0004 R 000345 DEP 0004 R 001335 DEPN 0003 R 007742 DI 0003 R 001354 DOS 0004 R 000223 DTHK
0003 R 007246 DXR 0004 R 000126 ERFK 0003 R 000036 H 0003 R 000267 H2 0003 R 010014 I
0003 I 010080 180Y 0001 000011 1C1 0001 000016 1C2 0001 000012 1C3 0003 I 007436 IFLAG
0004 I 000344 1I 0003 I 010036 1LK 0001 000004 1S 0003 I 000000 1SKIP 0003 I 000008 1S85
0003 I 007402 1TAG 0003 I 000474 1TGP 0003 I 00074C 1ZMDD 0004 I 000114 JBOT 0004 I 000114 JBOT
0004 I 000041 JF 0004 I 000134 JTOP 0003 I 010016 KK 0003 R 010110 LAMBDA 0003 R 010110 LAMBDA
0003 R 000426 LAT 0004 I 000322 LBI 0004 I 000324 LB2 0004 I 000326 LB4 0004 I 000326 LB4
0003 I 010010 M 0004 R 000272 MPWR 0001 000015 M5 0003 I 010035 M8K 0003 I 010093 MCI
0003 I 010042 M01 0003 I 010044 M0XR 0001 000000 MF 0003 I 010037 MNS 0003 I 010040 NYS 0003 I 000744 NPT
0004 I 000321 NVR 0004 I 000320 NVS 0004 I 001334 NCI 0004 R 000243 PERCB 0004 R 000243 PERCB
0003 R 003442 PLY 0004 R 000270 PPWR 0003 R 000132 Q 0004 R 000271 QPAR 0003 R 010095 RAD 0003 R 010095 RAD
0003 R 003540 SIGAK 0004 R 000013 SIGAL 0004 R 025122 SIGANK 0003 R 000360 SIGAP 0003 R 033631 SIGARK
0004 R 000040 SIGAKL 0003 R 033604 SIGER 0004 R 000035 SIGEL 0004 R 024754 SIGENK 0003 R 000560 SIEP
0003 R 033632 SIGERK 0004 R 000042 SIGERL 0003 R 010010 SIGX 0003 R 010107 SIGXNK 0003 R 000416 SIGXO
0003 R 010007 SIGY 0004 R 024755 SIGYAK 0003 R 000322 SIGYO 0003 R 010006 SIGZ 0003 R 000512 SIGZO

```



```

00136 450 DCS(LJ) = DCS(J)*AF
00137 460 127 CONTINUE
00138 470 CALL ALONGD(X,T(YK))
00139 480 PEAKC(J) = DCS(J)*UBARZ(K)/(SCR2*SIGX)
00140 490 CON(J) = PEAKC(J)*ALONG(J)
00141 500 130 IF (IS.EQ. 1) GO TO 310
00142 510 GO TO 140
00143 520 135 IS = 0
00144 530 IF (K.LE. XAST(KK).AND.N.EQ. 9) GO TO 125
00145 540 C 140 DO 200 M=1BOT,ITOP
00146 550 140 DO 200 M=1BOT,ITOP
00147 560 150 S = 1
00148 570 N = NF
00149 580 CALL COORD(M,MX,YXO,YO,ASP,XS,2)
00150 590 IF (N.EQ. 9) GO TO 200
00151 600 CALL EL(XAST(M),H)
00152 610 CALL SIGMA(XAST(M),O,H)
00153 620 CALL EL(X,-1)
00154 630 CALL SIGMA(X,M,O)
00155 640 IF (K.EQ. KK) PPRC(2) = SIGYX
00156 650 STC2 = 1.0
00157 660 IF (ISKIP(13).EQ. 1.OR.IZMOD(M).EQ. 3) GO TO 180
00158 670 ST01 = 1.0/4214516Z
00159 680 ST02 = 0.0
00160 690 IF (SIG2 = 0.0) 148,175,148
00161 700 148 IC1 = -1
00162 710 IC3 = 0
00163 720 S1 = -1.0
00164 730 S2 = 2.0*51*(Z(IITOP+1)-Z(1BOT))
00165 740 ERFX(1) = (S2-2.0*Z(1BOT)-Z(H)-ZZL(K))/ST01
00166 750 IF (ERFX(3).GT. 3.0) IC3 = IC3+1
00167 760 IF (IC3.GE. 2) GO TO 140
00168 770 ERFX(1) = (S2-2*(H)+ZZL(K))/ST01
00169 780 ERFX(2) = (S2-2*(H)-ZZL(K))/ST01
00170 790 ERFX(4) = (S2-2.0*Z(1BOT)+Z(H)+ZZL(K))/ST01
00171 800 CALL ISG(1,4)
00172 810 IC1 = IC1 + 1
00173 820 DO 155 M=1,4
00174 830 155 ST02 = ST02+ERFX(MS)
00175 840 GO TO 150
00176 850 160 S1 = 0.0
00177 860 IC2 = 0
00178 870 IC3 = 0
00179 880 165 S1 = S1+1.0
00180 890 S2 = 2.0*51*(Z(IITOP+1)-Z(1BOT))
00181 900 ERFX(4) = (S2-2.0*Z(1BOT)+Z(H)+ZZL(K))/ST01
00182 910 IF (-3.0.GT. ERFX(4)) IC3 = IC3+1
00183 920 IF (IC3.GE. 2) GO TO 175
00184 930 ERFX(1) = (S2-2*(H)+ZZL(K))/ST01
00185 940 ERFX(2) = (S2-2*(H)-ZZL(K))/ST01
00186 950 ERFX(3) = (S2+2.0*Z(1BOT)-Z(H)-ZZL(K))/ST01
00187 960 CALL ISG(1,4)
00188 970 IC2 = IC2+1
00189 980 DO 170 M=1,4
00190 990 170 ST02 = ST02+ERFX(MS)
00191 1000 GO TO 165
00192 1010 175 ST03 = 1.0
00193 1020

```

```

00251 103* IF (IC1.EQ. IC2) GO TO 185
00254 104* IF (IC1.GT. IC2) ST02 = ST02+4.*FLOA*(IC1-IC2)
00255 105* IF (IC1.LT. IC2) ST02 = ST02+4.*FLOA*(IC2-IC1)
00260 106* GO TO 185
00261 107* 18J ST03 = 2.*(Z(I**1)-Z(M))/Z((ITOP+1)-Z(ITOT))
00262 108* 18S CONTINUE
00263 109* XBARX = EXP(-5.*(Y/SIGYIM)**2)
00264 110* YBARX(I) = 1.*
00265 111* IF (ISKIP16).EQ. 0) GO TO 195
00267 112* YBARX(I) = EXP(-5.*(Y-UMAP(I)/2.*K-1)*(Y(M)-TAST/ILK-1))/SIGXNK
00268 113* 11**2)
00270 114* 19J S1 = ((IC(M)*ST03)/Z(5*ST02*UMAPZL(K)*5IAYNK))*XBARX*ST02*
00271 115* IF (ISKIP12).EQ. 2.0P.TIM1.0F. Y/UMAP(NM2*ILK-1)+TAST(ILK-1))
00272 116* GO TO 195
00273 117* IF (Z(M).GT. ZLI) GO TO 195
00275 118* S1 = S1*FAP(-1.*AMPDA*(X/UMAP(NM2*ILK-1)+TAST(ILK-1)-TIM1))
00276 119* 19S CONTINUE
00277 120* S2 = (S1*UMAPZL(I)/ISOP2P*SIGYIM))*YBARX(I)
00300 121* D05(J) = D05(I)+S1
00301 122* CON(J) = CON(I)+S2
00302 123* CONTINUE
00304 124* 20* CONTINUE
00305 125* 31C CONTINUE
00306 126* ** CALCULATE WASHOUT **
00307 127* IF (ISKIP12).EQ. 0) GO TO 340
00312 128* IF (Z(KK)-ZL(K)) 340, 15, 340
00314 129* 315 IF (Z(KK).GT. ZLI) GO TO 340
00315 130* CALL WASHOUT(X,Y,I5,5,AC,YO,H,K)
00316 131* 34C CONTINUE
00317 132* RETURN
00318 133* END

```

END OF F11VAC 1108 FORTHAN V COMPILATION. 0 *DIAGNOSTIC MESSAGE(S)

MULTILAYER DIFFUSION MODEL SCA CORP BUCKLELOND

PI FOR CEPOS
 JMIAC IICS FORTRAN V.1E.1L 2206 0018 FSOIHP
 THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:34156

SUBROUTINE DEPOS ENTRY POINT 001014

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE CC1034
 0000 *DATA 000450
 0002 *BLANK 000000
 0003 *PARAM 033754
 0004 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 SGP
 0006 UBARS
 0007 RETAX
 0010 COUFD
 0011 DEFSO
 0012 NADUS
 0013 NI025
 0014 NI015
 0015 NEXP45
 0016 SORT
 0017 SIN
 0020 COS
 0021 EXP
 0022 NERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000014	1126	0001	000211	12L	0001	000157	2126	0001	000200	2236	0001	000251	2446
0001	000257	2516	0001	000301	2426	0001	000323	2726	0001	000367	3136	0001	000500	3406
0001	000346	3516	0001	000556	3536	0001	000570	3566	0001	000622	3656	0001	000361	40L
0001	000730	4116	0001	000737	4216	0001	000753	4316	0001	000754	4346	0001	000363	45L
0001	000467	50L	0001	000474	55L	0001	000664	7L	0001	000675	70L	0001	000677	71L
0001	000116	8L	0000	000021	871F	0000	000023	8C2F	0000	000024	8C3F	0000	000131	9L
0000	000031	9C0F	0000	000144	9C1F	0000	000167	9C2F	0000	000210	9C3F	0000	000226	904F
0000	000232	9F5F	0000	000243	9C6F	0000	000342	907F	0000	000346	908F	0004	000216	ACCUR
0003	R 007102	ALPHA	0003	R 000226	ALPHA	0004	R 001C23	ALPHA	0004	R 001170	ANG	0000	R 000016	ASP
0003	R 000249	BETA	0004	R 000657	BETA	0003	R 007774	CI	0003	R 001522	CON	0004	R 000342	DATE
0004	R 000030	DECA	0004	R 025246	DELPHI	0003	R 000454	DELTA	0003	R 001010	DELU	0004	R 000606	DELX
0003	R 000644	DELY	0004	R 000345	DEP	0004	R 001335	DEPN	0000	R 000012	DMK	0003	R 007762	DI
0003	R 0001356	DOS	0003	R 000273	DTMS	0003	R 007246	DY	0004	R 000126	ERFX	0003	R 000036	H
0004	R 000267	HR	0003	R 010014	I	0003	R 010050	IBUT	0004	R 007436	IFLAG	0004	R 000344	I1
0003	R 010036	ILK	0003	R 000000	ISLIP	0003	R 017602	ITAG	0003	R 010047	ITOP	0000	R 000013	I2
0003	R 000740	IZMOD	0003	R 010015	J	0004	R 000114	JBUT	0004	R 000041	JF	0004	R 000134	JTOP
0003	R 010016	K5	0003	R 010012	L	0003	R 000110	LANB-A	0003	R 000426	LAT	0004	R 000322	LBI
0004	R 000326	LP2	0004	R 000332	LP3	0004	R 000336	LM	0000	R 000000	LS	0000	R 000003	M
0004	R 000272	MPR	0000	R 000002	N	0003	R 010035	PEX	0003	R 010043	NCI	0003	R 010042	NDI
0003	R 010044	YHR	0003	R 010046	Z	0003	R 000764	NPT	0000	R 000004	NTAD	0000	R 000006	NTAK

MULTILAYER DIFFUSION MODEL GCA COPP BUCKLOW

```

00151 370 2*TAUCK(I),T(I),DELPHI,7(I)
00175 380 6 IF (I.LT.NNZ) GO TO 7
00177 390 WRITE (A,907) Z(I+1)
00202 400 9 SIGAK(I) = SIGAK(I)+TAUK(I)/TAUCK(I)+((1.0/5.0)*C)
00203 410 10 CONTINUE
00205 420 SIGARK = SIGARK+TAUK(I)/TAUCK(I)+((1.0/5.0)*C)
00206 430 WRITE (A,901) (I,VS(I),PERC(I),I=1,NVS)
00217 440 IF (ISKIP(3).EQ.0) GO TO 12
00221 450 WRITE (A,908) (I,VB(I),PERC(I),I=1,NVS)
00232 460 12 CONTINUE
00233 470 TETA(I) = T-TETAK(I)
00234 480 TH = TETA(I)*RAD
00235 490 TRD = .5*DELPHI*RAD
00236 500 IF (TETA(I).LT.180.0) THEN = (TETA(I)+180.0)*RAD
00240 510 IF (TETA(I).GE.180.0) THEN = (TETA(I)-180.0)*RAD
00242 520 DTHK(I) = 0.0
00243 530 DO 20 I=2,NZS
00244 540 20 DTHK(I) = DTHK(N-I)+DELTHP(N-I)
00250 550 DO 25 I=2,NZS
00253 560 25 DTHK(I) = DTHK(N)*RAD
00255 570 M = ISKIP(2)+1
00256 580 NTAG = 1
00257 590 IF (ISKIP(3).EQ.1) NTAD = 2
00261 600 DO 73 JF=1,NTAD
00264 610 NTAP = NVS
00265 620 IF (JF.EQ.2) NTAP = NVB
00267 630 DO 73 I=1,NTAP
00272 640 IF (JF.EQ.2) DOR=VS(I) *LE.10.0) GO TO 35
00274 650 WRITE (A,903) VS(I)
00277 660 RETURN
00300 670 35 CONTINUE
00301 680 NTAK = 1
00302 690 NTAR = NNZ
00303 700 IF (ISKIP(3).EQ.0) GO TO 45
00305 710 IF (JF.EQ.2) GO TO 40
00307 720 NTAR = NTAK-1
00310 730 GO TO 45
00311 740 40 NTAK = NNZ
00312 750 45 DO 72 KK=TAK,NTAR
00315 760 IF (JF.EQ.2) GO TO 50
00317 770 S = ((Z(KK+1)-Z(KK))/3.0)*Z(KK)
00320 780 CALL SGP(S,KK,SIGENK(I),1)
00321 790 CALL UBARS(S,KK,UBHKK)
00322 800 DHK = ACCURSIGENK(I)*SQBAR*SRRT(1.0+VS(I)/UBHKK)
00323 810 IF (DHK.LT.10.0) DHK = 10.0
00325 820 S = (Z(KK+1)-Z(KK))/DHK
00326 830 NXCI = S+1.0
00327 840 IF (NXCI.LT.3) NXCI = 3
00331 850 DHK = (Z(KK+1)-Z(KK))/FLOAT(NXCI)
00332 860 STOI = Z(KK)
00333 870 GO TO 55
00334 880 50 NXCI = 1
00335 890 STOI = 0.0
00336 900 DHK = HB
00337 910 DO 95 IZ=1,NXCI
00342 920 STOI = STOI+DHK
00343 930 ZL(IZ) = STOI
00344 940 CALL SGP(ZL(IZ),KK,SIGENK(IZ),1)

```


MULTILAYER DIFFUSION MODEL GCA CURF 8J000000

1RCB(1,12,20)=,F10.5,2H, /11X,3(3 'VR(,12,2H)=,F10.5,8H, PERCB(,12,2HDEP01743
 2)=,F10.5,2H, 1))
 DEP01770
 DEPC1780

00460 1530
 00460 1540
 00461 1550

END

END OF UNIVAC 1108 FORTRAN 77 COMPILATION. C *DIAGNOSTIC MESSAGE(15)

HI FOR CENTRL
UNIVAC 1108 FORTRAN V LEVEL 2204 GC18 FSCIPP
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17134158

SUBROUTINE CENTRL ENTRY POINT 000323

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *C07E 000334
0000 *DATA 000156
0002 *BLANK 000000
0003 *PARAMT 033754
0004 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 EL
0006 SIGMA
0007 PEAK
0010 VERT
0011 NADDS
0012 *1025
0013 EXP
0014 N1015
0015 NERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000014	1136	0001	000236	1276	0001	000055	1276	0001	000246	130L	0001	000231	1456
0001	000043	20L	0001	000261	2016	0001	000275	400L	0001	000154	80L	0000	000003	900F
0000	000024	901F	0000	000035	902F	0000	000044	903F	0000	000061	904F	0000	000077	905F
0000	000103	904F	0000	000115	907F	0000	000126	ALPHA	0003	R	000224	0003	R	000224
0004	R	001023	ALPHAK	0004	R	001170	ALG	0003	R	000457	BETANK	0003	R	000457
0003	R	001522	CON	0004	R	000342	DATE	0004	R	000000	DECAY	0004	R	000457
0003	R	001010	DELU	0003	R	000406	DELX	0003	R	000457	DELPHI	0003	R	000457
0003	R	000762	DI	0003	R	001356	DELX	0004	R	000345	DEP	0004	R	001335
0003	R	000034	H	0004	R	000247	DELX	0003	R	000345	DEP	0004	R	001335
0004	I	000344	II	0003	I	010036	ILK	0003	I	010036	ILK	0003	I	010036
0003	I	000740	ITMOO	0003	I	010015	J	0003	I	000000	ISKIP	0003	I	010047
0000	I	000000	K	0003	I	010016	K	0004	I	000041	JF	0004	I	000134
0004	I	000322	LRI	0004	I	000324	LRI	0003	R	010110	LANBDA	0003	R	000426
0004	R	000272	MP/R	0003	I	010035	N3K	0004	I	000336	LB4	0000	I	000001
0003	I	010046	NZ	0003	I	000764	N3T	0004	I	010042	N.I	0003	I	010044
0003	I	010037	N3S	0003	I	010040	N3S	0004	I	000330	N.S	0004	I	010044
0004	R	000172	PERC	0004	R	000243	PERC	0003	R	000242	PEAKC	0003	R	000166
0004	R	000271	PP/R	0003	R	010045	PP/R	0004	R	000270	PP/R	0003	R	000132
0003	R	000360	SIGAP	0003	R	033631	SIGARK	0004	R	000013	SIGAL	0004	R	028122
0004	R	024756	SIGEX	0003	R	000550	SIGEP	0004	R	000040	SIGERL	0004	R	000025
0003	R	010107	SIGANK	0003	R	000416	SIGAP	0003	R	000042	SIGERL	0003	R	010010
0003	R	010006	SIGZ	0003	R	000512	SIGZ	0004	R	024755	SIGYK	0003	R	000322
0003	R	010020	STC	0003	R	010021	STC	0004	R	010011	STZP	0003	R	010017
0004	R	000070	TALL	0003	R	033730	TALL	0003	R	010023	TAST	0003	R	033704
0003	R	000702	T.ETA	0003	R	033624	THETA	0004	R	000102	THETA	0003	R	010112

0003 R C10022 T-D 0003 R 000170 U-AR 0003 R 033534 UBARZK 0004 R 000001 ULARL 0004 R 000513 UBARK
 0003 R 033633 UARRR 0004 R 000003 UARRZL 0004 R 025433 UARRZL 0004 R 000217 V8 0004 R 010051 XAST
 0003 R 006572 VEF 0004 R 000176 V8 0003 R 010119 XASHGU 0000 R 000002 Y0 0004 R 000037 ZRL
 0004 R 000512 XARRX 0003 R 001212 X 0003 R 002032 XX 0004 R 000346 YBARY 0000 R 000002 Y0 0004 R 000037 ZRL
 0003 R 002176 YY 0003 R 000074 Z 0003 R 010113 ZLIN 0003 R 033630 ZRK 0004 R 000037 ZRL
 0003 R 001046 ZZL

```

00101 SUBROUTINE CENTRL
00102 COMMON/PARAMT/ISKIP(30),H(30),Z(30),Z(30),UBAR(30),ALPHA(30),
00103 1BETA(30),SIGY(30),SIGX(30),SIGZ(30),DELTA(30),DELTA(30),DELTA(30),DELTA(30),
00104 2SIGE(30),DELTA(30),DELTA(30),DELTA(30),DELTA(30),DELTA(30),DELTA(30),DELTA(30),
00105 3ZL(100),XRI(100),DOS(100),CON(100),PEAK(100),XX(100),YY(100),
00106 4PLT(12,100),PEAKC(100),LAT(100),VER(100),VREF(100),ALONG(100),
00107 5XCRI(100),YI(20),IFLAG(100),ITAG(100),TESTNO(12),DI(10),CI(10),SIGZ,
00108 6SIGY,SIGX,SORZP,L,TH,I,J,K,KSTOL,STO2,STO3,TRN,TAST(10),ABK,ILK,
00109 7NAX,PYS,NZS,NDI,NCI,NDXR,PRAD,NMZ,ITOP,IROT,XAST(30),
00110 8SIGANK,LAMBDA,TIMI,TIM2,ZLIN,ASHOU(100,100),UBARK(20),SIGAK(20),
00111 9SIGEK(20),ZAK,SIGARK,SIGERK,UBARKK,THETAK(40),TAUK(20),TAUK(20),
00112 10COMMON/PARAMS/DECAY,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF,
00113 11SIGERL,UBARRL,THETAL(20),TAUL(10),TAUL(10),JBOT(10),ERFAL(6),
00114 12JTOP(10),VS(20),PERC(20),ACCUR,VB(20),PERCB(20),HD,PP,R,OPRR,
00115 13JMPAR,DTHK(21),NVS,NVB,LBI(4),LB2(4),LB3(4),LB4(4),DATE(12),I,DEP,
00116 14YBARY(100),XBARK,UBARKK(100),RETANK(100),ALPHAK(100),SGBAR,
00117 15SANG(100),NCCI,DEPN(100,100),SIGYNK,SIGENK(100),SIGANK(100),
00118 16DELPHI,UBARZK(100),UBARZL(100)
00119 INTEGER TESTNO
00120 REAL HP,R,L,LAT,LAMBDA
00121 *** THIS SUBROUTINE CALCULATES PEAK DOSAGE AND PEAK CONCENTRATION
00122 *** AT RADIAL DISTANCES CXR ALONG THE CLOUD AXIS.
00123 *** CONTROLS THE PLOTTING OF PEAK DOSAGE AND PEAK CONCENTRATION
00124 *** VS. CXR.
00125 WRITE(6,907)
00126 K = 0
00127 DO 400 KK=1,NMZ
00128 TH = RAD*THETAK(K)
00129 J = 1
00130 M = 0
00131 IF (THETAK(K) .LT. 180.0) YD = THETAK(K)+180.0
00132 IF (THETAK(K) .GE. 180.0) YD = THETAK(K)-180.0
00133 2. Y = YD
00134 K = K+1
00135 DO 100 I=1,NDXR
00136 ***** CALCULATION SECTION *****
00137 CALL EL(DXR(I),0)
00138 CALL SIGMA(DXR(I),0,0)
00139 CALL PEAK(2,K)
00140 CALL VERT(K,2)
00141 DOS(I) = STO1*STO2*STO3*EXP(-DECAY*DXR(I)/UBAR(K))
00142 IF (ISKIP(I) .NE. 2.0) ATIMI .GE. DXR(I)/UBAR(K) GO TO 80
00143 IF (ZIK(K) .GT. ZLIN) GO TO 80
00144 DOS(I) = DOS(I)*EXP(-LAMBDA*(DXR(I)/UBAR(K)-TIMI))
00145 80 CONTINUE
00146 CON(I) = COS(I)*UBARZK(K)/(SQRP2*SIGX)
00147 100 CONTINUE
00148 *** SOLUTION OUTPUT SECTION ***
00149

```

```

00147      WRITE (A,900) KK,ZZL(K)          CNTL 500
00150      IF (ISKIP(1)) .EQ. 1) WRITE (A,906) CNTL 510
00151      IF (ISKIP(8)) .EQ. 2) GO TO 120    CNTL 520
00152      WRITE (A,903) Y0                  CNTL 530
00153      WRITE (A,901) (DNR(I),DOS(I),I=1,NXNR) CNTL 540
00154      120 IF (ISKIP(8)) .EQ. 1) GO TO 130 CNTL 550
00155      WRITE (A,904) Y0                  CNTL 560
00156      WRITE (A,902) (DNR(I),CON(I),I=1,NXNR) CNTL 570
00157      130 CONTINUE                     CNTL 580
00158      C                                  CNTL 590
00159      380 IF (M-1 .GE. NPT(KK)) 3N TO 400 CNTL 600
00160      GO TO 20                          CNTL 610
00161      400 CONTINUE                       CNTL 620
00162      WRITE (A,905)                     CNTL 630
00163      RETURN                             CNTL 640
00164      900 FORMAT (1H0,08(13H---),53H00 MAX PEAK CONCENTRATION AND/OR PEAK DOS,CNTL 720
00165      PAGE IN LAYER,13,11H AT HEIGHT ,F10.2,3H 00.8(13H---)) CNTL 740
00166      901 FORMAT (13(18X,5H 0000,F10.2,7H, DOS=,E14.8)) CNTL 760
00167      902 FORMAT (13(18X,5H 0000,F10.2,7H, CON=,E14.8)) CNTL 780
00168      903 FORMAT (13(18X,5H 0000,DCSAGE, CLOUD AXIS IS AT,PS.3,30H DEGREES RELAT,CNTL 770
00169      IVE TO SOURCE 00) CNTL 790
00170      904 FORMAT (13(18X,5H 0000, CONCENTRATION, CLOUD AXIS IS AT,PS.3,30H DEGREES,CNTL 790
00171      I RELATIVE TO SOURCE 00) CNTL 800
00172      905 FORMAT (12X,18(16H-----)) CNTL 810
00173      906 FORMAT (11X,49H DECAY IS INCLUDED IN DOSAGE AND CONCENTRATION 0) CNTL 820
00174      907 FORMAT (11X,40X,5H0000 MAXIMUM PEAK DOSAGE AND/OR CONCENTRATION 0,CNTL 830
00175      1000////) CNTL 840
00176      END                                CNTL 850

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC MESSAGE(S)

91 FOR ISOXY
UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5018P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:00

SUBROUTINE ISOXY ENTRY POINT C00607

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000625
0002 *DATA C00215
0003 *BLANK C00000
0004 *PARAM 033754
0005 *PARAM 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 EL
0006 SIGMA
0007 PEAK
0010 TERT
0011 ALONGD
0012 ALOG
0013 MADUS
0014 N1025
0015 EXP
0016 SGR
0017 N1015
0020 PERK35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000025 1166	0001 000070 1346	0001 000101 1436	0001 000133 1406	0001 000060 201
0001 000304 2036	0001 000352 2206	0001 000455 2446	0001 000464 2516	0001 000524 2646
0001 000533 2716	0001 000121 501	0001 000335 5301	0001 000377 5351	0001 000400 5361
0001 000403 5401	0001 000474 5701	0001 000545 5901	0001 000126 601	0001 000234 621
0001 000545 6201	0001 000554 6301	0001 000331 651	0001 000332 661	0000 000008 907F
0000 000013 908F	0000 000021 909F	0000 000046 910F	0000 000062 911F	0000 000071 912F
0000 000075 913F	0000 000116 919F	0000 000133 920F	0000 000216 ACCUR	0012 R 000000 ALO6
0003 R 007102 ALONG	0003 R 000226 ALPHA	0004 R 001023 ALPHAK	0004 R 001170 ANG	0000 R 000004 B
0003 R 000264 BETA	0004 R 000657 RETANK	0003 R 007774 CI	0003 R 001522 CUN	0004 R 000342 DATE
0004 R 000000 DECAY	0004 R 002666 DELPHI	0003 R 000454 DELTMP	0003 R 001010 DELU	0003 R 000606 DELX
0003 R 000644 DELY	0004 R 000345 DEP	0004 R 001335 DEPN	0003 R 007742 DI	0003 R 001356 003
0003 R 000273 DTHK	0003 R 007246 DTHK	0004 R 000126 DFRX	0003 R 000036 DI	0004 R 000247 HB
0003 R 000014 I	0003 I 010050 IBUT	0003 I 007436 IFLAG	0003 I 000344 II	0003 I 010036 ILK
0003 I 000000 ISKIP	0003 I 007402 ITAG	0003 I 010047 ITOP	0003 I 010015 J	0003 I 010016 KK
0004 R 010014 JDOT	0004 I 000041 JF	0004 I 000134 JTOP	0004 I 000000 K	0004 I 000326 LB2
0003 R 010012 L	0003 R 010110 LAMEDA	0003 R 000426 LAT	0004 I 000322 LB1	0000 I 000003 N
0004 I 000332 L33	0004 I 000336 LB4	0000 I 000001 M	0004 R 000372 MPWR	0003 I 010046 MN2
0003 I 010035 M2K	0003 I 010043 NC1	0003 I 010042 NC1	0004 I 001334 MCI	0003 I 010037 MNS
0003 I 010040 NPT	0004 I 000321 N2B	0004 I 000320 N2S	0004 I 001334 MCI	0003 I 010037 MNS
0003 I 010040 NYS	0003 I 010041 N2S	0003 R 000262 PEAKC	0003 R 001666 PEAKD	0004 R 000172 PERC
0004 R 000243 PERC8	0003 R 002342 PLT	0004 R 000270 PP.R	0003 R 000132 Q	0004 R 000271 QPWR
0003 R 010045 RAD	0000 R 000002 S	0003 R 003560 SIGAK	0004 R 000013 SIGAL	0004 R 025122 SIGANK

MULTILAYER DIFFUSION MODEL GCA CORP DURLAND

```

0003 R 000360 SIGAP      0002 R 033631 SIGARK      0004 R 000040 SIGARL      0003 R 000028 SIGEL
0004 R 024756 SIGENK      0003 R 000550 SIGEP      0003 R 033632 SIGERK      0004 R 000042 SIGERL
0003 R 010107 SIGANK      0003 R 000416 SIGAL      0004 R 024755 SIGENK      0003 R 000322 SIGYO
0003 R 010006 SIGZ      0003 R 000512 SIGC      0004 R 001167 SGRAR      0003 R 010017 SDOI
0003 R 010020 SIOZ      0003 R 010021 SIOZ      0003 R 007412 T      0003 R 010023 TAST      0003 R 033704 TARK
0004 R 000070 TAU      0003 R 033730 TACK      0004 R 000102 TADUL      0003 R 010013 TH      0003 R 010112 TIMZ
0003 R 000702 T-ET      0002 R 033634 T-ETAY      0004 R 000044 TETAL      0003 R 010111 TIMI      0003 R 010112 TIMZ
0003 R 010022 TFC      0003 R 000170 TGRAR      0004 R 033534 TGRAR      0004 R 000001 UBARL      0004 R 000313 UBARNK
0003 R 033633 UBARX      0004 R 000043 UBARL      0004 R 025247 UBARX      0004 R 025433 UBARZL      0004 R 000317 V8
0003 R 004572 VER      0004 R 000736 VER      0004 R 000146 V8      0003 R 010114 VASHOU      0003 R 010051 VAST
0004 R 000512 XBARX      0003 R 001212 X      0003 R 002032 XA      0004 R 000346 YBARX      0003 R 002174 YV
0003 R 000074 Z      0003 R 010113 ZLI*      0003 R 033630 ZFN      0004 R 000037 ZNL      0003 R 001046 ZEL

```

```

SUBROUTINE ISCKY
COMMON/PARAMY/ISKIP(30),HIC(30),HIC(30),Q(30),UBARX(30),ALPHA(30),
1BETA(30),SIGYO(30),SIGAP(30),SIGX(30),DELTHP(30),SIGZO(30),
2SIGEP(30),DELX(30),DELY(30),THETA(30),IZMO(20),NP(20),DELU(30),
3ZLZ(100),XR(100),CCS(100),CON(100),PEAK(100),XF(100),YF(100),
4PLT(100),I(100),PEAK(100),ALAT(100),VER(100),VREF(100),ALOMG(100),
5SAR(100),AT(20),IFLAG(100),ITAG(100),TESTNO(12),DILLO(10),C(10),SIGZ,
6SIGY,SIGX,SGRZP,L,TH,J,KK,STOI,STO2,STO3,TRCTASTY(10),NBRK(10),
7NKS,NYS,NZS,NDI,NCI,NDR,RAD,NZL,ITOP,IBOT,XAST(30),
8SIGANK,LANNOA,TINI,TINZ,ZLIM,VASHOU(100,100),UBARX(20),SIGAK(20),
9SIGEK(20),ZNRK,SIGARK,SIGERK,UBARXK,THETAK(40),TAURK(20),TAURK(20),
10COMMON/PARAMS/DEKAY,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF,
11SIGERL,UBARL,THETA(20),TAUL(10),TAUD(10),JROT(10),PERX(8),
12JTOP(10),VSI(20),PERC(20),ACCUR,V8(20),PERC(20),MB,PPAR,QPAR,
13JPAR,DTHK(2),NVS,NVRLR(14),LBZ(4),LB3(4),LB4(4),DATE(2),I,DEP,
14YBARV(100),NBARX,UBARXK(100),BETANK(100),ALPHANK(100),SQBAR,
15BANG(100),NYCI,DEPH(100,100),SIGYK,SIGENK(100),SIGANK(100),
16DELPHI,UBARZK(100),UBARZL(100)
INTEGER TESTNO
REAL HPW,L,LAT,LANBDA
*** THIS SUBROUTINE CALCULATES DOSAGE AND CONCENTRATION ISOPLETHS
*** IN THE X-Y PLANE AROUND THE CLOUD AXIS. THE ISOPLETH PRODUCED
*** IS THE LATERAL DISTANCE FROM THE CLOUD AXIS. ISKIP(9)
*** CONTROLS AT HIGH HEIGHTS ISOPLETHS ARE CALCULATED)
WRITE (6,909)
IF (ISKIP(11) .EQ. 1) WRITE (4,913)
K = 0
DO 330 Y=1,NYZ
TH = R0*THETA(KK)
H = 0
IF (THETA(KK) .GE. 180.0) S = THETA(KK)-180.0
IF (THETA(KK) .LT. 180.0) S = THETA(KK)+180.0
WRITE (6,910) S
20 H = H+1
K = K+1
DO 330 H=3,9,3
IF (ISKIP(9) .EQ. N) GO TO 60
30 CONTINUE
DO 40 H=2,N,3
IF (ISKIP(9) .EQ. N) GO TO 50
40 CONTINUE
50 IF (.ST. 1) RETURN

```

```

00153 430 60 TO 60
00154 440 SC IF (Z(K)-ZL(K)) 620,60,620
00155 450 CALCULATION SECTION
00156 460 DO 540 I=1,NDXR
00157 470 J = I
00158 480 CALL ELIDAR(I,J)
00159 490 CALL SIGMA(DXR(I),O,O)
00160 500 CALL FEAK(Z(I))
00161 510 CALL VERT(K,I)
00162 520 DOR(I) = STOI*(STC(2*STC(I))*EXP(-DECAYDAR(I))/UBAR(K(K)))
00163 530 IF (ISKIP(I)) .LE. 2,OR,TINI .GE. DXR(I)/UBAR(K(K)) GO TO 62
00164 540 IF (Z(K) - ST. ZL(I)) GO TO 62
00165 550 COS(I) = DOSTI*EXP(-LAMBDA*(DXR(I)/UBAR(K(K))-TINI))
00166 560 CONTINUE
00167 570 CALL ALONG(DXR(I),TICK)
00168 580 CON(I) = COS(I)*UBAR(K(K))/(SER2*POSIS(K)*ALOG(G(I)))
00169 590 IF (ISKIP(I)) .LE. 6,AND,ISKIP(I) .GE. 4) GO TO 530
00170 600 DO 66 J=1,NDI
00171 610 R = COS(I)/DI(J)
00172 620 IF (R .LE. 1.0) GO TO 45
00173 630 PLT(I,J) = SQR(2.0*STC(I)*2.0*ALOG(R))
00174 640 GO TO 66
00175 650 PLT(I,J) = C.C
00176 660 CONTINUE
00177 670 DO 536 J=1,NCI
00178 680 R = CON(I)/CI(J)
00179 690 IF (R .LE. 1.0) GO TO 535
00180 700 PLT(2,I,J) = SQR(2.0*STC(I)*2.0*ALOG(R))
00181 710 GO TO 536
00182 720 PLT(2,I,J) = C.C
00183 730 CONTINUE
00184 740 540 CONTINUE
00185 750 WRITE (6,907) ZL(K)
00186 760 IF (ISKIP(I)) .LE. 6,AND,ISKIP(I) .GE. 4) GO TO 570
00187 770 IF (ISKIP(I)) .LE. 6,AND,ISKIP(I) .GE. 4) GO TO 570
00188 780 *****WRITE ISOPLETHS *****
00189 790 WRITE (6,908)
00190 800 DO 560 J=1,NDXR
00191 810 560 WRITE (6,919) DXR(I),DI(J),PLT(I,J),J=1,NDI
00192 820 570 IF (ISKIP(I)) .LE. 3) GO TO 590
00193 830 WRITE (6,911)
00194 840 DO 580 I=1,NDXR
00195 850 580 WRITE (6,920) DXR(I),CI(J),PLT(2,I,J),J=1,NCI
00196 860 590 CONTINUE
00197 870 620 IF (I=1 .GE. NPT(K)) GO TO 630
00198 880 GO TO 22
00199 890 630 CONTINUE
00200 900 WRITE (6,912)
00201 910 RETURN
00202 920 907 FORMAT (1H,5X,10H HEIGHT =,F10.2,2X,*)
00203 930 908 FORMAT (1H,5X,20H COSAGE ISOPLETHS =,
00204 940 909 FORMAT (1H,13X,56H***** ISOPLETHS *GRIZZLY PLANE AROUND CLOUD
00205 950 910 *****/45,43H Y IS LATERAL DISTANCE FROM CLOUD AXIS **//)
00206 960 910 FORMAT (30X,23H ANGLE TO CLOUD AXIS =,6.3,30H DEGREES RELATIVE
00207 970 910 SOURCE **)
00208 980 911 FORMAT (1H,53X,27H CONCENTRATION ISOPLETHS =)
00209 990 912 FORMAT (12X,181H-----//)
00210 1000

```

913 FORMAT (2X,89) THE DECAY TERM HAS BEEN INCLUDED IN DOSAGE AND COISXV1090
 INCENTRATION IN CALCULATING ISOTOPES 01 ISXV1100
 919 FORMAT (1M,16) ISOTOPICAL DISTANCE TO P10.2/(9X,3110H) * DJSAGEP,ELISXV1110
 14.6.4M, Y0,P10.2))) ISXV1120
 920 FORMAT (1M,16X,18) RADIAL DISTANCE R0,P10.2/(3116H) * CONCENTRATION=ISXV1130
 1.614.6.4M, Y0,P10.2))) ISXV1140
 END ISXV1150

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 * DIAGNOSTIC MESSAGE(S)

00314 101
 00316 102
 00317 103
 00318 104
 00319 105
 00320 106
 00321 107

MULTILAYER DIFFUSION MODEL GCA CORP WORKLOAD

BI FOR ISOVZ
 UNIVAC 1100 FORTRAN V LEVEL 2200 C010 F5010P
 THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:01

SUBROUTINE ISOVZ ENTRY POINT 000506

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000521
 0002 *DATA 000204
 0003 *BLANK 000000
 0004 *PARAM 000754
 0005 *PARAM 000577

EXTERNAL REFERENCES (BLOCK, NAME)

0006 EL
 0006 SIGMA
 0007 PEAK
 0010 GERT
 0011 ALONGD
 0012 ALONG
 0013 NMODS
 0014 NMODS
 0015 EXP
 0016 SORT
 0017 PLOT
 0020 NERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000024 1156	0001 000036 1246	0001 000224 1566	0001 000271 1736	0001 000060 2016
0001 000166 2216	0001 000367 2236	0001 000376 2306	0001 000251 2416	0001 000435 2436
0001 000444 2506	0001 000252 2416	0001 000255 2416	0001 000316 2416	0001 000317 2416
0001 000322 2606	0001 000331 2716	0001 000410 2806	0001 000456 2906	0001 000456 2906
0000 000005 915F	0000 000031 916F	0000 000035 917F	0000 000044 918F	0000 000046 919F
0000 000073 922F	0000 000077 921F	0000 000120 925F	0004 000216 925F	0012 000000 925F
0003 000710 2ALONG	0003 000226 2ALONG	0004 000102 2ALPHAX	0004 000170 2ALPHAX	0000 000003 925F
0003 000264 BETA	0004 000657 2ALPHAX	0003 000774 2ALPHAX	0003 000152 2CON	0004 000342 2DATE
0004 000000 2DECAY	0004 000266 2ELPHI	0003 000454 2ELTHP	0003 000101 2DELU	0003 000606 2ELX
0003 000444 2DELY	0004 000345 2EP	0004 000135 2EPH	0003 000762 2I	0003 000136 2DS
0004 000273 2THK	0003 000246 2TR	0004 000126 2ERFX	0003 000036 2H	0004 000267 2H
0003 000019 2I	0003 000350 2IPOT	0003 000436 2FLAG	0003 000344 2I	0003 000036 2ILK
0003 000000 2SKIP	0003 000762 2ITP	0003 000047 2ITP	0003 000740 2IMOD	0003 000015 2J
0004 000214 2JPT	0004 000041 2I	0004 000134 2JTP	0000 000000 2K	0003 000016 2KK
0003 000012 2L	0003 000110 2LAMP	0003 000626 2LAT	0004 000322 2LSI	0004 000326 2LB2
0004 000332 2L3	0004 000336 2L4	0000 000002 2	0004 000272 2MPIR	0000 000004 2N
0003 000735 2NRK	0003 000243 2CI	0003 000142 2NI	0003 000044 2NLX	0003 000046 2NZ
0003 000764 2NY	0004 000321 2YH	0004 000320 2YS	0004 000134 2NACI	0003 000037 2NXS
0003 000040 2YS	0003 000041 2YS	0003 000626 2PEAC	0003 000166 2PEAKD	0004 000172 2PERC
0004 000243 2PERCH	0003 000242 2PLT	0004 000270 2PP-R	0003 000132 2S	0004 000271 2P4R
0003 000045 2RAC	0000 000001 2S	0003 000560 2SIGAK	0004 000013 2SIGAL	0004 000212 2SIGANK
0003 000360 2SIGAP	0003 000363 2SIGAPK	0004 000340 2SIGARL	0003 000360 2SIGEL	0004 000025 2SIGEL

```

0004 R 024756 SIGENY      0003 R 00055L SIEGP      0003 R 033632 SIEGRK      0004 R 000042 SIEGRL      0003 R 010010 SIGX
0003 R 010107 SIEGK      0003 R 000416 SIGAO      0003 R 010007 SIEY      0004 R 024758 SIEYNK      0003 R 000322 SIEYO
0003 R 010006 SIGZ      0003 R 000512 SIGYM      0004 R 001147 SIEH4      0003 R 010017 SIOI      0003 R 033704 TALK
0003 R 010020 ST02      0003 R 010021 ST03      0003 R 007912 T      0003 R 010023 TAST      0003 R 010013 TH
0004 R 000070 TALL      0003 R 033730 TADCK      0004 R 000132 TALOL      0003 R 007746 TESTNO      0003 R 010112 TIMZ
0003 R 000702 TLET      0003 R 033634 TETAK      0004 R 000044 THETAL      0003 R 010111 TIMI      0004 R 000813 UBARKK
0003 R 010022 TFD      0003 R 000170 UEAR      0003 R 033534 UNARK      0004 R 000001 UEARL      0004 R 000217 VB
0003 R 033633 UEARX      0004 R 000043 UEARL      0004 R 025267 UEARZK      0004 R 025433 UASHOU      0003 R 010081 KAST
0003 R 006872 VEM      0003 R 006736 VREF      0004 R 000146 VS      0003 R 010176 VY      0003 R 002176 VY
0004 R 000812 X4YX      0003 R 001212 X4      0003 R 002032 XK      0004 R 000346 YHARY      0003 R 001046 ZEL
0003 R 000074 Z      0003 R 010113 ZLI      0003 R 033635 ZMK      0004 R 000037 ZRL

```

```

SUBROUTINE ISOYZ
COMMON/PARAMT/ISVIP(30),M(30),T(30),G(30),UBAP(30),ALPHA(30),
1METAL(30),SIGMO(30),SIGAP(30),SIGK(30),DELTHP(30),SIGZ(30),
2SIEG(30),DELX(30),DELY(30),THETA(30),H2ACO(20),HPT(20),DELU(30),
3ZZL(100),X(100),DCE(100),CON(100),PEAK(100),XN(100),YN(100),
4PLT(2,100),PEAKC(100),LAT(100),VER(100),REF(100),ALPHG(100),
5DNR(100),AT(20),IFLAG(100),ITAG(100),TESTNO(12),DI(10),CI(10),SIGZ,
6XISY,SIGK,SIGAP,L,THETA,CK,STOI,STG2,STG3,TKD,TAST(10),WBK,ILK,
7XAS,YS,75,DI,CL,DOX,RAD,ANZ,ITP,ISUT,XAST(30),
8SIGANK,LAMBDA,TIR,TIR2,ZLIP,ASHOU(100),COI,UBAR(20),SIGAK(20),
9SIGEK(20),7RK,SIGAK,SIGER,UBARK,THETAK(40),TAUK(20),TAUOK(20),
10COMMON/PARAMS/DECAT,UBAR(100),SIGAL(100),SIGEL(100),ZRL,SIGARL,JP,
11SIEGRL,UBARLT,THETAL(20),TALL(10),TAUOL(10),JBD(10),PERK(4),
12JTOPI(10),VS(20),PERC(20),ACCUR(8(20)),PERC(20),PP,R,WPR,
13JMPWR,DTHK(21),MVS,MVE,ALF(4),LBZ(4),LBZ(4),LB4(4),DATE(2),I,DEP,
14YBARV(100),XBAR,UBARK(100),DETAK(100),ALPHAK(100),S2BAR,
15SANG(100),NICI,DEPH(100),SIY,K,SIGEK(100),SIGA,Y(100),
16DELPHI,UBARZK(100),UBAPZL(100)
17INTEGER TESTNO
18REAL MPWR,L,LAT,LAMBFA
19C
20C
21C
22C
23C
24C
25C
26C
27C
28C
29C
30C
31C
32C
33C
34C
35C
36C
37C
38C
39C
40C
41C
42C
43C

```

```

00142 440 D05(I) = SYD1*(STOZ*STO1)*EXP(-DECAY*DXR(I))/UBAR(KK1) 15Y7 450
00143 450 IF (ISKIP(I) .NE. 2.0*RTIME) .GE. DXR(I)/UBAR(KK1) GO TO 22 15Y2 460
00145 460 IF (ZIKK) .GT. ZLIM) GO TO 22 15Y2 470
00147 470 D05(I) = D05(I)*EXP(-LA*HGA*(DXR(I)/UBAR(KK1)-T(I))) 15Y2 480
00150 480 22 CONTINUE 15Y2 490
00151 490 CALL ALONGCUDOR(I),T(KK1) 15Y2 500
00152 500 CON(I) = D05(I)*UBARZK(K1)/(SQRT2*SIGMA)*ALONGW(J) 15Y2 510
00153 510 IF (ISKIP(I0) .EQ. 2) GO TO 40 15Y2 520
00155 520 DO 26 J=1,NC1 15Y2 530
00160 530 8 = D05(I)/CI(J) 15Y2 540
00161 540 IF (B .LE. 1.0) GO TO 24 15Y2 550
00163 550 PLT(I,K,J) = SQRT(2.0*SIGMA**2*ALOG(R1)) 15Y2 560
00164 560 40 TO 26 15Y2 570
00165 570 24 PLT(I,K,J) = 0.0 15Y2 580
00166 580 26 CONTINUE 15Y2 590
00170 590 40 IF (ISKIP(I0) .EQ. 1) GO TO 620 15Y2 600
00172 600 DO 44 J=1,NC1 15Y2 610
00175 610 8 = CON(I)/CI(J) 15Y2 620
00176 620 IF (B .LE. 1.0) GO TO 42 15Y2 630
00200 630 PLT(2,K,J) = SQRT(2.0*SIGMA**2*ALOG(B1)) 15Y2 640
00201 640 GO TO 44 15Y2 650
00202 650 42 PLT(2,K,J) = 0.0 15Y2 660
00203 660 44 CONTINUE 15Y2 670
00205 670 620 CONTINUE 15Y2 680
00206 680 IF (M-1) .GE. HPT(KK1) GO TO 670 15Y2 690
00210 690 GO TO 20 15Y2 700
00211 700 670 CONTINUE 15Y2 710
00211 710 C 15Y2 720
00213 720 WRITE (6,917) DXR(I) 15Y2 730
00216 730 IF (ISKIP(I0) .EQ. 2) GO TO 680 15Y2 740
00220 740 WRITE (6,916) 15Y2 750
00222 750 DO 675 I=1,K 15Y2 760
00225 760 675 WRITE (6,918) ZZL(I),DI(J),PLT(I,K,J),J=1,NC1 15Y2 770
00236 770 680 IF (ISKIP(I0) .EQ. 1) GO TO 690 15Y2 780
00240 780 WRITE (6,919) 15Y2 790
00242 790 DO 685 I=1,K 15Y2 800
00245 800 685 WRITE (6,925) ZZL(I),CI(J),PLT(2,K,J),J=1,NC1 15Y2 810
00254 810 690 CONTINUE 15Y2 820
00256 820 710 CONTINUE 15Y2 830
00257 830 WRITE (6,920) 15Y2 840
00261 840 RETURN 15Y2 850
00263 850 915 FORMAT (I11,30X,54H***** ISOPLETHS VERTICAL PLANE AROUND CLOUD AXIS ***** 15Y2 920
00264 860 15 *****/40X,42H Y IS LATERAL DISTANCE FROM CLOUD AXIS ***** 15Y2 930
00265 870 916 FORMAT (60X,12H** DOSAGE ** 15Y2 940
00266 880 917 FORMAT (54X,21H** RADIAL DISTANCE R=F10.2,3H ** 15Y2 950
00267 900 918 FORMAT (10H HEIGHT Z=F10.2,2(11H, * DOSAGE=E14.6,5H, Y=F10.2)/15Y2 970
00267 910 1(2CX,2(11H, * DOSAGE=E14.6,5H, Y=F10.2))) 15Y2 980
00270 920 919 FORMAT (57X,19H** CONCENTRATION ** 15Y2 990
00271 930 920 FORMAT (12X,10(6H*****)/) 15Y2 1000
00271 930 921 FORMAT (22X,89H** THE DECAY TERM HAS BEEN INCLUDED IN DOSAGE AND COISY21010 15Y2 1010
00272 950 INCENTRATION IN CALCULATING ISOPLETHS * 15Y2 1020
00273 960 925 FORMAT (10H HEIGHT Z=F10.2,2(18H, * CONCENTRATION=E14.8,5H, Y=F10.2) 15Y2 1030
00273 970 1F10.2)/(20X,2(18H, * CONCENTRATION=E14.8,5H, Y=F10.2))) 15Y2 1040
00274 980 ENO 15Y2 1050

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. D *DIAG*OSTIC* MESSAGE(S)

91 FOR WASHT
UNIVAC 1108 FORTMAN V LEVEL 2206 0018 F5018P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:03

SUBROUTINE WASHT ENTRY POINT 000333

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000374
0002 *DATA 000053
0003 *BLANK 000000
0004 *PARAM 033784
0005 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME,

0005 *COORD
0006 *MODUS
0007 *HIOZS
0010 *EXP
0011 *ERRORS

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000068 IOL	0001 000101 ISL	0001 000124 ZOL	0001 000027 SL
0001 000171 BNL	0001 000174 BDL	0001 000213 4NL	0001 000041 9L
0000 000011 920F	0000 R 000001 A	0004 R 000216 ACCUM	0003 R 000226 ALPHA
0004 R 001023 ALPHNK	0004 R 001170 ANG	0000 R 000007 ASP	0003 R 000264 BETA
0004 R 000657 BETANK	0000 R 000003 C	0003 R 007774 CI	0000 R 000004 J
0004 R 000342 CATE	0004 R 000000 DECAT	0004 R 025264 DELPHI	0003 R 001010 DELU
0003 R 000806 DFLA	0003 R 000844 DELY	0004 R 000345 DEP	0003 R 007742 DI
0003 R 001356 DDF	0004 R 000273 DTHK	0003 R 007246 DTK	0004 R 000126 ERFX
0000 R 000006 G	0003 R 000034 H	0004 R 000267 HB	0003 I 010080 ISOT
0003 I 007334 IFLAG	0004 I 000344 II	0003 I 010036 ILK	0000 I 000000 ISWA
0003 I 007602 ITAG	0003 I 010047 ITOP	0003 I 000740 ITHOD	0004 I 000114 JBOT
0004 I 000041 JF	0004 I 000134 JTOP	0003 I 010016 KK	0003 R 010110 LAMDA
0004 R 000426 LAT	0004 I 000322 LHI	0004 I 000324 LBZ	0004 I 000326 LB4
0004 R 000272 MPNR	0003 I 010035 MNK	0003 I 010043 NCI	0003 I 010044 NDXR
0003 I 010046 NIZ	0003 I 000764 NPT	0003 I 010041 NZS	0004 I 001334 NXCI
0003 I 010037 NAS	0003 I 010040 NYS	0003 R 000321 NVB	0003 R 001466 PEAKO
0004 R 000172 PERC	0004 R 000243 PERCB	0003 R 002342 PLT	0003 R 000132 Q
0004 R 000271 QPHR	0003 R 010045 RAD	0003 R 000360 SIGAK	0004 R 028122 SIGANK
0003 R 000360 SIGAP	0003 P 033431 SIGARK	0004 R 000040 SIGARL	0004 R 000025 SIGEL
0004 R 024756 SIGENK	0003 R 000850 SIGEP	0003 R 033432 SIGERK	0003 R 010010 SIGR
0003 R 010107 SIGENY	0003 R 000016 SIGYD	0003 R 010107 SIGY	0003 R 000322 SIAYO
0003 R 010006 SIGZ	0003 P 000812 SIGZO	0003 P 010011 SIKZP	0003 R 010017 STOI
0003 R 010020 STOI	0003 R 010021 STOK	0003 R 007412 T	0003 R 033704 TALK
0004 R 000070 TAIL	0003 R 033730 TALK	0004 R 000142 TAUUL	0003 R 010013 TH
0003 R 000702 THETA	0003 R 033634 THETA	0004 R 000044 THETAK	0003 R 010112 TIME
0003 R 010022 TRD	0003 R 000170 USAR	0003 R 033634 USARK	0004 R 000813 USARKK
0003 R 033633 USARKK	0004 R 000043 USARKL	0004 R 025267 USARZK	0004 R 000217 VB
0003 R 000572 VEN	0003 R 000736 VREF	0004 R 000146 VS	0003 R 010051 VAST
0004 R 000512 XBARX	0003 R 001212 XN	0000 R 000010 XS	0004 R 000346 YBARY

```

00101 10 SURROUTINE WASH(X,Y,ISWS,XD,YD,N,K)
00102 20 COMMON/PARAMT/ISKIP(30),HIS(30),SIG(30),DELTP(30),SIG2(30),
00103 30 1BETAL(30),SIGY(30),SIGAP(30),SIGYO(30),DELTP(30),SIG2(30),
00104 40 2SIGEP(30),DELX(30),DELY(30),THETA(30),IZMOD(20),NPT(20),DELU(30),
00105 50 3ZL(100),XP(100),DOS(100),CDH(100),PEAKD(100),XK(100),YY(100),
00106 60 4PLT(2,100,100),PEAKC(100),LAT(100),VER(100),REF(100),ALONG(100),
00107 70 5DPR(100),T(20),IFLAG(100),ITAG(100),TESTQC(12),DI(10),CI(10),SIG,
00108 80 6SIGY,SIGX,SORZPL,THA1,J,K,KSTOI,STO2,STO3,TRO,TAST(10),NBK,ILK,
00109 90 7XIS,NYS,WZS,NDI,NCI,MDAR,RAD,NMZ,ITOP,ISOT,XAST(30),
00110 100 8SIGANK,LAMBDA,TINI,TIM2,ZLIM,WASHOUT(100),UBARK(20),SIGANK(20),
00111 110 9SIGEN(20),7RK,SIGARK,SIGERK,UBARK,THETA(40),TAUK(20),TAUD(20),
00112 120 COMMON/PARAMT/DECAY,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF,
00113 130 1SIGERL,UBARRL,THETA(20),TAUL(10),TAUL(10),TAUL(10),JBOT(10),ERFX(6),
00114 140 2UTOP(10),VS(20),PERC(20),ACCU,VB(20),PERCB(20),MB,PPMR,QPAR,
00115 150 3PPMRDTHK(21),VS,NVBALRI(4),LB2(4),LB3(4),LB4(4),DATE(2),ILDEP,
00116 160 4YBAR(100),XBARK,UBARK(100),BETANK(100),ALPHNKK(100),SQBAR,
00117 170 5ANG(100),NKCI,DEPN(100,100),SIGYK,SIGENK(100),SIGANK(100),
00118 180 6DELPHI,UBARKZ(100),UBARZL(100)
00119 190 REAL MPNR,L,LAT,LAMBDA
00120 200 INTEGER TESTC
00121 210 THIS SURROUTINE CALCULATES WASHOUT DEPOSITION FOR ALL MODELS .
00122 220 ISW6 = 0
00123 230 IF (ISKIP(13) .NE. 0.AND.IAOT .LE. KK.AND.KK .LE. ITDP) GO TO 60
00124 240 IF (IN .EQ. 9) GO TO 50
00125 250 5 IF (TIM1 .LT. X/UBAR(KK)) GO TO 9
00126 260 GO TO 50
00127 270 9 IF (TIM1 .LT. (X-2.15*PERC(13))/UBAR(KK)) GO TO 10
00128 280 WRITE (6,920) XX(1),YY(1)
00129 290 10 A = UBARK(KK)
00130 300 SIGY = PERC(1)
00131 310 B = SIGY
00132 320 C = 1.0
00133 330 D = 1.0
00134 340 E = 1.0
00135 350 G = TIM1
00136 360 15 CONTINUE
00137 370 IF (IZMOD(KK) .EQ. 3.AND.ISKIP(13) .NE. 2) GO TO 20
00138 380 D = Z(KK(1))-Z(KK)
00139 390 20 E = EXP(-.5*(Y/D)**2)
00140 400 IF (ISKIP(12) .NE. 2) GO TO 35
00141 410 C = EXP(-LAMBDA*(X/A-G))
00142 420 35 CONTINUE
00143 430 WASHOUT(I,J) = WASHOUT(I,J)+(LAMBDA*(KK)/(SQRT(A*B)))*CODE
00144 440 50 CONTINUE
00145 450 RETURN
00146 460 60 IF (ISWS .EQ. 0) GO TO 64
00147 470 N = 1
00148 480 CALL COORD(M,KK,X,Y,XD,YD,ASP,XS,1)
00149 490 64 IF (X .GT. XAST(KK).OR.N .EQ. 9) GO TO 66
00150 500 SIGY = PERC(1)
00151 510 GO TO 5
00152 520 66 N = 1
00153 530 WASH 20
00154 540 WASH 30
00155 550 WASH 40
00156 560 WASH 50
00157 570 WASH 60
00158 580 WASH 70
00159 590 WASH 80
00160 600 WASH 90
00161 610 WASH 100
00162 620 WASH 110
00163 630 WASH 120
00164 640 WASH 130
00165 650 WASH 140
00166 660 WASH 150
00167 670 WASH 160
00168 680 WASH 170
00169 690 WASH 180
00170 700 WASH 190
00171 710 WASH 200
00172 720 WASH 210
00173 730 WASH 220
00174 740 WASH 230
00175 750 WASH 240
00176 760 WASH 250
00177 770 WASH 260
00178 780 WASH 270
00179 790 WASH 280
00180 800 WASH 290
00181 810 WASH 300
00182 820 WASH 310
00183 830 WASH 320
00184 840 WASH 330
00185 850 WASH 340
00186 860 WASH 350
00187 870 WASH 360
00188 880 WASH 370
00189 890 WASH 380
00190 900 WASH 390
00191 910 WASH 400
00192 920 WASH 410
00193 930 WASH 420
00194 940 WASH 430
00195 950 WASH 440
00196 960 WASH 450
00197 970 WASH 460
00198 980 WASH 470
00199 990 WASH 480
00200 1000 WASH 490
00201 1010 WASH 500
00202 1020 WASH 510
00203 1030 WASH 520
00204 1040 WASH 530

```

```

00161      CALL COORDIN(KX,X,Y,XU,YU,ASP,X5,2)
00162      70 IF (N.EQ. 91 GO TO 50
00163      IF (X/UBAR(INNZ+ILK-1)+TAST(ILK-1) .LE. TIM1) GO TO 50
00164      ISV6 = 1
00165      SIGYNK = PERC(2)
00166      A = UBAR(INNZ+ILK-1)
00167      B = SIGYNK
00168      C = 1.0
00169      D = 1.0
00170      E = 1.0
00171      IF (ISKIP(12) .EQ. 1) GO TO 15
00172      G = TIM1-TAST(ILK-1)
00173      GO TO 15
00174      920 FORMAT (110,29H *** WASHOUT DEPOSITION AT X=,F10.3,4H, Y=,F10.3,2H)
00175      1H MAY BE OVER ESTIMATED ***
00176      END
00177
00200      WASH 540
00201      WASH 550
00202      WASH 560
00203      WASH 570
00204      WASH 580
00205      WASH 590
00206      WASH 600
00207      WASH 610
00208      WASH 620
00209      WASH 630
00210      WASH 640
00211      WASH 650
00212      WASH 660
00213      WASH 670
00214      WASH 680
00215      WASH 690

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. D DIAGNOSTIC MESSAGE(S)

SI FOR TESTP
UNIZAC 1108 FORTRAN V LEVEL 2216 C018 F501PP
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:05

SUBROUTINE TESTR ENTRY POINT 000210

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000224
0002 *DATA 000030
0003 *BLANK 000000
0004 *PARAM 033754
0005 *PARAM 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 NEXP65
0006 NEXP35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000172	100L	0001	000025	116G	0001	000043	131G	0001	000034	61L	0001	000045	80L
0001	000123	82L	0001	000126	84L	0001	000131	86L	0001	000146	88L	0001	000155	90L
0004	R 000216	ACCUR	0003	R 007102	ALPHA	0003	R 000226	ALPHA	0004	R 001023	ALPHNK	0004	R 001170	ANG
0003	R 000244	BETA	0004	P 000657	RETNK	0003	R 000774	CI	0003	R 001522	CON	0004	R 000342	CATE
0004	R 000000	DECAY	0004	P 000246	DELPHI	0003	R 000454	DELTHP	0003	R 001010	DELU	0003	R 000806	DELX
0003	R 000644	DELY	0004	R 000345	DRF	0004	R 001335	DEPN	0003	R 000762	DI	0003	R 001356	DOS
0004	R 000273	OTHK	0003	R 007246	DXR	0004	R 000126	ERFX	0004	R 000036	H	0004	R 000267	HB
0003	I 010014	I	0003	I 010050	IBOT	0003	I 007436	IFLAG	0004	I 000344	II	0003	I 010034	ILK
0003	I 000000	ISLIP	0003	I 007602	ITAG	0003	I 010047	ITOP	0003	I 000740	I2MOD	0003	I 010015	J
0004	I 000114	JBOT	0004	I 000041	JF	0003	I 000134	JTOP	0003	I 000001	KF	0003	I 010016	KK
0004	I 000000	KS	0003	R 010012	L	0003	R 010110	LA5PA	0004	I 000322	LB1	0004	I 000322	LB1
0004	I 000826	LB2	0004	I 010032	LB3	0004	I 000136	LB4	0000	I 000003	M	0000	I 000002	MM
0004	R 000272	MPWH	0003	I 010035	NHA	0003	I 010043	NCT	0003	I 010042	NOI	0003	I 010044	NOAR
0003	I 010046	NMZ	0003	I 000764	NPT	0004	I 000321	NV9	0004	I 000320	NVS	0004	I 001334	NXCI
0003	I 010037	NYS	0003	I 010040	NYS	0003	I 010041	NZ5	0003	R 000362	PEAKC	0003	R 001464	PEAKD
0004	R 000172	PERC	0004	R 000243	PERCB	0003	P 000242	PLT	0004	R 000370	PPMR	0003	R 000132	Q
0004	R 000271	QPR	0003	P 010045	RAC	0003	P 033560	SIGAK	0004	R 000013	SIGAL	0004	R 025122	SIGANK
0003	R 000340	SIGAP	0003	R 033631	SIGARK	0004	R 000040	SIGARL	0003	R 033604	SIGEL	0004	R 000028	SIGEL
0004	R 027754	SIGENK	0003	P 000550	SIGEP	0003	R 033632	SIGERK	0004	R 000042	SIGERL	0003	R 010010	SIGEX
0003	R 010107	SIGXNK	0003	R 000416	SIGXD	0003	R 010007	SIGY	0004	R 024765	SIGYMK	0003	R 000322	SIGYO
0003	R 010006	SIGZ	0003	R 000512	SIGZD	0004	R 001167	SQBAR	0003	R 010011	SQR2P	0003	R 010017	STDI
0003	R 010020	STO2	0003	R 010021	STO3	0003	R 007412	T	0003	R 010023	TAST	0003	R 033704	TAUK
0004	R 000070	TAUL	0003	R 033730	TAUOK	0004	R 000102	TAUOL	0003	R 010013	TH	0003	R 010013	TH
0003	R 000072	THETA	0003	P 033634	THETAR	0004	R 000144	THETAL	0003	R 010111	TIMI	0003	R 010112	TIM2
0003	R 010022	TBL	0003	R 000170	UBAR	0003	R 033534	UBARK	0004	R 000001	UBARL	0004	R 000513	UBARK
0003	R 033633	UBARRR	0004	R 000043	UBARL	0004	R 025267	UBARTK	0004	R 025433	UBARZL	0000	R 000004	UBZ4
0004	R 000217	VB	0003	R 000572	VEAR	0003	R 000736	VREF	0004	R 000746	VS	0003	R 010114	WASHOU
0003	R 010051	XAST	0004	R 000512	XBARX	0003	R 001212	XK	0003	R 000346	YBARY	0004	R 000346	YBARY
0003	R 002175	YI	0003	R 000074	Z	0003	R 010113	ZLIM	0003	R 000330	ZFK	0004	R 000037	ZRL
0003	R 001046	ZZL												

```

00101 SUBROUTINE TEST(KIKI)
00102 COMMON/PARAM/ISKIP(30),H(30),Z(30),Q(30),UBAR(30),ALPHA(30),
00103 1BETA(30),SIGVO(30),SIGAP(30),SIGX(30),DELTHP(30),SIGZ(30),
00104 2SIGEF(30),DELA(30),DELY(30),THETA(30),IZMOD(20),NPT(23),DELU(30),
00105 3JZL(100),XRI(100),JOS(100),CON(100),PEAK(100),XK(100),YY(100),
00106 4PLT(100,100),PEAKC(100),LAT(100),VER(100),MFP(100),ALCNG(100),
00107 5SXR(100),T(20),IFLAG(100),ITAG(100),TESTNO(12),DI(100),C(100),SIGZ,
00108 6SIGV,SIGX,SCR2PAL,THI,JAKF,STCI,STO2,STO3,TRD,TAST(100),NBR,ILK,
00109 7NYS,NYS2,PCIC,CI,DOX,PPAC,NZ,ITOP,IBOT,XAST(30),
00110 8SIGXK,LAMBDA,TIM,TIM2,ZLIM,ASHCH(100,100),UBARF(20),SIGAK(20),
00111 9SISEK(20),ZRK,SIGARK,SIGARK,UBARK,THETAK(40),TAUK(20),TAUKX(20),
00112 10CU,ON/PARAMS/DECAY,UBARL(100),SIGAL(100),SIGEL(100),ZRL,SIGARL,JF,
00113 11SIGERL,UBARL,THETA(20),TAUL(100),TAUL(100),JBOT(100),ERFA(10),
00114 12ZJTOP(100),VS(20),PERC(20),ACCU,V(20),PERCB(20),HB,PP,R,PP,R,
00115 13JAPW,OTK(21),VS,NVB,LS(14),LB2(4),LB3(4),LB4(4),DOTE(2),II,DEP,
00116 14YBARY(100),XBARX,UBARX(100),BETANK(100),ALPHA(100),SQBAR,
00117 15SANG(100),NACI,DEPH(100,100),SIGYK,SIGENK(100),SIGANK(100),
00118 16DELPHI,UBARZK(100),UBARZL(100)
00119 INTEGER TESTING
00120 NEAL,PPK,LALAT,LAMBDA
00121 THIS SUBROUTINE DETERMINES THE STRUCTURAL CHANGE IN LAYERS FOR
00122 BOX MODEL AND FULL TRANSITION MODEL. ALSO, YIND SPEED AT HEIGHT
00123 ZL(K) (UBARZL(K)) IN THE NEW LAYER IS CALCULATED.
00124 IF (ISKIP(13) .EQ. 0) GO TO 100
00125 IF (KK .NE. JBOT(ILK)) GO TO 61
00126 1BOT = KK
00127 1TOP = JTOP(ILK)
00128 DO 60 J=JBOT,1TOP
00129 ILK = ILK+1
00130 60 XAST(J) = UBAR(J)*TAST(ILK)
00131 61 CONTINUE
00132 IF (KTK .EQ. 0) GO TO 100
00133 K5 = 0
00134 KF = 1
00135 DU 95 MH=1,NMZ
00136 M = 0
00137 KS = KS+1
00138 IF (MH .LT. JBOT(NF)+OR,MH .GT. JTOP(KF)) GO TO 88
00139 IF (KF .GT. 1) GO TO 84
00140 IF (JBOT(1) .GT. 1) GO TO 82
00141 UBARZL(K5) = UBARHL(ZZL(K5)/ZHL)*QPMW
00142 GO TO 88
00143 82 UBZH = UBARRL
00144 GO TO 86
00145 84 UBZH = UBARL(KF-1)
00146 86 UBARZL(K5) = UBZH+((UBARL(KF)-UBZH)/IZ(MH+1)-Z(M)))*ZZL(K5)-Z(M))
00147 88 IF (M=1 .OR. NPT(MH)) GO TO 90
00148 GO TO 80
00149 90 IF (MH .EQ. JTOP(KF)) KF = KF+1
00150 95 CONTINUE
00151 KTK = 0
00152 100 CC=TIM-E
00153 RETURN
00154 END

```


MULTILAYER DIFFUSION MODEL GCA CORP BJORKLUND DATE 121269 PAGE 33
END OF UNIVAC IIOP FORTRAN V COMPILATION 3 DIALECTIC MESSAGES

BI FOR ACH
UNIVAC 1108 FORTRAN V LEVEL 2206 QUIP FSCIRP
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:06

SUBROUTINE ACH ENTRY POINT 000201
EL ENTRY POINT 000204
LATER ENTRY POINT 000216
ALONGD ENTRY POINT 000222

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000231
0002 *DATA 000023
0002 *BLANK 000000
0003 *PARAM 000074
0004 *PARAMS 000077

EXTERNAL REFERENCES (BLOCK, NAME)

0005 EXP
0006 NERR38

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000032	23L	0001	000081	24L	0001	000066	25L	0001	000103	33L	0001	000117	40L
0001	000143	SOL	0004	R	000216	ACCUR	0003	R	0007102	ALPHA	0003	R	001023	ALPHMK
0004	R	001170	ANG	0003	R	000244	BETA	0004	R	000657	BETANK	0003	R	001622
0004	R	000342	DATE	0004	R	000000	DECAY	0004	R	000454	DELTA	0003	R	001010
0003	R	000604	DELA	0003	R	000444	DELY	0004	R	000345	DEP	0004	R	000742
0003	R	001346	DOS	0004	R	000273	DTXK	0003	R	000246	DRR	0003	R	000034
0004	R	000247	HB	0003	R	010014	I	0003	R	010050	IBDT	0004	R	000344
0003	R	010034	ILK	0003	R	000300	ISLIP	0003	R	010042	ITAG	0003	R	000740
0003	R	010015	J	0004	R	000114	JROT	0004	R	000041	JF	0004	R	010016
0003	R	010012	L	0003	R	010112	LARHDA	0003	R	004426	LAT	0004	R	000324
0004	R	000332	LK3	0004	R	000336	LB4	0004	R	000272	MP-R	0003	R	010043
0003	R	010042	NOI	0003	R	010044	VDXR	0003	R	010046	NM2	0004	R	000321
0004	R	000320	NYS	0004	R	001334	VXCI	0003	R	010037	NYS	0003	R	010041
0003	R	004232	PEAKC	0003	R	001466	PEAKD	0004	R	000172	PERC	0004	R	000342
0004	R	000270	PP-R	0003	R	000132	Q	0004	R	000271	OP-R	0003	R	000340
0004	R	000013	SIGAL	0004	R	000122	SIGAPP	0003	R	000360	SIGAP	0003	R	000340
0003	R	003604	SIGERL	0004	R	000025	SIGEL	0004	R	004756	SIGEVK	0003	R	000040
0004	R	000042	SIGERL	0003	R	010010	SIGK	0003	R	010107	SIGK-R	0003	R	000040
0004	R	024756	SIGYK	0003	R	000322	SIGYO	0003	R	010004	SIGZ	0003	R	010007
0003	R	010011	SARZP	0003	R	010017	STOI	0003	R	010020	STCZ	0003	R	001167
0003	R	010033	TAST	0003	R	003704	TAUK	0004	R	000070	TALL	0003	R	007412
0003	R	007746	TESTNC	0003	R	010013	TH	0003	R	000702	THETA	0004	R	000102
0003	R	010111	THI	0003	R	010112	THI2	0003	R	010022	TRD	0004	R	000044
0003	R	003824	USARK	0004	R	000001	USARL	0004	R	000013	USARMK	0003	R	000170
0004	R	025247	USARZK	0004	R	025432	USARZL	0004	R	000217	VA	0003	R	000043
0004	R	000144	VS	0003	R	010114	WASHCU	0003	R	010051	XAST	0003	R	000736

```

00101 1* SUBROUTINE ACH
00102 2* COMMON/PARAMT/ISKIP(30),HIS(30),Z(30),Q(30),UBAR(30),ILP-A(30),
00103 3* IBETA(30),SIGD(30),SIGAP(30),SIGX(30),DELTA-P(30),SIGZ(30),
00104 4* ZSIGEP(30),DELTA(30),DELTA(30),THETA(30),IZMOD(20),NPT(20),DELTA(30),
00105 5* 3ZL(100),X(100),COS(100),COS(100),PEAK(100),X(100),Y(100),
00106 6* 4PLT(2,100,10),PEAK(100),LAT(100),VER(100),VREF(100),ALONG(100),
00107 7* 5DRI(100),T(20),IFLAG(100),ITAG(100),TESTNG(12),D(10),C(10),SIGZ,ACH
00108 8* 4SIGV,SIGX,SQRZP,L,T,M,I,J,K,STC1,S72,STC3,TAC,TAST(10),P&K,ILK,
00109 9* 7X&S,NYS,NZS,DI,PCI,MDIR,R,NZ,NZ,INOP,INOT,NAST(30),
00110 10* 8SIE&K,LAMBDA,TIP,TIMZ,ZLI,WAS-0(100,100),UBAR(20),SIGAK(20),
00111 11* 9SIGEL(20),Z&K,SIGAK,SIGER,UBARK,THETA(40),TAUK(20),TAUD(20),
00112 12* COMMON/PARAMS/VECAT,UBARL(10),SIGAL(10),SIGEL(10),Z&L,SIGARL,JF,
00113 13* 1SIGERL,UBARRL,THETA(20),TAUL(10),TALOL(10),J&BOT(10),ERFA(6),
00114 14* 2JTOP(10),VS(20),PERC(20),ACCUR(8(20),PERCB(20),P&R,P&R,
00115 15* 3MPLR,INTK(21),MNS,NV&LB(14),LBZ(4),LB3(4),LB4(4),DATE(2),I,DEP,
00116 16* 4Y&ARY(100),X&R&F,UBAR&K(100),BETA&K(100),ALPH&K(100),SQ&AR,
00117 17* 5ANG(100),IN&CI,DEPN(100,100),SIGY&K,SIG&K(100),SIG&K(100),
00118 18* 6DELPHI,UBAR&K(100),UBAR&ZL(100)
00119 19* INTEGER TESTNG
00120 20* REAL MP,R,L,LAT,LAMBDA
00121 21* C *** THIS SUBROUTINE CALCULATES L
00122 22* C *** LATERAL TERM OF OPTIM AND ALCN6 *** TWO TERM CA ***PTION.
00123 23* 20 RETURN
00124 24* ENTRY ELIX,N)
00125 25* IF (M .GT. 0) GO TO 24
00126 26* IF (M .LT. 0) GO TO 23
00127 27* L = C.28*ABS(DELTA(KK1))/UBAR(KK1)*X
00128 28* IF (DELTA(KK1) .LT. 0.0) L = 0.0
00129 29* GO TO 25
00130 30* L = 0.28*ABS(DELTA(NNZ+ILK-1))/UBAR(NNZ+ILK-1)*X
00131 31* IF (DELTA(NNZ+ILK-1) .LT. 0.0) L = 0.0
00132 32* GO TO 25
00133 33* L = 0.28*ABS(DELTA(M))/UBAR(M)*X
00134 34* IF (DELTA(M) .LT. 0.0) L = 0.0
00135 35* 25 CONTINUE
00136 36* RETURN
00137 37* ENTRY LATER(1)
00138 38* IF (ISKIP(3) .EQ. 1) GO TO 30
00139 39* LAT(1) = 1.0
00140 40* GO TO 40
00141 41* LAT(1) = EXP(-Y*02/(2.0*SIGY*02))
00142 42* 40 RETURN
00143 43* ENTRY ALONG&K,TT)
00144 44* ALONG&K(J) = 1.0
00145 45* IF (ISKIP(6) .EQ. 2) GO TO 50
00146 46* TS = 'T'
00147 47* IF (ISKIP(6) .EQ. 0) TS = X/UBAR(KK1)
00148 48* ALONG&K(J) = EXP(-IX-UBAR(KK1)*TS*02/(2.0*SIGX*02))
00149 49* 50 RETURN
00150 50* END
    
```

END OF UNIVAC 1108 FORTRAN V. COMPILATION. C ODIAS ESTIC MESSAGE(S)

BI FOR VERT
UNIVAC 1108 FORTRAN V LEVEL 220A 0018 F5018P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17135:07

SUBROUTINE VERT ENTRY POINT 000231
STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000241
0000 *DATA 000030
0002 *BLANK 000000
0003 PARAMT 033784
0004 PARANS 028877

EXTERNAL REFERENCES (BLOCK, NAME)

0005 MERR2S
0006 EXP
0007 MERR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000084	LOL	0001	000047	30L	0001	000077	40L	0001	000017	5L
0001	000000	50L	0001	000212	70L	0001	000216	80L	0004	000016	ACCUR
0003	R 007102	ALONG	0004	R 001023	ALPHA	0004	R 001170	ANG	0003	000034	BETA
0004	R 000457	BETANK	0003	R 007774	CI	0004	R 000342	DATE	0004	R 000000	DECAY
0004	R 025446	DELPHI	0003	R 000454	DELTHP	0003	R 000406	DELA	0003	R 000444	DELY
0004	R 000345	DEP	0004	R 001335	DEPN	0003	R 001354	DOS	0004	R 000273	DTMK
0003	R 007246	DER	0004	R 000126	ERPA	0004	R 000267	H	0003	I 010014	I
0003	I 010050	IRDT	0003	I 007434	IFLAG	0004	I 000344	II	0003	I 000000	ISKIP
0003	I 007602	ITAG	0003	I 010047	ITOP	0004	I 010036	ILK	0004	I 000114	JDOT
0004	I 000041	JF	0004	I 000134	JTUP	0003	I 010015	J	0003	R 010110	LAMBDA
0003	R 004474	LAT	0004	I 000322	LRI	0004	I 000332	LB2	0004	I 000336	LB4
0004	R 000272	HPNR	0003	I 010044	NDXN	0003	I 010043	NC1	0003	I 010042	NO1
0004	I 001334	MXCI	0003	I 010034	NHZ	0004	I 000321	NVB	0004	I 000320	NVS
0003	R 001464	PEAKD	0003	I 010037	NAS	0003	I 010041	NZS	0003	R 000262	PEAKC
0003	R 000132	Q	0004	R 000172	PERC	0004	R 000243	PERCB	0004	R 000370	PPRR
0004	R 025132	SIGANK	0004	R 000271	QPIN	0003	R 010045	RAD	0004	R 000013	SIGAL
0004	R 000038	SIGEL	0003	R 000360	SIGAP	0003	R 033631	SIGARK	0003	R 033604	SIGERL
0003	R 010010	SIGX	0004	R 024756	SIGENK	0003	R 000550	SIGEP	0004	R 000042	SIGERL
0003	R 000322	SIGYO	0003	R 010107	SIGXNK	0003	R 000414	SIGXO	0004	R 024755	SIGYNK
0003	R 010017	STOI	0003	R 010004	SIGZ	0003	R 000812	SIGZO	0003	R 010011	SOR2P
0003	R 033704	TAK	0003	R 010020	STD2	0003	R 010021	STO3	0003	R 010023	TAST
0003	R 010013	TH	0004	R 000070	TAUL	0003	R 000730	TAUOL	0003	I 007746	TESTND
0003	R 010011	TIH1	0003	R 000702	TETA	0003	R 033634	THETAK	0000	R 000001	TI
0003	R 000170	UBAM	0003	R 010112	YIN2	0000	R 000003	TLIM	0003	R 010022	TRD
0004	R 000043	UBARRL	0003	R 033634	UBARK	0004	R 000001	UBARL	0003	R 033633	UBARRK
0003	R 000736	VREF	0004	R 025247	UBARZK	0004	R 025443	UBARZL	0003	R 004872	VER
0003	R 001212	XC	0004	R 000146	VS	0003	R 010114	YASHOU	0004	R 000512	XBARK
0003	R 010113	ZLIM	0003	R 002032	XX	0004	R 000346	YBARY	0003	R 000074	Z
			0003	R 033630	ZNK	0004	R 000037	ZNL	0003	R 001046	ZZL

```

00101 SUBROUTINE VERT(K,MW) VERT 20
00102 COMMON/PARAMT/ISAIP(30),M(30),Z(30),Z(30),U(AR(30),ALPHA(30), VERT 30
00103 1BETA(30),SIGV(30),SIGAP(30),SIGX(30),DELTHP(30),SIGZ(30), VERT 40
00104 2SIGEP(30),DELX(30),DELY(30),THETA(30),ZMOD(20),NPT(20),DELU(30), VERT 50
00105 3ZL(100),XR(100),EOS(100),CON(100),PEAKD(100),XX(100),YY(100), VERT 60
00106 4PLT(2,100,10),PEAKC(100),LAT(100),VER(100),WEP(100),ALCNGW(100), VERT 70
00107 5DXR(100),Y(20),IFLAG(100),ITAG(100),TEST(100),DI(100),CI(100),SIGZ, VERT 80
00108 6SIGY,SIGX,SQRZP,LTH,10,KK,ST01,ST02,ST03,TRD,TAST(10),NBK,ILK, VERT 90
00109 7KXS,NYS,NZS,NOL,HCI,NDR,RAD,RNZ,ITOP,IBOT,KAST(30), VERT 100
00110 8SIGXNK,LAHEDA,TPI,TIMZ,ZLTH,WASHOU(100,100),UPARK(20),SIGAK(20), VERT 110
00111 9SIGEK(20),ZRK,SIGARK,SIGERK,UBARRY,THETAK(40),TAUK(20),TAUOK(20), VERT 120
00112 10COMMON/PARAMS/DECAY,UBARPL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF, VERT 130
00113 11SIGERL,UBARRL,THETAL(20),TAUL(10),TAUOL(10),J30T(10),ERFK(4), VERT 140
00114 12UTOP(10),AVS(20),PERC(20),ACCU,VB(20),PERCB(20),HR,PP,R,JFPR, VERT 150
00115 13HPWK,DTM(21),NVS,AVP,ALB(14),LBZ(4),LB3(4),LB4(4),DATE(2),FIDEP, VERT 160
00116 14YBAPY(100),XBARK,UGARK(100),RETAK(100),ALPHNK(100),SQBAR, VERT 170
00117 15SANG(100),ANXCI,DEPH(100,100),SIGYNK,SIGENK(100),SIGAK(100), VERT 180
00118 16DELPHI,UBARZK(100),UBARZL(100) VERT 190
00119 INTEGER TEST10 VERT 200
00120 REAL HP,RL,LAT,LAHDA VERT 210
00121 ***** THIS SUBROUTINE CALCULATES VERTICAL AND VERTICAL REFLECTION VERT 220
00122 STC2 = 0.0 VERT 230
00123 N = IZMOD(KK) VERT 240
00124 GO TO (50,50.5),N VERT 250
00125 5 IF (ISKIP(4) .EQ. 0) GO TO 10 VERT 260
00126 ST02 = EXP(-(H(KK)-ZL(KK))**2/(2.0*SIGZ**2))+EXP(-(H(KK)-(Z.0*SIGZ**2)) VERT 270
00127 1)+ZL(KK)**2/(2.0*SIGZ**2)) VERT 280
00128 10 ST03 = 0.0 VERT 290
00129 IF (ISKIP(5) .EQ. 1) GO TO 20 VERT 300
00130 IF (ISKIP(4) .EQ. 0) ST03 = 1.0 VERT 310
00131 GO TO 60 VERT 320
00132 20 YI = 0.0 VERT 330
00133 30 YI = YI+1.0 VERT 340
00134 IF (SIGZ=0.0) 40,35,40 VERT 350
00135 35 ST03 = 0.0 VERT 360
00136 GO TO 60 VERT 370
00137 40 CONTINUE VERT 380
00138 TR = 2.0*TI*(Z(KK+1)-Z(KK)) VERT 390
00139 TLIH = ((-TR-H(KK))+2.0*COZ(KK))-ZL(KK)**2/(2.0*SIGZ**2)) VERT 400
00140 IF (LI=10.0 .GT. TLIH) GO TO 60 VERT 410
00141 ST03 = ST03+EXP(TLIH)*EXP(-(TR-H(KK)+ZL(KK)**2)/(2.0*SIGZ**2)) VERT 420
00142 1+EXP(-(TR-H(KK)-ZL(KK)**2)/(2.0*SIGZ**2)) VERT 430
00143 2+EXP(-(TR-H(KK)-(Z.0*SIGZ(KK))+ZL(KK)**2)/(2.0*SIGZ**2)) VERT 440
00144 GO TO 30 VERT 450
00145 50 ST03 = 1.0 VERT 460
00146 60 GO TO (70,60),NR VERT 470
00147 70 VERT(J) = ST03 VERT 480
00148 VREF(IJ) = ST03 VERT 490
00149 80 RETURN VERT 500
00150 END VERT 510

```

END OF LALVAC 1108 FORTRAN V COMPILATION. 7 *DIAGNOSTIC MESSAGE(S)

51 FOR PEAK
UNIVAC 1100 FORTRAN V LEVEL 2206 0018 F5010P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17135108

SUBROUTINE PEAK ENTRY POINT C00000

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000047
0000 *DATA 000014
0002 *BLANK 000000
0003 PARAMT C33754
0004 PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 NERP25
0006 NERP35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000010	IOL	0001	000034	2SL	0001	000046	40L			
0004	R	000214	ACCUR	0003	R	000324	ALPHA	0004	R	001170	ANG
0003	R	000244	BETA	0004	R	000457	METANK	0004	R	000392	DATE
0004	R	000000	DECAY	0004	R	023246	DELPHI	0003	R	000606	DELX
0003	R	000644	DELY	0004	R	000346	DEP	0003	R	001384	DO3
0004	R	000273	OTHK	0003	R	007244	DKR	0004	R	000247	HB
0003	I	010014	I	0003	I	010050	IPOT	0003	I	010036	ILK
0003	I	000000	ISKIP	0003	I	007402	ITAG	0003	I	010018	J
0004	I	000114	JBOT	0004	I	000041	JF	0003	R	010012	L
0003	R	010110	LANBDA	0003	R	004426	LAT	0004	I	000332	L83
0004	I	000334	L34	0000	I	000000	M	0003	I	010043	NCL
0003	I	010042	N01	0003	I	010044	NDXR	0004	I	000321	NVB
0004	I	000320	NVS	0004	I	001334	MXCI	0003	I	010041	NZS
0003	R	004282	PEAKC	0003	R	001666	PEAKD	0003	R	002342	PLT
0004	R	000270	PP-R	0003	R	000132	Q	0003	R	033560	SIGAK
0004	R	000013	SIGAL	0004	R	025122	SIGANK	0004	R	000040	SIGARL
0003	R	033604	SIGEL	0004	R	000025	SIGEL	0003	R	033632	SIGERK
0004	R	000042	SIGERL	0003	R	010010	SIGA	0003	R	010007	SIGV
0004	R	024755	SIGYK	0003	R	000322	SIGYD	0004	R	001147	SEBAR
0003	R	010011	SIRP	0003	R	010017	STOI	0003	R	007412	T
0003	R	010023	TAST	0003	R	033704	TAUK	0004	R	000102	TAUOL
0003	I	007746	TESTND	0003	R	010013	TH	0004	R	000044	THETAL
0003	R	010111	TIM1	0003	R	010112	TIR2	0003	R	033534	UBARK
0004	R	000001	USARL	0004	R	000613	UBARKK	0004	R	025267	UBARZK
0004	R	025433	USARZL	0004	R	000217	VP	0004	R	000146	VS
0003	R	010114	WASHOU	0003	R	010051	XAST	0003	R	002032	XX
0004	R	000346	YBAKY	0003	R	003174	YY	0003	R	033630	ZRK
0004	R	000037	ZRL	0003	R	001044	ZZL				
0001	000034	30L	0001	000034	30L	0001	000046	40L			
0004	R	001023	ALPHMK	0004	R	001023	ALPHMK	0004	R	001170	ANG
0003	R	001822	CON	0003	R	001822	CON	0004	R	000392	DATE
0003	R	001010	DELU	0003	R	001010	DELU	0003	R	000606	DELX
0003	R	007742	DI	0003	R	007742	DI	0003	R	001384	DO3
0003	R	000034	H	0003	R	000034	H	0004	R	000247	HB
0004	I	000344	II	0004	I	000344	II	0003	I	010036	ILK
0003	I	000740	ITMOD	0003	I	000740	ITMOD	0003	I	010018	J
0003	I	010016	KK	0003	I	010016	KK	0004	I	000332	L83
0004	I	000326	L82	0004	I	000326	L82	0003	I	010043	NCL
0003	I	000734	NKT	0003	I	000734	NKT	0004	I	000321	NVB
0003	I	010040	NVS	0003	I	010040	NVS	0003	I	010041	NZS
0004	R	000243	PERCB	0004	R	000243	PERCB	0003	R	002342	PLT
0003	R	010045	RAD	0003	R	010045	RAD	0003	R	033560	SIGAK
0003	R	033431	SIGARK	0003	R	033431	SIGARK	0004	R	000040	SIGARL
0003	R	000850	SIGEP	0003	R	000850	SIGEP	0003	R	033632	SIGERK
0003	R	000816	SIGEXD	0003	R	000816	SIGEXD	0003	R	010007	SIGV
0003	R	000812	SIGZO	0003	R	000812	SIGZO	0004	R	001147	SEBAR
0003	R	010021	STO3	0003	R	010021	STO3	0003	R	007412	T
0003	R	033730	TAUOK	0003	R	033730	TAUOK	0004	R	000102	TAUOL
0003	R	033334	THETAK	0003	R	033334	THETAK	0004	R	000044	THETAL
0003	R	000170	UBARL	0003	R	000170	UBARL	0003	R	033534	UBARK
0004	R	000043	UBARRL	0004	R	000043	UBARRL	0004	R	025267	UBARZK
0003	R	004736	VERP	0003	R	004736	VERP	0004	R	000146	VS
0003	R	001212	XR	0003	R	001212	XR	0003	R	002032	XX
0003	R	010113	ZLIM	0003	R	010113	ZLIM	0003	R	033630	ZRK

```

00101 10 SURFUTTE PEAK(NH,K)
00103 20 COMON/PARANT/IS=1E(30),P(30),Z(30),S(30),UBAR(30),ALPHA(30),
00103 30 1E(130),SIG U(30),SIGAP(30),SIGX(30),DELTP(30),SIGZ(30),
00103 40 2SIGEP(30),DELX(30),DELY(30),THETA(30),IZMOD(20),MPT(20),DELU(30),
00103 50 3ZL(100),XR(100),COS(100),CUN(100),PEAK(100),XX(100),YY(100),
00103 60 4PL(2,100),PEAKC(100),LAT(100),VER(100),XREF(100),ALONG(100),
00103 70 5DKR(100),T(20),IFLAG(100),ITAG(100),TESTNG(12),DI(10),CI(10),SIGZ,PEAK 80
00103 80 6SIGY,SIGA,SORZP,L,TH,I,J,KK,STOI,STOZ,STO3,TRO,TASTY(10),NRK,ILK,
00103 90 7KXS,NYS,NZS,CI,ACI,DPF,RAD,M,Z,IYCP,IBOT,XASTY(30),
00103 100 8SIGXNK,LAMBDA,TINI,TIMZ,ZLIM,ASHDU(100,100),LBARK(20),SIGAK(20),
00103 110 9SIGER(20),ZRK,SIGAK,SIGERK,UBARRK,THETAK(40),TAUK(20),TAUCK(20),
00103 120 10COMON/PARAMS/DECAY,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF,
00103 130 11SIGERL,UBARRL,THETAL(20),TALL(10),TAUOL(10),JBOT(10),ERFX(6),
00103 140 12JTOP(10),AVS(20),PERC(20),ACCUR,B(20),PERCB(20),MB,PP,R,QPMR,
00103 150 13JMP,R,OTHK(21),NYS,NVB,SL(14),LQZ(4),LB3(4),LB4(4),DATE(21),I,UEP,
00103 160 14YBARY(100),XBARX,UBARK(100),BETAN(100),ALPHA,K(100),SQBAR,
00103 170 15SANG(100),MYCI,DEPN(100,100),SIGYK,SIGENK(100),SIGAK(100),
00103 180 16DELPMI,UBARZK(100),UBARZL(100)
00103 190 17INTEGER TESTNO
00103 200 18REAL HP,R,L,LAT,LAMBDA
00103 210 19**** THIS SUBROUTINE CALCULATES THE PEAK TERM *****
00103 220 20M = 12*ND(KK)
00103 230 21GO TO (10,10,20),M
00103 240 2210 STO1 = 6(KK)/(SQRZP*SISY*UBARZK(K))
00103 250 23GO TO 25
00103 260 2420 STO1 = 6(KK)/(16.2631953072*SISY*SIGZ*UBARZK(K))
00103 270 25GO TO (30,40),N
00103 280 2630 PEAKD(J) = STO1
00103 290 2740 RETURN
00103 300 28END

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC MESSAGE(S)

91 FOR SIGMA
UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5016P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:109

SUBROUTINE SIGMA ENTRY POINT 000311
STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE C00326
0002 *DATA C00027
0003 *BLANK C00000
0004 *PARAM C33784
0005 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 NEXPAS
0006 NENR2S
0007 SCRT
0010 CCS
0011 SIN
0012 NENR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000082	10L	0001	000060	20L	0001	C00144	30L	0001	000007	4L	0001	000153	40L
0001	000014	6L	0001	000300	40L	0001	000020	8L	0004	R	000210	ACCUR	0003	R
0002	R	000226	ALPHA	0000	R	000001	ALPHAP	0004	R	001170	ANG	0003	R	000249
0004	R	000487	BETANK	0000	R	000002	BETAP	0003	R	001822	CON	0004	R	000342
0004	R	000000	DECAY	0004	R	025246	DELPHI	0003	R	000484	DELTHP	0003	R	000606
0003	R	000444	DELY	0004	R	000345	DEP	0004	R	001358	DEPN	0003	R	001384
0004	R	000373	OTHK	0003	R	007246	PAR	0004	R	000036	H	0004	R	000267
0003	I	010014	I	0003	I	010050	IRDT	0003	I	000344	II	0003	I	010036
0000	I	000000	ISAVE	0003	I	000000	ISFIP	0003	I	010047	ITOP	0003	I	000740
0003	I	010015	J	0004	I	000114	JRDT	0004	I	000134	JTOP	0003	I	010016
0003	R	010012	L	0003	R	010110	LAMBDA	0003	R	000322	LB1	0004	I	000326
0004	I	000332	LS3	0004	I	000336	LS4	0004	I	000004	N	0003	I	010035
0003	I	010043	NCT	0003	I	010042	CI	0003	I	010046	NHZ	0003	I	000744
0004	I	000321	NVS	0004	I	000320	NVS	0004	R	000172	NXS	0003	I	010040
0003	I	010041	NZS	0003	R	006342	PEAC	0004	R	000164	PEAKD	0004	R	000243
0003	R	002342	PLT	0004	R	000270	PPH	0003	R	000132	Q	0004	R	010045
0003	R	033540	SIGAK	0004	R	000013	SIGAL	0004	R	025122	SIGANK	0003	R	033631
0004	R	000440	SIGARL	0003	R	033604	SIGEL	0004	R	024786	SIGELN	0003	R	000850
0003	R	033432	SIGERL	0004	R	000042	SIGERL	0003	R	010010	SIGX	0003	R	000416
0003	R	010007	SIGY	0004	R	024755	SIGYAK	0003	R	000322	SIGYD	0003	R	000812
0004	R	001167	SRAP	0003	R	010011	SRAP	0003	R	010017	ST01	0003	R	010021
0003	R	007412	T	0003	R	010023	TAST	0003	R	000070	TAUL	0003	R	033730
0004	R	000102	TAUOL	0003	I	007746	TESTNO	0003	R	000702	THETA	0003	R	033634
0004	R	000044	THETAL	0003	R	010111	TIK1	0003	R	010022	TRD	0000	R	000008
0000	R	000046	T2	0003	R	000170	UAK	0004	R	000001	UAKL	0004	R	000813
0003	R	033433	UAKRZ	0004	R	000043	UAKRZ	0004	R	025433	UAKRZL	0004	R	000217
0003	R	004572	VER	0004	R	004576	VER	0003	R	010114	VASHOU	0003	R	010081
0004	R	000512	XBARX	0003	R	001212	X2	0003	R	000003	XY	0000	R	000007


```

00101 10 SUBROUTINE SIGMA(X,M,N,K)
00102 20 COMMON/PARAMT/ISKIP(30),M(30),Z(30),R(30),UBAR(30),ALPHA(30),
00103 30 IBETA(30),SIGV(30),SIGP(30),SIGX(30),DELTHP(30),SIGZ(30),
00104 40 SIGEP(30),DELTA(30),DELTA(30),THETA(30),IZPO(20),NPT(20),DELU(30),
00105 50 ZZLL(100),XR(100),DOS(100),CON(100),PEAKP(100),XX(100),YY(100),
00106 60 4PLT2(100,100),PEAKC(100),LAT(100),VER(100),VREF(100),ALCHGM(100),
00107 70 5DRT(100),T(20),IFLAG(100),ITAG(100),TESTNO(12),DT(10),CT(10),SIGZ,
00108 80 SIGY,SIGX,SRZPL,TH1,J,K,ST01,ST02,ST03,TRD,TAST(10),NBK,ILK,
00109 90 7NKS,MYS,NZS,NDI,NCI,NDXR,RAP,NNZ,ITOP,IJCT,XAST(30),
00110 100 SIGYNK,LAPROA,TINI,TI*2,ZLIM,WASQ(100,100),UBARK(20),SIGAK(20),
00111 110 95IGK(20),ZRK,SIGARK,SIGERK,UBARK,THETAK(40),TAUK(20),TAUK(20),
00112 120 COMMON/PARAMS/DECAY,UBAR(100),SIGAL(10),SIGEL(10),ZKL,SIGARL,JF,
00113 130 ISIGERL,UBARL,THETAL(20),TAUL(10),TAUOL(10),JBCT(10),ERFX(4),
00114 140 3MPV,DTWK(21),NVS,NVB,LB(14),LB2(4),LB3(4),LB4(4),DATE(2),I,DEP,
00115 150 4YBARY(100),XBARY,UBARK(100),ABETANK(100),ALPHNK(100),SQBAR,
00116 160 5ANG(100),NXCI,DEPA(100,100),SIGYNK,SIGENK(100),SIGAK(100),
00117 170 6DELPHI,UBARK(100),UBARZL(100),
00118 180 INTEGER TESTNO
00119 190 REAL NPWK,L,LAT,LAPROA
00120 200 ***** THIS SUBROUTINE CALCULATES THE STANDARD DEVIATIONS OF X,Y,Z,SIGM 20
00121 210 IF (IMH.GT. 0) GO TO 4
00122 220 GO TO 6
00123 230 4 ISAVE = KK
00124 240 KK = MH
00125 250 GO TO 8
00126 260 6 IF (M.GT. 0) GO TO 4C
00127 270 8 CONTINUE
00128 280 ALPHAP = 1.0/ALPHA(KK)
00129 290 BETAP = 1.0/BETA(KK)
00130 300 XY = (SIGY(KK)/SIGAP(KK))**ALPHAP
00131 310 N = IZMOD(KK)
00132 320 GO TO (20,10,20),N
00133 330 10 SIGX = SIGY(KK)
00134 340 SIGY = SIGX(KK)
00135 350 GO TO 3C
00136 360 20 T1 = SIGAP(KK)*(X+XY)**ALPHA(KK)
00137 370 T2 = (ARS(DELTHP(KK))**RAD*(X/4.3)**2
00138 380 SIGY = SQR(T1**2+T2)
00139 390 SIGX = SQR(T1/4.3)**2+SIGY(KK)**2
00140 400 XZ = (SIGZ(KK)/SIGEP(KK))**BETAP
00141 410 SIGZ = SIGEP(KK)*(X+XZ)**BETA(KK)
00142 420 30 IF (IMH.EQ. 0) GO TO 6C
00143 430 KK = ISAVE
00144 440 GO TO 6C
00145 450 40 SIGYNK = SQR((SIGX**SIN((T-ETA(M))-THETA(NNZ+ILK-1))**RAD)**2+
00146 460 1.0C5((THETA(M)-THETA(NNZ+ILK-1))**RAD)**2)
00147 470 SQBAR = (SIGYNK/SIGAP(NNZ+ILK-1))**((1.0/ALPHAP(NNZ+ILK-1))
00148 480 SIGYNK = SQR((SIGAP(NNZ+ILK-1)*(X+SQBAR)**ALPHA(NNZ+ILK-1))**2+
00149 490 1.0C5((DELTHP(NNZ+ILK-1))**RAD*(X/4.3)**2)
00150 500 SIGZ = SQR((NZZ+ILK-1)**BETA(NNZ+ILK-1))
00151 510 SQBAR = SQR((SIGZ**CDS((THETA(4)-THETA(NNZ+ILK-1))**RAD)**2+
00152 520 (SIGY**SIN((T-ETA(M))-THETA(NNZ+ILK-1))**RAD)**2)
00153 530
00154 540
00155 550
00156 560
00157 570
00158 580
00159 590
00160 600
00161 610
00162 620
00163 630
00164 640
00165 650
00166 660
00167 670
00168 680
00169 690
00170 700
00171 710
00172 720
00173 730
00174 740
00175 750
00176 760
00177 770
00178 780
00179 790
00180 800
00181 810
00182 820
00183 830
00184 840
00185 850
00186 860
00187 870
00188 880
00189 890
00190 900
00191 910
00192 920
00193 930
00194 940
00195 950
00196 960
00197 970
00198 980
00199 990
00200 1000

```

MULTILAYER DIFFUSION MODEL GCA CORP BJORKLUND

SIGN 540
SIGN 560
SIGN 560
SIGN 570
SIGN 580

ISIN(THETA(M)-THETA(INZ+ILK-1))RAD))002)
SIGNK = SQRT((L/4.31002+50BAR002)
GO CONTINUE
RETURN
END

00146
00147
00150
00151
00152

END OF UNIVAC 1108 FORTRAN V COMPILATION. O DIAGNOSTIC MESSAGE(S)

31 FOR ISO
UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5018P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17135110

SUBROUTINE ISO ENTRY POINT 000121

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 000130
0000 *DATA 000044
0002 *BLANK 000000
0003 *PARAM 033754
0004 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 NERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	000021	1176	0004	R	000216	ACCUR	0003	R	007102	ALONGW	0004	R	001023	ALPHNK	
0004	R	001170	ANG	0000	D	000010	AIC	0000	D	000002	A7	0000	D	000002	A7
0000	D	000004	A8	0000	D	000004	A9	0003	R	000264	BETA	0003	R	000264	BETA
0003	R	001822	CON	0004	R	000342	DATE	0004	R	000000	DECAY	0004	R	000000	DECAY
0003	R	001010	DELU	0003	R	000806	DELX	0003	R	000806	DELX	0004	R	000806	DELX
0003	R	007762	DI	0003	R	001356	DOS	0004	R	000273	DTMK	0004	R	000273	DTMK
0004	R	000126	ERFX	0003	R	000036	H	0004	R	000267	H8	0003	I	010014	I
0003	I	007436	IPLAG	0004	I	000344	II	0003	I	010036	ILK	0000	I	000017	I4
0003	I	007602	ITAG	0003	I	010047	ITQP	0003	I	000740	I2MOD	0003	I	010015	J
0004	I	000041	JF	0004	I	000134	JTDP	0003	I	010016	KK	0003	R	010110	LAMBDA
0003	R	000426	LAT	0004	I	000322	L81	0004	I	000326	L82	0004	I	000326	L84
0000	I	000016	M	0004	R	000272	MPAF	0003	I	010035	N8K	0003	I	010042	ND1
0003	I	010044	NOXR	0003	I	010046	NH2	0003	I	000764	NPT	0004	I	000320	NVS
0004	I	001334	NXCI	0003	I	010037	NXS	0003	I	010040	NYS	0003	I	000320	NVS
0003	R	001466	PEAKD	0004	R	000172	PERC	0004	R	000243	PERCB	0003	R	000242	PLT
0003	R	000132	Q	0004	R	000271	QPMK	0003	R	010045	RAD	0003	R	000270	PPWR
0004	R	000122	SIGANK	0003	R	000360	SIGAP	0003	R	000360	SIGAK	0003	R	000013	SIGAL
0004	R	000025	SIGEL	0004	R	000256	SIGENK	0003	R	000550	SIGEP	0004	R	000040	SIGEL
0003	R	010010	SIGX	0003	R	010107	SIGANK	0003	R	000416	SIGXD	0003	R	000042	SIGERL
0003	R	000322	SIGTO	0003	R	010006	SIGZ	0003	R	000512	SIGZD	0004	R	000042	SIGERL
0003	R	010017	STOI	0003	R	010020	STOZ	0003	R	000416	SIGXD	0004	R	000042	SIGERL
0003	R	033704	TAUK	0004	R	000070	TAUL	0003	R	010021	STO3	0003	R	010011	SQR2P
0003	R	010013	TM	0003	R	000702	THEA	0003	R	000712	T	0003	R	010023	TAST
0003	R	010112	THZ	0003	R	010022	TRC	0003	R	000102	TAJOL	0003	R	000774	TESTNO
0004	R	000513	UBARK	0003	R	000416	UBARK	0003	R	000044	THETAL	0003	R	010111	TIM1
0004	R	000217	VB	0003	R	000572	VER	0004	R	000043	UBARL	0004	R	000001	UBARL
0003	R	010051	XAST	0004	R	000512	YBARX	0003	R	000416	VS	0004	R	010114	WASHOU
0003	R	002176	YY	0003	R	000074	Z	0003	R	000322	XX	0004	R	000326	YBAR
0003	R	001046	ZZL					0003	R	000320	ZRK	0004	R	000037	ZRL

```

00101 SUBROUTINE ISO(INR,MT)
00102 COMMON/PARAMT/ISIP(30),MISO(1,2,30),Q(30),UBARK(30),ALPHA(30),
00103 1BETAL(30),SIGVD(30),SIGAP(30),SIGXC(30),DELTHP(30),SIGZC(30),
00104 2SIGEP(30),DELX(30),DELY(30),THETA(30),JZMD(20),NPT(20),DELU(30),
00105 3ZL(100),ARI(100),DOS(100),CON(100),PEAK(100),XX(100),YY(100),
00106 4PLT(2,100,100),PEAK(100),LAT(100),VER(100),VREF(100),ALONGW(100),
00107 5UKR(100),T(20),IFLAG(100),ITAG(100),TESTNO(12),DI(10),CI(10),SIGZ,
00108 6SIGY,SIGZ,SQZP,L,THI,J,K,K,STOI,STO2,STO3,TRD,TAST(10),PBR,ILK,
00109 7NXS,NYS,NZS,NO1,NCI,NDIR,RAD,NW2,ITOP,IBOT,XAST(30),
00110 8SIGENK,LAMBDA,TIM1,TIM2,ZLIM,WASHOU(100,100),UBARK(20),SIGAK(20),
00111 9SIGEK(20),ZRR,SIGARK,SIGERK,UBARK,THETAK(40),TAUK(20),TAUDK(20),
00112 10COMMON/PARAMS/DECAY,UBARK(10),SIGAL(10),SIGEL(10),ZRL,SIGRL,JF,
00113 11SIGERL,USARL,THETA(20),TAUL(10),TAUL(10),JDOT(10),ERFX(4),
00114 12JTOP(10),V(20),PERC(20),ACCUR,V(20),PERCB(20),H9,PPWR,PPWR,
00115 13JMPIN,DTMK(21),NVS,HVB,LB(14),LB2(14),LB3(4),LB(4),DATE(12),II,DEP,
00116 14YBARY(100),XBARK,UBARK(100),XBETANK(100),ALPHNK(100),SQBAR,
00117 15SANG(100),NXCI,DEPN(100,100),SIGYNK,SIGENK(100),SIGANK(100),
00118 16DELPHI,UBARK(100),UBARZL(100)
00119 17
00120 18
00121 19
00122 20
00123 21
00124 22
00125 23
00126 24
00127 25
00128 26
00129 27
00130 28
00131 29
00132 30
00133 31
00134 32
00135 33
00136 34
00137 35
00138 36
00139 37
00140 38
00141 39
00142 40
00143 41
00144 42
00145 43
00146 44
00147 45
00148 46
00149 47
00150 48
00151 49
00152 50
00153 51
00154 52
00155 53
00156 54
00157 55
00158 56
00159 57
00160 58
00161 59
00162 60
00163 61
00164 62
00165 63
00166 64
00167 65
00168 66
00169 67
00170 68
00171 69
00172 70
00173 71
00174 72
00175 73
00176 74
00177 75
00178 76
00179 77
00180 78
00181 79
00182 80
00183 81
00184 82
00185 83
00186 84
00187 85
00188 86
00189 87
00190 88
00191 89
00192 90
00193 91
00194 92
00195 93
00196 94
00197 95
00198 96
00199 97
00200 98
00201 99
00202 100
00203 101
00204 102
00205 103
00206 104
00207 105
00208 106
00209 107
00210 108
00211 109
00212 110
00213 111
00214 112
00215 113
00216 114
00217 115
00218 116
00219 117
00220 118
00221 119
00222 120
00223 121
00224 122
00225 123
00226 124
00227 125
00228 126
00229 127
00230 128
00231 129
00232 130
00233 131
00234 132
00235 133
00236 134
00237 135
00238 136
00239 137
00240 138
00241 139
00242 140
00243 141
00244 142
00245 143
00246 144
00247 145
00248 146
00249 147
00250 148
00251 149
00252 150
00253 151
00254 152
00255 153
00256 154
00257 155
00258 156
00259 157
00260 158
00261 159
00262 160
00263 161
00264 162
00265 163
00266 164
00267 165
00268 166
00269 167
00270 168
00271 169
00272 170
00273 171
00274 172
00275 173
00276 174
00277 175
00278 176
00279 177
00280 178
00281 179
00282 180
00283 181
00284 182
00285 183
00286 184
00287 185
00288 186
00289 187
00290 188
00291 189
00292 190
00293 191
00294 192
00295 193
00296 194
00297 195
00298 196
00299 197
00300 198
00301 199
00302 200
00303 201
00304 202
00305 203
00306 204
00307 205
00308 206
00309 207
00310 208
00311 209
00312 210
00313 211
00314 212
00315 213
00316 214
00317 215
00318 216
00319 217
00320 218
00321 219
00322 220
00323 221
00324 222
00325 223
00326 224
00327 225
00328 226
00329 227
00330 228
00331 229
00332 230
00333 231
00334 232
00335 233
00336 234
00337 235
00338 236
00339 237
00340 238
00341 239
00342 240
00343 241
00344 242
00345 243
00346 244
00347 245
00348 246
00349 247
00350 248
00351 249
00352 250
00353 251
00354 252
00355 253
00356 254
00357 255
00358 256
00359 257
00360 258
00361 259
00362 260
00363 261
00364 262
00365 263
00366 264
00367 265
00368 266
00369 267
00370 268
00371 269
00372 270
00373 271
00374 272
00375 273
00376 274
00377 275
00378 276
00379 277
00380 278
00381 279
00382 280
00383 281
00384 282
00385 283
00386 284
00387 285
00388 286
00389 287
00390 288
00391 289
00392 290
00393 291
00394 292
00395 293
00396 294
00397 295
00398 296
00399 297
00400 298
00401 299
00402 300
00403 301
00404 302
00405 303
00406 304
00407 305
00408 306
00409 307
00410 308
00411 309
00412 310
00413 311
00414 312
00415 313
00416 314
00417 315
00418 316
00419 317
00420 318
00421 319
00422 320
00423 321
00424 322
00425 323
00426 324
00427 325
00428 326
00429 327
00430 328
00431 329
00432 330
00433 331
00434 332
00435 333
00436 334
00437 335
00438 336
00439 337
00440 338
00441 339
00442 340
00443 341
00444 342
00445 343
00446 344
00447 345
00448 346
00449 347
00450 348
00451 349
00452 350
00453 351
00454 352
00455 353
00456 354
00457 355
00458 356
00459 357
00460 358
00461 359
00462 360
00463 361
00464 362
00465 363
00466 364
00467 365
00468 366
00469 367
00470 368
00471 369
00472 370
00473 371
00474 372
00475 373
00476 374
00477 375
00478 376
00479 377
00480 378
00481 379
00482 380
00483 381
00484 382
00485 383
00486 384
00487 385
00488 386
00489 387
00490 388
00491 389
00492 390
00493 391
00494 392
00495 393
00496 394
00497 395
00498 396
00499 397
00500 398
00501 399
00502 400
00503 401
00504 402
00505 403
00506 404
00507 405
00508 406
00509 407
00510 408
00511 409
00512 410
00513 411
00514 412
00515 413
00516 414
00517 415
00518 416
00519 417
00520 418
00521 419
00522 420
00523 421
00524 422
00525 423
00526 424
00527 425
00528 426
00529 427
00530 428
00531 429
00532 430
00533 431
00534 432
00535 433
00536 434
00537 435
00538 436
00539 437
00540 438
00541 439
00542 440
00543 441
00544 442
00545 443
00546 444
00547 445
00548 446
00549 447
00550 448
00551 449
00552 450
00553 451
00554 452
00555 453
00556 454
00557 455
00558 456
00559 457
00560 458
00561 459
00562 460
00563 461
00564 462
00565 463
00566 464
00567 465
00568 466
00569 467
00570 468
00571 469
00572 470
00573 471
00574 472
00575 473
00576 474
00577 475
00578 476
00579 477
00580 478
00581 479
00582 480
00583 481
00584 482
00585 483
00586 484
00587 485
00588 486
00589 487
00590 488
00591 489
00592 490
00593 491
00594 492
00595 493
00596 494
00597 495
00598 496
00599 497
00600 498
00601 499
00602 500
00603 501
00604 502
00605 503
00606 504
00607 505
00608 506
00609 507
00610 508
00611 509
00612 510
00613 511
00614 512
00615 513
00616 514
00617 515
00618 516
00619 517
00620 518
00621 519
00622 520
00623 521
00624 522
00625 523
00626 524
00627 525
00628 526
00629 527
00630 528
00631 529
00632 530
00633 531
00634 532
00635 533
00636 534
00637 535
00638 536
00639 537
00640 538
00641 539
00642 540
00643 541
00644 542
00645 543
00646 544
00647 545
00648 546
00649 547
00650 548
00651 549
00652 550
00653 551
00654 552
00655 553
00656 554
00657 555
00658 556
00659 557
00660 558
00661 559
00662 560
00663 561
00664 562
00665 563
00666 564
00667 565
00668 566
00669 567
00670 568
00671 569
00672 570
00673 571
00674 572
00675 573
00676 574
00677 575
00678 576
00679 577
00680 578
00681 579
00682 580
00683 581
00684 582
00685 583
00686 584
00687 585
00688 586
00689 587
00690 588
00691 589
00692 590
00693 591
00694 592
00695 593
00696 594
00697 595
00698 596
00699 597
00700 598
00701 599
00702 600
00703 601
00704 602
00705 603
00706 604
00707 605
00708 606
00709 607
00710 608
00711 609
00712 610
00713 611
00714 612
00715 613
00716 614
00717 615
00718 616
00719 617
00720 618
00721 619
00722 620
00723 621
00724 622
00725 623
00726 624
00727 625
00728 626
00729 627
00730 628
00731 629
00732 630
00733 631
00734 632
00735 633
00736 634
00737 635
00738 636
00739 637
00740 638
00741 639
00742 640
00743 641
00744 642
00745 643
00746 644
00747 645
00748 646
00749 647
00750 648
00751 649
00752 650
00753 651
00754 652
00755 653
00756 654
00757 655
00758 656
00759 657
00760 658
00761 659
00762 660
00763 661
00764 662
00765 663
00766 664
00767 665
00768 666
00769 667
00770 668
00771 669
00772 670
00773 671
00774 672
00775 673
00776 674
00777 675
00778 676
00779 677
00780 678
00781 679
00782 680
00783 681
00784 682
00785 683
00786 684
00787 685
00788 686
00789 687
00790 688
00791 689
00792 690
00793 691
00794 692
00795 693
00796 694
00797 695
00798 696
00799 697
00800 698
00801 699
00802 700
00803 701
00804 702
00805 703
00806 704
00807 705
00808 706
00809 707
00810 708
00811 709
00812 710
00813 711
00814 712
00815 713
00816 714
00817 715
00818 716
00819 717
00820 718
00821 719
00822 720
00823 721
00824 722
00825 723
00826 724
00827 725
00828 726
00829 727
00830 728
00831 729
00832 730
00833 731
00834 732
00835 733
00836 734
00837 735
00838 736
00839 737
00840 738
00841 739
00842 740
00843 741
00844 742
00845 743
00846 744
00847 745
00848 746
00849 747
00850 748
00851 749
00852 750
00853 751
00854 752
00855 753
00856 754
00857 755
00858 756
00859 757
00860 758
00861 759
00862 760
00863 761
00864 762
00865 763
00866 764
00867 765
00868 766
00869 767
00870 768
00871 769
00872 770
00873 771
00874 772
00875 773
00876 774
00877 775
00878 776
00879 777
00880 778
00881 779
00882 780
00883 781
00884 782
00885 783
00886 784
00887 785
00888 786
00889 787
00890 788
00891 789
00892 790
00893 791
00894 792
00895 793
00896 794
00897 795
00898 796
00899 797
00900 798
00901 799
00902 800
00903 801
00904 802
00905 803
00906 804
00907 805
00908 806
00909 807
00910 808
00911 809
00912 810
00913 811
00914 812
00915 813
00916 814
00917 815
00918 816
00919 817
00920 818
00921 819
00922 820
00923 821
00924 822
00925 823
00926 824
00927 825
00928 826
00929 827
00930 828
00931 829
00932 830
00933 831
00934 832
00935 833
00936 834
00937 835
00938 836
00939 837
00940 838
00941 839
00942 840
00943 841
00944 842
00945 843
00946 844
00947 845
00948 846
00949 847
00950 848
00951 849
00952 850
00953 851
00954 852
00955 853
00956 854
00957 855
00958 856
00959 857
00960 858
00961 859
00962 860
00963 861
00964 862
00965 863
00966 864
00967 865
00968 866
00969 867
00970 868
00971 869
00972 870
00973 871
00974 872
00975 873
00976 874
00977 875
00978 876
00979 877
00980 878
00981 879
00982 880
00983 881
00984 882
00985 883
00986 884
00987 885
00988 886
00989 887
00990 888
00991 889
00992 890
00993 891
00994 892
00995 893
00996 894
00997 895
00998 896
00999 897
01000 898

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC MESSAGE(S)

MULTILAYER DIFFUSION MODEL GCA COPP BJORNLUND

DATE 121249 PAGE 51

```

0004 R 025433 UBARZL      0004 R 000217 VB      0003 R 006572 VER      0003 R 006734 VREF      0004 R 000146 VS
0003 R 010114 WASHOU      0003 R 010051 XAST      0004 R 000512 XBARY      0000 R 000013 XCI      0003 R 001212 XR
0003 R 002032 XA          0000 R 000002 X1          0004 R 000344 XBARY      0003 R 002176 YI      0000 R 000003 YI
0003 R 000074 Z          0003 R 010113 ZLIM          0003 R 033430 ZRK      0004 R 000037 ZRL      0003 R 001046 ZZL

```

```

00101 10 SUBROUTINE COORD(N,M,X,Y,ZD,YO,ASP,XS,ICK) CORD 20
00102 20 COMMON/PARAMT/ISKIP(30),H(30),Z(30),Q(30),UBAR(30),ALPHA(30), CORD 30
00103 30 IBETA(30),SIGYD(30),SIGAP(30),SIGX(30),DELTHP(30),SIGZ(30), CORD 40
00104 40 SIGEPI(30),DELX(30),DELY(30),THETA(30),IZMOD(20),NPT(20),DELU(30), CORD 50
00105 50 SZL(100),XR(100),DGS(100),CON(100),PEAKD(100),XR(100),YY(100), CORD 60
00106 60 NPT(12,100,10),PEAKC(100),LAT(100),VER(100),VREF(100),ALONG(100), CORD 70
00107 70 SDXR(100),T(20),IFLAG(100),ITAG(100),TESTNO(12),DI(10),C(10),SIGZ, CORD 80
00108 80 SIGYASIGZ,SDREP,LATH,J,K,KSTOI,STOZ,STO3,TRD,PAST(10),NBR,ILY, CORD 90
00109 90 7AKS,NYS,MZS,NDI,NCI,NOKR,RAD,NHZ,ITOP,ISOT,XAST(30), CORD 100
00110 100 SIGENK,LAMBDA,T(1),T(2),ZLIM,WASHOU(100,100),UBARK(20),SIGAK(20), CORD 110
00111 110 SIGEK(20),ZRP,SIGARK,SIGENK,UBARK,THEYAK(40),TAUK(20),TAUDK(20), CORD 120
00112 120 COMMON/PARAMS/DECAV,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF, CORD 130
00113 130 SIGERL,UBARRL,THEYAL(20),TAUL(10),TAUDL(10),JBCY(10),ERFK(1), CORD 140
00114 140 ZJTOP(10),VS(20),PERC(20),ACCUR,VB(20),PERCB(20),MB,PPWR,UPWR, CORD 150
00115 150 JHPWR,DTKH(2),NVS,NVB,LB(14),LBZ(4),LB3(4),LB4(4),DATE(2),II,DEP, CORD 160
00116 160 YBARY(100),XBARK,UBARK(100),GETANK(100),ALPHMK(100),SGBAR, CORD 170
00117 170 SANG(100),NXC1,DEPH(100,100),SIGYNK,SIGENK(100),SIGANK(100), CORD 180
00118 180 DELPHI,UBARK(100),UBARKZ(100) CORD 190
00119 190 INTEGER TESTNO CORD 200
00120 200 REAL MPWR,L,LAT,LAMBDA CORD 210
00121 210 ***** THIS SUBROUTINE TRANSLATES AND ROTATES THE FIXED INPUT ***** CORD 220
00122 220 C ***** COORDINATES RELATIVE TO A SYSTEM WITH POSITIVE X AXIS ***** CORD 230
00123 230 C ***** ALONG THE WIND DIRECTION THETA. IT ALSO DETERMINES IF ***** CORD 240
00124 240 C ***** THE RECEPTOR COORDINATES LY WITHIN AN ANGLE OF ONE- ***** CORD 250
00125 250 C ***** HALF DELPHI FROM THETA CORD 260
00126 260 IF (ICK .NE. 2) GO TO 20 CORD 270
00127 270 IF (THETA(NNZ+ILK-1) .GE. 180.0) THPL = (THETA(NNZ+ILK-1)-180.0)* CORD 280
00128 280 IRAD CORD 290
00129 290 IF (THETA(NNZ+ILK-1) .LT. 180.0) THPL = (THETA(NNZ+ILK-1)+180.0)* CORD 300
00130 300 IRAD CORD 310
00131 310 20 IF (THETA(H) .GE. 180.0) THP = (THETA(H)-180.0)*RAD CORD 320
00132 320 IF (THETA(H) .LT. 180.0) THP = (THETA(H)+180.0)*RAD CORD 330
00133 330 IF (ISKIP(2) .EQ. 1) GO TO 40 CORD 340
00134 340 X1 = SQRT(XD**2+YD**2) CORD 350
00135 350 Y1 = ACOS(YD/X1) CORD 360
00136 360 IF (X1 .EQ. 0) Z3,22,23 CORD 370
00137 370 22 Y1 = 0.0 CORD 380
00138 380 23 IF (XD .LT. 0) Y1 = 6.2831853072-Y1 CORD 390
00139 390 DA = SORT(DELY(H)*2+DELY(H)*2) CORD 400
00140 400 DY = ACS(DELY(H)/DX) CORD 410
00141 410 IF (DX = 0) 26,25,26 CORD 420
00142 420 25 DY = 0.0 CORD 430
00143 430 26 IF (DELY(H) .LT. 0) DY = 6.2831853072-DY CORD 440
00144 440 GU TO 60 CORD 450
00145 450 40 X1 = XC CORD 460
00146 460 Y1 = YD*RAD CORD 470
00147 470 DX = DELX(H) CORD 480
00148 480 DY = DELY(H)*RAD CORD 490
00149 490 60 IF (ICK .NE. 2) GO TO 100 CORD 500
00150 500 IF (ITH-DY) 70,100,70 CORD 510
00152 510

```

```

00155 510 70 IF (THP-DY) 60,100,80 CORD 520
00160 510 80 ALP = ABS(TM-DY) CORD 530
00161 510 IF (ALP .GT. 3.1415926536) ALP = 6.2831853072-ALP CORD 540
00163 510 EXP = SORT(XAST(M)*2-DX*2-2.0*XAST(M)*DX*CD5(ALP)) CORD 550
00164 510 R = (DX*2+XAST(M)*2-DX*2)/(2.0*DX*XAST(M)) CORD 560
00165 510 IF (B .GT. 1.0) B = 1.0 CORD 570
00167 510 IF (B .LT. -1.0) B = -1.0 CORD 580
00171 510 DEL = ACOS(B) CORD 590
00172 510 DX = DXP CORD 600
00173 510 IF (DXP=0.0) 81,.81 CORD 610
00176 510 DY = 0.0 CORD 620
00177 510 GO TO 100 CORD 630
00200 510 81 CONTINUE CORD 640
00201 510 IF (ABS(TM-DY) .GT. 3.1415926536) 60 TO 82 CORD 650
00203 510 IF (TM-DY) 85,90,95 CORD 660
00204 510 82 IF (TM-DY) 95,90,85 CORD 670
00211 510 85 DY = THP-DEL CORD 680
00212 510 IF (DY .LT. 0.0) DY = 6.2831853072-DY CORD 690
00214 510 GO TO 100 CORD 700
00215 510 90 DY = THP CORD 710
00216 510 GO TO 100 CORD 720
00217 510 95 DY = THP+DEL CORD 730
00220 510 IF (DY .GE. 6.2831853072) DY = DY-6.2831853072 CORD 740
00222 510 100 S = ABS(YI-DY) CORD 750
00223 510 IF (S .GT. 3.1415926536) S = 6.2831853072-S CORD 760
00225 510 XS = SORT(XI*2-DX*2-2.0*XI*DX*CD5(S)) CORD 770
00226 510 R = (XI*2+XS*2-DX*2)/(2.0*XI*XS) CORD 780
00227 510 IF (B .GT. 1.0) B = 1.0 CORD 790
00231 510 IF (B .LT. -1.0) B = -1.0 CORD 800
00233 510 XCI = ACOS(B) CORD 810
00234 510 IF (ABS(YI-DY) .GT. 3.1415926536) 60 TO 110 CORD 820
00236 510 IF (YI-DY) 130,120,140 CORD 830
00241 510 110 IF (YI-DY) 140,120,130 CORD 840
00244 510 120 ASP = YI CORD 850
00245 510 IF (XCI .GE. 3.0) ASP = ASP+3.1415926536 CORD 860
00247 510 GO TO 150 CORD 870
00250 510 130 ASP = YI-XCI CORD 880
00251 510 IF (ASP .LT. 0.0) ASP = 6.2831853072+ASP CORD 890
00253 510 GO TO 150 CORD 900
00254 510 140 ASP = YI+XCI CORD 910
00255 510 IF (ASP .GE. 6.2831853072) ASP = ASP-6.2831853072 CORD 920
00257 510 150 CONTINUE CORD 930
00260 510 TI = THP CORD 940
00261 510 IF (ICK .EQ. 2) TI = THPL CORD 950
00263 510 PHI = ADS(ASP-TI) CORD 960
00264 510 IF (PHI .GT. 3.1415926536) PHI = 6.2831853072-PHI CORD 970
00266 510 IF (PHI .LE. TRD) GO TO 180 CORD 980
00270 510 N = 9 CORD 990
00271 510 ITAG(J) = 9 CORD 1000
00272 510 X = XS CORD 1010
00273 510 RETURN CORD 1020
00274 510 180 X = X*CD5(PHI) CORD 1030
00275 510 Y = Y*ASIN(PHI) CORD 1040
00276 510 IF (ABS(ASP-TI) .GT. 3.1415926536) 60 TO 182 CORD 1050
00300 510 IF (ASP-TI) 185,190,190 CORD 1060
00303 510 182 IF (ASP-TI) 190,190,185 CORD 1070
00306 510 185 Y = -Y CORD 1080
00307 510 190 CONTINUE CORD 1090

```

MULTILAYER DIFFUSION MODEL GCA CORP BJORKLUND

DATE 121269 PAGE 53

CORD1100
CORD1110
CORD1120

00310 1090
00311 1100
00312 1110
ITAG(J) = 0
RETURN
END

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 DIAGNOSTIC MESSAGE(S)

SI FOR SGP

UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F5019P
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:113

SUBROUTINE SGP ENTRY POINT 001071

USARS ENTRY POINT 001151

DEPSO ENTRY POINT 001231

BETAK ENTRY POINT 001265

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 001341
0000 *DATA 000063
0002 *BLANK 000000
0003 PARAMT 033754
0004 PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 NEXP68
0006 SIN
0007 COS
0010 ATAN
0011 SQRT
0012 EXP
0013 NERR35

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001 000053 10L	0001 000042 1256	0001 000240 1736	0001 000057 20L	0001 001000 2726
0001 000070 30L	0001 000107 35L	0001 000117 40L	0001 000142 42L	0001 000020 5L
0001 000312 50L	0001 000376 52L	0001 000427 58L	0001 000475 58L	0001 000501 40L
0001 000373 65L	0001 001031 90L	0001 001037 95L	0004 R 000216 ACCUR	0003 R 007102 ALONG#
0003 R 000326 ALPHA	0004 R 001023 ALPHNK	0004 R 001170 ANG	0003 R 000264 BETA	0004 R 000657 BETANK
0003 R 007774 CI	0003 R 001522 CON	0004 R 000342 DATE	0004 R 000000 DECAY	0004 R 025266 DELPHI
0003 R 000454 DELTMP	0003 R 001010 DELU	0003 R 000606 DELX	0003 R 000644 DELY	0004 R 000348 DEP
0004 R 001335 DEPN	0003 R 007762 DI	0003 R 001356 DOS	0004 R 000273 DTHK	0004 R 007246 DXR
0004 R 000126 ERFX	0003 R 000034 H	0004 R 000267 HB	0000 R 000002 HHNK	0000 R 000003 HMRK
0003 I 010014 I	0003 I 010050 ICDT	0003 I 007436 IFLAG	0004 I 000344 II	0003 I 010036 ILX
0003 I 000000 ISKIP	0003 I 007602 ITAG	0003 I 010047 ITOP	0003 I 000740 IZMOD	0003 I 010015 J
0004 I 000114 JBOT	0004 I 000041 JF	0004 I 000134 JTOP	0003 I 010016 KK	0003 R 010012 L
0003 R 010110 LAMDA	0003 R 004426 LAT	0004 I 000322 LBI	0004 I 000326 LB2	0004 I 000332 LB3
0004 I 000336 L94	0000 I 000005 M	0000 I 000001 MN	0004 R 000272 MPAR	0003 I 010035 N8K
0003 I 010043 NC1	0003 I 010042 NC1	0003 I 010046 NDXR	0003 I 010046 NX2	0003 I 000764 NPT
0004 I 000321 NVB	0004 I 000320 NVS	0004 I 001334 NXCI	0003 I 010040 NYS	0003 I 000743 PERC8
0003 I 010041 NZS	0003 R 006262 PEAKC	0003 R 001666 PEAKO	0004 R 000172 PERC	0004 R 000132 Q
0000 R 000015 PERK	0003 R 002342 PLT	0004 R 000270 PPWR	0000 R 000010 PWR	0003 R 000132 Q
0004 R 000071 QPXR	0003 R 010045 RAD	0000 R 000000 S	0000 R 000006 S61	0003 R 000007 S62
0000 R 000004 S63	0003 R 003560 RIGAK	0004 R 000013 SIGAL	0004 R 025122 SIGANK	0003 R 000360 SIGAP
0003 R 033631 SIGARY	0004 R 000040 SIGARL	0003 R 033604 SIGEL	0004 R 000025 SIGEL	0004 R 024756 SIGENK


```

00141 420 30 IF (IN.EQ.2) GO TO 35
00143 430 S61 = SIGEK(N)
00144 440 S62 = SIGEK(N-1)
00145 450 PWR = PWR+1.0
00146 460 GO TO 40
00147 470 35 S61 = SIGAK(N)
00148 480 S62 = SIGAK(N-1)
00149 490 PWR = PWR+1.0
00150 500 IF (IN.EQ.1) GO TO 42
00151 510 S = S+(ZH-Z(N))*((S61-S62)/(Z(N+1)-Z(N)))+(ZH-Z(N))*S62/2.0
00152 520 42 S16 = (S+(S63*(HMK*PWR-ZRK*PWR)/(PWR*(HMK-ZRK)*ZRK*(PWR-1.0
00153 530 )))))/(RAD/HMK)
00154 540 RETURN
00155 550 ENTRY UBARS(ZH,N,Z,UBHK)
00156 560 SUBROUTINE UBARS CALCULATES UBARK, X NK, Y NK, CAP THETA (ANG)
00157 570 XBARA = 0.0
00158 580 YBARY(12) = 0.0
00159 590 VV = VS(11)
00160 600 PWR = PWR+1.0
00161 610 IF (JF.EQ.2) VV = -VB(11)
00162 620 IF (IN.EQ.1) GO TO 50
00163 630 MN = N-1
00164 640 DO 45 M=1,MN
00165 650 S1 = SIN(DTHK(N+1))-SIN(DTHK(1))
00166 660 S2 = COS(DTHK(N+1))-COS(DTHK(1))
00167 670 S = UBARK(N)/(VV*(DTHK(N+1)-DTHK(1)))/(Z(N+1)-Z(N))
00168 680 XBARX = XBARX+(S1*S)
00169 690 YBARY(12) = YBARY(12)+(S2*(-S))
00170 700 45 CONTINUE
00171 710 S = ((DTHK(N+1)-DTHK(1))/(Z(N+1)-Z(N)))+(ZH-Z(N))*DTHK(N)
00172 720 S1 = SIN(S)-SIN(DTHK(N))
00173 730 S2 = COS(S)-COS(DTHK(N))
00174 740 IF (IN.EQ.1) GO TO 52
00175 750 UBHK = ((UBARK(N)-UBARK(N-1))/(Z(N+1)-Z(N)))+(ZH-Z(N))/2.0*
00176 760 1(UBARK(N-1)/2.0)
00177 770 GO TO 54
00178 780 52 UBHK = (UBARK*(ZH*PWR-ZRK*PWR))/(PWR*(ZH-ZRK)*ZRK*(PWR-1.0))
00179 790 54 S = UBHK/(VV*(DTHK(N+1)-DTHK(1)))/(Z(N+1)-Z(N))
00180 800 XBARX = XBARX+(S1*S)
00181 810 YBARY(12) = YBARY(12)+(S2*(-S))
00182 820 ANG(12) = ATANIYBARY(12)/XBARX
00183 830 IF (XBARX.GE.0.0) GO TO 60
00184 840 IF (YBARY(12).GE.0.0) GO TO 56
00185 850 ANG(12) = ANG(12)-3.1415926536
00186 860 GO TO 60
00187 870 56 ANG(12) = ANG(12)+3.1415926536
00188 880 60 SQBAR = SQR(XBARX**2+YBARY(12)**2)
00189 890 UBARK(12) = SQBAR*VV/ZH
00190 900 RETURN
00191 910 ENTRY DEPSO(X,N,IZ)
00192 920 SUBROUTINE DEPSO CALCULATES ALL OF THE DEPOSITION EQUATION EXCEPT
00193 930 THE LATERAL TERM
00194 940 ZH = ZL(12)
00195 950 VV = VS(11)
00196 960 XXX = X
00197 970 PERK = PERC(11)
00198 980 IF (JF.EQ.1) GO TO 65
00199 990 ZH = HB
00200 1000

```

```

00243 100* VV = VB(11) SGP 1010
00244 101* XXX = X*(SIGZD(N)/SIGENK(IZ))*((1.0/BETANK(IZ)) SGP 1020
00245 102* PERK = PERCB(11) SGP 1030
00246 103* T(N) = 1.0 SGP 1040
00247 104* 65 S3 = VV*XXX/UBARK(IZ) SGP 1050
00250 105* S2 = SIGENK(IZ)*XXX*BETANK(IZ) SGP 1060
00251 106* S1 = EXP(-0.8*((IZH-ZH)/S2)**2) SGP 1070
00252 107* S2 = EXP(-0.8*((IZH-ZH)/S2)**2) SGP 1080
00253 108* XNKK = SIGENK(IZ)*XXX*(BETANK(IZ)+1.0) SGP 1090
00254 109* XJNK = (((1.0-BETANK(IZ))*S3*BETANK(IZ)+ZH)/XNKK)*S1 SGP 1100
00255 110* XNKK = ((2.0*BETANK(IZ)+Z(N+1))-BETANK(IZ)+ZH*(1.0-BETANK(IZ))*S3)/SGP 1110
00256 111* XNKK)*S2 SGP 1120
00257 112* XY = (SIGYQ(N)/SIGENK(IZ))*((1.0/ALPHNKK(IZ)) SGP 1130
00258 113* SIGNKK = SQR((SIGENK(IZ)*(X+Y)*ALPHNKK(IZ))*2+SIGENK(IZ)*XXX)*SGP 1140
00259 114* 10BETANK(IZ)*YBAPY(IZ)/ZH)*S2 SGP 1150
00260 115* DEP = ((N)*PERK*(N)/((6.2831853072*SIGNKK*FLOAT(INXC1)))*XJNK* SGP 1160
00261 116* XNKK) SGP 1170
00262 117* RETURN SGP 1180
00263 118* ENTRY BETAK(IZH,N,IZ) SGP 1190
00264 119* SUBROUTINE DETAK CALCULATES BETA NK AND ALPHA NK SGP 1200
00265 120* S1 = 0.0 SGP 1210
00266 121* S2 = 0.0 SGP 1220
00267 122* IF (N.EQ. 1) GO TO 90 SGP 1230
00270 123* DO 70 M=1,MN SGP 1240
00271 124* MN = N-1 SGP 1250
00272 125* S1 = S1+BETA(M)*(Z(N+1)-Z(M)) SGP 1260
00273 126* S2 = S2+ALPHA(M)*(Z(N+1)-Z(M)) SGP 1270
00274 127* 70 CONTINUE SGP 1280
00275 128* BETANK(IZ) = (S1*BETA(N)*(ZH-Z(N)))/ZH SGP 1290
00300 129* ALPHNKK(IZ) = (S2*ALPHA(N)*(ZH-Z(N)))/ZH SGP 1300
00301 130* GO TO 95 SGP 1310
00302 131* 90 BETANK(IZ) = BETA(N) SGP 1320
00303 132* ALPHNKK(IZ) = ALPHA(N) SGP 1330
00304 133* 95 CONTINUE SGP 1340
00305 134* RETURN SGP 1350
00306 135* END SGP 1360

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. C *DIAGNOSTIC* MESSAGE(S)

Q1 FOR HEADER
UNIVAC 1108 FORTRAN V LEVEL 2206 0018 F501BP
THIS COMPILATION WAS DONE ON 12 DEC 69 AT 17:35:16

SUBROUTINE READER ENTRY POINT 002544

STORAGE USED (BLOCK, NAME, LENGTH)

0001 *CODE 002577
0000 *DATA 000136
0002 *BLANK 000000
0003 *PARAM 033754
0004 *PARAMS 025577

EXTERNAL REFERENCES (BLOCK, NAME)

0005 ALOG
0006 HNDUS
0007 NI02S
0010 HNDUS
0011 NI01S
0012 NEXPAS
0013 NERR3S

STORAGE ASSIGNMENT FOR VARIABLES (BLOCK, TYPE, RELATIVE LOCATION, NAME)

0001	00013	10L	0001	001522	1006G	0001	001615	10236	0001	001715	10406	0001	001725	10456
0001	002016	1066G	0001	002144	1116G	0001	002262	1136G	0001	002274	11436	0001	002367	11496
0001	000132	12L	0001	0025C3	1205G	0001	000151	14L	0001	001544	155L	0001	000170	16L
0001	001450	145L	0001	001766	179L	0001	002066	192L	0001	002127	193L	0001	002134	197L
0001	000017	2L	0001	000207	20L	0001	002173	205L	0001	002233	210L	0001	002241	215L
0001	002335	228L	0001	002415	240L	0001	002465	242L	0001	002473	243L	0001	002221	246G
0001	000212	25L	0001	002521	250L	0001	002524	260L	0001	000324	266G	0001	000336	274G
0001	000247	30L	0001	000350	302G	0001	000362	310G	0001	000375	317G	0001	000407	325G
0001	000421	333G	0001	000433	341G	0001	000445	347G	0001	000457	355G	0001	000471	363G
0001	000503	371G	0001	000515	377G	0001	000536	4L	0001	000546	415G	0001	000560	423G
0001	000572	431G	0001	000604	437G	0001	000616	445G	0001	000624	452G	0001	000712	476G
0001	001331	50L	0001	000724	501G	0001	000747	520G	0001	000741	524G	0001	000773	534G
0001	001005	542G	0001	001021	552G	0001	001033	560G	0001	001057	570G	0001	001071	574G
0001	000055	6L	0001	001425	60L	0001	001104	604G	0001	001117	612G	0001	001436	62L
0001	001132	620G	0001	001145	626G	0001	001175	643G	0001	001162	65L	0001	001207	651G
0001	001221	657G	0001	001233	665G	0001	001245	673G	0001	001254	701G	0001	001345	725G
0001	001357	733G	0001	001401	746G	0001	001413	754G	0001	000074	8L	0000	000030	800F
0000	000032	801F	0000	000034	803F	0000	000035	803F	0000	000037	900F	0000	000053	901F
0004	R 000216	ACCUR	0005	R 000000	ALDE	0003	R 007102	ALONG	0000	R 000226	ALPHA	0004	R 001023	ALPHNK
0004	R 000170	ANG	0003	R 000284	BETANK	0004	R 006657	BETANK	0003	R 007774	CI	0003	R 001522	CON
0004	R 000342	DATE	0004	R 000000	DECKY	0004	R 025266	DELPHI	0003	R 000454	DELTHP	0003	R 001010	DELU
0003	R 000406	DELX	0003	R 000644	DELY	0004	R 000345	DEP	0004	R 001335	DEPN	0003	R 007762	DI
0003	R 000136	DOS	0004	R 000273	DTK	0003	R 007246	DXR	0004	R 000126	ERFX	0003	R 000036	H
0004	R 000247	H8	0003	I 010014	I	0000	I 000020	IA	0003	I 010050	IBOT	0003	I 007436	IPLAG
0004	I 000344	II	0003	I 010036	ILK	0000	I 000012	IRD	0003	I 000000	ISKIP	0003	I 007602	ITAG
0003	I 010047	ITOP	0000	I 000000	IND	0003	I 000746	I2MOD	0003	I 010015	J	0000	I 000017	JA
0004	I 000114	JBUT	0004	I 000041	JF	0004	I 000134	JTCP	0003	I 010016	KK	0003	R 010012	L

MULTILAYER DIFFUSION MODEL GCA CORP SJOEKLUND

DATE 121289 PAGE 59

```

0003 R 010110 LAMBDA      0003 R 004426 LAT      0004 I 000322 LBI      0004 I 000326 L82      0004 I 000332 L83
0004 I 000336 L84      0000 I 000027 M      0004 M 000272 MPWR      0003 I 010035 N6K      0003 I 010043 N61
0003 I 010042 N61      0003 I 010044 N6K      0004 I 010046 N6Z      0003 I 000744 NPT      0000 I 000022 N7AK
0000 I 000023 N7AP      0000 I 000021 N7AR      0004 I 000321 NVR      0004 I 000320 NVS      0004 I 001334 N61
0003 I 010037 N6S      0003 I 010040 NYS      0003 I 010041 N2S      0000 R 000026 P      0003 R 000828 PRACK
0003 R 000166 PEAKD      0004 R 000172 PERC      0004 R 000243 PERCB      0003 R 000342 PLT      0004 R 000270 PPPR
0003 R 000013 Q      0004 R 000271 QPR      0003 R 010045 RAD      0000 R 000024 S      0003 R 033600 SIGAK
0004 R 000013 SIGAL      0004 R 028122 SIGANK      0003 R 000360 SIGAP      0003 R 033630 SIGARK      0004 R 000090 SIGARL
0004 R 000013 SIGEK      0004 R 000025 SIGEL      0004 R 024756 SIGENK      0003 R 000850 SIGEP      0003 R 033632 SIGERK
0004 R 000042 SIGERL      0003 R 010010 SIGK      0003 R 010017 SIGXNK      0003 M 000414 SIGXO      0003 R 010007 SIGY
0004 R 024758 SIGYNK      0003 R 000322 SIGYO      0003 R 010004 SIGZ      0003 R 000812 SIGZO      0004 R 01147 S8AR
0003 R 010011 SGR2P      0003 R 010017 STOI      0003 R 010020 STO2      0003 R 010021 STO3      0000 R 000828 SI
0003 R 000712 T      0003 R 010023 TAST      0003 R 033704 TAU      0004 R 000702 TAUOK      0003 R 033634 THETAK
0004 R 000044 THETAL      0003 I 007746 TESTNO      0003 R 010013 TH      0003 R 000702 THETA      0003 R 000170 UBARR
0003 R 033634 UBARAK      0004 R 010111 TH1      0003 R 010112 TH2      0003 R 010022 TRD      0003 R 000013 UBARRL
0004 R 025423 UBARZL      0004 R 000001 UBARL      0004 R 000513 UBARK      0003 R 000217 VB      0003 R 036572 VER
0004 R 000146 VS      0003 R 010114 WASHOU      0003 M 010051 XAST      0004 R 000812 XBARK      0003 R 001212 XR
0003 R 002032 XX      0004 R 000346 YBAR      0003 R 002176 YY      0003 R 000074 Z      0003 R 010113 ZLIM
0003 R 033630 ZRK      0004 R 000037 ZRL      0003 R 001046 ZZL

```

```

10 SUBROUTINE READER(IERR,NP,JLJ)
20 COMMON/PARAM/TSKIP(30),M(30),Z(30),N(30),UBAR(30),ALPHA(30),
30 1BETA(30),SIGVO(30),SIGAP(30),SIGX(30),DELTHP(30),SIGZ(30),
40 2SIGEP(30),DELK(30),DELY(30),THETA(30),I2HND(20),NPT(20),DELU(30),
50 3ZL(100),NR(100),DOS(100),CON(100),PEAKD(100),XZ(100),YY(100),
60 4PLT(2100,10),PEAKT(100),LAT(100),VER(100),VREF(100),ALONGA(100),
70 5DNR(100),T(20),IFLAG(100),ITAG(100),TESTNO(12),D(10),C(10),SIGZ,
80 6SIGY,SIGX,SQR2P,L,TH,I,J,K,R,N2,STOI,STO2,STO3,TRD,TAST(10),NBK,ILK,
90 7NYS,N2S,D,NCI,NDAR,NR,N2,ITOP,ISOT,XAST(30),
100 8SIGXNK,LAMBDA,TH1,TH2,ZLIM,WASHOU(100,100),UBARK(20),SIGAK(20),
110 9SIGERK(20),ZRK,SIGARK,SIGERK,UBARK,THETAK(40),TAUK(20),TAUKK(20),
120 10COMMON/PARAMS/DECAY,UBARL(10),SIGAL(10),SIGEL(10),ZRL,SIGARL,JF,
130 11SIGERL,UBARRL,THETAL(20),TAUL(10),TAUOL(10),JBC(10),SERFX(6),
140 12JTOP(10),VS(20),PERC(20),ACCUR,V8(20),PERCB(20),MB,PP,R,MP,R,
150 13NPNR,OTHK(21),NVS,NVB,LPI(4),LB2(4),LB3(4),LB4(4),DATE(21),I,INEP,
160 14NBARY(100),XBARX,UBARK(100),SETANK(100),ALPHNK(100),SQBAR,
170 15BANG(100),XCI,DEPN(100,100),SIGYNK,SIGENK(100),SIGANK(100),
180 16DELPHI,UBARZK(100),UBARZL(100)
190 DIMENSION IWD(10),IRD(5)
200 DATA 1WD(1),4M NYS/,IWD(2),4M NYS/,IWD(3),4M N2S/,IWD(4),4M NDI/,
210 1IWD(5),4M NCI/,IWD(6),4MNDXR/,IWD(7),4M NVS/,IWD(8),4M NBK/,
220 2IWD(9),4M NVB/,IRD(1),3H100/,IRD(2),3H 20/,IRD(3),3H 21/,IRD(4)
230 3/3H 1C/
240 INTEGER TESTNO
250 NEAL MPWR,LAT,LAMBDA
260 DATA JA/JNA/
270 C THIS SUBROUTINE READS ALL MODEL AND PROGRAM PARAMETERS AND CHECKS
280 CC TO MAKE SURE CRITICAL LIMITS ARE NOT EXCEEDED. ALSO, CALCULATED
290 C MODEL PARAMETERS ARE DETERMINED HERE.
300 IF (NYS.LE.100) GO TO 2
310 WRITE (6,770) IWD(1),NYS,IRD(1)
320 IERN = 1
330 2 IF (NYS.LE.100) GO TO 4
340 WRITE (6,700) IWD(2),NYS,IRD(1)

```

```

00147 350 IERR = 1 READ 350
00150 360 4 IF (NZS .LE. 21) GO TO 4 READ 360
00152 370 WRITE (6,900) IND(3),M75,IRD(3) READ 370
00157 380 IERR = 1 READ 380
00160 390 6 IF (IND1 .LE. 10) GO TO 6 READ 390
00162 400 WRITE (6,900) IND(4),ND1,IRD(4) READ 400
00167 410 IERR = 1 READ 410
00170 420 8 IF (INC1 .LE. 10) GO TO 8 READ 420
00172 430 WRITE (6,900) IND(5),NC1,IRD(4) READ 430
00177 440 IERR = 1 READ 440
00200 450 10 IF (NDXR .LE. 100) GO TO 12 READ 450
00202 460 WRITE (6,900) IND(6),NDXR,IRD(1) READ 460
00207 470 IERR = 1 READ 470
00210 480 12 IF (INVS .LE. 20) GO TO 14 READ 480
00212 490 WRITE (6,900) IND(7),INVS,IRD(2) READ 490
00217 500 IERR = 1 READ 500
00220 510 14 IF (INBK .LE. 10) GO TO 16 READ 510
00222 520 WRITE (6,900) IND(8),INBK,IRD(4) READ 520
00227 530 IERR = 1 READ 530
00230 540 16 IF (INVB .LE. 20) GO TO 20 READ 540
00232 550 WRITE (6,900) IND(9),INVB,IRD(2) READ 550
00237 560 IERR = 1 READ 560
00240 570 20 J = 0 READ 570
00241 580 IF (IERR .EQ. 0) GO TO 30 READ 580
00243 590 25 READ (5,903) IA,TESTNO(1),I=1,12 READ 590
00248 600 J = J+1 IF (IA .EQ. JA) RETURN READ 600
00253 610 IF (J .LT. 102) AND .NP .GT. JXJ GO TO 25 READ 610
00255 620 WRITE (6,901) IERR = 2 READ 620
00257 630 RETURN READ 630
00261 640 30 CONTINUE READ 640
00263 650 READ (5,800) (XX(I),I=1,NXS) READ 650
00264 660 READ (5,800) (YY(I),I=1,NYS) READ 660
00269 670 READ (5,800) (ZZ(I),I=1,NZS) READ 670
00272 680 READ (5,800) (DELX(I),DELY(I),I=1,NNZ) READ 680
00274 690 READ (5,800) (Q(I),I=1,NNZ) READ 690
00276 700 READ (5,800) (UBARK(I),I=1,NNZ) READ 700
00278 710 READ (5,800) (SIGAK(I),I=1,NNZ) READ 710
00280 720 READ (5,800) (SIGYD(I),I=1,NNZ) READ 720
00282 730 READ (5,800) (SIGEK(I),I=1,NNZ) READ 730
00284 740 READ (5,800) (ALPHA(I),I=1,NNZ) READ 740
00286 750 READ (5,800) (BETA(I),I=1,NNZ) READ 750
00288 760 READ (5,800) (SIGZD(I),I=1,NNZ) READ 760
00290 770 READ (5,800) (SIGXD(I),I=1,NNZ) READ 770
00292 780 READ (5,800) (SIGYD(I),I=1,NNZ) READ 780
00294 790 READ (5,800) (SIGEK(I),I=1,NNZ) READ 790
00296 800 READ (5,800) ZPK,SIGARK,SIGERK,UBARK,DELPHI READ 800
00298 810 NTAR = NNZ*2 READ 810
00300 820 (THETAK(I),I=1,NTAR) READ 820
00302 830 (TAUK(I),I=1,NNZ) READ 830
00304 840 (TA-OK(I),I=1,NNZ) READ 840
00306 850 READ (5,800) (T(I),I=1,NNZ) READ 850
00308 860 READ (5,800) (M(I),I=1,NNZ) READ 860
00310 870 DO 34 I=1,NNZ READ 870
00312 880 IF (SIGAK(I) .LT. .5) SIGAK(I) = .5 READ 880
00314 890 IF (SIGEK(I) .LT. .1) SIGEK(I) = .1 READ 890
00316 900 IF (UBARK(I) .LT. .1) UBARK(I) = .1 READ 900
00318 910 34 CONTINUE READ 910
00320 920 IF (SIGARK .LT. .5) SIGARK = .5 READ 920

```

```

00466 930 IF (SIGERK .LT. .1) SIGERK = .1
00470 940 IF (UBARRK .LT. .1) UBARRK = .1
00472 950 IF (ISKIP(1) .EQ. 2) GO TO 50
00474 960 READ (5,602) (I2MOD(1),I=1,NMZ)
00502 970 READ (5,602) (NPT(1),I=1,NNZ)
00510 980 READ (5,600) DECAY,ZLIM,TIM,LAMBDA
00514 990 READ (5,600) (DPR(1),I=1,NDRR)
00524 1000 READ (5,602) (IFLAG(1),I=1,NDR)
00532 1010 READ (5,601) (DI(1),I=1,NDI)
00540 1020 READ (5,601) (CI(1),I=1,NCI)
00546 1030 IF (ISKIP(13) .EQ. 0) GO TO 40
00550 1040 READ (5,600) (UBARL(1),I=1,NBK)
00554 1050 READ (5,600) (SIGAL(1),I=1,NBK)
00564 1060 NTAK = NZ+1
00566 1070 NTAP = NMZ+NBK
00568 1080 READ (5,600) (SIGVO(1),I=1,NTAK,NTAP)
00574 1090 READ (5,600) (SIGEL(1),I=1,NBK)
00602 1100 READ (5,600) (ALPHA(1),I=1,NTAK,NTAP)
00610 1110 READ (5,600) (BETA(1),I=1,NTAX,NTAP)
00616 1120 READ (5,600) (SIGZO(1),I=1,NTAK,NTAP)
00624 1130 READ (5,600) (SIGZO(1),I=1,NTAK,NTAP)
00632 1140 READ (5,600) (ZRL,SIGARL,SIGELR,UBARL)
00640 1150 NTAR = NBK*2
00641 1160 READ (5,600) (THETA(1),I=1,NTAR)
00647 1170 READ (5,600) (TAUL(1),I=1,NBK)
00655 1180 READ (5,600) (TAUL(1),I=1,NBK)
00663 1190 READ (5,600) (TAST(1),I=1,NBK)
00671 1200 READ (5,602) (JBDT(1),JTOP(1),I=1,NBK)
00700 1210 DO 43 I=1,NBK
00703 1220 IF (SIGAL(I) .LT. .5) SIGAL(I) = .5
00705 1230 IF (SIGEL(I) .LT. .1) SIGEL(I) = .1
00707 1240 IF (UBARL(I) .LT. .1) UBARL(I) = .1
00711 1250 43 CONTINUE
00713 1260 IF (SIGARL .LT. .5) SIGARL = .5
00715 1270 IF (SIGERL .LT. .1) SIGERL = .1
00717 1280 IF (UBARRL .LT. .1) UBARRL = .1
00721 1290 GO TO 60
00722 1300 50 CONTINUE
00723 1310 READ (5,600) (VSI(1),I=1,NVS)
00731 1320 READ (5,600) (PERC(1),I=1,NVS)
00737 1330 READ (5,600) ACCUR
00742 1340 IF (ISKIP(3) .EQ. 0) GO TO 60
00744 1350 READ (5,600) (VBI(1),I=1,NVB)
00752 1360 READ (5,600) (PERCB(1),I=1,NVB)
00760 1370 READ (5,600) PR
00763 1380 60 CONTINUE
00764 1390 IF (ISKIP(1) .EQ. 2) GO TO 62
00771 1400 IF (Z(1) .EQ. 0) Z=0.1,0.2
00772 1410 Z(1) = 2.0
00773 1420 62 CONTINUE
00774 1430 S = (Z(1)/2**K)
00775 1440 S1 = ALOG(S)
00776 1450 P = ALOG(UBARRK(1)/UBARRK)/S1
00777 1460 IF (P+.0) 65,64,65
00778 1470 64 P = -.9999999
00779 1480 65 CONTINUE
00780 1490 UBAR(1) = (UBARRK/(1.0+P))+(Z(2)-ZRK)*ZRK*P)+(Z(2)*.01+.0,P)-ZRK*READ(1490)
00803 1500 10(1.0+P)

```



```

01133 2090  GO TO 215
01134 2100  SIGEP(NNZ+1) = ((SIGEL(1)+SIGEL(1)*RAD)/2.0
01135 2110  DO 220 1=2,NK
01136 2120  SIGEP(NNZ+1) = ((SIGEL(1)+SIGEL(1-1))*RAD)/2.0
01137 2130  DO 230 1=1,NK
01138 2140  J = 102-1
01139 2150  IF (ABS(THETAL(J)-THETAL(J+1)) .LT. 190.0) GO TO 228
01140 2160  IF (THETAL(J) .GT. THETAL(J+1)) THETAL(J+1) = THETAL(J)+360.0
01141 2170  IF (THETAL(J) .LT. THETAL(J+1)) THETAL(J) = THETAL(J)+360.0
01142 2180  THETA(NNZ+1) = (THETAL(J)+THETAL(J+1))/2.0
01143 2190  IF (THETA(NNZ+1) .GE. 360.0) THETA(NNZ+1) = THETA(NNZ+1)-360.0
01144 2200  DELTNP(NNZ+1) = (THETAL(J+1)-THETAL(J))
01145 2210  DELU(NNZ+1) = UBARL(1)-UBARL
01146 2220  DO 235 1=2,NK
01147 2230  DELU(NNZ+1) = UBARL(1)-UBARL(1-1)
01148 2240  IF (J00T(1) .GT. 1) GO TO 242
01149 2250  P = ALOG10(SIGEL(1)/SIGEL(1)/5)
01150 2260  IF (P + 1.0) 240,239,240
01151 2270  239 P = -.9999999
01152 2280  240 CONTINUE
01153 2290  SIGEP(NNZ+1) = ((SIGEL(1)+TAUOL(1))*((1.0/5.0)*RAD)/((1.0+P)
01154 2300  1*(Z(N+1)-ZRL)*ZRL*OP))+(Z(N+1))*((1.0+P)-ZRL*OP))
01155 2310  GO TO 243
01156 2320  242 SIGEP(NNZ+1) = ((SIGEL(1)+SIGEL(1)*RAD)/2.0
01157 2330  243 CONTINUE
01158 2340  DO 245 1=2,NK
01159 2350  SIGEP(NNZ+1) = ((SIGEL(1)+SIGEL(1-1))*((TAUOL(1))/TAUOL(1))*((1.0/5.0)*RAD)/2.0
01160 2360  1)*RAD)/2.0
01161 2370  250 CONTINUE
01162 2380  IF (18KIP(1) .EQ. 0) DECAY = 0.0
01163 2390  260 CONTINUE
01164 2400  RETURN
01165 2410  800 FORMAT (9F10.0)
01166 2420  801 FORMAT (4E12.4)
01167 2430  802 FORMAT (40I2)
01168 2440  803 FORMAT (A1,12A6)
01169 2450  900 FORMAT (1H,12H***** ERROR 1A,1H=,14,10H LIMIT IS .A3,17H, GO TO
01170 2460  INEXT CASE//)
01171 2470  901 FORMAT (51H ***** ERROR (A) INDICATOR FOR NEXT CASE NOT FOUND)
01172 2480  END
01173 2490

```

END OF UNIVAC 1108 FORTRAN V COMPILATION. 0 *DIAGNOSTIC MESSAGE(S)

DATE 121269 PAGE 64

MULTILAYER DIFFUSION MODEL GCA CORP BJOEKLUND

Q XOT MODEL

APPENDIX C

FLOW CHART FOR MULTI-LAYER DIFFUSION MODEL COMPUTER PROGRAM

Appendix C contains the complete flow diagram of the computer program for the Multi-Layer Diffusion Model. The program requires 102034_8 locations of executable storage and consists of the main driver routine plus 21 subroutines. Diagrams of the call linkage between subroutines are given in Sections A. 7 and A. 8 of Appendix A.

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
C. 1	MAIN PROGRAM	C- 3
C. 2	SUBROUTINE BREAK	C-21
C. 3	SUBROUTINE DEPOS	C-32
C. 4	SUBROUTINE CENTRL	C-43
C. 5	SUBROUTINE ISOXY	C-48
C. 6	SUBROUTINE ISOYZ	C-56
C. 7	SUBROUTINE WASHT	C-63
C. 8	SUBROUTINE TESTR	C-68
C. 9	SUBROUTINE ACH	C-72
	ENTRY POINT EL	C-73
	ENTRY POINT LATER	C-74
	ENTRY POINT ALONGD	C-75
C. 10	SUBROUTINE VERT	C-77
C. 11	SUBROUTINE PEAK	C-81
C. 12	SUBROUTINE SIGMA	C-83
C. 13	SUBROUTINE ISO	C-87
C. 14	SUBROUTINE COORD	C-90
C. 15	SUBROUTINE SGP	C-103
	ENTRY POINT UBARS	C-106
	ENTRY POINT DEPSO	C-108
	ENTRY POINT BETAK	C-110
C. 16	SUBROUTINE READER	C-111

SECTION C.1

MAIN PROGRAM

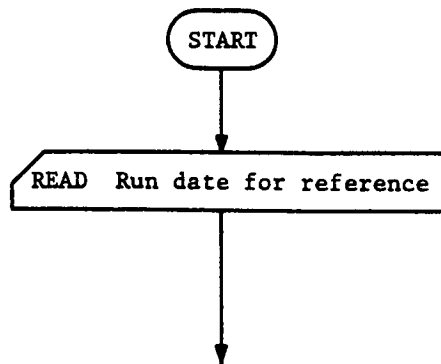
This section contains the flow chart for the main driver routine that initiates communication between the various subroutines. This routine is executed NP times, or until an end-of-file is read. Storage used for the main driver routine is 2742₈.

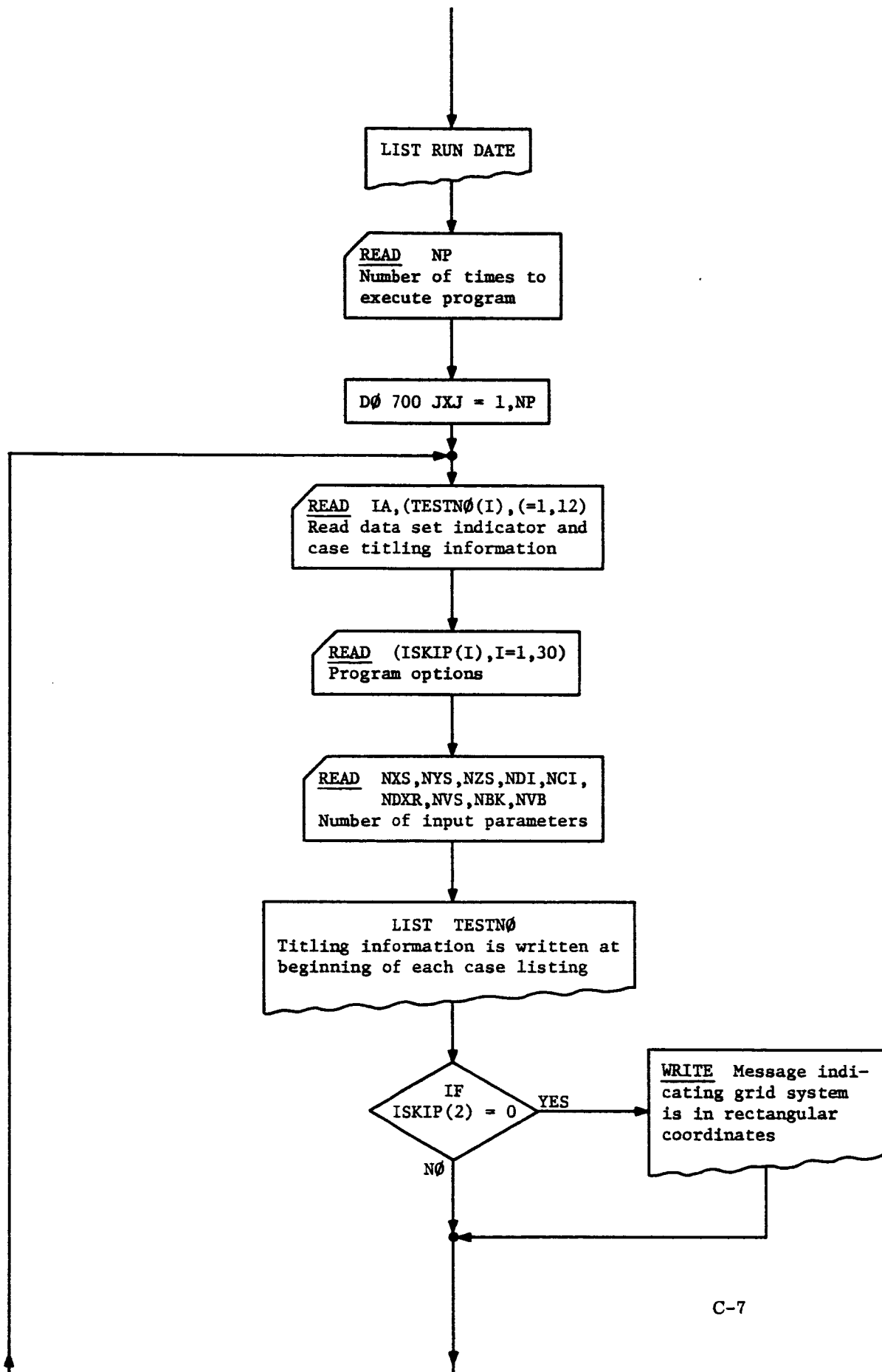
ISKIP = PROGRAM CONTROL OPTIONS
 H = EFFECTIVE RELEASE HEIGHT IN LAYER (METERS)
 Z = BOUNDARY HEIGHTS OF LAYERS (METERS)
 Q = SOURCE STRENGTH IN LAYER (MASS/HEIGHT)
 UBAR = CALCULATED TRANSPORT SPEED IN LAYER
 ALPHA = LATERAL POWER LAW EXPANSION COEFFICIENT
 BETA = VERTICAL POWER LAW EXPANSION COEFFICIENT
 SIGYØ = STANDARD DEVIATION OF THE LATERAL SOURCE DIMENSION (METER)
 SIGAP = CALCULATED LATERAL DIFFUSION COEFFICIENT IN LAYER
 SIGXØ = STANDARD DEVIATION OF THE ALONGWIND SOURCE DIMENSION (METERS)
 DELTHP = CALCULATED WIND DIRECTION SHEAR IN LAYER
 SIGZØ = STANDARD DEVIATION OF THE VERTICAL SOURCE DIMENSION (METERS)
 SIGEP = CALCULATED VERTICAL DIFFUSION COEFFICIENT
 DELX = X COORDINATE OF SOURCE IN LAYER RELATIVE TO ORIGIN OF FIXED GRID SYSTEM (METERS, RECTANGULAR OR POLAR)
 DELY = Y COORDINATE OF SOURCE IN LAYER RELATIVE TO ORIGIN OF FIXED GRID SYSTEM (METERS, DEGREES**RECTANGULAR, POLAR)
 THETA = CALCULATED MEAN WIND DIRECTION IN LAYER
 IZMØD = MODEL NO TO USE IN LAYER (1, 2 OR 3)
 NPT = NUMBER OF CALCULATION HEIGHTS ZZL DESIRED IN LAYER
 DELU = CALCULATED WIND SPEED SHEAR
 ZZL = CALCULATION HEIGHTS IN LAYER
 XR = CLOUD HALF WIDTHS
 DØS = CALCULATED VALUE OF DOSAGE
 CØN = CALCULATED VALUE OF CONCENTRATION
 PEAKD = PART OF DOSAGE EQUATION
 XX = X COORDINATE OF RECEPTOR RELATIVE TO FIXED GRID SYSTEM (POSITIVE X AXIS EAST 90 DEGREES, METERS, RECTANGULAR OR POLAR)
 YY = Y COORDINATE OF RECEPTOR RELATIVE TO FIXED GRID SYSTEM (POSITIVE Y AXIS NORTH 0 DEGREES, METERS OR DEGREES, RECTANGULAR OR POLAR)
 PLT = CALCULATED VALUES OF DOSAGE AND CONCENTRATION ISOPLETHS
 LAT = LATERAL TERM OF DOSAGE EQUATION
 VER = VERTICAL TERM OF DOSAGE EQUATION
 VREF = REFLECTION TERM OF DOSAGE EQUATION
 ALØNGW = ALONGWIND TERM OF CONCENTRATION EQUATION
 DXR = RADIAL DISTANCES FOR MAXIMUM PEAK DOSAGE AND CONCENTRATION AND ISOPLETH AND CLOUD HALF-WIDTH CALCULATIONS
 T = TIME AFTER CLOUD STABILIZATION EXCEPT IN GRAVITATIONAL DEPOSITION MODEL SOURCE EMISSION TIME IN LAYER (SECONDS)
 IFLAG = FLAG TO INDICATE AT WHICH DISTANCES DXR VERTICAL ISOPLETHS ARE TO BE CALCULATED
 ITAG = FLAG TO INDICATE WHICH RECEPTOR COORDINATES ARE OUTSIDE OF CALCULATION SECTOR DELPHI
 TESTNØ = CASE TITLE
 DI = DOSAGE ISOPLETH VALUES OF INTEREST
 CI = CONCENTRATION ISOPLETH VALUES OF INTEREST
 SIGZ = CALCULATED STANDARD DEVIATION OF THE VERTICAL DOSAGE DISTRIBUTION
 SIGY = CALCULATED STANDARD DEVIATION OF THE LATERAL DOSAGE DISTRIBUTION
 SIGX = CALCULATED STANDARD DEVIATION OF THE ALONGWIND DOSAGE DISTRIBUTION
 SQR2P = SQUARE ROOT TWO PI
 L = LENGTH OF CLOUD IN ALONGWIND DIRECTION
 TH = $\text{THETA} \times \text{PI} / 180$
 I = INDEX OF X COORDINATES
 J = INDEX OF Y COORDINATES

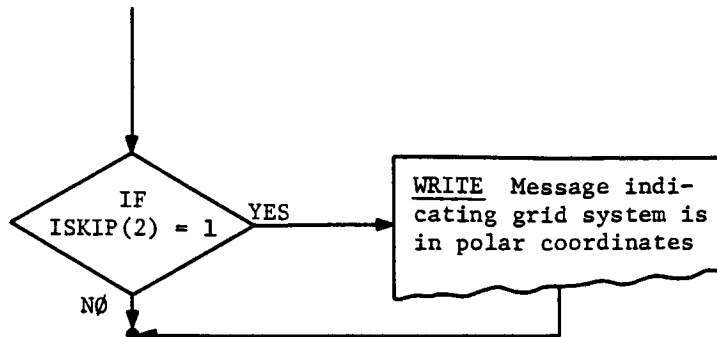
KK = INDEX OF LAYERS
 K = INDEX OVER CALCULATION HEIGHTS ZZL
 ST01 = TEMP STORAGE
 ST02 = TEMP STORAGE
 ST03 = TEMP STORAGE
 TRD = HALF CALCULATION SECTOR DELPHI
 TAST = TIME OF LAYER STRUCTURE CHANGE (SECONDS)
 NBK = NO OF DISTINCT GROUPS OF LAYERS THAT FORM INTO ONE AT TIME TAST
 ILK = INDEX ON NEW LAYERS AFTER TIME TAST
 NXS = NO OF X COORDINATES
 NYS = NO OF Y COORDINATES
 NZS = NO OF LAYER BOUNDARIES
 NDI = NO OF DOSAGE ISOPLETHS
 NCI = NO OF CONCENTRATION ISOPLETHS
 NDXR = NO OF RADIAL DISTANCES DXR ALONG CLOUD AXIS
 RAD = $\pi/180$
 NNZ = NZS-1 NO OF LAYERS
 IT0P = TOP OF NEW LAYER AFTER TAST IN TERMS OF OLD LAYER STRUCTURE
 IB0T = BOTTOM OF NEW LAYER AFTER TAST IN TERMS OF OLD LAYER STRUCTURE
 (IT0P AND IB0T INDEXES)
 XAST = CALCULATE DISTANCE TO TAST
 SIGXNK = SIGX OF NEW LAYER STRUCTURE
 LAMBDA = WASHOUT COEFFICIENT
 TIM1 = TIME OF START OF RAIN (SECONDS)
 TIM2 = TIME RAIN STOPS (SECONDS)
 ZLIM = MAXIMUM HEIGHT OF WASHOUT
 WASHOU = CALCULATE WASHOUT AT GROUND
 UBARK = WIND SPEED AT TOP OF LAYER (METERS/SEC)
 SIGAK = SIGAP AT TOP OF LAYER (DEGREES)
 SIGEK = SIGEP AT TOP OF LAYER (DEGREES)
 ZRK = REFERENCE HEIGHT IN SURFACE LAYER (METERS)
 SIGARK = SIGAP AT ZRK (DEGREES)
 SIGERK = SIGEP AT ZRK (DEGREES)
 UBARRK = WIND SPEED AT ZRK (METERS/SEC)
 THETAK = WIND DIRECTION AT LAYER BOUNDARIES (DEGREES)
 TAUk = TIME IN SECONDS REQUIRED FOR LATERAL CLOUD STABILIZATION
 TAU0K = SAMPLING PERIOD IN SECONDS AT THE TOP OF THE LAYER
 DECAY = DECAY COEFFICIENT IN DOSAGE EQUATION
 UBARL = WIND SPEED AT TOP OF NEW LAYER AFTER TAST (METERS/SEC)
 SIGAL = SIGAP AT TOP OF NEW LAYER AFTER TAST (DEGREES)
 SIGEL = SIGEP AT TOP OF NEW LAYER AFTER TAST (DEGREES)
 ZRL = REFERENCE HEIGHT IN SURFACE LAYER OF NEW STRUCTURE (METERS)
 SIGARL = SIGAP AT ZRL IF FIRST LAYER INCLUDES OLD SURFACE LAYER ELSE
 EQUALS SIGAP AT BOTTOM OF FIRST NEW LAYER (DEGREES)
 SIGERL = SIGAP AT ZRL IF FIRST LAYER INCLUDES OLD SURFACE LAYER ELSE
 EQUALS SIGEP AT BOTTOM OF FIRST NEW LAYER (DEGREES)
 UBARRL = WIND SPEED AT ZRL IF FIRST LAYER INCLUDES OLD SURFACE LAYER
 ELSE EQUALS WIND SPEED AT BOTTOM OF FIRST NEW LAYER (METERS/SEC)
 THETAL = WIND DIRECTION AT BOUNDARIES OF NEW LAYER STRUCTURE (DEGREES)
 TAUl = TIME IN SECONDS FOR LATERAL CLOUD STABILIZATION IN NEW LAYER
 STRUCTURE
 TAU0L = TIME IN SECONDS OF SAMPLING PERIOD AT TOP OF NEW LAYER
 JB0T = INPUT LAYER NUMBER OF BOTTOM OF NEW LAYER STRUCTURE RELATIVE TO
 OLD

JTØP = INPUT LAYER NUMBER OF TOP OF NEW LAYER STRUCTURE RELATIVE TO OLD
 VS = SETTLING VELOCITY IN GRAVITATIONAL DEPOSITION MODEL
 PERC = FREQUENCY OF VS
 ACCUR = DESIRED ACCURACY COEFFICIENT (.45) INSURES THAT GROUND DEPOSITION
 FROM NXCI POINT SOURCES IN THE LAYER VARIES LESS THAN TEN PERCENT
 FROM DEPOSITION EXPECTED FROM A VERTICAL LINE SOURCE IN THE LAYER.
 FOR (.32) REDUCED TO FIVE PERCENT
 VB = SETTLING VELOCITIES FROM A BURST OR DESTRUCT IN LAYER NNZ
 PERCB = FREQUENCY OF VB
 HB = HEIGHT OF BURST (METERS)
 PPWR = CALCULATED WIND SPEED POWER LAW EXPONENT
 QPWR = CALCULATED SIGEP POWER LAW EXPONENT
 MPWR = CALCULATED SIGAP POWER LAW EXPONENT
 DTHK = WIND ANGLE SHEAR
 NVS = NUMBER OF SETTLING VELOCITIES VS
 NVB = NUMBER OF SETTLING VELOCITIES VB
 LB1 = PRINTED INFORMATION =LB2, LB3, LB4
 DATE = RUN DATE
 II = INDEX ON VS AND VB
 DEP = TEMP STORAGE
 YBARY = CALCULATED COORDINATE OF POINT ON CLOUD AXIS OF VS AT INTERSECTION
 WITH GROUND (DEPOSITION)
 XBARX = CALCULATED COORDINATE OF POINT ON CLOUD AXIS OF VS AT INTERSECTION
 WITH GROUND (DEPOSITION)
 UBARNK = CALCULATED WIND SPEED (DEPOSITION)
 BETANK = CALCULATED BETA (DEPOSITION)
 ALPHNK = CALCULATED ALPHA (DEPOSITION)
 SQBAR = TEMP STORAGE
 ANG = ANGLE TO POINT XBARX, YBARY (DEPOSITION)
 NXCI = NUMBER OF POINT SOURCES IN LAYER (DEPOSITION)
 DEPN = CALCULATED VALUE OF GRAVITATIONAL DEPOSITION
 SIGYNK = SIGY OF NEW LAYER STRUCTURE IN CALCULATION OF DOSAGE AND
 CONCENTRATION
 SIGENK = CALCULATED SIGEP (DEPOSITION)
 SIGANK = CALCULATED SIGAP (DEPOSITION)

DIMENSION AND COMMON SUBSCRIPTED VARIABLES COMMON TO THE VARIOUS SUBROUTINES.
 (COMMON STORAGE USED 61553₈)

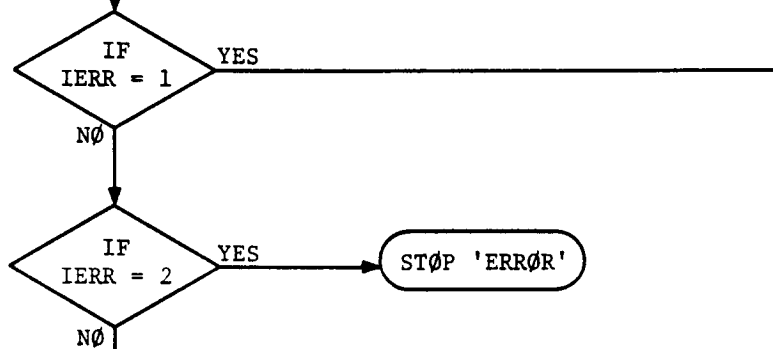


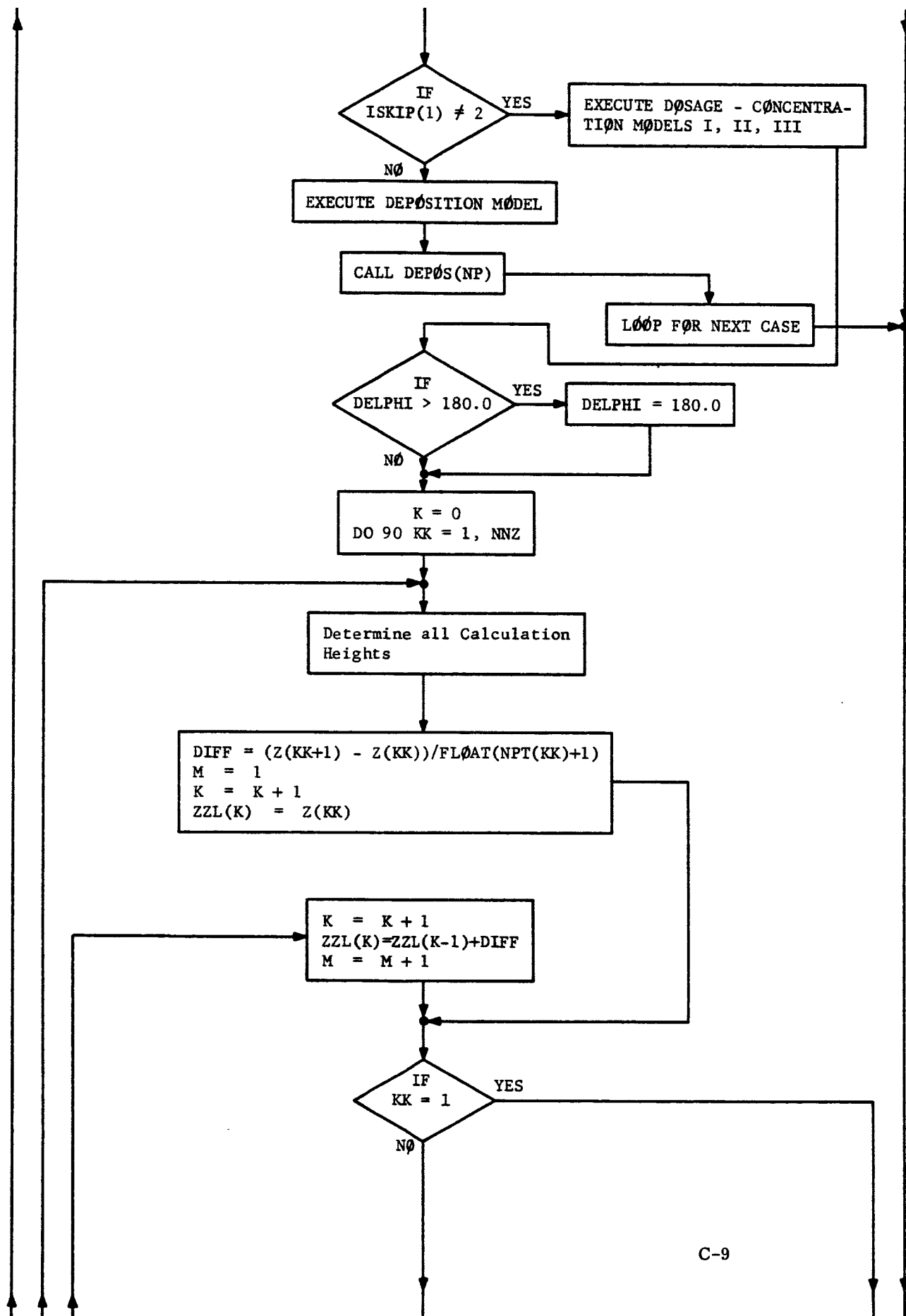


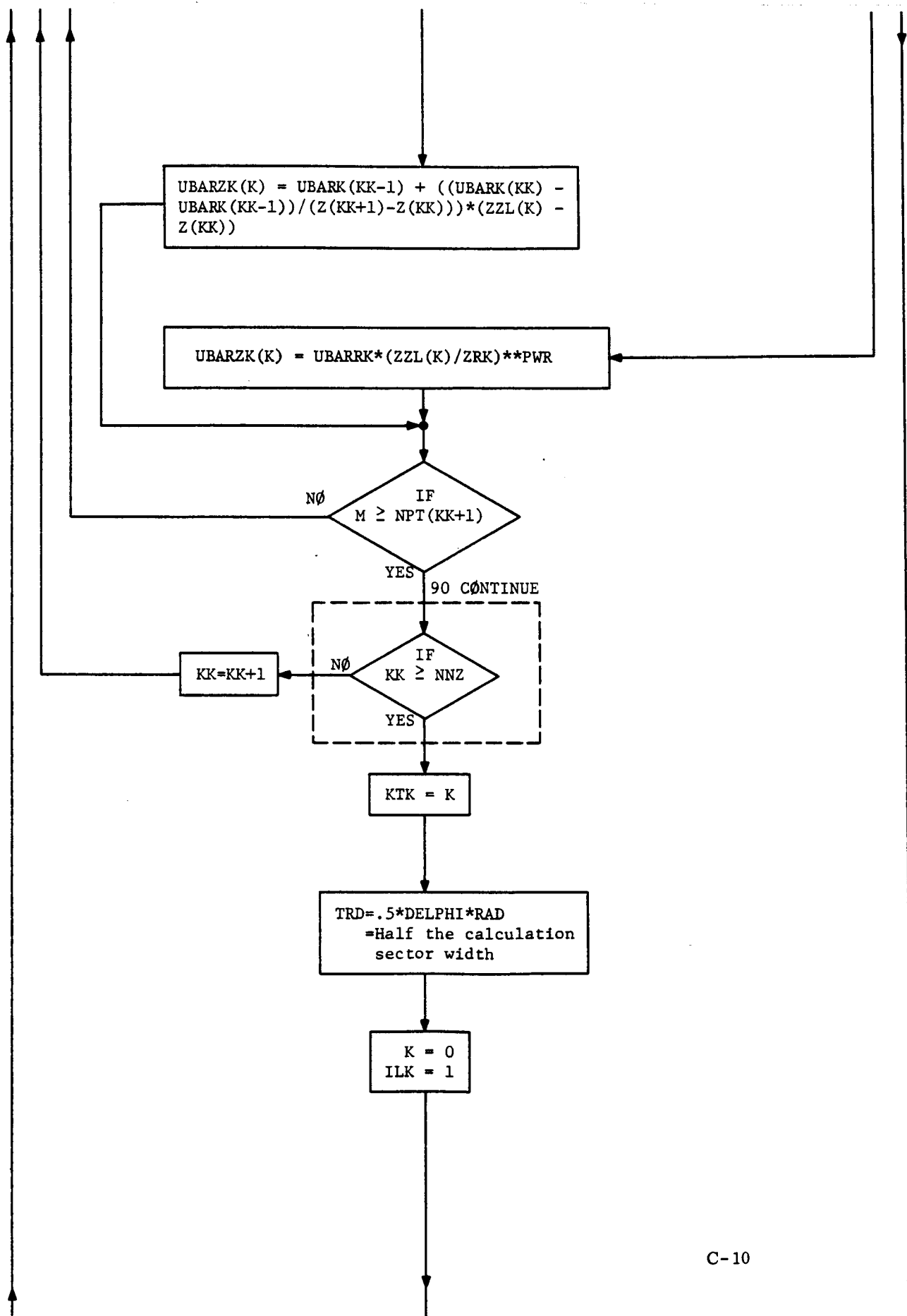


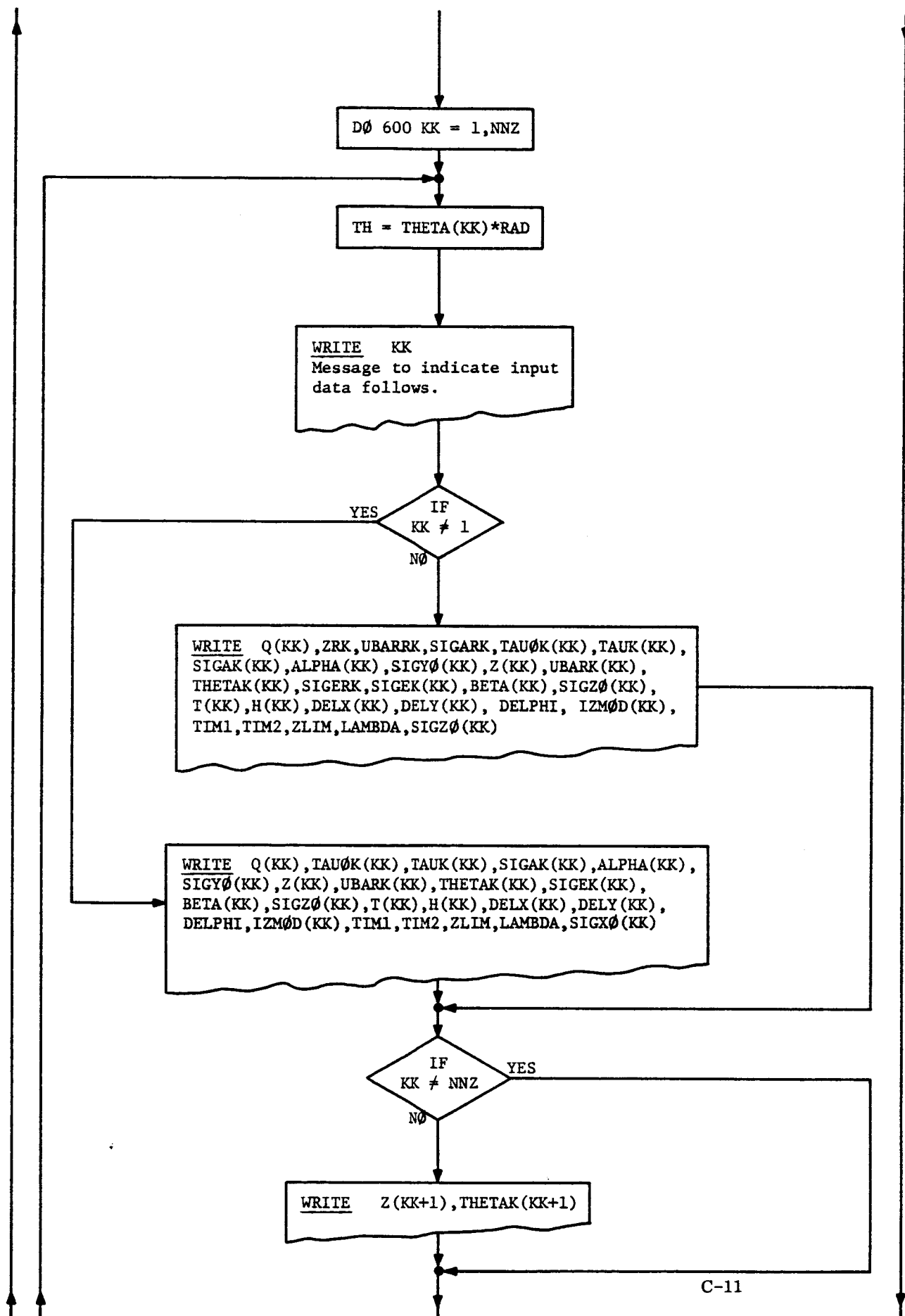
NNZ=NZS-1 Number of
layers equals number of
boundaries minus one.
SQR2P = SQRT(6.2831853072)
RAD = 3.1415926536/180.0
IERR = 0

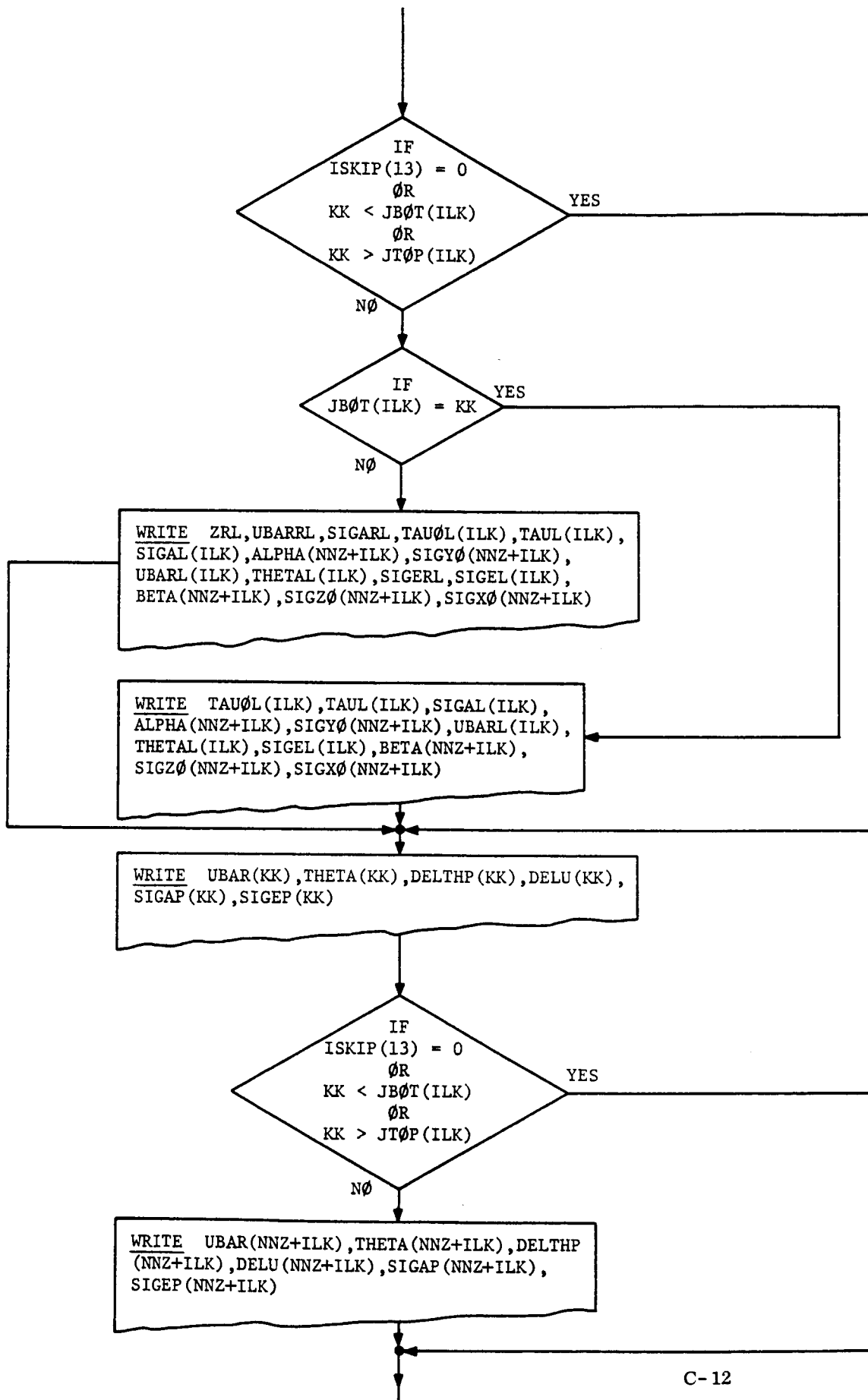
CALL READER (IERR,NP,JXJ)
Read remaining program
parameters.

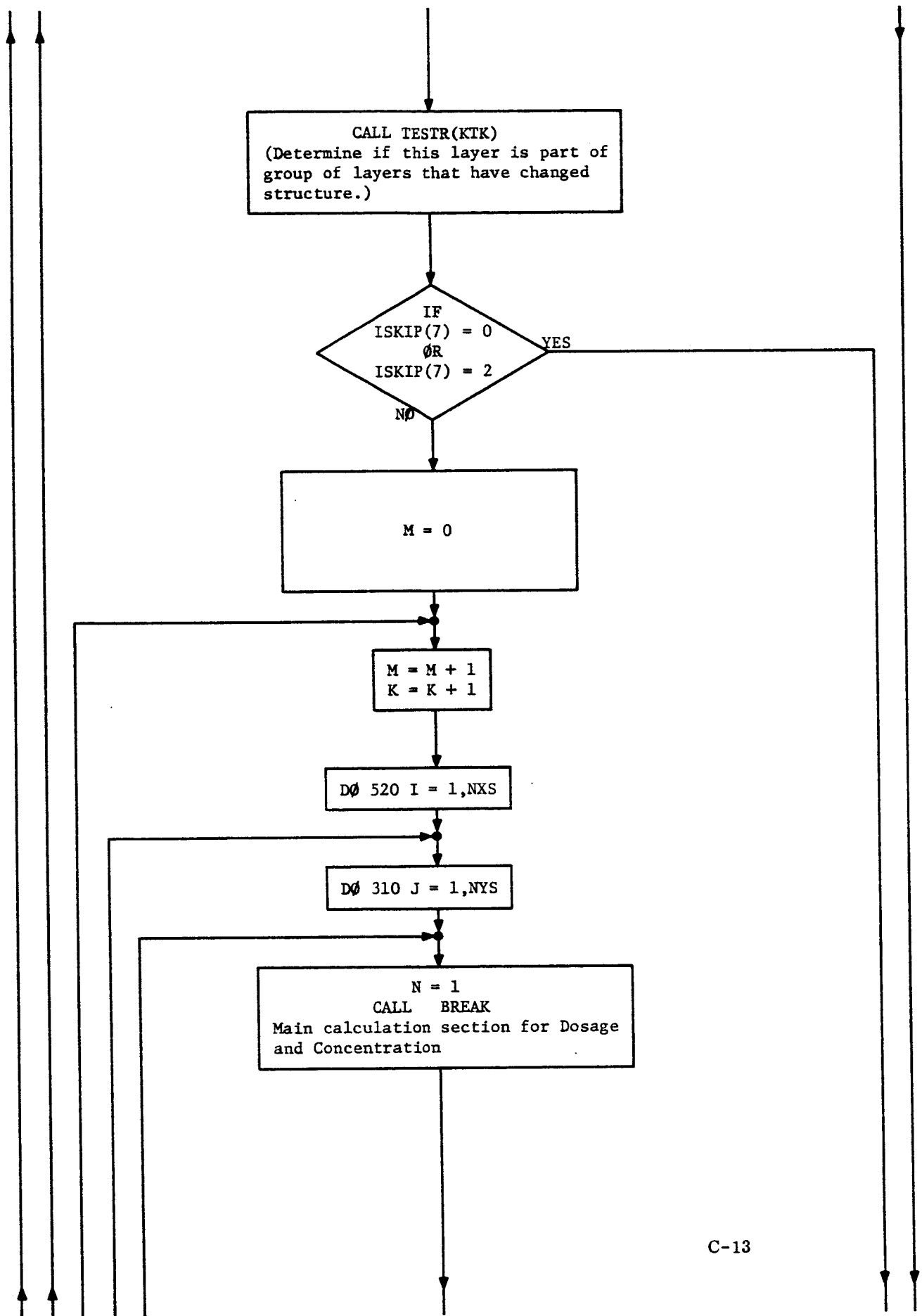


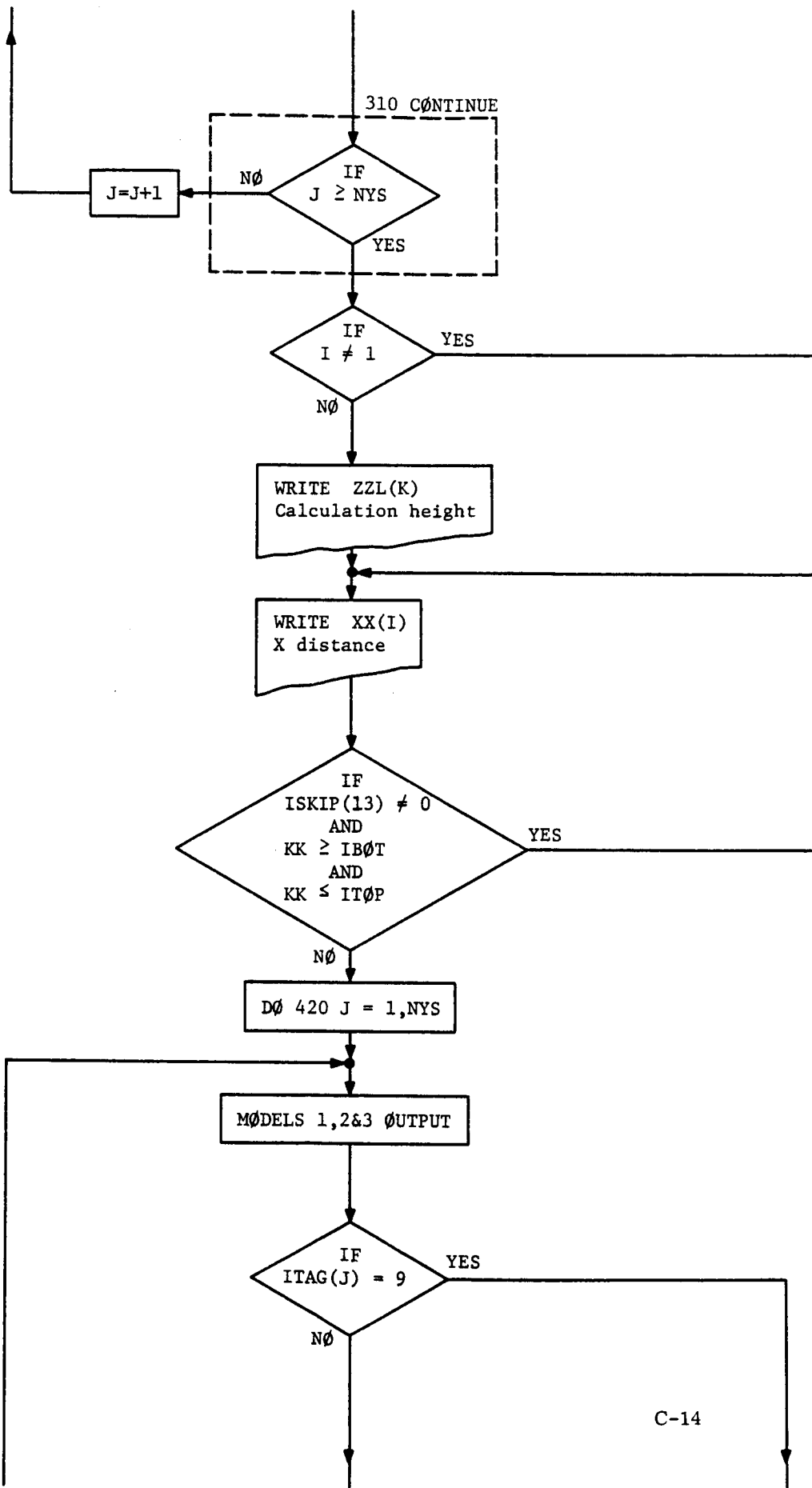


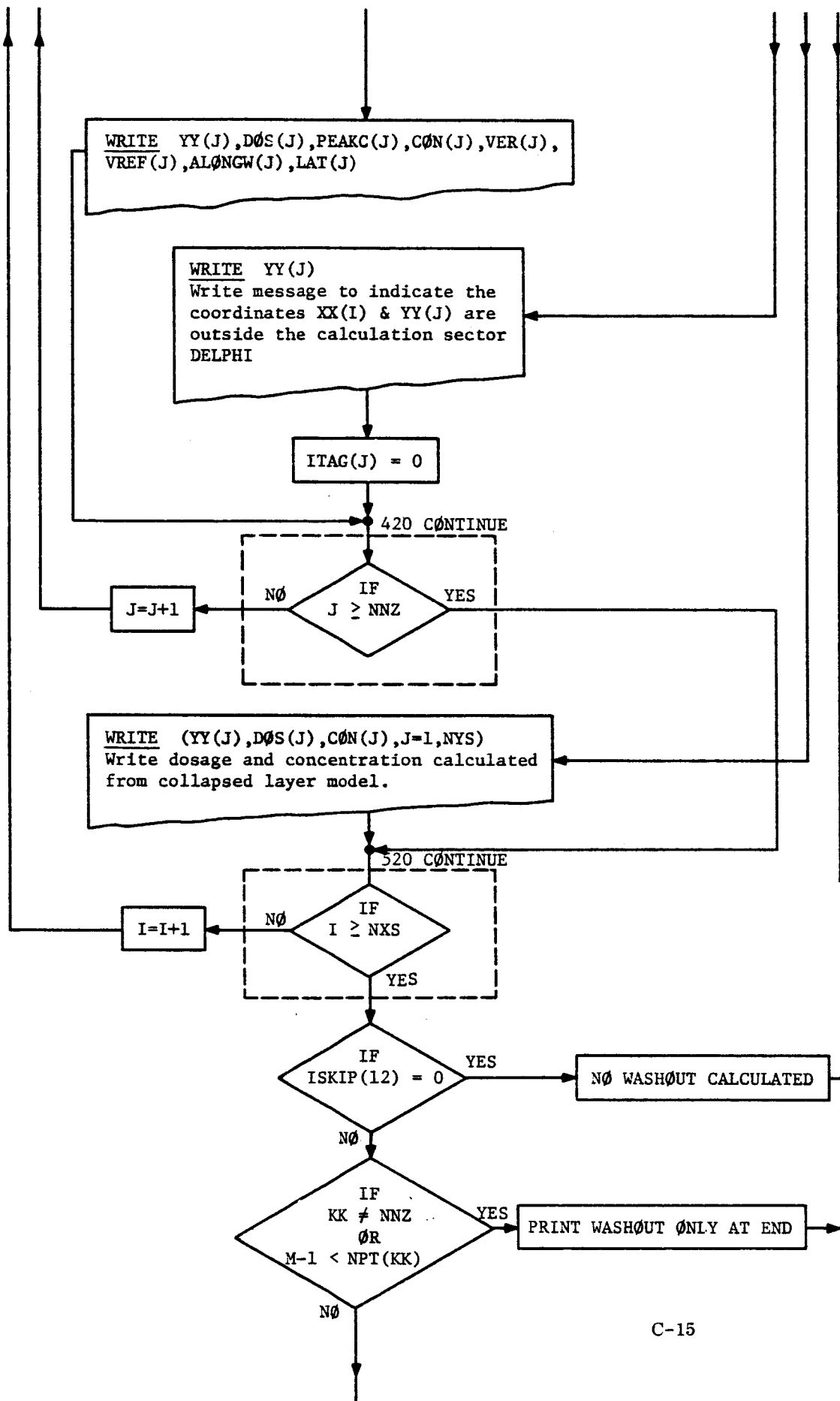


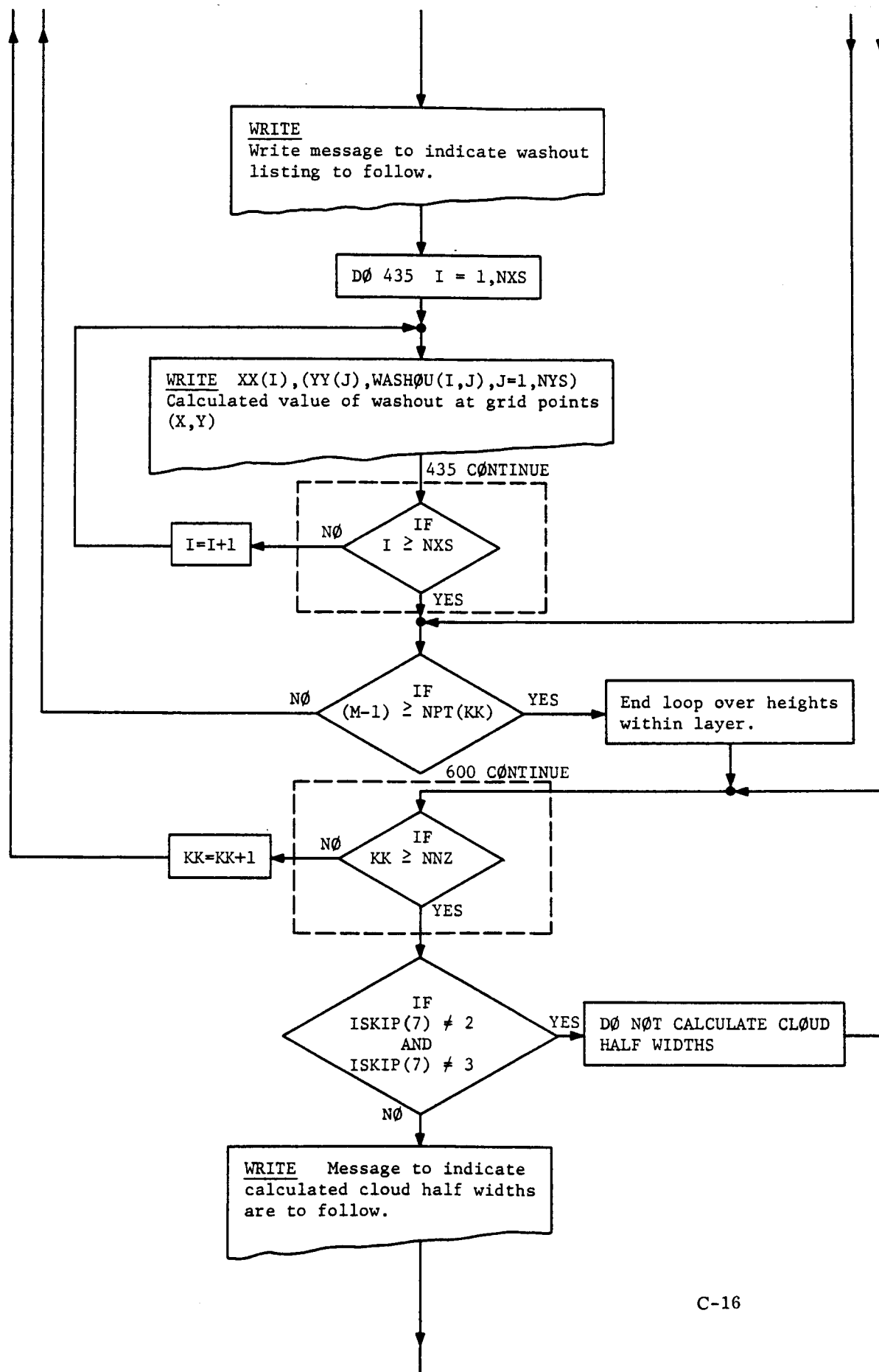


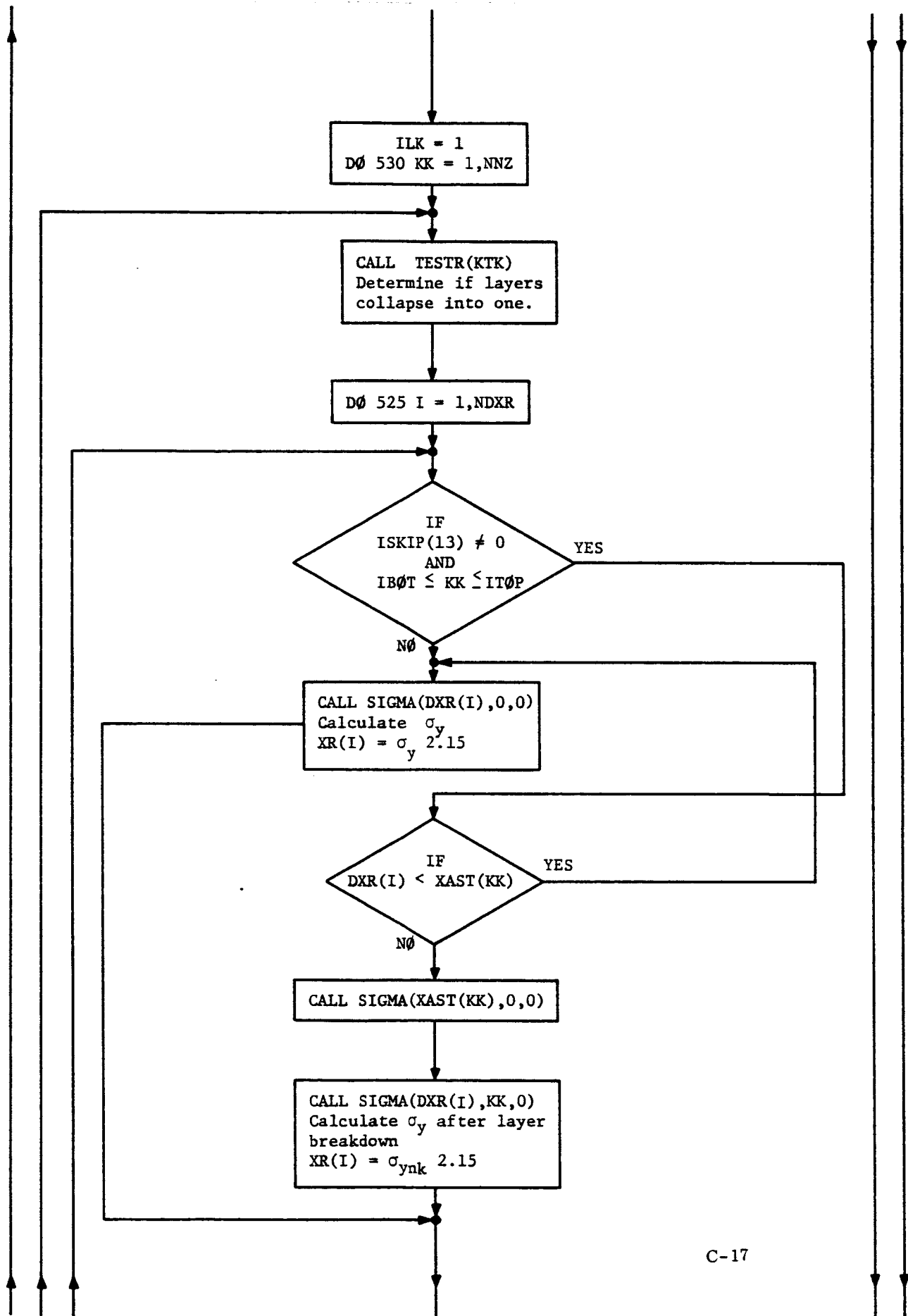


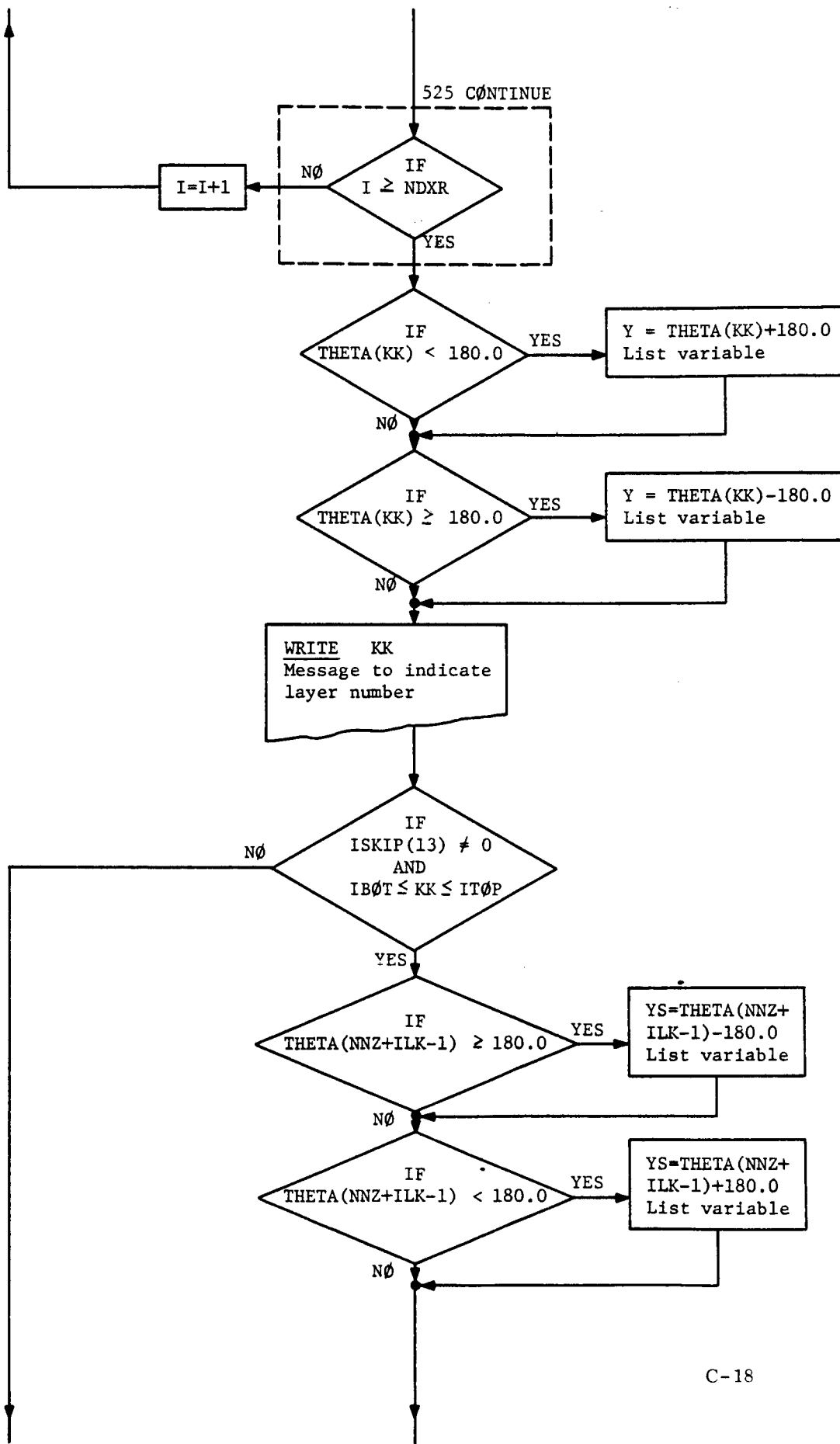


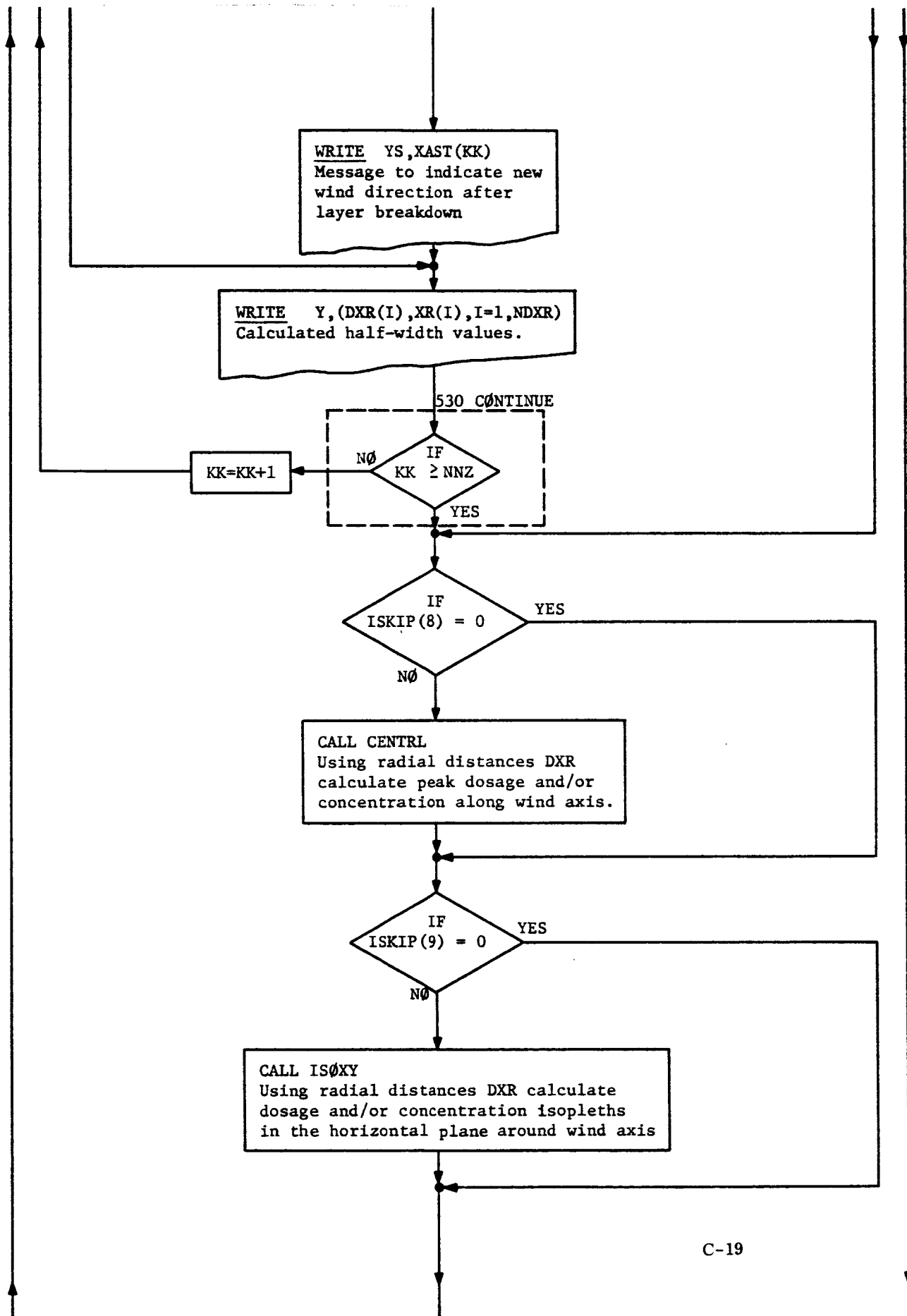


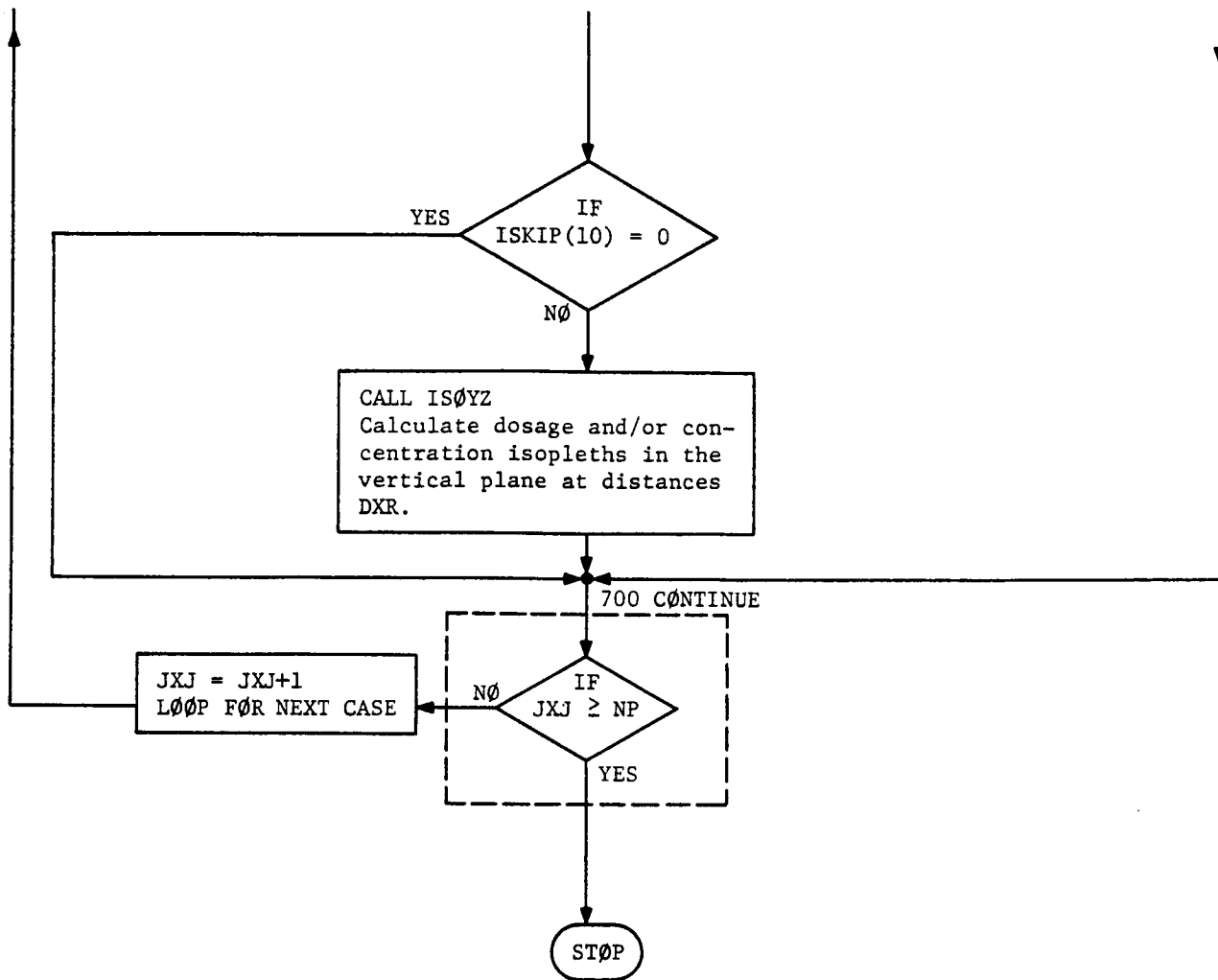












E - N - D

SECTION C.2

SUBROUTINE BREAK

SUBROUTINE BREAK (K,N,X0,Y0)
 THIS SUBROUTINE IS THE MAIN CALCULATION ROUTINE FOR GENERAL DOSAGE AND CONCENTRATION PATTERNS. THIS ROUTINE CONTAINS CHANGE IN LAYER STRUCTURE MODELS AND ASSEMBLES PARTS OF MODELS I, II, III FOR CALCULATIONS. THIS ROUTINE ALSO CALLS THE WASHOUT MODEL ON OPTION (ISKIP(12) = 1 OR = 2).
 (STORAGE USED 1155₈)

ENTRY

DIMENSION AND COMMON SUBSCRIPTED VARIABLES AND VARIABLES COMMON TO THE VARIOUS SUBROUTINES.

NF = N
 CALL C00RD(N,KK,X,Y,X0,Y0,ASP,XS,1)
 Obtain coordinates of grid point (X0,Y0)
 relative to wind direction.
 (x_K,y_K)

D0S(J) = 0.0
 C0N(J) = 0.0
 ISW5 = 0

IF
 ISKIP(13) ≠ 0
 AND
 IB0T ≤ KK ≤ IT0P

YES

NO

IS = 1

IF
 N = 9

YES

NO

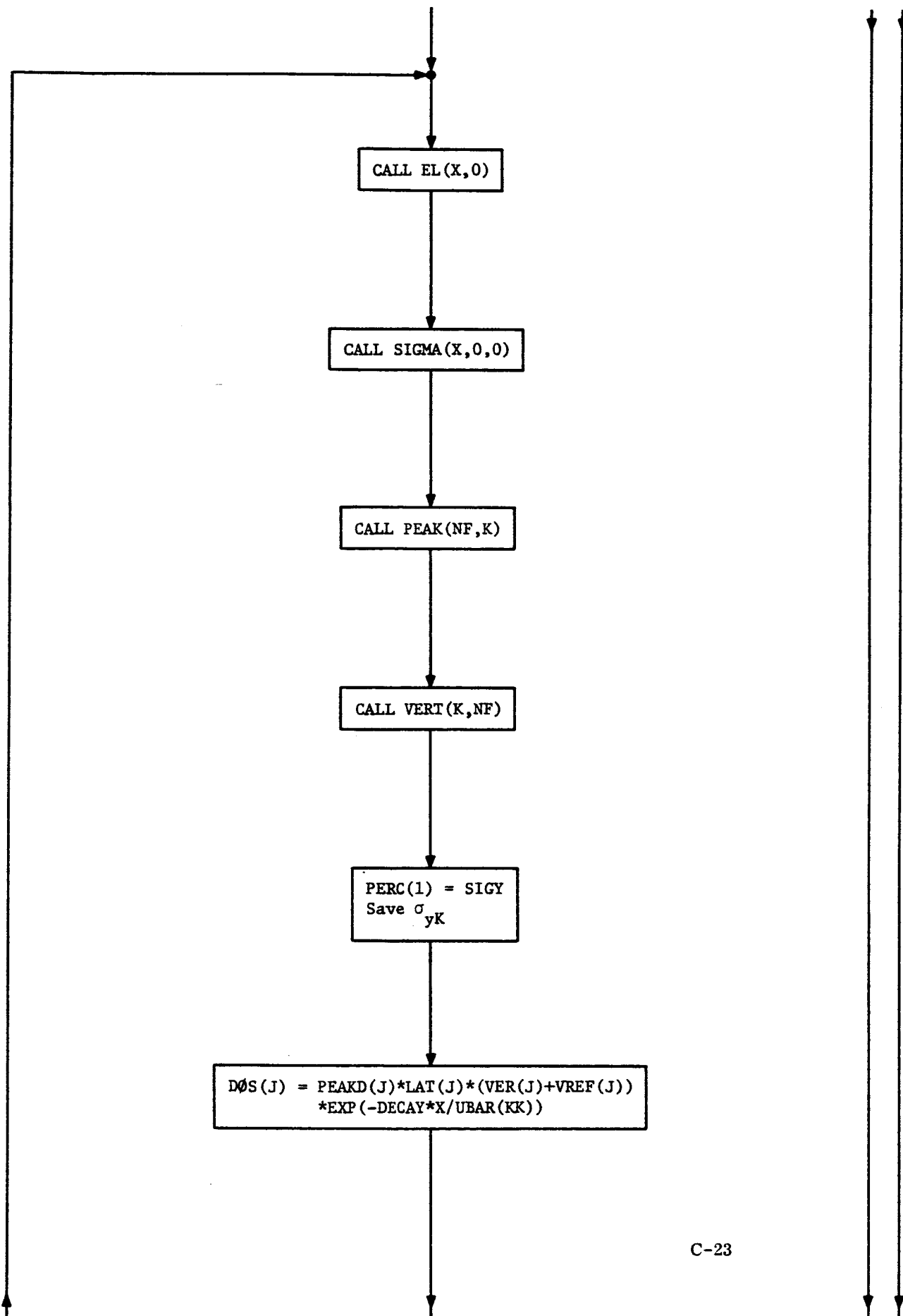
COORDINATES OUTSIDE
 OF SECTOR DELPHI

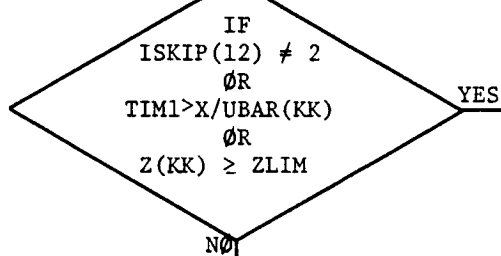
C-22

↓

↓

↓

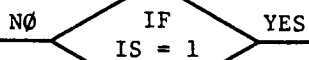


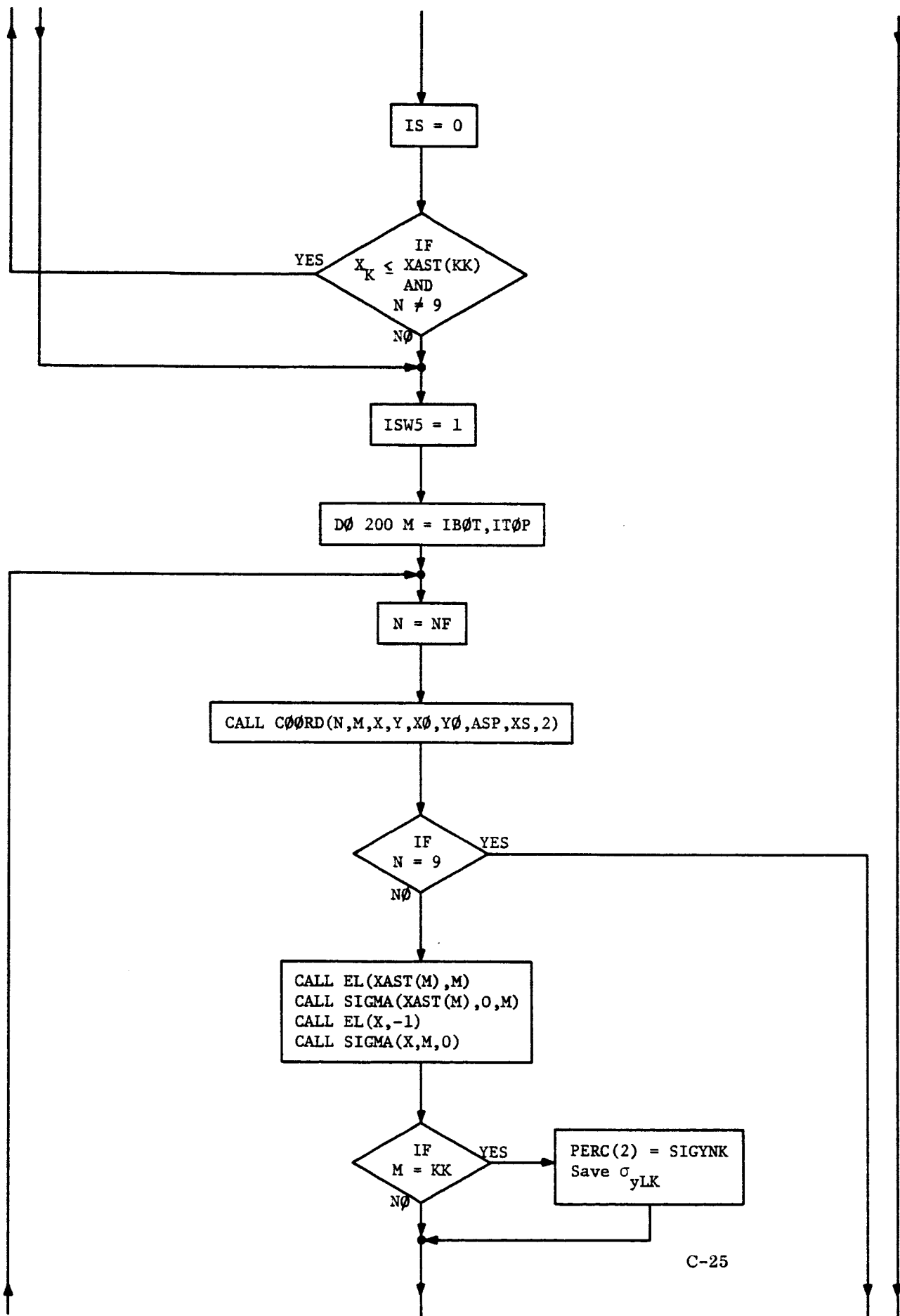


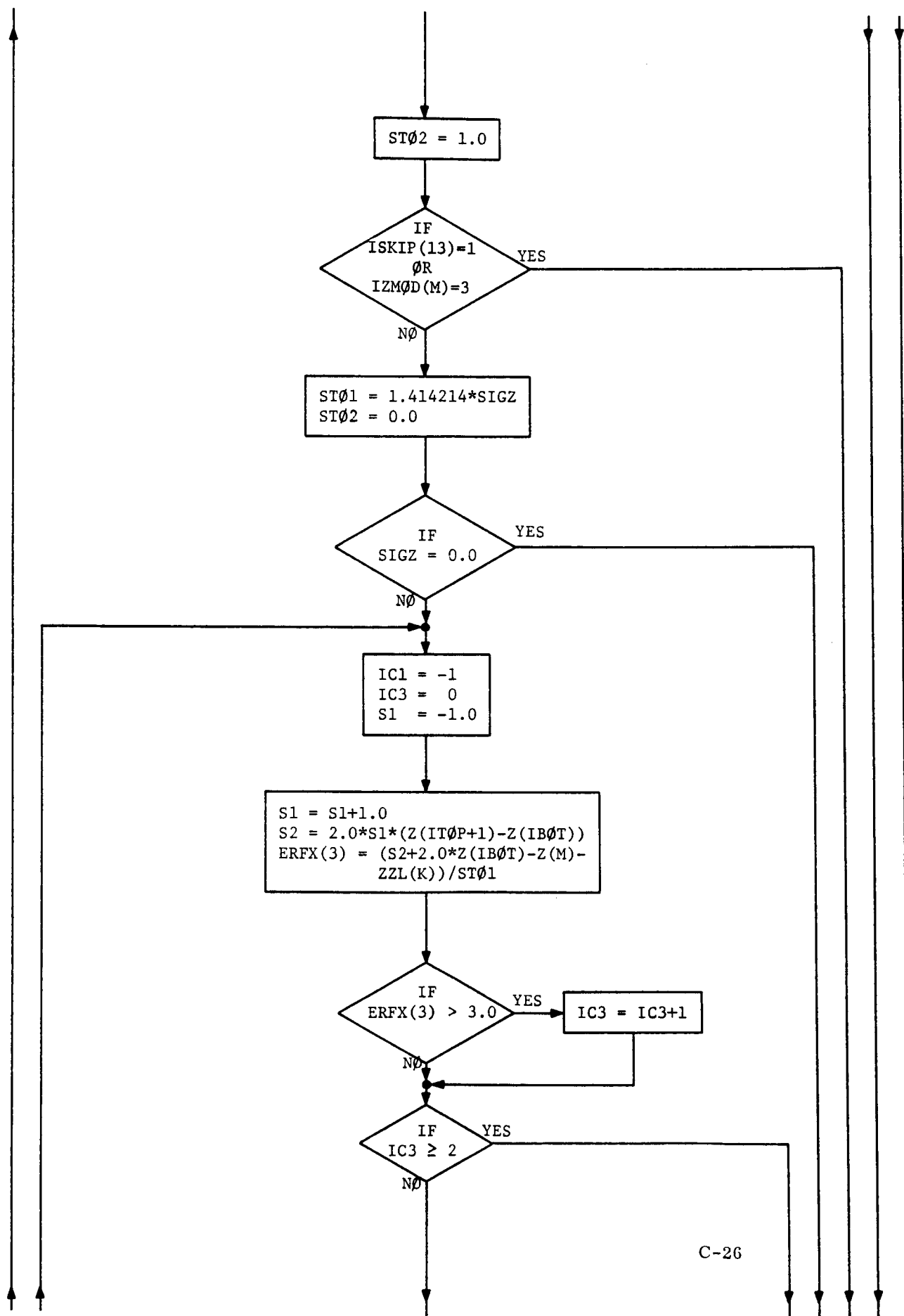
$DØS(J) = DØS(J) * \exp(-LAMBDA * (X / UBAR(KK) - TIM1))$

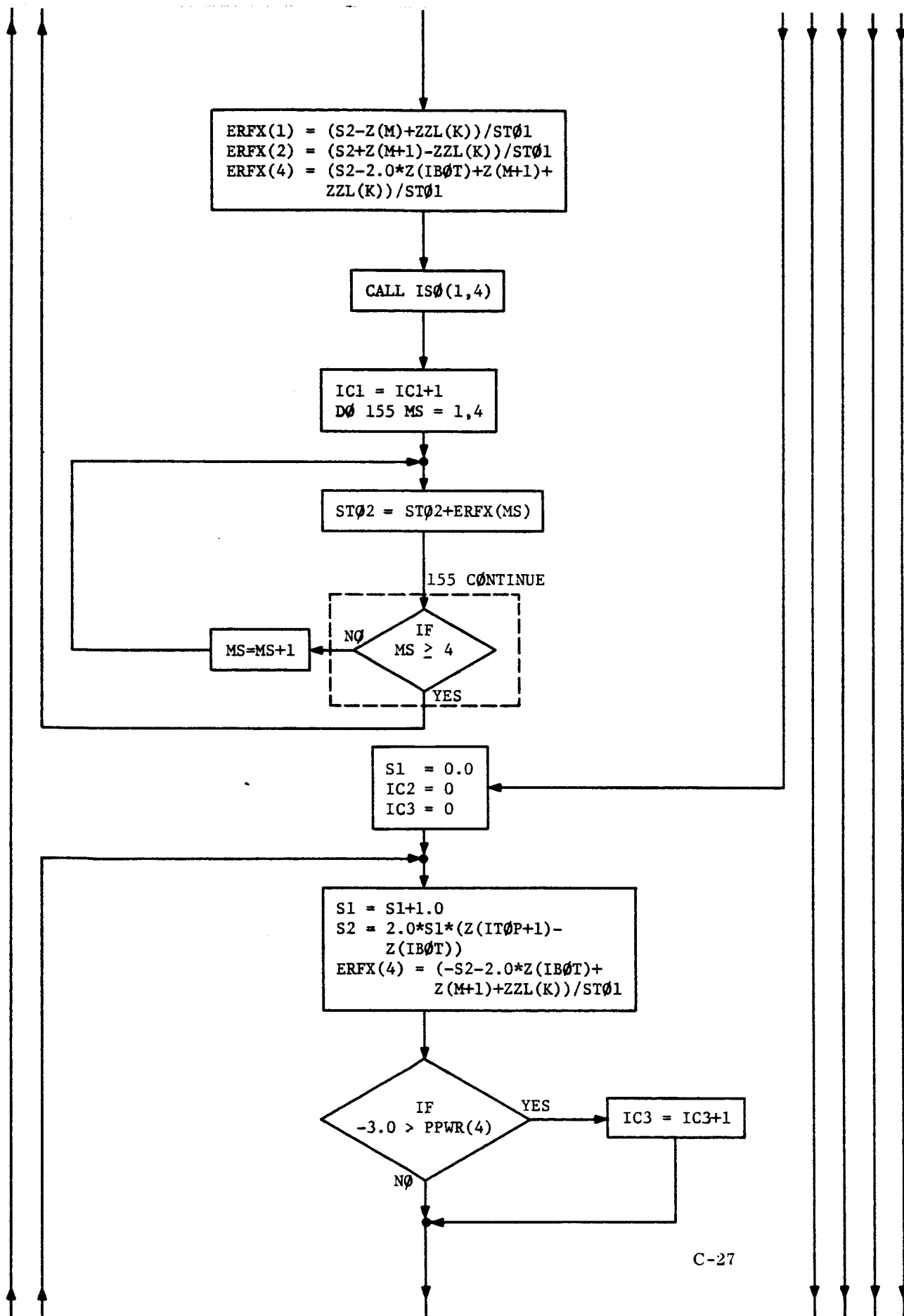
CALL ALØNGD(X_K , T(KK))

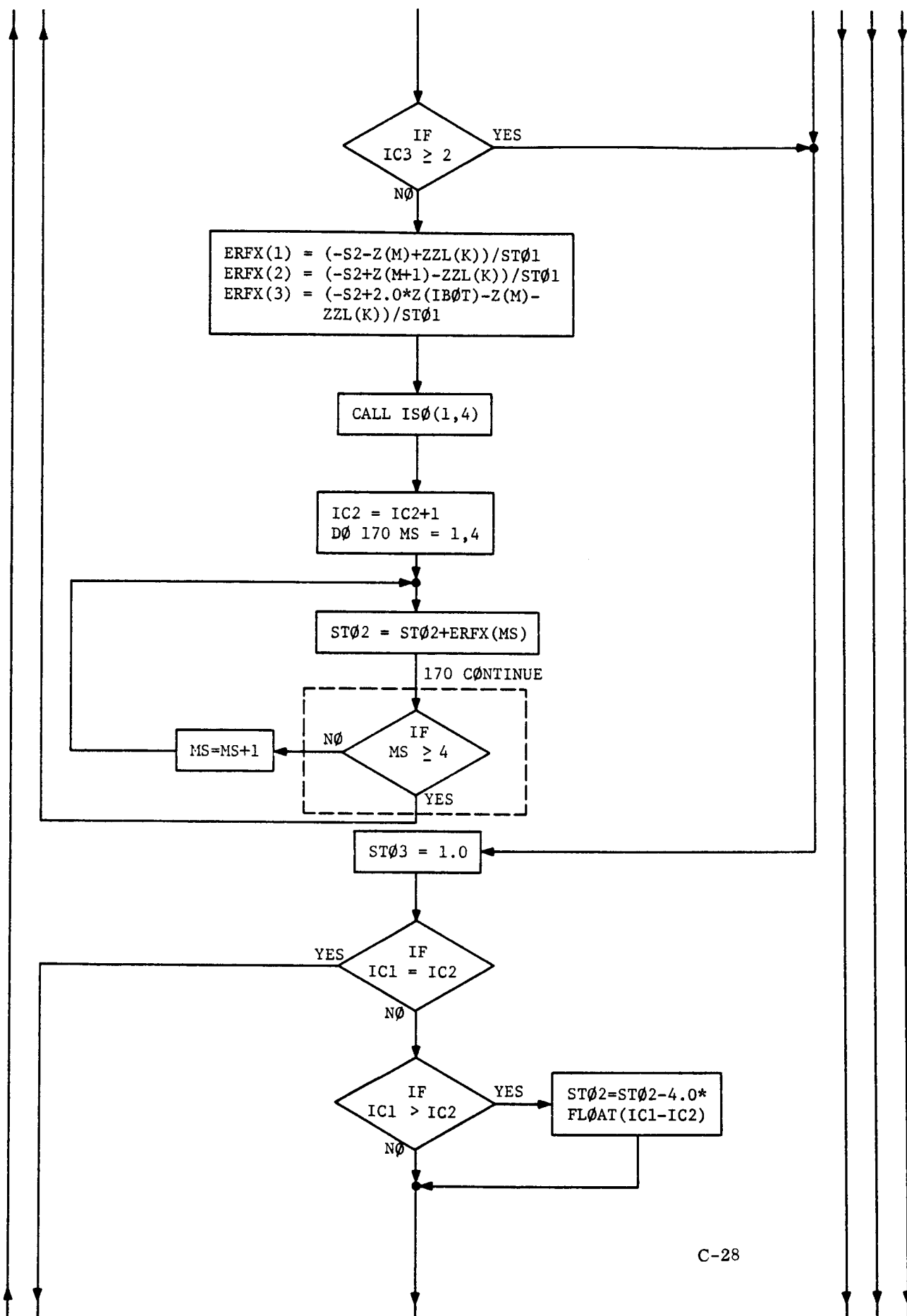
$CØN(J) = DØS(J) * UBARZK(K) / (SQR2P * SIGX) * ALØNGW(J)$

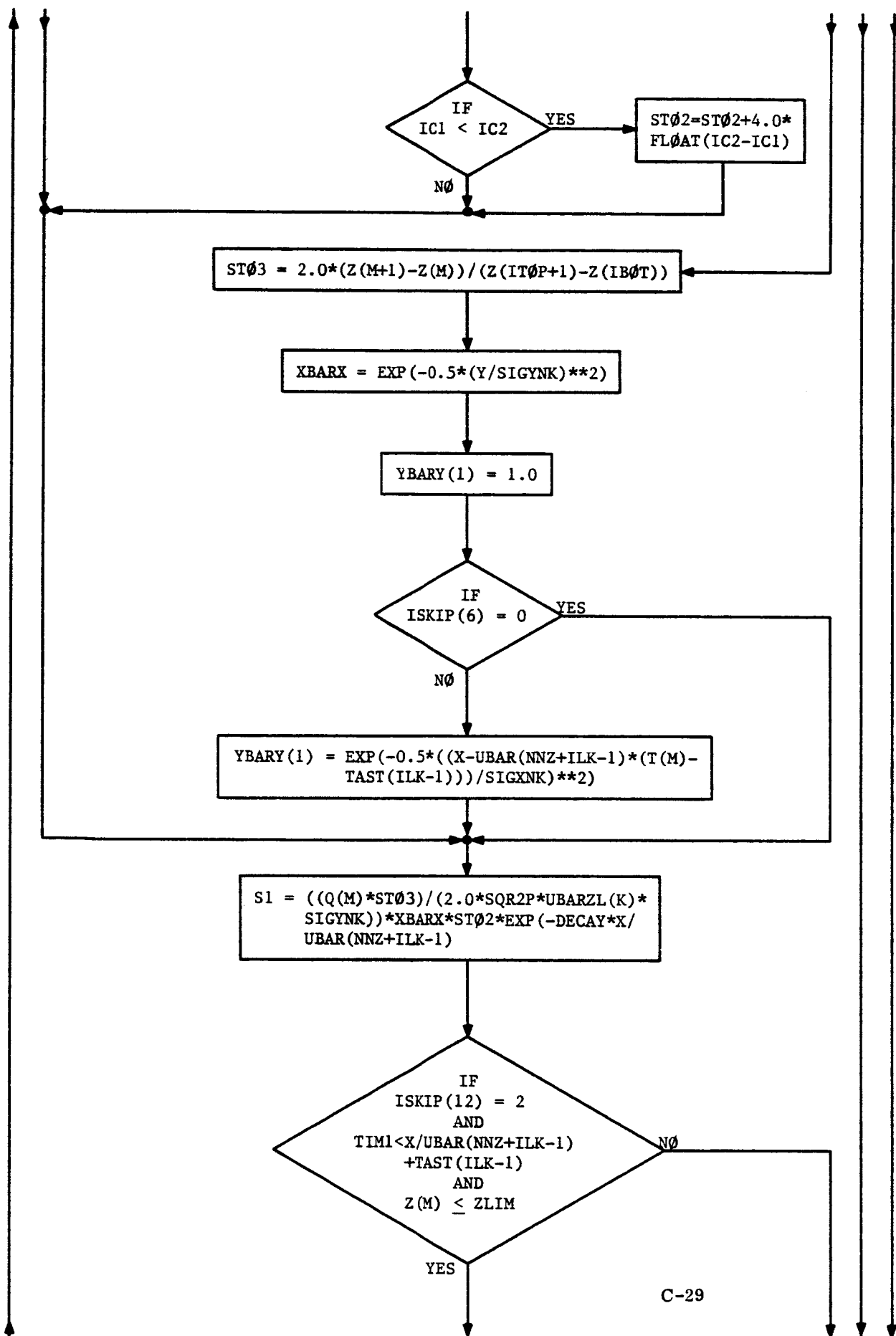


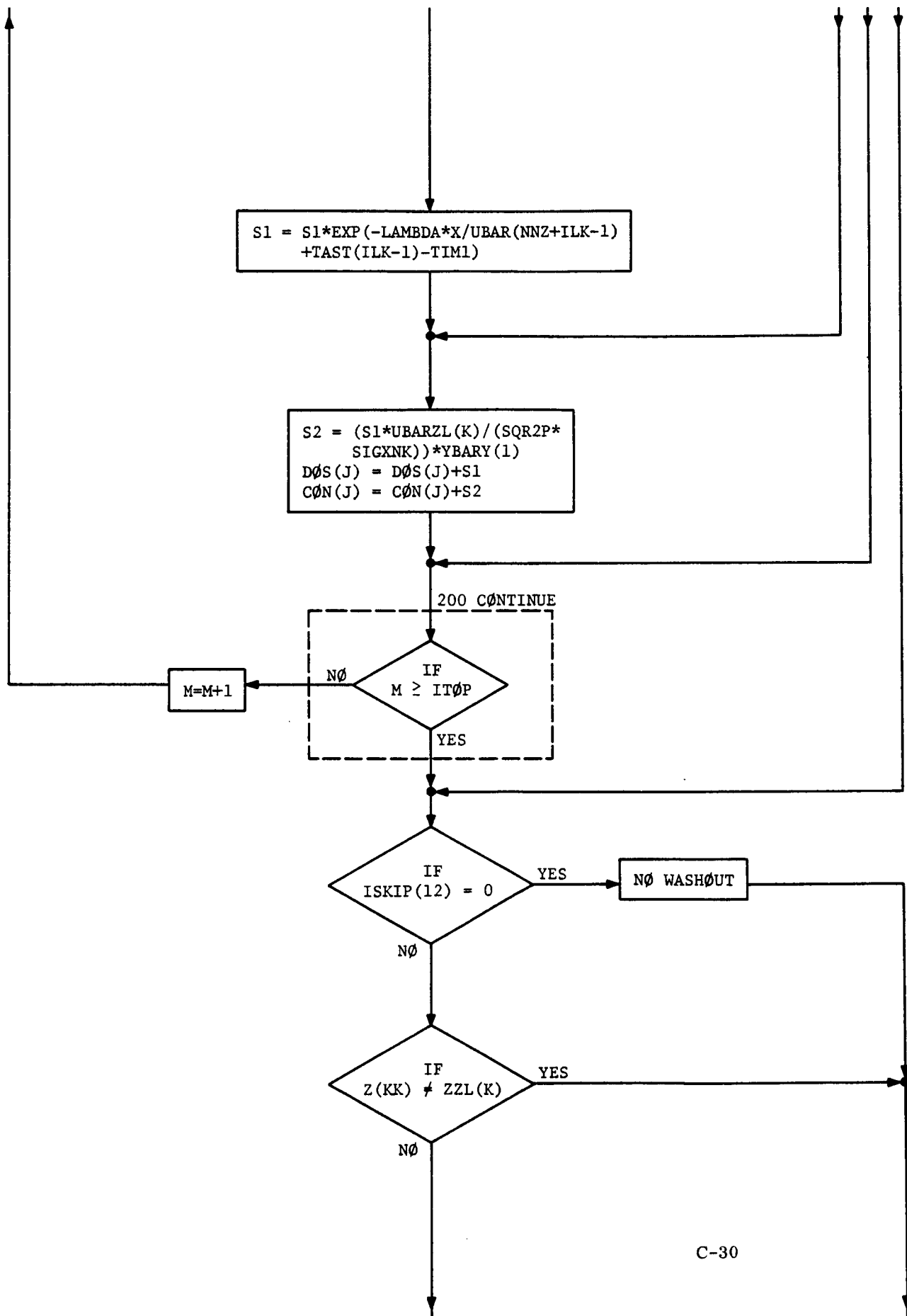


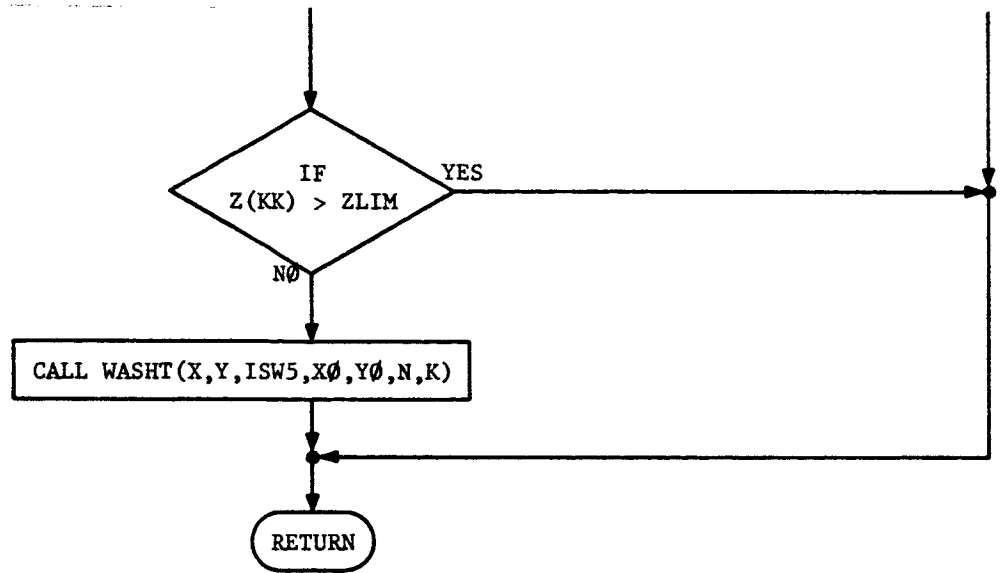












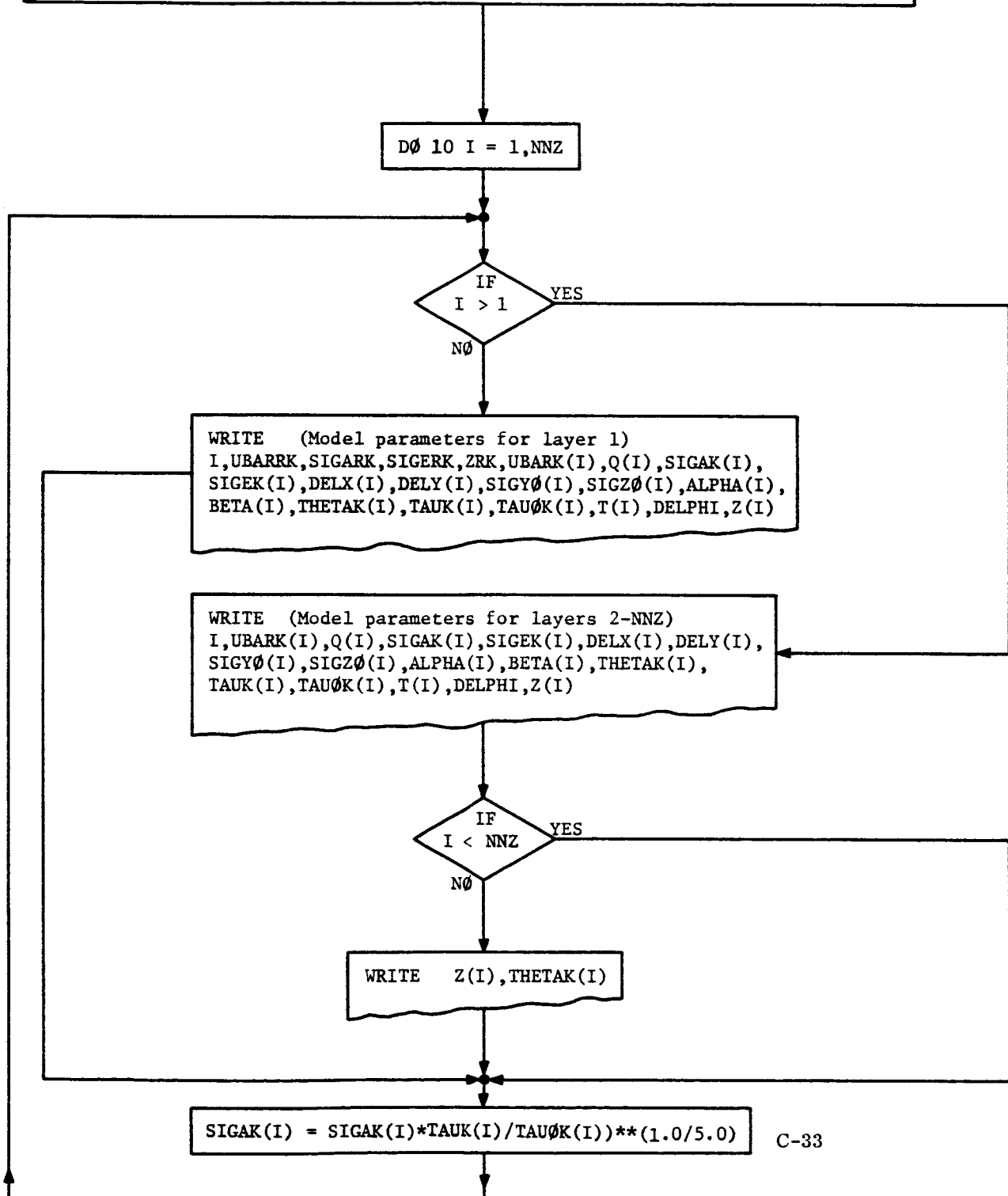
SECTION C.3

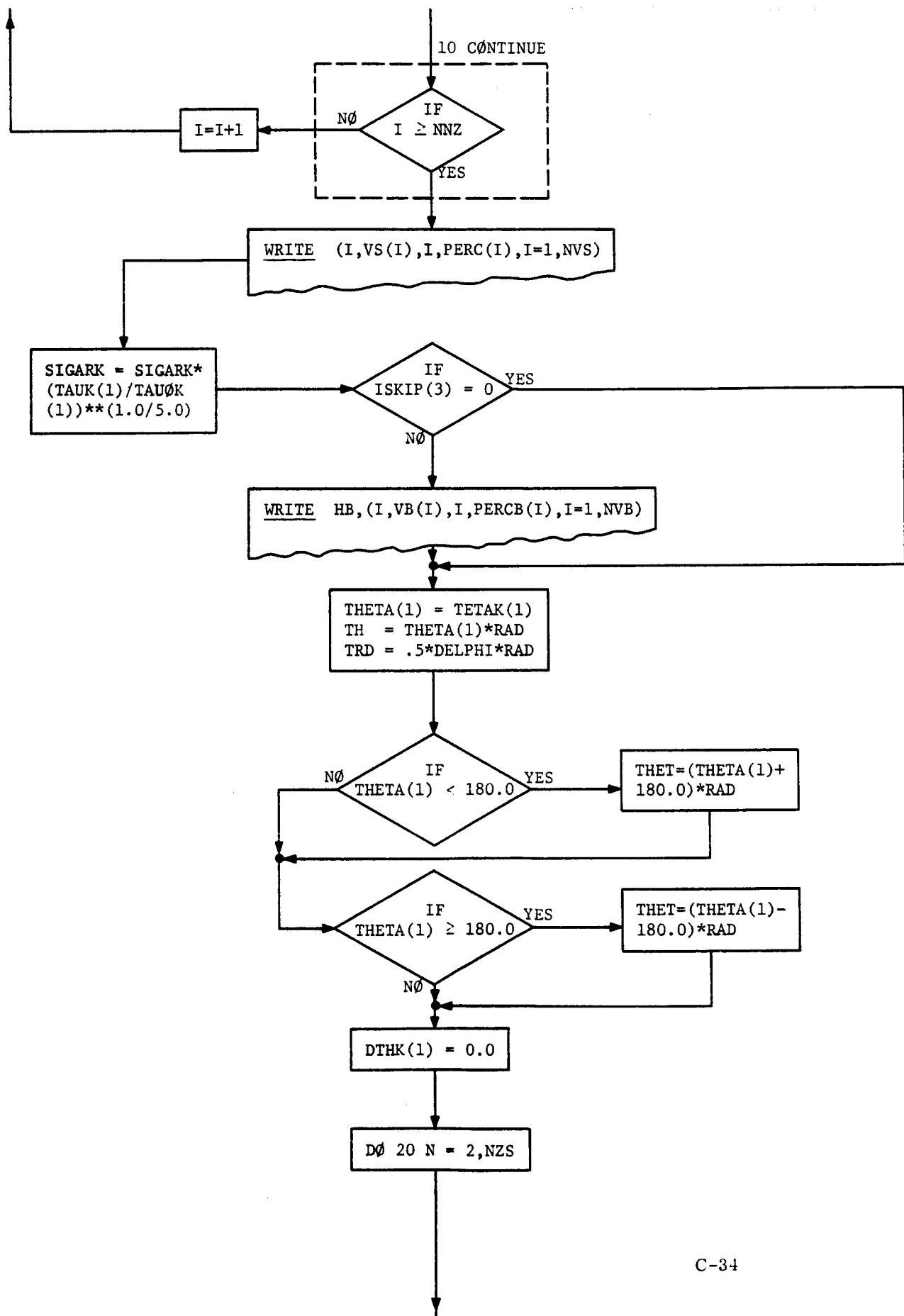
SUBROUTINE DEPOS

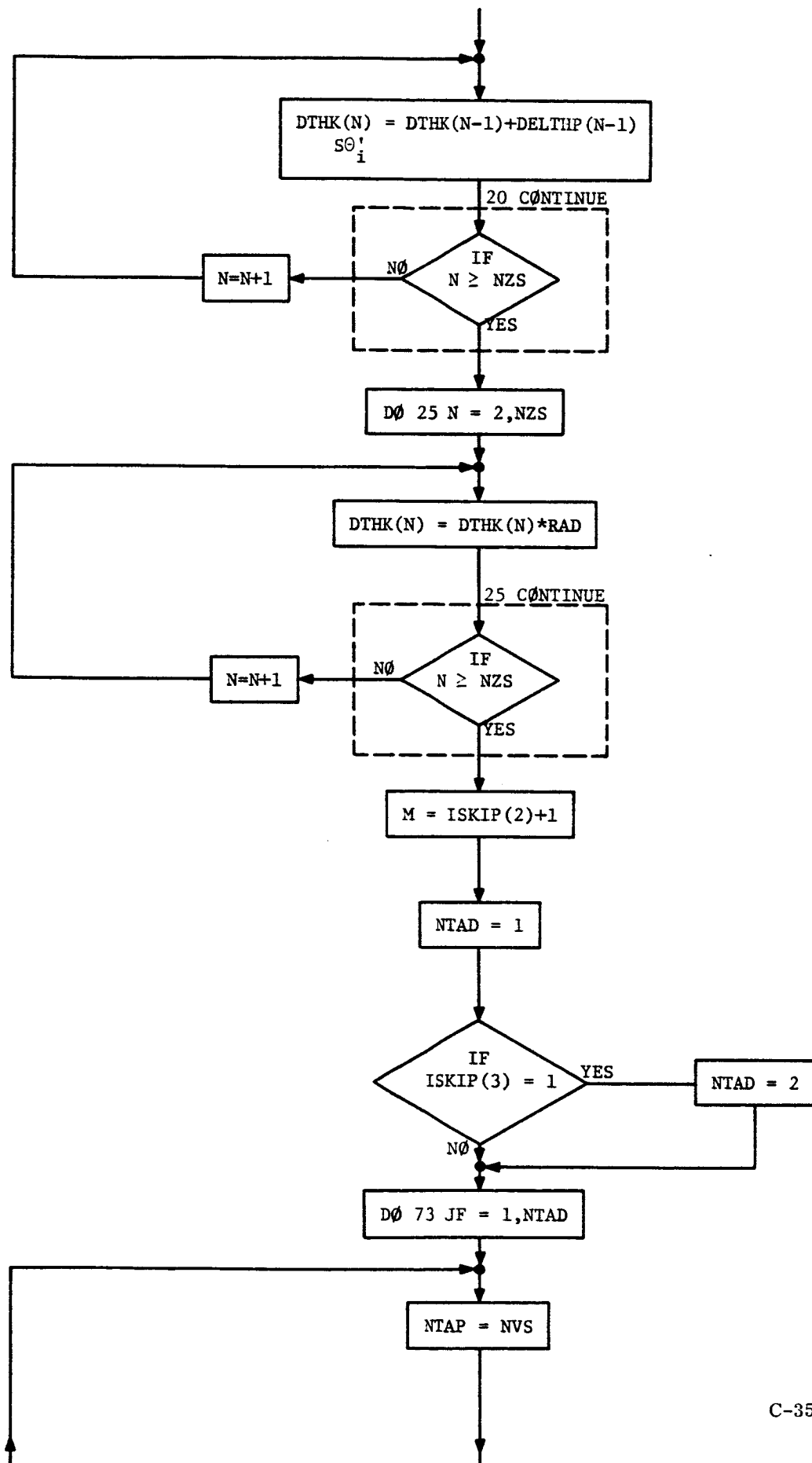
SUBROUTINE DEPOS(NP)

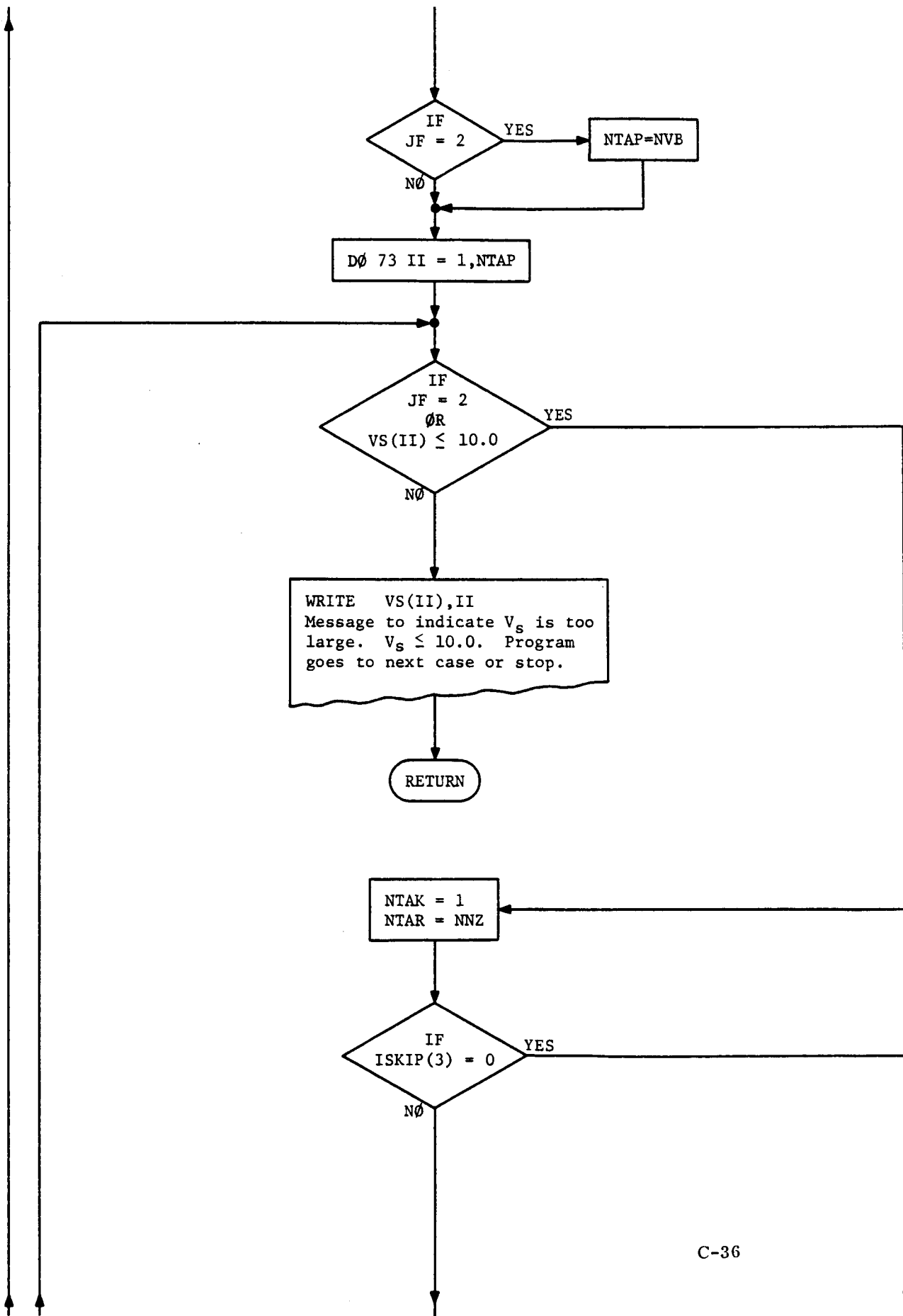
THIS SUBROUTINE CALCULATES GRAVITATIONAL DEPOSITION FOR THE MULTILAYER MODEL ONLY IF ISKIP(1) = 2. IF ISKIP(3) = 1 A BURST IS ASSUMED TO HAVE OCCURRED IN LAYER NNZ AND ALL MET PARAMETERS IN LAYER NNZ ARE RELATIVE TO THE BURST.

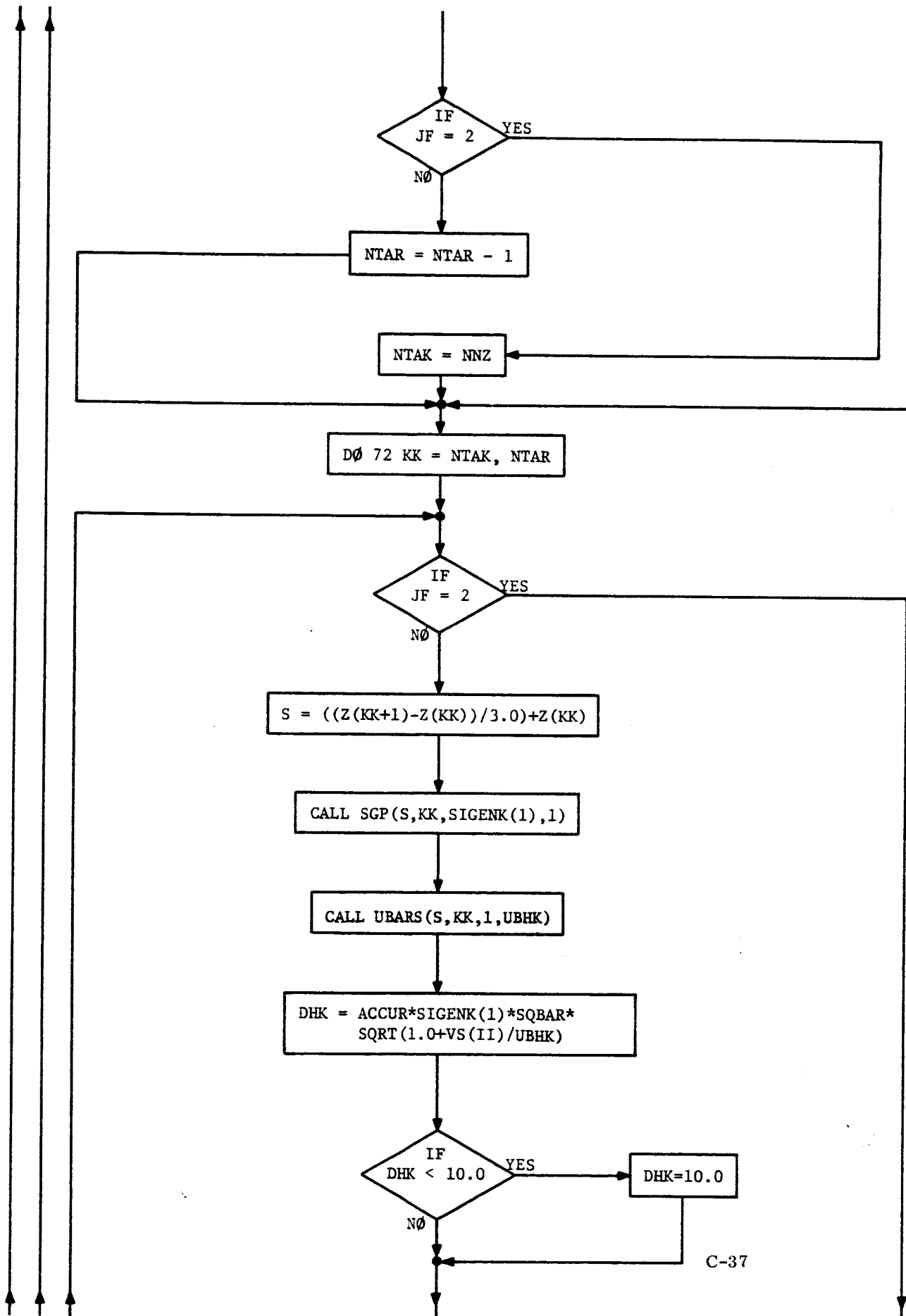
(STORAGE USED 1504₈)

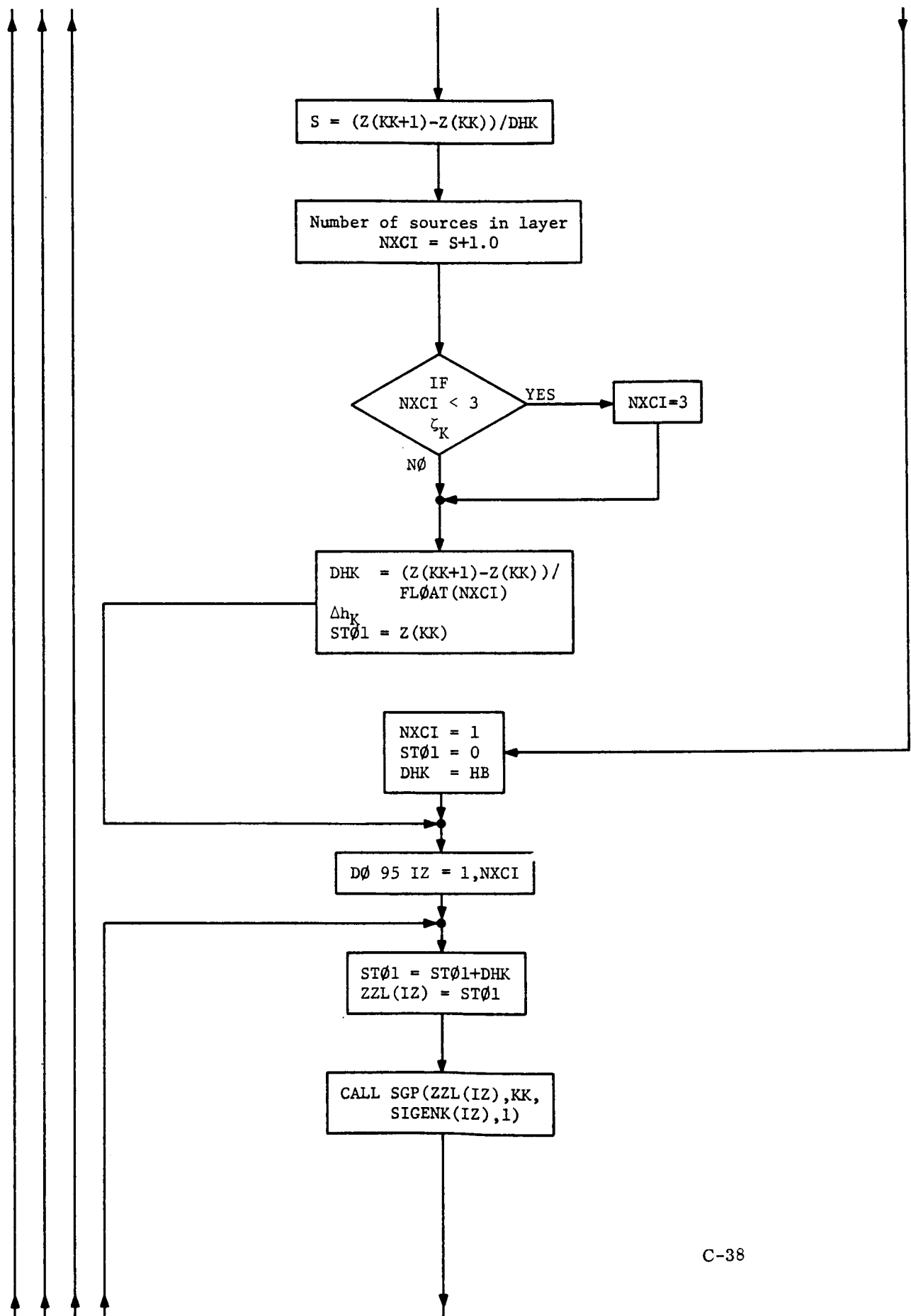


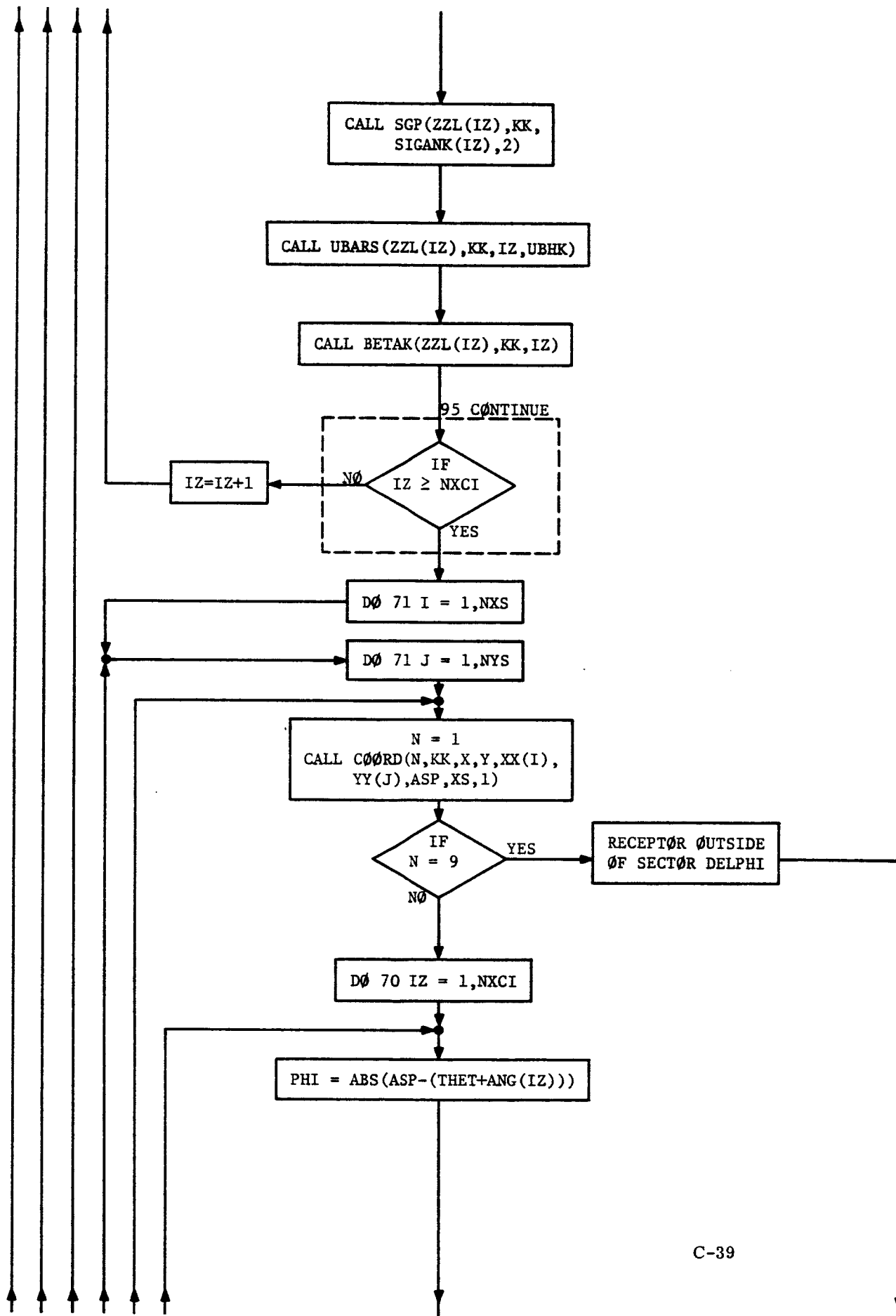


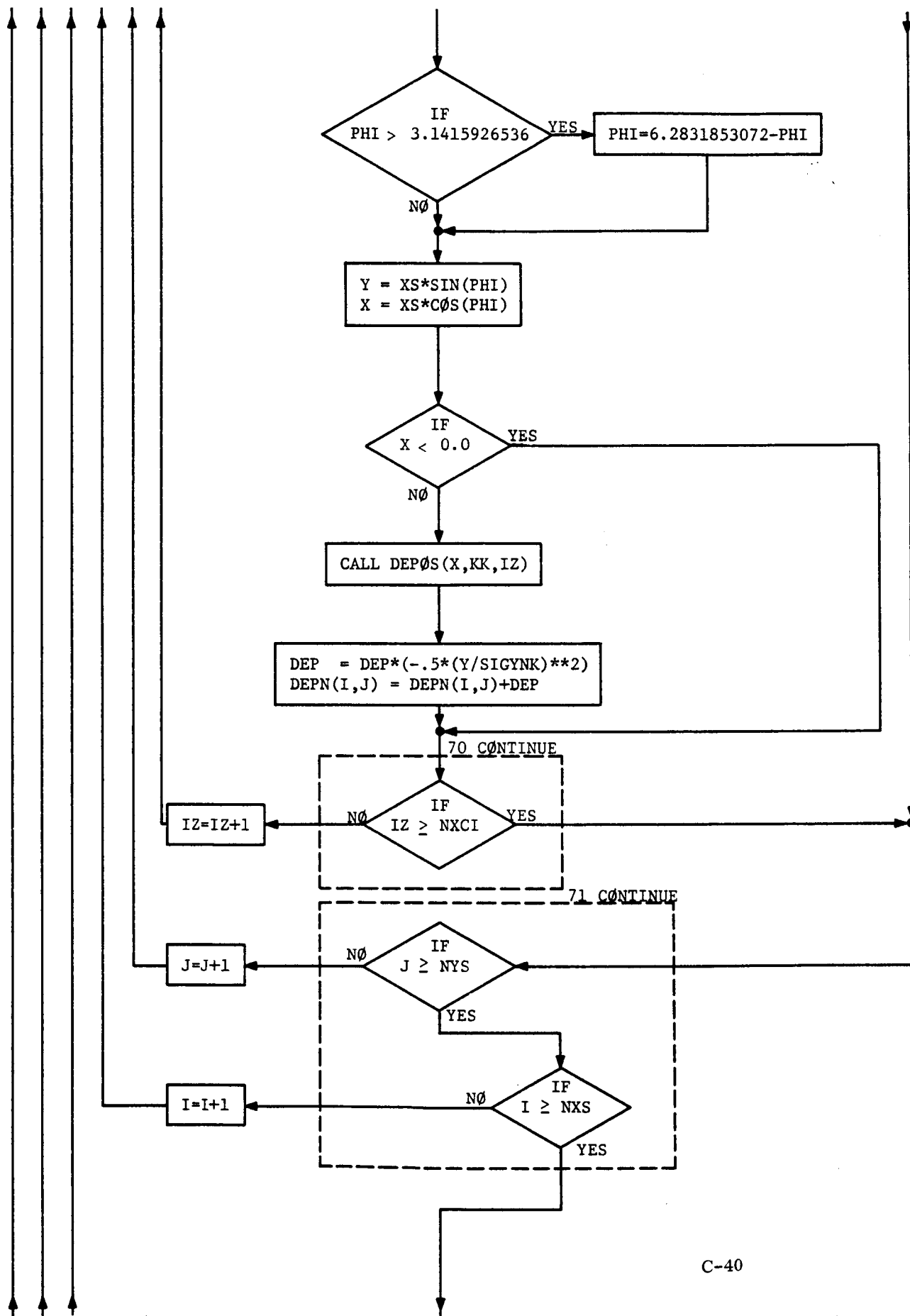


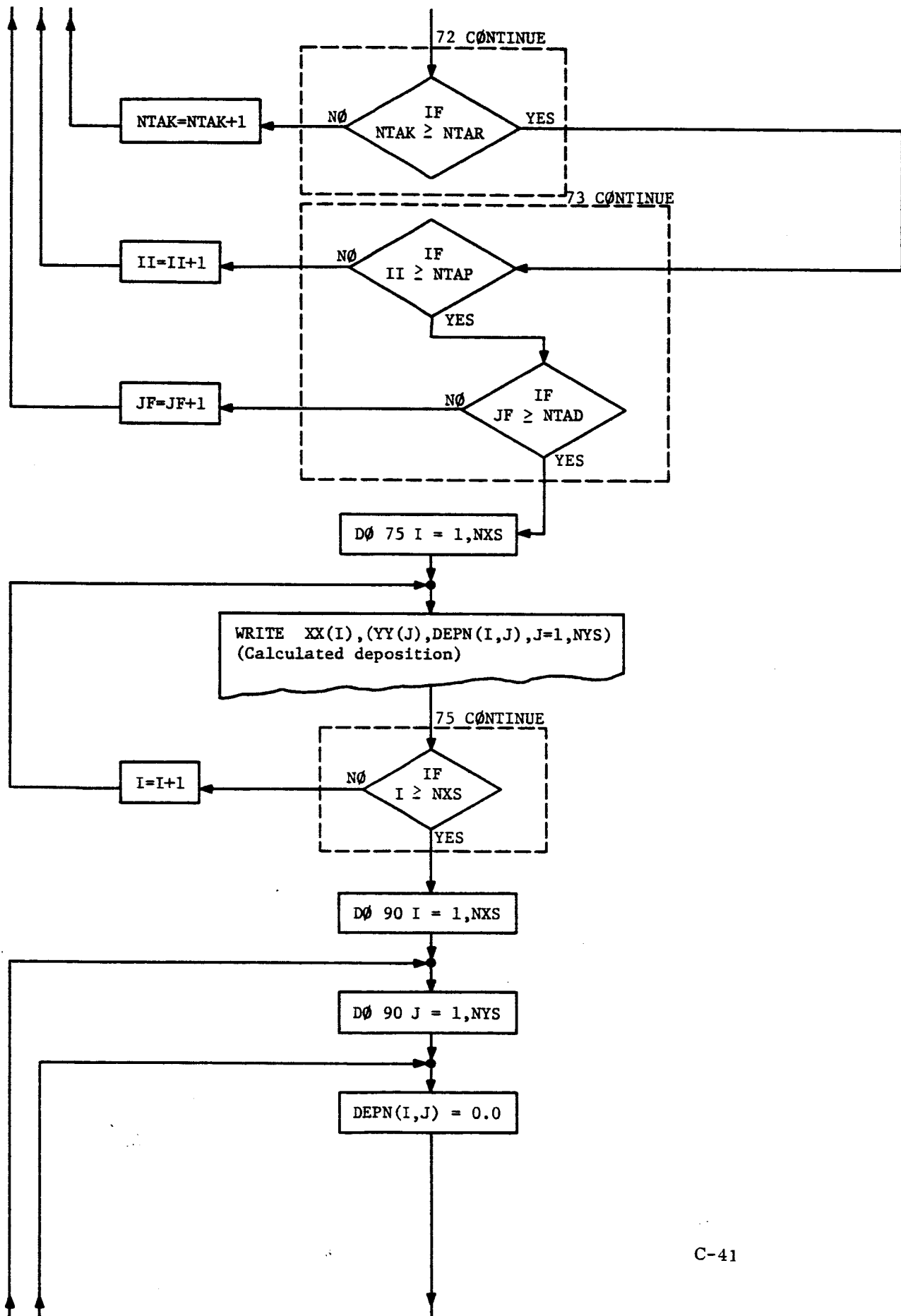


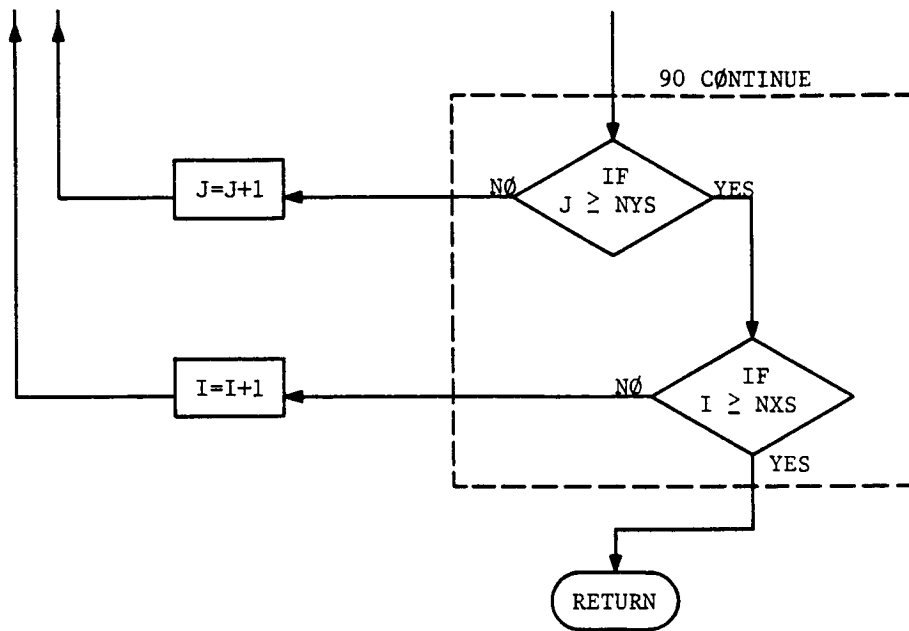








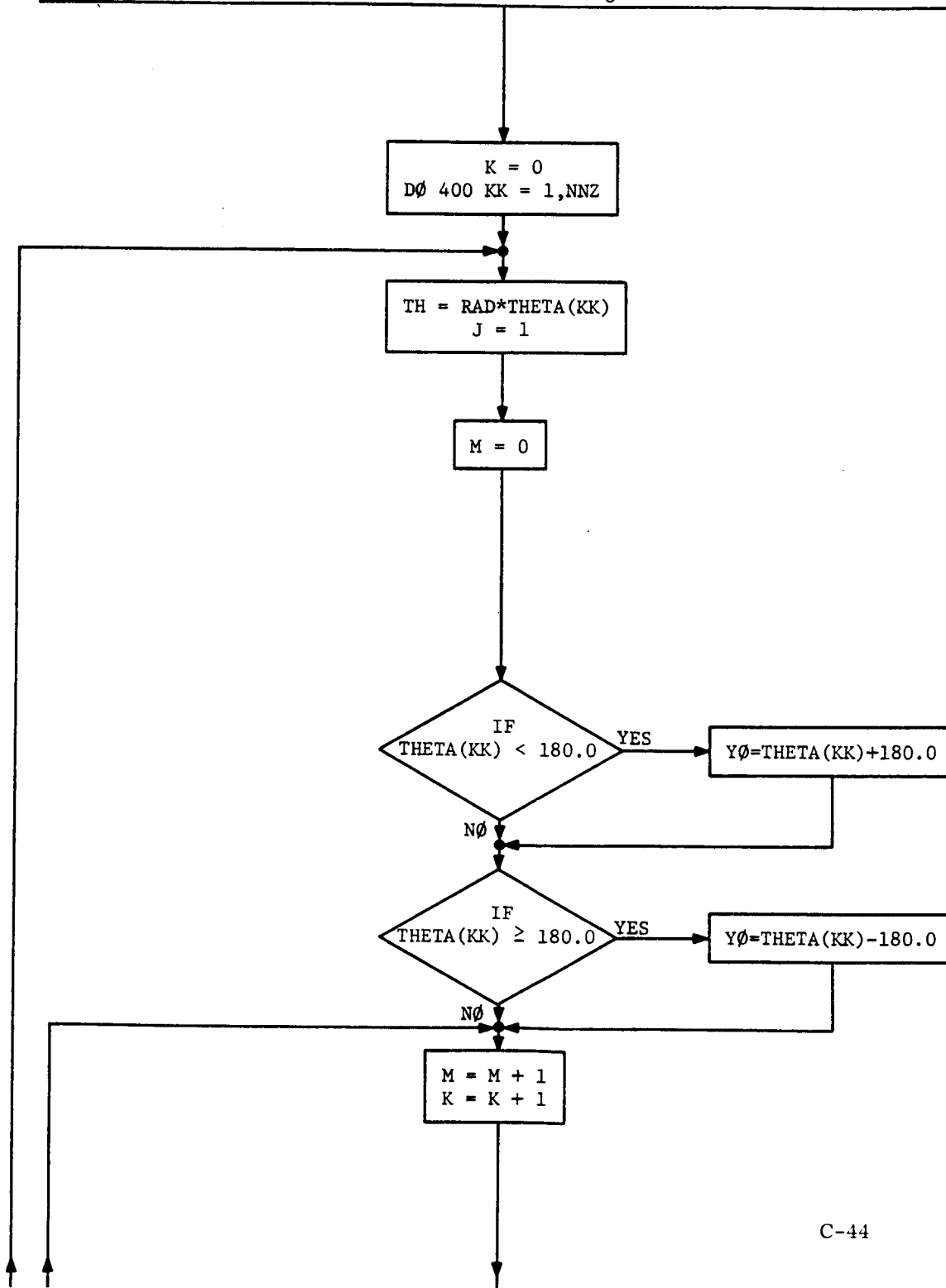


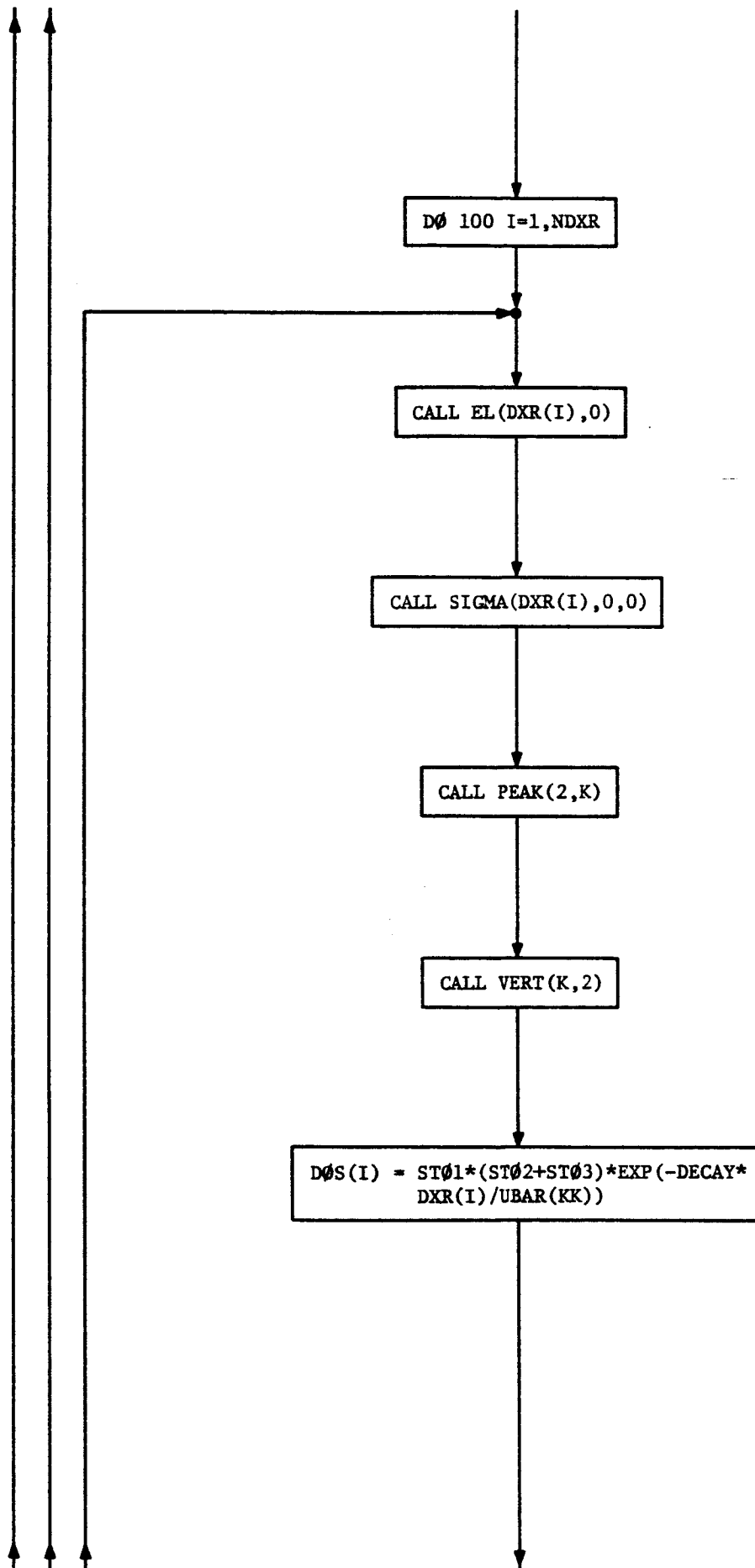


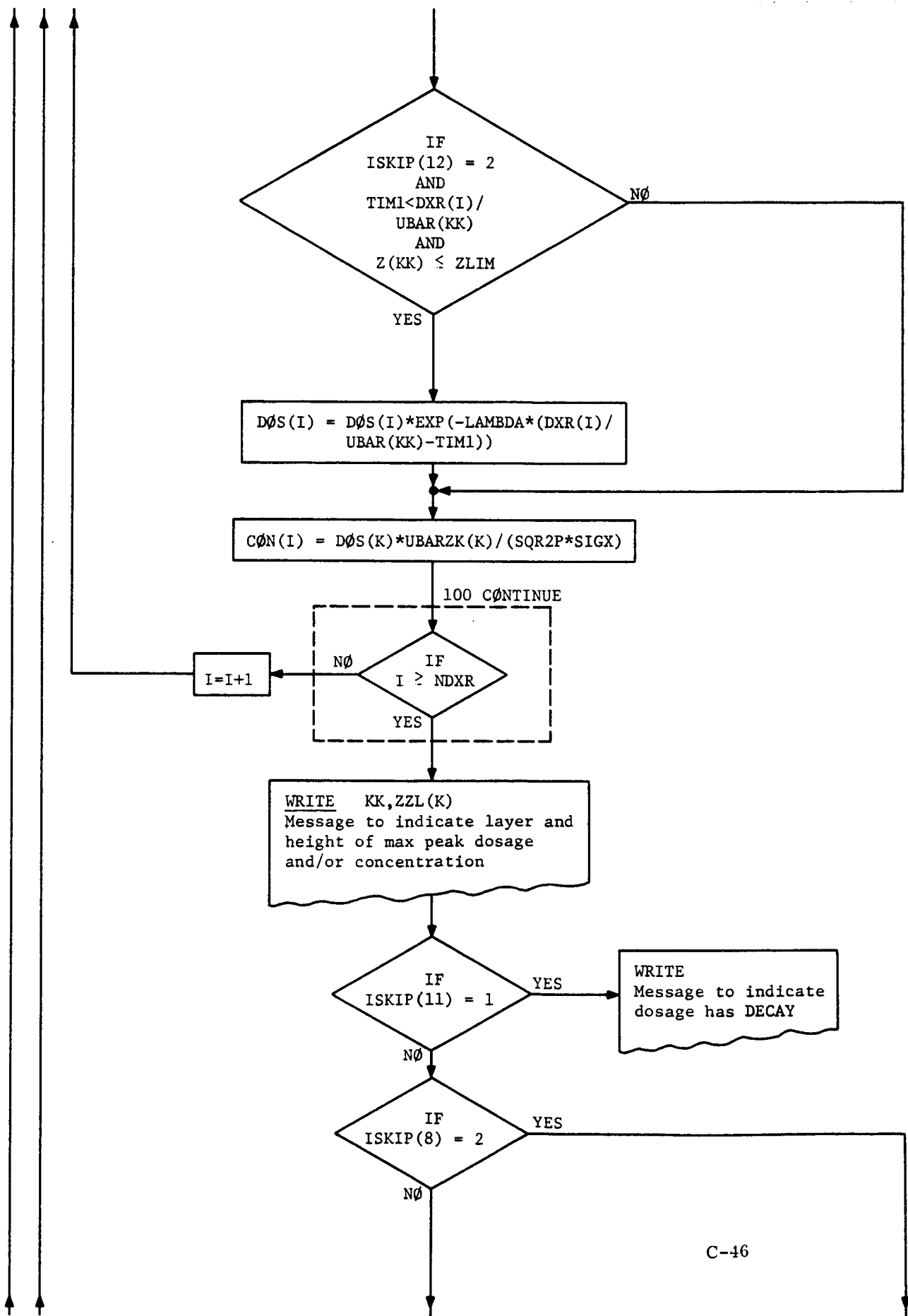
SECTION C.4

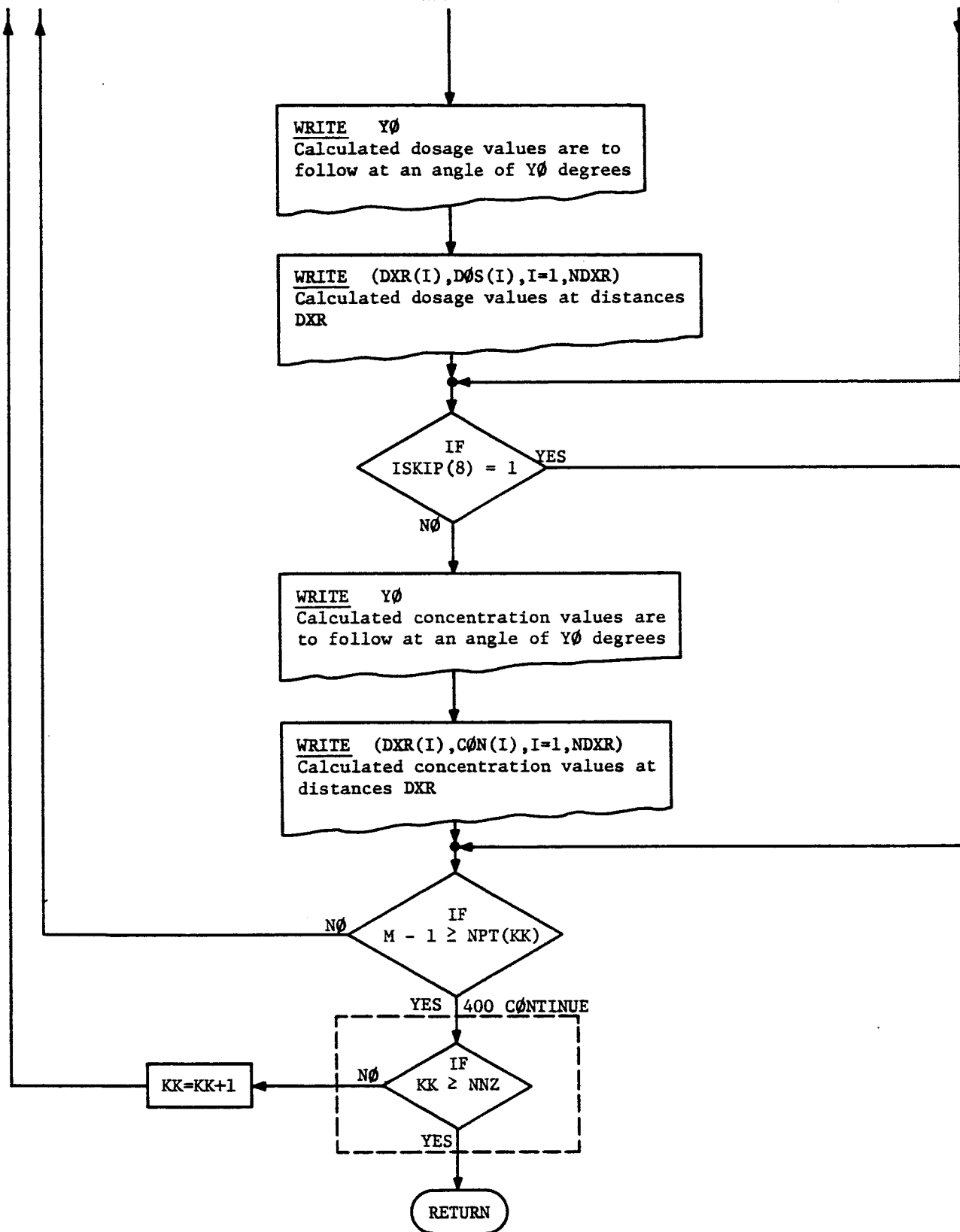
SUBROUTINE CENTRL

SUBROUTINE CENTRL
SUBROUTINE CENTRL CALCULATES AXIAL DOSAGE AND CONCENTRATION AT RADIAL DISTANCES
DXR WITH OR WITHOUT DECAY DEPENDING ON ISKIP(14).
(STORAGE USED 512₈)









SECTION C. 5

SUBROUTINE ISOXY

SUBROUTINE ISOXY
SUBROUTINE ISOXY CALCULATES ISOPLETHS IN THE HORIZONTAL PLANE. THE HEIGHTS AT WHICH CALCULATIONS ARE MADE IS DETERMINED BY ISKIP(15). CALCULATIONS ARE MADE AT DISTANCES DXR.
(STORAGE USED 1042₈)

WRITE
Message to indicate horizontal
isopleths are to follow

K = 0
DO 630 KK = 1, NNZ

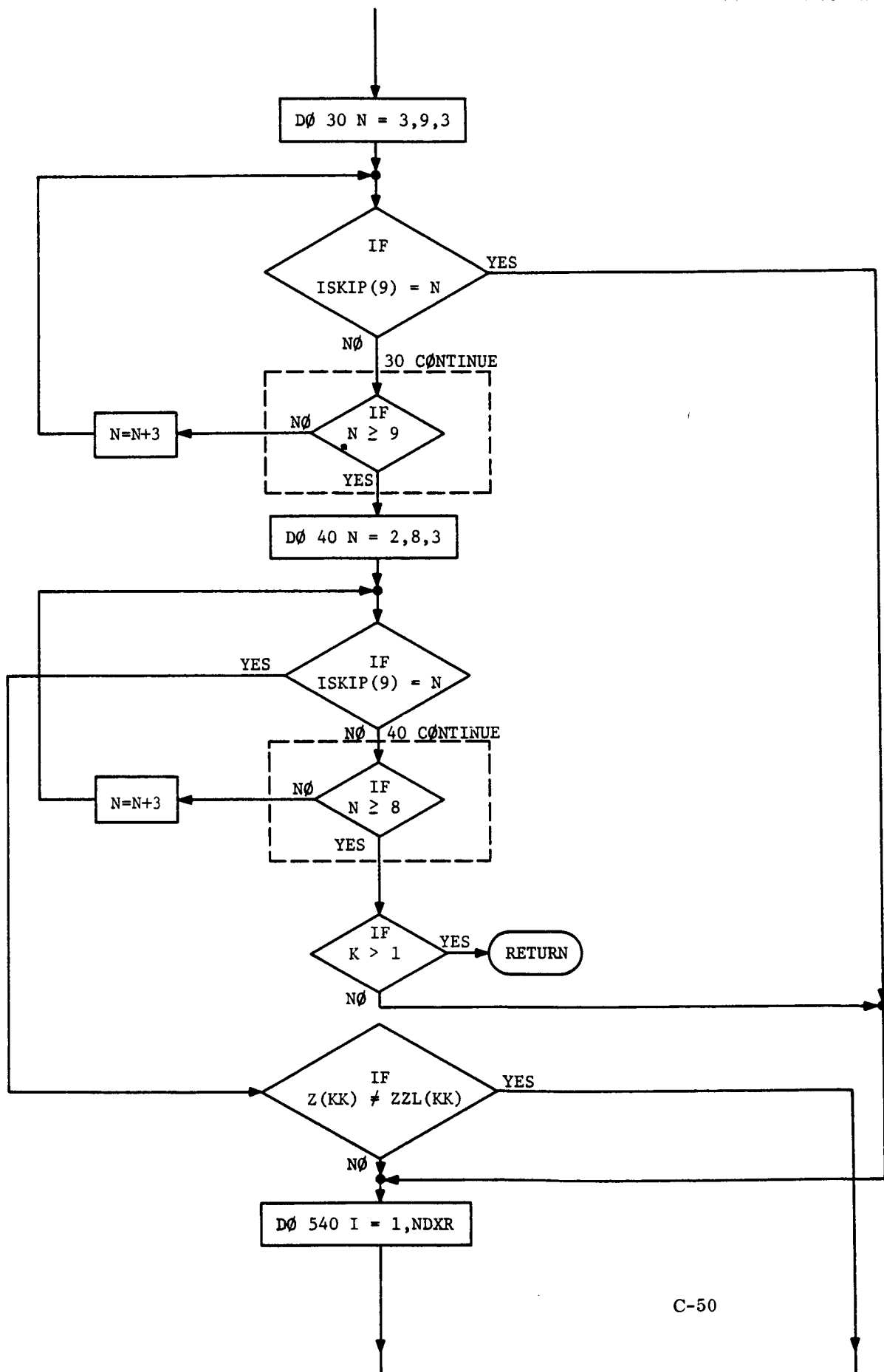
TH = RAD*THETA(KK)
M = 0

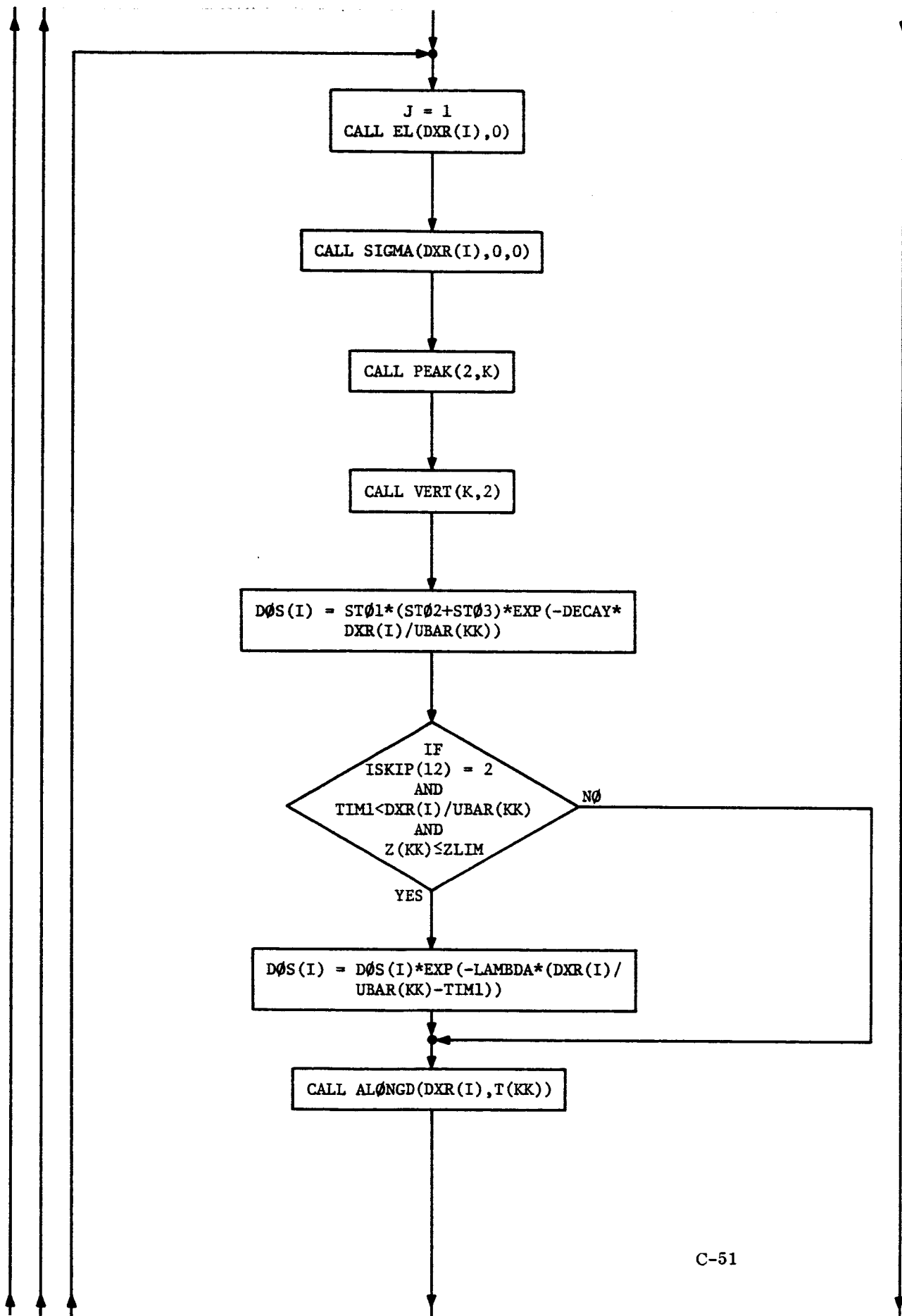
IF
THETA(KK) ≥ 180.0 YES
S = THETA(KK) - 180.0
NO

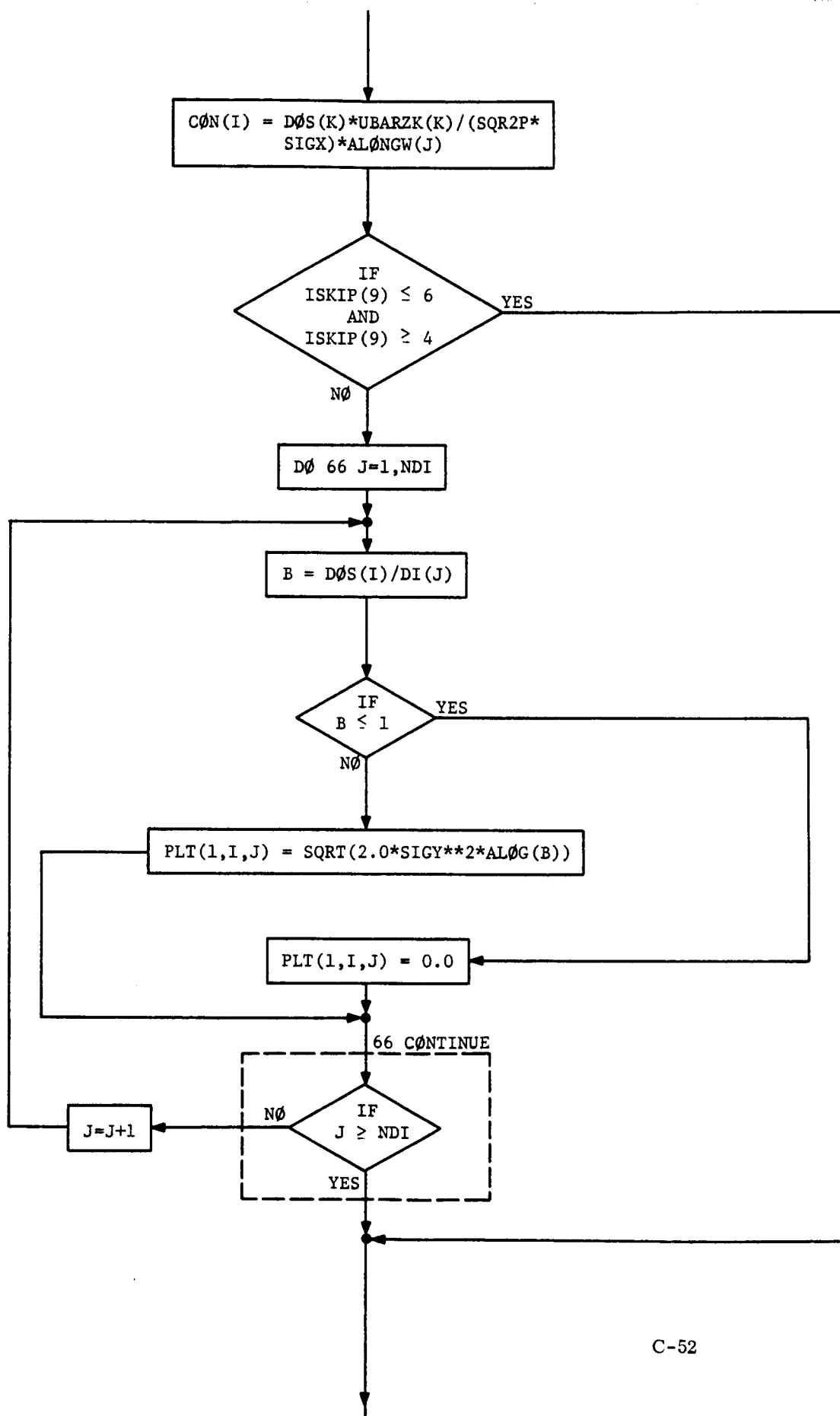
IF
THETA(KK) < 180.0 YES
S = THETA(KK) + 180.0
NO

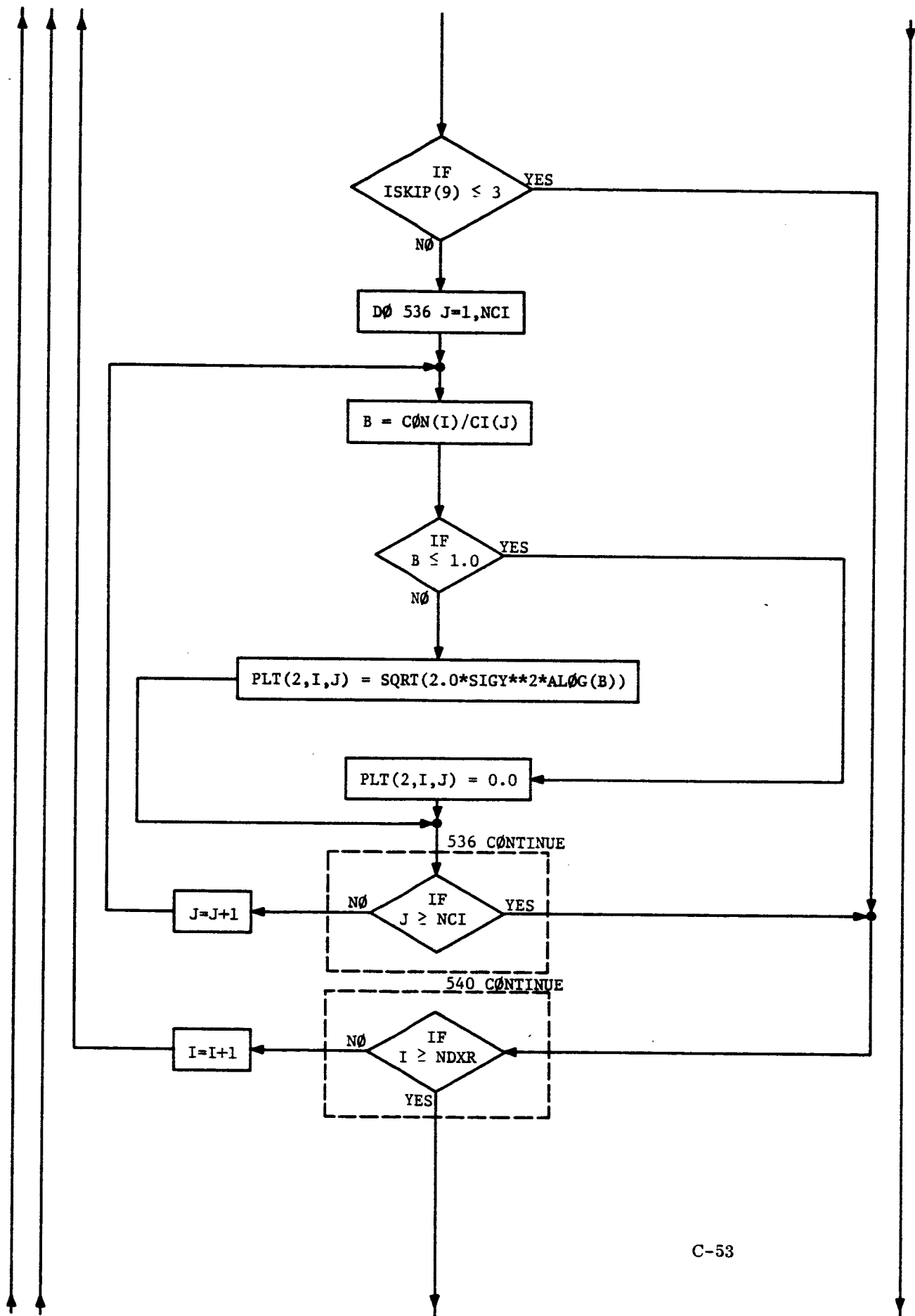
WRITE S
Message to indicate wind direc-
tion relative to source

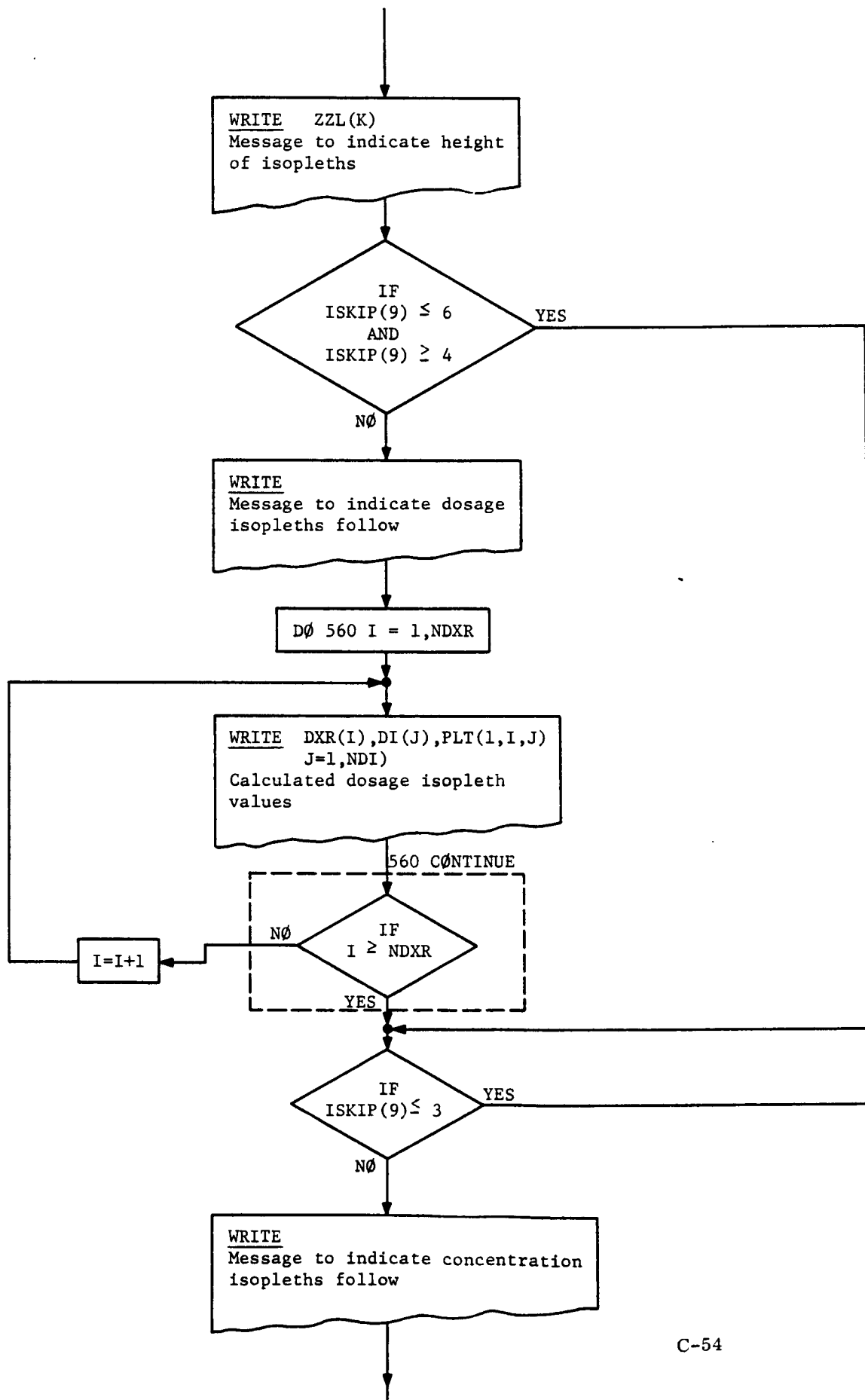
M = M + 1
K = K + 1

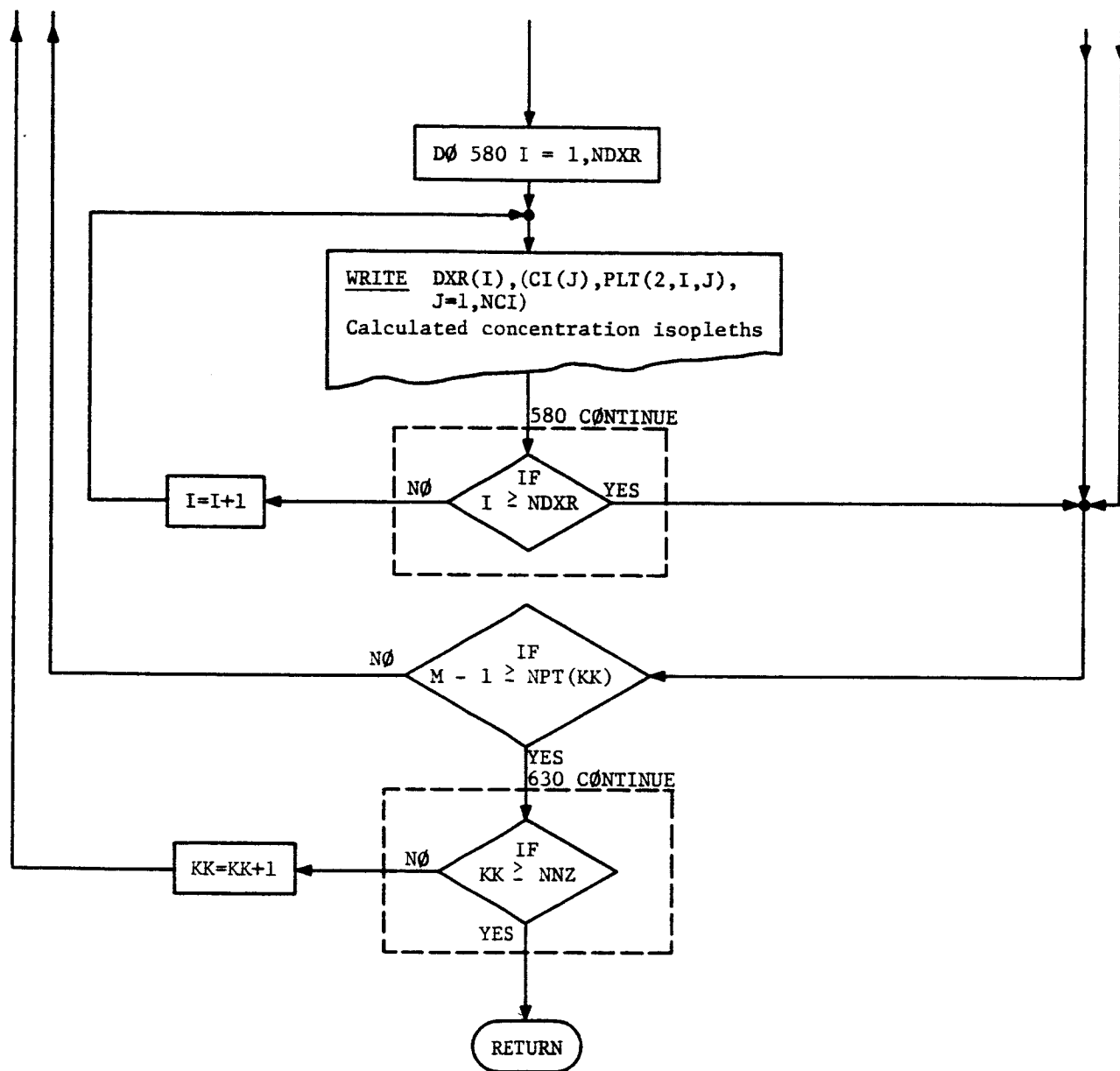












SECTION C. 6

SUBROUTINE ISOYZ

SUBROUTINE ISOYZ

SUBROUTINE ISOYZ CALCULATES ISOPLETHS IN THE VERTICAL PLANE. THE CALCULATIONS ARE MADE IN EACH PLANE AT A DISTANCE DXR FROM THE SOURCE. IF AT DISTANCE DXR(I) THE CORRESPONDING ARRAY IFLAG(I) = 0 NO CALCULATIONS OCCUR. IF IFLAG(I) = 1 ISOPLETHS ARE CALCULATED. ISKIP(10) CONTROLS WHETHER DOSAGE AND/OR CONCENTRATION IS CALCULATED.

(STORAGE USED 725₈)

WRITE

Message to indicate vertical
isopleths to follow

DØ 710 I = 1,NDXR

IF
IFLAG(I) = 0

YES

NO

K = 0
S = 0.0

DØ 670 KK = 1,NNZ

M = 0

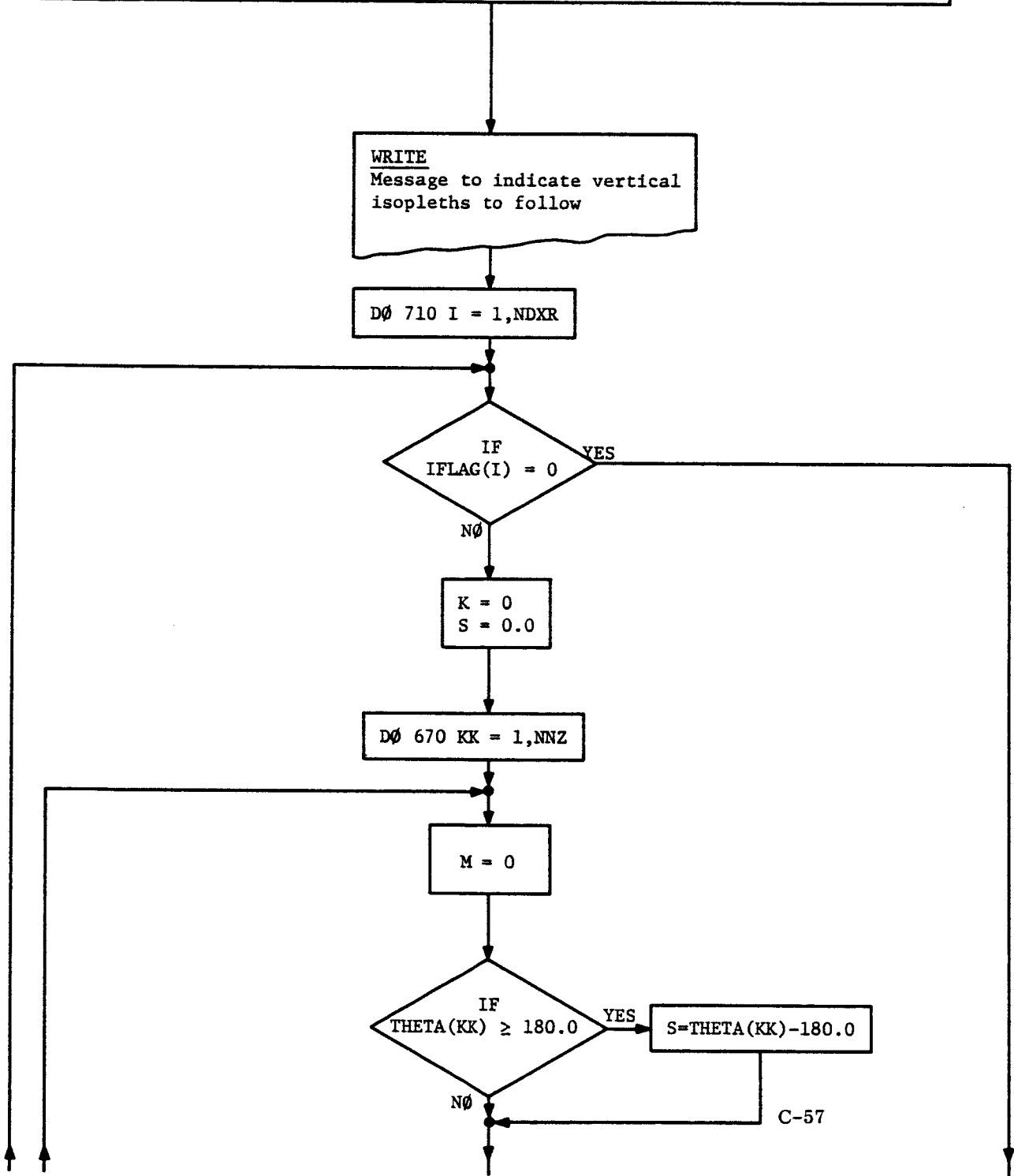
IF
THETA(KK) ≥ 180.0

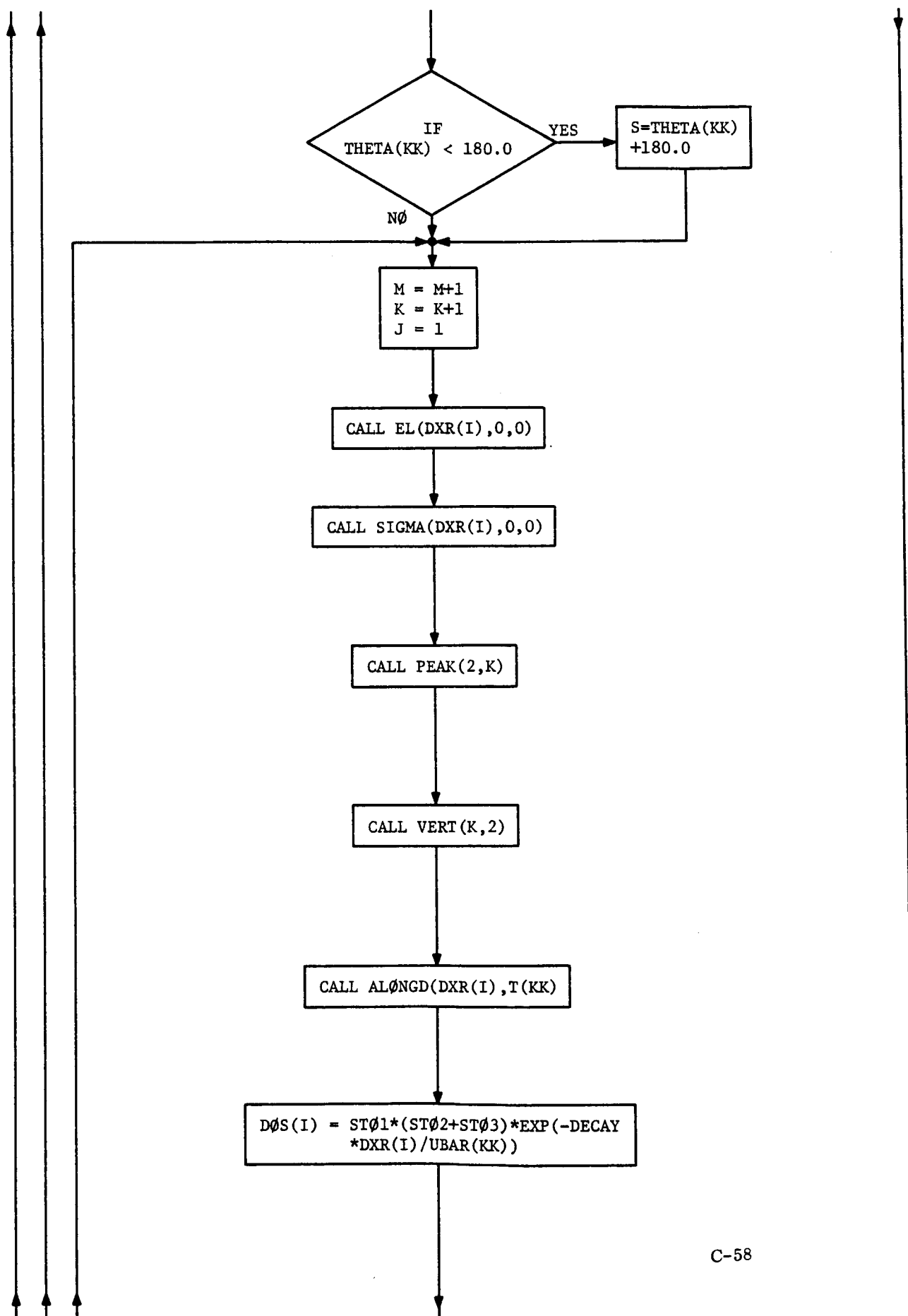
YES

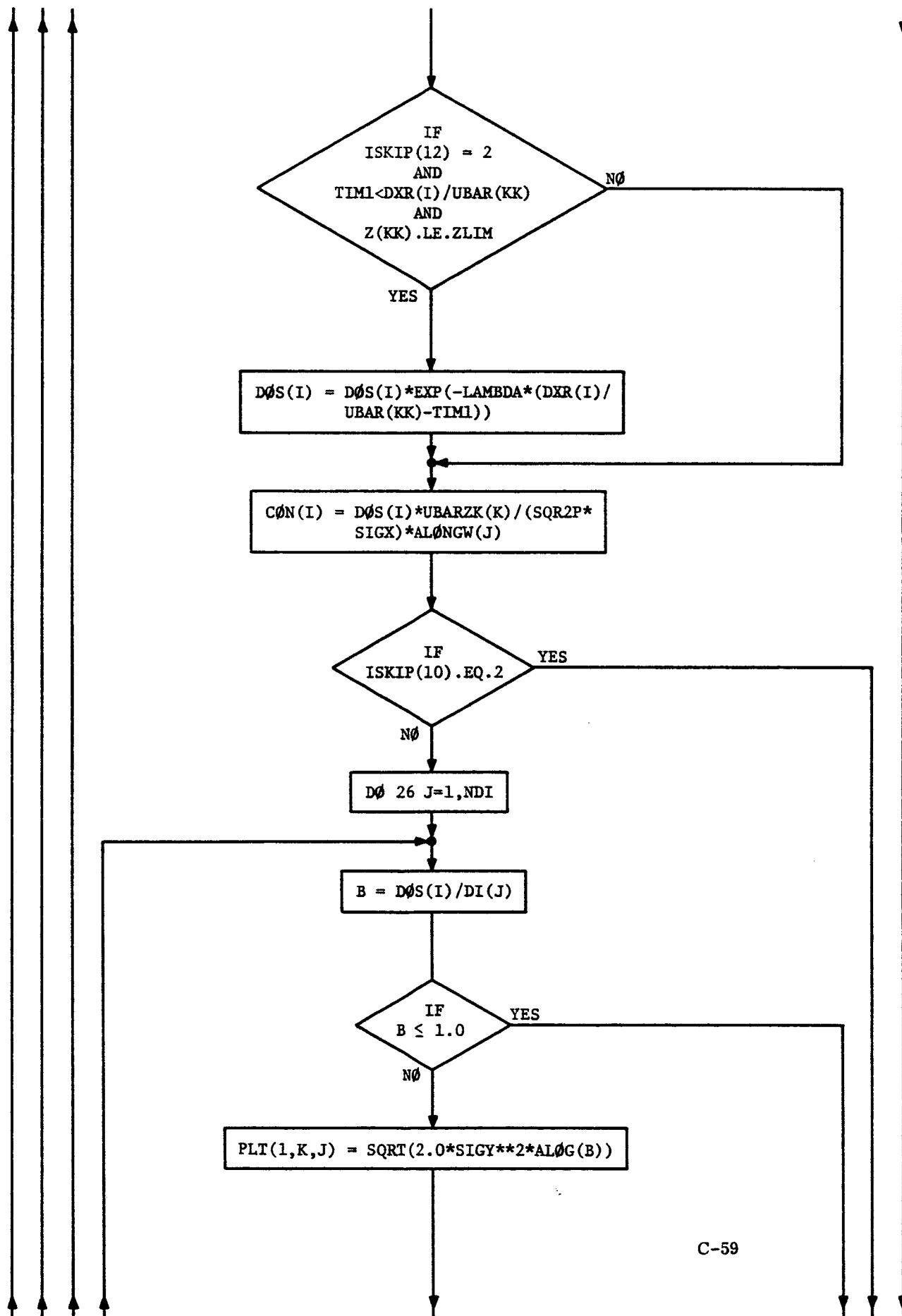
S=THETA(KK)-180.0

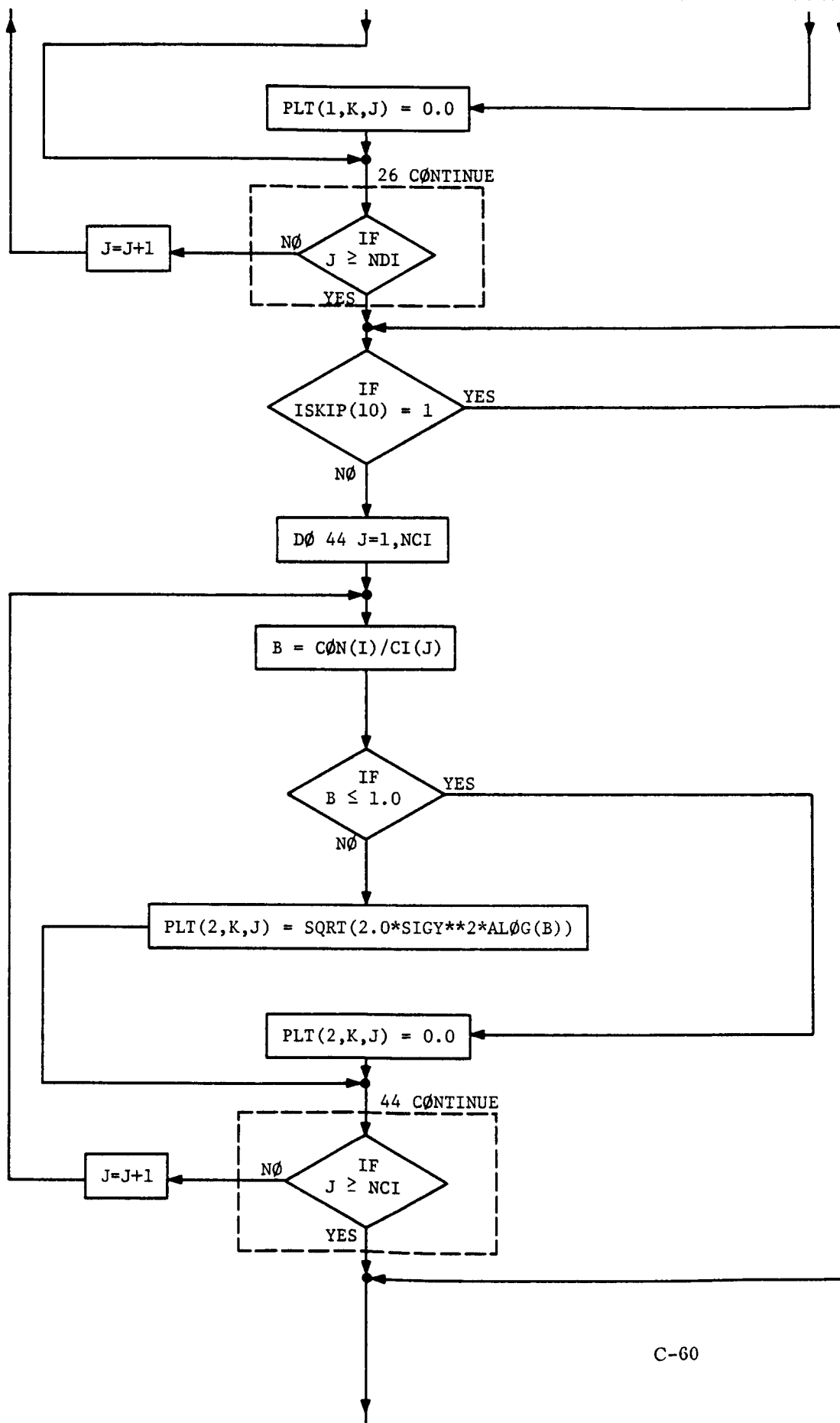
NO

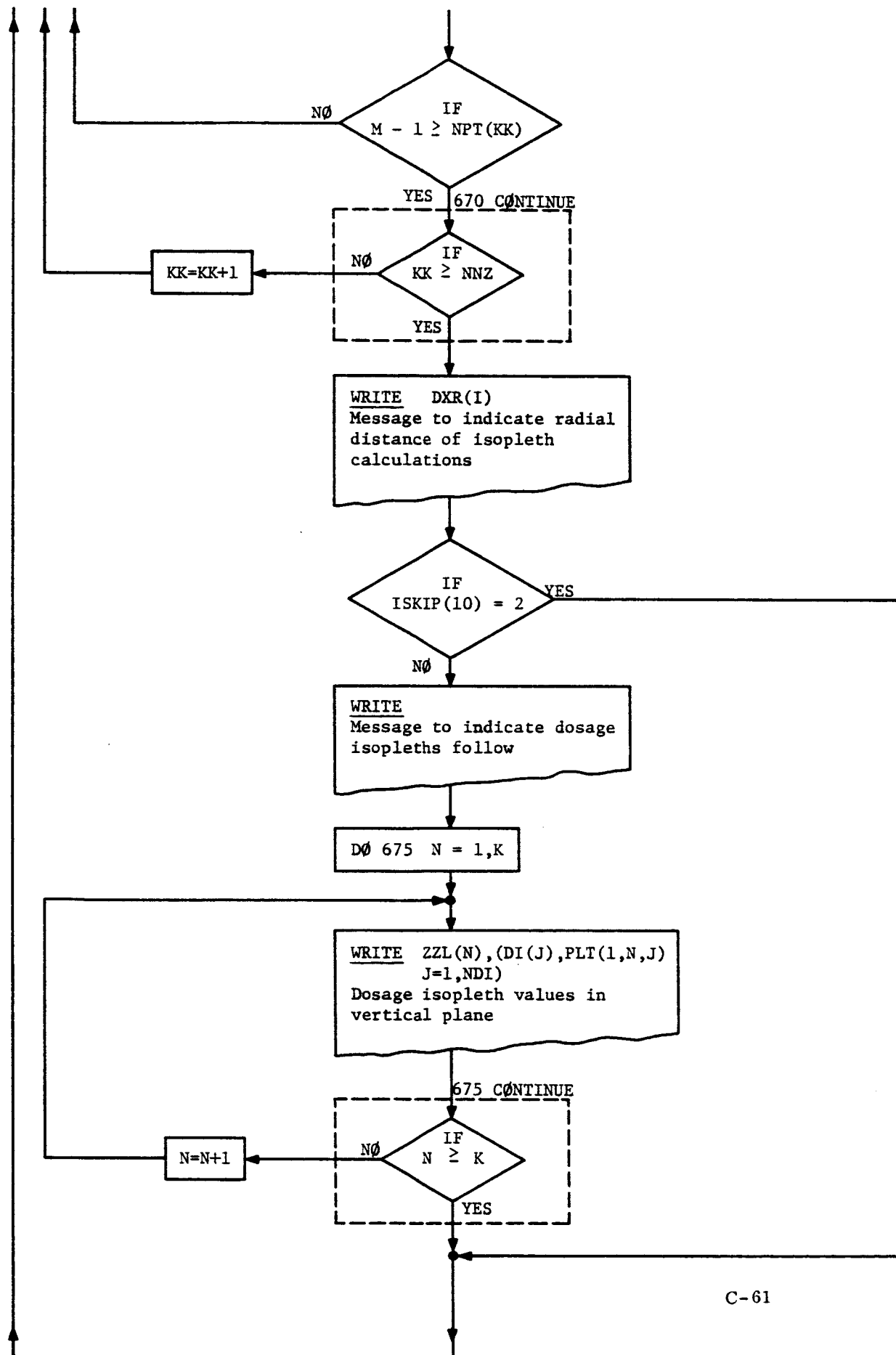
C-57

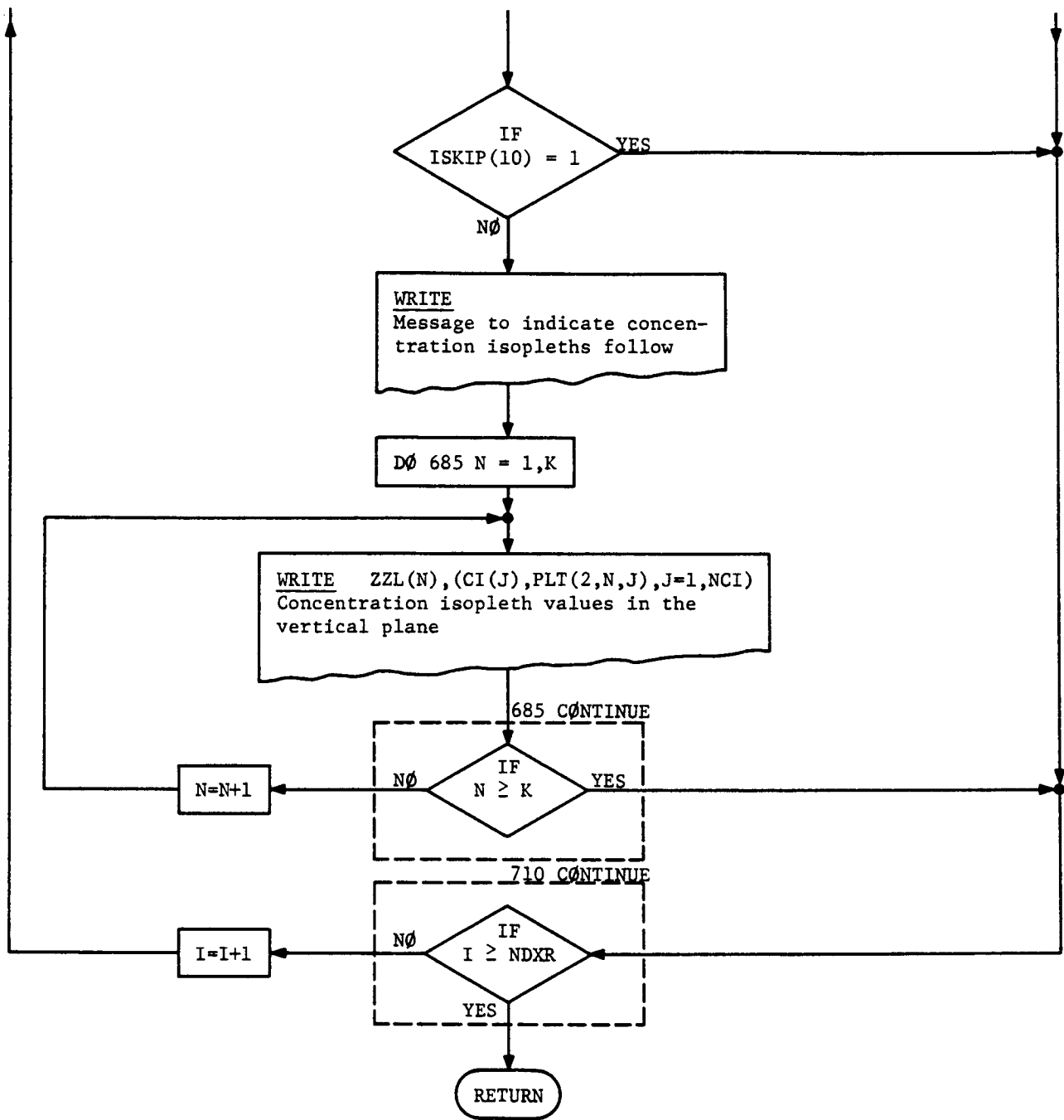












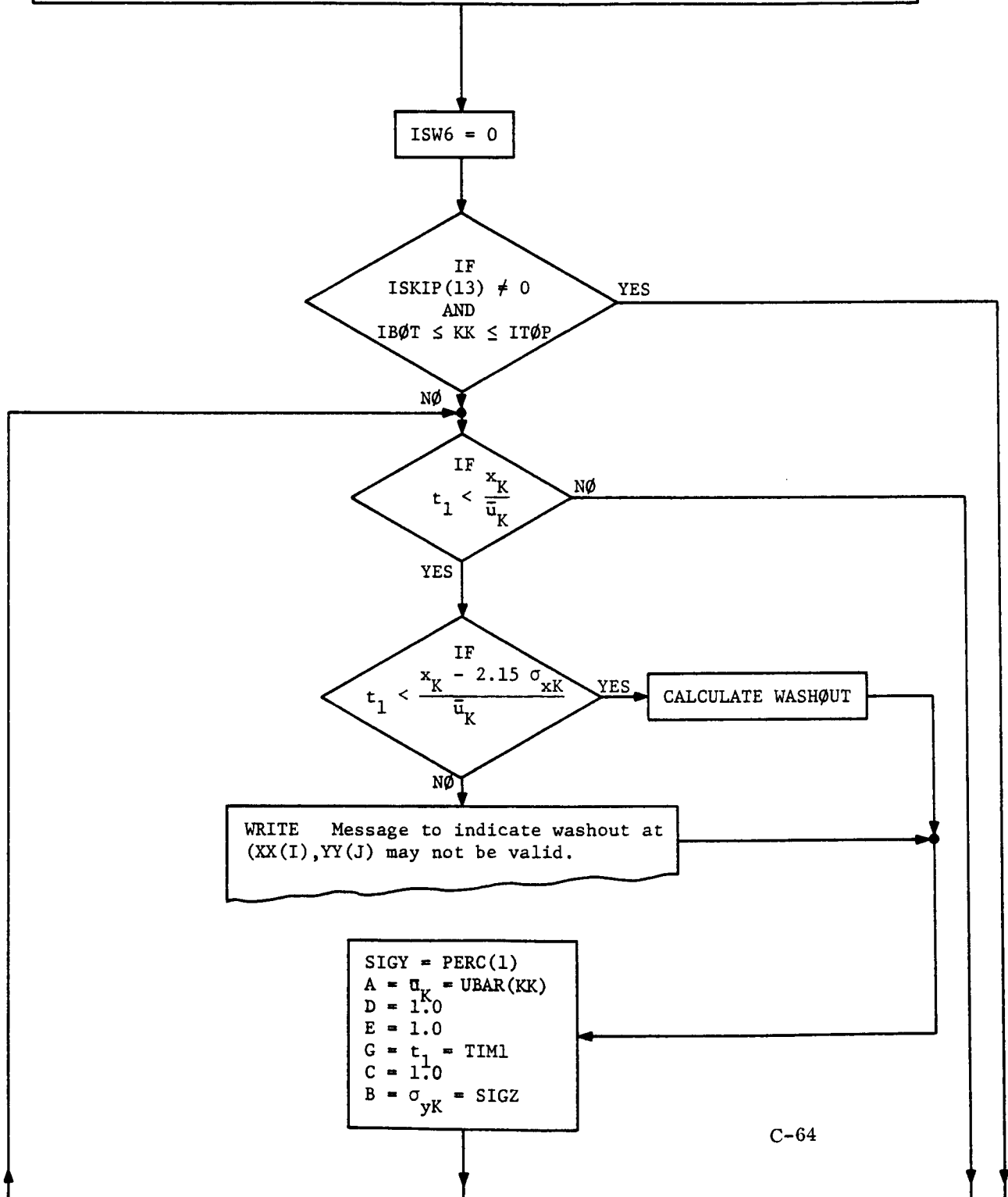
SECTION C. 7

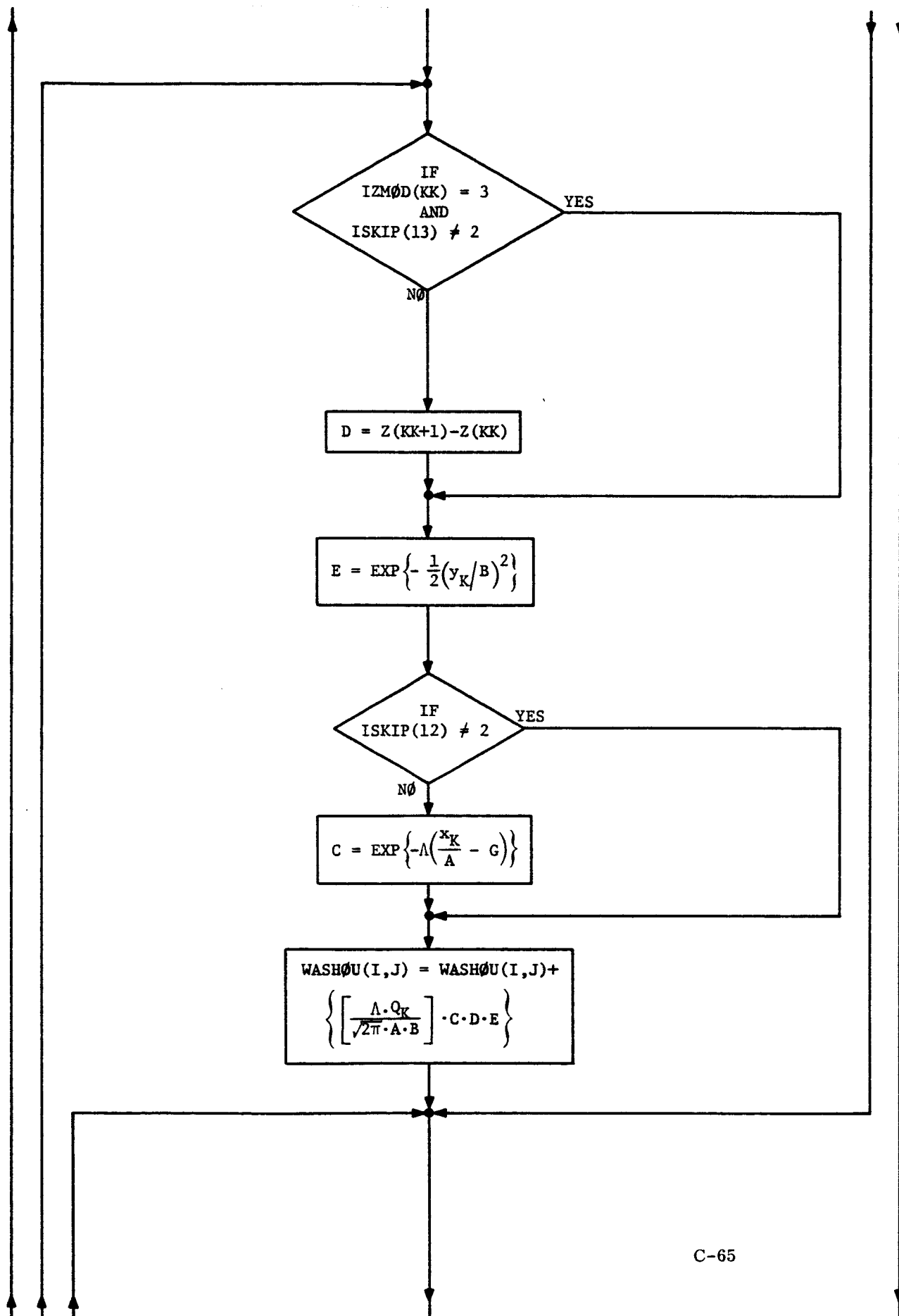
SUBROUTINE WASHT

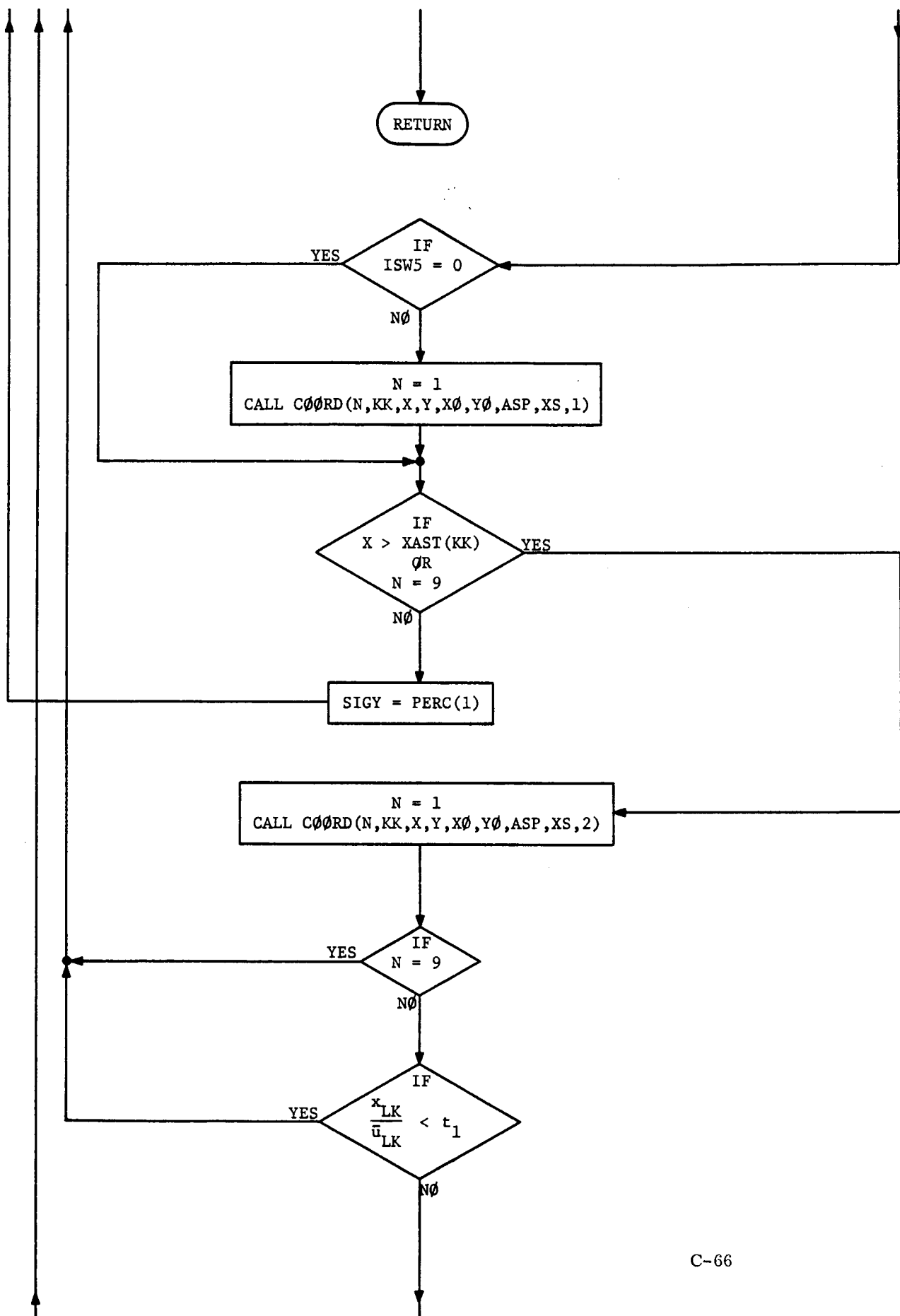
SUBROUTINE WASHT(X,Y,ISW5,X0,Y0,N)

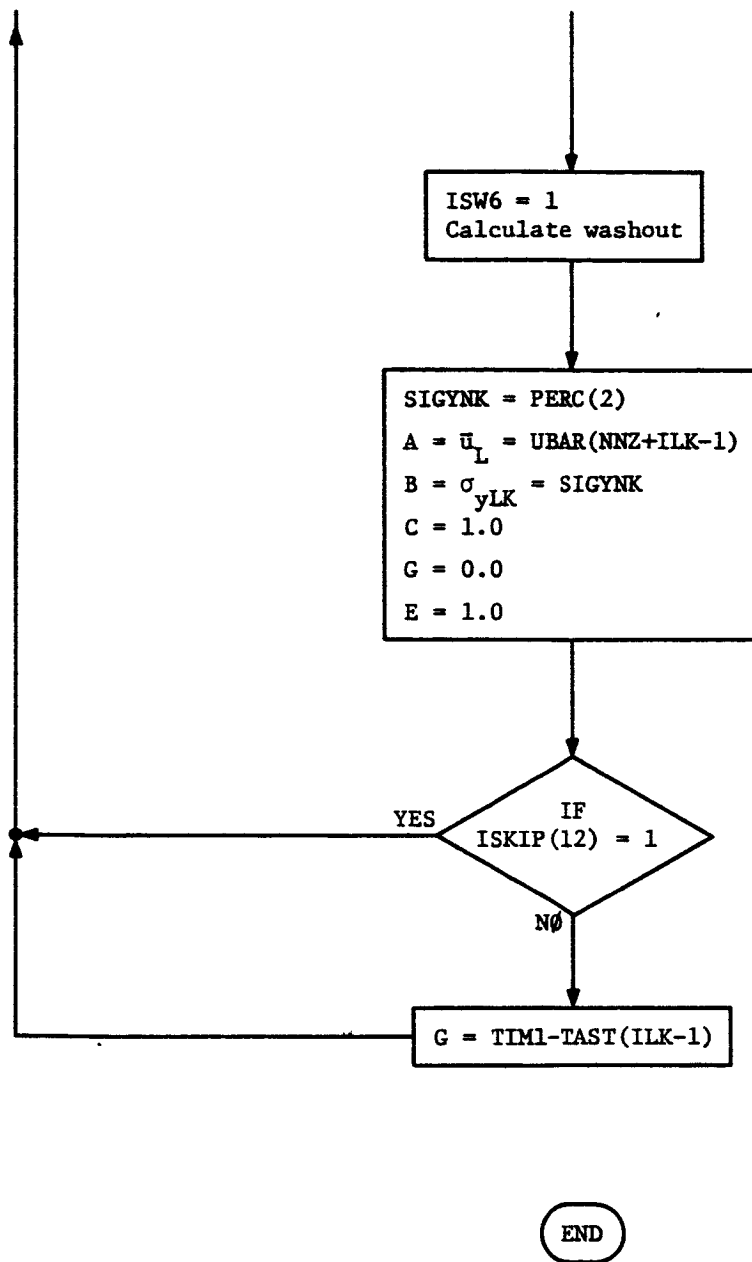
THIS SUBROUTINE CALCULATES GROUND WASHOUT. THIS SUBROUTINE IS EXECUTED ONLY IF ISKIP(12)≠0. IF ISKIP(12)=1 MAXIMUM WASHOUT IS CALCULATED. IF ISKIP(12)=2 RELATIVE WASHOUT IS CALCULATED USING TIM1.

(STORAGE USED 447₈)









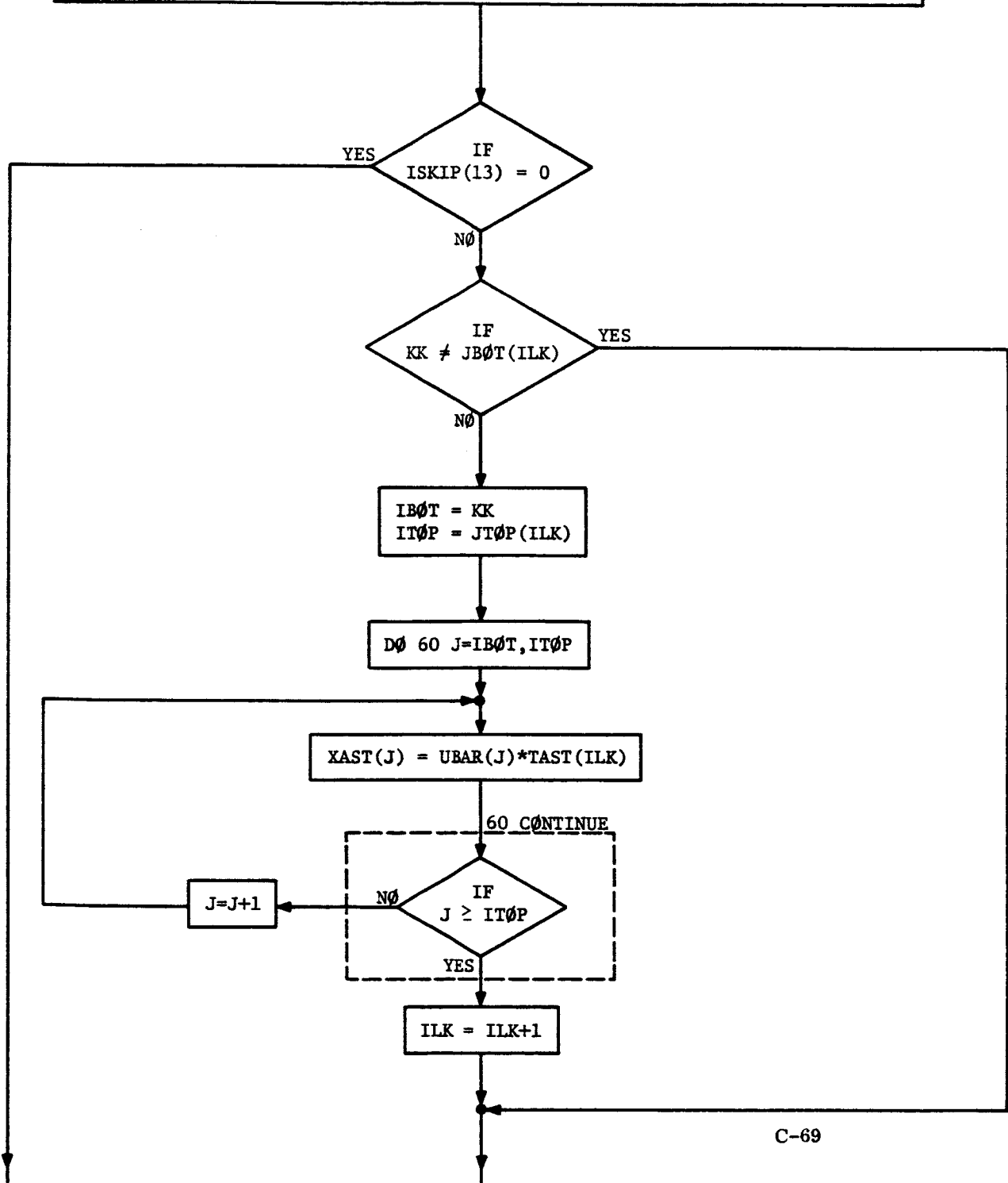
SECTION C. 8

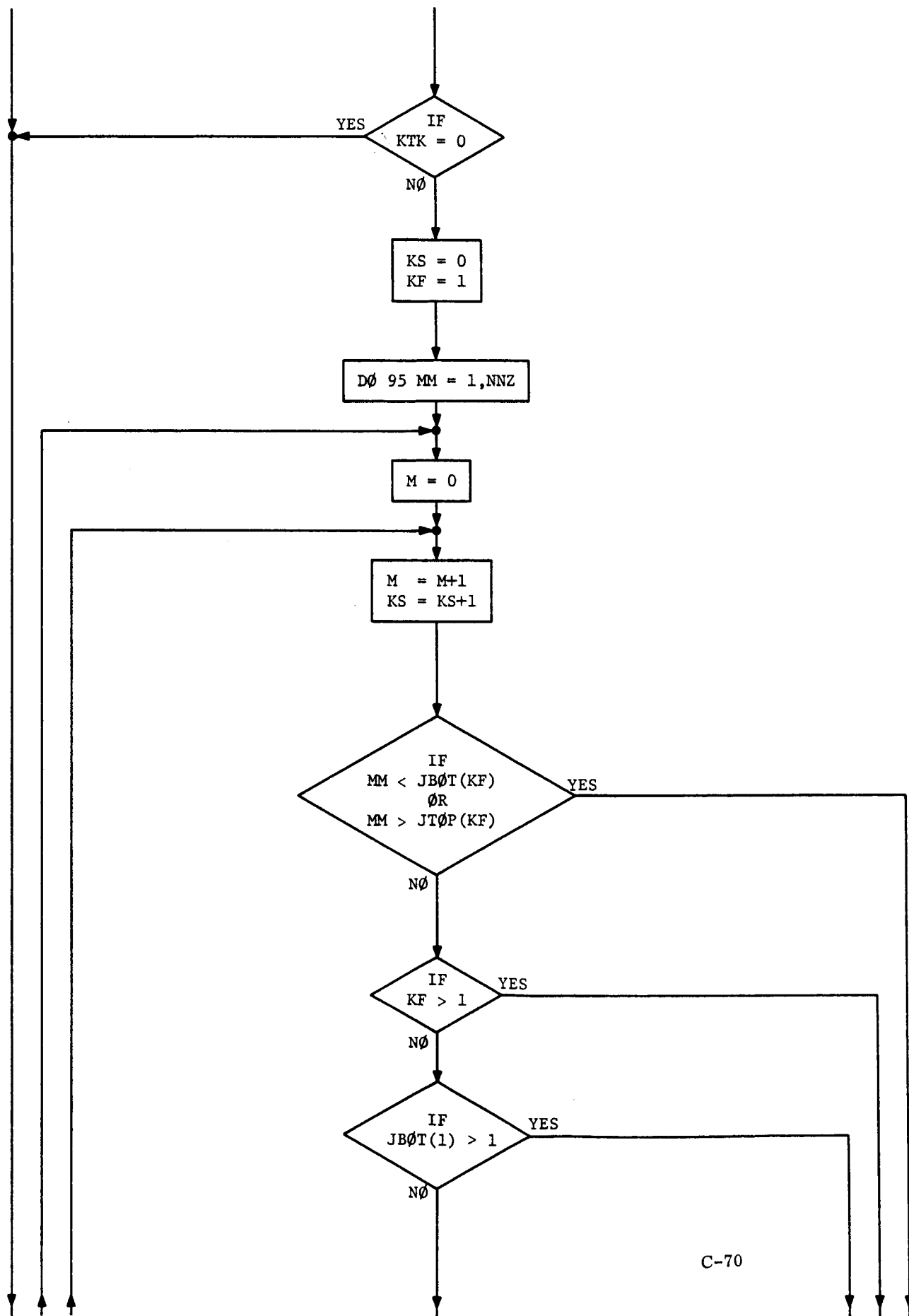
SUBROUTINE TESTR

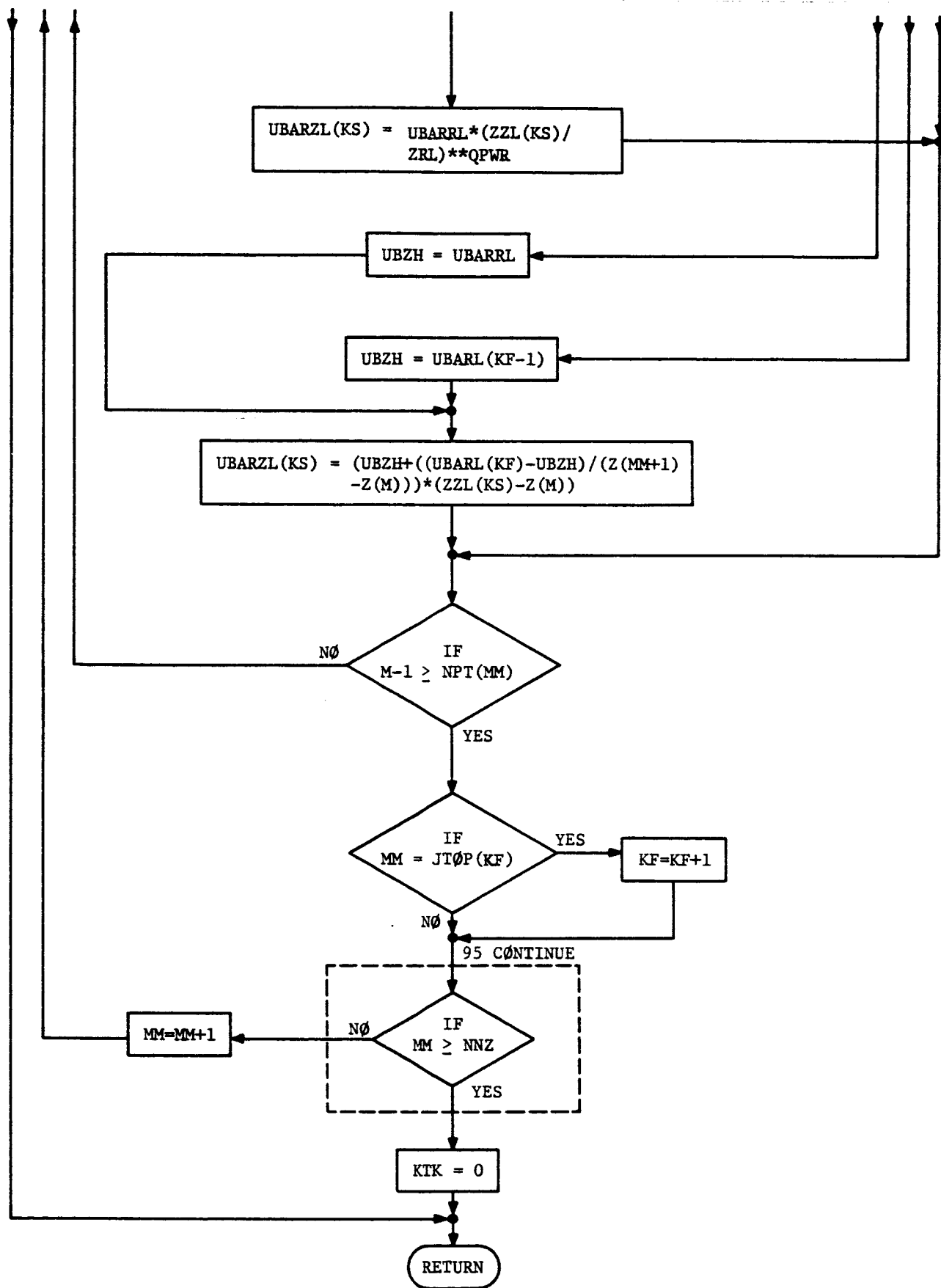
SUBROUTINE TESTR(KTK)

THIS SUBROUTINE DETERMINES THE INDEX VALUES OF MET PARAMETERS USED IN LAYER TRANSITION. THE PROGRAM ALSO CALCULATES THE DISTANCE AT WHICH T* OCCURS IN EACH LAYER CONTAINED IN THE NEW LAYER. IT ALSO CALCULATES WIND SPEED AT EACH CALCULATION HEIGHT IN THE NEW LAYER.

(STORAGE USED 254₈)







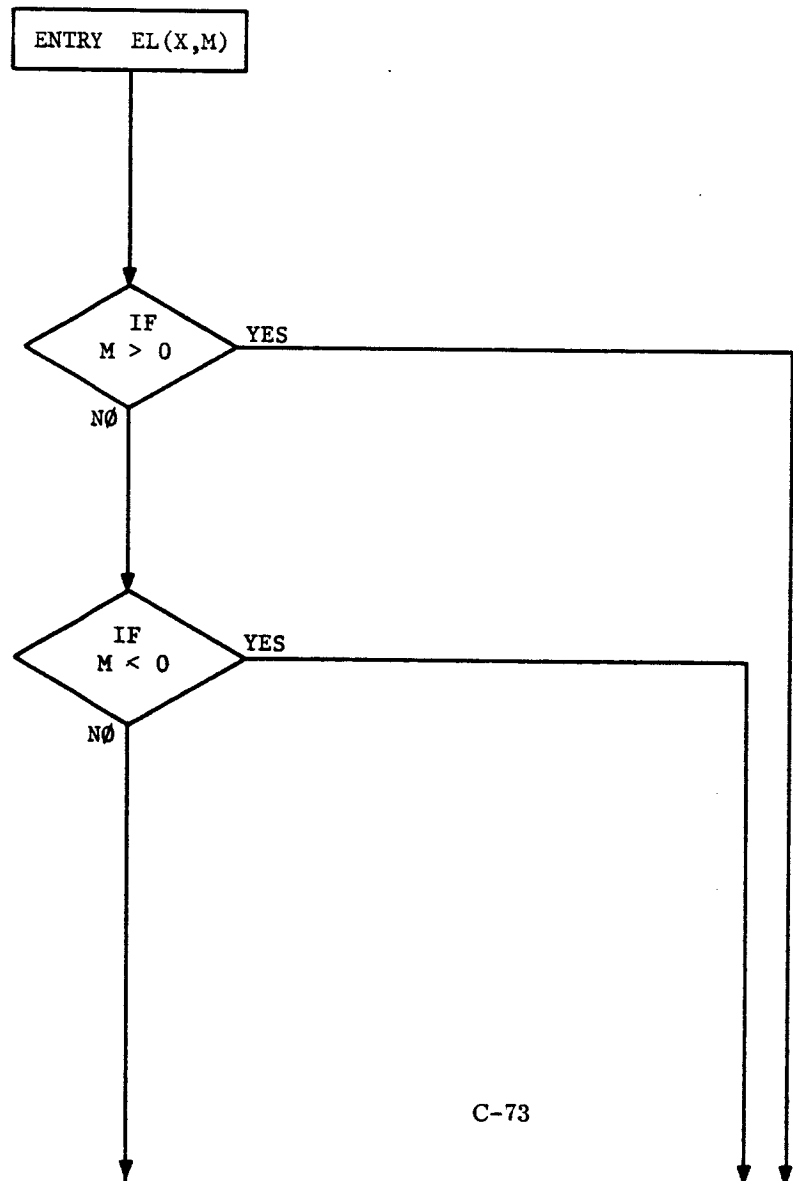
SECTION C.9

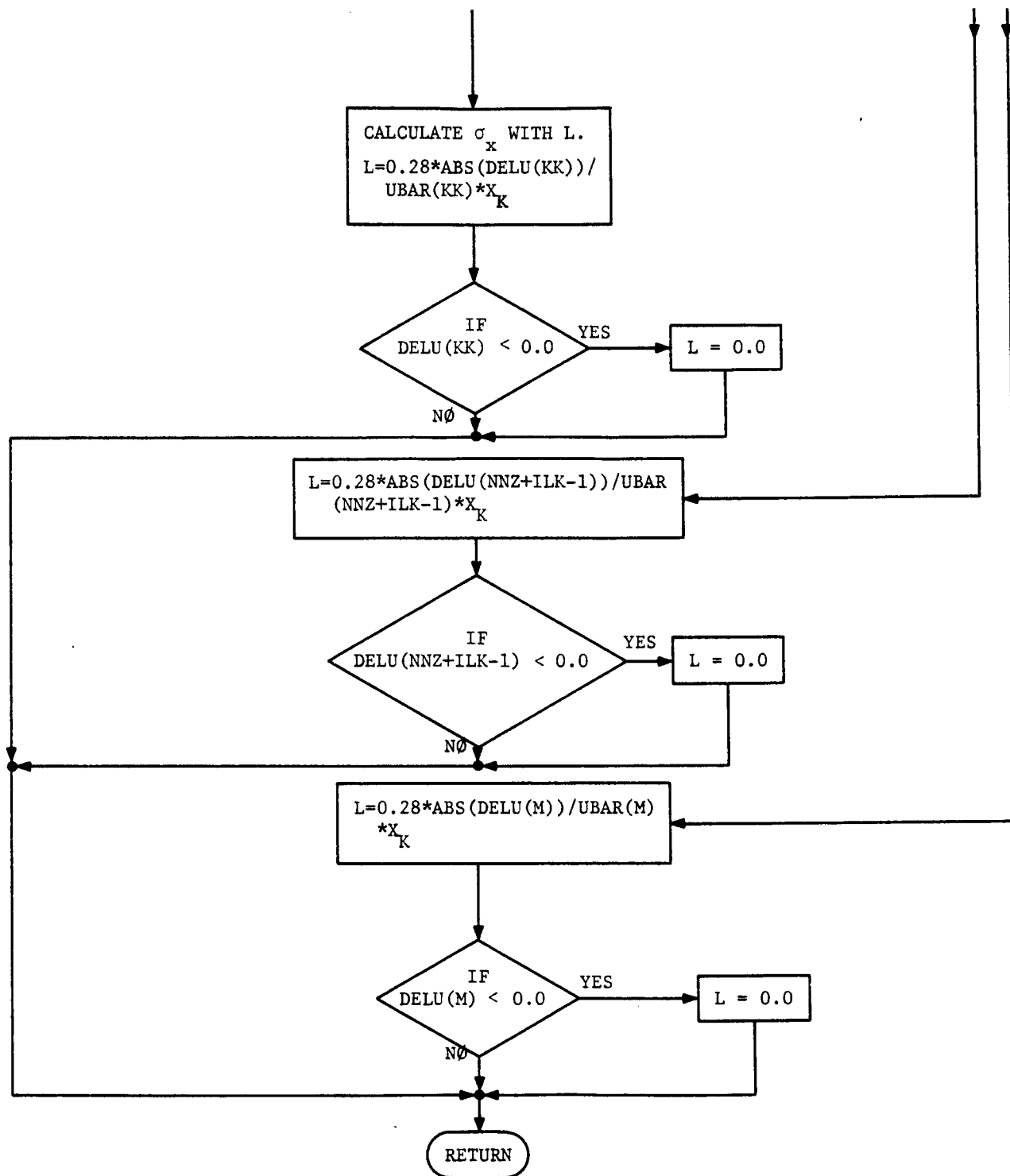
SUBROUTINE ACH

SUBROUTINE ACH

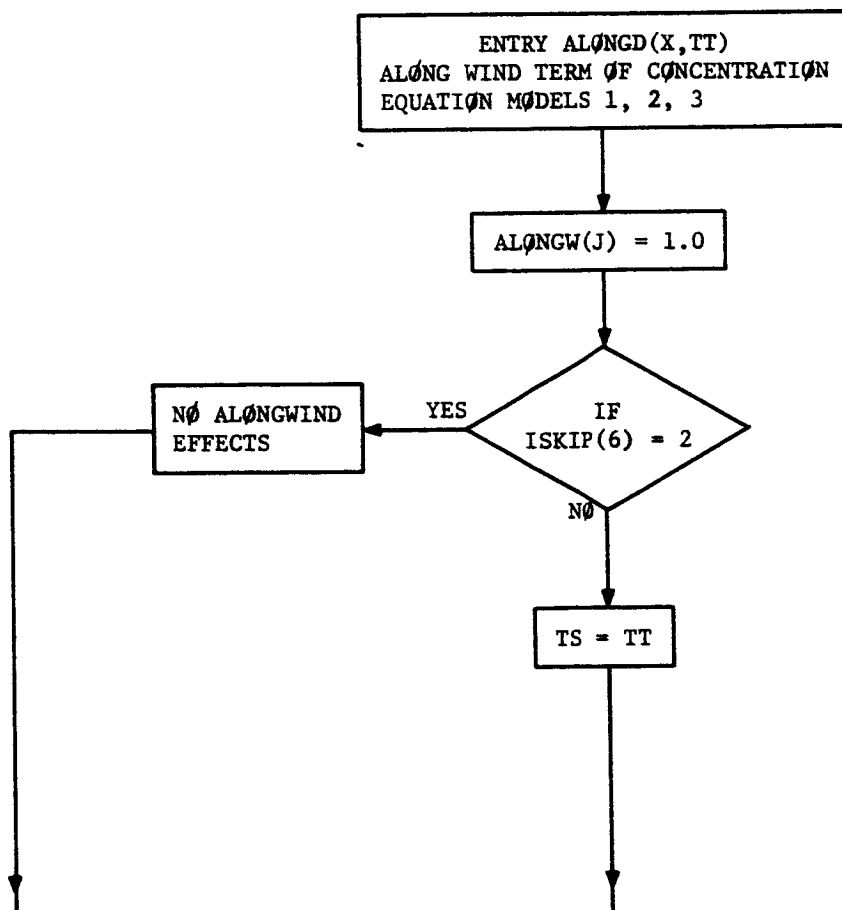
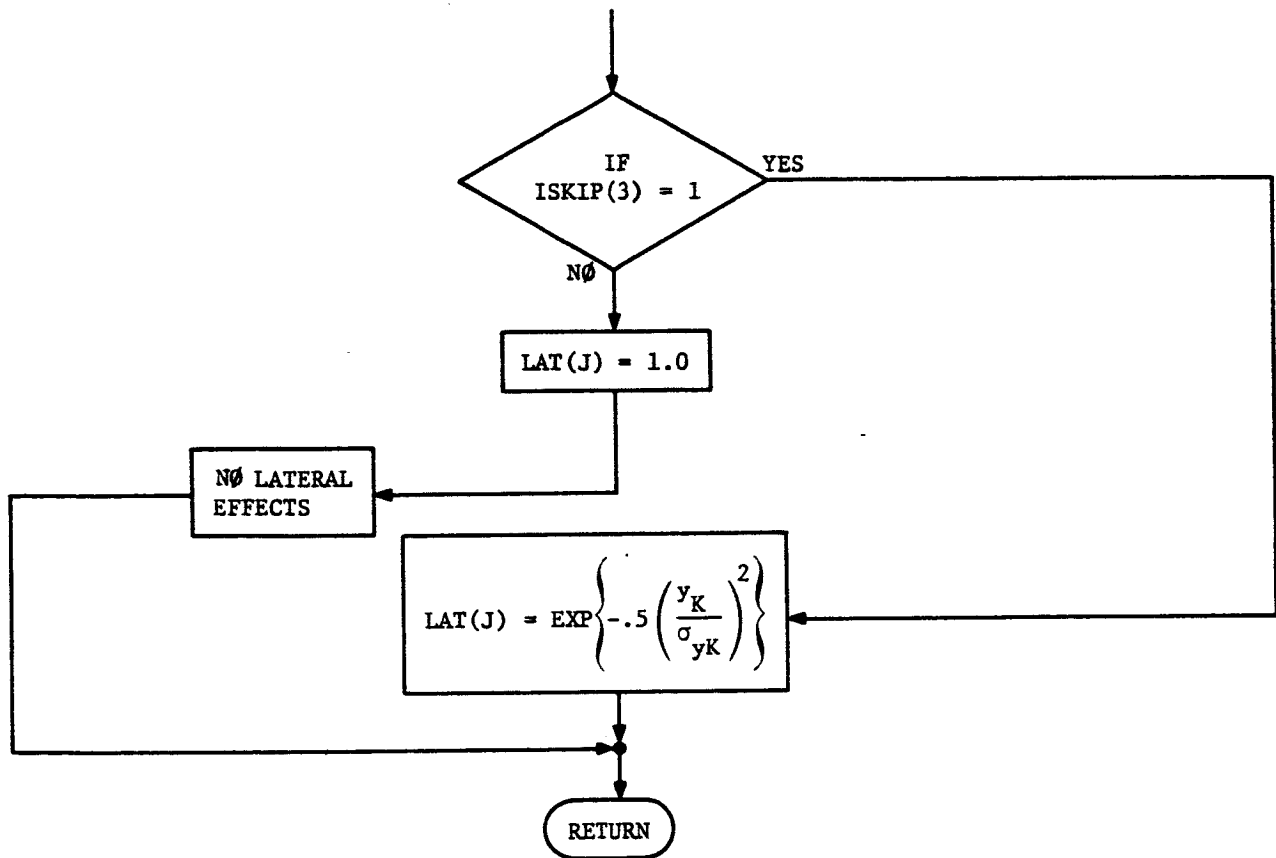
SUBROUTINE ACH CONSISTS OF THREE SUBROUTINES. THE ENTRY TO EL CALCULATES $L \{x_j\}$. THE ENTRY TO LATER CALCULATES THE LATERAL TERM ON OPTION. THE ENTRY TO ALONGD CALCULATES THE ALONGWIND TERM OF THE CONCENTRATION EQUATION ON OPTION

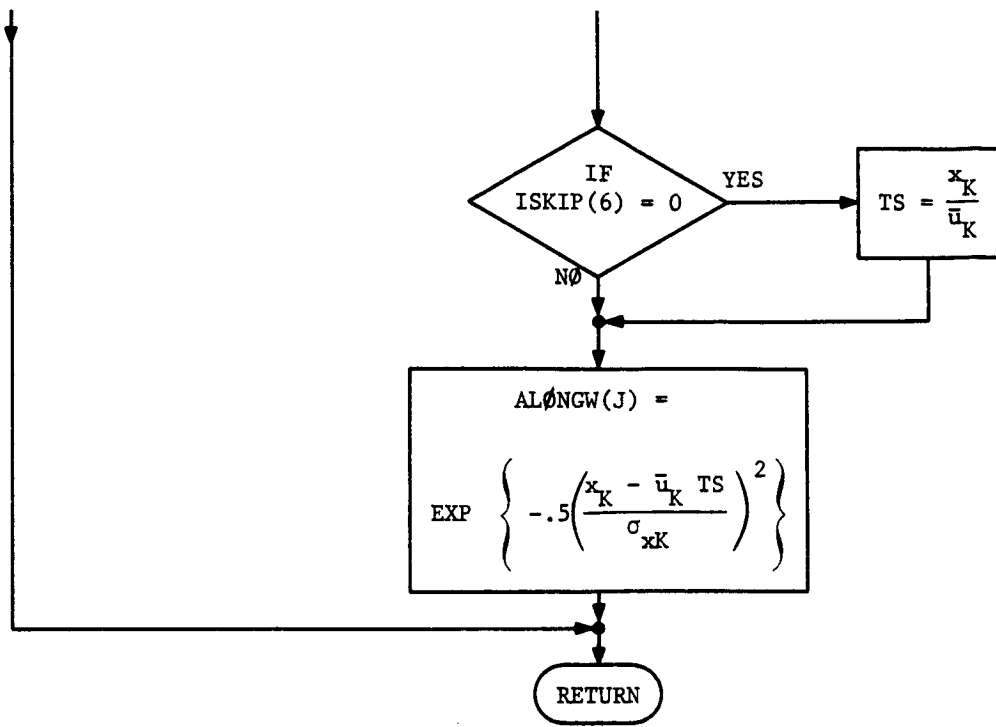
(STORAGE USED 254_8)





ENTRY LATER(Y)
LATERAL TERM OF DOSAGE EQUATION.
MODELS 1, 2, 3





SECTION C. 10

SUBROUTINE VERT

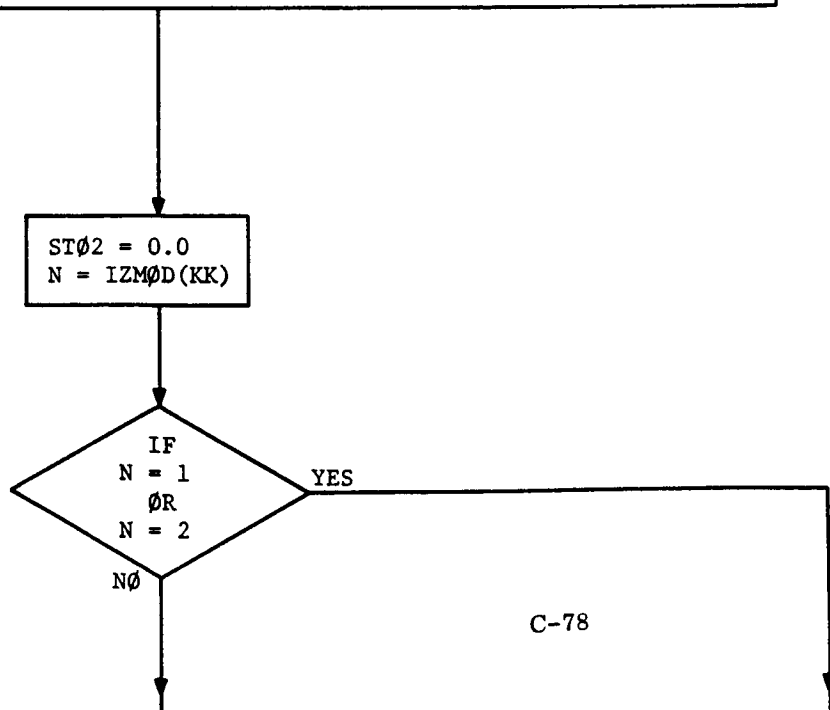
SUBROUTINE VERT(K,NN)

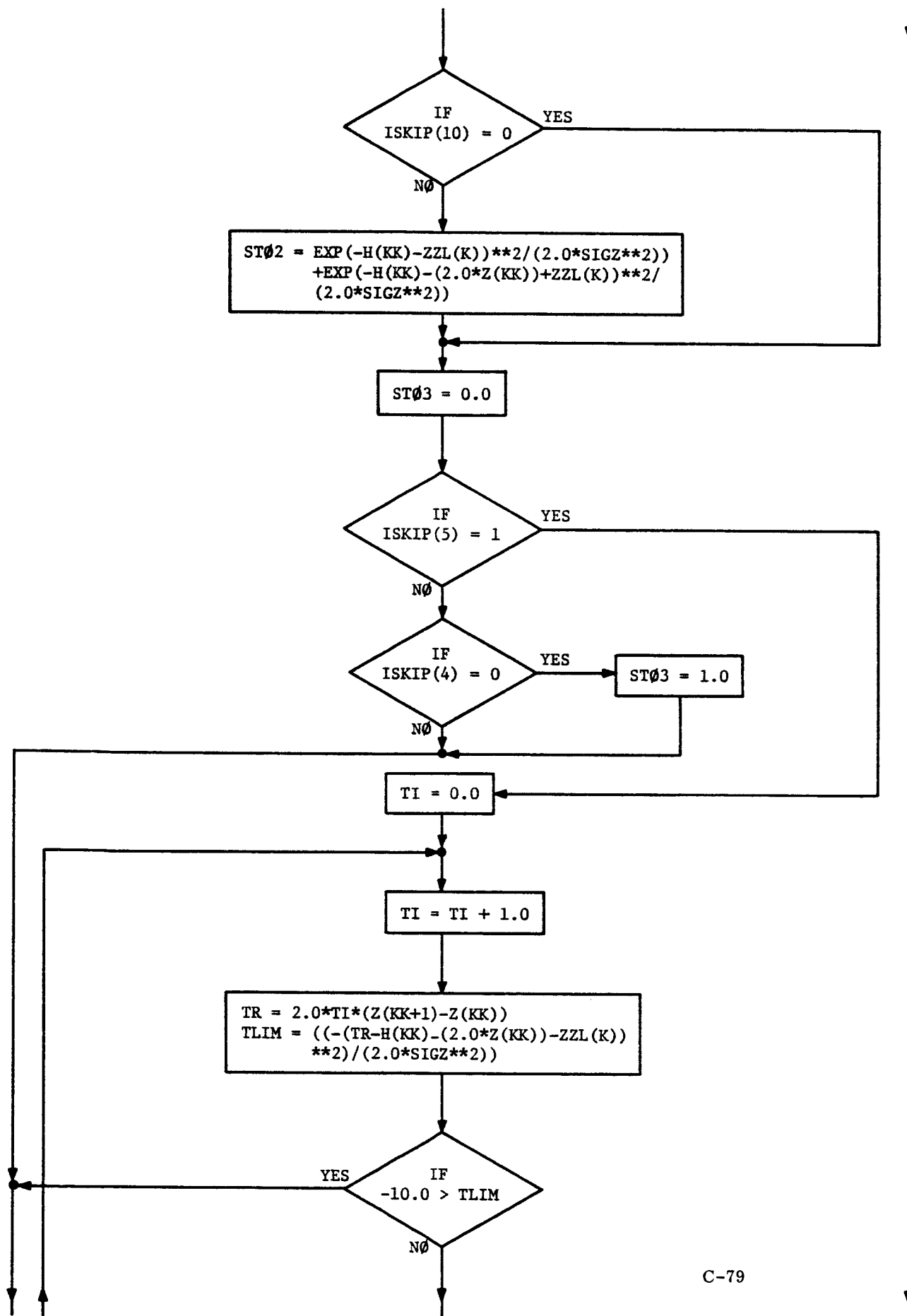
THIS SUBROUTINE CALCULATES THE VERTICAL AND VERTICAL REFLECTION TERMS IN THE DOSAGE EQUATION. IF ISKIP(4) EQUALS 1 VERTICAL IS CALCULATED. IF ISKIP(5) EQUALS 1 VERTICAL REFLECTION IS CALCULATED. VERTICAL AND VERTICAL REFLECTION ARE CALCULATED ONLY FOR MODEL 3 FOR CASE IN WHICH PLUME VERTICAL EXTENT IS LESS THAN THE DEPTH OF THE LAYER AND TURBULENT MIXING IS OCCURRING.

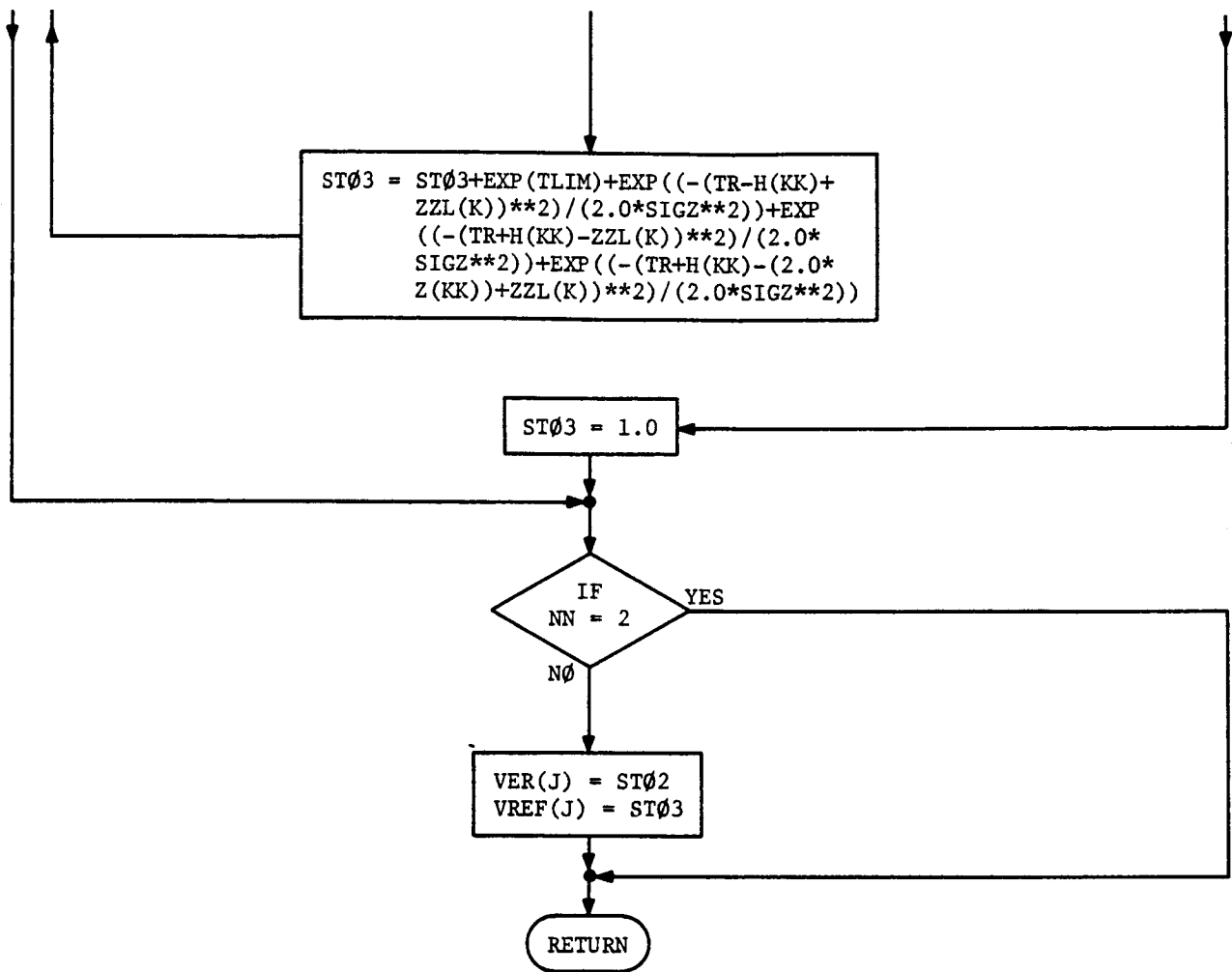
$$\text{VERTICAL TERM VER(J)} = \text{STØ2} = \left\{ \text{EXP} \left\{ \frac{-(H_K - Z_K)^2}{2\sigma_{Z_K}^2} \right\} + \text{EXP} \left\{ \frac{-(H_K - 2Z_1 + Z_K)^2}{2\sigma_{Z_K}^2} \right\} \right\}$$

$$\begin{aligned} \text{VERTICAL REFLECTION TERM VREF(J)} = \text{STØ3} = & \sum_{i=1}^{\infty} \left\{ \text{EXP} \left\{ \frac{-(2i(Z_2 - Z_1) + H_K - 2Z_1 + Z_K)^2}{2\sigma_{Z_K}^2} \right\} + \right. \\ & \text{EXP} \left\{ \frac{-(2i(Z_2 - Z_1) - H_K + Z_K)^2}{2\sigma_{Z_K}^2} \right\} + \\ & \left. \text{EXP} \left\{ \frac{-(2i(Z_2 - Z_1) + H_K - 2Z_1 + Z_K)^2}{2\sigma_{Z_K}^2} \right\} \right\} \end{aligned}$$

(STØRAGE USED 263₈)







SECTION C.11

SUBROUTINE PEAK

SUBROUTINE PEAK(K)

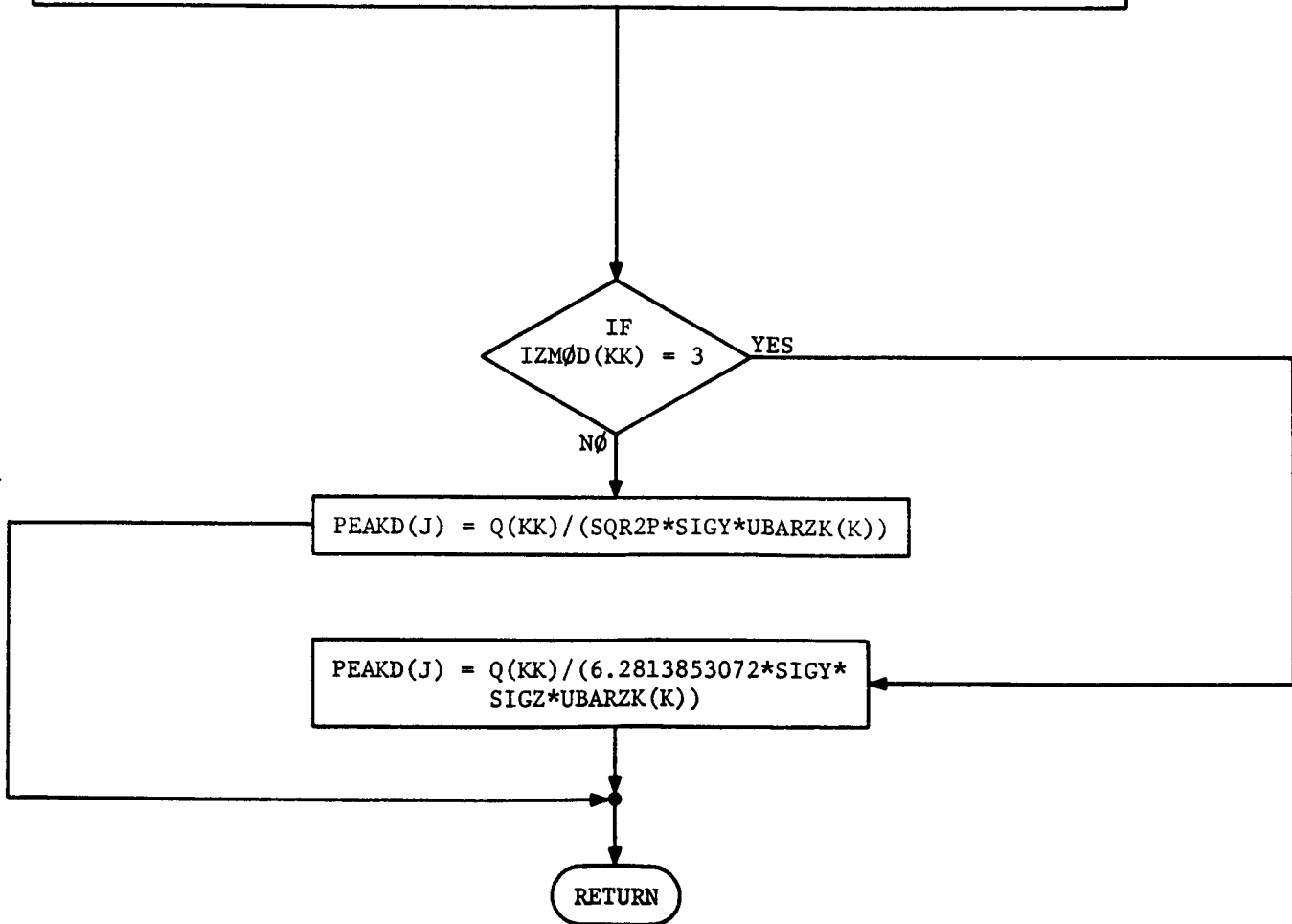
THIS SUBROUTINE CALCULATES THE PEAK TERM OF THE DOSAGE EQUATION. THE PEAK TERM FOR MODELS 1 AND 2 IS GIVEN BY

$$\frac{Q_K}{\sqrt{2\pi} \sigma_{yK} \bar{u}_{zK}}$$

THE PEAK TERM FOR MODEL 3 IS GIVEN BY

$$\frac{Q_K}{2\pi \sigma_{yK} \sigma_{zK} \bar{u}_{zK}}$$

(STORAGE USED 103₈)

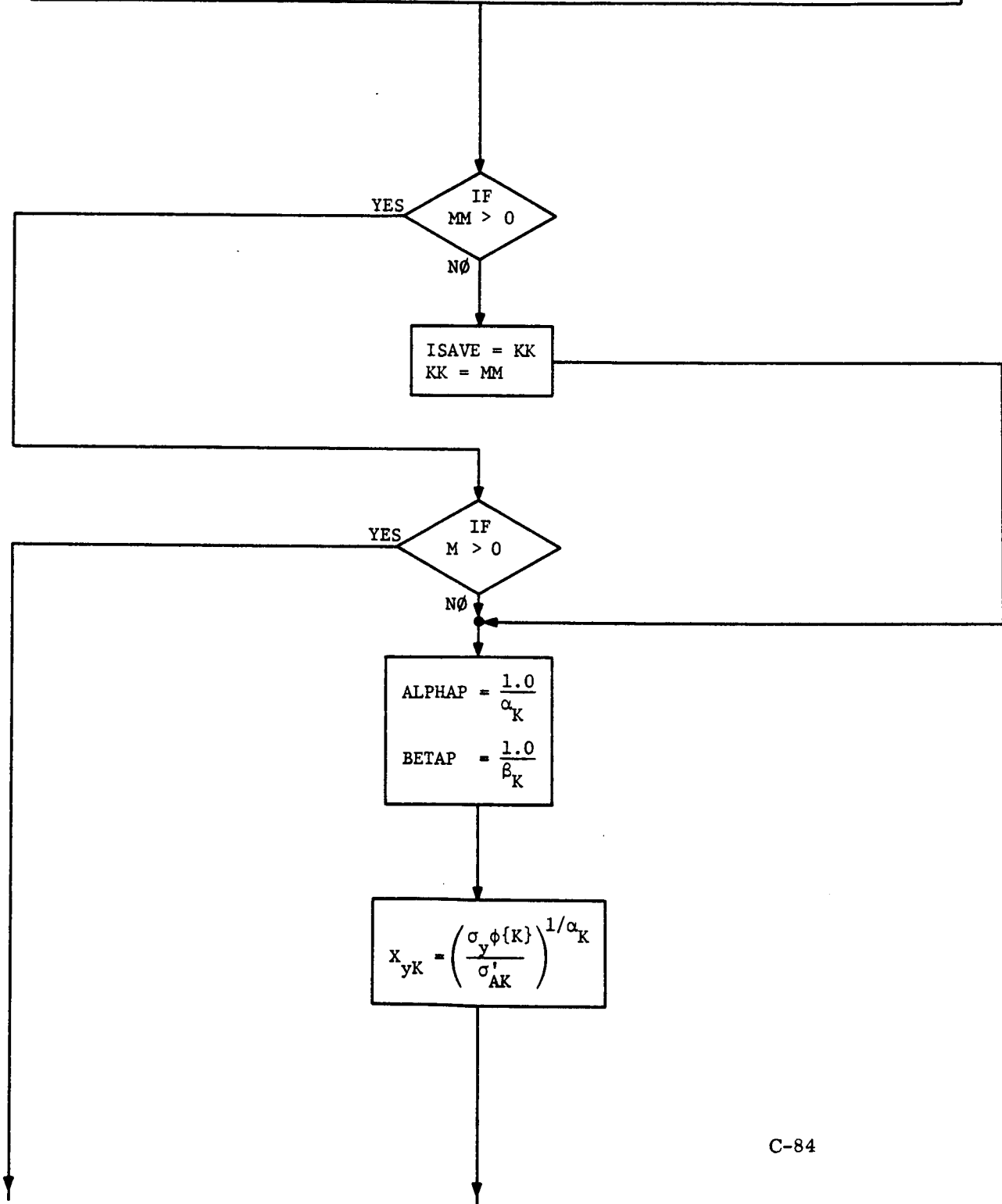


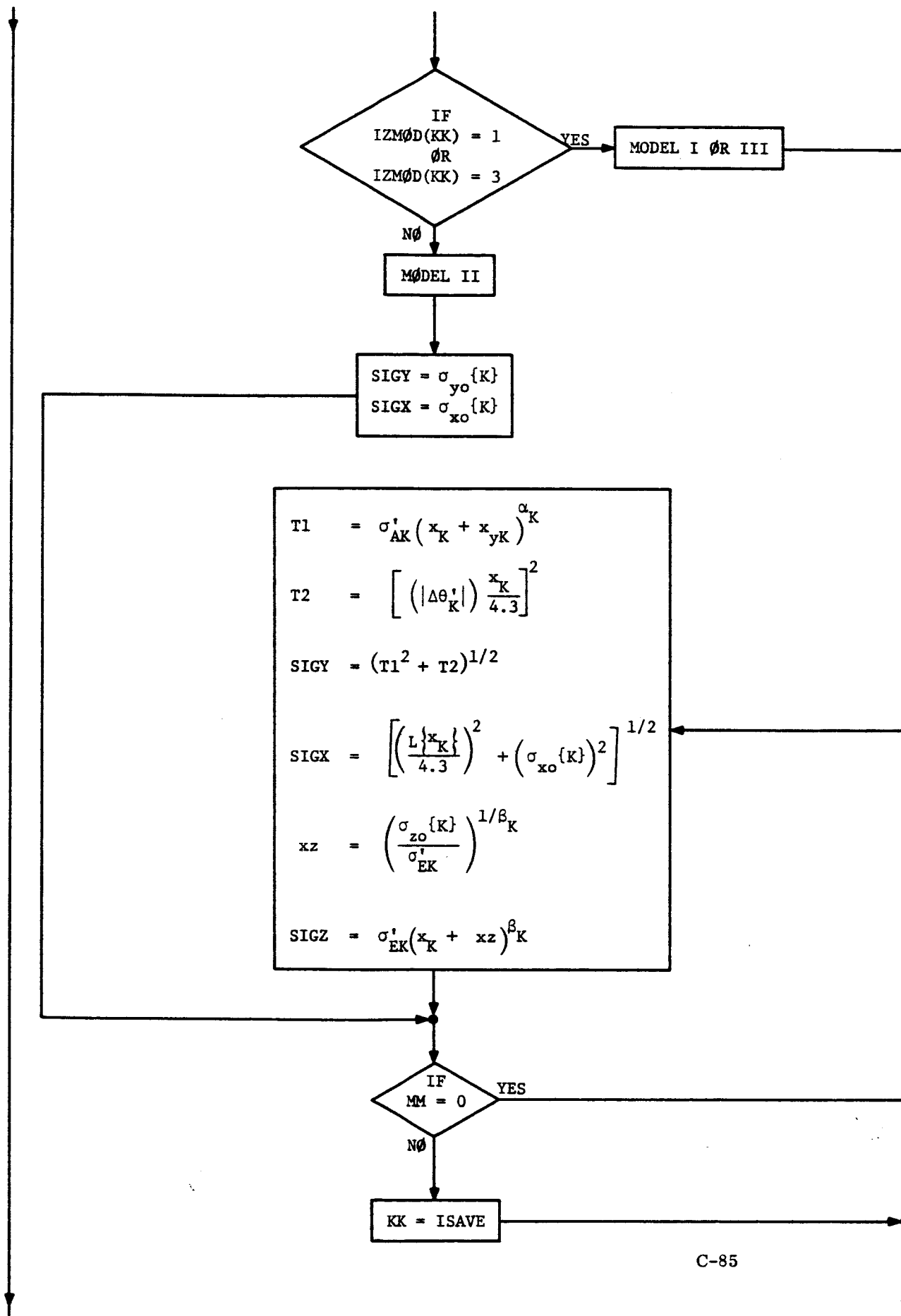
SECTION C. 12

SUBROUTINE SIGMA

SUBROUTINE SIGMA(X,M,MM)

THIS SUBROUTINE CALCULATES THE STANDARD DEVIATIONS OF THE VERTICAL, HORIZONTAL AND LATERAL DOSAGE DISTRIBUTIONS (σ_{zK} , σ_{xK} , σ_{yK}) AND (σ_{xL} , σ_{yL}).
(STORAGE USED 355₈)





$$\text{SIGYNK} = \left\{ \left[\sigma_{xK} \sin(\theta'_K - \theta'_L) \right]^2 + \left[\sigma_{yK} \cos(\theta'_K - \theta'_L) \right]^2 \right\}^{1/2}$$

$$\text{SQBAR} = \left(\frac{\text{SIGYNK}}{\sigma'_{AL}} \right)^{1/\alpha_L}$$

$$\text{SIGYNK} = \sigma_{yLK} = \left\{ \left[\sigma'_{AL} \{ \tau \} (x_{LK} + \text{SQBAR})^{\alpha_L} \right]^2 + \left[\left(\left| \frac{\Delta \theta'_L}{4.3} \right| \right) (x_{LK}) \right]^2 \right\}^{1/2}$$

$$\text{SIGZ} = \sigma'_{EL} x_{LK}^{\beta_L}$$

$$\text{SQBAR} = \left\{ \left[\sigma_x \cos(\theta'_K - \theta'_L) \right]^2 + \left[\sigma_y \sin(\theta'_K - \theta'_L) \right]^2 \right\}^{1/2}$$

$$\text{SIGXNK} = \left\{ \left(\frac{L \{ x_K \}}{4.3} \right)^2 + (\text{SQBAR})^2 \right\}^{1/2}$$

RETURN

SECTION C.13

SUBROUTINE ISO

SUBROUTINE ISO(MR,MT)
THIS SUBROUTINE CALCULATES ERF(X) WHERE X = ERFX(I).
(STORAGE USED 231₈)

DOUBLE PRECISION

A6 = .0705230784D0
A7 = .0422820123D0
A8 = .0092705272D0
A9 = .0001520143D0
A10 = .0002765672D0
A11 = .0000430638D0

DO 10 M = MR,MT

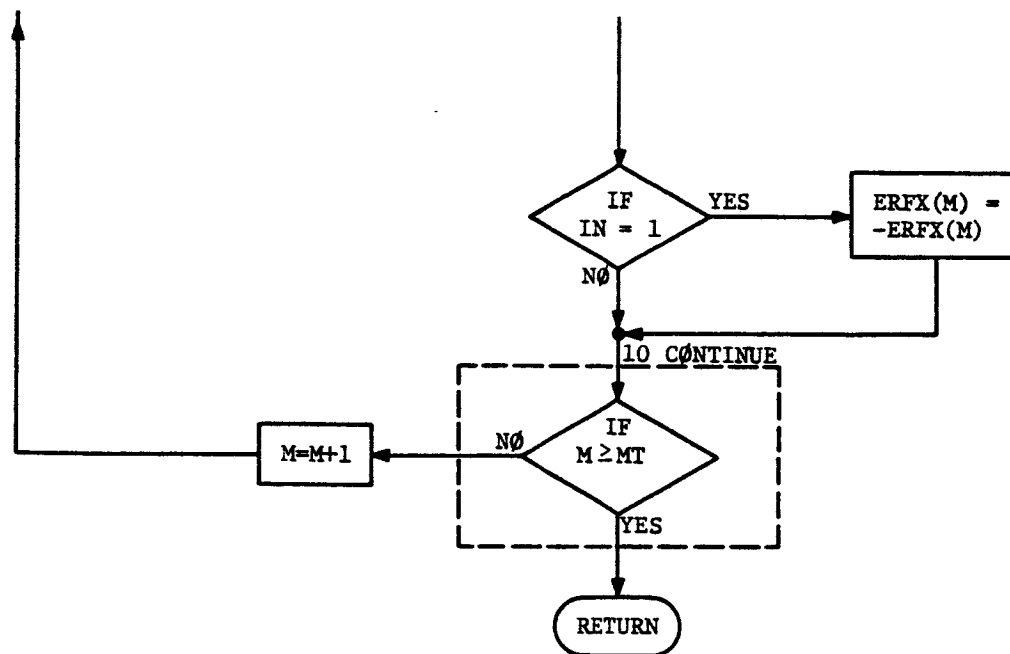
IN = 0

IF
ERFX(M) < 0.0
YES
IN = 1
NO

ERFX(M) = ABS(ERFX(M))

DTX = 1.0D0+A6*ERFX(M)+A7*ERFX(M)**2+A8*
ERFX(M)**3+A9*ERFX(M)**4+A10*ERFX(M)
5+A11*ERFX(M)6

ERFX(M) = 1.0D0-(1.0D0/
DTX**16)

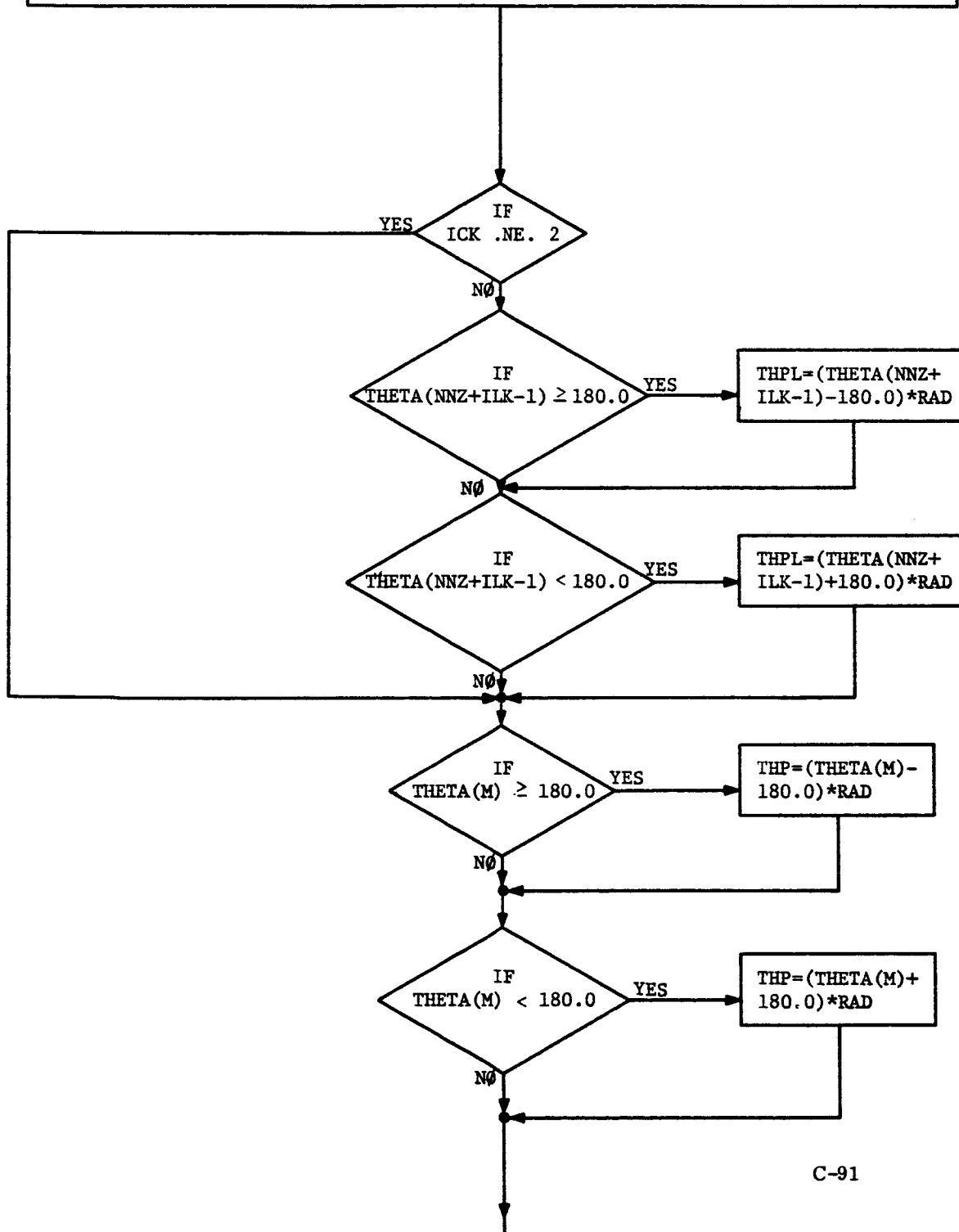


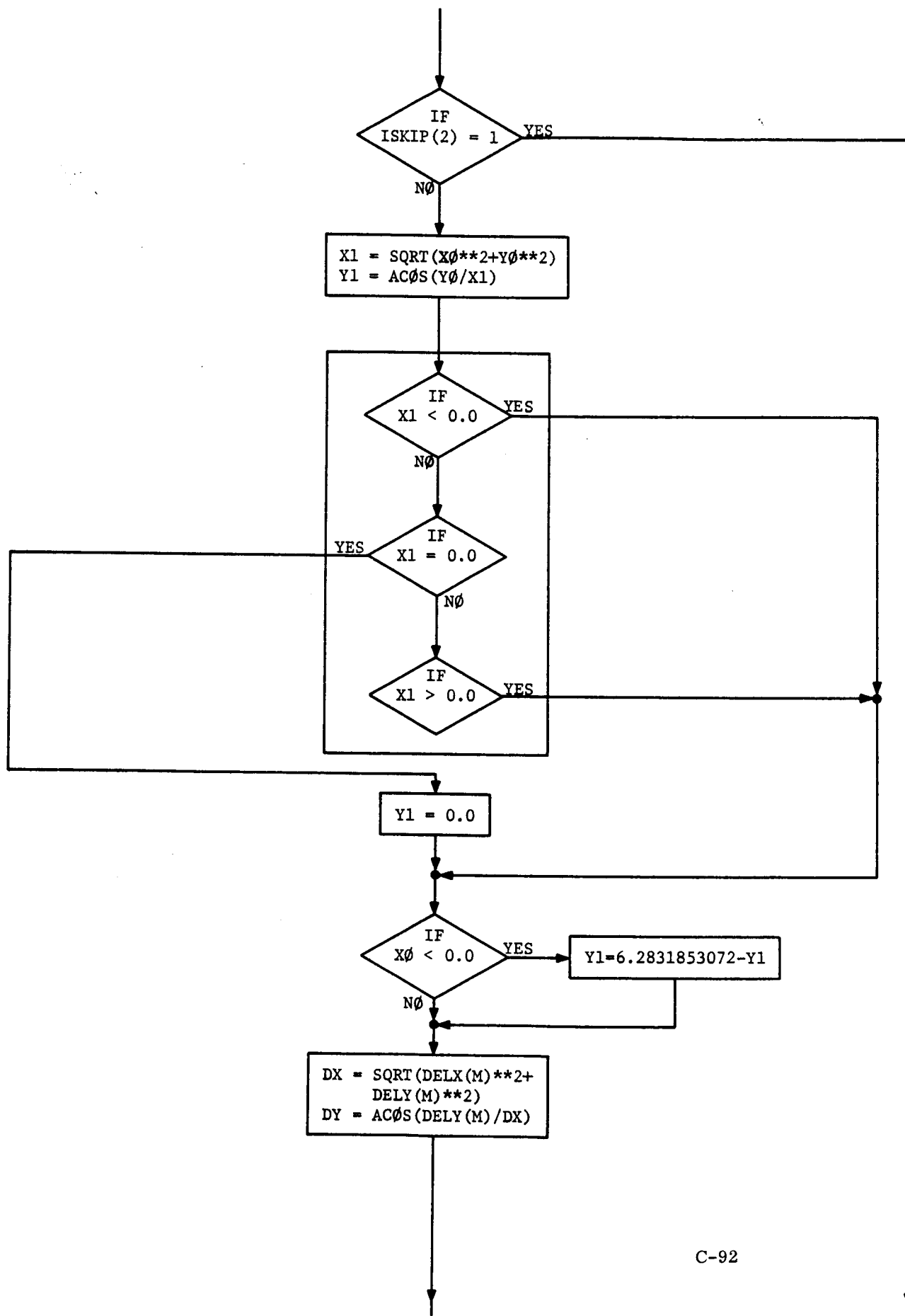
SECTION C.14

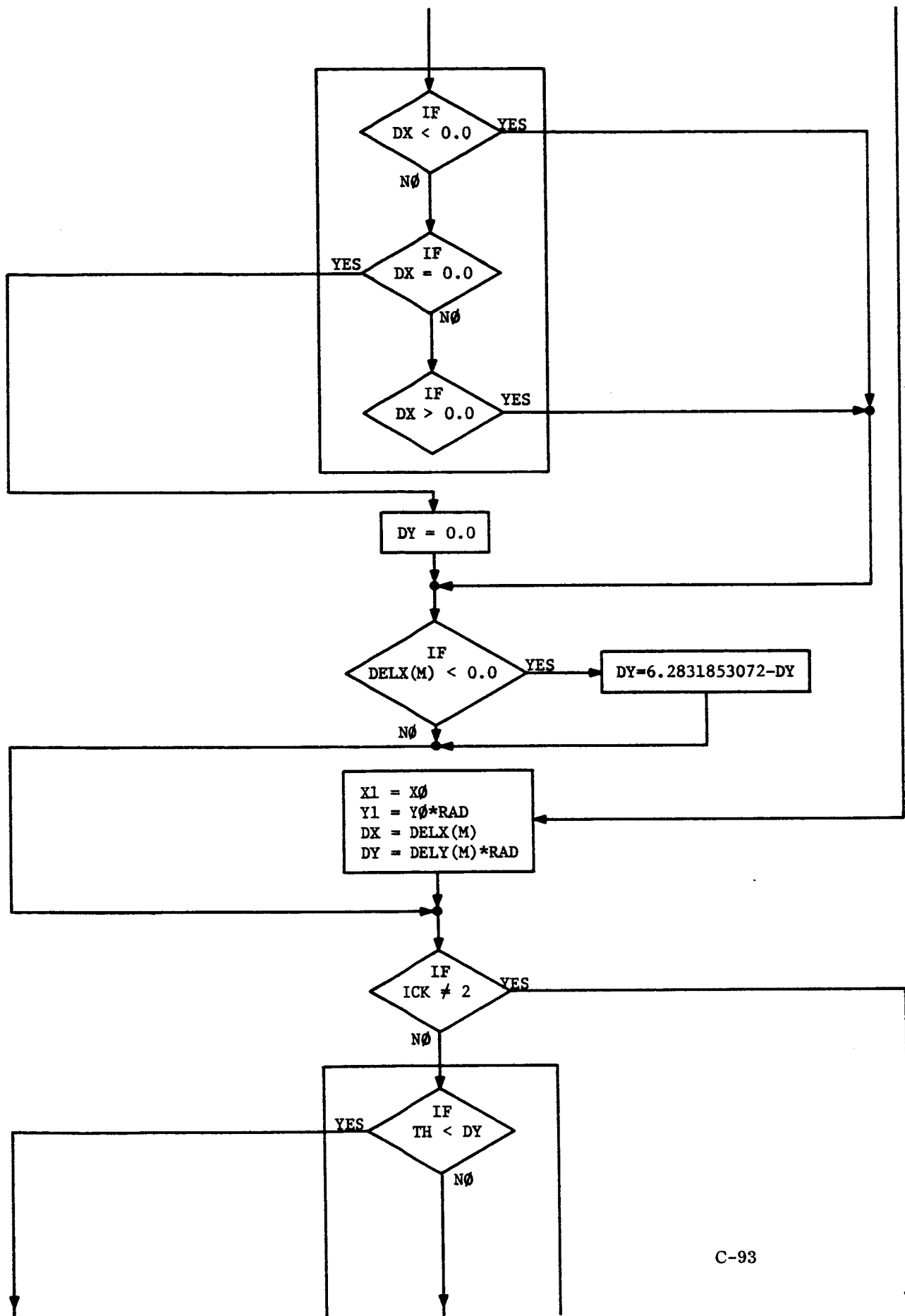
SUBROUTINE COORD

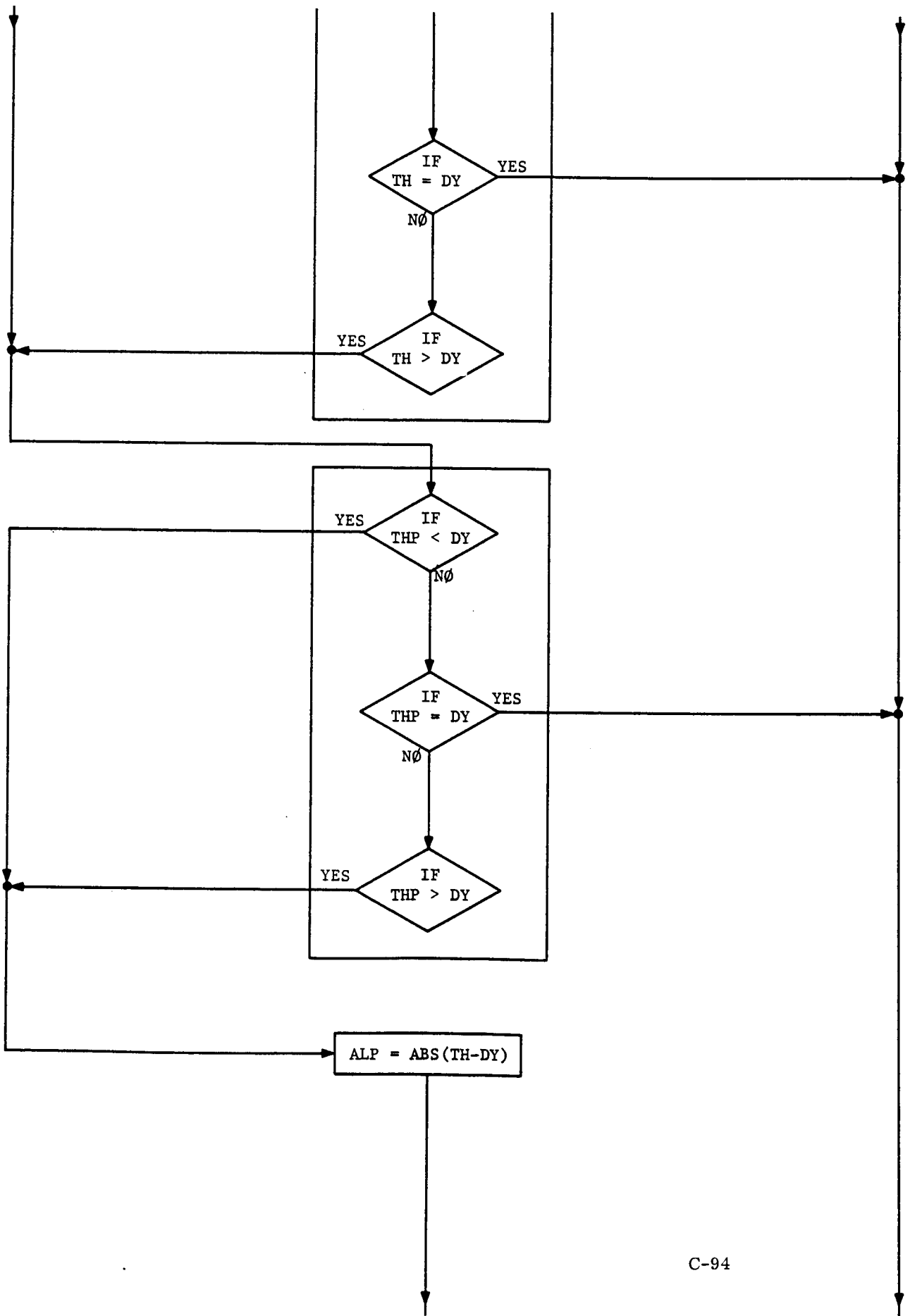
SUBROUTINE COORD(N,M,X,Y,XO,YO,ASP,XS,ICK)

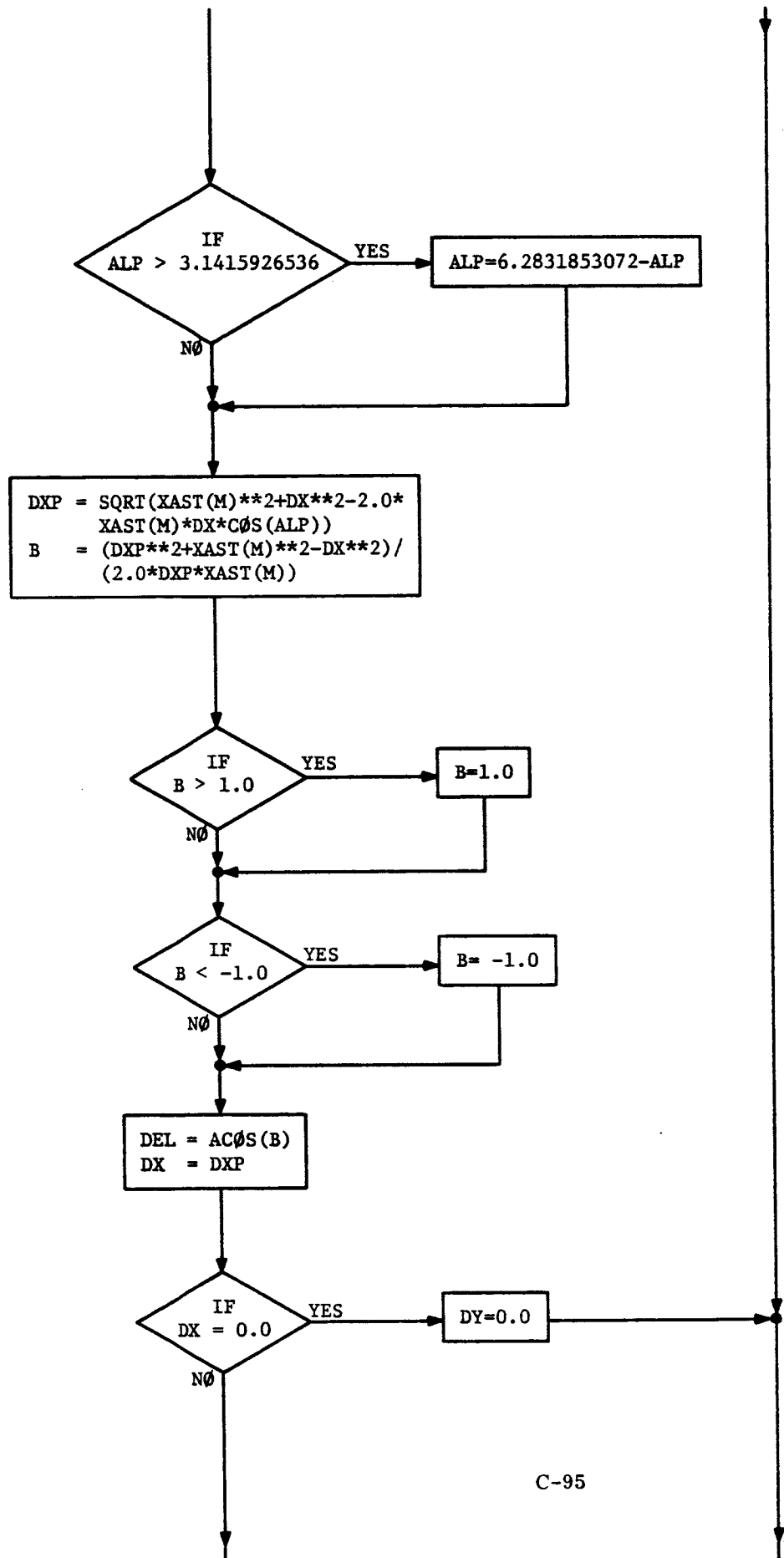
THIS SUBROUTINE TRANSFORMS THE RECEPTOR COORDINATES OF THE FIXED GRID SYSTEM TO COORDINATES RELATIVE TO A SYSTEM WITH POSITIVE X AXIS ALONG THE WIND DIRECTION THETA. IT ALSO DETERMINES IF THE RECEPTOR COORDINATES LIE WITHIN THE SECTOR OF CALCULATION DELPHI. DELPHI IS LESS THAN OR EQUAL TO 180.0 DEGREES. (STORAGE USED 753₈)

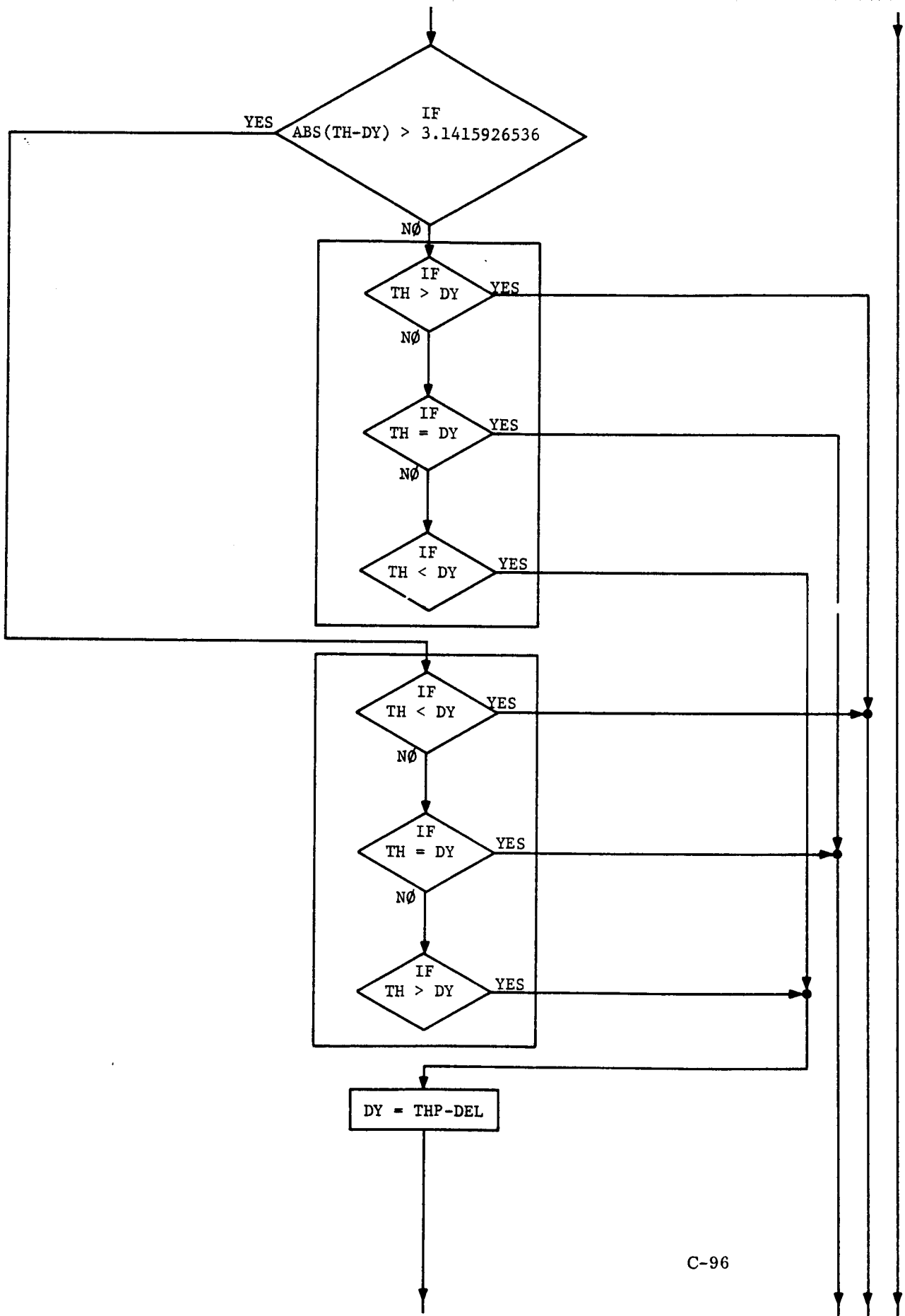


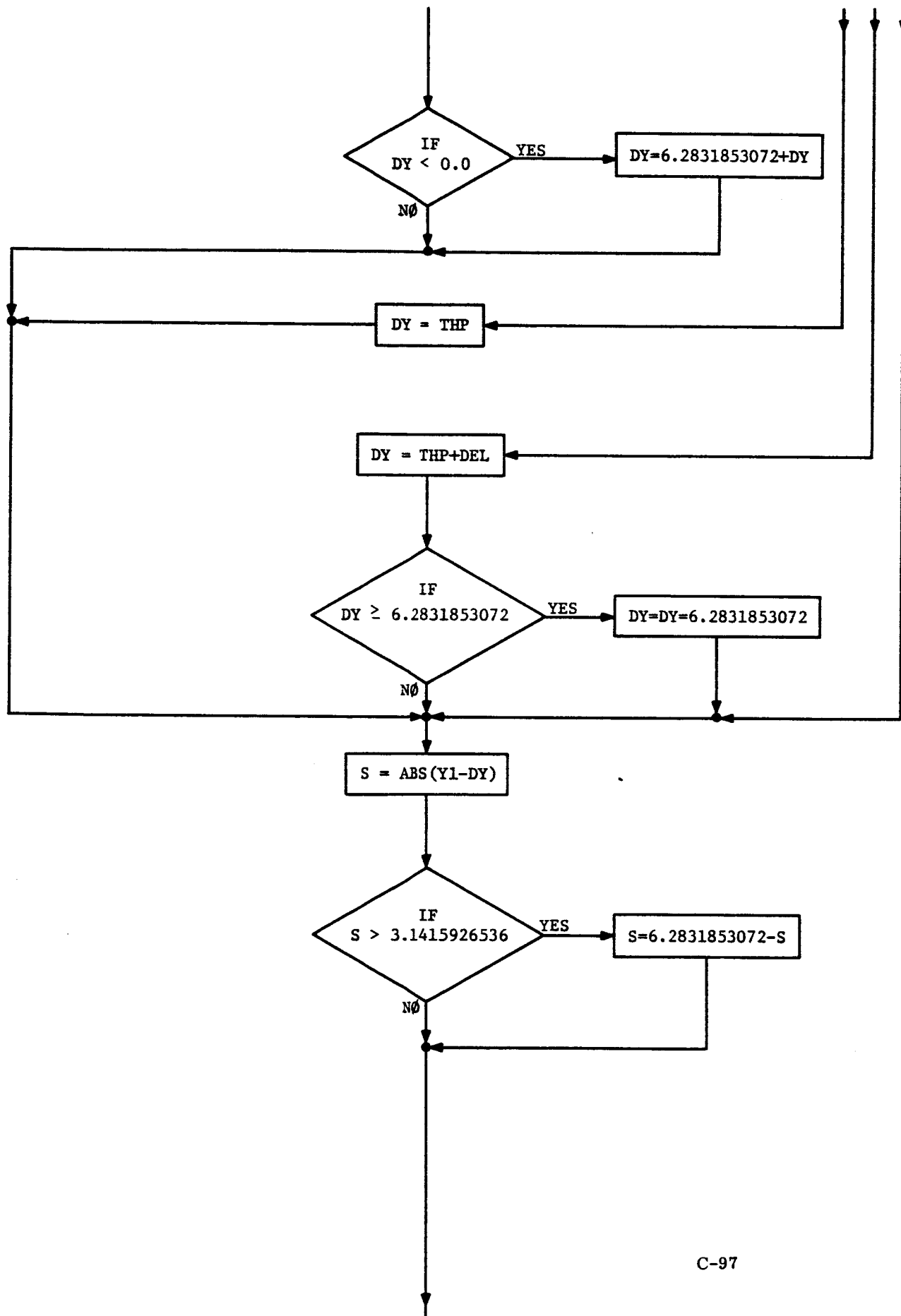




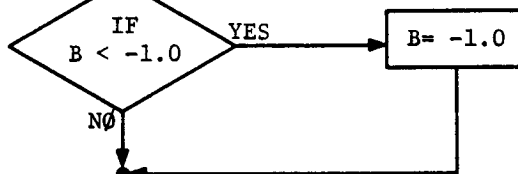
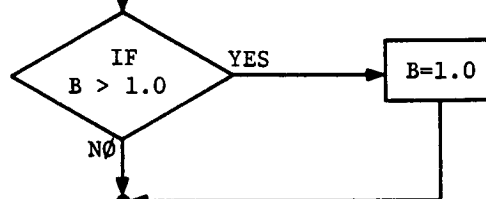




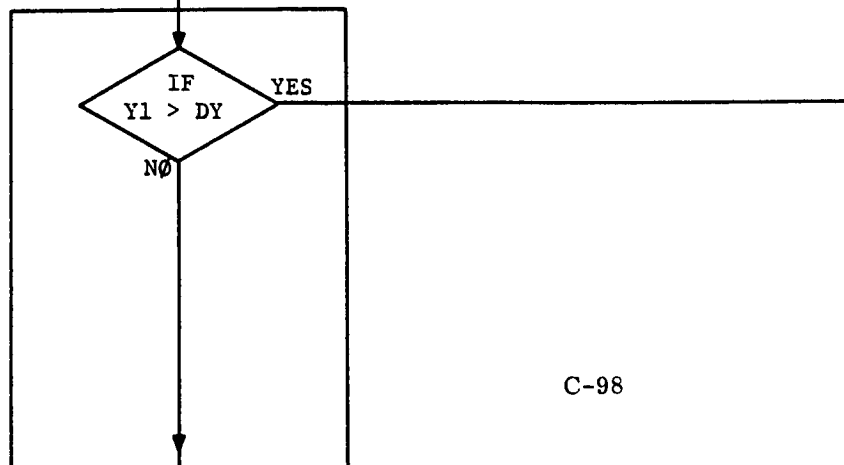
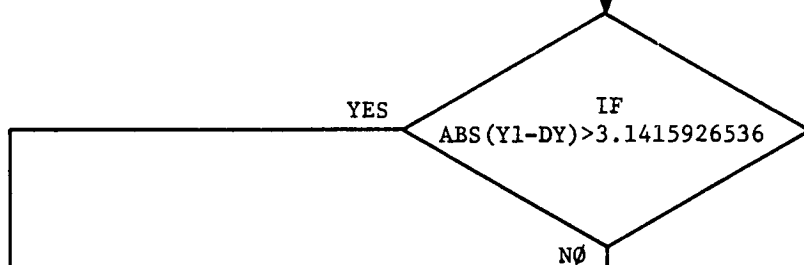


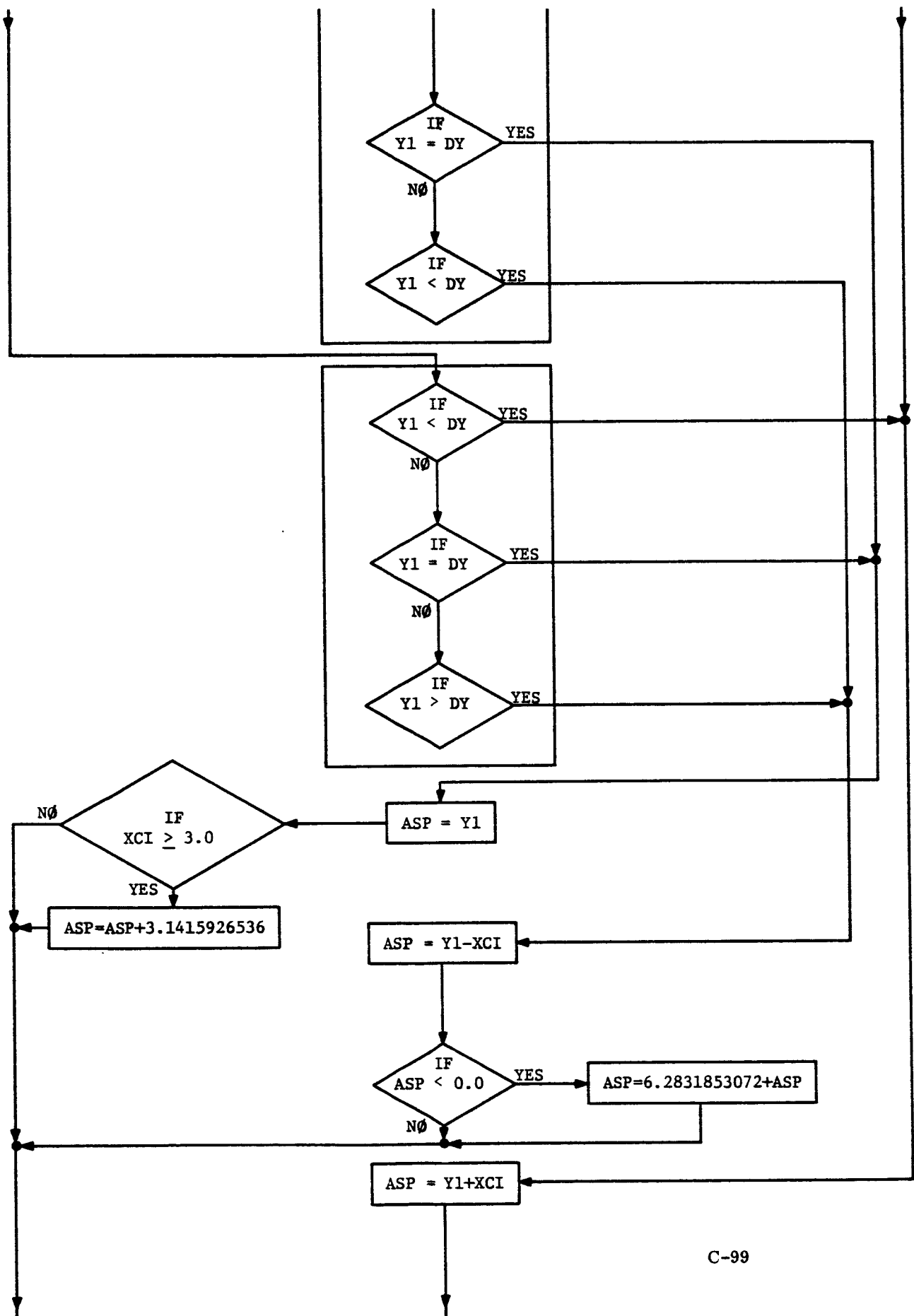


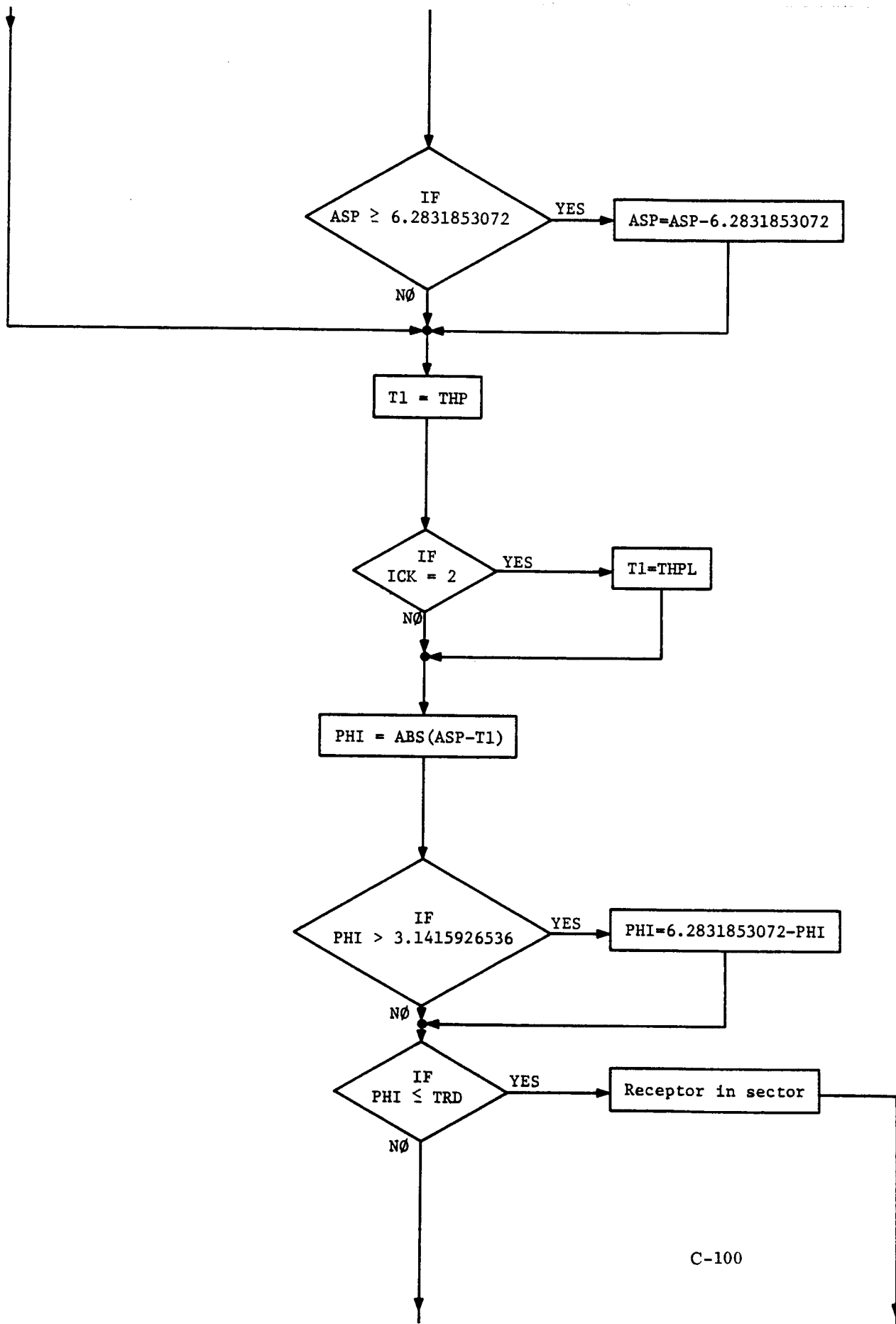
$XS = \text{SQRT}(X1^{**2} + DX^{**2} - 2.0 * X1 * DX * \text{COS}(S))$
 $B = (X1^{**2} + XS^{**2} - DX^{**2}) / (2.0 * X1 * XS)$



$XCI = \text{ACOS}(B)$







N = 9
ITAG(J) = 9
X = XS
Receptor outside of
sector DELPHI

RETURN

X = XS * COS(PHI)
Y = XS * SIN(PHI)

IF
ABS(ASP-T1) > 3.1415926536

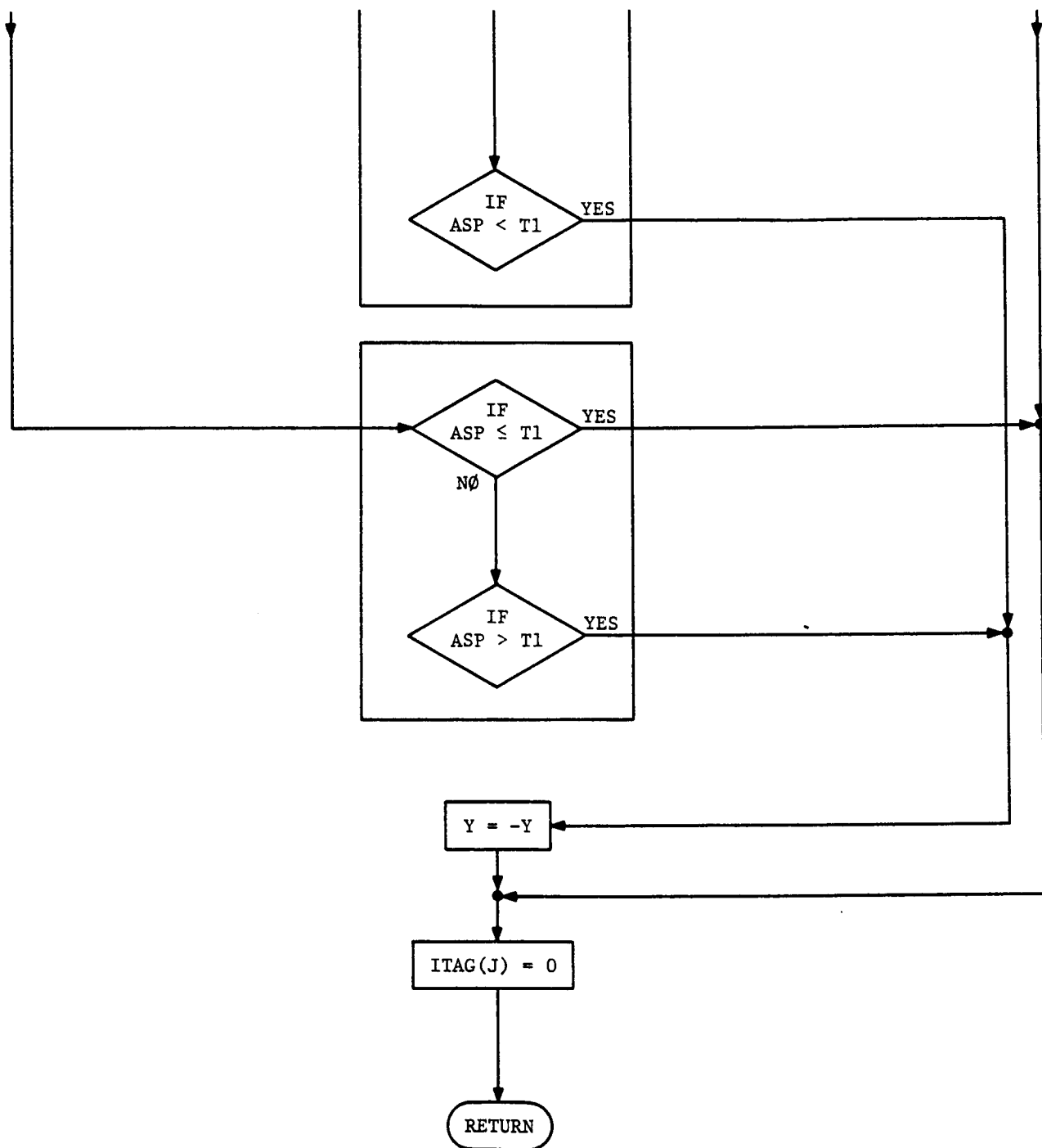
NO

IF
ASP ≥ T1

NO

YES

C-101



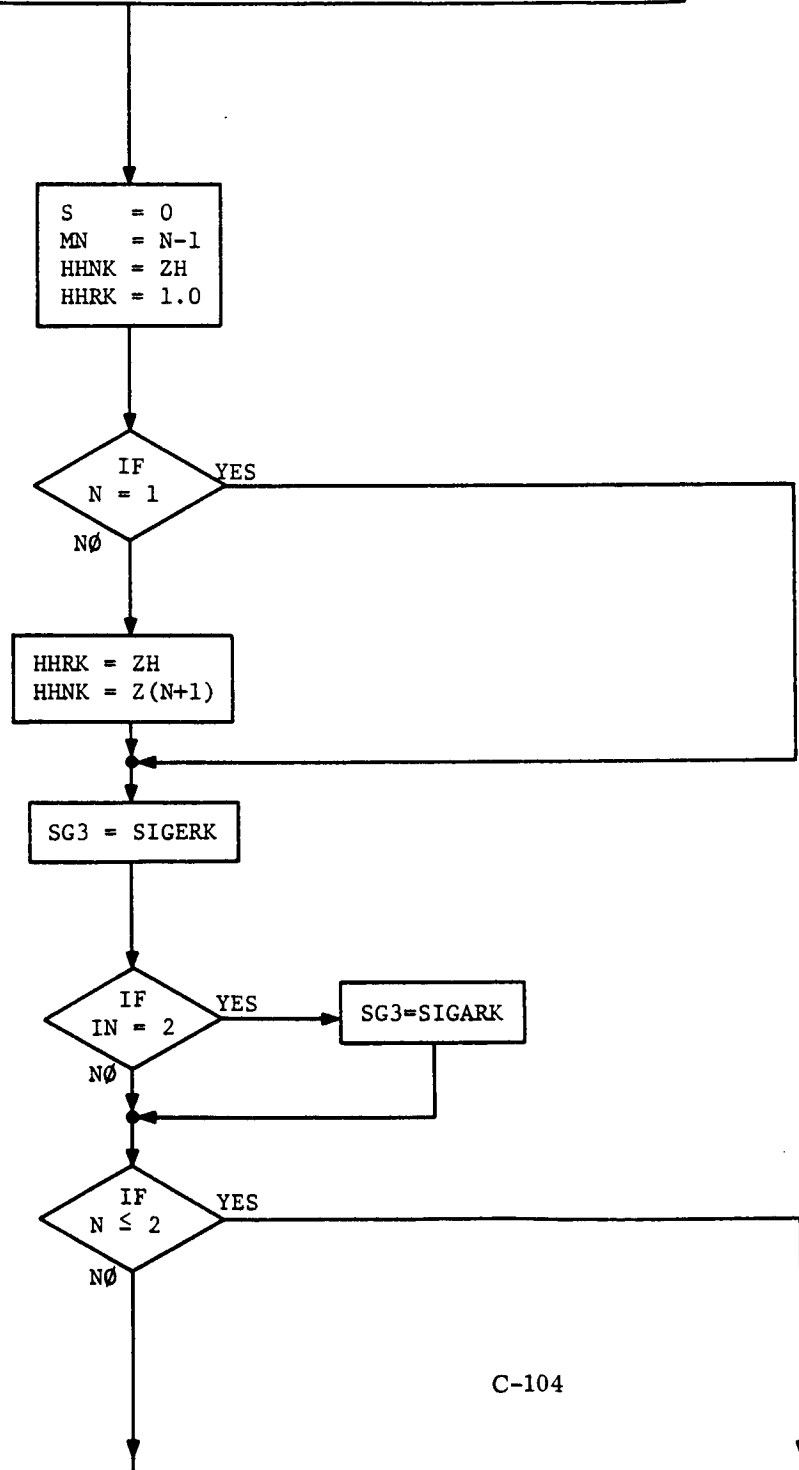
SECTION C. 15

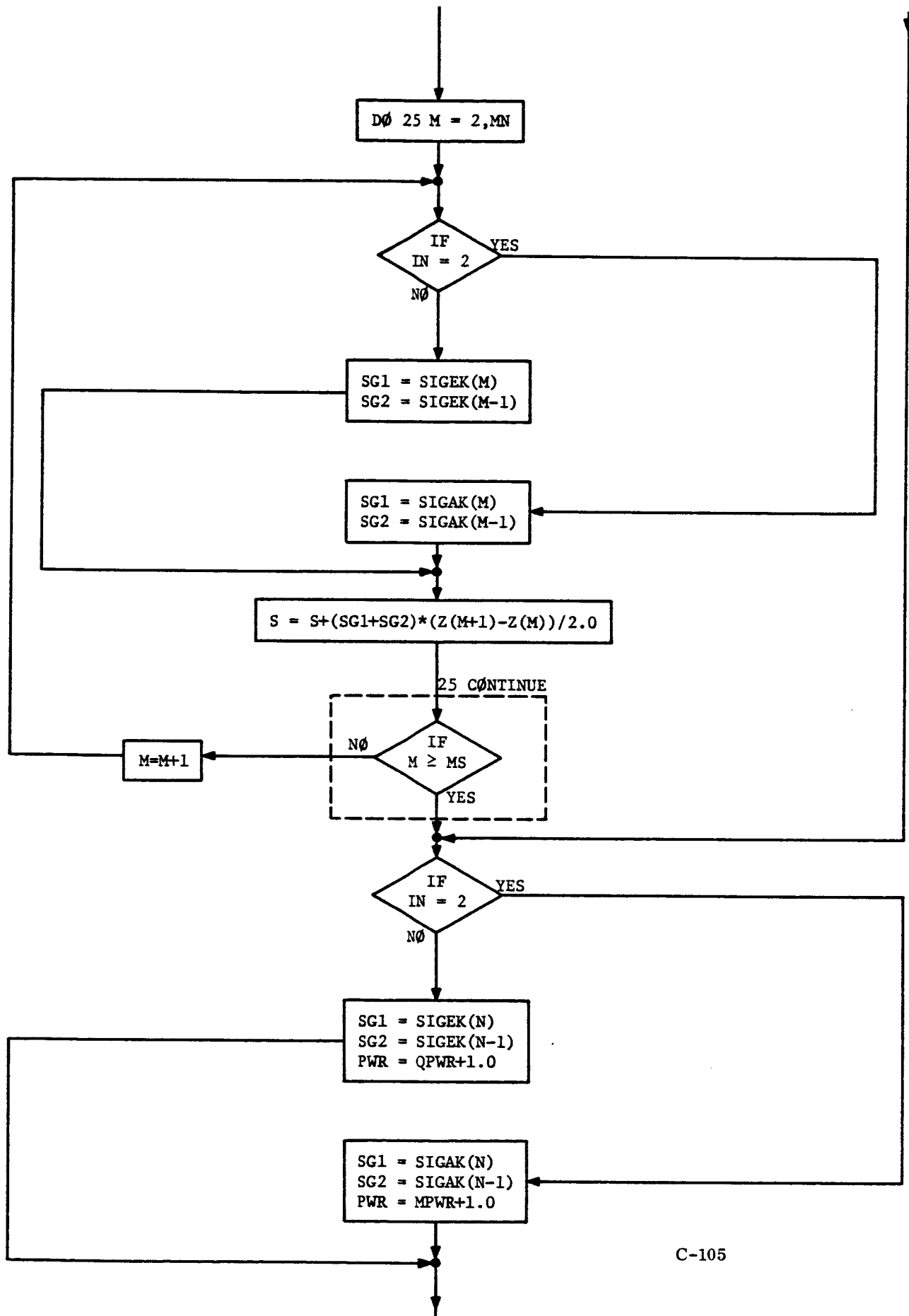
SUBROUTINE SGP

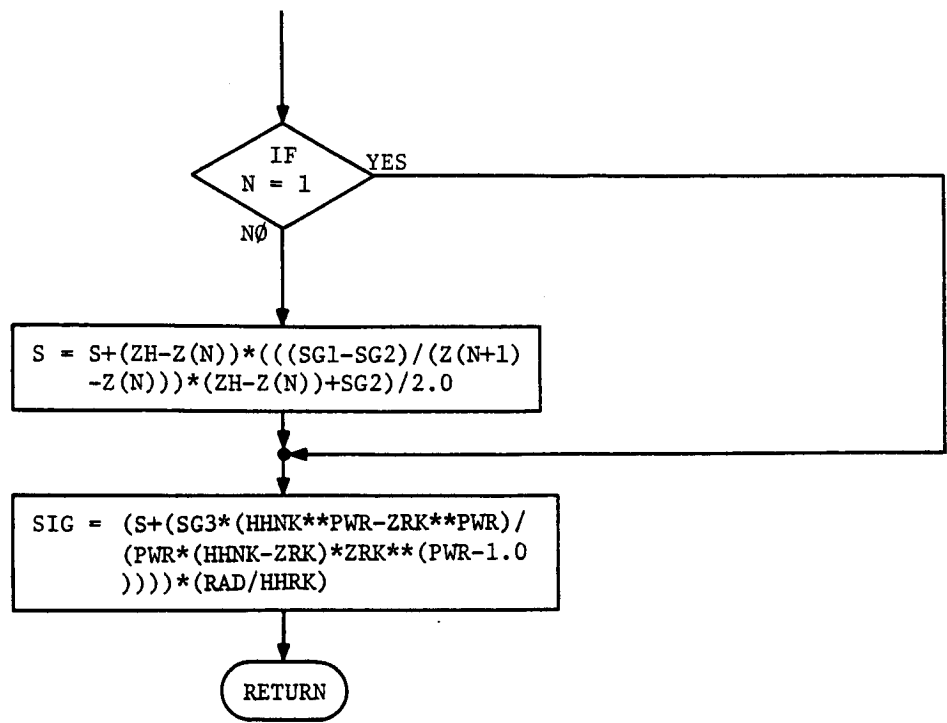
SUBROUTINE SGP(ZH,N,SIG,IN)

THIS SUBROUTINE CONSISTS OF THREE SUBROUTINES. SGP CALCULATES σ'_{ENK} OR σ'_{EB} AND σ'_{ANK} OR σ'_{EB} . SUBROUTINE UBARS CALCULATES $\bar{u}_{NK}$, x_{NK} , y_{NK} , θ 'S. SUBROUTINE DEPSO CALCULATES ALL OF THE DEPOSITION EQUATION EXCEPT THE LATERAL TERM.

(STORAGE USED 1424₈)







ENTRY UBARS (ZH,H,IZ,UBHK)

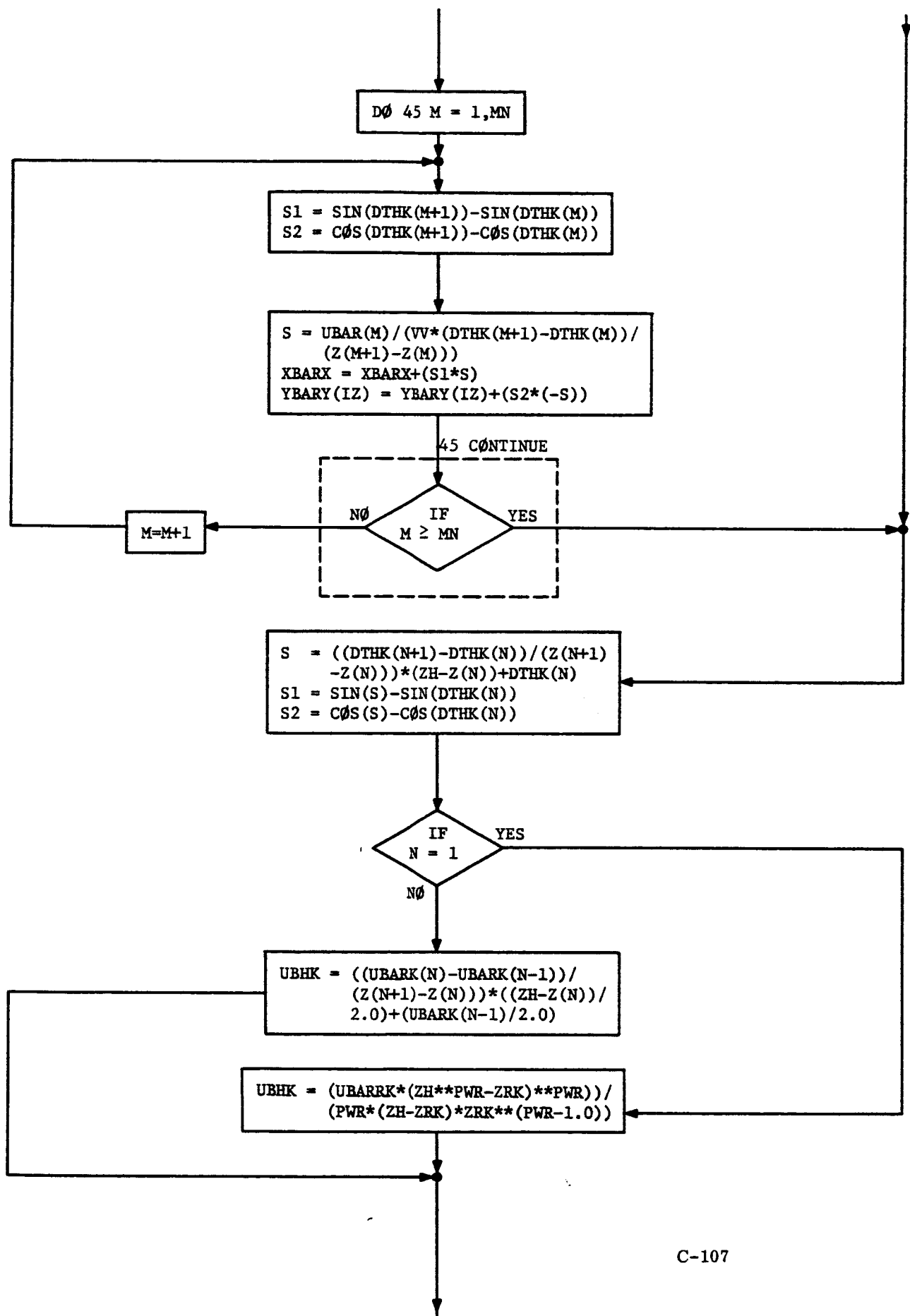
XBARX = 0.0
 YBARY (IZ) = 0.0
 VV = VS (II)
 PWR = PPWR+1.0

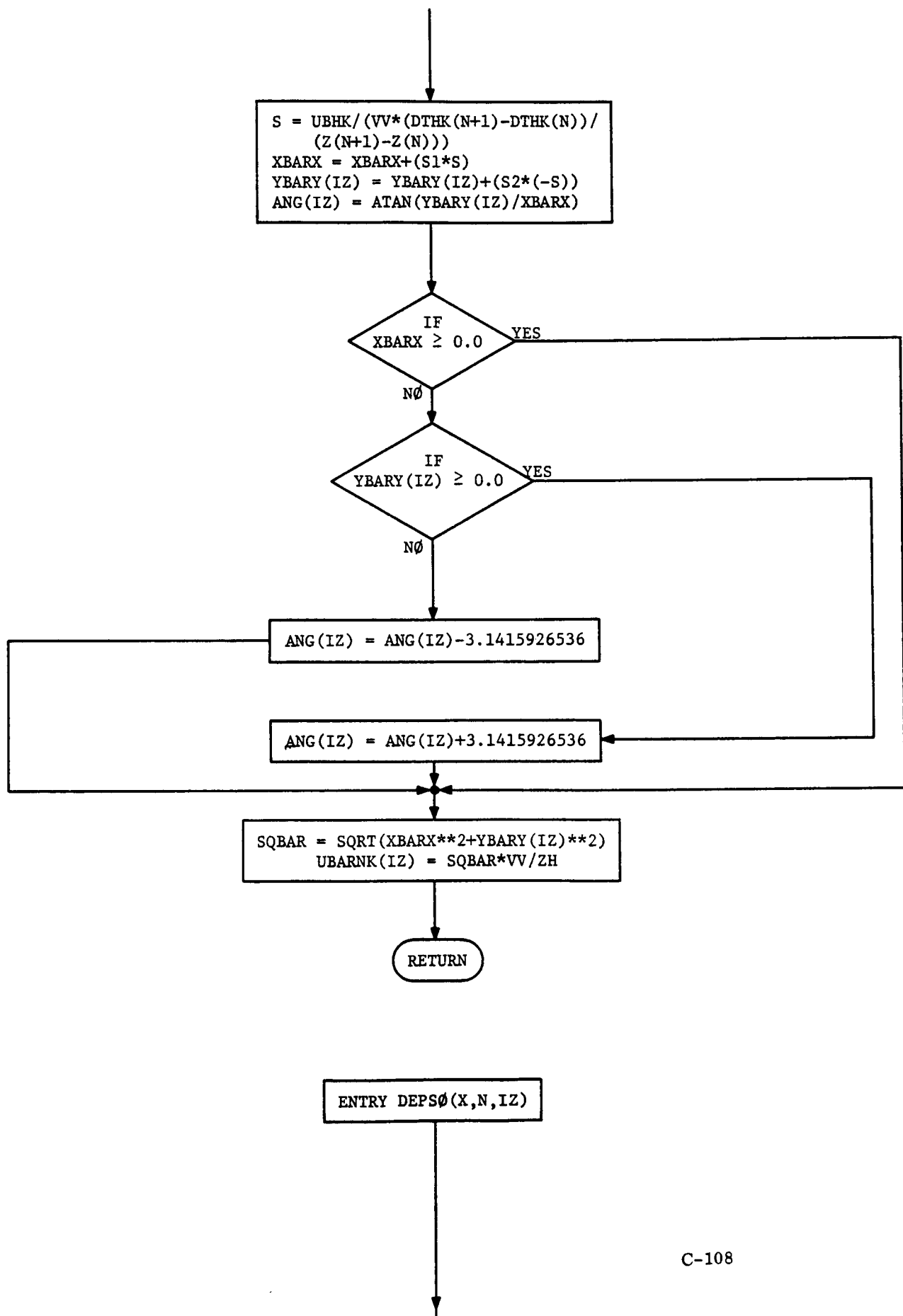
IF JF = 2

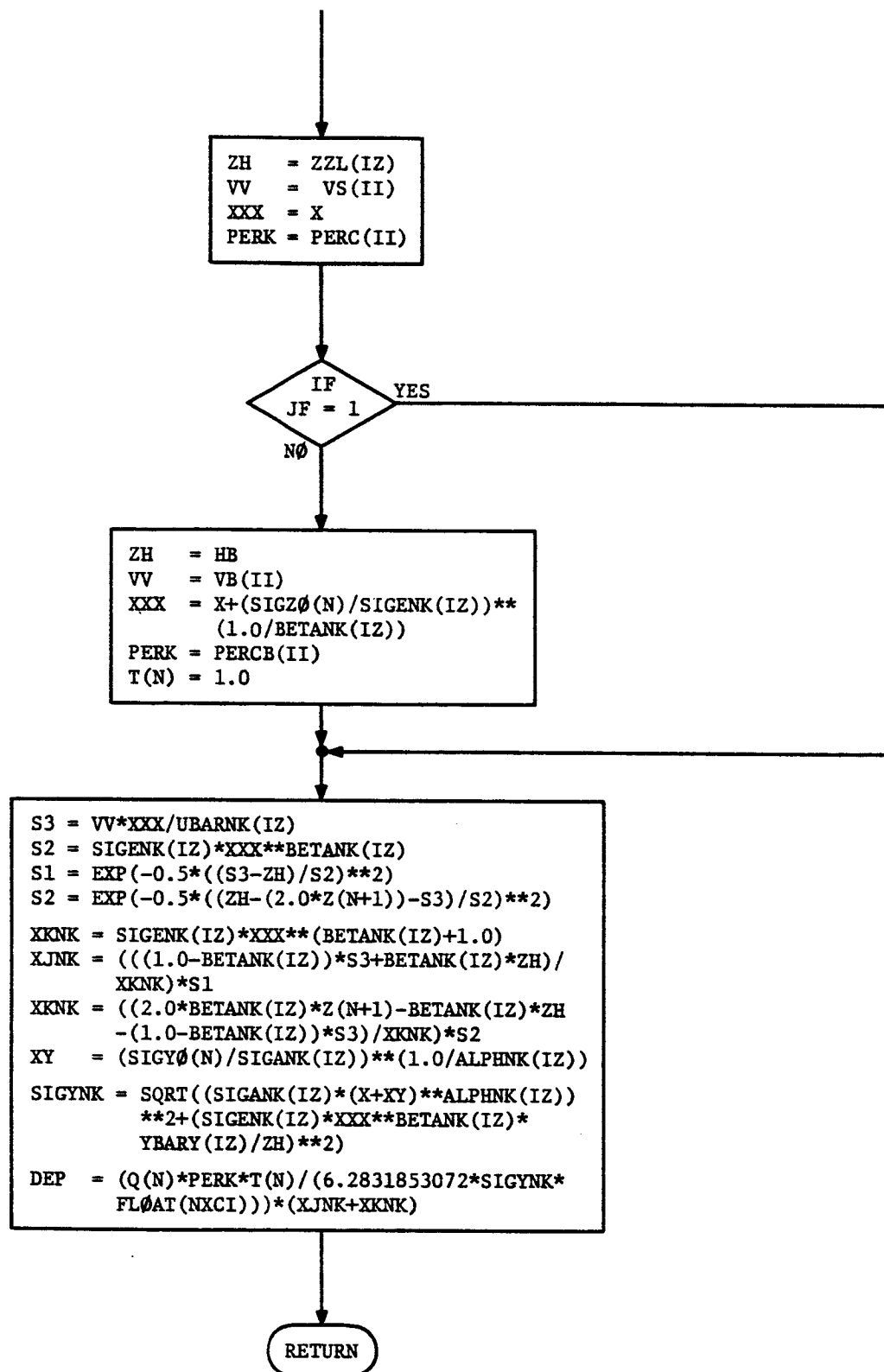
VV=VB(II)

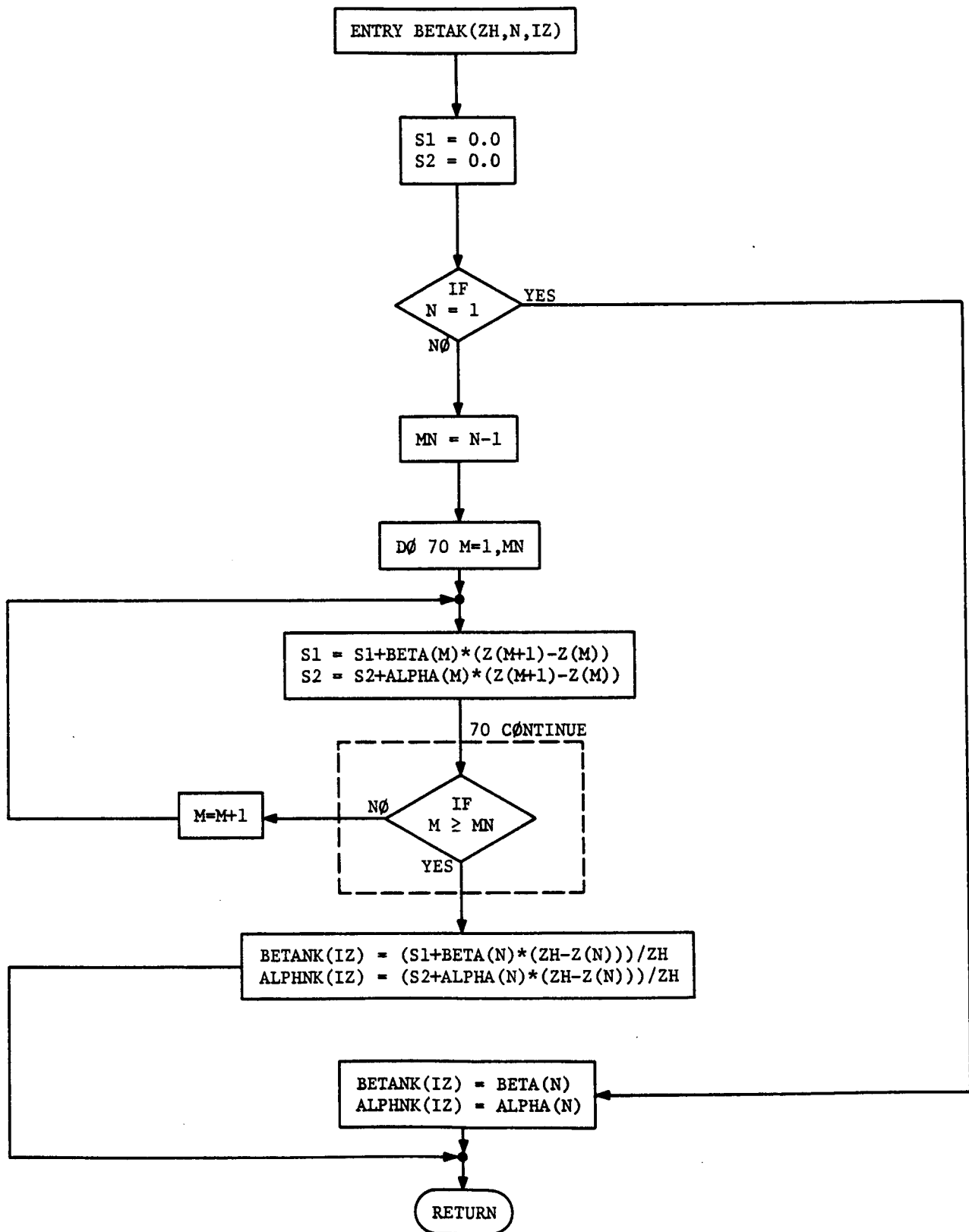
IF N = 1

MN = N - 1









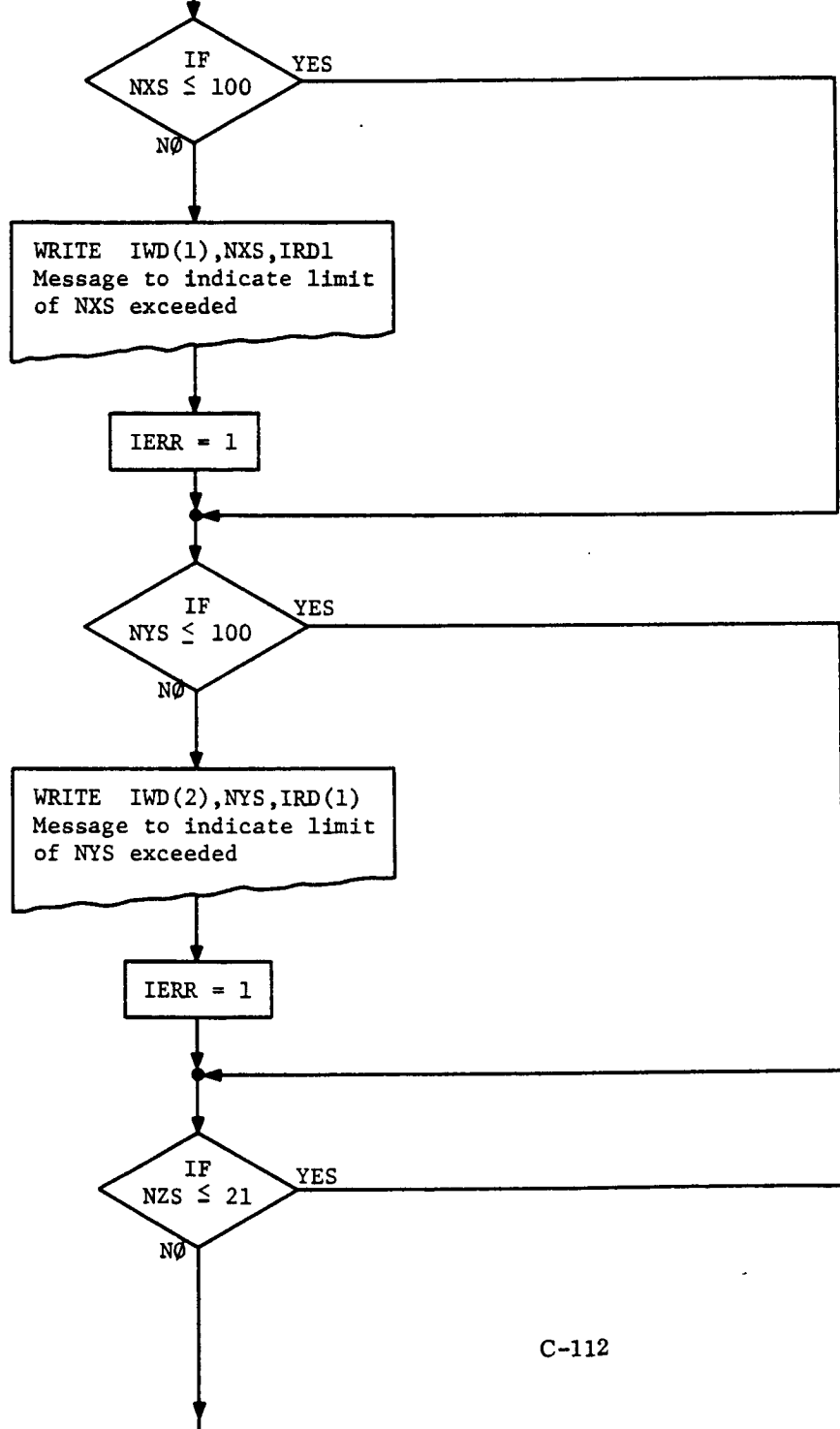
SECTION C. 16

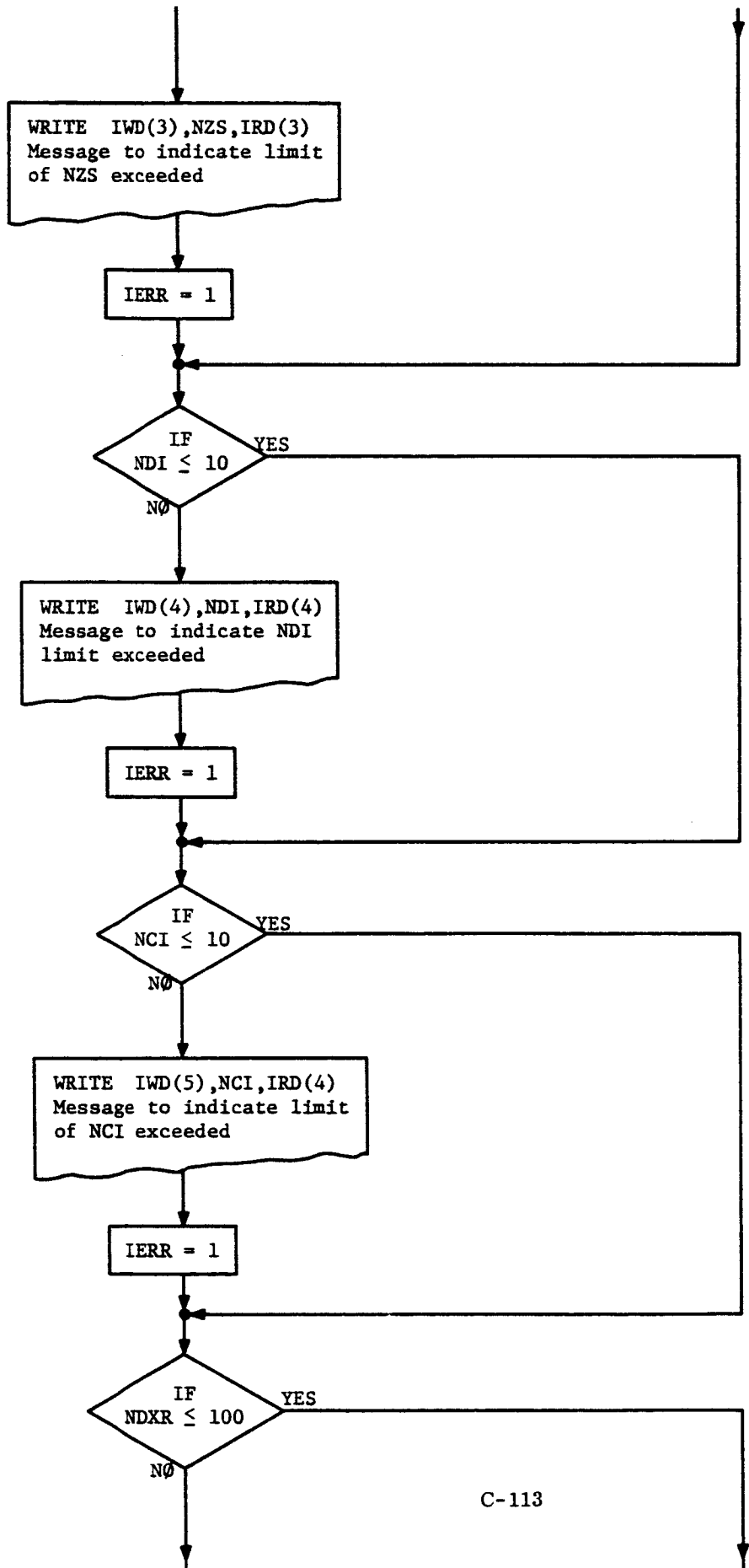
SUBROUTINE READER

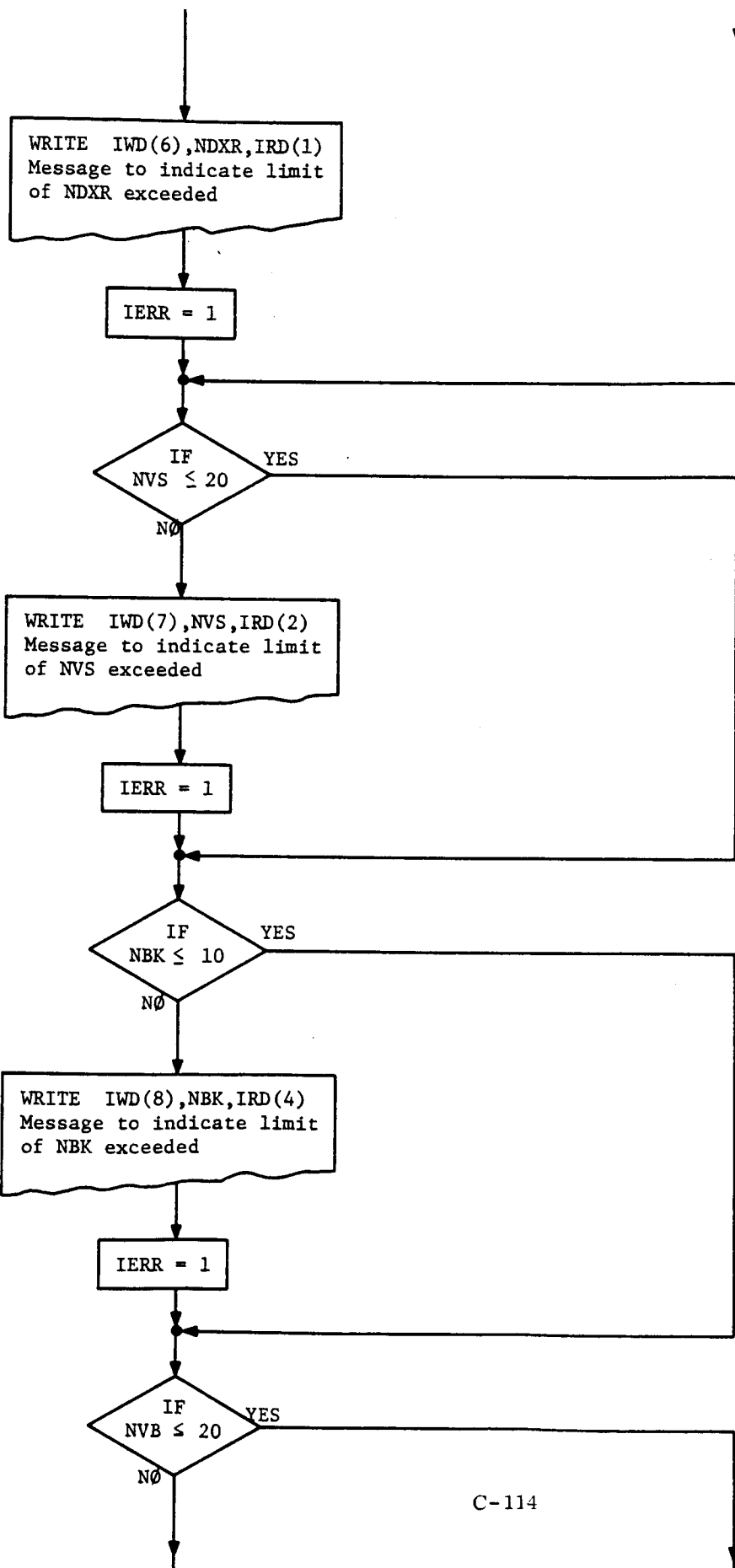
SUBROUTINE READER (IERR,NP,JXJ)

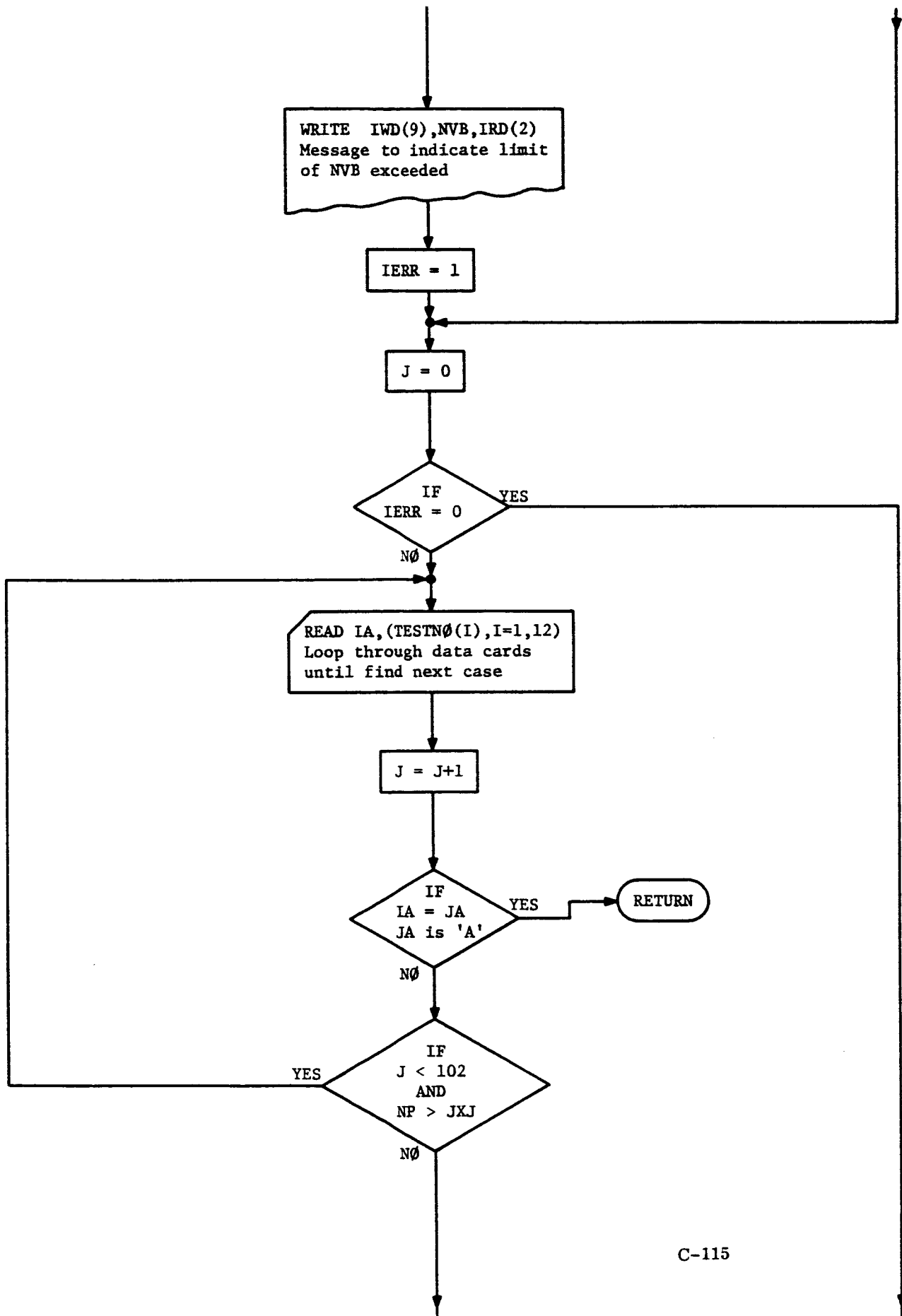
THIS SUBROUTINE READS ALL INPUT PARAMETERS AND PREPARES THEM FOR CALCULATIONS.

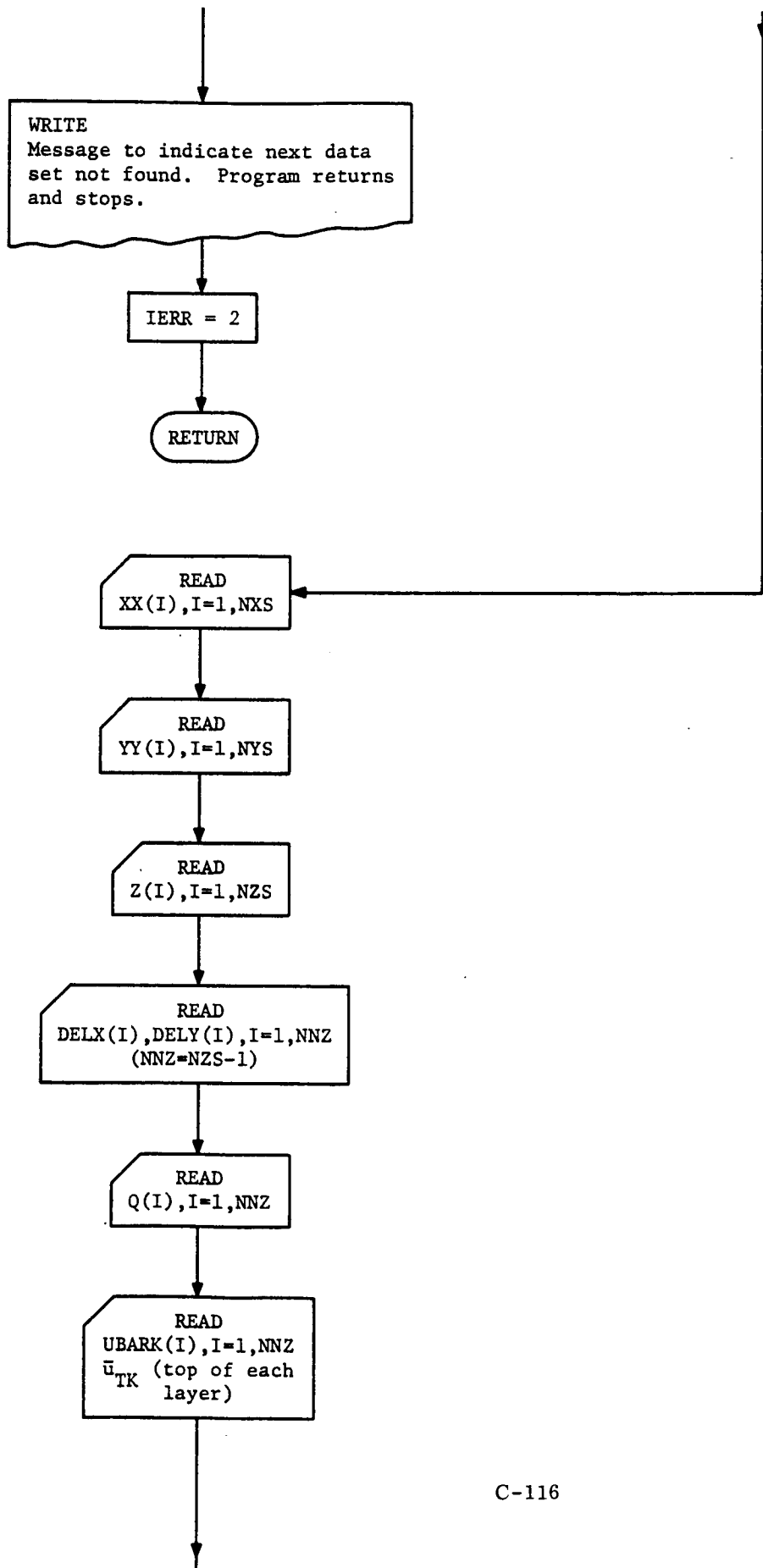
(STORAGE USED 2735₈)

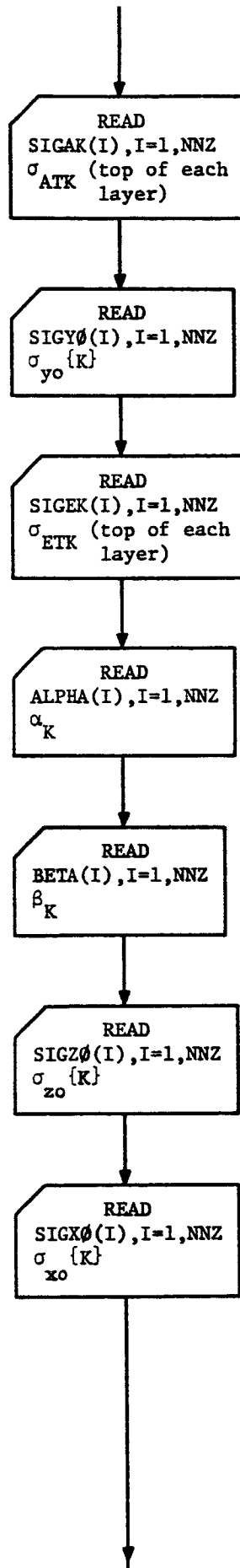


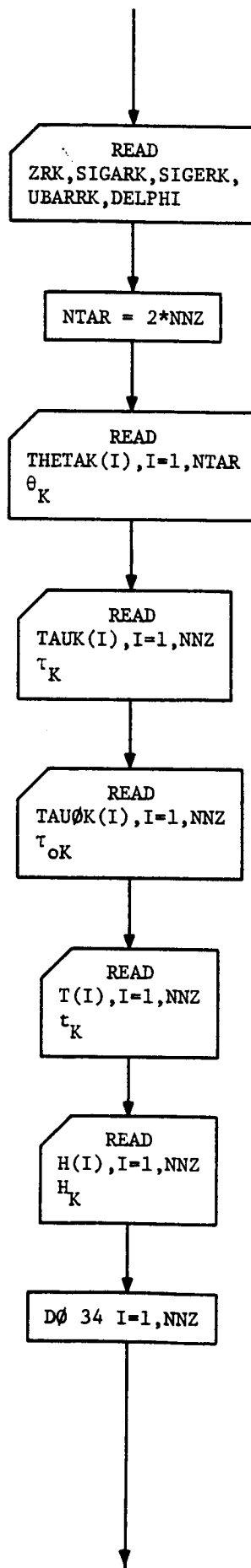


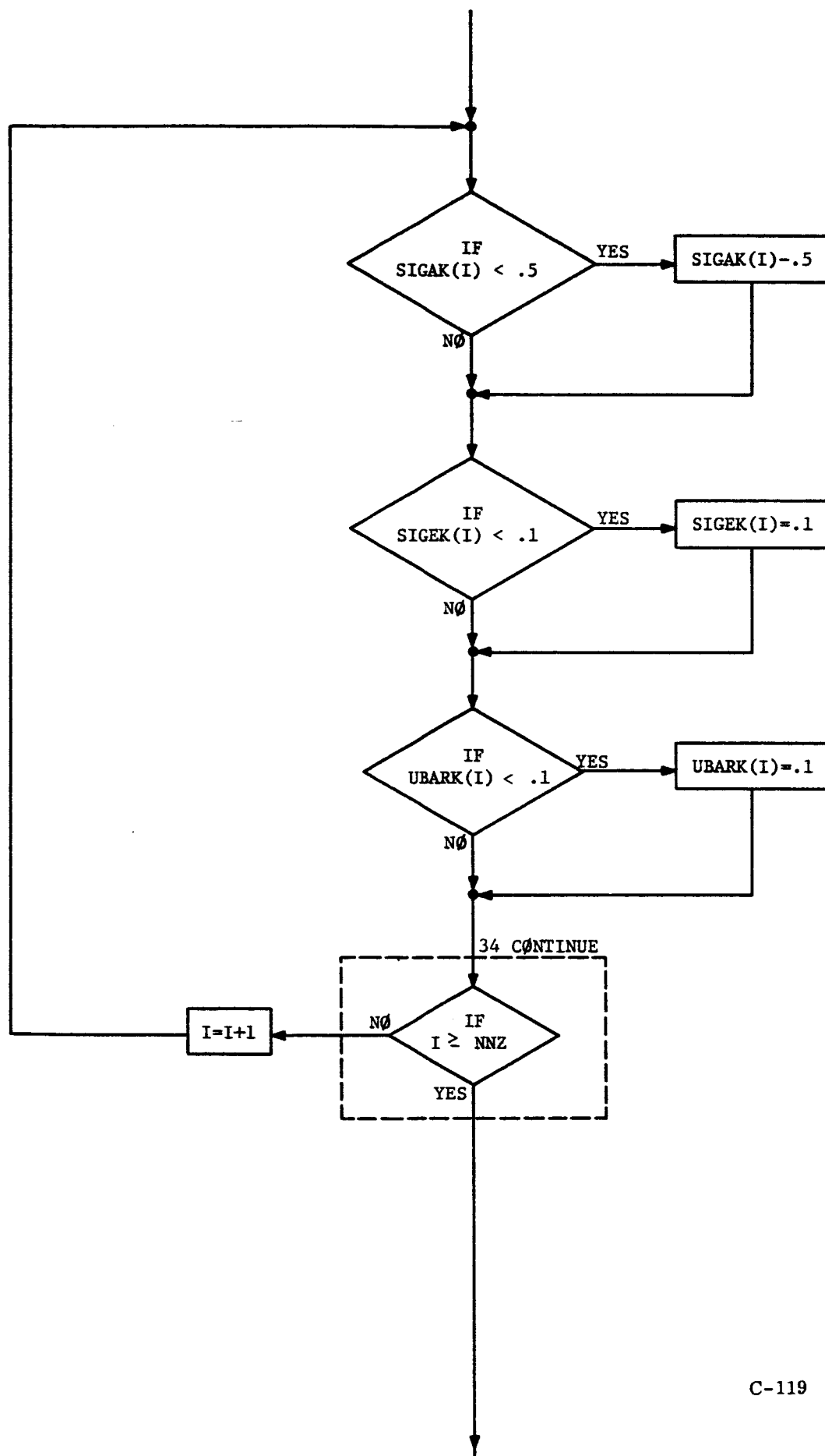


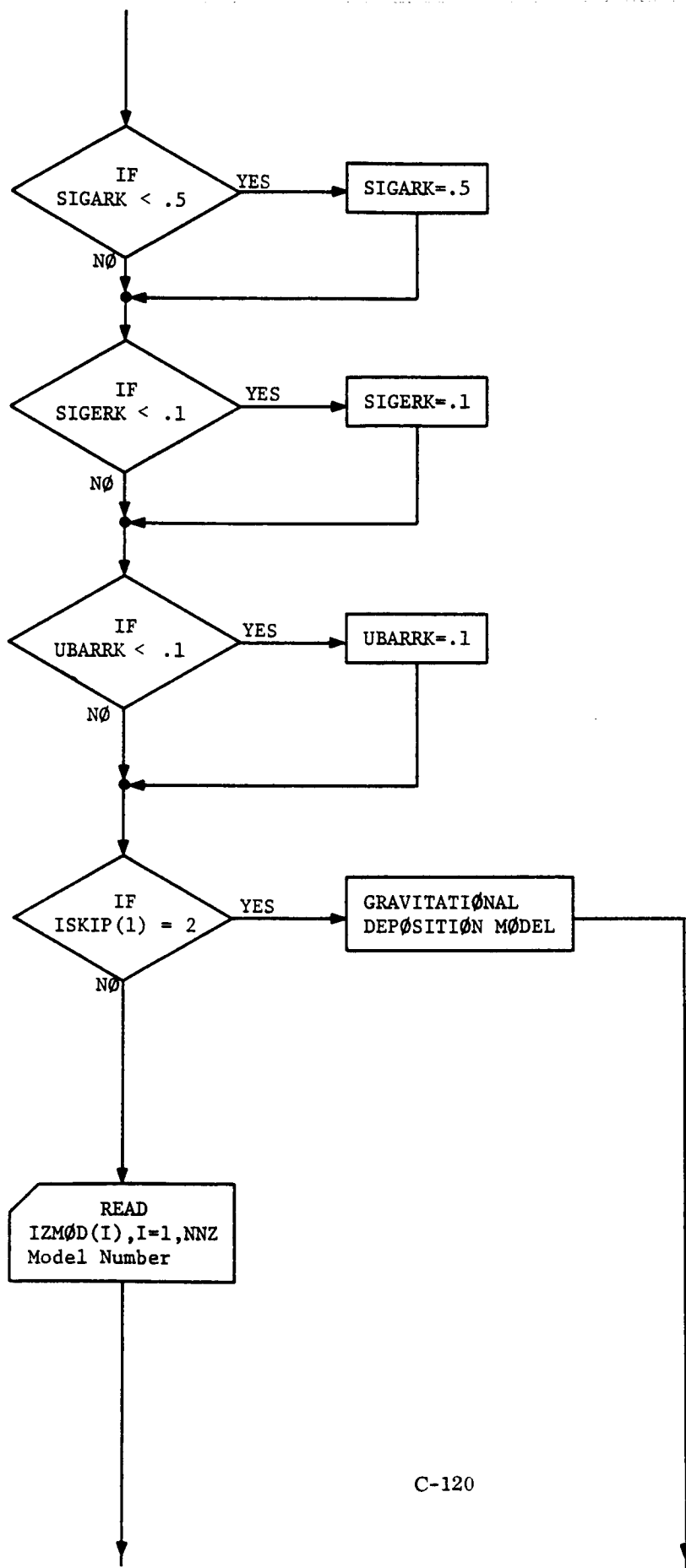


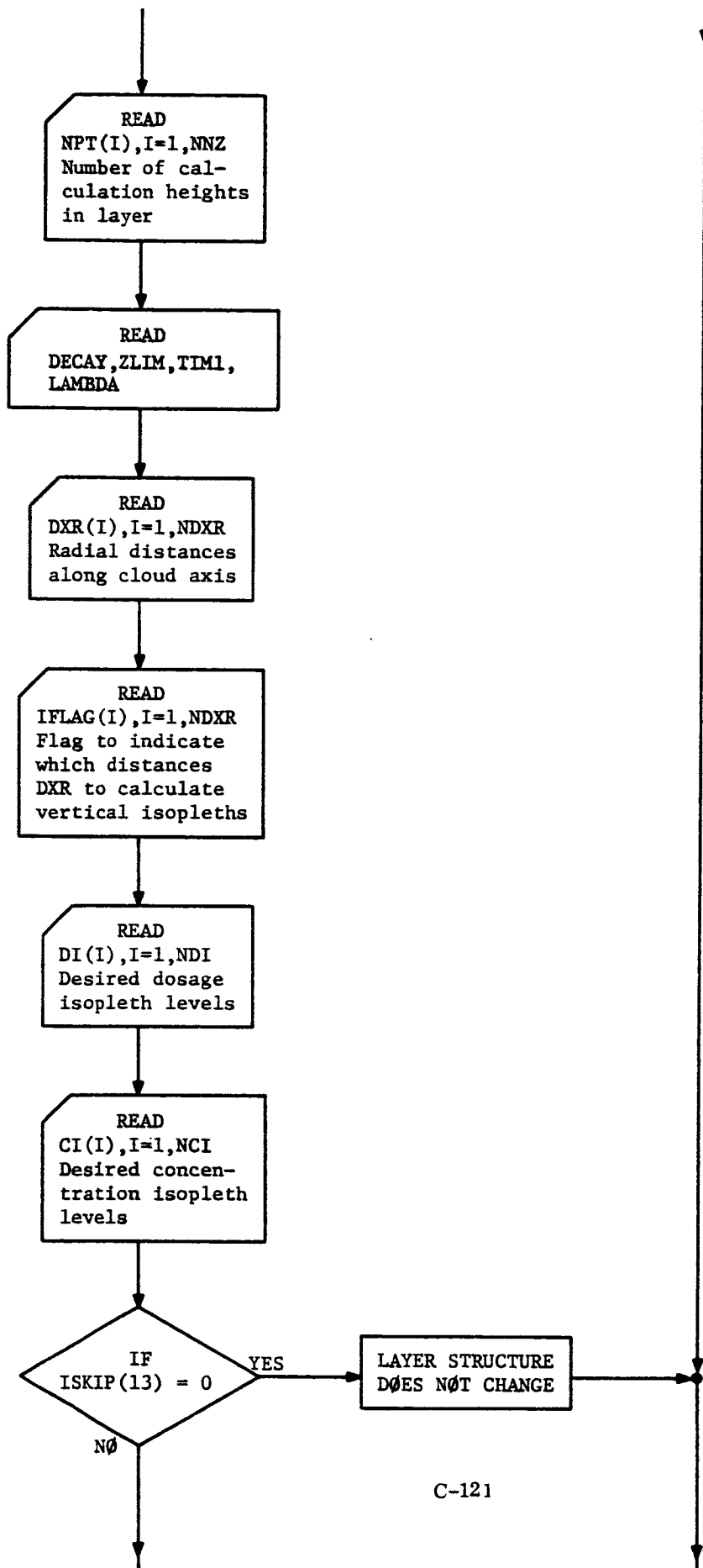


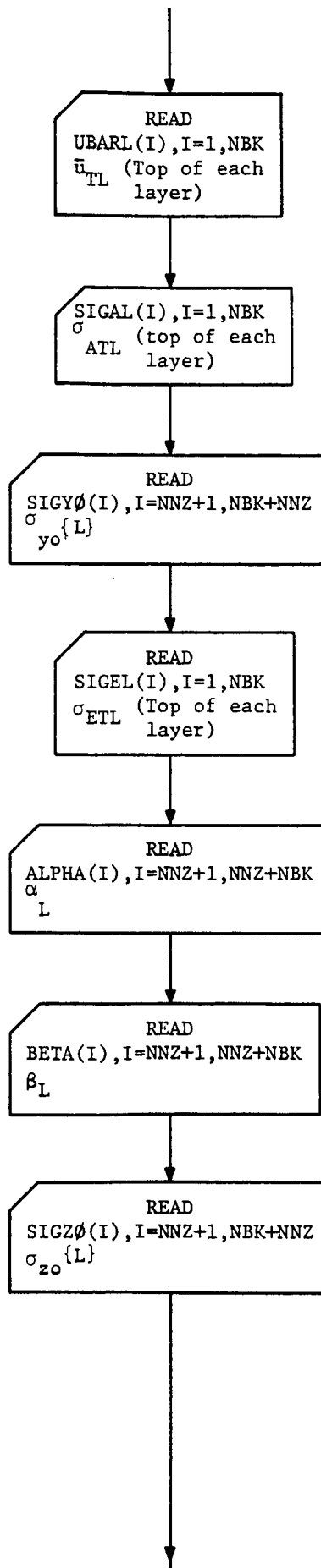


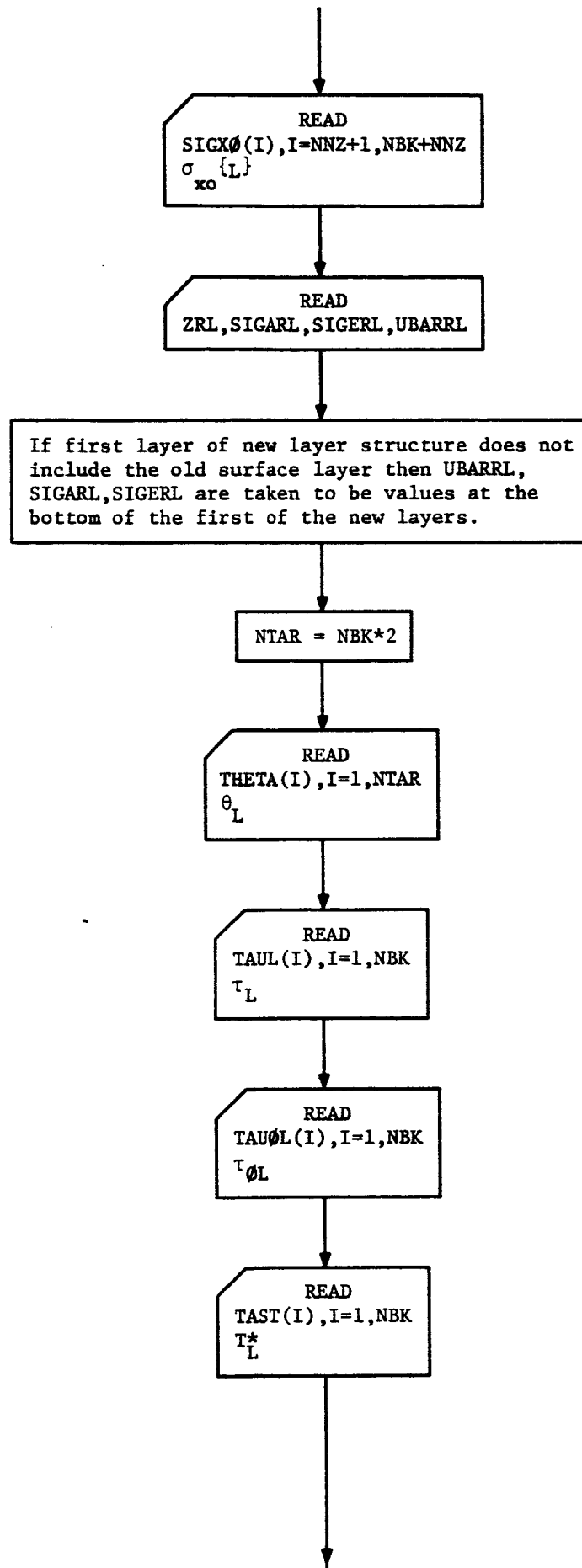


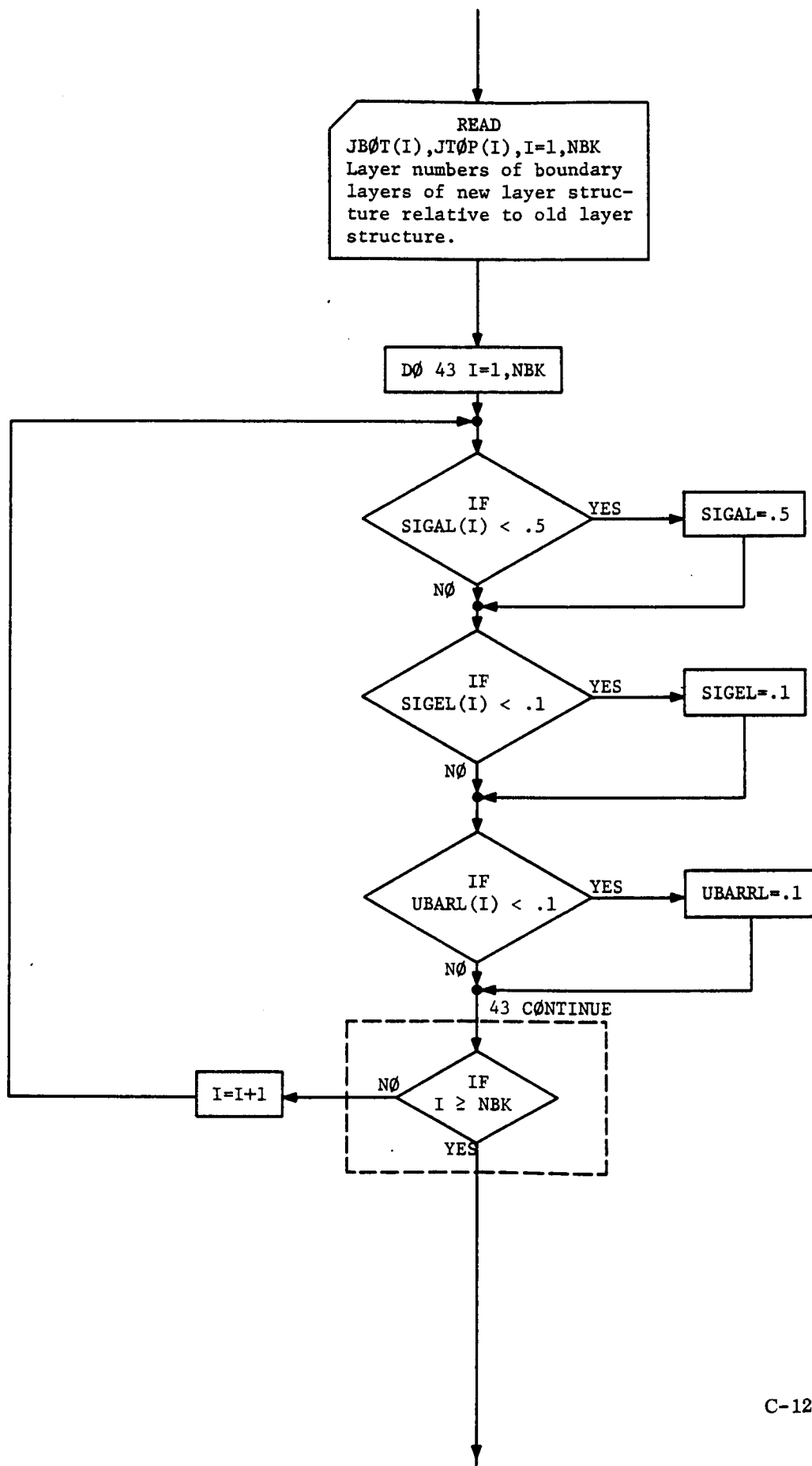


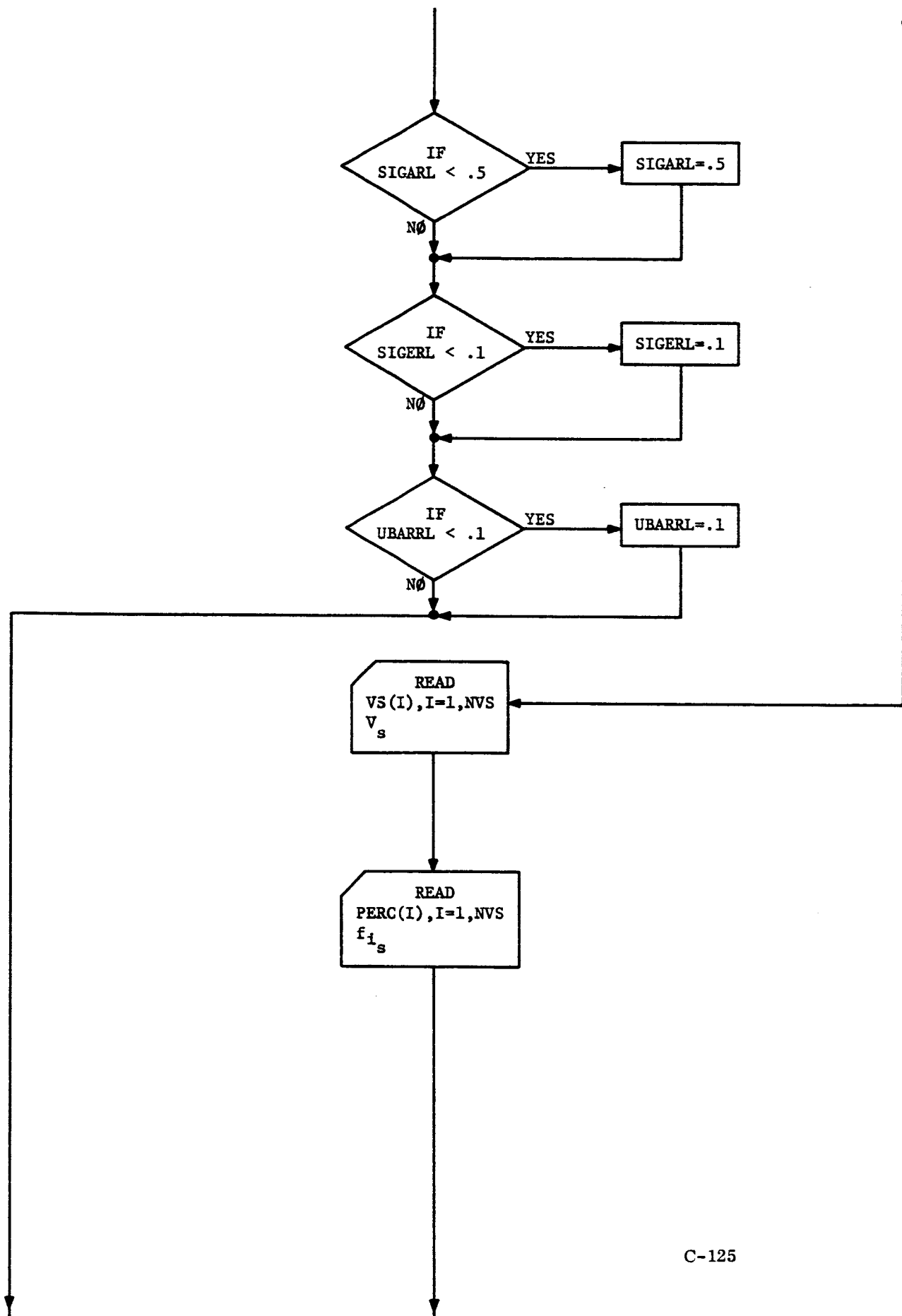


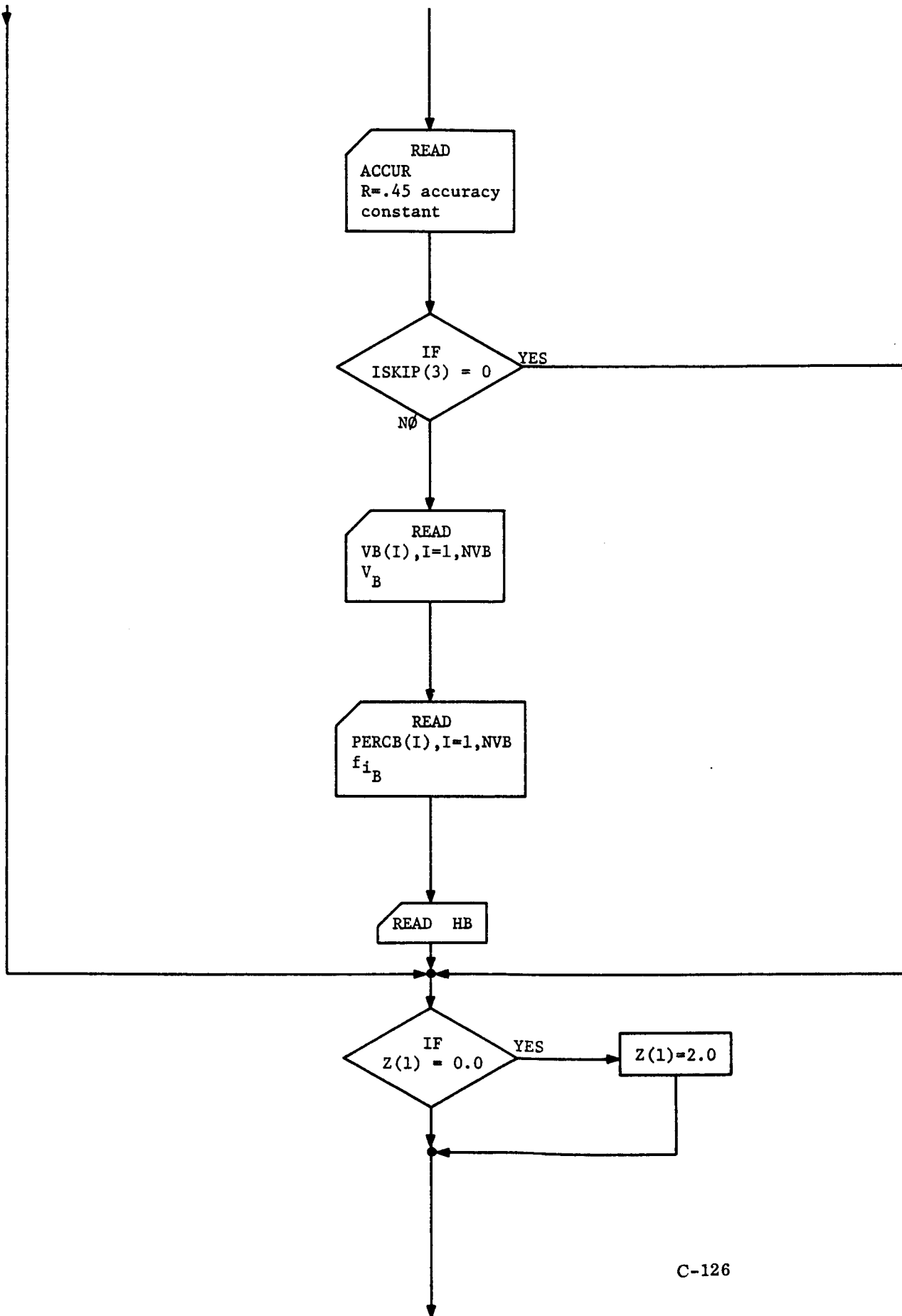


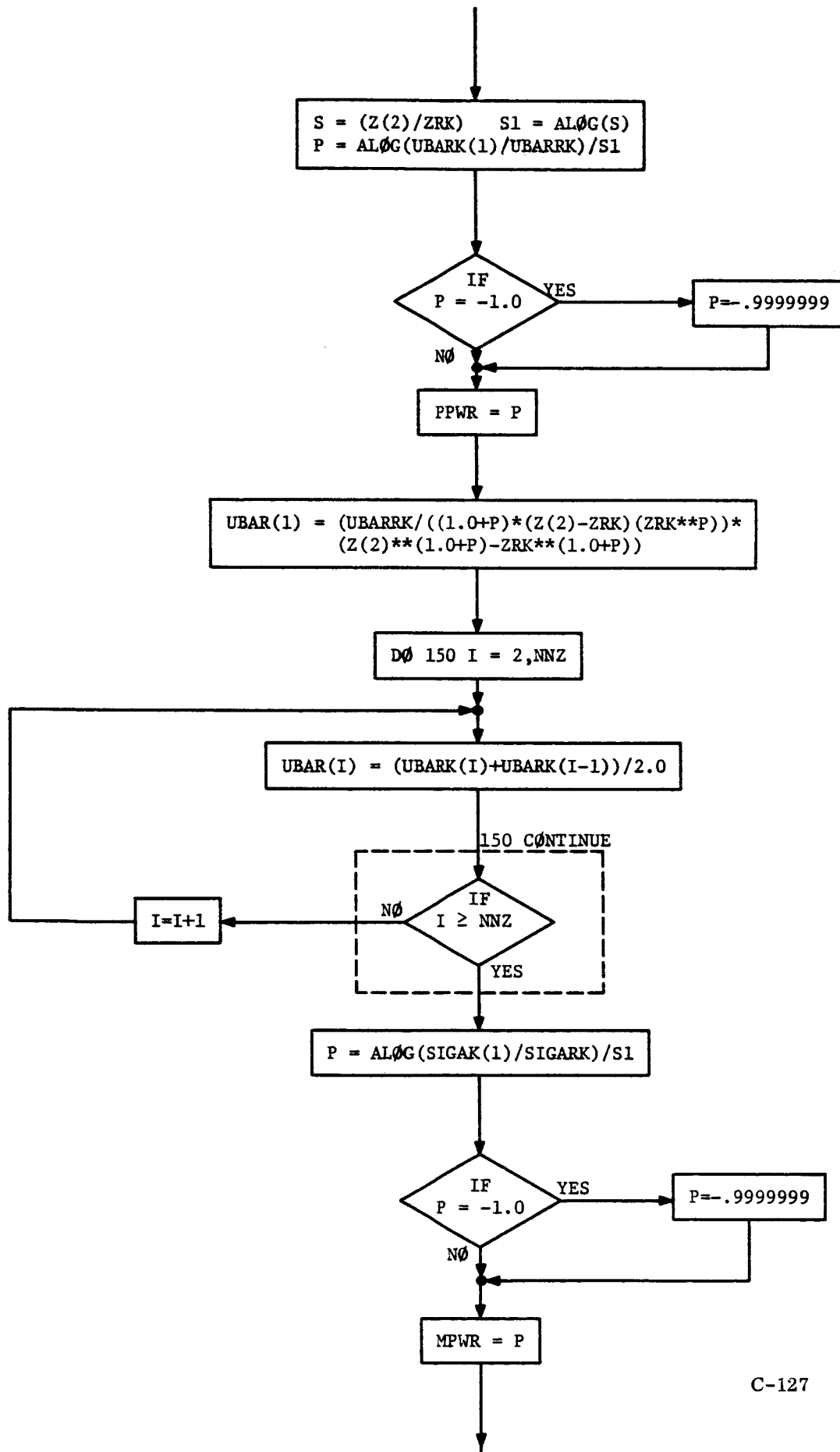


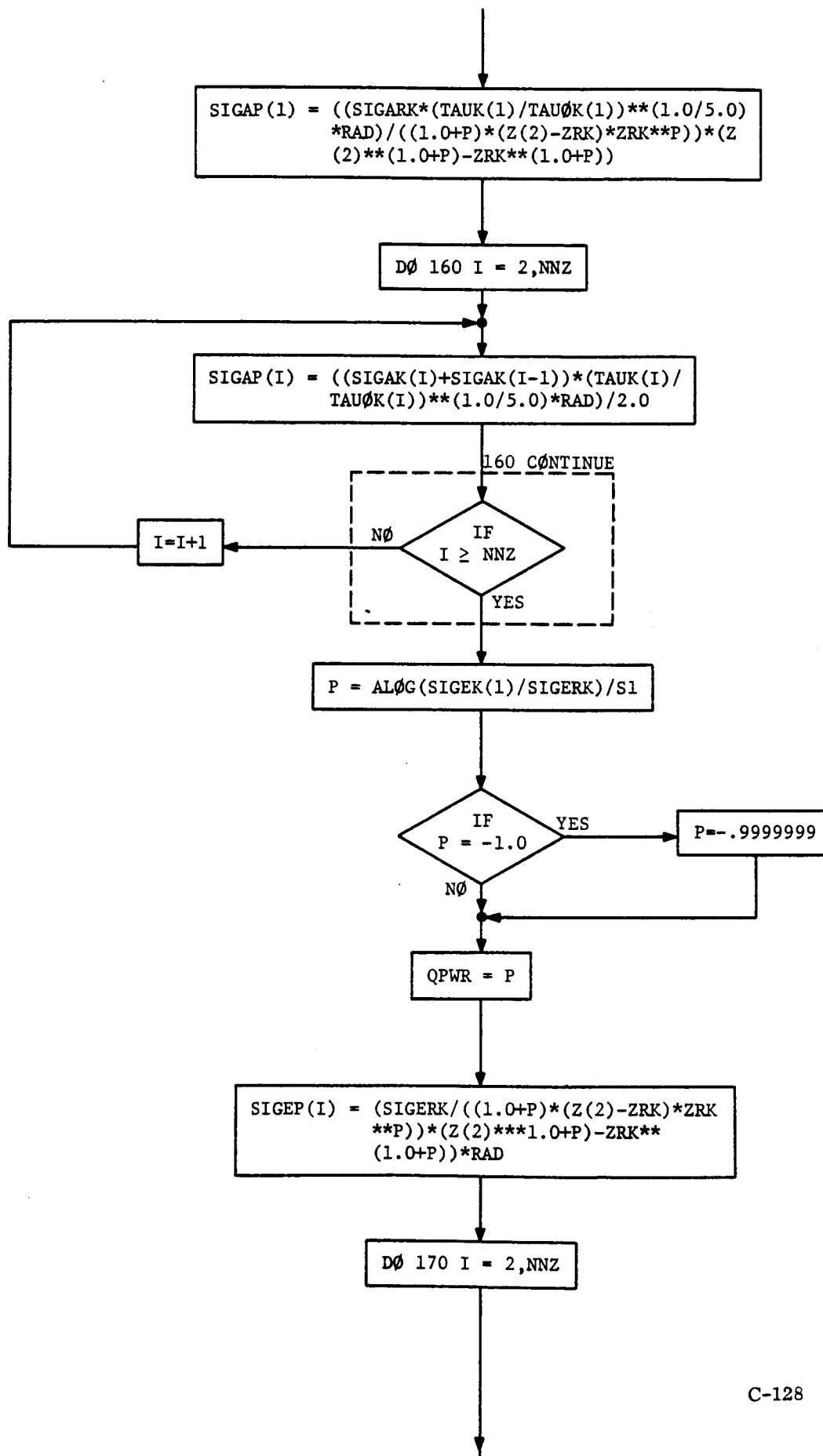


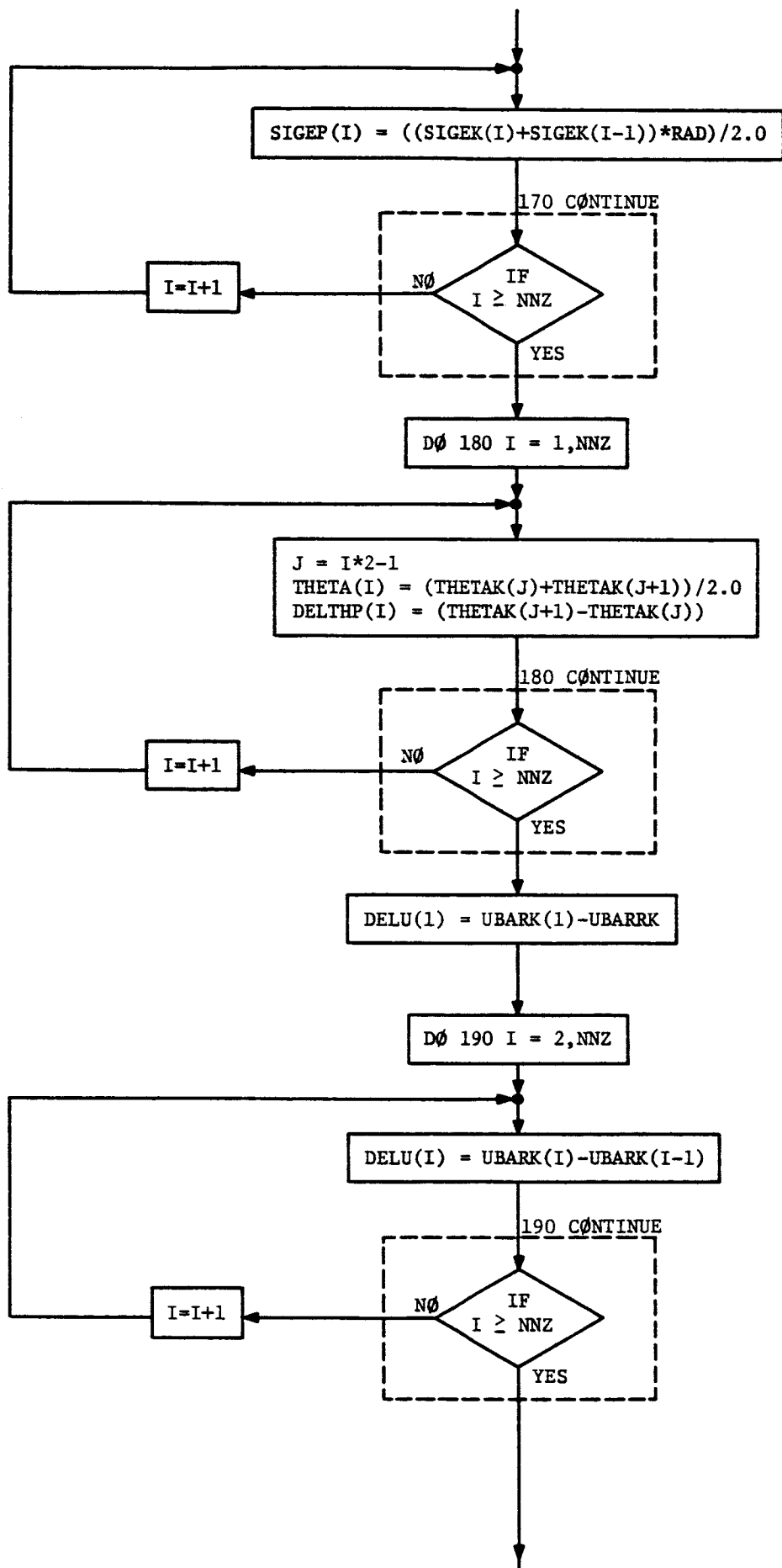


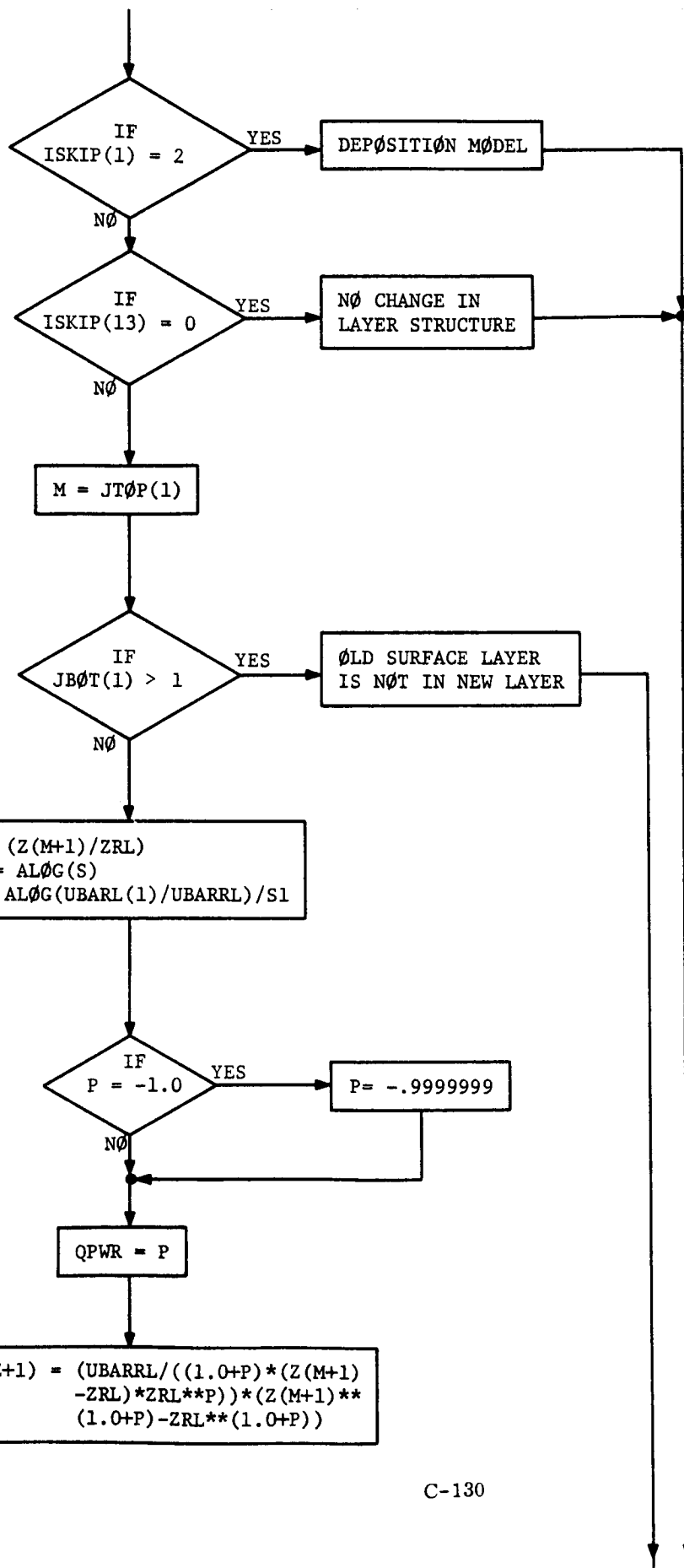


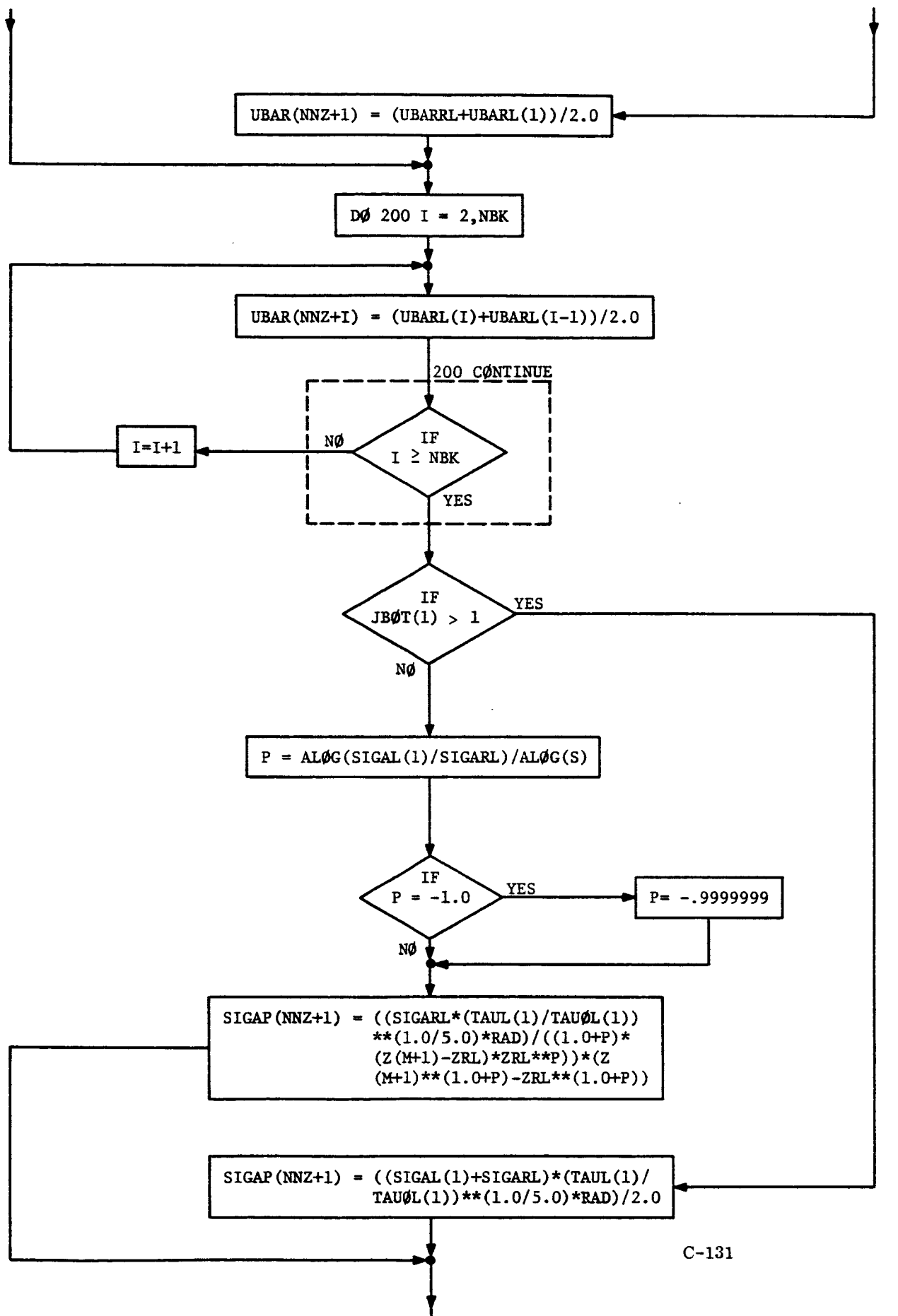


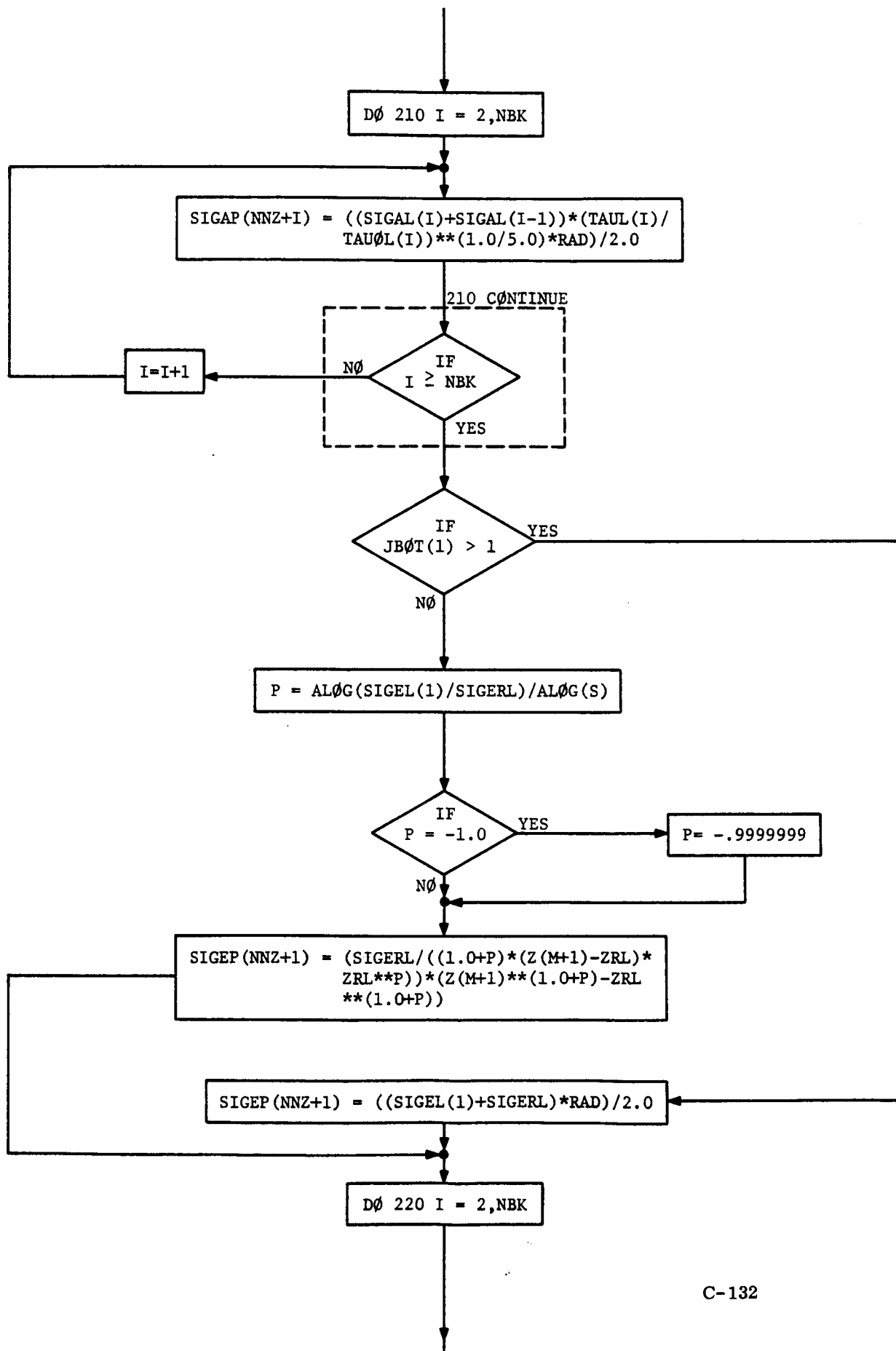


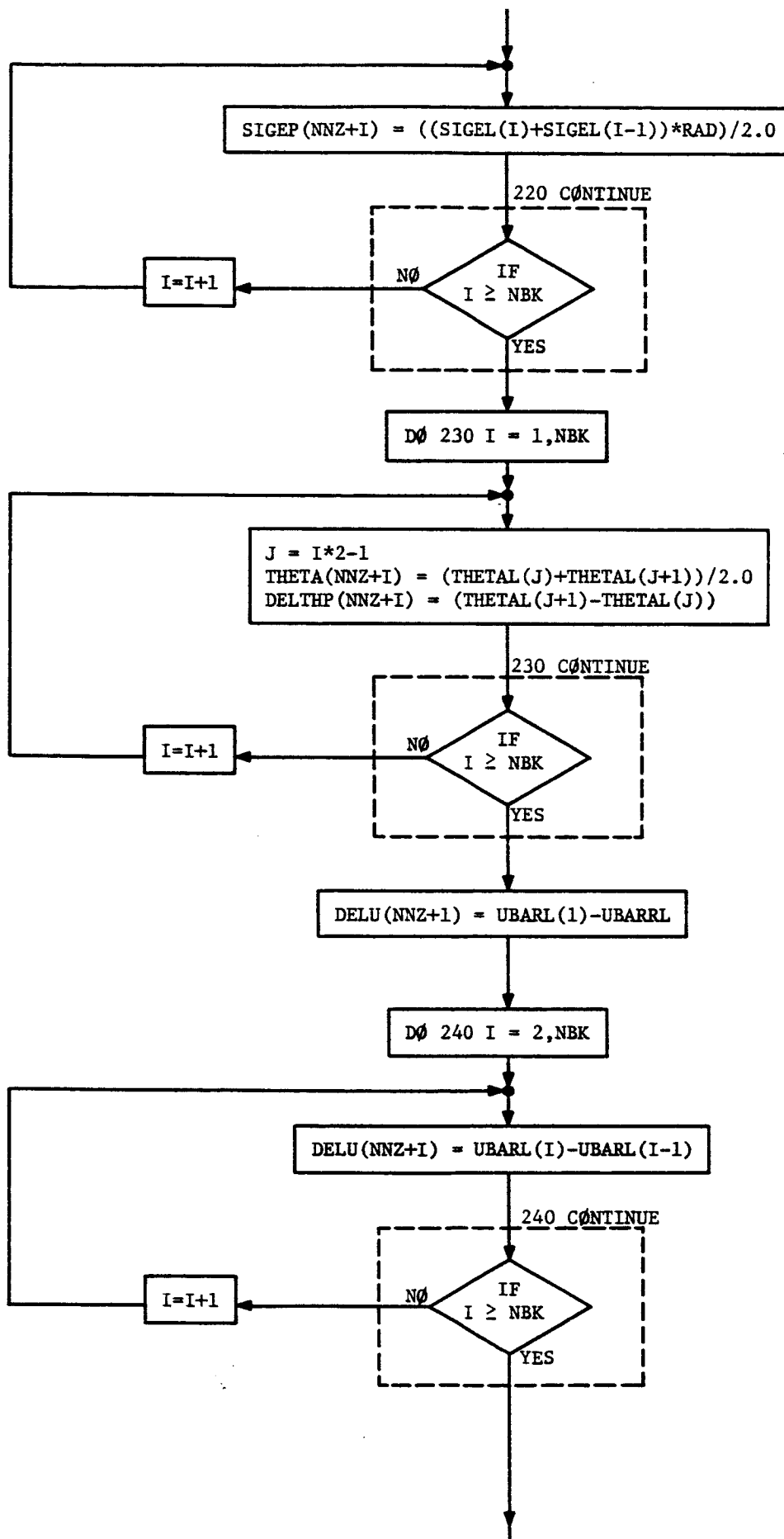


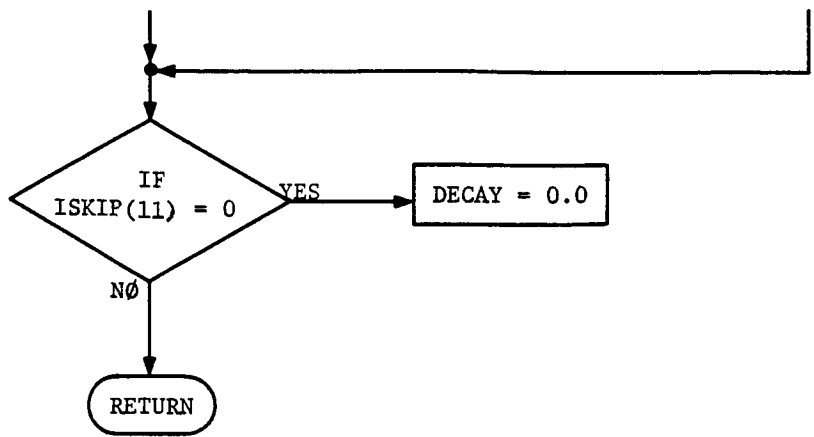












APPENDIX D

COMPUTER OUTPUT FOR SAMPLE PROBLEM

The sample problem refers to calculations of concentration and dosage fields downwind from a normal launch, using meteorological input information for the pre-cold front weather regime of 27 November 1966. A description of the synoptic weather situation and the meteorological inputs is contained in Appendix E, Section E.1. Source inputs for this example are discussed in Section E.2, Appendix E. For convenience, these inputs are repeated here in Table D-1. The completed program card input for this problem, as specified in Figure A-2 of Appendix A, is shown in Figure D-1.

A partial listing of the computer output for the example problem is given in Figure D-2. The output listing begins with the input parameters for the first layer. Calculated values for the mean layer wind speed and wind direction angle are then shown. These are followed by the values of the wind shear angle in the layer, the wind speed shear, and the mean layer values of σ_A and σ_E in radians. At this point, the program lists the dosage, peak concentration, and concentration at the first input receptor distance of 100 meters, at the base of the first layer, for each radial specified in the input. For convenience, the contribution of the vertical and vertical reflection terms in Equation (3-15) in the main body of text are listed at each receptor position. Calculated values of both the alongwind and lateral terms are also given. This output sequence continues until the concentration and dosage at each receptor position in each layer are specified. In Figure D-2, the sample listing is limited to the first two distances at the base of the first layer. This sequence is followed by a listing of the peak dosage and maximum peak concentration at the heights specified in the input. Finally, the output listing shows the crosswind distance from the cloud axis to input dosage and concentration isopleths. In Figure D-2, only the crosswind distances to dosage isopleths are shown.

TABLE D-1
PROGRAM INPUTS

Example Problem: Normal Launch for the Pre-Cold Front Situation,
2315 GMT, 27 November 1966

MODEL NO. 1				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
Q_K (g m^{-1})	1.479×10^4	5.382×10^3	3.793×10^3	2.818×10^3
$\sigma_{yo}\{K\}$ (m)	290	150	100	75
$\sigma_{zo}\{K\}$ (m)	-	-	-	-
$\sigma_{xo}\{K\}$ (m)	290	150	100	75
τ_K (sec)	25	11	10	11
H_K (m)	-			
k	-			

TABLE D-1 (Continued)

MODEL NO. 1				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR} \{\tau_{oR}\}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK} \{\tau_{oK}\}$ (deg)	5	0	0	0
$\sigma_{ABK} \{\tau_{oK}\}$ (deg)		5	0	0
τ_{oK} (sec)	600	600	600	600
σ_{ETK} (deg)	4	0	0	0
σ_{EBK} (deg)		4	0	0
α_K	1	1	1	1
β_K	1	1	1	1
$\bar{u}_{TK}$ (m sec ⁻¹)	6.70	7.73	10.82	20.60
$\bar{u}_{BK}$ (m sec ⁻¹)		6.70	7.73	10.82
θ_{TK} (deg)	231	258	229	256
θ_{BK} (deg)	160	231	258	229
z_{TK} (m)	853.4	1828.8	3048	5000
z_{BK} (m)	2	853.4	1828.8	3048
Λ (sec ⁻¹)	-			
z_{lim} (m)	-			
t_1 (sec)	-			
t^* (sec)	-			

FIGURE D-1. Sample problem input.

REQUESTED BY		DEPARTMENT										JOB NO. & CODE										DATE										PAGE																																																																														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80																															
A NORMAL LAUNCH 11-27-66 2315Z PRE - COLD FRONT																																																																																																														
1	1											1	3	8																																																																																																
23	25	5											10	10	23																																																																																															
100.0											200.0											300.0											500.0											700.0											1000.0											1500.0											2000.0																																	
2500.0											5000.0											7500.0											10000.0											15000.0											20000.0											25000.0											30000.0																																	
40000.0											50000.0											60000.0											70000.0											80000.0											90000.0											100000.0																																												
280.0											290.0											300.0											310.0											320.0											330.0											340.0											350.0																																	
0.0											10.0											20.0											30.0											40.0											50.0											60.0											70.0																																	
80.0											90.0											100.0											110.0											120.0											130.0											140.0											150.0																																	
160.0																																																																																																														
2.0											853.4											1828.8											3048.0											5000.0																																																																		
0.0											0.0											0.0											0.0											0.0											0.0											0.0											0.0																																	
1.479	E+	045.382											E+033.793											E+032.818											E+03																																																																											
6.7											7.73											10.82											20.6																																																																													
5.0											0.0											0.0											0.0																																																																													
290.0											150.0											100.0											75.0																																																																													
4.0											0.0											0.0											0.0																																																																													
1.0											1.0											1.0											1.0																																																																													
1.0											1.0											1.0											1.0																																																																													
0.0											0.0											0.0											0.0																																																																													
290.0											150.0											100.0											75.0																																																																													
18.0											8.0											4.5											4.1											180.0																																																																		
160.0											231.0											231.0											258.0											258.0											229.0											229.0											256.0																																	
25.0											11.0											10.0											11.0																																																																													
600.0											600.0											600.0											600.0																																																																													

FIGURE D-1. (Continued)

[illegible]

***** THE TEST IS NORMAL LAUNCH 11-27-66 2315Z PRE-COLD FRONT

X IS RADIAL DISTANCE Y IS ANGLE IN DEGREES

***** LAYER 1 *****

** INPUT DATA **

Y= .147900+05, ZRK= 18.0000, UNARRK= 4.10000, SIGARK= 8.00000, TAUARK= 6.00000, TAU= 25.00+00
 SIGAK AT TOP= 5.00000, ALPHA= 1.00000, SIGT= 290.00000, Z= 2.000, UBARK AT TOP= 6.70000, THETAK AT 80770 = 160.00000
 THETAK AT TOP= 231.00000, SIGERK= 4.50000, SIGEK AT TOP= 4.00000, BETA= 1.00000, SIGZ= .00000, T= .0000
 M= .0000, DELX= .00000, DELY= .00000, DELPHI= 180.00000, MODEL= 1, T= 1, ZLIM= .0000, ZLIM= .0000
 LAMBDA= .00000, SIGXD= 290.00000

CALCULATED INPUT PARAMETERS FOR MODELS 1,2,3 *** UBARK= 5.99325, THETA= 195.80000, DELIMP= 71.30000, DELU= 2.60000
 SIGEP= .05195, SIGEP= .07182

*** CALCULATION HEIGHT Z = 2.000 ***

Y	RECEPTOR OUTSIDE OF SECTOR DELTA PHI	X	CONCENTRATION	VERTICAL
280.00	DOSAGE= .61792113+01, PEAK CON= .26350050+01, CONCENTRATION= .26350050+01, VERTICAL= .00000000	100.00		
290.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .94278431+00			
300.00	DOSAGE= .61815338+01, PEAK CON= .26359871+01, CONCENTRATION= .26359871+01, VERTICAL= .00000000			
310.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .94630009+00			
320.00	DOSAGE= .62020420+01, PEAK CON= .26447285+01, CONCENTRATION= .26447285+01, VERTICAL= .00000000			
330.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .95272923+00			
340.00	DOSAGE= .62366827+01, PEAK CON= .26599729+01, CONCENTRATION= .26599729+01, VERTICAL= .00000000			
350.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .96131802+00			
360.00	DOSAGE= .62778420+01, PEAK CON= .26778555+01, CONCENTRATION= .26778555+01, VERTICAL= .00000000			
370.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .97106586+00			
380.00	DOSAGE= .63282891+01, PEAK CON= .26971779+01, CONCENTRATION= .26971779+01, VERTICAL= .00000000			
390.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .98083280+00			
400.00	DOSAGE= .63644097+01, PEAK CON= .27147281+01, CONCENTRATION= .27147281+01, VERTICAL= .00000000			
410.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .98946718+00			
420.00	DOSAGE= .63977779+01, PEAK CON= .27280900+01, CONCENTRATION= .27280900+01, VERTICAL= .00000000			
430.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .99594124+00			
440.00	DOSAGE= .64150552+01, PEAK CON= .27364483+01, CONCENTRATION= .27364483+01, VERTICAL= .00000000			
450.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .99947787+00			
460.00	DOSAGE= .64158987+01, PEAK CON= .27358076+01, CONCENTRATION= .27358076+01, VERTICAL= .00000000			
470.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .99948011+00			
480.00	DOSAGE= .64001967+01, PEAK CON= .27291194+01, CONCENTRATION= .27291194+01, VERTICAL= .00000000			
490.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .99443714+00			
500.00	DOSAGE= .63700725+01, PEAK CON= .27162882+01, CONCENTRATION= .27162882+01, VERTICAL= .00000000			
510.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .99022488+00			
520.00	DOSAGE= .63296182+01, PEAK CON= .26990570+01, CONCENTRATION= .26990570+01, VERTICAL= .00000000			
530.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .98176558+00			
540.00	DOSAGE= .62843866+01, PEAK CON= .26797911+01, CONCENTRATION= .26797911+01, VERTICAL= .00000000			
550.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .97206105+00			
560.00	DOSAGE= .62707150+01, PEAK CON= .26611903+01, CONCENTRATION= .26611903+01, VERTICAL= .00000000			
570.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .96325874+00			
580.00	DOSAGE= .62049723+01, PEAK CON= .26458967+01, CONCENTRATION= .26458967+01, VERTICAL= .00000000			
590.00	REFLECTION= .10000000+01, ALONG WIND= .10000000+01, LATERAL= .95350581+00			
600.00	DOSAGE= .61826187+01, PEAK CON= .26365352+01, CONCENTRATION= .26365352+01, VERTICAL= .00000000			

FIGURE D-2. Partial listing of computer output for sample problem.

*** MAXIMUM PEAK DOSAGE AND/OR CONCENTRATION ***

MAX PEAK CONCENTRATION AND/OR PEAK DOSAGE IN LAYER 1 AT HEIGHT 2.00									
DOSE, CLOUD AXIS IS AT 15.500 DEGREES RELATIVE TO SOURCE									
100.00	DOSE	.44174130+01	DOSE	200.00	DOSE	.62230970+01	DOSE	300.00	DOSE
500.00	DOSE	.54810714+01	DOSE	700.00	DOSE	.79210978+01	DOSE	1000.00	DOSE
1500.00	DOSE	.33532173+01	DOSE	2000.00	DOSE	.27264034+01	DOSE	2500.00	DOSE
5000.00	DOSE	.12342308+01	DOSE	7500.00	DOSE	.84011874+00	DOSE	10000.00	DOSE
15000.00	DOSE	.42749353+00	DOSE	20000.00	DOSE	.32180982+00	DOSE	25000.00	DOSE
30000.00	DOSE	.21530172+00	DOSE	40000.00	DOSE	.14174870+00	DOSE	50000.00	DOSE
40000.00	DOSE	.10800728+00	DOSE	70000.00	DOSE	.92419518+01	DOSE	80000.00	DOSE
90000.00	DOSE	.72080242+01	DOSE	100000.00	DOSE	.64885874+01	DOSE		
CONCENTRATION, CLOUD AXIS IS AT 15.500 DEGREES RELATIVE TO SOURCE									
100.00	CONC	.27365378+01	CONC	200.00	CONC	.24832148+01	CONC	300.00	CONC
500.00	CONC	.23395303+01	CONC	700.00	CONC	.21106474+01	CONC	1000.00	CONC
1500.00	CONC	.14148912+01	CONC	2000.00	CONC	.11412518+01	CONC	2500.00	CONC
5000.00	CONC	.47317521+02	CONC	7500.00	CONC	.28927492+02	CONC	10000.00	CONC
15000.00	CONC	.10294908+02	CONC	20000.00	CONC	.42465704+03	CONC	25000.00	CONC
30000.00	CONC	.29725327+03	CONC	40000.00	CONC	.17146462+03	CONC	50000.00	CONC
40000.00	CONC	.77475203+04	CONC	70000.00	CONC	.57309225+04	CONC	80000.00	CONC
90000.00	CONC	.34834767+04	CONC	100000.00	CONC	.28254470+04	CONC		
MAX PEAK CONCENTRATION AND/OR PEAK DOSAGE IN LAYER 2 AT HEIGHT 853.70									
DOSE, CLOUD AXIS IS AT 49.500 DEGREES RELATIVE TO SOURCE									
100.00	DOSE	.21004948+01	DOSE	200.00	DOSE	.20560423+01	DOSE	300.00	DOSE
500.00	DOSE	.18865702+01	DOSE	700.00	DOSE	.17602931+01	DOSE	1000.00	DOSE
1500.00	DOSE	.13052849+01	DOSE	2000.00	DOSE	.10949464+01	DOSE	2500.00	DOSE
5000.00	DOSE	.52917614+00	DOSE	7500.00	DOSE	.34494846+00	DOSE	10000.00	DOSE
15000.00	DOSE	.18732823+00	DOSE	20000.00	DOSE	.14132218+00	DOSE	25000.00	DOSE
30000.00	DOSE	.94728701+01	DOSE	40000.00	DOSE	.71238424+01	DOSE	50000.00	DOSE
40000.00	DOSE	.47401908+01	DOSE	70000.00	DOSE	.40829318+01	DOSE	80000.00	DOSE
90000.00	DOSE	.31784409+01	DOSE	100000.00	DOSE	.28419748+01	DOSE		
CONCENTRATION, CLOUD AXIS IS AT 49.500 DEGREES RELATIVE TO SOURCE									
100.00	CONC	.37432484+01	CONC	200.00	CONC	.36630288+01	CONC	300.00	CONC
500.00	CONC	.33601443+01	CONC	700.00	CONC	.31337032+01	CONC	1000.00	CONC
1500.00	CONC	.23159409+01	CONC	2000.00	CONC	.19398873+01	CONC	2500.00	CONC
5000.00	CONC	.90071138+02	CONC	7500.00	CONC	.58907993+02	CONC	10000.00	CONC
15000.00	CONC	.24448843+02	CONC	20000.00	CONC	.158112807+02	CONC	25000.00	CONC
30000.00	CONC	.79940493+03	CONC	40000.00	CONC	.47484003+03	CONC	50000.00	CONC
40000.00	CONC	.22029447+03	CONC	70000.00	CONC	.16342774+03	CONC	80000.00	CONC
90000.00	CONC	.99952982+04	CONC	100000.00	CONC	.81227482+04	CONC		
MAX PEAK CONCENTRATION AND/OR PEAK DOSAGE IN LAYER 3 AT HEIGHT 1826.60									
DOSE, CLOUD AXIS IS AT 43.500 DEGREES RELATIVE TO SOURCE									
100.00	DOSE	.19364779+01	DOSE	200.00	DOSE	.18910473+01	DOSE	300.00	DOSE
500.00	DOSE	.16432310+01	DOSE	700.00	DOSE	.14847957+01	DOSE	1000.00	DOSE
1500.00	DOSE	.93109854+00	DOSE	2000.00	DOSE	.75611949+00	DOSE	2500.00	DOSE
5000.00	DOSE	.32598774+00	DOSE	7500.00	DOSE	.21941556+00	DOSE	10000.00	DOSE
15000.00	DOSE	.11043041+00	DOSE	20000.00	DOSE	.82910810+01	DOSE	25000.00	DOSE
30000.00	DOSE	.55332277+01	DOSE	40000.00	DOSE	.15151040+01	DOSE	50000.00	DOSE
40000.00	DOSE	.27487210+01	DOSE	70000.00	DOSE	.23737090+01	DOSE	80000.00	DOSE
90000.00	DOSE	.18442008+01	DOSE	100000.00	DOSE	.14414440+01	DOSE		
CONCENTRATION, CLOUD AXIS IS AT 43.500 DEGREES RELATIVE TO SOURCE									
100.00	CONC	.59712831+01	CONC	200.00	CONC	.58280854+01	CONC	300.00	CONC
500.00	CONC	.50992021+01	CONC	700.00	CONC	.45330473+01	CONC	1000.00	CONC

FIGURE D-2. (Continued)

MULTILAYER DIFFUSION MODEL GCA CORP BJCRLND										DATE	121269	PAGE	140
1500.00	CON	.27890494-01	000	2000.00	CON	.21391917-01	00R	2500.00	CON	.14698528-01			
5000.00	CON	.68140783-02	00R	7500.00	CO	.35430375-02	00R	10000.00	CON	.21322527-02			
15000.00	CO	.1003638-02	00R	20000.00	CON	.87430085-03	00R	25000.00	CON	.37118816-03			
30000.00	CON	.25914445-03	00R	40000.00	CON	.14487049-03	00R	50000.00	CON	.99047839-04			
60000.00	CON	.65404173-04	00R	70000.00	CON	.48093943-04	00R	80000.00	CON	.34843028-04			
90000.00	CON	.29122120-04	00R	100000.00	CON	.23595709-04	00R						
-----MAX PEAK CONCENTRATION AND/OR PEAK DOSAGE IN LAYER 4 AT HEIGHT 3048.00-----													
00 DOSAGE, CLOUD AXIS IS AT 62500 DEGREES RELATIVE TO SOURCE 00													
100.00	DOS	.13438199-01	00R	200.00	DOS	.13170443-01	00R	300.00	DOS	.12523060-01			
500.00	DOS	.10972841-01	00R	700.00	DOS	.98129777-00	00R	1000.00	DOS	.74933553-00			
1500.00	DOS	.86712992-00	00R	2000.00	DOS	.44342829-00	00R	2500.00	DOS	.34227914-00			
5000.00	DOS	.1868394-00	00R	7500.00	DOS	.1254041-00	00R	10000.00	DOS	.94298847-01			
15000.00	DOS	.4297805-01	00R	20000.00	DOS	.47288238-01	00R	25000.00	DOS	.37848317-01			
30000.00	DOS	.31548992-01	00R	40000.00	DOS	.23669746-01	00R	50000.00	DOS	.19938708-01			
60000.00	DOS	.18783990-01	00R	70000.00	DOS	.13530155-01	00R	80000.00	DOS	.11839834-01			
90000.00	DOS	.10524449-01	00R	100000.00	DOS	.94723309-02	00R						
00 CONCENTRATION, CLOUD AXIS IS AT 42.800 DEGREES RELATIVE TO SOURCE 00													
100.00	CON	.78378987-01	00R	200.00	CON	.75362224-01	00R	300.00	CON	.71144692-01			
500.00	CON	.61105018-01	00R	700.00	CON	.51208520-01	00R	1000.00	CON	.38953709-01			
1500.00	CON	.25354444-01	00R	2000.00	CON	.17330743-01	00R	2500.00	CON	.12403546-01			
5000.00	CON	.37320847-02	00R	7500.00	CON	.17286891-02	00R	10000.00	CON	.98737541-03			
15000.00	CON	.44385438-03	00R	20000.00	CON	.28070874-03	00R	25000.00	CON	.16077022-03			
30000.00	CON	.11174994-03	00R	40000.00	CON	.42942710-04	00R	50000.00	CON	.40308564-04			
60000.00	CON	.27999113-04	00R	70000.00	CON	.20874420-04	00R	80000.00	CON	.18754826-04			
90000.00	CON	.12449474-04	00R	100000.00	CON	.10084808-04	00R						

FIGURE D-2. (Continued)

• CSAGE=	•50000000-03, Y=	83264.38 • DOSAGE=	•10000000-03, Y=	95800.01 • DOSAGE=	•50000000-04, Y=	100719.28
• DOSAGE=	•100000000-04, Y=	111304.15 • DOSAGE=				
• DOSAGE=	•500000000-00, Y=	.00 • DOSAGE=	•100000000-00, Y=	100000.00		
• DOSAGE=	•100000000-01, Y=	56732.78 • DOSAGE=	•50000000-02, Y=	64419.99 • DOSAGE=	•10000000-02, Y=	84744.88
• DOSAGE=	•500000000-03, Y=	91513.34 • DOSAGE=	•100000000-03, Y=	105568.79 • DOSAGE=	•50000000-04, Y=	111078.34
• DOSAGE=	•100000000-04, Y=	122914.00 • DOSAGE=				
		• CONCENTRATION ISOPLETMS •				
		RADIAL DISTANCE R=	100.00			
• CONCENTRATION=	•50000000-02, Y=	546.87 • CONCENTRATION=	•10000000-02, Y=	763.04 • CONCENTRATION=	•50000000-03, Y=	839.14
• CONCENTRATION=	•10000000-03, Y=	993.46 • CONCENTRATION=	•50000000-04, Y=	1053.24 • CONCENTRATION=	•10000000-04, Y=	1180.03
• CONCENTRATION=	•50000000-05, Y=	1230.42 • CONCENTRATION=	•100000000-05, Y=	1340.74 • CONCENTRATION=	•50000000-06, Y=	1388.48
• CONCENTRATION=	•100000000-06, Y=	1484.15 • CONCENTRATION=				
		RADIAL DISTANCE R=	200.00			
• CONCENTRATION=	•50000000-02, Y=	558.81 • CONCENTRATION=	•100000000-02, Y=	783.21 • CONCENTRATION=	•50000000-03, Y=	862.04
• CONCENTRATION=	•10000000-03, Y=	1021.89 • CONCENTRATION=	•50000000-04, Y=	1083.49 • CONCENTRATION=	•100000000-04, Y=	1214.84
• CONCENTRATION=	•50000000-05, Y=	1266.80 • CONCENTRATION=	•100000000-05, Y=	1380.56 • CONCENTRATION=	•50000000-06, Y=	1426.76
• CONCENTRATION=	•100000000-06, Y=	1528.65 • CONCENTRATION=				
		RADIAL DISTANCE R=	300.00			
• CONCENTRATION=	•50000000-02, Y=	573.60 • CONCENTRATION=	•100000000-02, Y=	808.49 • CONCENTRATION=	•50000000-03, Y=	890.77
• CONCENTRATION=	•10000000-03, Y=	1057.41 • CONCENTRATION=	•50000000-04, Y=	1121.58 • CONCENTRATION=	•100000000-04, Y=	1258.01
• CONCENTRATION=	•50000000-05, Y=	1312.40 • CONCENTRATION=	•100000000-05, Y=	1430.75 • CONCENTRATION=	•50000000-06, Y=	1478.50
• CONCENTRATION=	•100000000-06, Y=	1584.77 • CONCENTRATION=				
		RADIAL DISTANCE R=	500.00			
• CONCENTRATION=	•50000000-02, Y=	409.44 • CONCENTRATION=	•100000000-02, Y=	871.71 • CONCENTRATION=	•50000000-03, Y=	962.88
• CONCENTRATION=	•10000000-03, Y=	1144.85 • CONCENTRATION=	•50000000-04, Y=	1217.84 • CONCENTRATION=	•100000000-04, Y=	1367.72
• CONCENTRATION=	•50000000-05, Y=	1427.53 • CONCENTRATION=	•100000000-05, Y=	1557.58 • CONCENTRATION=	•50000000-06, Y=	1610.36
• CONCENTRATION=	•100000000-06, Y=	1724.69 • CONCENTRATION=				
		RADIAL DISTANCE R=	700.00			
• CONCENTRATION=	•50000000-02, Y=	451.15 • CONCENTRATION=	•100000000-02, Y=	947.54 • CONCENTRATION=	•50000000-03, Y=	1049.72
• CONCENTRATION=	•10000000-03, Y=	1255.29 • CONCENTRATION=	•50000000-04, Y=	1334.10 • CONCENTRATION=	•100000000-04, Y=	1501.22
• CONCENTRATION=	•50000000-05, Y=	1567.72 • CONCENTRATION=	•100000000-05, Y=	1712.18 • CONCENTRATION=	•50000000-06, Y=	1770.78
• CONCENTRATION=	•100000000-06, Y=	1899.87 • CONCENTRATION=				
		RADIAL DISTANCE R=	1000.00			
• CONCENTRATION=	•50000000-02, Y=	716.78 • CONCENTRATION=	•100000000-02, Y=	1075.84 • CONCENTRATION=	•50000000-03, Y=	1197.79
• CONCENTRATION=	•10000000-03, Y=	1441.66 • CONCENTRATION=	•50000000-04, Y=	1535.80 • CONCENTRATION=	•100000000-04, Y=	1731.86
• CONCENTRATION=	•50000000-05, Y=	1810.12 • CONCENTRATION=	•100000000-05, Y=	1979.96 • CONCENTRATION=	•50000000-06, Y=	2049.77
• CONCENTRATION=	•100000000-06, Y=	2200.27 • CONCENTRATION=				
		RADIAL DISTANCE R=	1500.00			
• CONCENTRATION=	•50000000-02, Y=	818.75 • CONCENTRATION=	•100000000-02, Y=	1304.74 • CONCENTRATION=	•50000000-03, Y=	1467.74
• CONCENTRATION=	•10000000-03, Y=	1784.47 • CONCENTRATION=	•50000000-04, Y=	1907.40 • CONCENTRATION=	•100000000-04, Y=	2165.26
• CONCENTRATION=	•50000000-05, Y=	2263.20 • CONCENTRATION=	•100000000-05, Y=	2481.79 • CONCENTRATION=	•50000000-06, Y=	2570.21
• CONCENTRATION=	•100000000-06, Y=	2744.63 • CONCENTRATION=				
		RADIAL DISTANCE R=	2000.00			
• CONCENTRATION=	•50000000-02, Y=	896.88 • CONCENTRATION=	•100000000-02, Y=	1540.49 • CONCENTRATION=	•50000000-03, Y=	1740.04
• CONCENTRATION=	•10000000-03, Y=	2148.82 • CONCENTRATION=	•50000000-04, Y=	2300.66 • CONCENTRATION=	•100000000-04, Y=	2419.99
• CONCENTRATION=	•50000000-05, Y=	2745.42 • CONCENTRATION=	•100000000-05, Y=	3017.63 • CONCENTRATION=	•50000000-06, Y=	3127.57
• CONCENTRATION=	•100000000-06, Y=	3349.03 • CONCENTRATION=				
		RADIAL DISTANCE R=	2500.00			
• CONCENTRATION=	•50000000-02, Y=	941.49 • CONCENTRATION=	•100000000-02, Y=	1737.66 • CONCENTRATION=	•50000000-03, Y=	2022.02
• CONCENTRATION=	•10000000-03, Y=	2515.31 • CONCENTRATION=	•50000000-04, Y=	2700.14 • CONCENTRATION=	•100000000-04, Y=	3088.91
• CONCENTRATION=	•50000000-05, Y=	3239.28 • CONCENTRATION=	•100000000-05, Y=	3568.08 • CONCENTRATION=	•50000000-06, Y=	3700.69
• CONCENTRATION=	•100000000-06, Y=	3991.66 • CONCENTRATION=				
		RADIAL DISTANCE R=	5000.00			
• CONCENTRATION=	•50000000-02, Y=	.00 • CONCENTRATION=	•100000000-02, Y=	2719.11 • CONCENTRATION=	•50000000-03, Y=	3249.68
• CONCENTRATION=	•10000000-03, Y=	4283.30 • CONCENTRATION=	•50000000-04, Y=	4452.30 • CONCENTRATION=	•100000000-04, Y=	5412.93
• CONCENTRATION=	•50000000-05, Y=	5709.38 • CONCENTRATION=	•100000000-05, Y=	6344.51 • CONCENTRATION=	•50000000-06, Y=	6597.25
• CONCENTRATION=	•100000000-06, Y=	7155.83 • CONCENTRATION=				

FIGURE D-2. (Continued)

APPENDIX E
EXAMPLE CALCULATIONS EMPLOYING THE MULTI-LAYER
DIFFUSION PROGRAM

This Appendix contains example calculations that illustrate the use of the multi-layer diffusion program discussed in Section 4 for the following modes of release of toxic fuels:

- Normal launch
- Vehicle destruct at the surface
- Vehicle destruct aloft
- Cold surface spill

The example calculations were carried out for two meteorological situations that occur frequently at Cape Kennedy:

- A pre-cold front regime typical of wintertime conditions
- An extension of the Bermuda High into the Gulf of Mexico typical of summertime conditions

The model layer boundaries and meteorological inputs for each situation were defined from vertical profile measurements taken at Cape Kennedy on two days selected as representative of these conditions under Contract NAS8-30503 (Record, et al., 1970).

The example calculations consist principally of concentration and dosage fields at the base of each layer. Surface deposition patterns due to gravitational settling and precipitation scavenging were also calculated. In the example

calculation of surface deposition due to precipitation scavenging, the layer structure is assumed to change at the onset of precipitation to illustrate the program's capability for handling changes in layer structure.

Results of all program calculations are presented in figures showing the concentration, dosage and deposition fields plotted on a reference polar-coordinate grid with the origin at the launch site. The grid consisted of 828 receptor positions located at 23 distances downwind from the origin on radials at an angular separation of 10 degrees. In any specific calculation, however, computation time was conserved by not requesting results for receptors that were clearly upwind from the source. If results had been requested for these positions, the program would have automatically rejected the positions as being outside the angular sectors of interest, but more computation time would have been consumed. All the figures except those showing deposition due to gravitational settling and precipitation scavenging and changes in layer structure were originally plotted on the GERBER 622 plotter at the University of Utah.

E.1 SELECTION OF METEOROLOGICAL INPUT PARAMETERS

The discussion below of the synoptic maps, vertical profiles, and meteorological inputs for the pre-cold front and Bermuda-high example cases, is taken from Sections 3.3.1 and 3.4.3, respectively, of the Final Report prepared under Contract NAS8-30503 (Record, et al., 1970). The required meteorological inputs for the multi-layer computer program are listed in Table 4-1 and the procedures followed in selecting these inputs for the example calculations are summarized in Section 4.2 of the present report.

E.1.1 Southwesterly Flow in Advance of a Cold Front - 2315 GMT, 27 November 1966

Figures E-1, E-2 and E-3 show the synoptic-scale circulation pattern and the vertical structure at Cape Kennedy during the approach of a

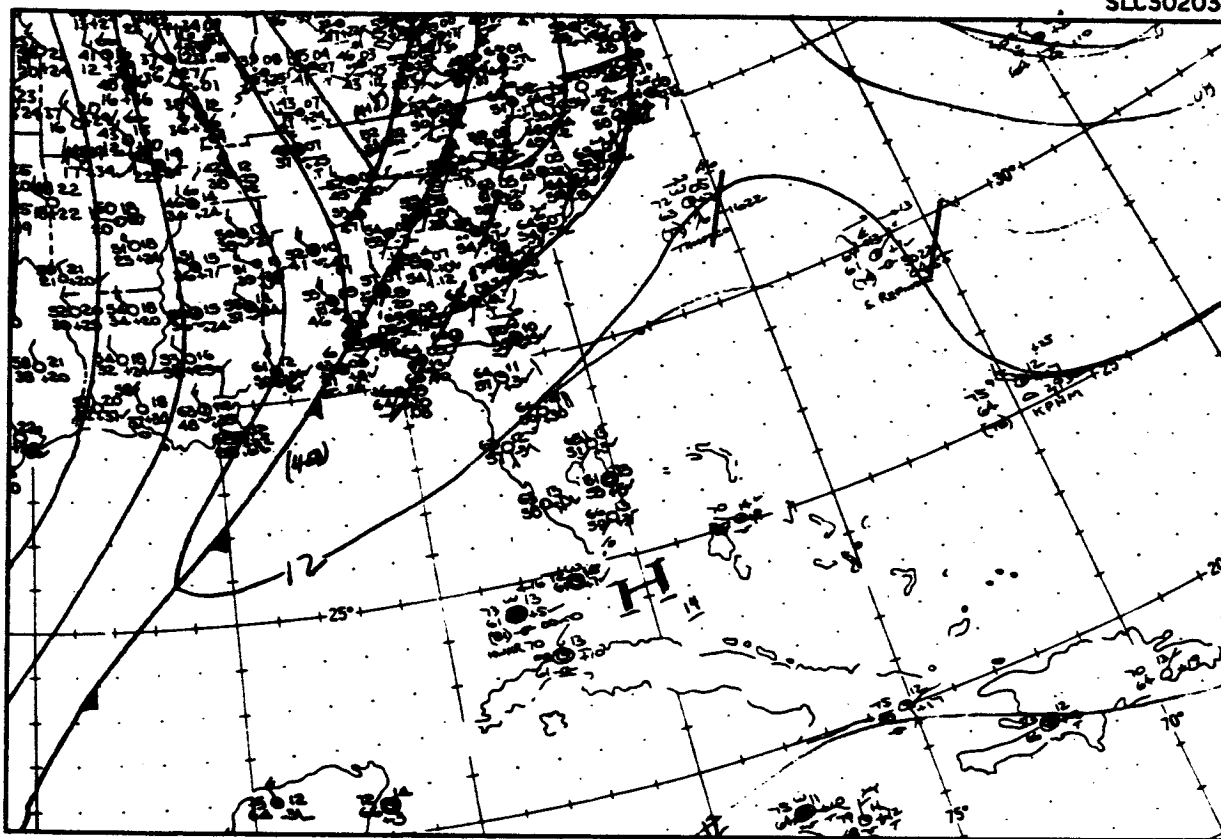


FIGURE E-1 Surface map for 0000 GMT, 28 November 1966.

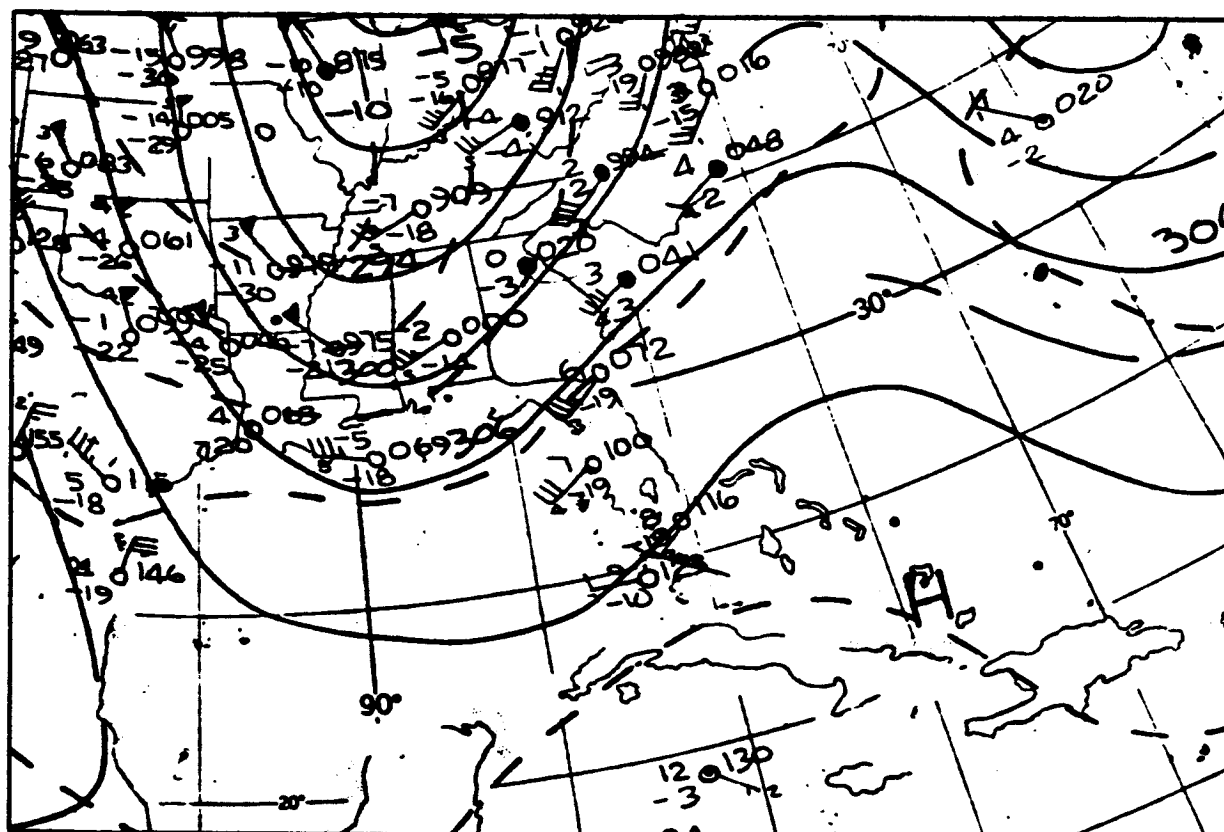


FIGURE E-2 700-mb map for 0000 GMT, 28 November 1966.

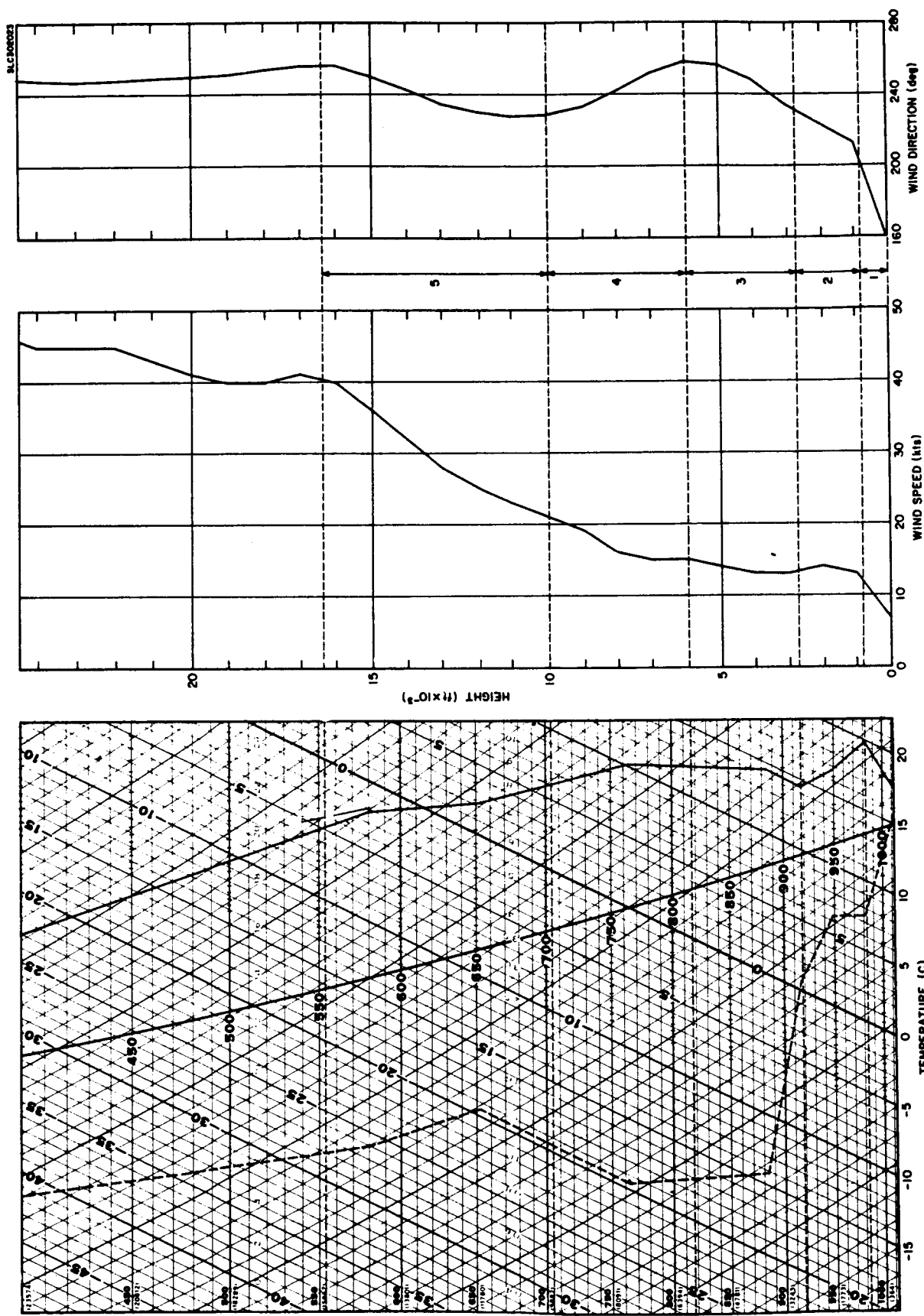


FIGURE E-3. Vertical profiles for 27 November 1966, 2315 GMT. Solid line on Skew T, Log P diagram is air temperature; dashed line is dew point temperature. Assignment of layers for diffusion model is indicated between wind speed and wind direction profiles.

major, rapidly-moving cold front. Figures E-1 and E-2 show the surface and 700-millibar maps, respectively, when the cold front was approximately 300 miles to the northwest of Cape Kennedy. Temperature and dewpoint values at the significant levels of the 2315 GMT Cape Kennedy sounding are plotted on a section of a USAF Modified Skew T, Log P Diagram at the left in Figure E-3. Wind speed and direction are plotted at 1000-foot intervals at the right in Figure E-3. The dashed horizontal lines indicate the division of the lowest 5 kilometers into five layers for multi-layer model calculations. Layer 1 comprises the surface inversion, and extends to about 900 feet. Layer 2 is approximately dry adiabatic and extends to about 2800 feet. Layer 3 is an isothermal layer within which the dewpoint decreases rapidly. The top of Layer 3 is at 6000 feet where the wind direction begins to back with height. The lapse rate between 6000 and 16,400 feet is approximately moist adiabatic and the wind speed increases steadily with height. However, this height interval has been divided into two layers on the basis of the wind direction shear. Table E-1 lists meteorological inputs to the diffusion model at the surface reference height and at the five layer boundaries obtained from the profiles in Figure E-3. The values of σ_A and σ_E given in Table E-1 were determined by the procedures outlined in Section 4.2. Within the surface inversion, $p = 0.14$ and σ_A and σ_E are assumed to vary as $z^{-0.14}$. The temperature and wind speed profiles indicate a lapse rate close to the dry adiabatic in Layer 2 and $p = 0.06$. According to the guidelines in Section 4.2, if Layer 2 is unstable, σ_A and σ_E may be assumed to vary, respectively, as $z^{-0.06}$ and $z^{0.24}$. However, Layer 2, which is the upper part of the daytime mixing layer, is becoming decoupled from the surface by the developing ground-level inversion and it would probably be equally valid either to let σ_E vary as z^{-p} , or to assign minimal values to both σ_A and σ_E at the 2800-foot boundary.

The wind direction in Layers 1 and 2 would cause a toxic cloud generated in these layers to be transported over the ocean to the north of Launch Complex 39 at KSC. In the calculations, it has been assumed that the

TABLE E-1
METEOROLOGICAL MODEL INPUTS FOR 2315 GMT
27 NOVEMBER 1966

Layer No.	Height (ft)	Wind Speed (knot)	Wind Direction (deg)	Potential Temperature (C)	σ_A (deg)	σ_E (deg)
1	59	8	160	17	8	4.5
2	870	12	206	22	6	3
3	2,800	13	231	22	5	4
4	6,000	15	258	29	0	0
5	10,000	21	229	36	0	0
	16,400	40	256	45	0	0

ground-based inversion would not be present over the water surface. Layers 1 and 2 have therefore been treated as a single layer in which the wind field is defined by the winds at the bottom of Layer 1 and the top of Layer 2.

E. 1. 2 Extension of the Bermuda High into the Gulf of Mexico -
0515 GMT, 12 May 1967

On 12 May 1967, the Bermuda High extended westward to the Gulf of Mexico and a weak surface pressure gradient existed over Florida. Figure E-4 shows the surface map for 0600 GMT and Figure E-5 shows the 700-millibar map for 0000 GMT on this date. The lowest 16,400 feet have been divided into the five layers shown in Figure E-6 for use in the multi-layer diffusion model. Layer 1 extends to the top of the weak ground-level inversion at 850 feet. Layer 2 extends from 850 feet to the base of the subsidence inversion at 3500 feet. Layer 3 contains the subsidence inversion and extends from 3500 to 5300 feet. The height interval from 5300 to 16,400 feet has been divided at 10,000 feet into Layers 4 and 5 on the basis of the wind speed profile. The wind speed decreases with height slightly between 5300 and 10,000 feet, and increases between 10,000 and 16,400 feet.

The meteorological inputs for this example are listed in Table E-2. Both σ_A and σ_E are assumed to vary as z^{-p} in Layers 1 and 2. The p values for Layers 1 and 2 are 0.20 and 0.27, respectively.

As in the previous case, the wind trajectory in the surface layer will transport toxic clouds generated in Layers 1 and 2 to the northeast of Launch Complex 39. It has been assumed that the weak ground-based inversion will not persist over the ocean. Layers 1 and 2 were treated as a single layer in the example calculations.

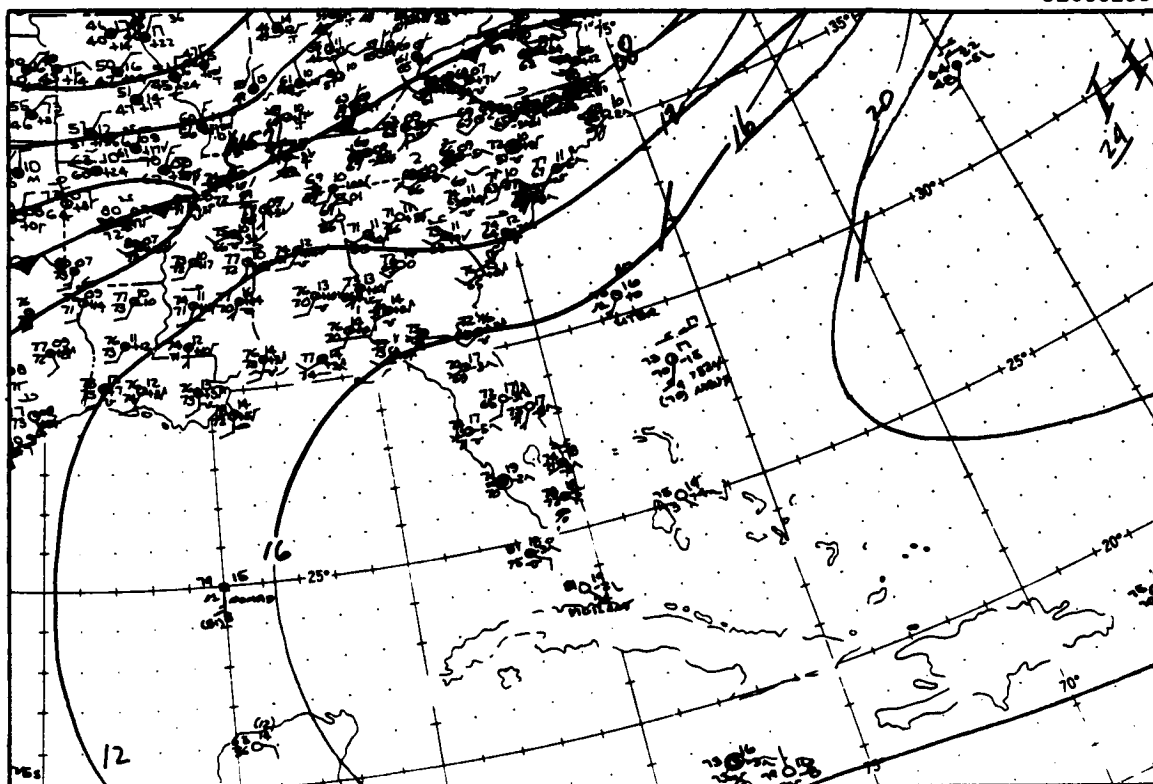


FIGURE E-4 Surface map for 0600 GMT, 12 May 1967.

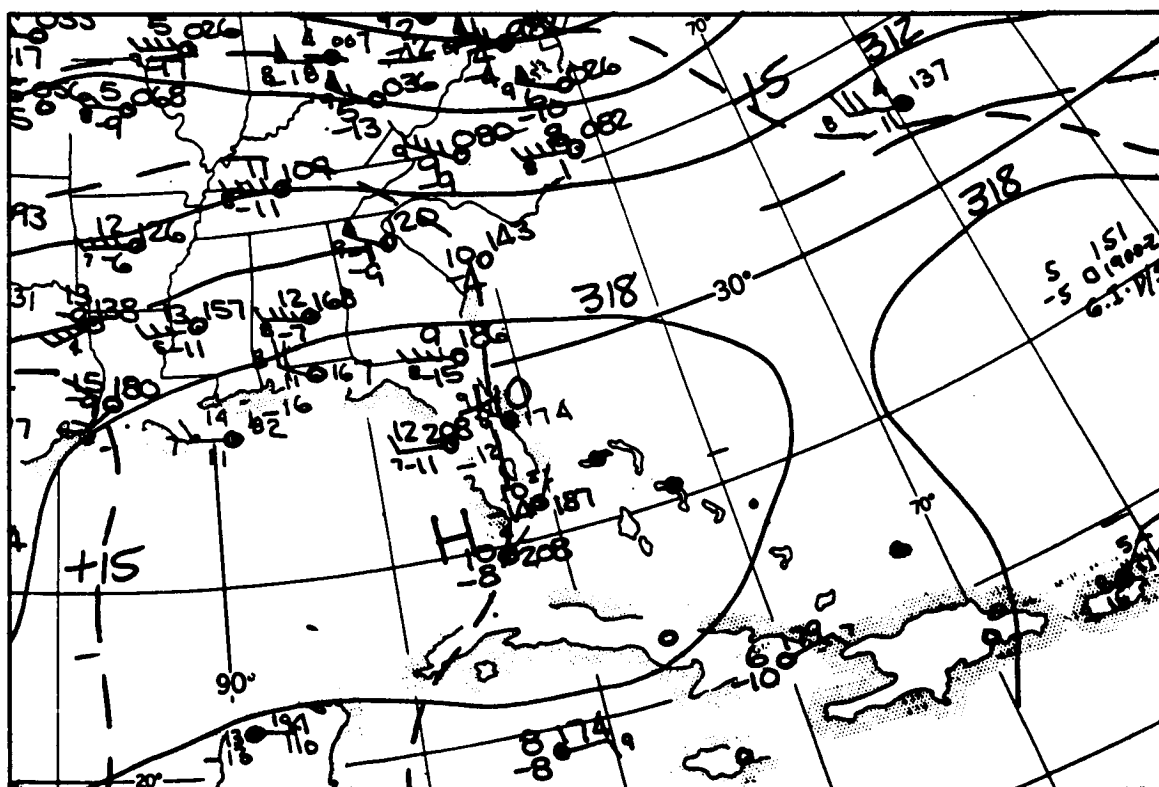


FIGURE E-5 700-mb map for 0000 GMT, 12 May 1967.

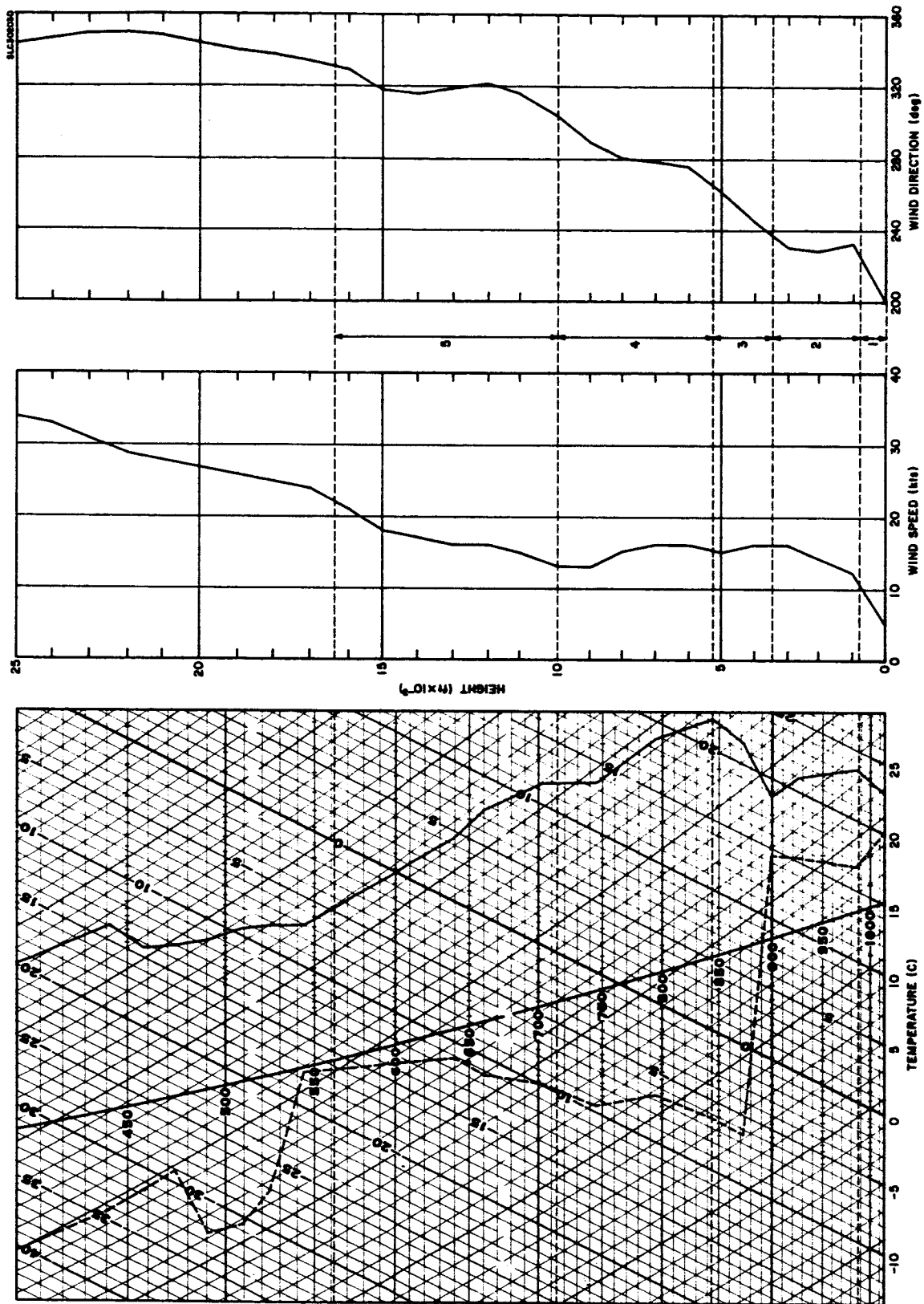


FIGURE E-6. Vertical profiles for 12 May 1967, 0515 GMT. Solid line on Skew T, Log P diagram is air temperature; dashed line is dew point temperature. Assignment of layers for diffusion model is indicated between wind speed and wind direction profiles.

TABLE E-2
METEOROLOGICAL MODEL INPUTS FOR 0515 GMT
12 MAY 1967

Layer No.	Height (ft)	Wind Speed (knot)	Wind Direction (deg)	Potential Temperature (C)	σ_A (deg)	σ_E (deg)
1	59	6	200	22	6	3
2	850	11	230	25	4	2
3	3,500	16	237	28	3	1
4	5,300	15	263	37	0	0
5	10,000	13	303	41	0	0
	16,400	22	328	44	0	0

E.2 SELECTION OF SOURCE INPUT PARAMETERS

Source inputs required for the multi-layer models are specified in Table 4-3. These inputs are clearly dependent on the type of vehicle and the physical properties of the toxic material comprising the source. The design features of the deflector in the base of the launch pad also affect the source dimensions and cloud rise in the surface layer. Because of these factors and because little information is available regarding the properties of toxic clouds formed during normal launches and vehicle destructs, the source inputs selected for the example calculations are somewhat arbitrary. Insofar as possible, information available from launches of Saturn V vehicles was used in specifying the source parameters.

E.2.1 $\underline{Q_K}$ - Source Strength

In the case of normal launches, model Equation (3-1) requires that source strength be stated in terms of mass per unit depth of layer. For the example problems, the emission rate of toxic material was arbitrarily set equal to 5×10^5 grams per second. The residence time of the Saturn vehicle in each layer was selected from Figure E-7, which shows vehicle height as a function of elapsed time after launch as given by Adelfang, Ashburn, and Court (1968). The source strength in the layer was determined through multiplication of the emission rate by the residence time of the vehicle in the layer and division of this product by the depth of the layer.

In examples where vehicle destruct occurs, the total amount of toxic material assumed available for atmospheric dispersal was 10^8 grams. This total mass was distributed approximately in the vertical according to the distribution shown in Figure E-8 which is taken from Hage, Bowne, and Hilst (1965).

In using Figure E-8, the radius r of the cloud in the plane of the horizon at the effective source height H_K was arbitrarily set equal to 305 meters. In the example calculations where vehicle destruct occurs at the surface, the amount of material in each layer was determined directly from Figure E-8. Where vehicle destruct occurs aloft, the source strength in the layers below the level of destruct was assumed equivalent to that produced by a normal launch. In the layers between the effective source height H_K and the destruct height h , the remaining material was distributed according to the distribution shown in Figure E-8.

In the examples of cold spills in the surface layer the source strength was assigned a value of 10^2 grams per second.

E. 2. 2 H_K - Effective Source Height

The effective source height was calculated using Equation (4-15) and the potential temperatures given in Tables E-1 and E-2. The value of Q' , the energy released in vehicle destruct situations, was arbitrarily set equal to 3.5×10^7 kilocalories.

E. 2. 3 τ_K - Cloud Stabilization Time

For example cases of normal launches, the cloud stabilization time τ_K was set equal to the residence time of the vehicle in the layer given by Figure E-7. The time τ_K was set equal to 10 seconds in the layers affected by vehicle destruct situations. In example cases of cold spills in the surface layer, τ_K was set equal to 10 minutes.

E.2.4 $\sigma_{x0}\{K\}, \sigma_{y0}\{K\}, \sigma_{z0}\{K\}$ - Source Dimensions

In the example calculations for normal launches, alongwind and lateral source dimensions in the surface layer $\sigma_{x0}\{K=1\}, \sigma_{y0}\{K=1\}$ were based on photographs supplied by NASA of the launch of Apollo 10. The photographs show the vehicle exhaust plume in the vicinity of the launch pad taken from a fixed camera position on the NASA 150-meter Meteorological Tower every 2 seconds. Beyond an elapsed time of about 30 seconds, the exhaust plume cannot be distinguished from the background. Figure E-9 shows estimates of the height of two portions of the plume issuing from the exhaust deflector and the total width of the exhaust plume as a function of elapsed time. Inspection of Figure E-9 shows the width of the cloud to be about 1250 meters 25 seconds after launch; in the example cases, this is the time the vehicle leaves the first layer. At this time, the two portions of the cloud from the exhaust deflector appear nearly merged in the photographs. The alongwind and crosswind dimensions were assumed equal to the width, 1250 meters, divided by 4.3 (see Section 4.3). In the layers aloft, the dimensions were arbitrarily decreased.

As mentioned earlier, the cloud radius at the height H_K for examples of vehicle destruct was assigned a value of 305 meters in the plane of the horizon and the alongwind and crosswind dimensions were assumed equal to 305 meters divided by 4.3. The vertical source dimension in the layer containing H_K was arbitrarily set equal to the height difference between H_K and the lower boundary of this layer divided by 2.15.

In the examples of cold spills in the surface layer, the spill was assumed to have dimensions of 50 meters in diameter; the alongwind and lateral dimensions were set equal to 50 meters divided by 4.3, or 11.6 meters. The vertical source dimension was set equal to unity.

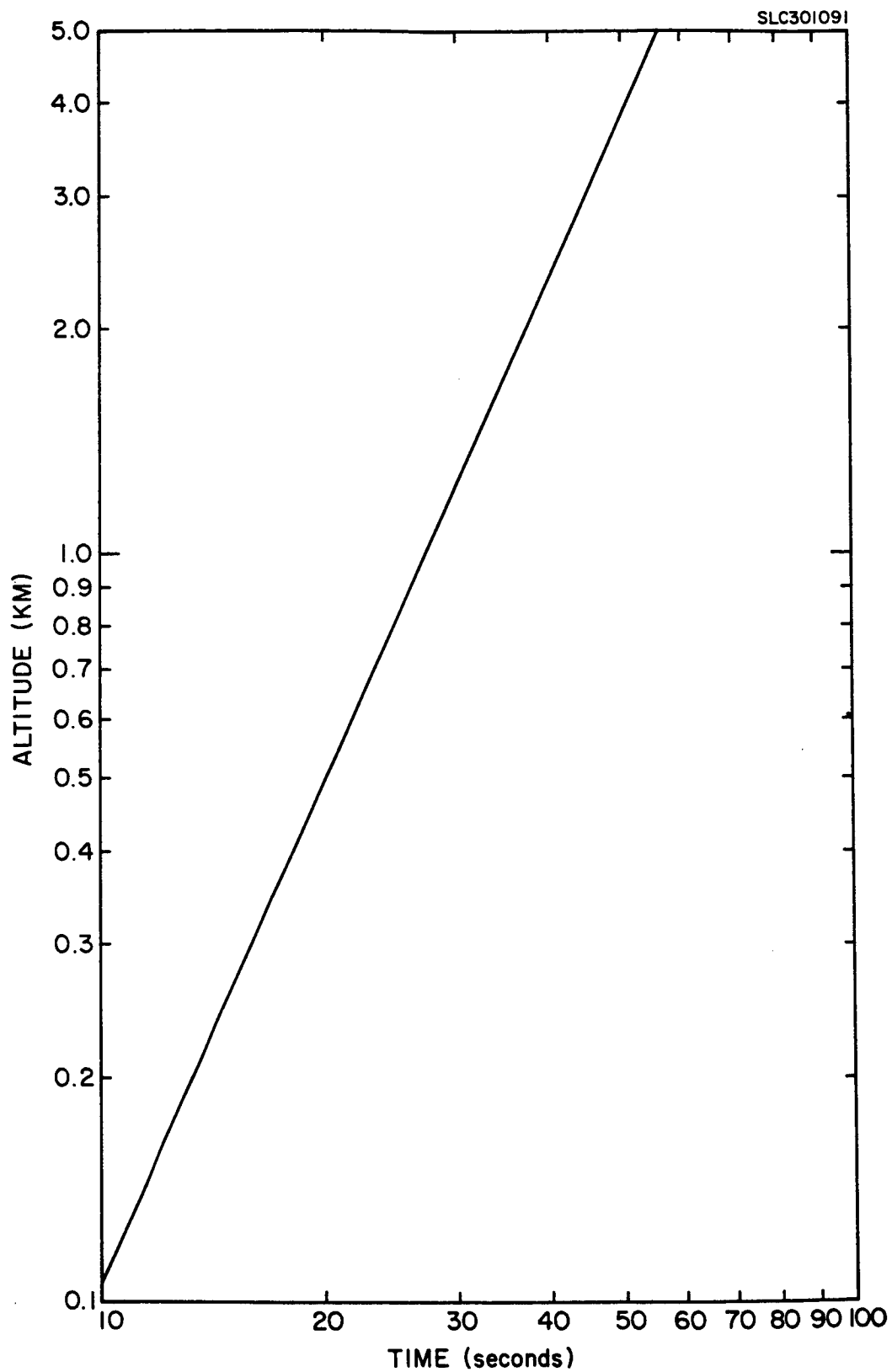


FIGURE E-7. Altitude of the SATURN AS-504 vehicle as a function of flight time (after Adelfang, Ashburn, and Court, 1968).

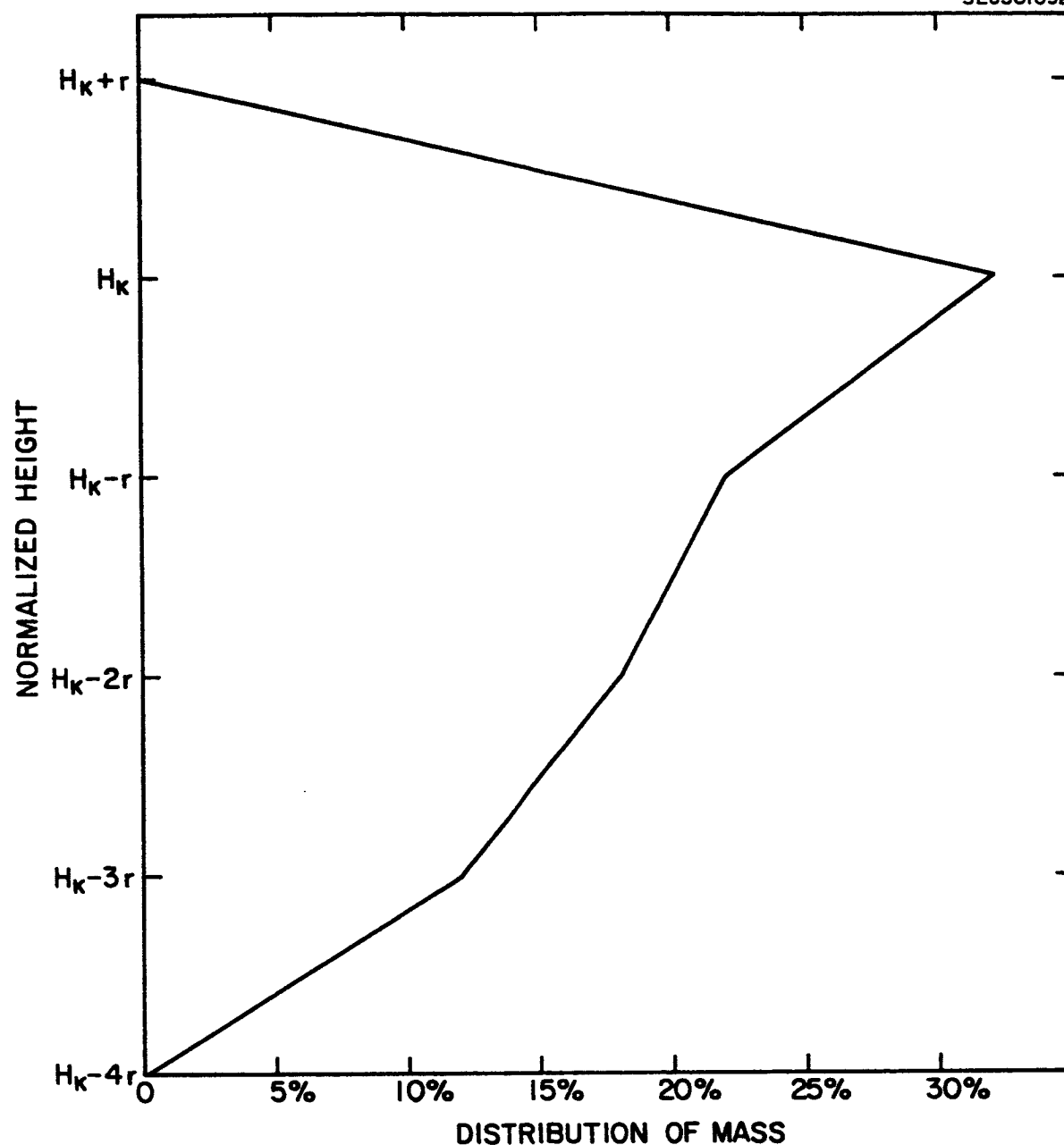


FIGURE E-8. Assumed distribution of mass in the cloud resulting from a vehicle destruct after Hage, K. D., N. E. Bowne, and G. R. Hilst (1965). In the figure, H_K is the effective release height and r is the radius in the plane of the horizon of the source at H_K .

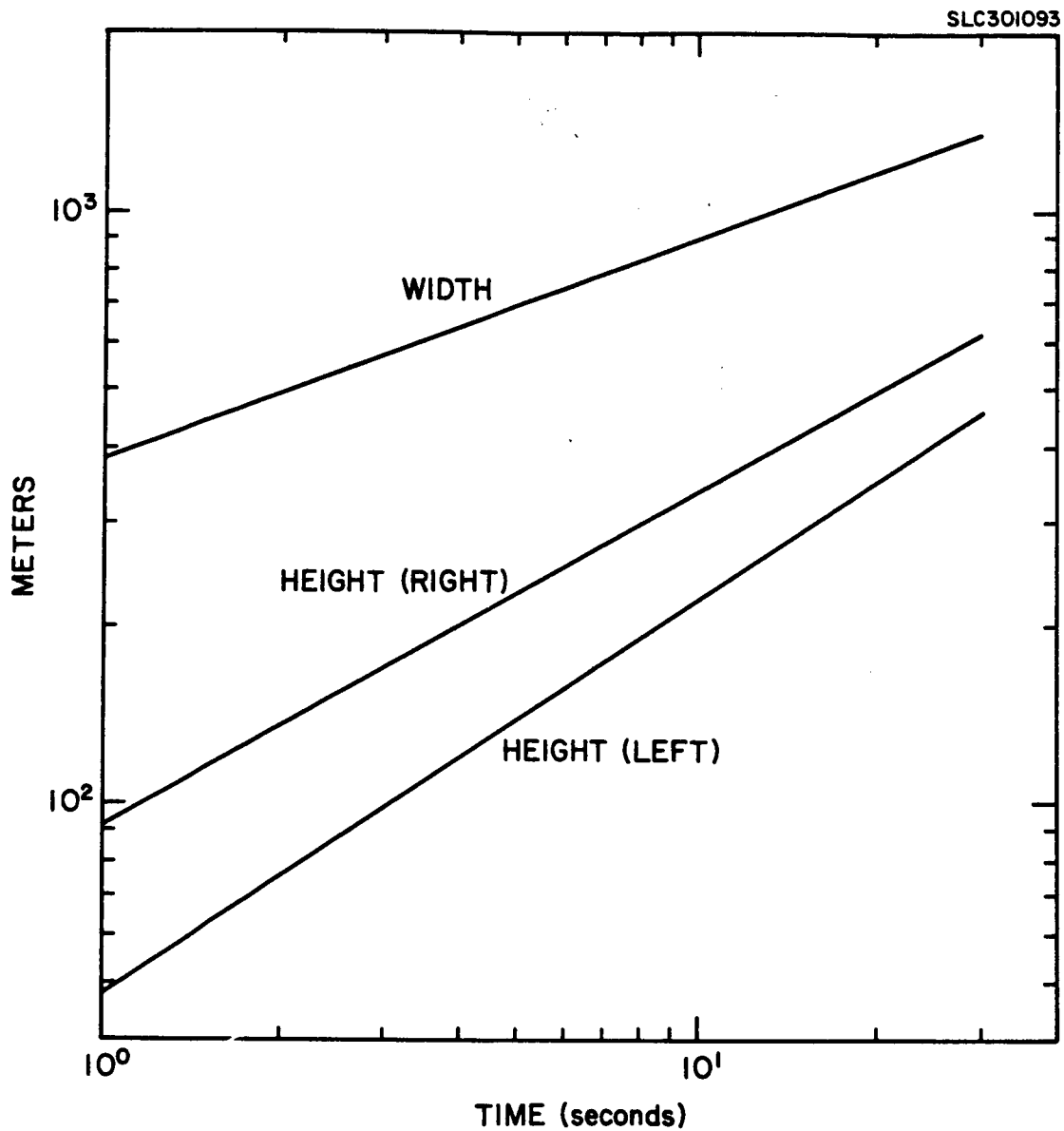


FIGURE E-9. Increase in height and width of plume formed by launch of Apollo 10 as a function of elapsed time. Lower curves represent height of the two portions of the plume formed by the deflector at the base of the launch pad.

E.2.5 V_s, f_i - Settling Velocity and Fraction of Material with Settling Velocity V_s

Table E-3 presents the median particle diameter of each particle size category of an assumed distribution used for the example in Section E.5 of ground-level deposition due to gravitational settling. Table E-3 shows the fraction of material assigned each particle size category and the settling velocities for droplets or particles having these median diameters and unit density (after Johnson, 1954).

E.3 CONCENTRATION AND DOSAGE PATTERNS FOR THE PRE-COLD FRONT SITUATION - 2315 GMT, 27 NOVEMBER 1966

This section contains the results of the example calculations for the various source modes for the pre-cold front regime discussed in Section E.1.1.

E.3.1 Normal Launch

The source and meteorological inputs for the normal launch calculation are given in Table E-4. Figures E-10 and E-11 respectively show the maximum ground-level concentrations and dosages downwind from the launch pad. Figures E-12 and E-13 show the corresponding ground-level concentration and dosage isopleths. Figures E-14 through E-19 contain the concentration and dosage isopleths at the base of the three layers above the surface layer.

E.3.2 Vehicle Destruct at the Surface

The source and meteorological inputs for a vehicle destruct at the surface are given in Table E-5. Figures E-20 and E-21 respectively show maximum ground-level concentrations and dosages downwind from the launch pad.

TABLE E-3

ASSUMED MEDIAN PARTICLE DIAMETERS, FRACTION OF
MATERIAL WITH SETTLING VELOCITY V_s , AND V_s

Particle Diameter (micrometers)	f_i	V_s (m sec ⁻¹)
37	1/10	0.043
53.5	1/10	0.090
67	1/10	0.140
84	1/10	0.209
100	1/10	0.275
120	1/10	0.355
150	1/10	0.485
190	1/10	0.660
270	1/10	1.000
660	1/10	2.700

TABLE E-4
PROGRAM INPUTS

Example Problem: Normal Launch for Pre-Cold Front Situation,
2315 GMT, 27 November 1966

MODEL NO. 1				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
$Q_K \text{ (gm}^{-1}\text{)}$	1.48×10^4	5.38×10^3	3.79×10^3	2.82×10^3
$\sigma_{yo} \{K\} \text{ (m)}$	290	150	100	75
$\sigma_{zo} \{K\} \text{ (m)}$	-	-	-	-
$\sigma_{xo} \{K\} \text{ (m)}$	290	150	100	75
$\tau_K \text{ (sec)}$	25	11	10	11
$H_K \text{ (m)}$				
k				

TABLE E-4 (Continued)

MODEL NO. 1				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	5	0	0	0
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)		5	0	0
τ_{oK} (sec)	600	600	600	600
σ_{ETK} (deg)	4	0	0	0
σ_{EBK} (deg)		4	0	0
α_K	1	1	1	1
β_K	1	1	1	1
$\bar{u}_{TK}$ (m sec ⁻¹)	6.70	7.73	10.8	20.6
$\bar{u}_{BK}$ (m sec ⁻¹)		6.70	7.73	10.8
θ_{TK} (deg)	231	258	229	256
θ_{BK} (deg)	160	231	258	229
z_{TK} (m)	853	1829	3048	5000
z_{BK} (m)	2	853	1829	3048
Λ (sec ⁻¹)				
z_{lim} (m)				
t_1 (sec)				
t^* (sec)				

TABLE E-5
PROGRAM INPUTS

Example Problem: Vehicle Destruct at Surface for Pre-Cold Front
Situation, 2315 GMT, 27 November 1966

MODEL NO. 1 (Layer 1), 3 (Layer 2)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
$Q_K \text{ (g m}^{-1}\text{)}$	4.45×10^4			
$Q_K \text{ (g)}$		6.2×10^7		
$\sigma_{yo}\{K\} \text{ (m)}$	35	142		
$\sigma_{zo}\{K\} \text{ (m)}$	-	142		
$\sigma_{xo}\{K\} \text{ (m)}$	35	142		
$\tau_K \text{ (sec)}$	10	10		
$H_K \text{ (m)}$		1285		
k	-			

TABLE E-5 (Continued)

MODEL NO. 1 (Layer 1), 3 (Layer 2)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	5	0		
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)				
τ_{oK} (sec)	600	600		
σ_{ETK} (deg)	4	0		
σ_{EBK} (deg)		4		
α_K	1	1		
β_K	1	1		
$\bar{u}_{TK}$ (m sec ⁻¹)	6.70	7.73		
$\bar{u}_{BK}$ (m sec ⁻¹)		6.70		
θ_{TK} (deg)		258		
θ_{BK} (deg)	160	231		
z_{TK} (m)	853	1829		
z_{BK} (m)	2	853		
Λ (sec ⁻¹)				
z_{lim} (m)				
t_1 (min)				
t^* (min)				

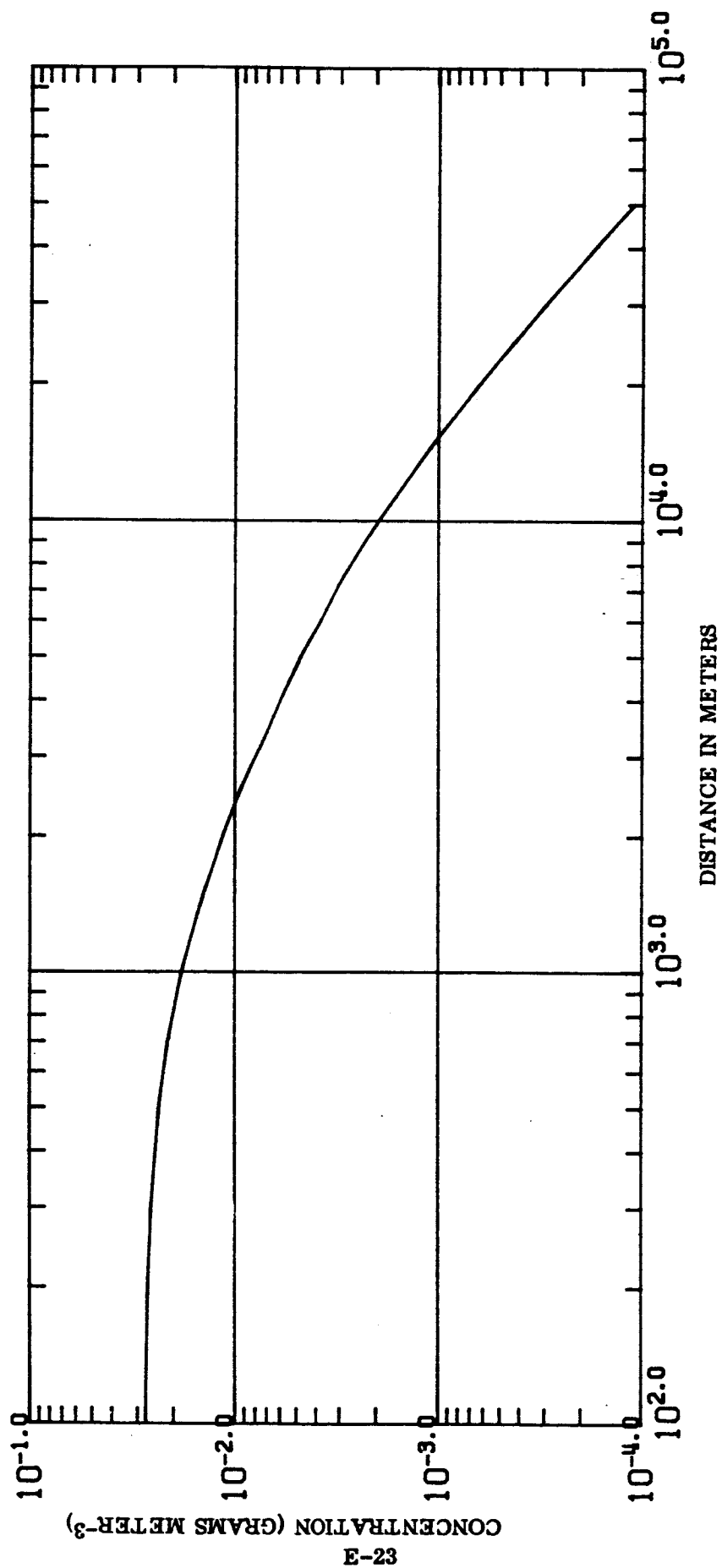


FIGURE E-10. Maximum ground-level concentration for a normal launch, 2315 GMT, 27 November 1966.

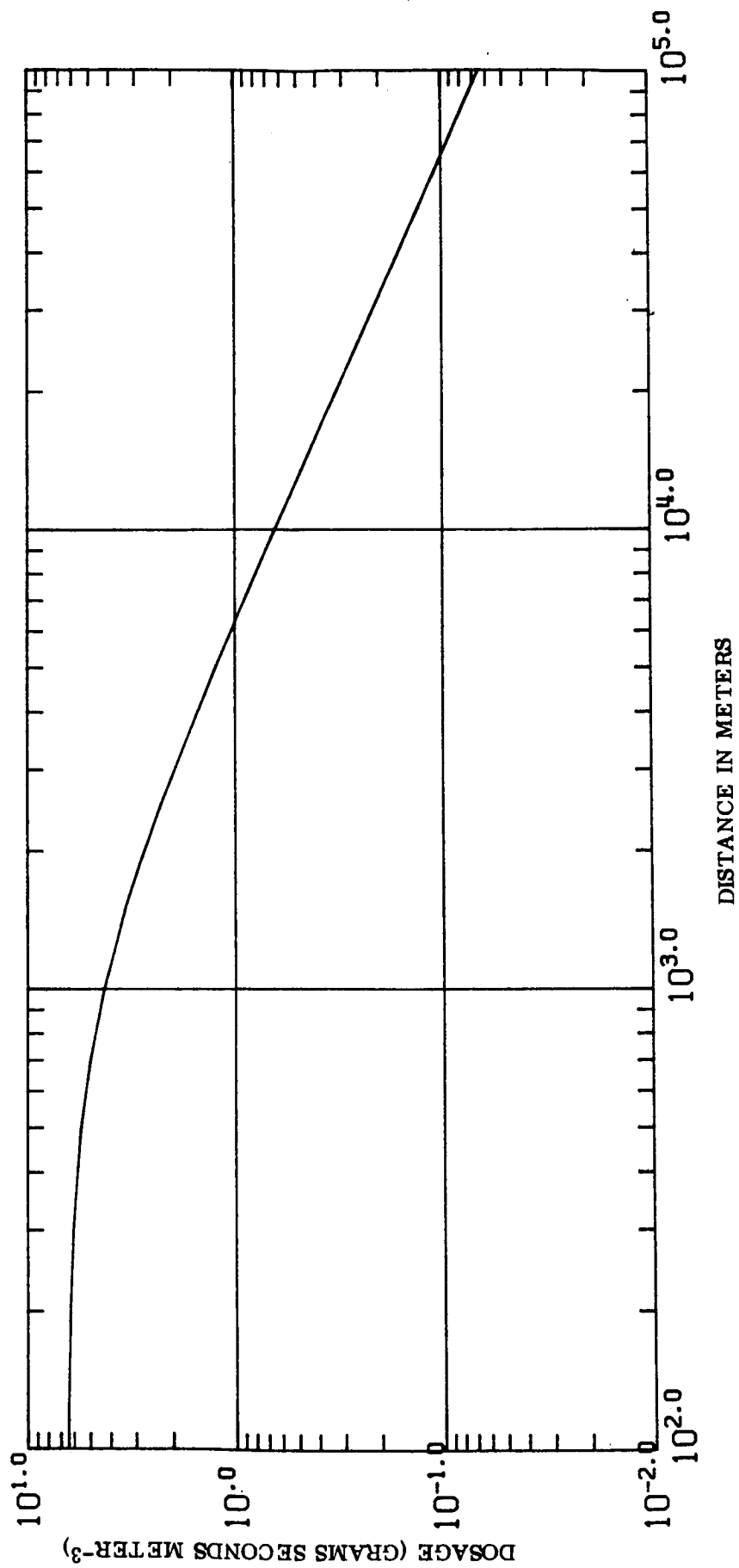


FIGURE E-11. Maximum ground-level dosage for a normal launch, 2315 GMT, 27 November 1966.

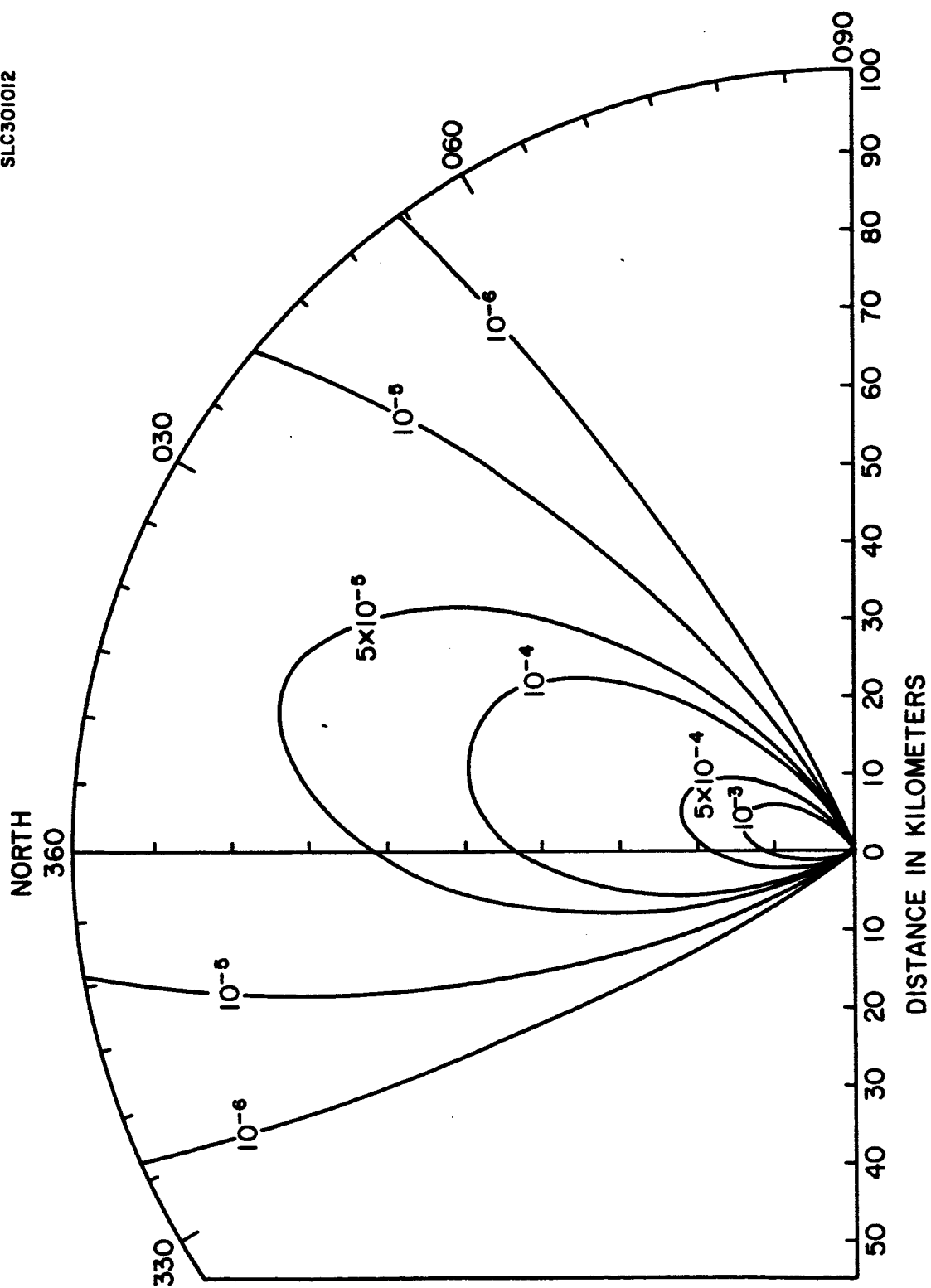


FIGURE E-12. Ground-level concentration isopleths in grams per cubic meter for a normal launch, 2315 GMT, 27 November 1966.

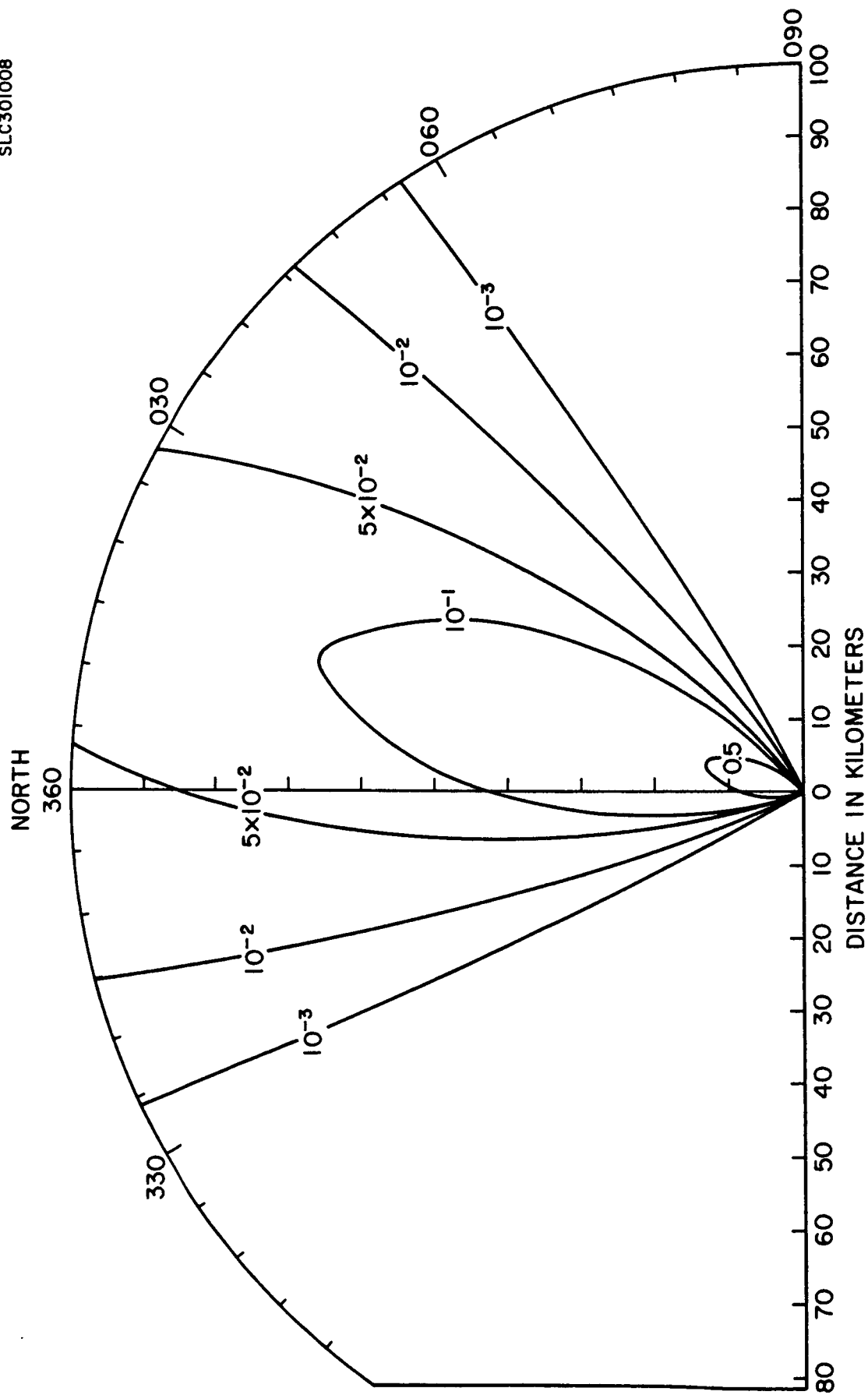


FIGURE E-13. Ground-level dosage isopleths in grams seconds per cubic meter for a normal launch, 2315 GMT, 27 November 1966.

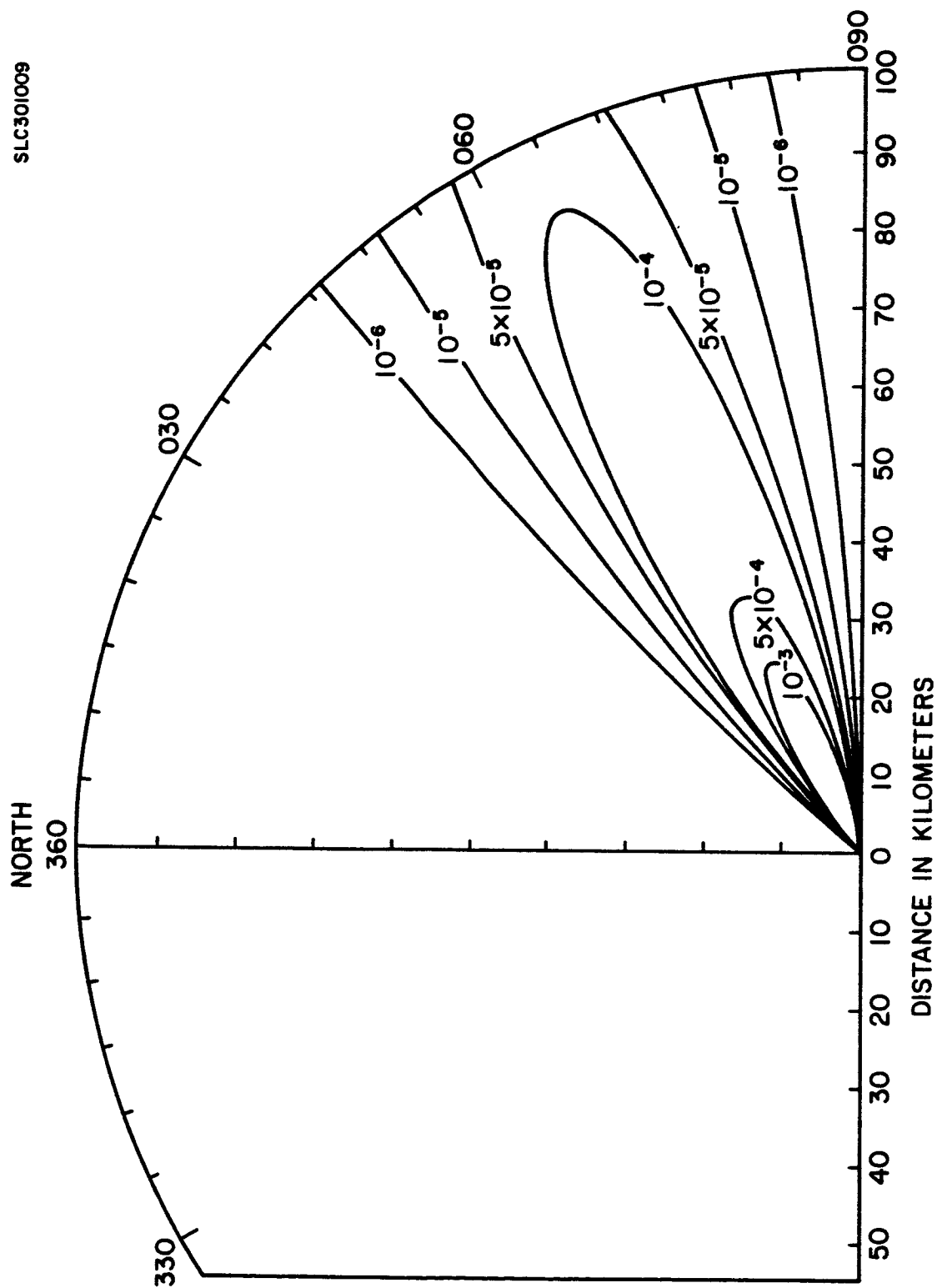


FIGURE E-14. Concentration isopleths in grams per cubic meter at a height of 853 meters for a normal launch, 2315 GMT, 27 November 1966.

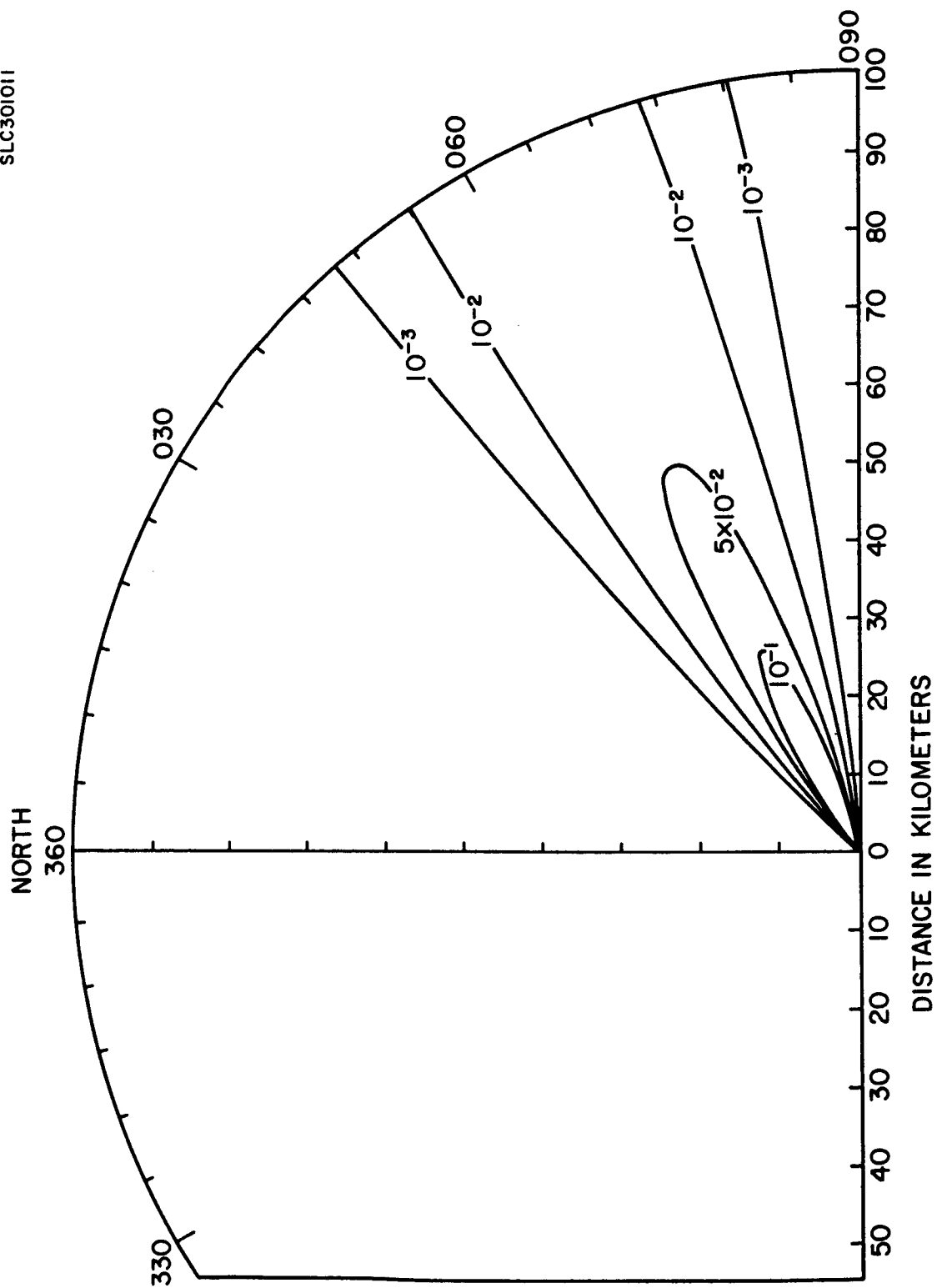


FIGURE E-15. Dosage isopleths in grams seconds per cubic meter at a height of 853 meters for a normal launch, 2315 GMT, 27 November 1966.

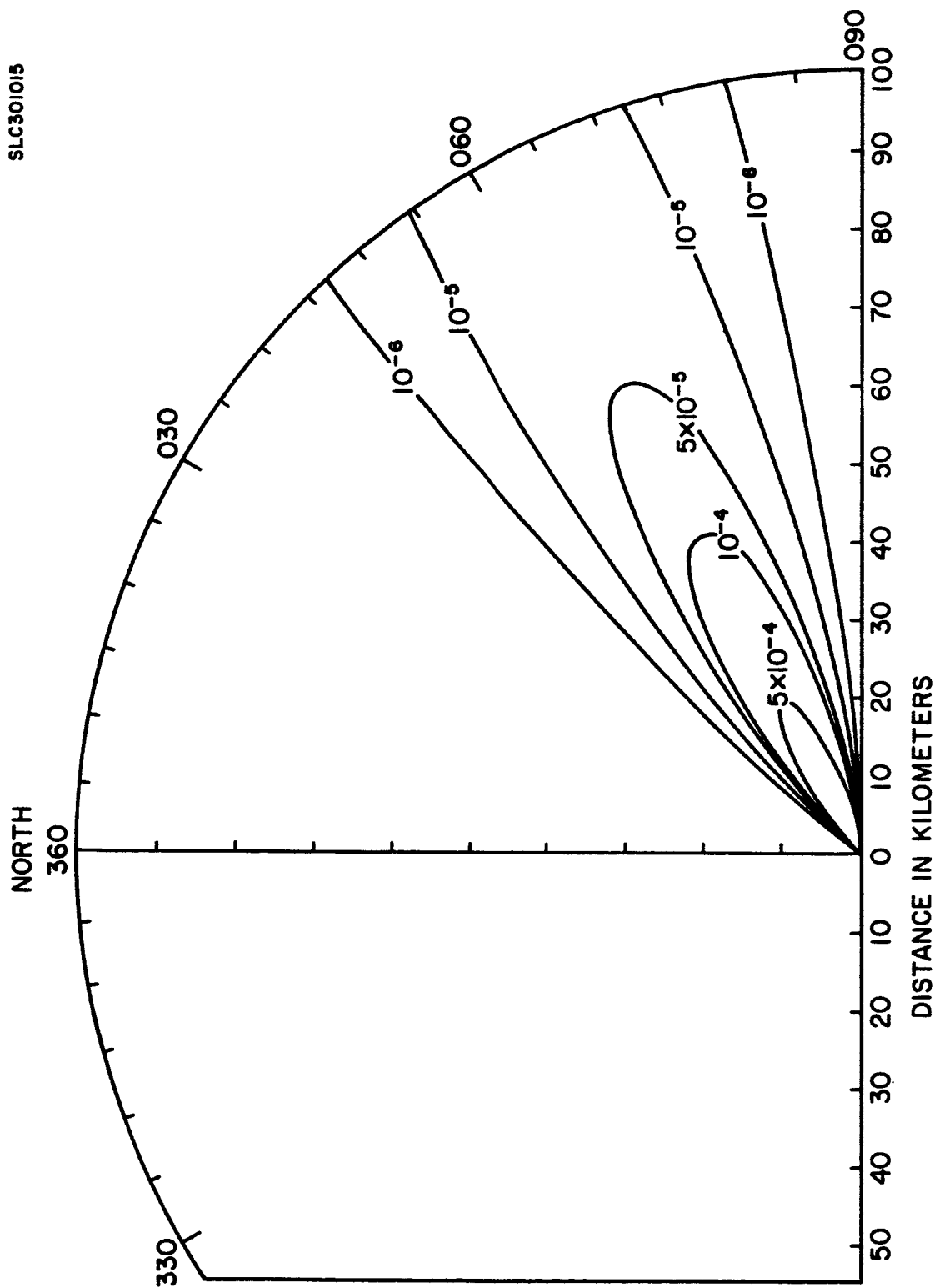


FIGURE E-16. Concentration isopleths in grams per cubic meter at a height of 1829 meters for a normal launch, 2315 GMT, 27 November 1966.

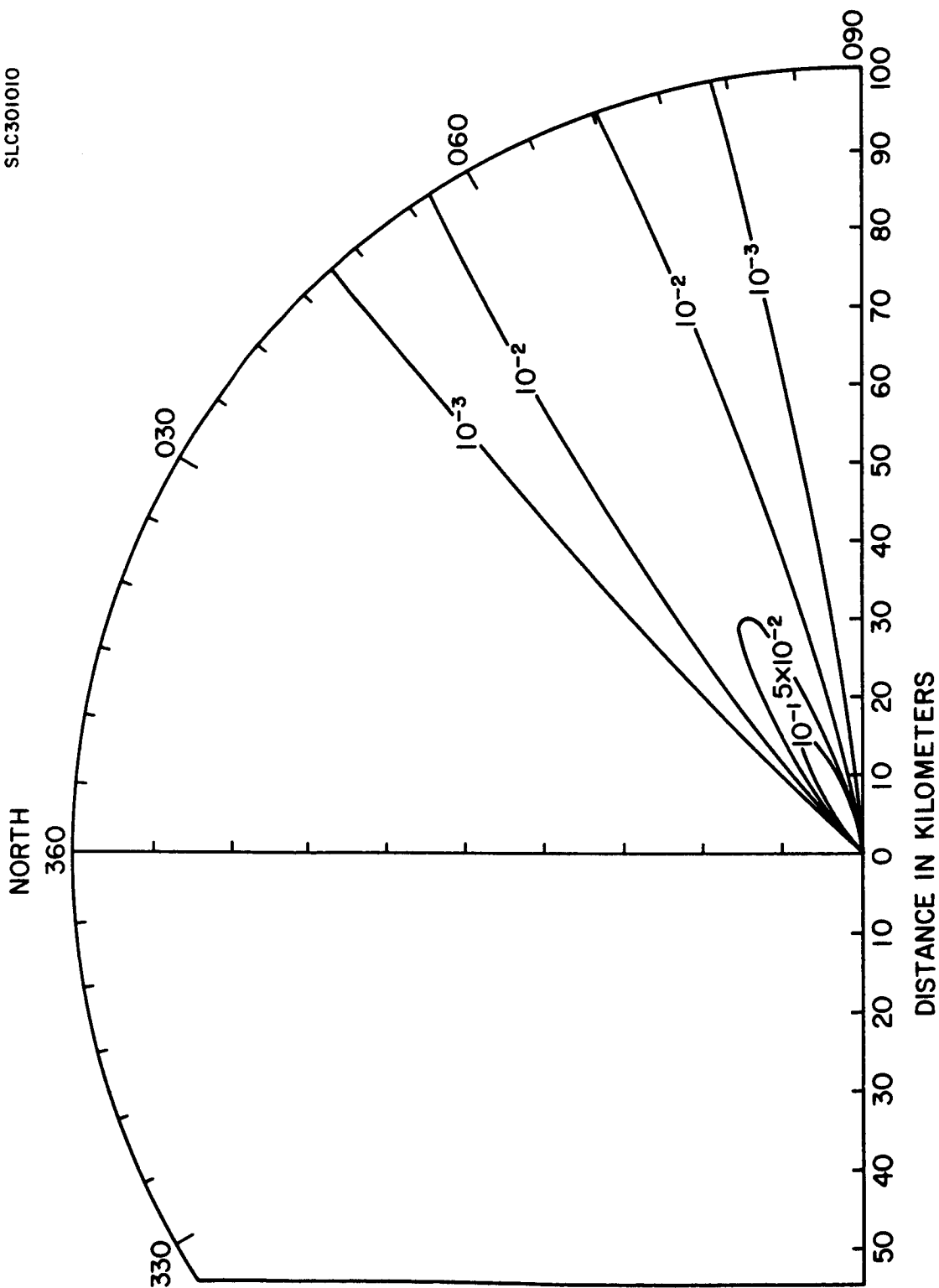


FIGURE E-17. Dosage isopleths in grams seconds per cubic meter at a height of 1829 meters for a normal launch, 2315 GMT, 27 November 1966.

SLC301013

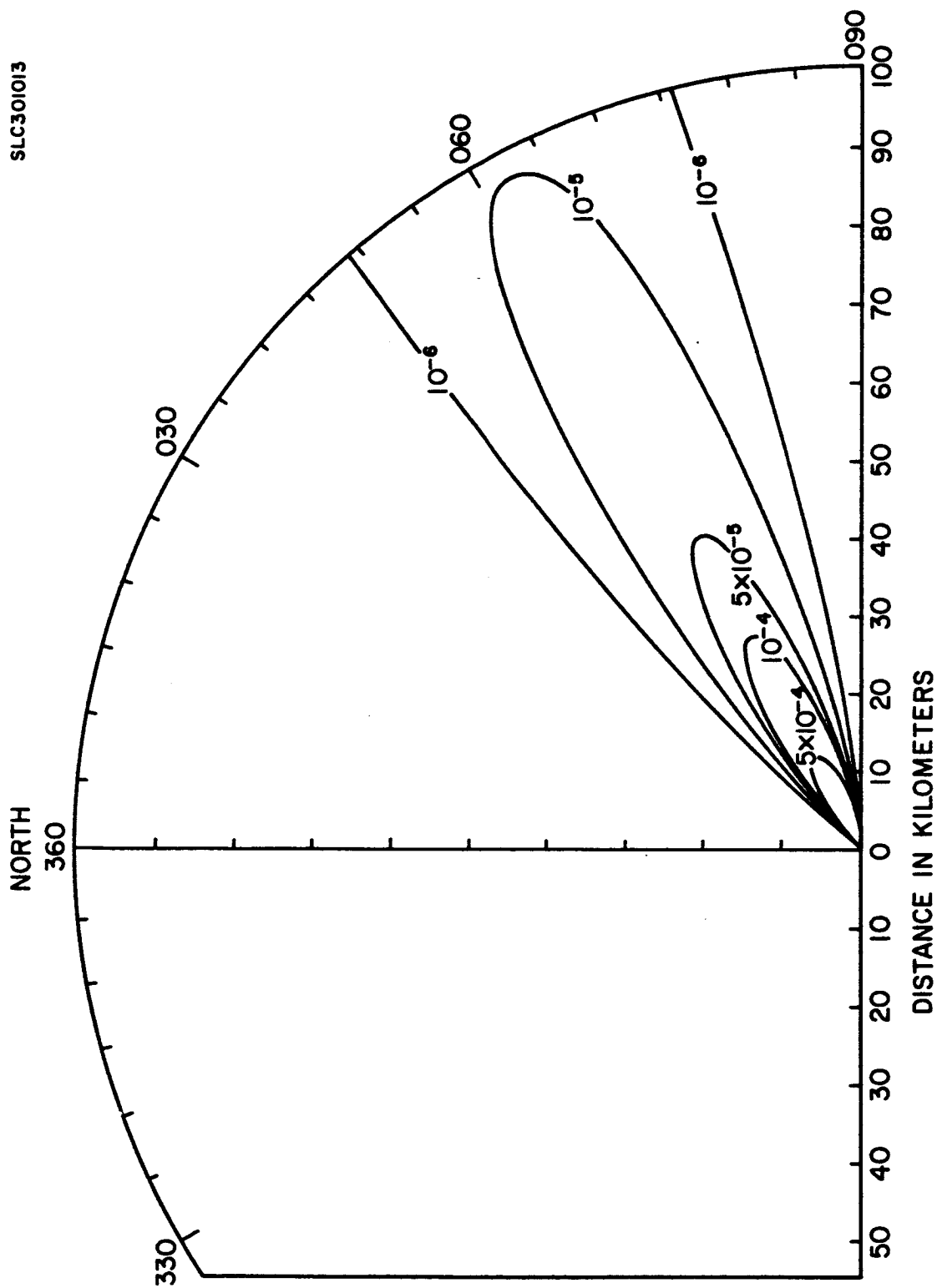


FIGURE E-18. Concentration isopleths in grams per cubic meter at a height of 3048 meters for a normal launch, 2315 GMT, 27 November 1966.

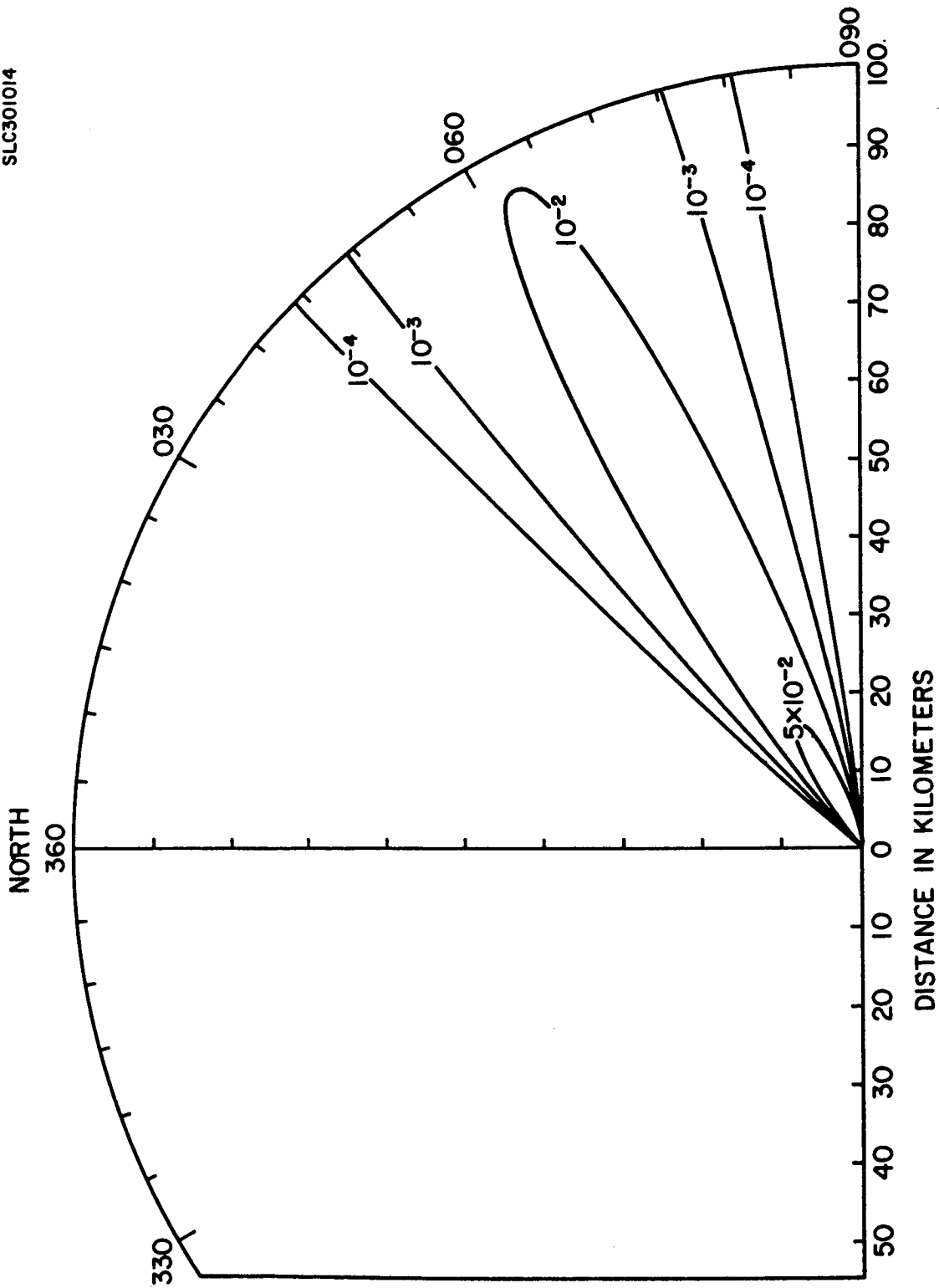


FIGURE E-19. Dosage isopleths in grams seconds per cubic meter at a height of 3048 meters for a normal launch, 2315 GMT, 27 November 1966.

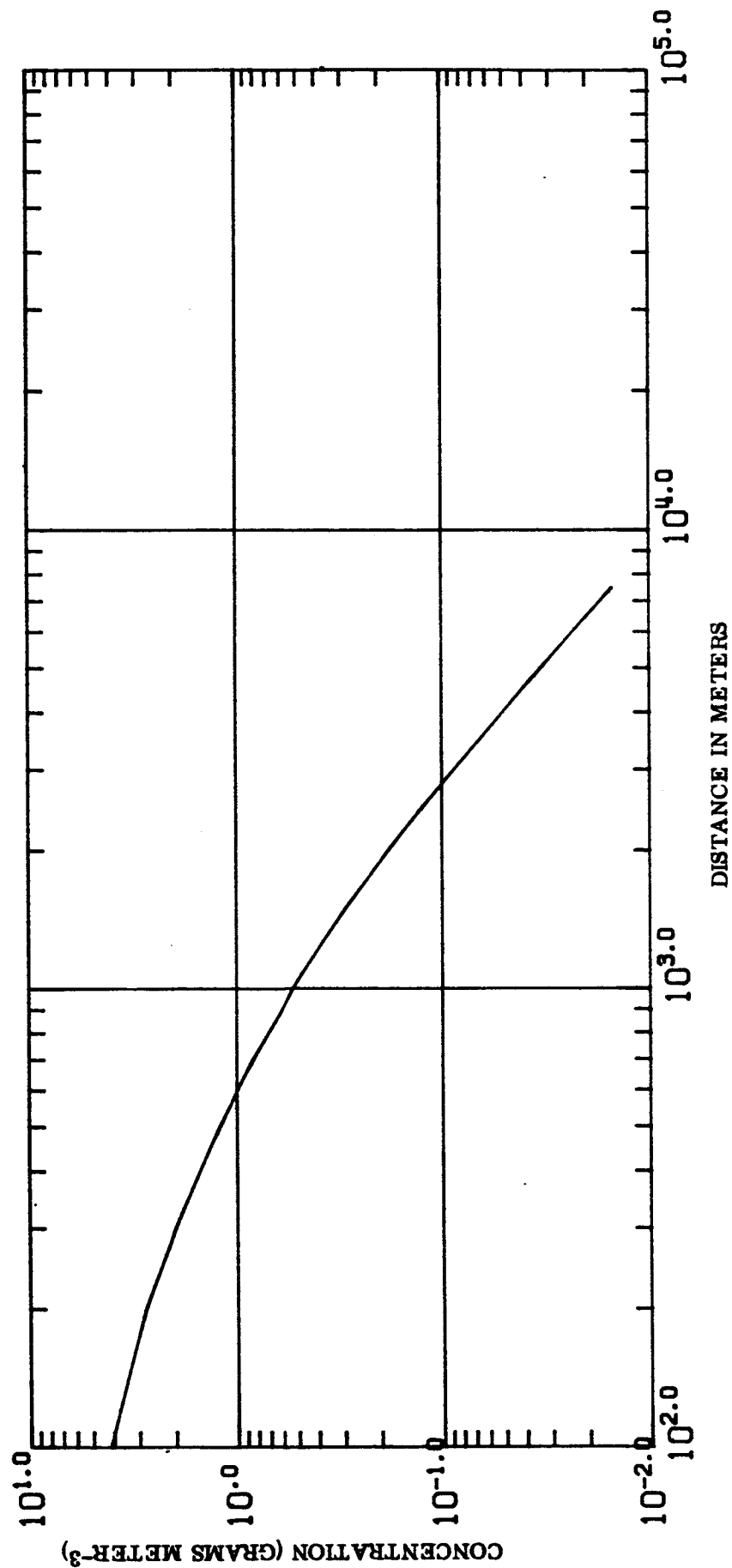


FIGURE E-20. Maximum ground-level concentration for a vehicle destruct on pad, 2315 GMT, 27 November 1966.

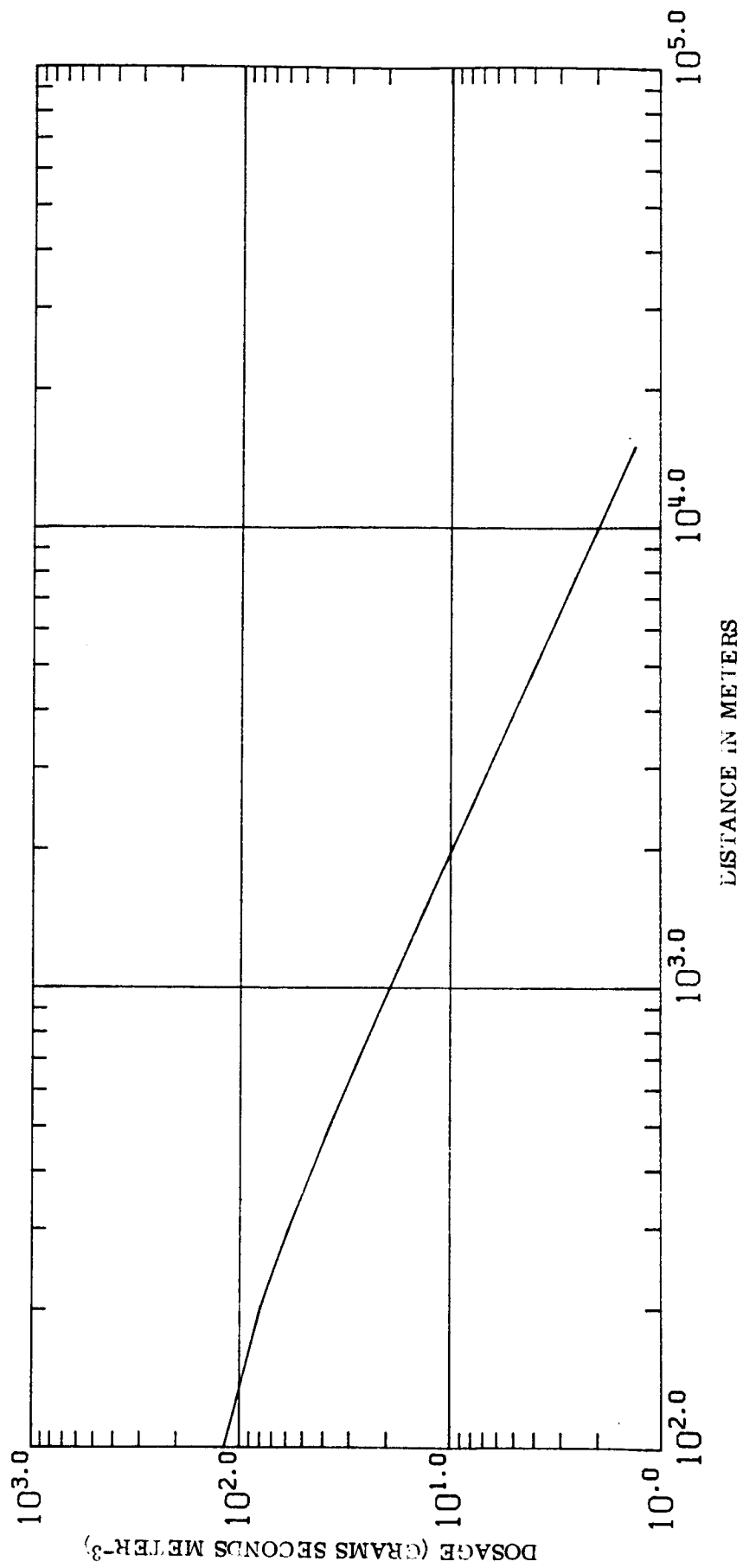


FIGURE E-21. Maximum ground-level dosage for a vehicle destruct on pad, 2315 GMT, 27 November 1966.

Figures E-22 and E-23 respectively show ground-level concentration and dosage isopleths. Figures E-24 and E-25 respectively show concentration and dosage isopleths at the base of the second layer. As expected, dosages and concentrations in the second layer are much higher than those in the surface layer, because of the buoyant rise of material.

E.3.3 Vehicle Destruct Aloft

The source and meteorological inputs for this example are given in Table E-6. Figures E-26 and E-27 respectively show maximum ground-level concentrations and dosages downwind from the launch pad. Because the vehicle destruct occurs at a height of 1350 meters, these results, as well as those for ground-level concentration and dosage isopleths shown in Figures E-28 and E-29, are the same as those for the normal launch case. Figures E-30 and E-31 respectively show concentration and dosage isopleths at the base of the second layer, the layer in which the vehicle is assumed to have been destructed. Finally, Figures E-32 and E-33 respectively show isopleths of concentration and dosage at the base of the third layer. The effective height of the volume source H_K from the destruct is in the third layer at a height of 2593 meters.

E.3.4 Cold Spill in the Surface Layer

The source and meteorological inputs for this example are given in Table E-7. Figure E-34 shows ground-level concentration isopleths for a spill 50 meters in diameter in the surface layer calculated using the multi-layer diffusion program.

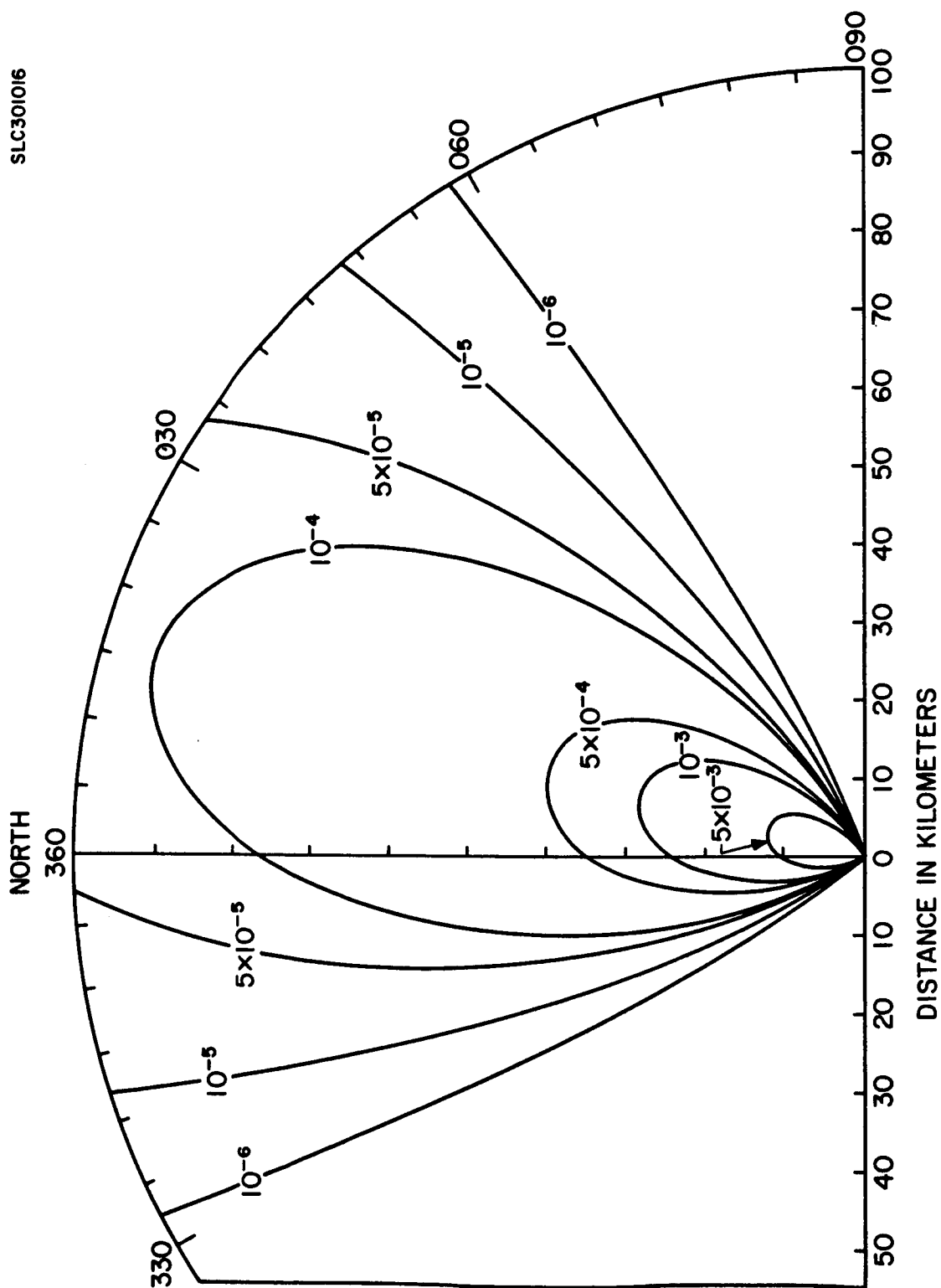


FIGURE E-22. Ground-level concentration isopleths in grams per cubic meter for a vehicle destruct on the pad, 2315 GMT, 27 November 1966.

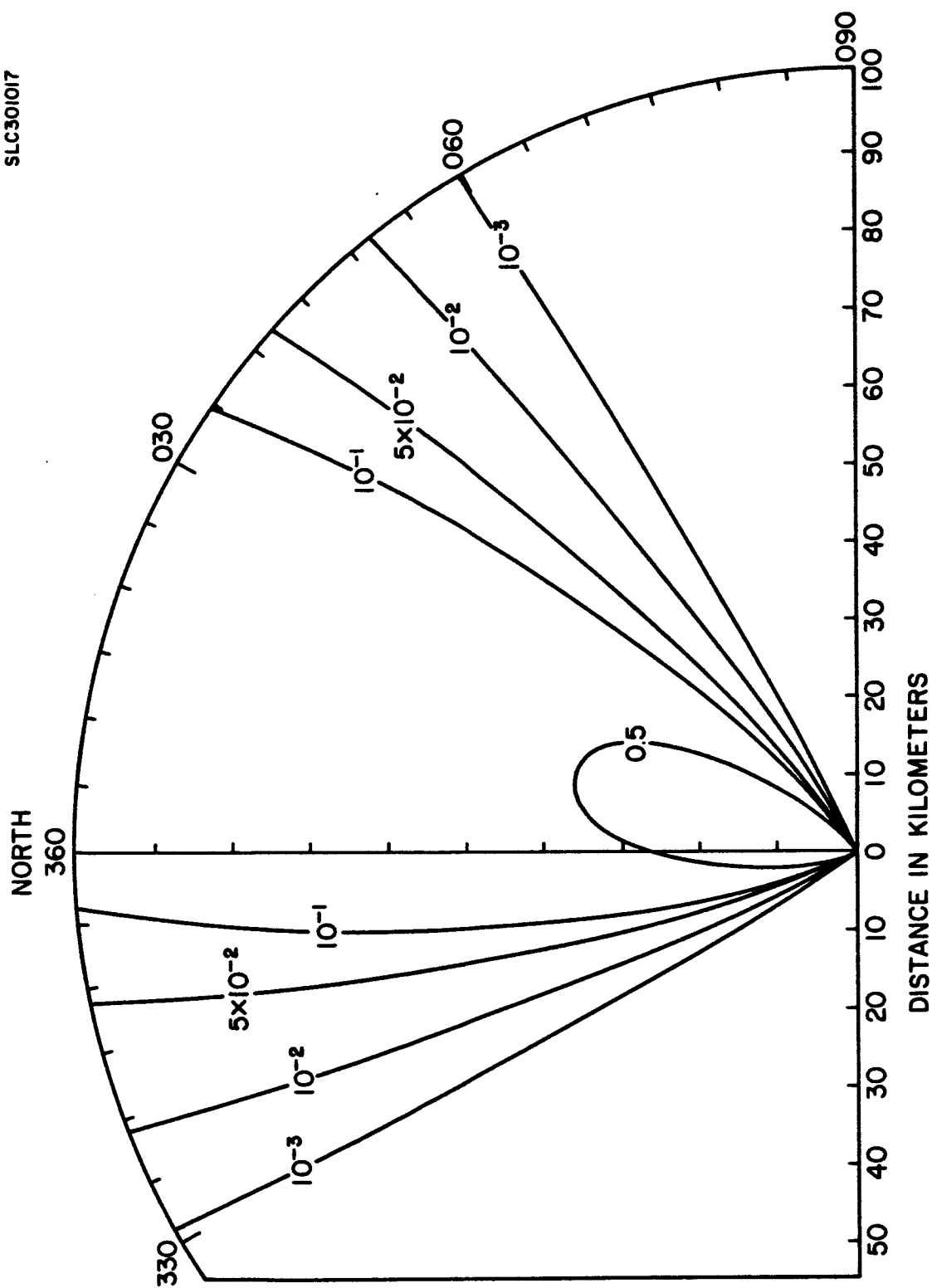


FIGURE E-23. Ground-level dosage isopleths in grams seconds per cubic meter for a vehicle destruct on the pad, 2315 GMT, 27 November 1966.

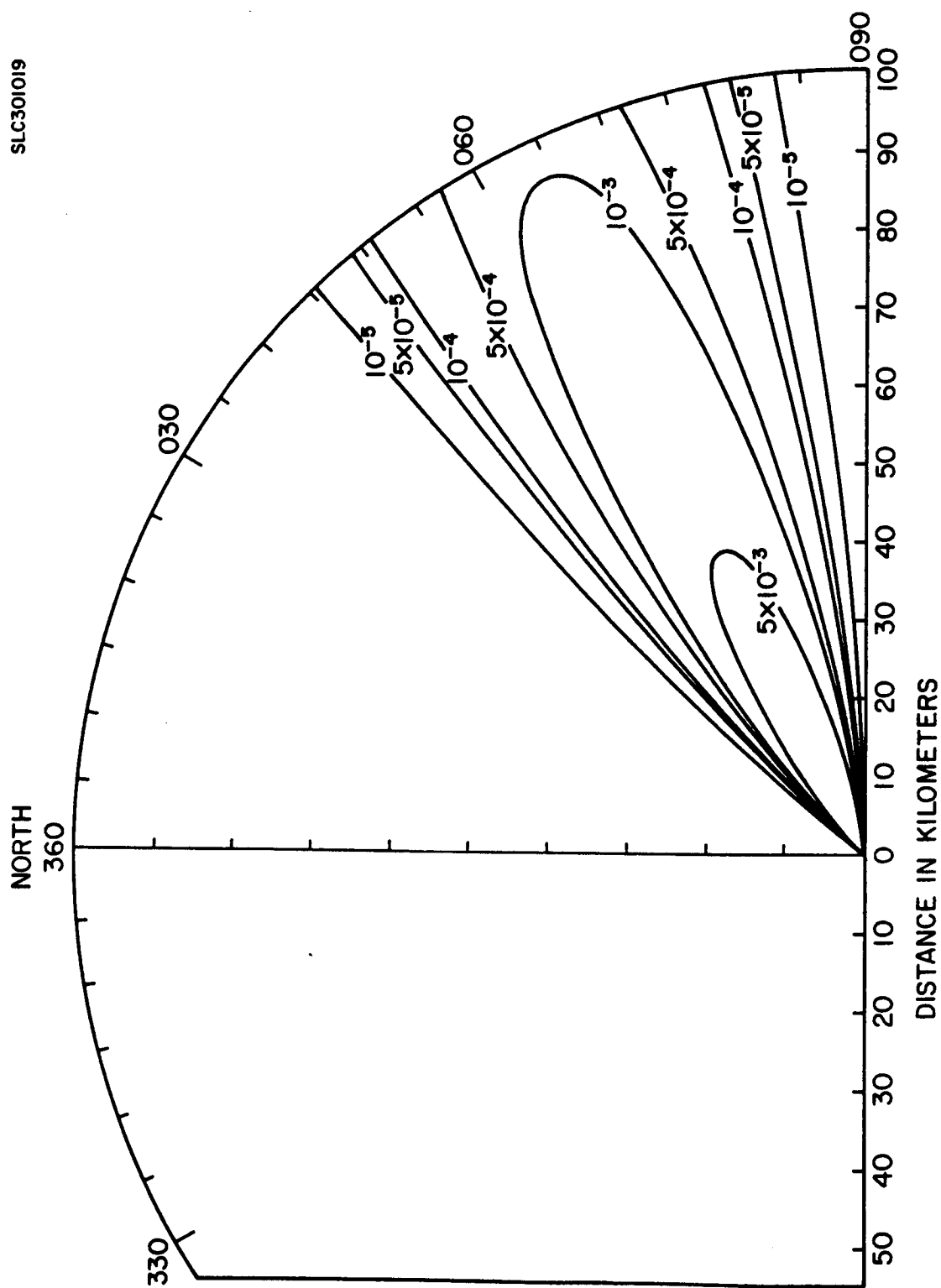


FIGURE E-24. Concentration isopleths in grams per cubic meter at a height of 853 meters for a vehicle destruct on the pad, 2315 GMT, 27 November 1966.

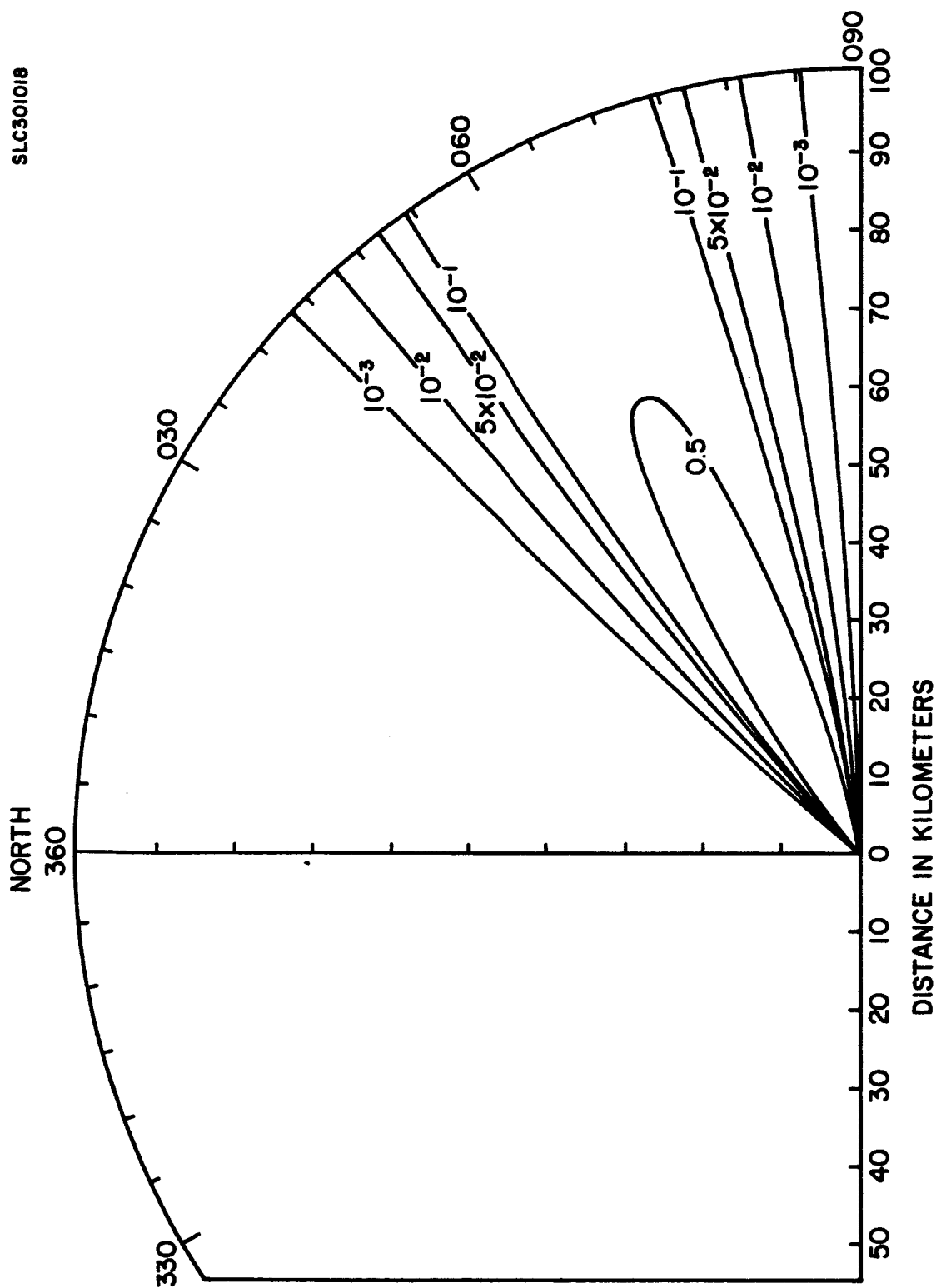


FIGURE E-25. Dosage isopleths in grams seconds per cubic meter at a height of 853 meters for a vehicle destruct on the pad, 2315 GMT, 27 November 1966.

TABLE E-6
PROGRAM INPUTS

Example Problem: Vehicle Destruct Aloft for Pre-Cold Front
Situation, 2315 GMT, 27 November 1966

MODEL NO. 1 (Layer 1), 1 (Layer 2), 3 (Layer 3)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
$Q_K \text{ (g m}^{-1}\text{)}$	1.48×10^4	1.34×10^4		
$Q_K \text{ (g)}$			7.43×10^7	
$\sigma_{yo} \{K\} \text{ (m)}$	290	100	142	
$\sigma_{zo} \{K\} \text{ (m)}$	-	-	355	
$\sigma_{xo} \{K\} \text{ (m)}$	290	100	142	
$\tau_K \text{ (sec)}$	25	10	10	
$H_K \text{ (m)}$			2593	
k				

TABLE E-6 (Continued)

MODEL NO. 1 (Layer 1), 1 (Layer 2), 3 (Layer 3)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}^{\{\tau_{oR}\}}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK}^{\{\tau_{oK}\}}$ (deg)	5	0	0	
$\sigma_{ABK}^{\{\tau_{oK}\}}$ (deg)		5	0	
τ_{oK} (sec)	600	600	600	
σ_{ETK} (deg)	4	0	0	
σ_{EBK} (deg)		4	0	
α_K	1	1	1	
β_K	1	1	1	
$\bar{u}_{TK}$ (m sec ⁻¹)	6.70	7.73	10.8	
$\bar{u}_{BK}$ (m sec ⁻¹)		6.70	7.73	
θ_{TK} (deg)	231	258	229	
θ_{BK} (deg)	160	231	258	
z_{TK} (m)	853	1829	3048	
z_{BK} (m)	2	853	1829	
Λ (sec ⁻¹)				
z_{lim} (m)				
t_1 (min)				
t^* (min)				

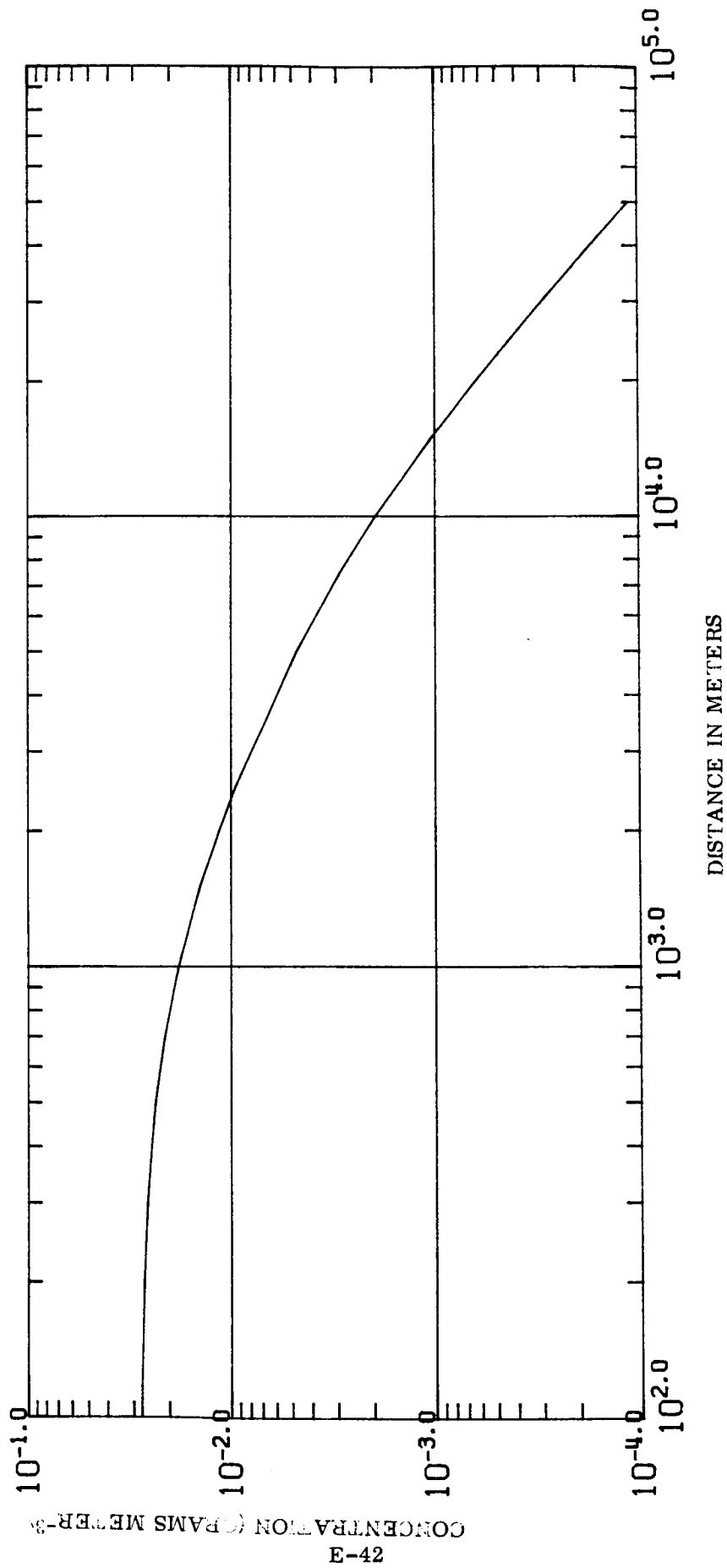


FIGURE E-26. Maximum ground-level concentration for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

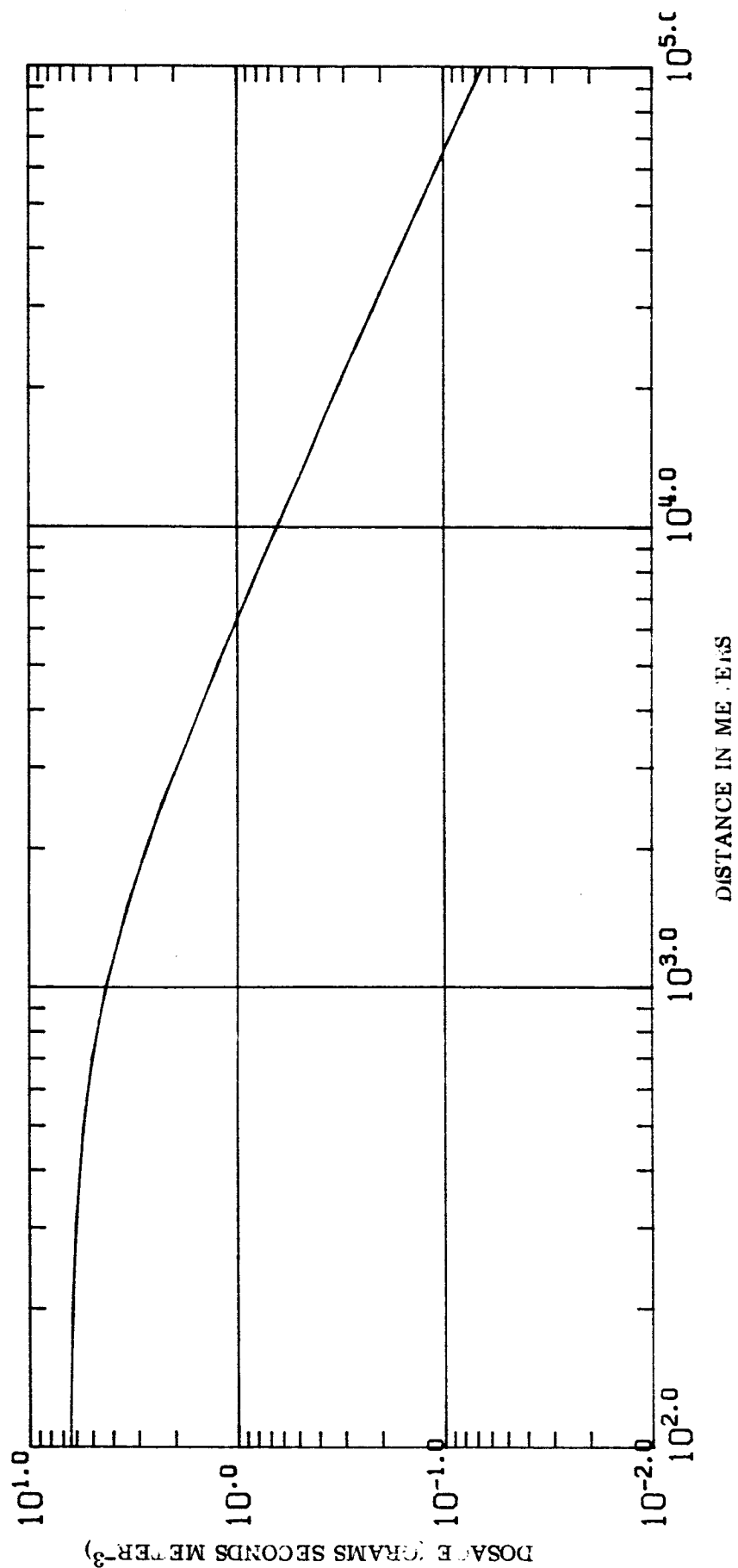


FIGURE F-27. Maximum ground-level dosage for a vehicle destroyed at 1350 meters, 2315 GMT, 27 November 1966.

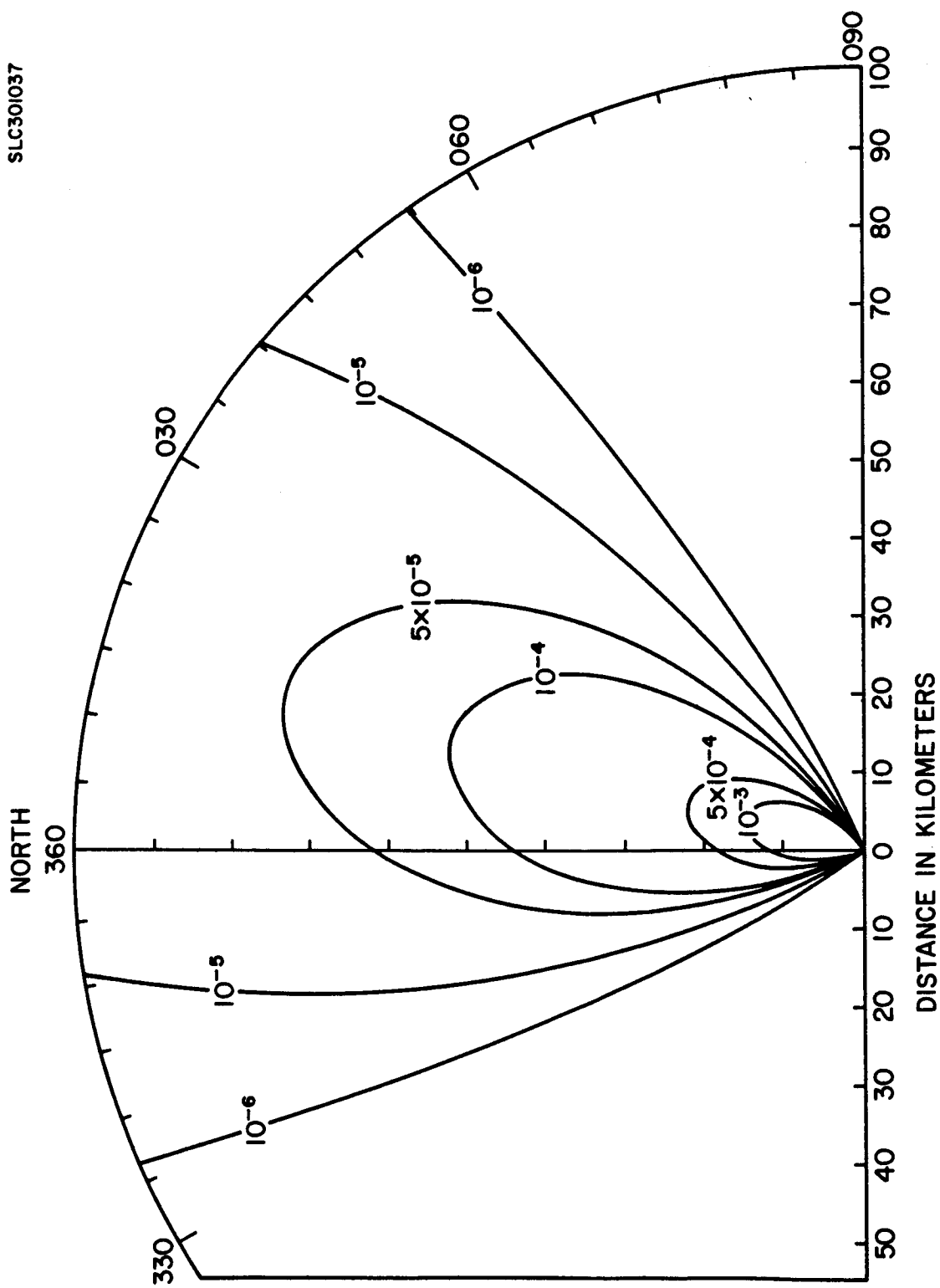


FIGURE E-28. Ground-level concentration isopleths in grams per cubic meter for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

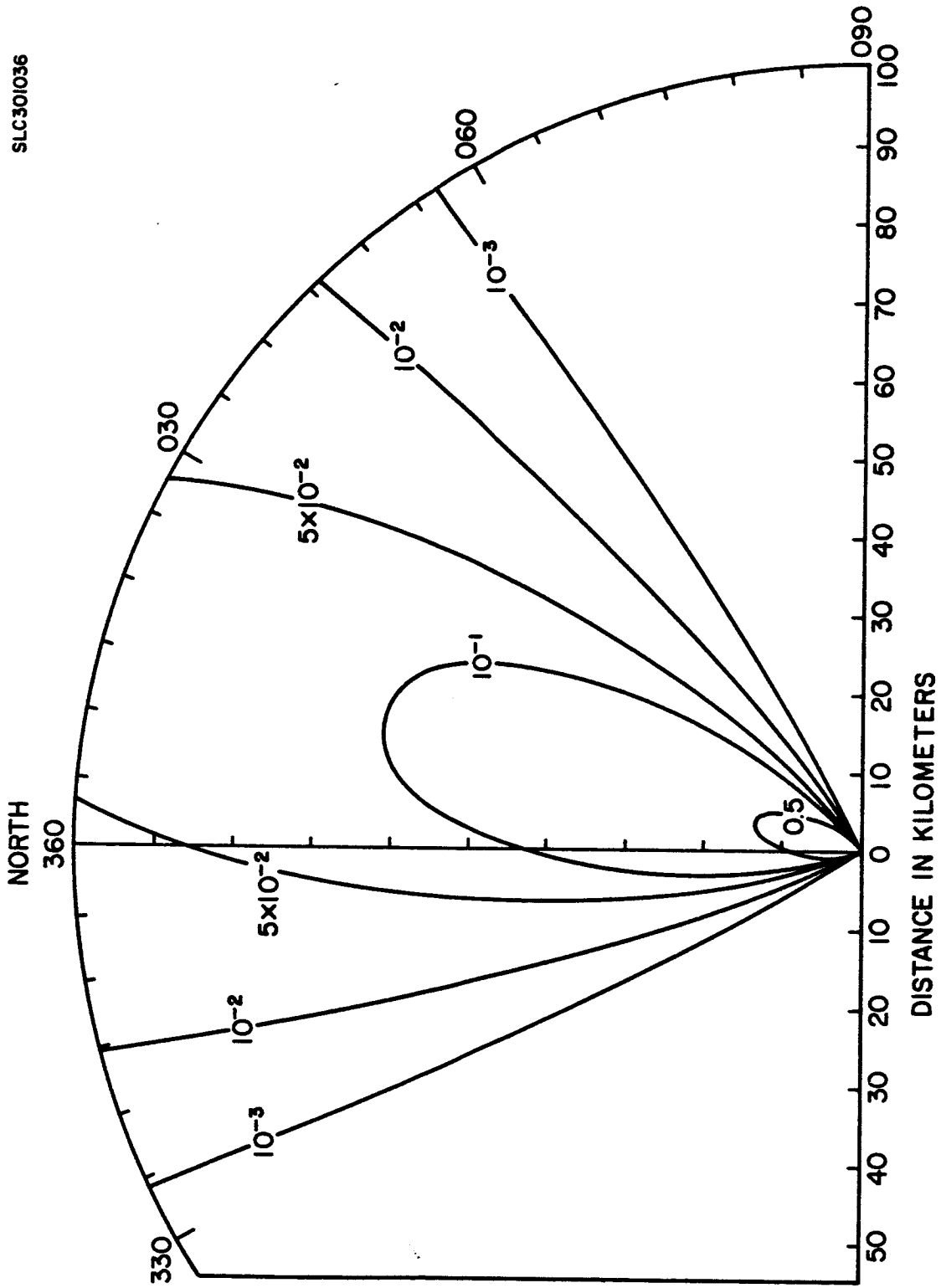


FIGURE E-29. Ground-level dosage isopleths in grams seconds per cubic meter for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

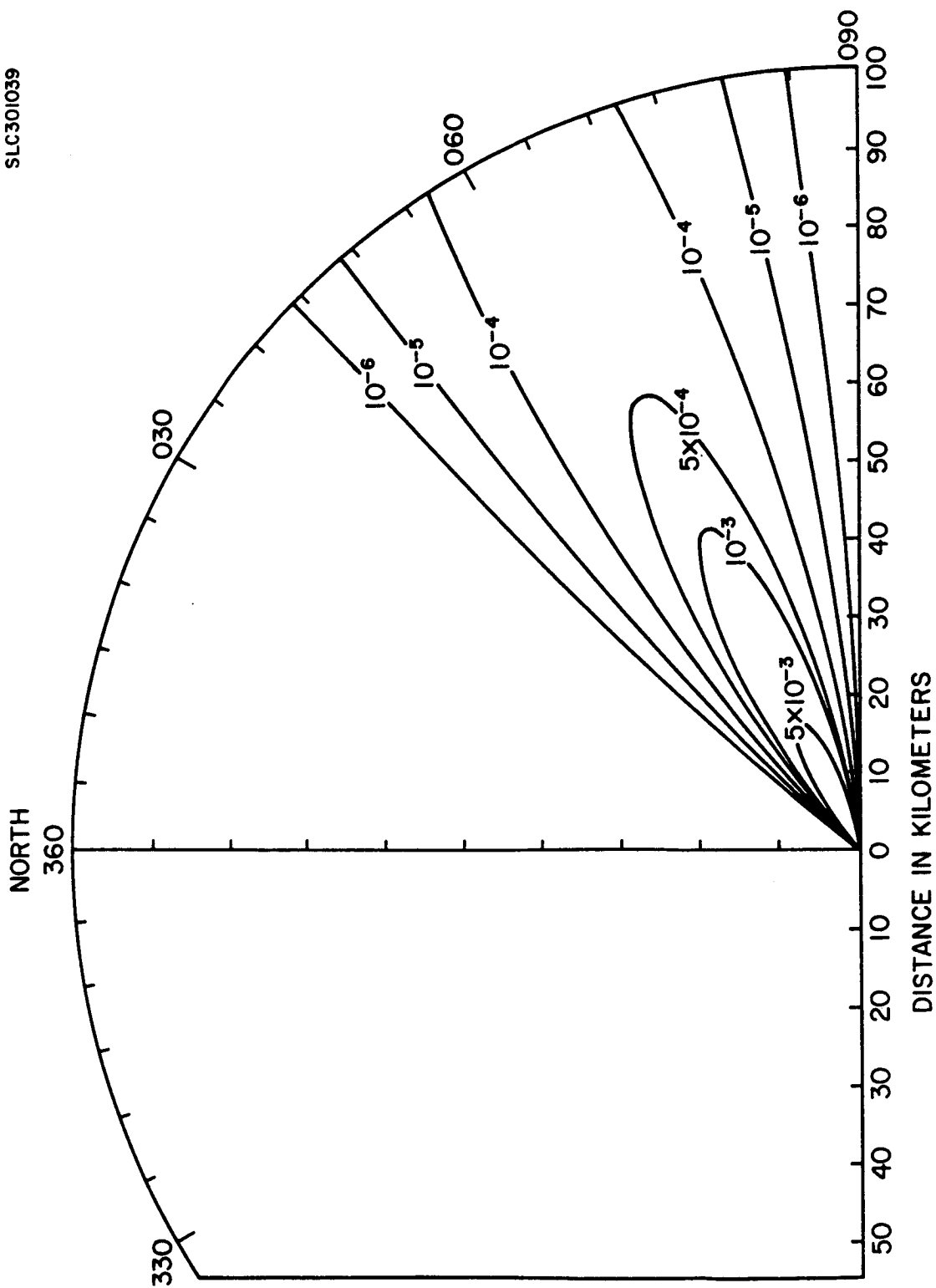


FIGURE E-30. Concentration isopleths in grams per cubic meter at a height of 853 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

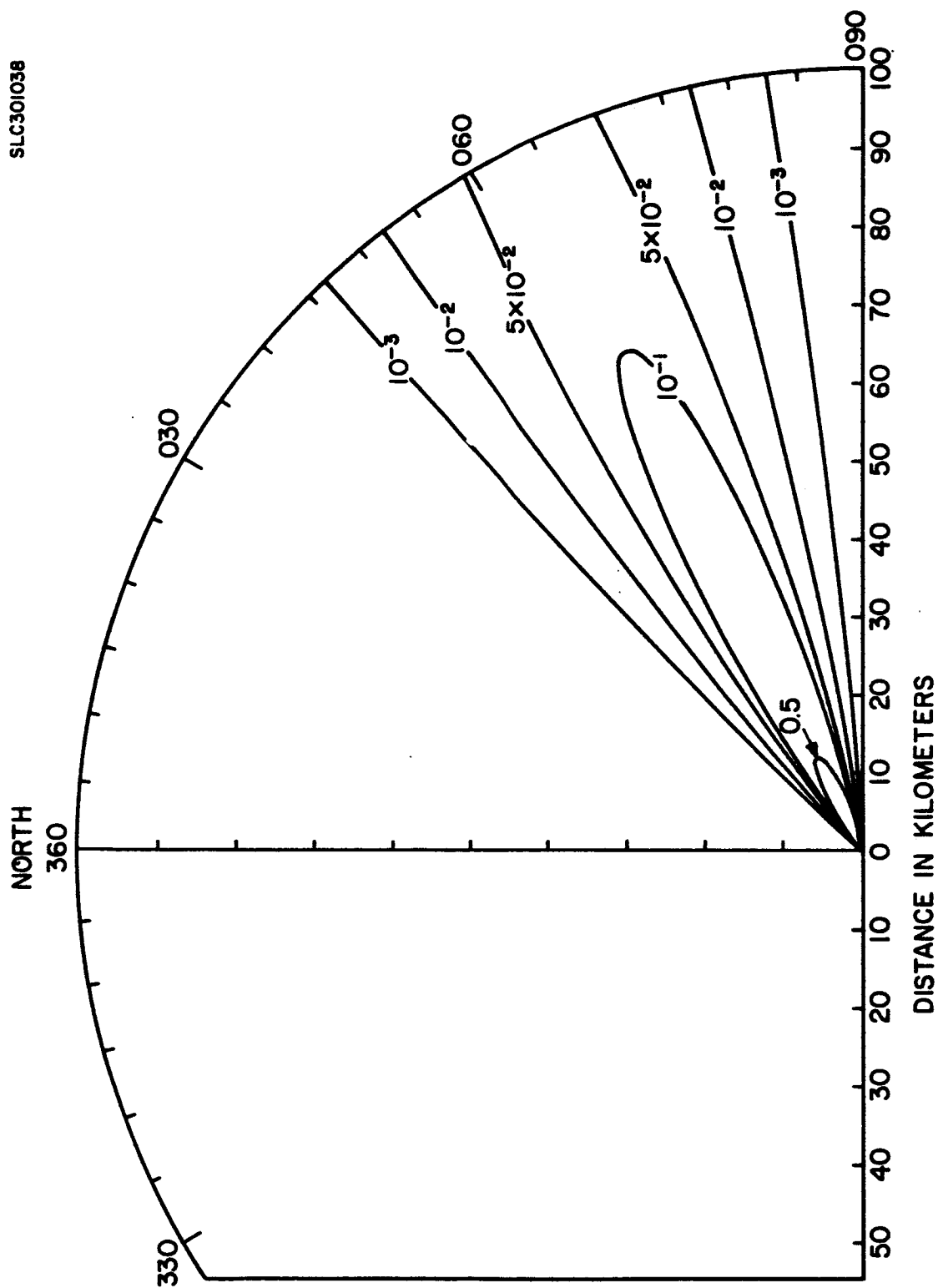


FIGURE E-31. Dosage isopleths in grams seconds per cubic meter at a height of 853 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

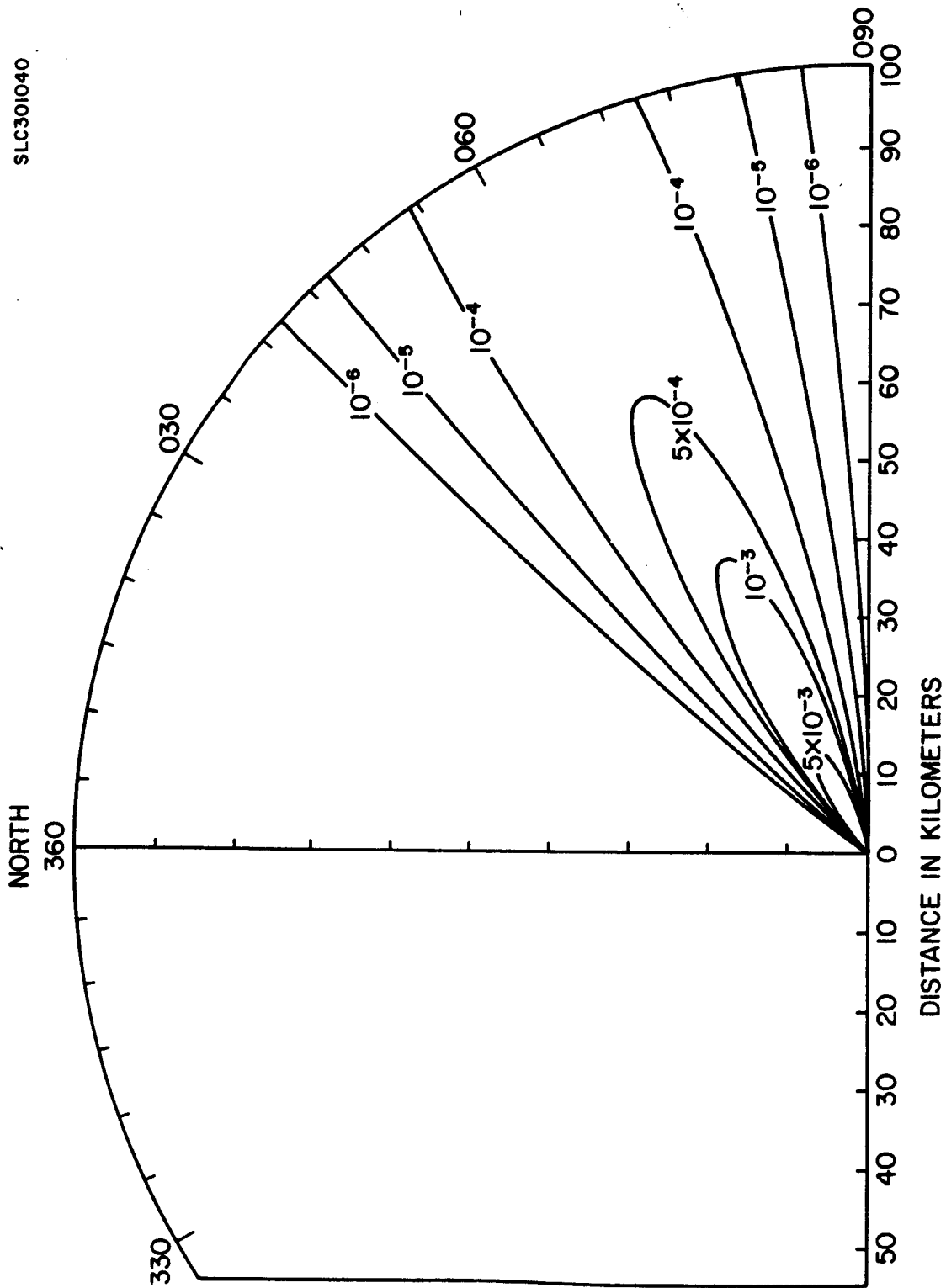


FIGURE E-32. Concentration isopleths in grams per cubic meter at a height of 1829 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

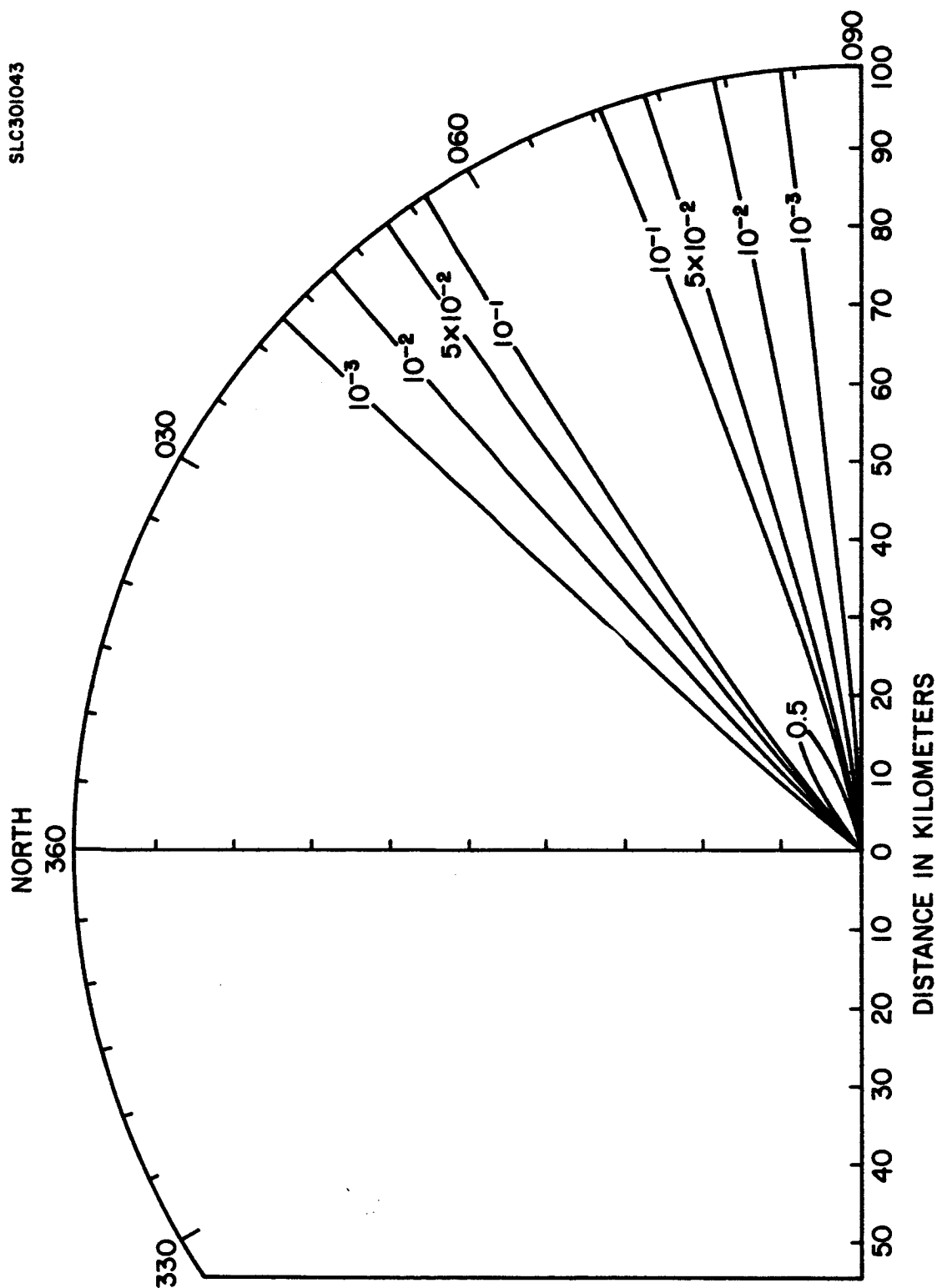


FIGURE E-33. Dosage isopleths in grams seconds per cubic meter at a height of 1829 meters for a vehicle destruct at 1350 meters, 2315 GMT, 27 November 1966.

TABLE E-7
PROGRAM INPUTS

Example Problem: Cold Spill in the Surface Layer for Pre-Cold Front
Situation, 2315 GMT, 27 November 1966

MODEL NO. 3				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
Q_K (g sec ⁻¹)	100			
$\sigma_{yo}\{K\}$ (m)	11.6			
$\sigma_{zo}\{K\}$ (m)	1			
$\sigma_{xo}\{K\}$ (m)	11.6			
τ_K (sec)	600			
H_K (m)	-			
k	-			

TABLE E-7 (Continued)

MODEL NO. 3				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$				
$\sigma_{ABK}\{\tau_{oK}\}$				
τ_{oK} (sec)	600			
σ_{ETK} (deg)	4.5			
σ_{EBK} (deg)				
α_K	1			
β_K	1			
$\bar{u}_{TK}$ (m sec ⁻¹)	6.7			
$\bar{u}_{BK}$ (m sec ⁻¹)				
θ_{TK} (deg)	231			
θ_{BK} (deg)	160			
z_{TK} (m)	853			
z_{BK} (m)	2			
Λ (sec ⁻¹)				
z_{lim} (m)				
t_1 (sec)				
t^* (sec)				

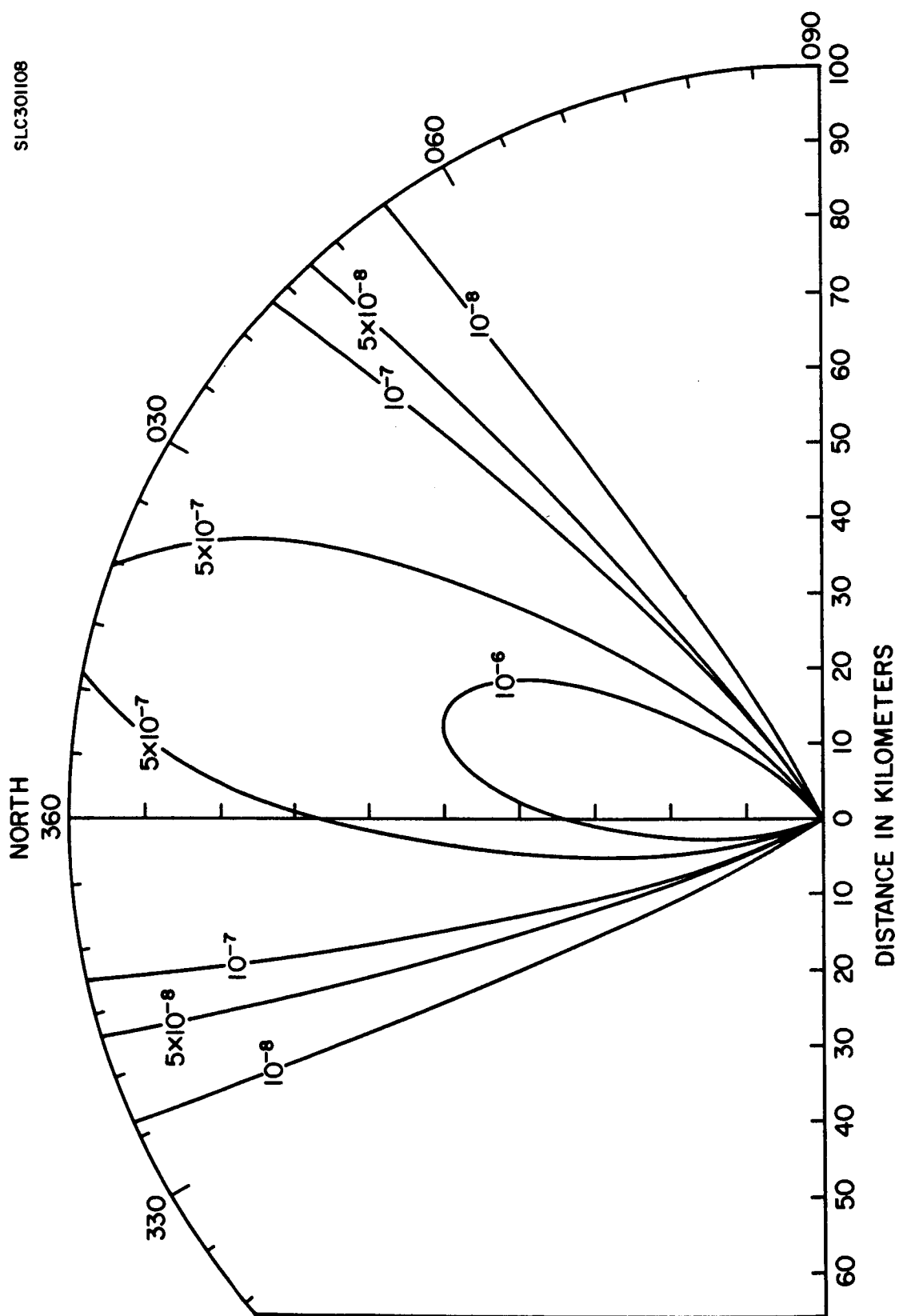


FIGURE E-34. Ground-level concentration isopleths in grams per cubic meter for a large surface spill, 2315 GMT, 27 November 1966.

E. 4 CONCENTRATION AND DOSAGE PATTERNS FOR THE SUMMERTIME BERMUDA HIGH SITUATION - 0515 GMT, 12 MAY 1967

This section contains the results of the example calculations for the various source modes for the summertime Bermuda High regime discussed in Section E. 1. 2.

E. 4. 1 Normal Launch

The source and meteorological inputs for the normal launch calculations are given in Table E-8. Figures E-35 and E-36 respectively show the maximum ground-level concentrations and dosages downwind from the launch pad. Figures E-37 and E-38 show ground-level concentration and dosage isopleths. Concentration and dosage isopleths at the bases of the three layers above the surface layer are shown in Figures E-39 through E-44.

E. 4. 2 Vehicle Destruct at the Surface

The source and meteorological inputs for the surface vehicle destruct example are given in Table E-9. Figures E-45 and E-46 respectively show the maximum ground-level concentrations and dosages downwind from the launch pad. Isopleths of ground-level concentration and dosage, respectively, are shown in Figures E-47 and E-48. Figures E-49 and E-50 show concentration and dosage isopleths at the base of the second layer. Since the bulk of the material released in the surface destruct ascended to the second layer due to buoyancy, the concentrations and dosages in the second layer are much higher than at the surface.

E. 4. 3 Vehicle Destruct Aloft

The source and meteorological inputs for the vehicle destruct aloft example are given in Table E-10. Maximum ground-level concentrations and

TABLE E-8
PROGRAM INPUTS

Example Problem: Normal Launch for Summertime Bermuda
High Situation, 0515 GMT, 12 May 1967

MODEL NO. 1				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
$Q_K \text{ (g m}^{-1}\text{)}$	1.32×10^4	5.24×10^3	3.84×10^3	2.82×10^3
$\sigma_{yo}\{K\} \text{ (m)}$	290	150	100	75
$\sigma_{zo}\{K\} \text{ (m)}$	-	-	-	-
$\sigma_{xo}\{K\} \text{ (m)}$	290	150	100	75
$\tau_K \text{ (sec)}$	28	6	11	11
$H_K \text{ (m)}$	-			
k	-			

TABLE E-8 (Continued)

MODEL NO. 1				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oK}\}$ (deg)	6			
σ_{ER} (deg)	3			
$\bar{u}_R$ (m sec ⁻¹)	3.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	3	0	0	0
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)		3	0	0
τ_{oK} (sec)	600	600	600	600
σ_{ETK} (deg)	1	0	0	0
σ_{EBK} (deg)		1	0	0
α_K	1	1	1	1
β_K	1	1	1	1
$\bar{u}_{TK}$ (m sec ⁻¹)	8.24	7.73	6.70	11.3
$\bar{u}_{BK}$ (m sec ⁻¹)		8.24	7.73	6.70
θ_{TK} (deg)	237	263	303	328
θ_{BK} (deg)	200	237	263	303
z_{TK} (m)	1067	1615	3048	5000
z_{BK} (m)	2	1067	1615	3048
Λ (sec ⁻¹)	-			
z_{lim} (m)	-			
t_1 (sec)	-			
t^* (sec)	-			

TABLE E-9
PROGRAM INPUTS

Example Problem: Vehicle Destruct at Surface for Summertime
Bermuda High Situation, 0515 GMT, 12 May 1967

MODEL NO: 1 (Layer 1), 3 (Layer 2)				
	Layer 1	Layer 2	Layer 3	Layer 4
Parameter	Source Inputs			
$Q_K \text{ (g m}^{-1}\text{)}$	5.63×10^4			
$Q_K \text{ (g)}$		4×10^7		
$\sigma_{yo} \{K\} \text{ (m)}$	35	142		
$\sigma_{zo} \{K\} \text{ (m)}$	-	142		
$\sigma_{xo} \{K\} \text{ (m)}$	35	142		
$\tau_K \text{ (sec)}$	10	10		
$H_K \text{ (m)}$		1127		
k	-			

TABLE E-9 (Continued)

MODEL NO: 1 (Layer 1), 3 (Layer 2)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oK}\}$ (deg)	6			
σ_{ER} (deg)	3			
$\bar{u}_R$ (m sec ⁻¹)	3.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	3	0		
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)		3		
τ_{oK} (sec)	600	600		
σ_{ETK} (deg)	1	0		
σ_{EBK} (deg)		1		
α_K	1	1		
β_K	1	1		
$\bar{u}_{TK}$ (m sec ⁻¹)	8.24	7.73		
$\bar{u}_{BK}$ (m sec ⁻¹)		8.24		
θ_{TK} (deg)	237	263		
θ_{BK} (deg)	200	237		
z_{TK} (m)	1067	1615		
z_{BK} (m)	2	1067		
Λ (sec ⁻¹)	-			
z_{lim} (m)	-			
t_1 (sec)	-			
t^* (sec)	-			

TABLE E-10

PROGRAM INPUTS

Example Problem: Vehicle Destruct Aloft for Summertime
Bermuda High Situation, 0515 GMT,
12 May 1967

MODEL NO. 1 (Layer 1), 1 (Layer 2), 3 (Layer 3)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
$Q_K \text{ (g m}^{-1}\text{)}$	1.32×10^4	1.72×10^4		
$Q_K \text{ (g)}$			7.64×10^7	
$\sigma_{yo}\{K\} \text{ (m)}$	290	100	142	
$\sigma_{zo}\{K\} \text{ (m)}$	-	-	400	
$\sigma_{xo}\{K\} \text{ (m)}$	290	100	142	
$\tau_K \text{ (sec)}$	28	10	10	
$H_K \text{ (m)}$			2473	
k	-			

TABLE E-10 (Continued)

MODEL NO. 1 (Layer 1), 1 (Layer 2), 3 (Layer 3)				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	6			
σ_{ER} (deg)	3			
$\bar{u}_R$ (m sec ⁻¹)	3.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	3	0	0	
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)		3	0	
τ_{oK} (sec)	600	600	600	
σ_{ETK} (deg)	1	0	0	
σ_{EBK} (deg)		1	0	
α_K	1	1	1	
β_K	1	1	1	
$\bar{u}_{TK}$ (m sec ⁻¹)	8.24	7.73	6.70	
$\bar{u}_{BK}$ (m sec ⁻¹)		8.24	7.73	
θ_{TK} (deg)	237	263	303	
θ_{BK} (deg)	200	237	263	
z_{TK} (m)	1067	1615	3048	
z_{BK} (m)	2	1067	1615	
Λ (sec ⁻¹)	-			
z_{lim} (m)	-			
t_1 (sec)	-			
t^* (sec)	-			

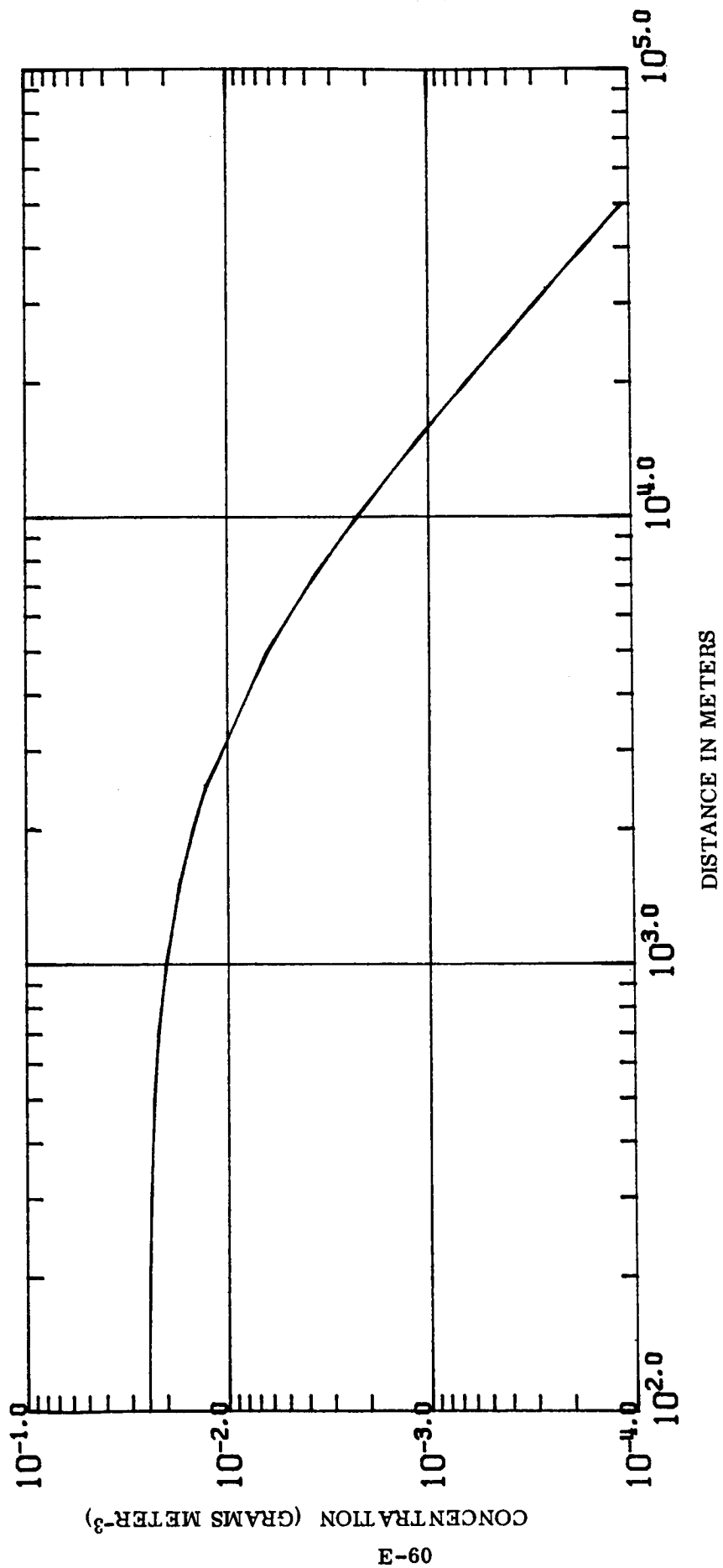


FIGURE E-35. Maximum ground-level concentration for a normal launch, 0515 GMT, 12 May 1967.

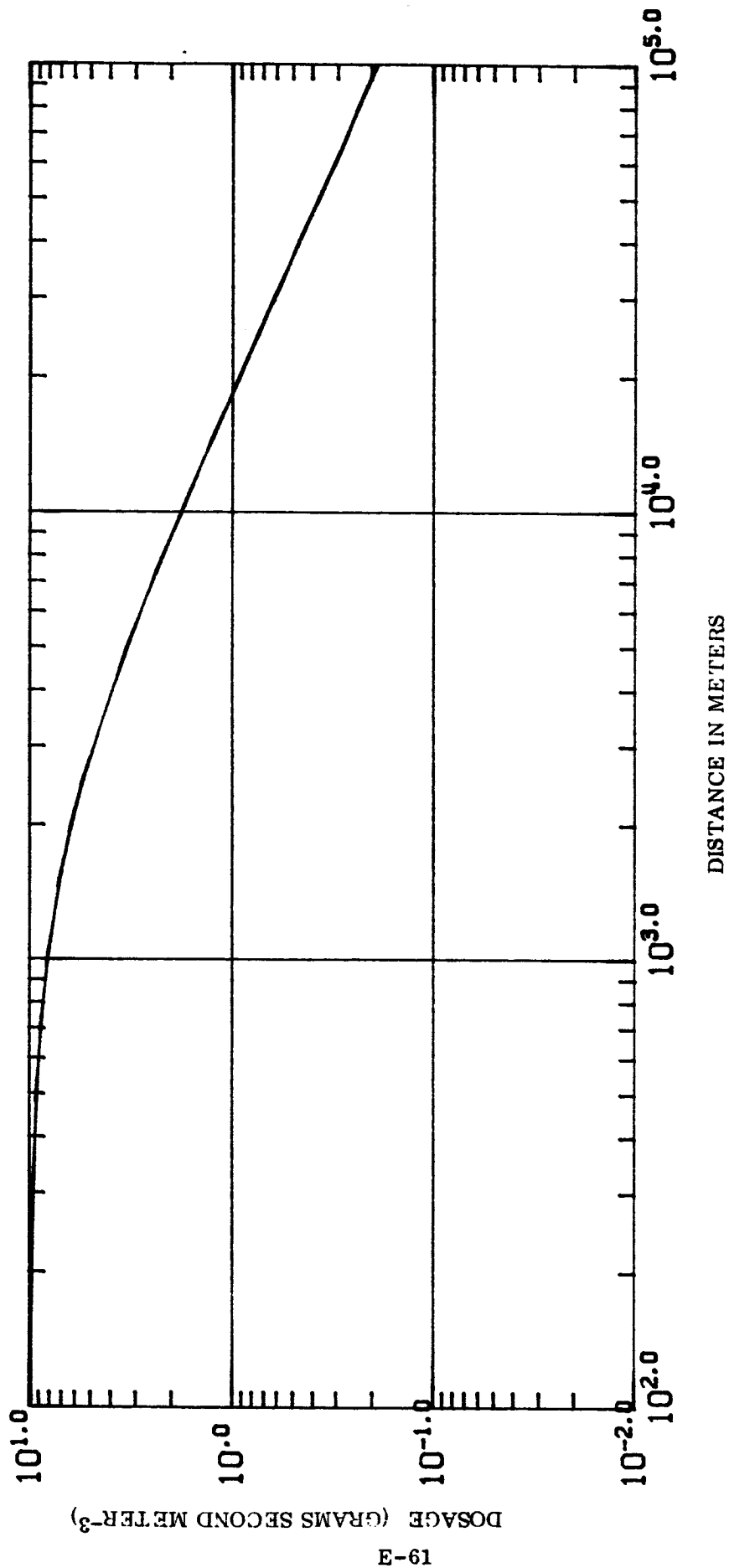


FIGURE E-36. Maximum ground-level dosage for a normal launch, 0515 GMT, 12 May 1967.

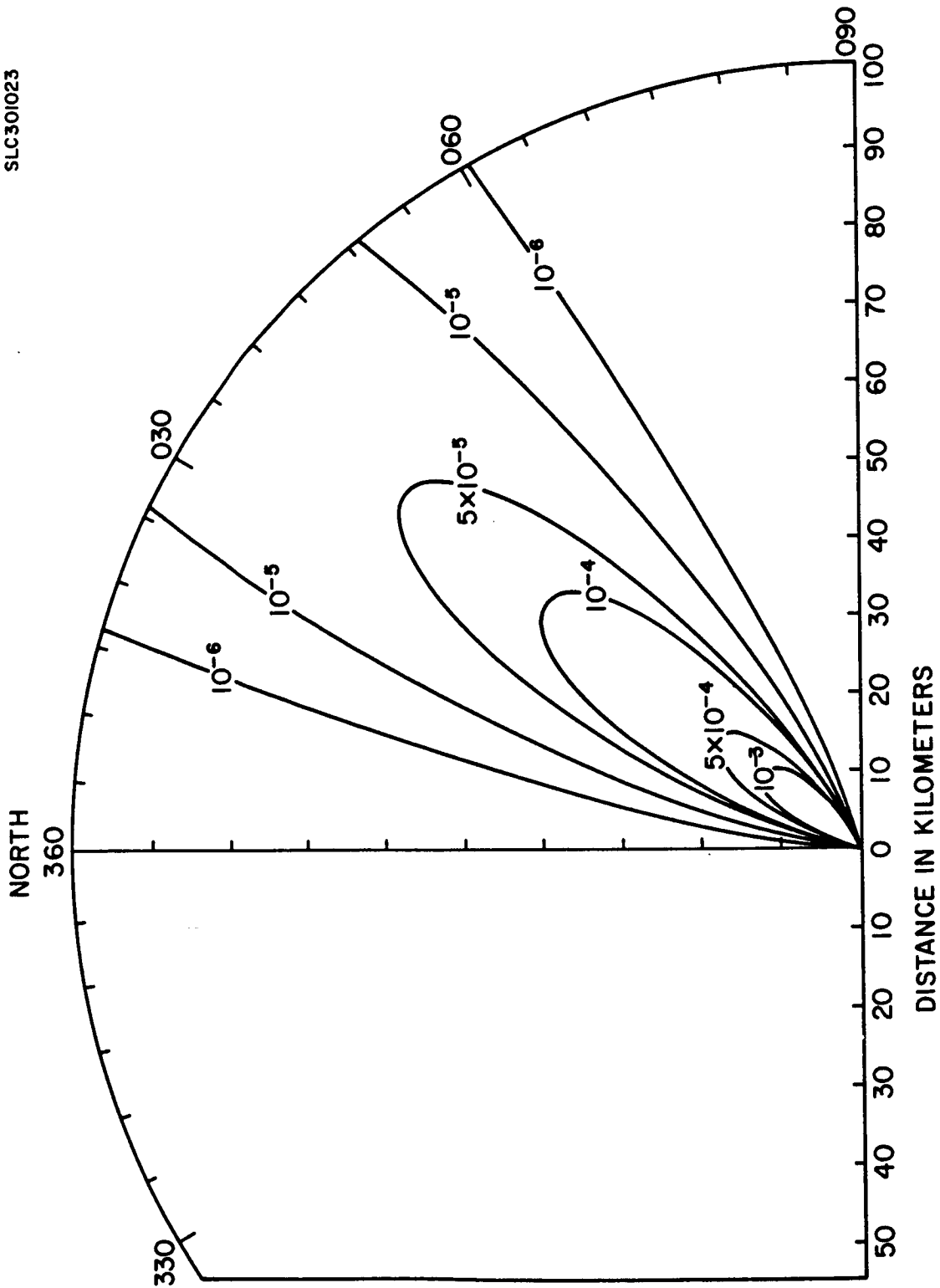


FIGURE E-37. Ground-level concentration isopleths in grams per cubic meter for a normal launch, 0515 GMT, 12 May 1967.

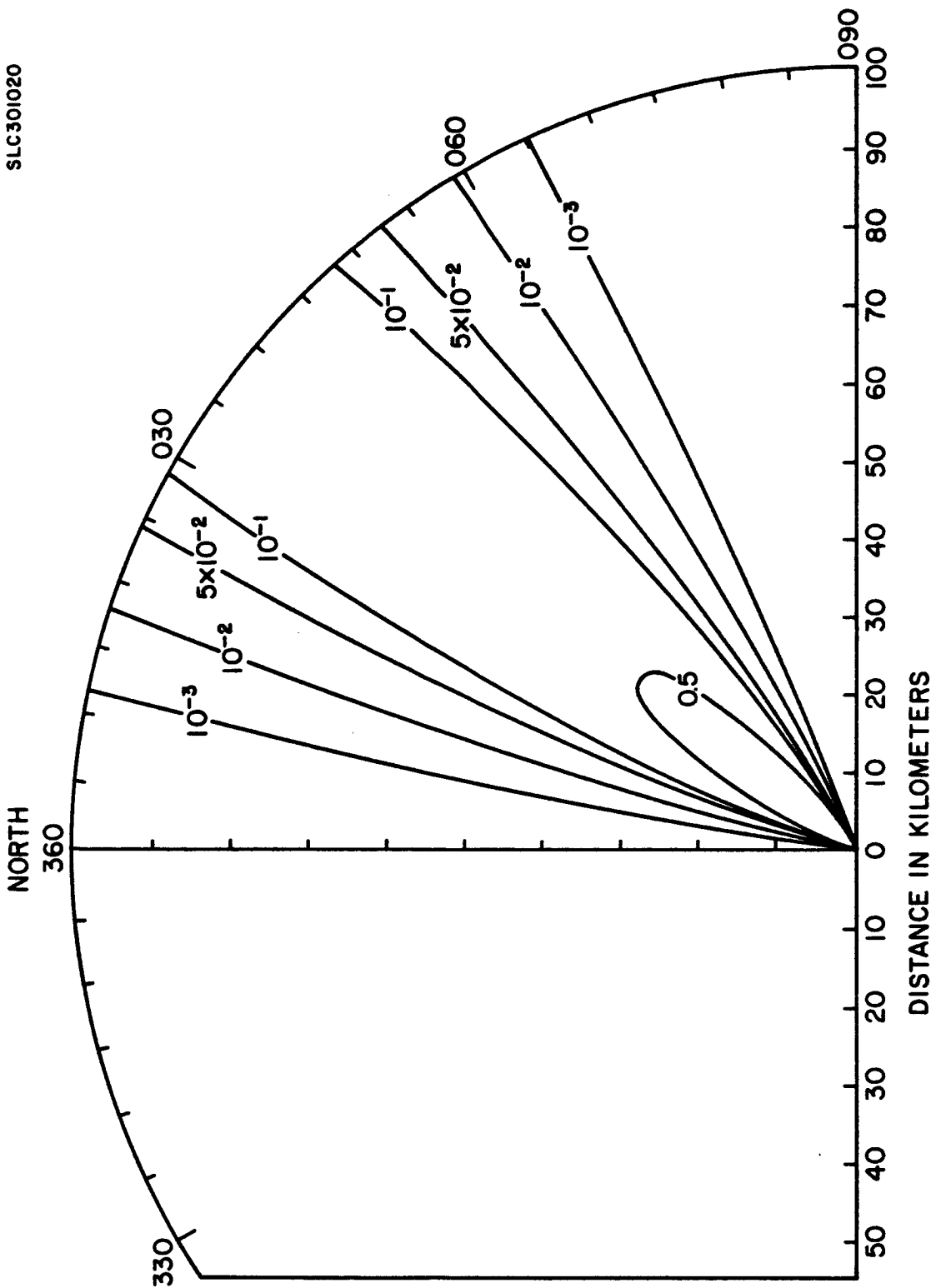


FIGURE E-38. Ground-level dosage isopleths in grams seconds per cubic meter for a normal launch, 0515 GMT, 12 May 1967.

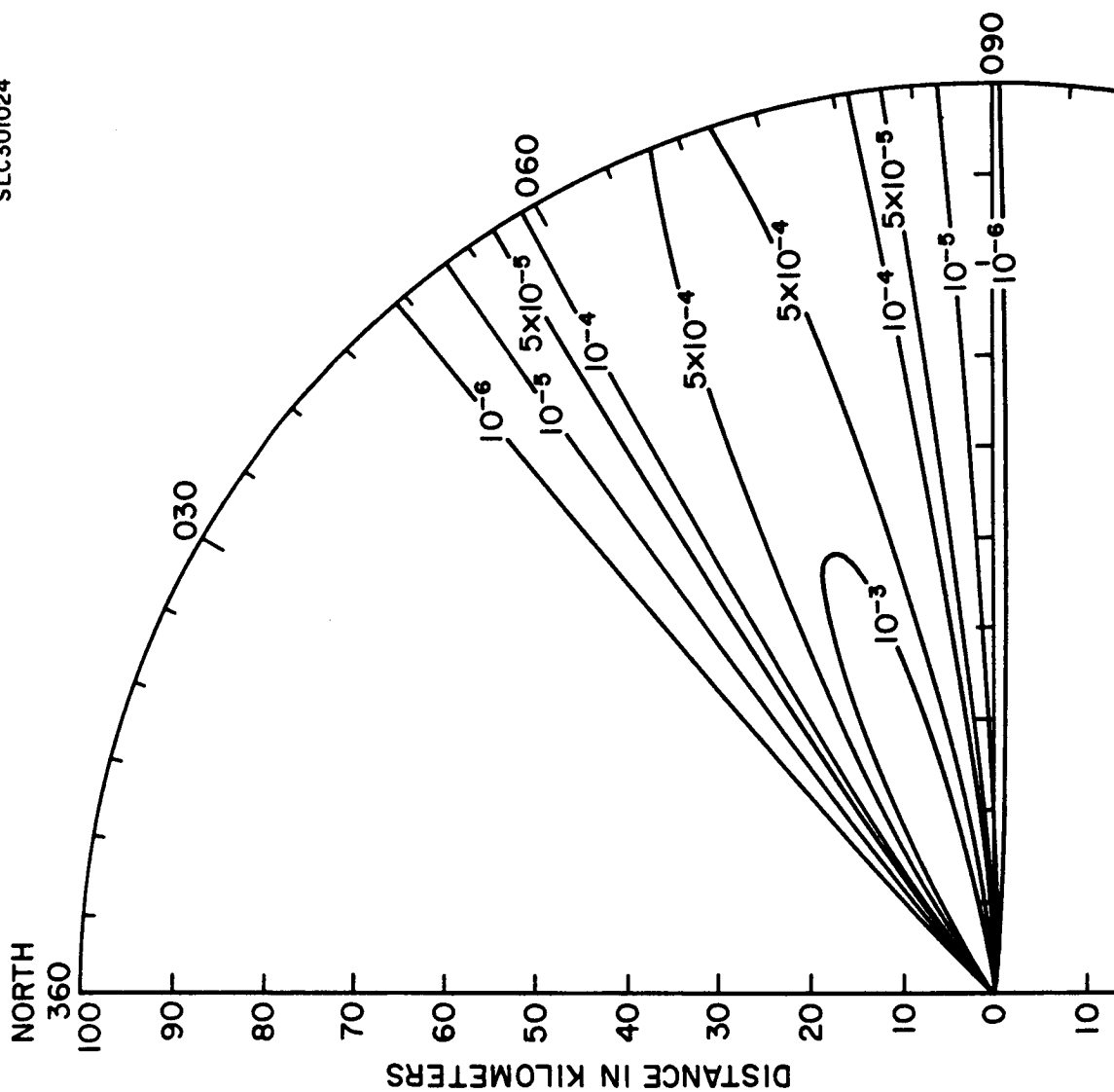


FIGURE E-39. Concentration isopleths in grams per cubic meter at a height of 1067 meters for a normal launch, 0515 GMT, 12 May 1967.

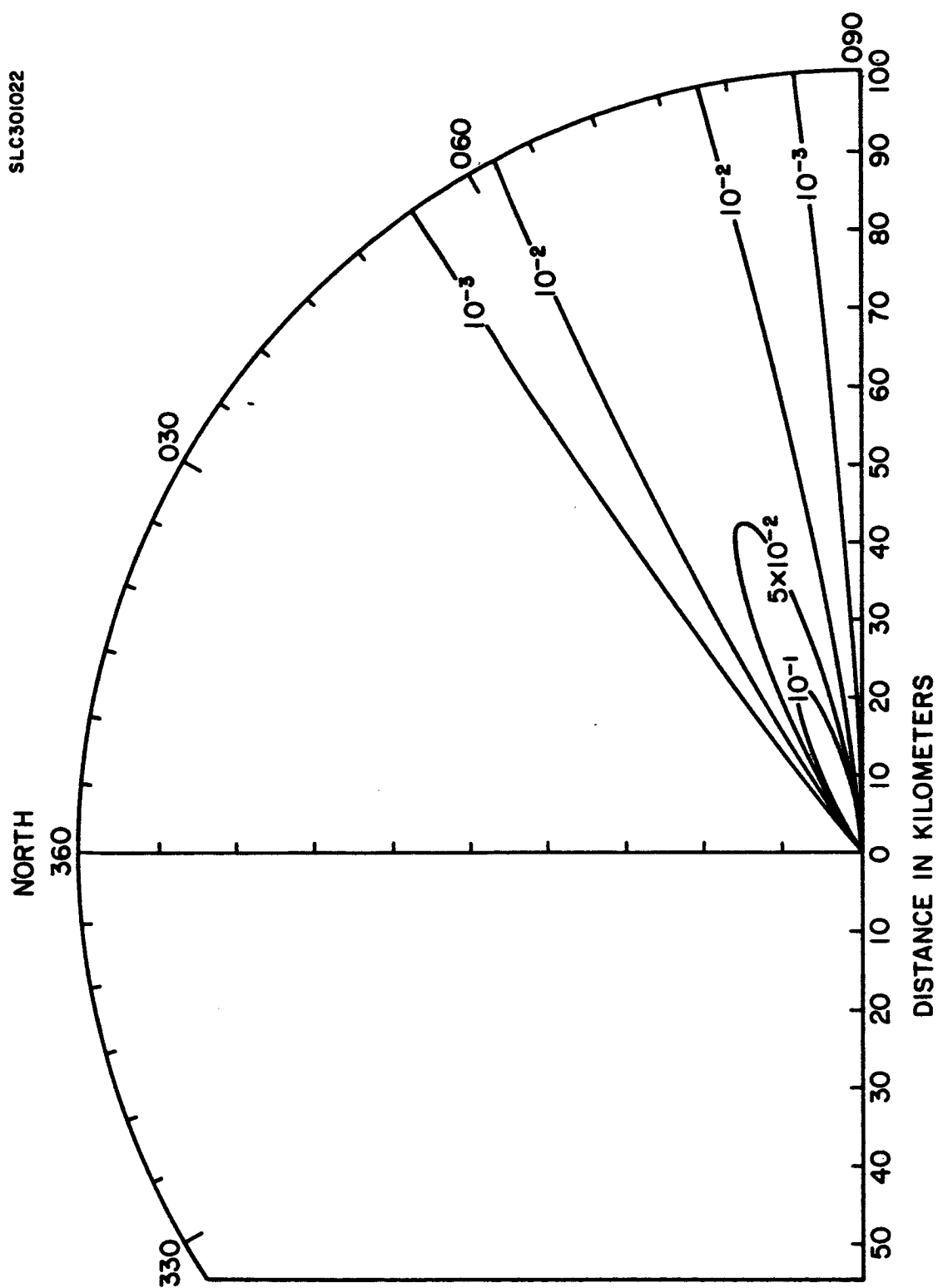


FIGURE E-40. Dosage isopleths in grams seconds per cubic meter at a height of 1067 meters for a normal launch, 0515 GMT, 12 May 1967.

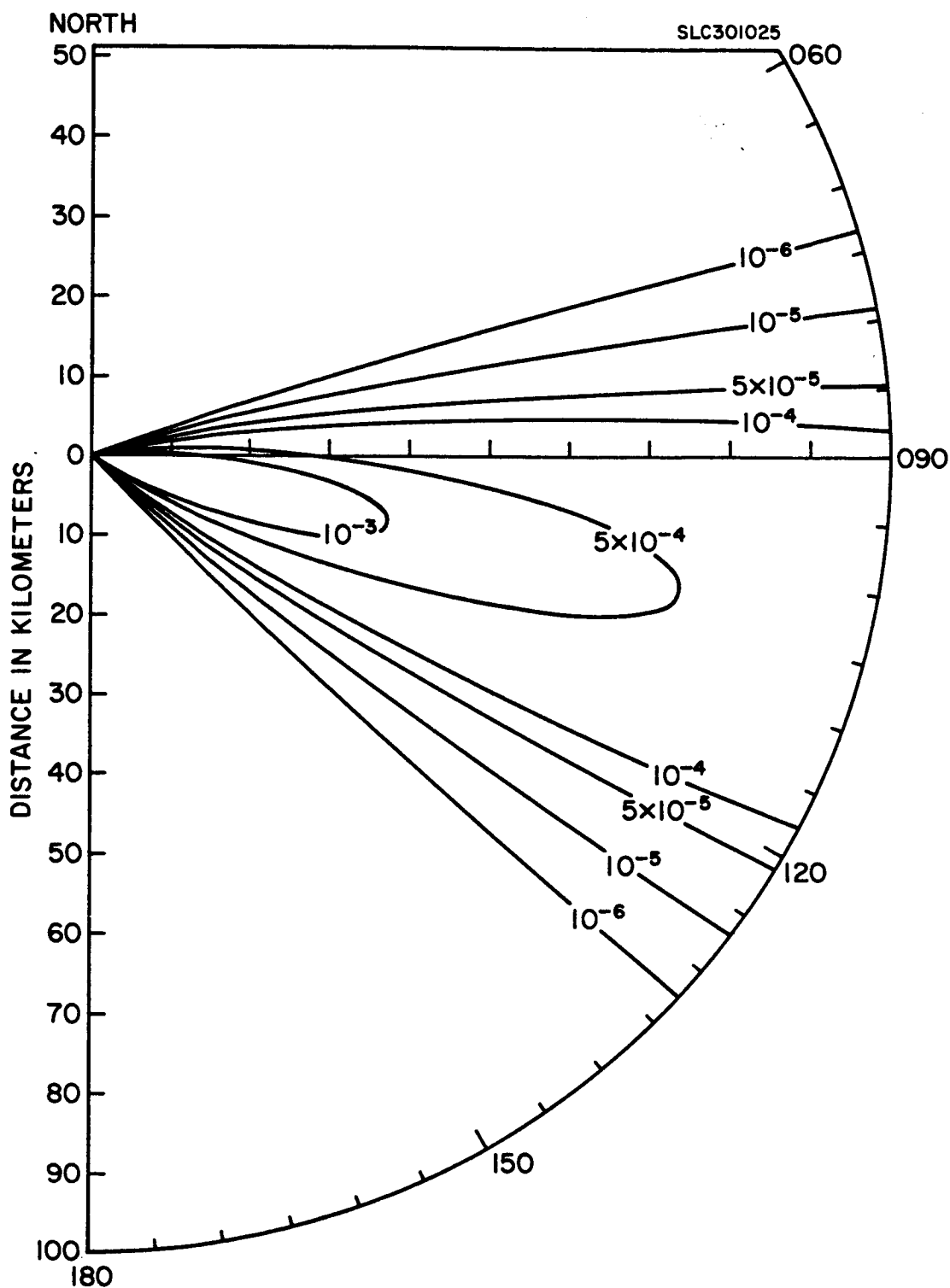


FIGURE E-41. Concentration isopleths in grams per cubic meter at a height of 1615 meters for a normal launch, 0515 GMT, 12 May 1967.

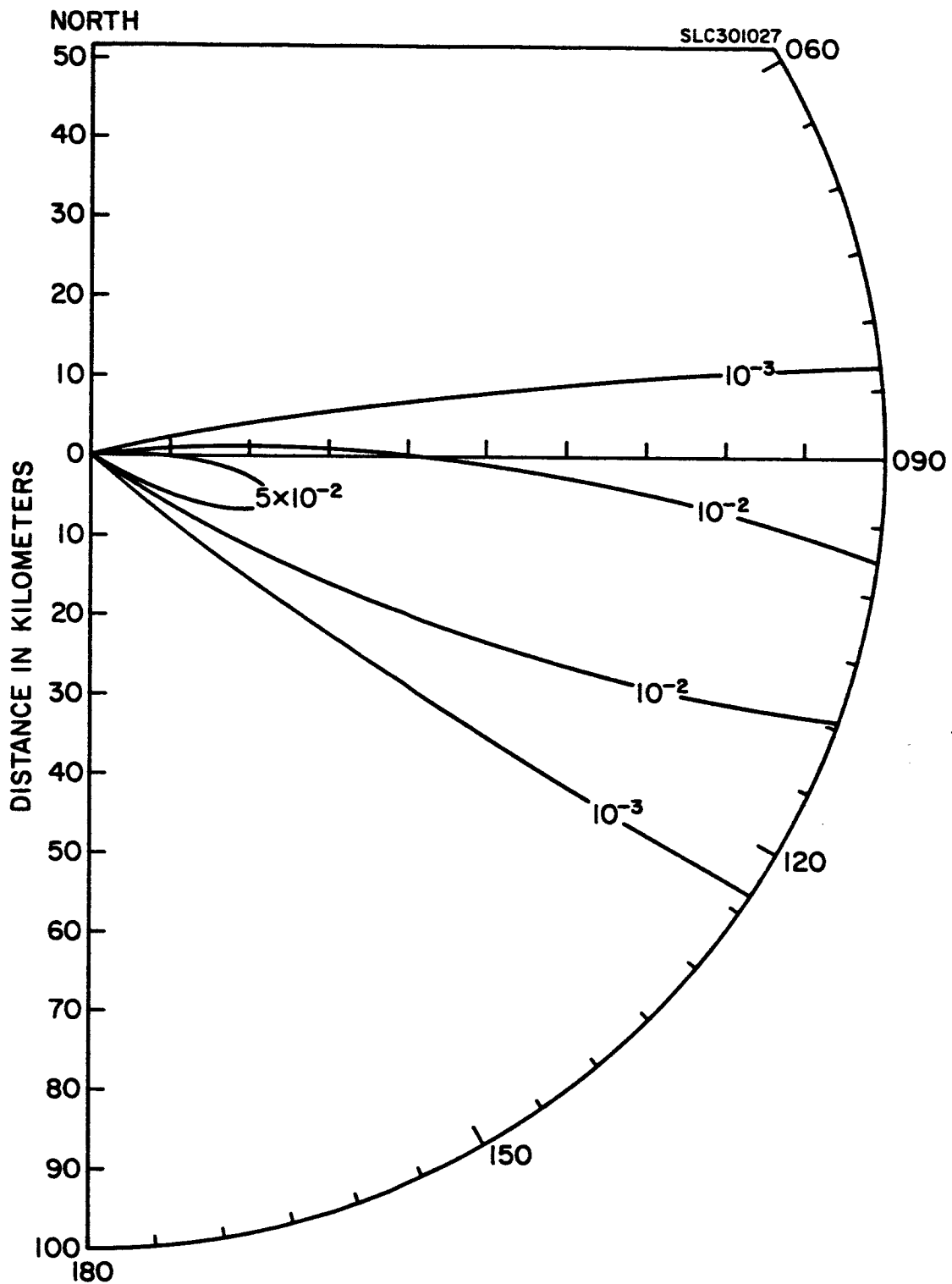


FIGURE E-42. Dosage isopleths in grams seconds per cubic meter at a height of 1615 meters for a normal launch, 0515 GMT, 12 May 1967.

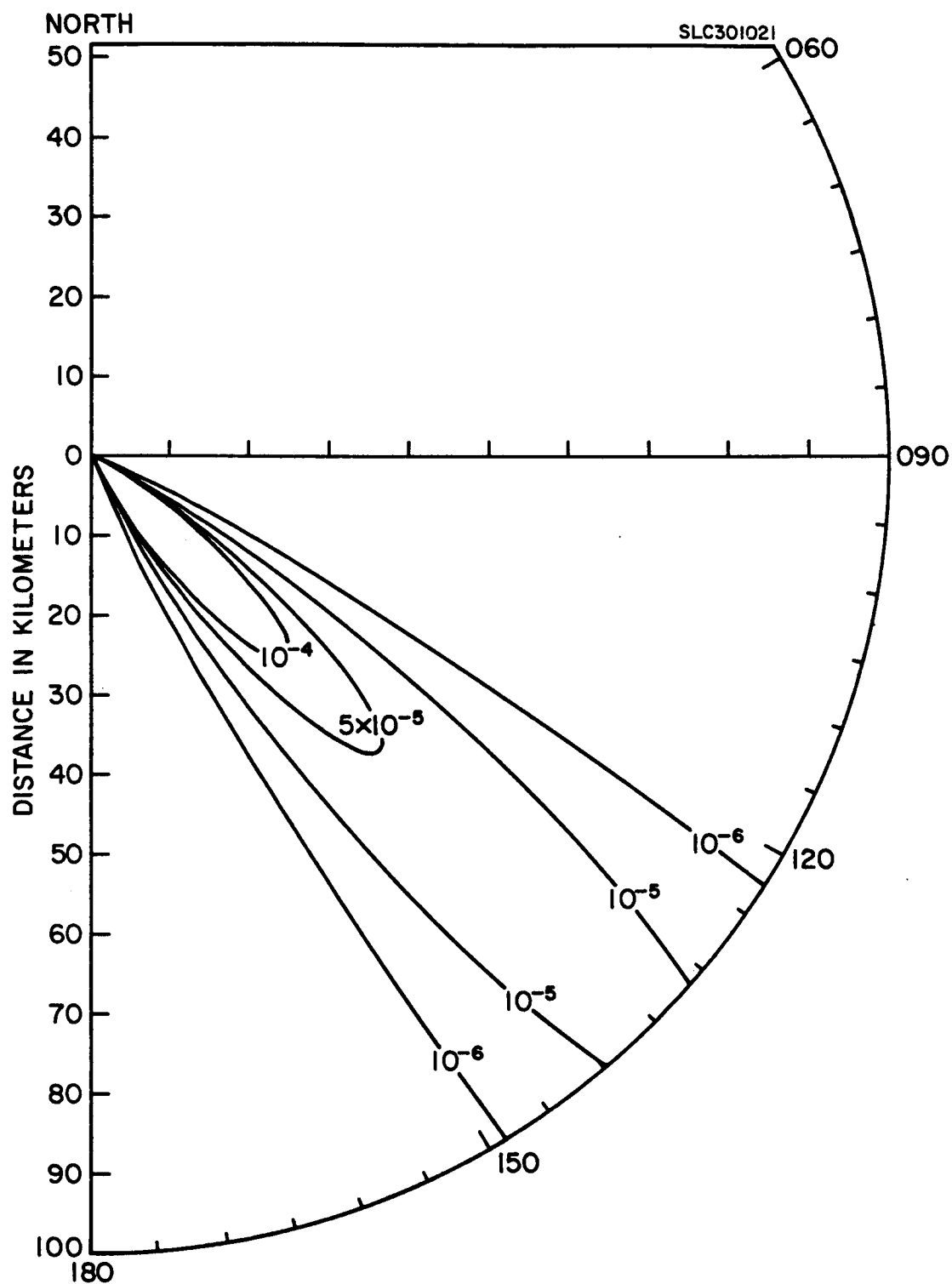


FIGURE E-43. Concentration isopleths in grams per cubic meter at a height of 3048 meters for a normal launch, 0515 GMT, 12 May 1967.

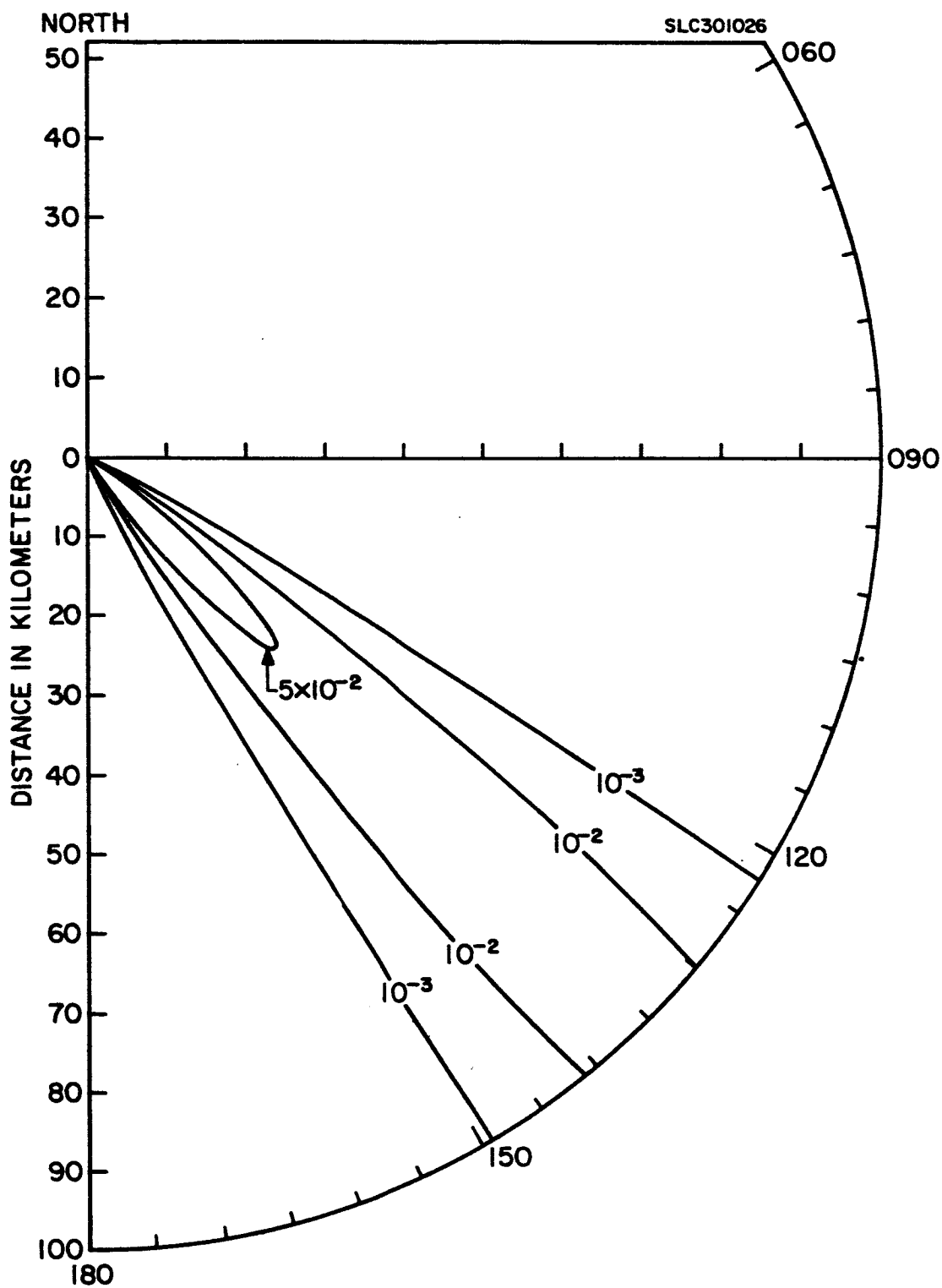


FIGURE E-44. Dosage isopleths in grams seconds per cubic meter at a height of 3048 meters for a normal launch, 0515 GMT, 12 May 1967.

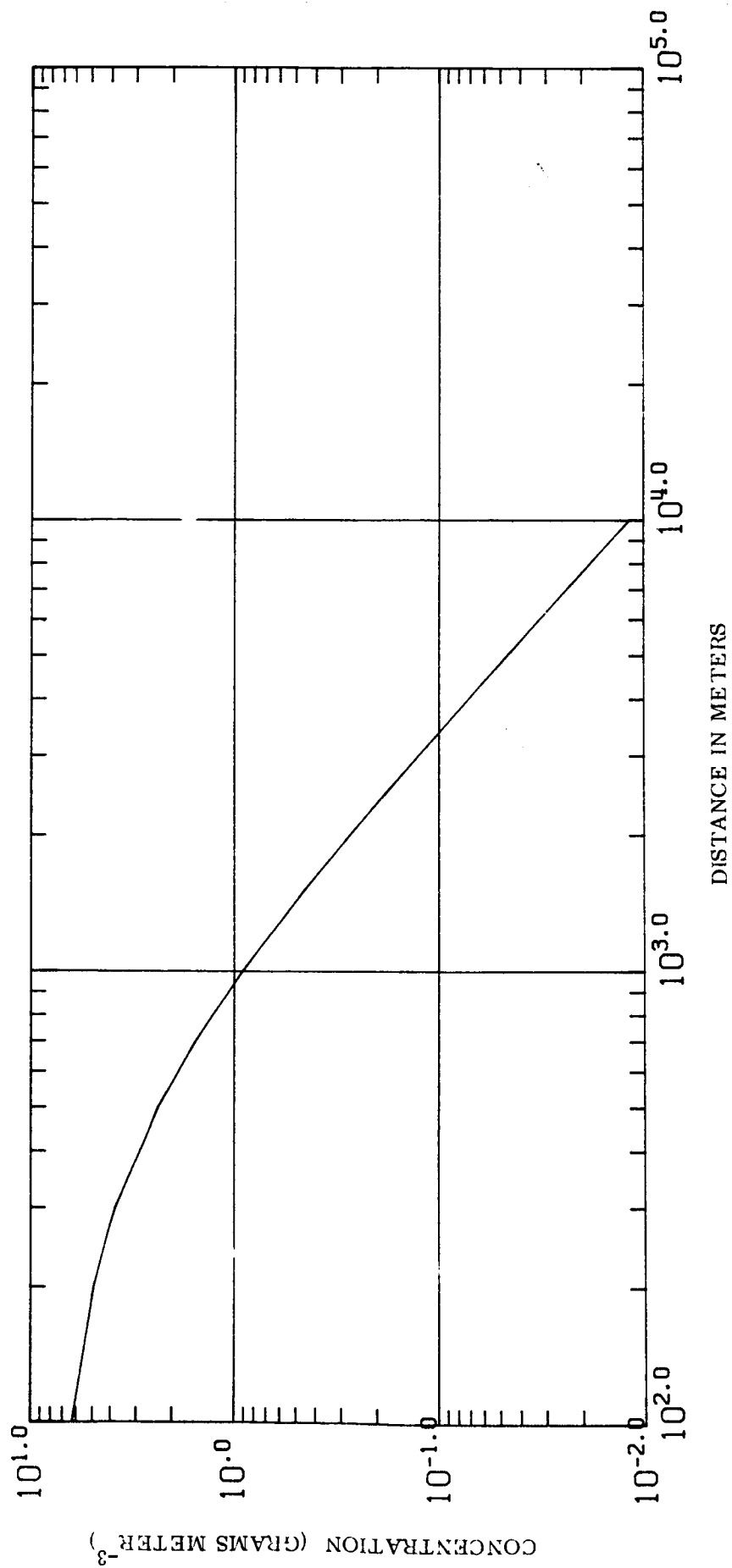


FIGURE E-45. Maximum ground-level concentration for a vehicle destruct on pad, 0515 GMT, 12 May 1967.

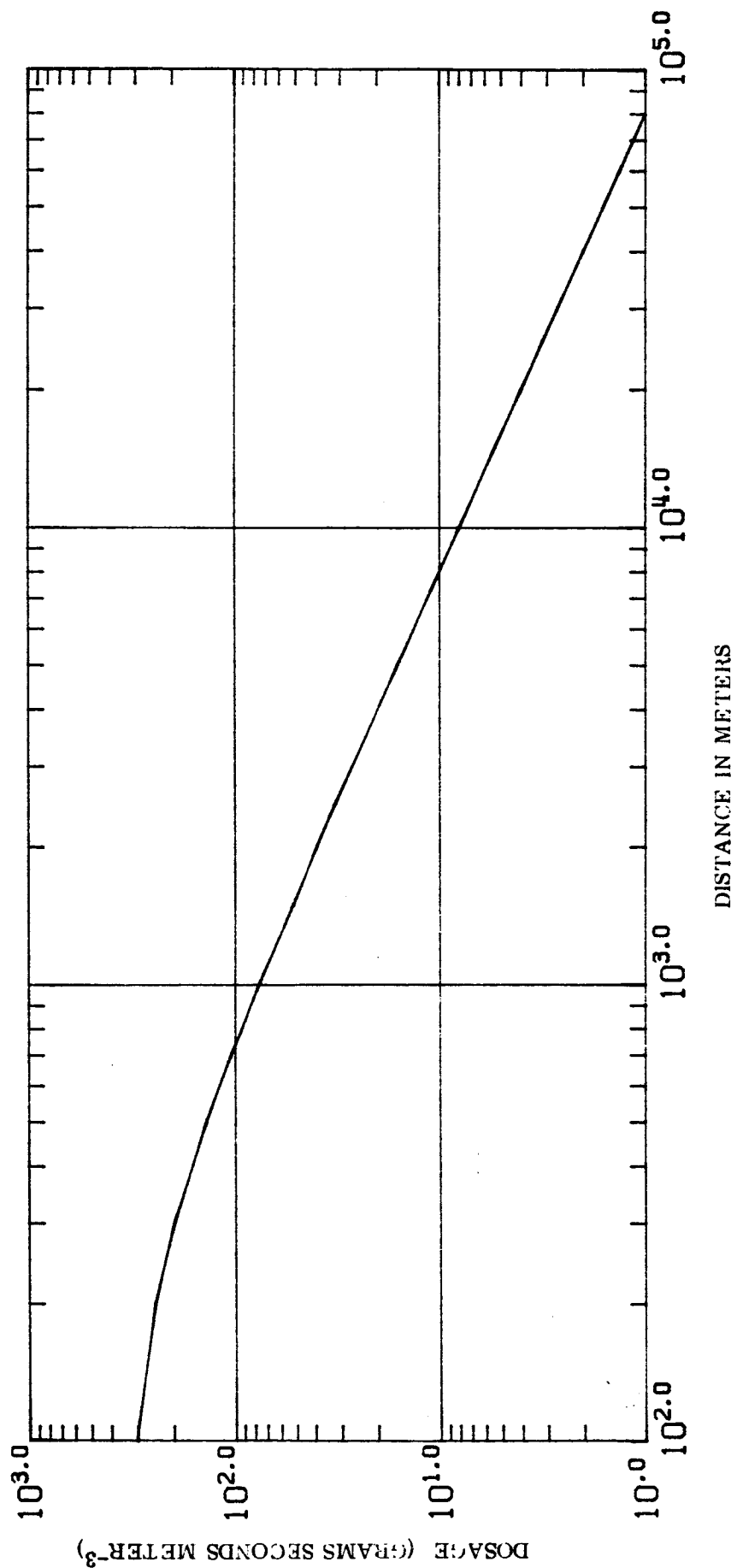


FIGURE E-46. Maximum ground-level dosage for a vehicle destruct on pad, 0515 GMT, 12 May 1967.

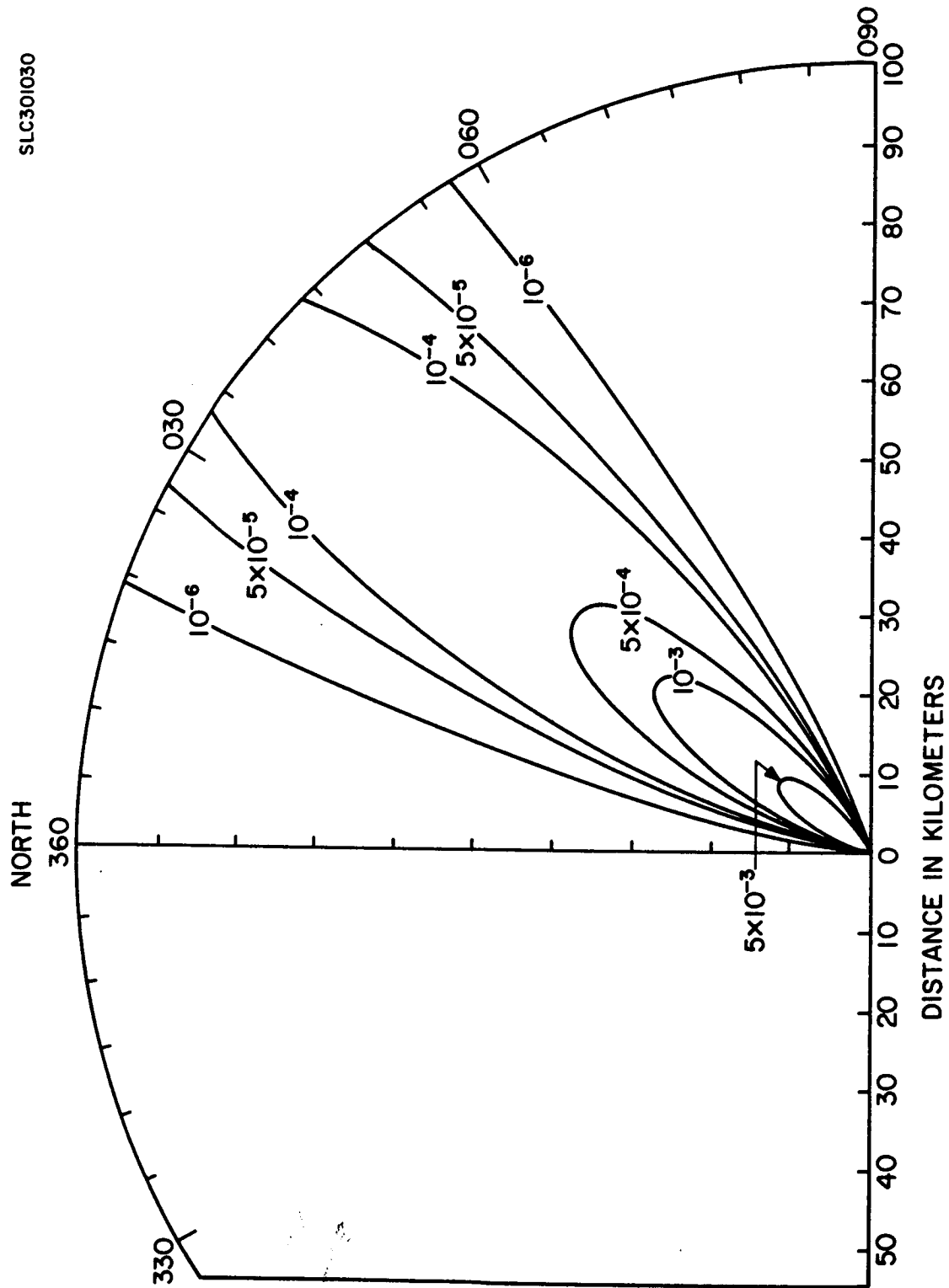


FIGURE E-47. Ground-level concentration isopleths in grams per cubic meter for a vehicle destruct on the pad, 0515 GMT, 12 May 1967.

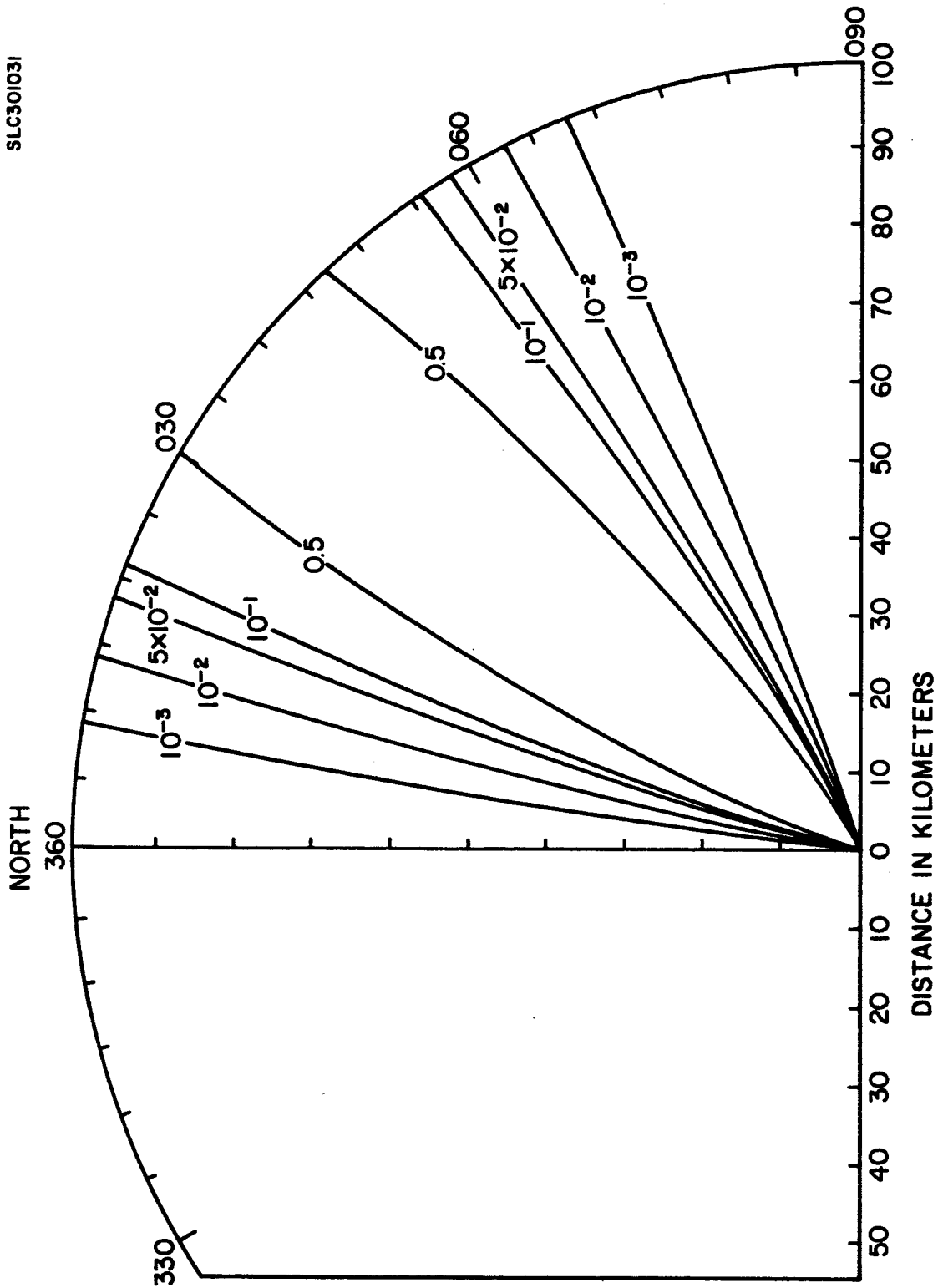


FIGURE E-48. Ground-level dosage isopleths in grams seconds per cubic meter for a vehicle destruct on the pad, 0515 GMT, 12 May 1967.

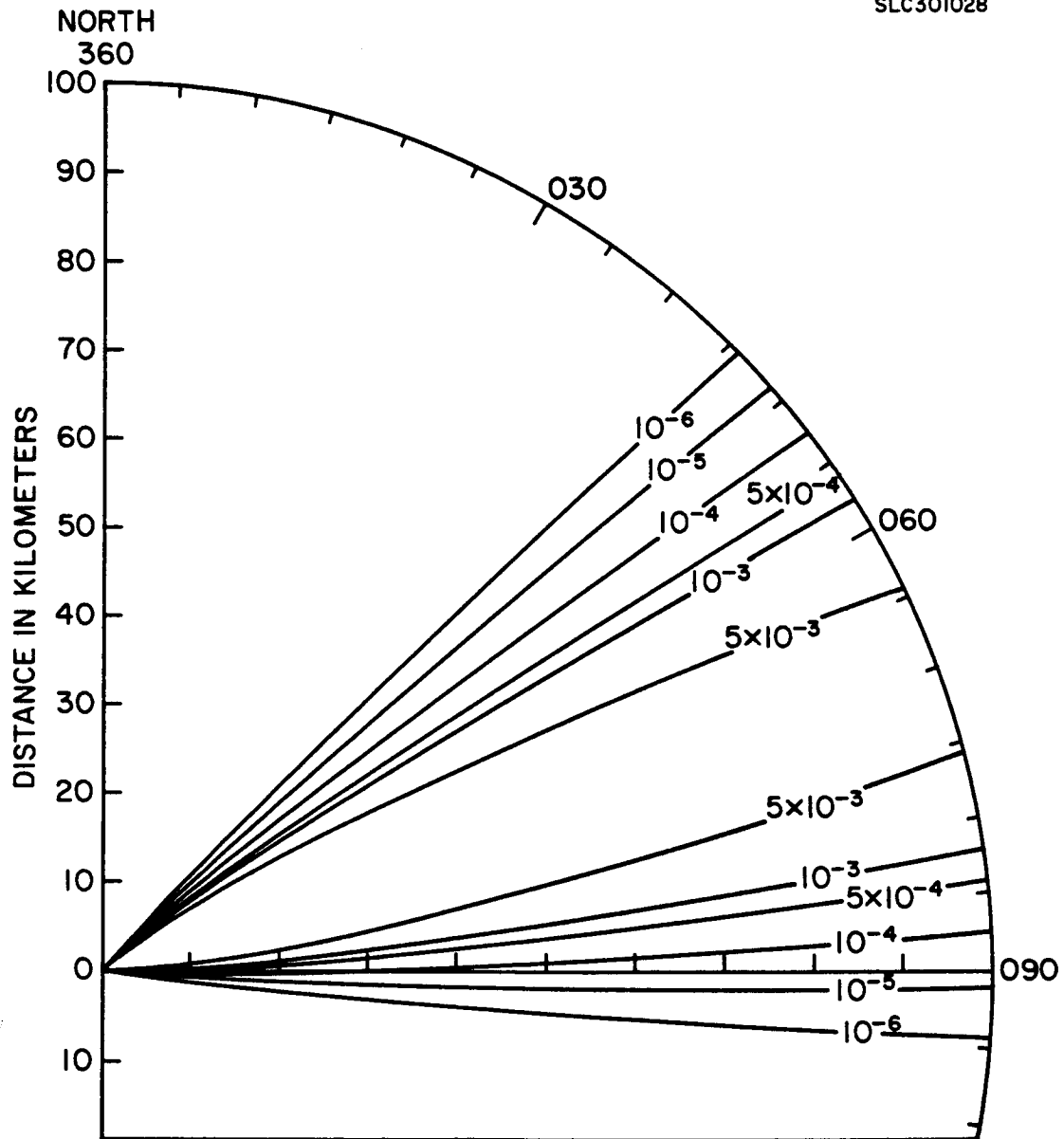


FIGURE E-49. Concentration isopleths in grams per cubic meter at a height of 1067 meters for a vehicle destruct on the pad, 0515 GMT, 12 May 1967.

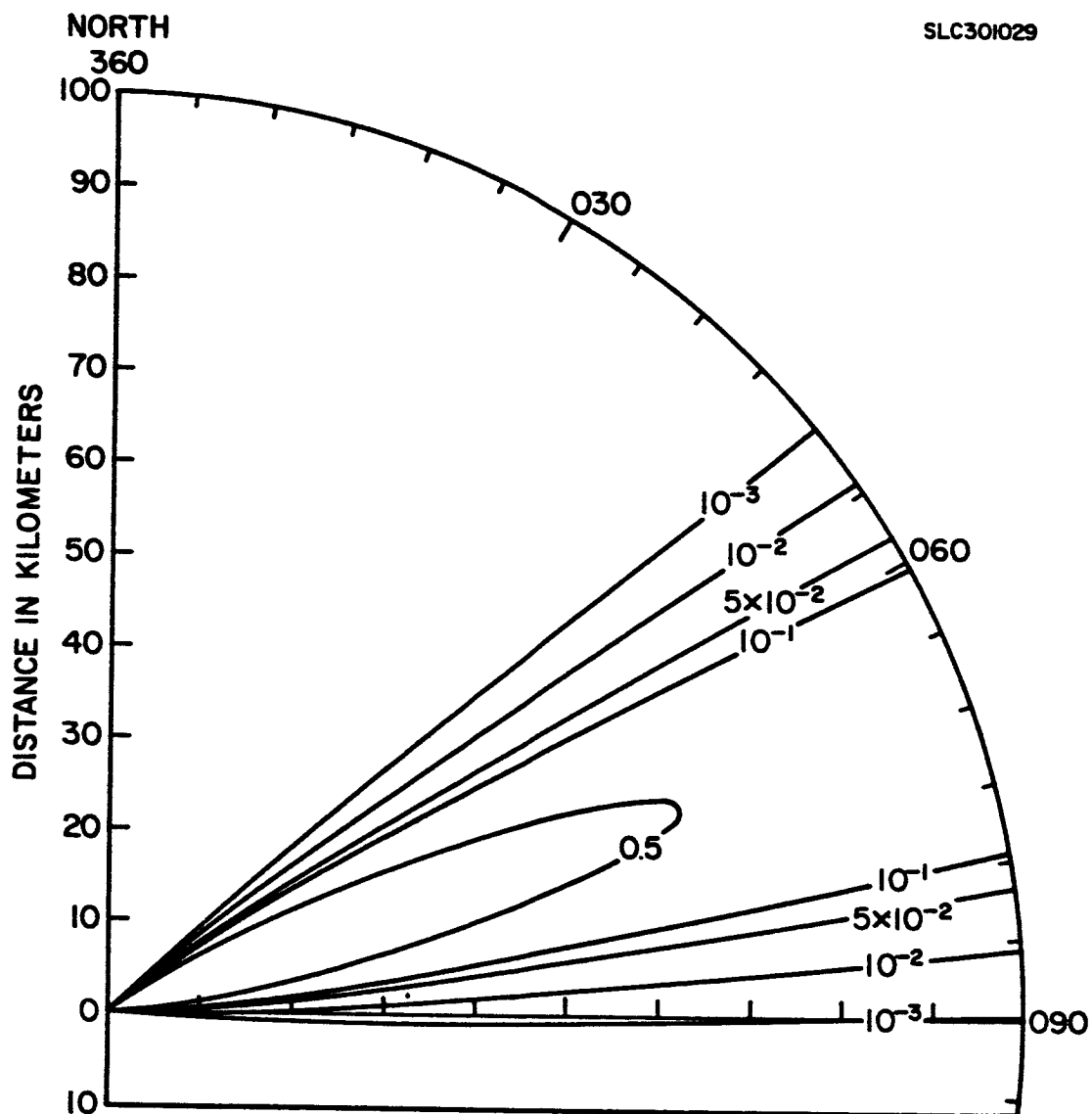


FIGURE E-50. Dosage isopleths in grams seconds per cubic meter at a height of 1067 meters for a vehicle destruct on the pad, 0515 GMT, 12 May 1967.

and dosages are shown, respectively, in Figures E-51 and E-52. Figures E-53 and E-54 respectively show ground-level isopleths of concentration and dosage. The curves in Figures E-51 through E-54 are similar to the corresponding curves in Figures E-35 through E-38, because only the normal launch mode contributed to the toxic fuel hazard in the surface layer. Figures E-55 and E-56 respectively show concentration and dosage isopleths at the base of the second layer. Concentration and dosage isopleths at the base of the third layer are shown in Figures E-57 and E-58.

E. 4. 4 Cold Spill in the Surface Layer

The source and meteorological inputs for the surface cold spill are given in Table E-11. Ground-level concentration isopleths for the spill at the surface are shown in Figure E-59.

E. 5 EXAMPLE CALCULATION OF GROUND-LEVEL DEPOSITION DUE TO GRAVITATIONAL SETTLING

The computer program for the multi-layer diffusion model was used to estimate the ground-level deposition pattern due to gravitational settling for a normal launch assumed to occur at 2315 GMT on 27 November 1966. The particle size distribution of material released as exhaust products and the settling velocities for various particle-size categories are given in Table E-3. The remaining source parameters and the meteorological parameters used in the example problem are given in Table E-12.

The calculated isopleths of ground-level deposition are given in Figure E-60. Inspection of Figure E-60 shows the isopleths are spread through a 180-degree sector north of the launch site, with the major ground-level deposition occurring along an east-northeast axis after the first 15 kilometers of cloud travel.

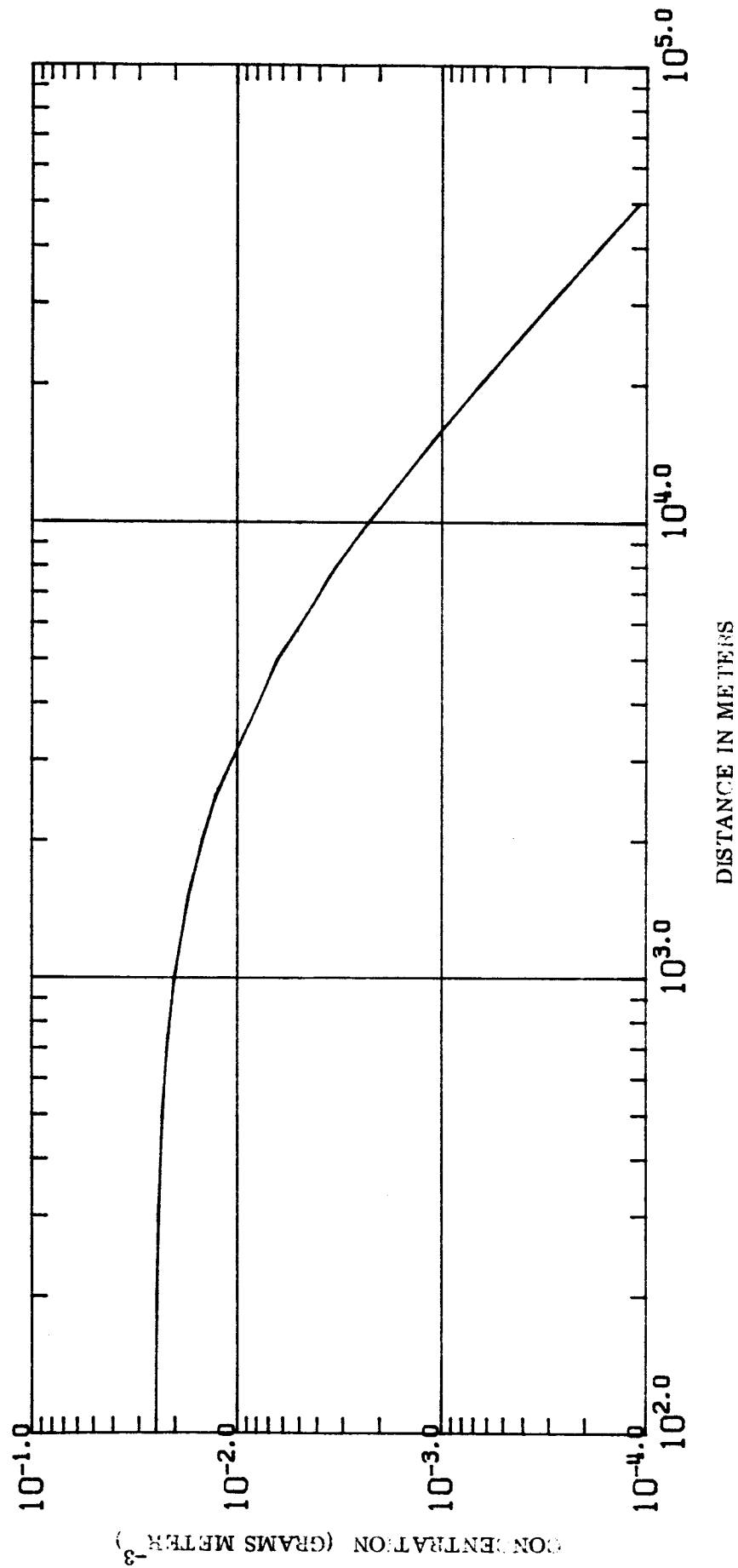


FIGURE E-51. Maximum ground-level concentration for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.

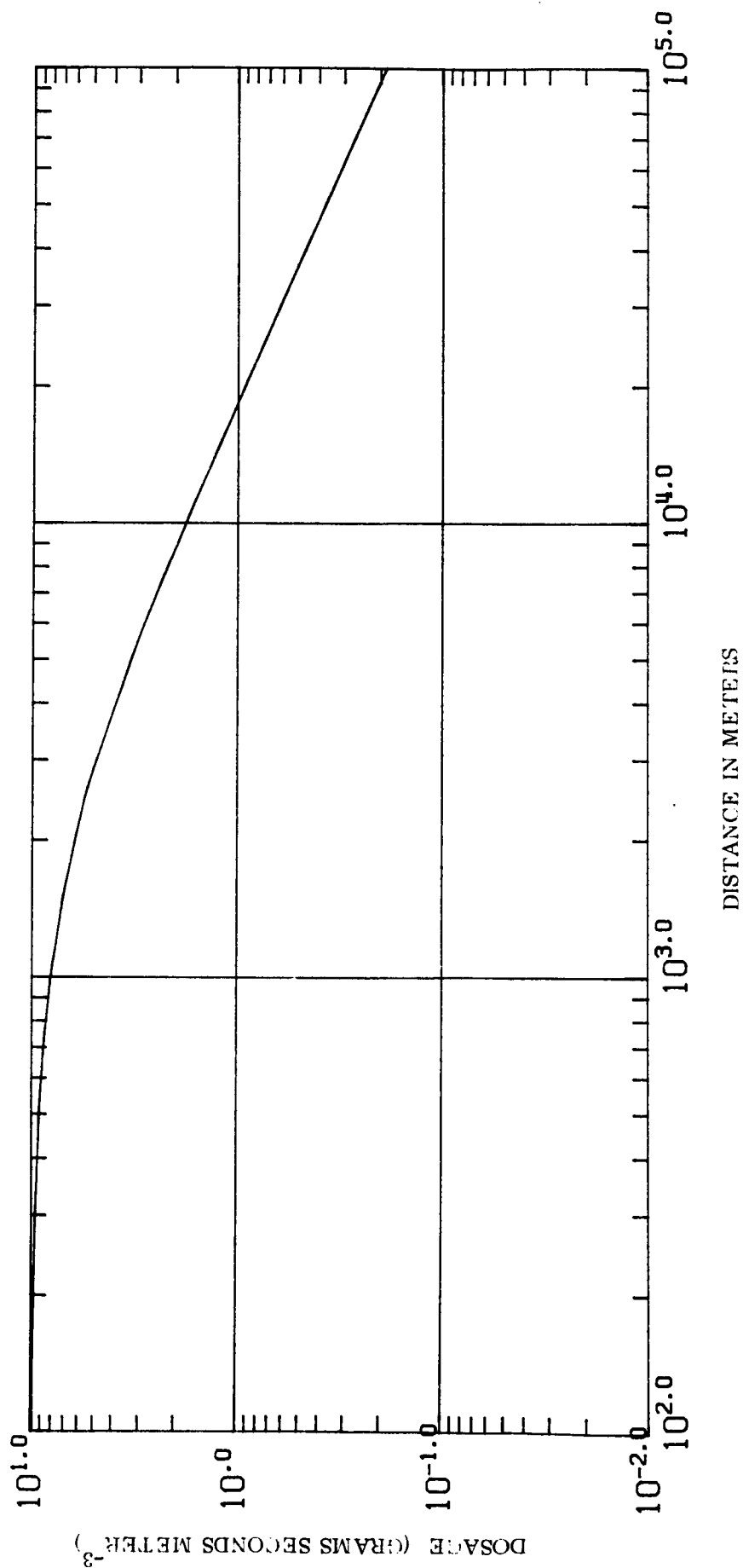


FIGURE E-52. Maximum ground-level dosage for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.

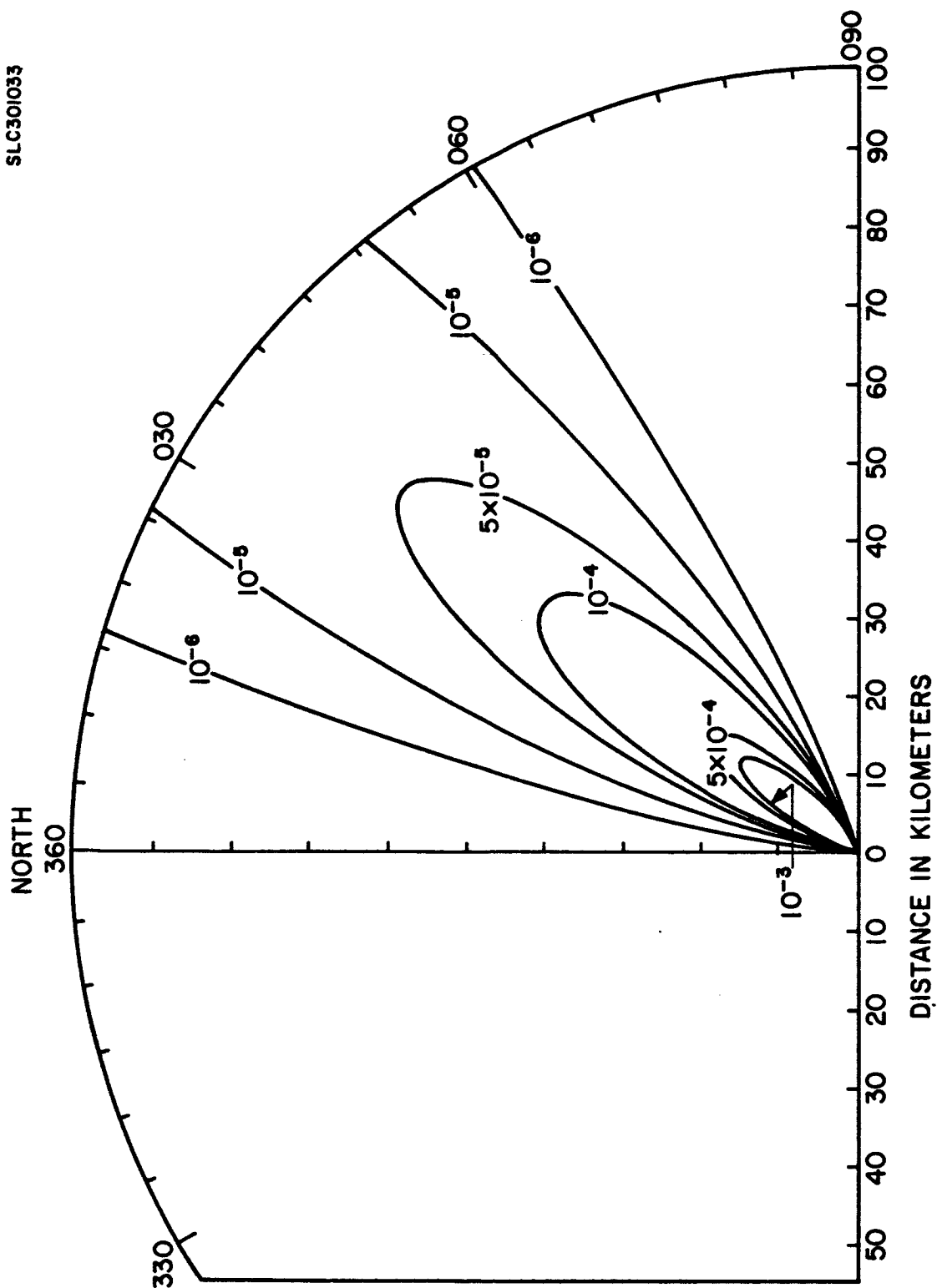
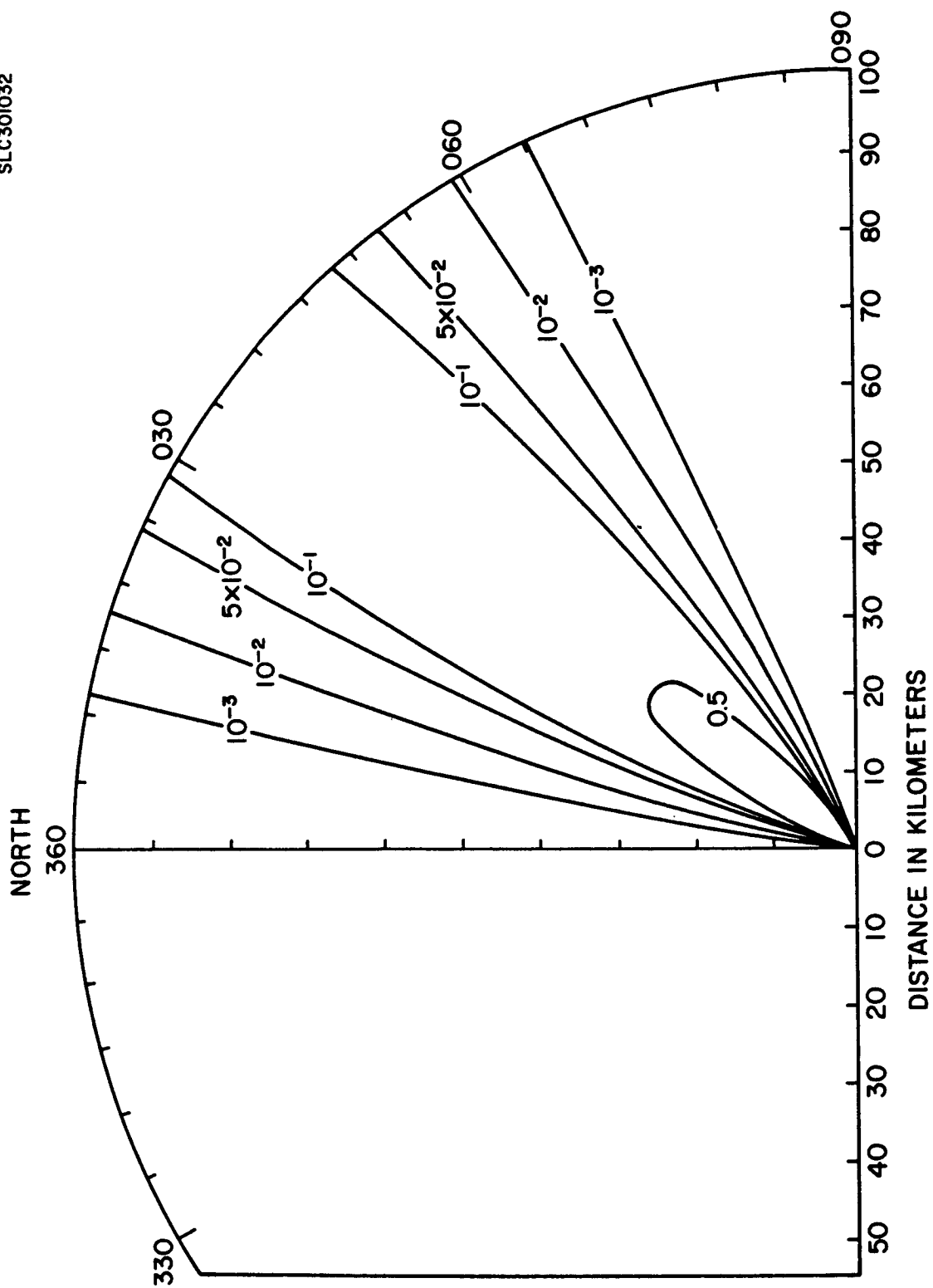


FIGURE E-53. Ground-level concentration isopleths in grams per cubic meter for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.



E-80

FIGURE E-54. Ground-level dosage isopleths in grams seconds per cubic meter for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.

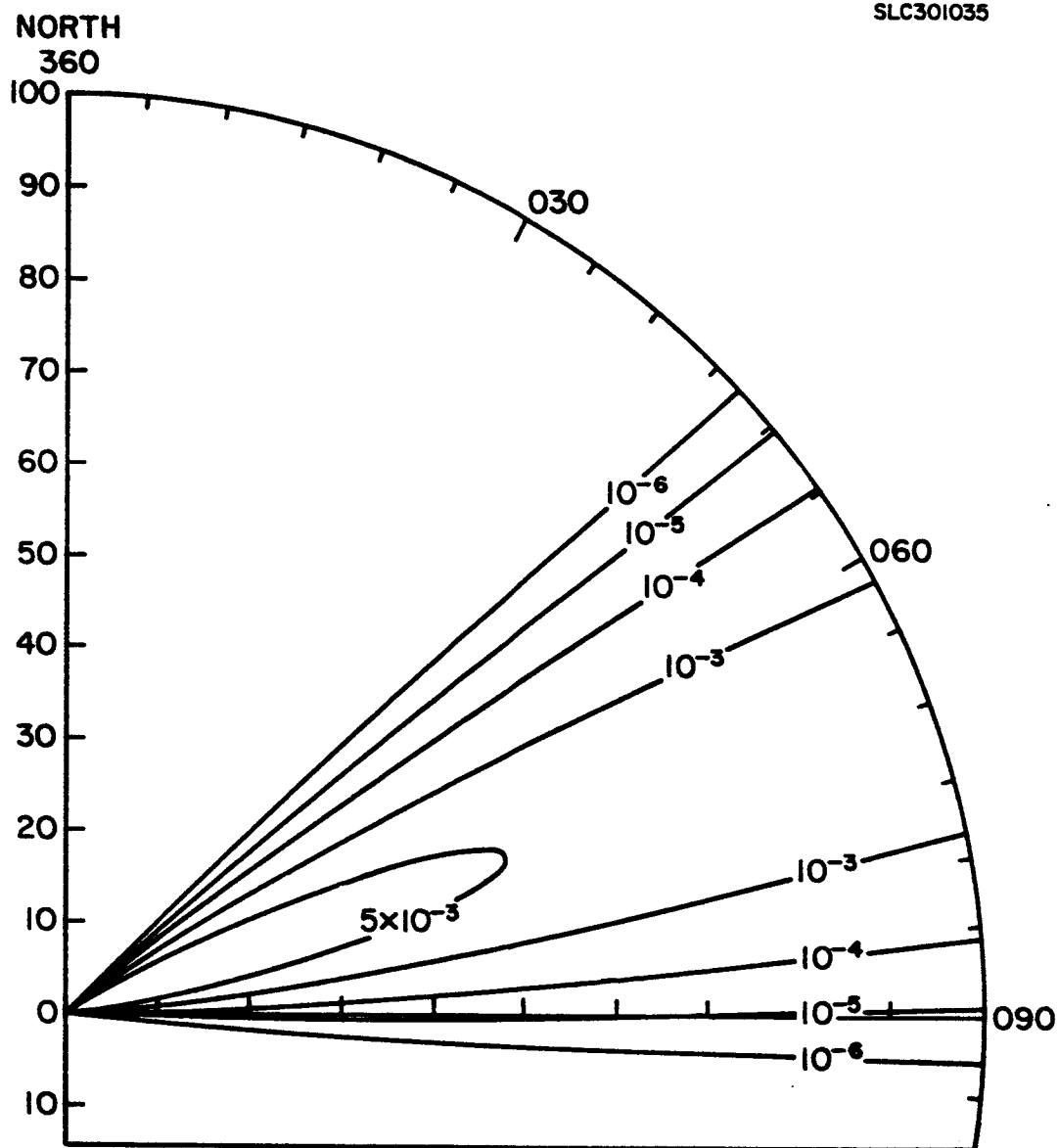


FIGURE E-55. Concentration isopleths in grams per cubic meter at a height of 1067 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May, 1967.

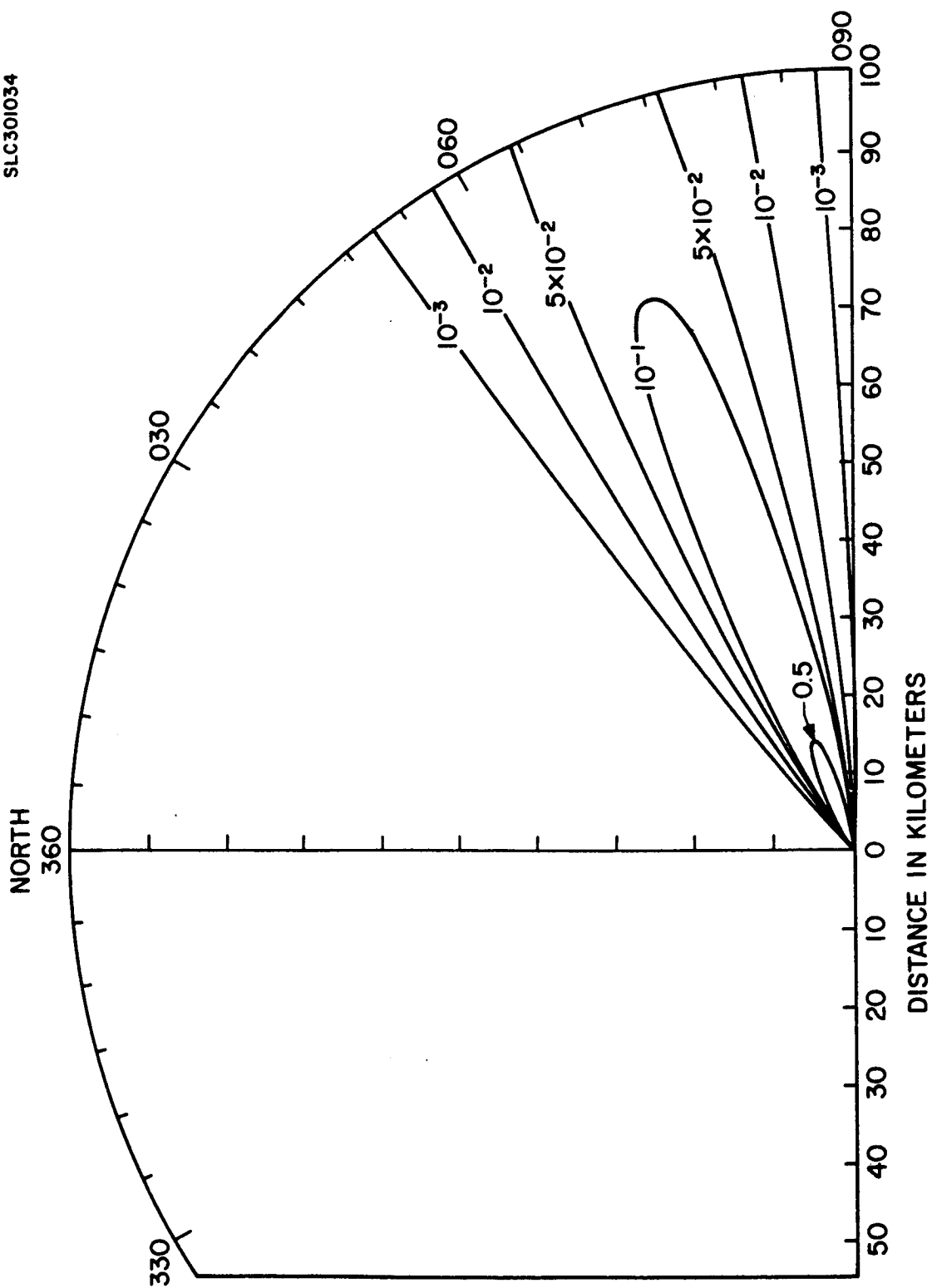


FIGURE E-56. Dosage isopleths in grams seconds per cubic meter at a height of 1067 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.

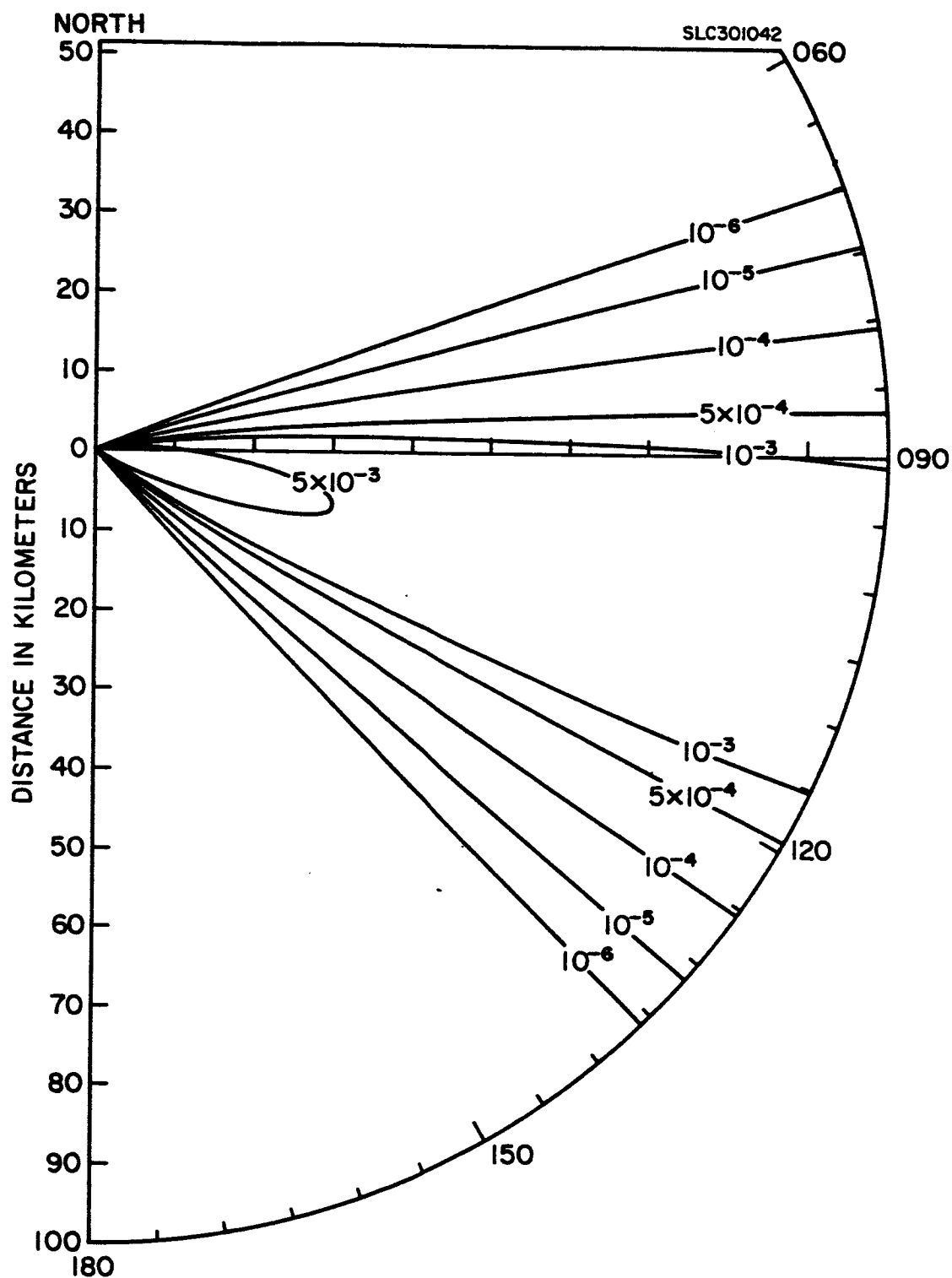


FIGURE E-57. Concentration isopleths in grams per cubic meter at a height of 1615 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.

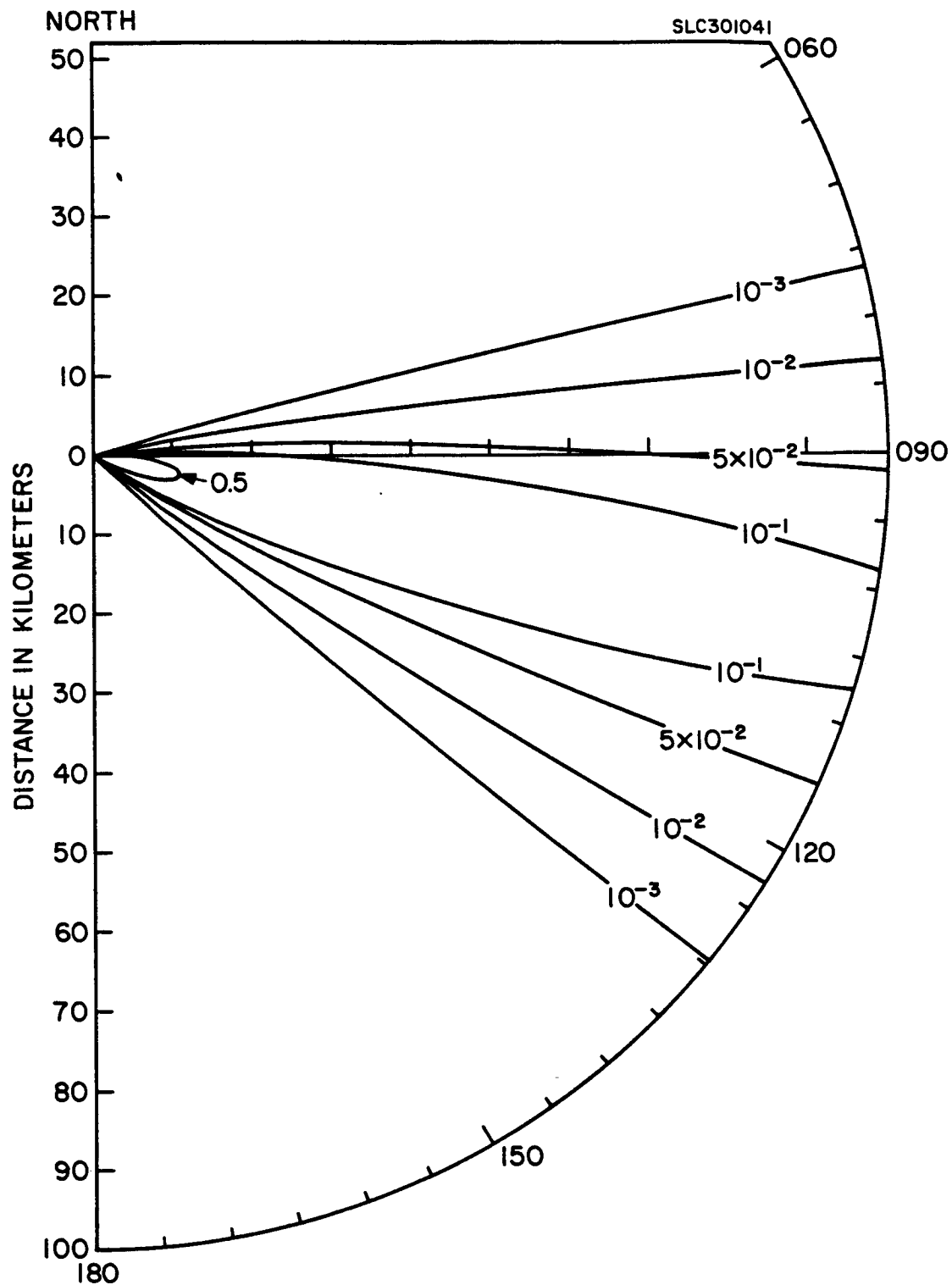


FIGURE E-58. Dosage isopleths in grams seconds per cubic meter at a height of 1615 meters for a vehicle destruct at 1350 meters, 0515 GMT, 12 May 1967.

TABLE E-11
PROGRAM INPUTS

Example Problem: Surface Cold Spill for Summertime Bermuda
High Situation, 0515 GMT, 12 May 1967

MODEL NO. 3				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
Q_K (g sec ⁻¹)	100			
$\sigma_{yo}\{K\}$ (m)	11.6			
$\sigma_{zo}\{K\}$ (m)	1			
$\sigma_{xo}\{K\}$ (m)				
τ_K (sec)	600			
H_K (m)	-			
k	-			

TABLE E-11 (Continued)

MODEL NO. 3				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	6			
σ_{ER} (deg)	3			
$\bar{u}_R$ (m sec ⁻¹)	3.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	6			
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)				
τ_{oK} (sec)	600			
σ_{ETK} (deg)	3			
σ_{EBK} (deg)				
α_K	1			
β_K	1			
$\bar{u}_{TK}$ (m sec ⁻¹)	8.24			
$\bar{u}_{BK}$ (m sec ⁻¹)				
θ_{TK} (deg)	237			
θ_{BK} (deg)	200			
z_{TK} (m)	1067			
z_{BK} (m)	2			
Λ (sec ⁻¹)	-			
z_{lim} (m)	-			
t_1 (sec)	-			
t^* (sec)	-			

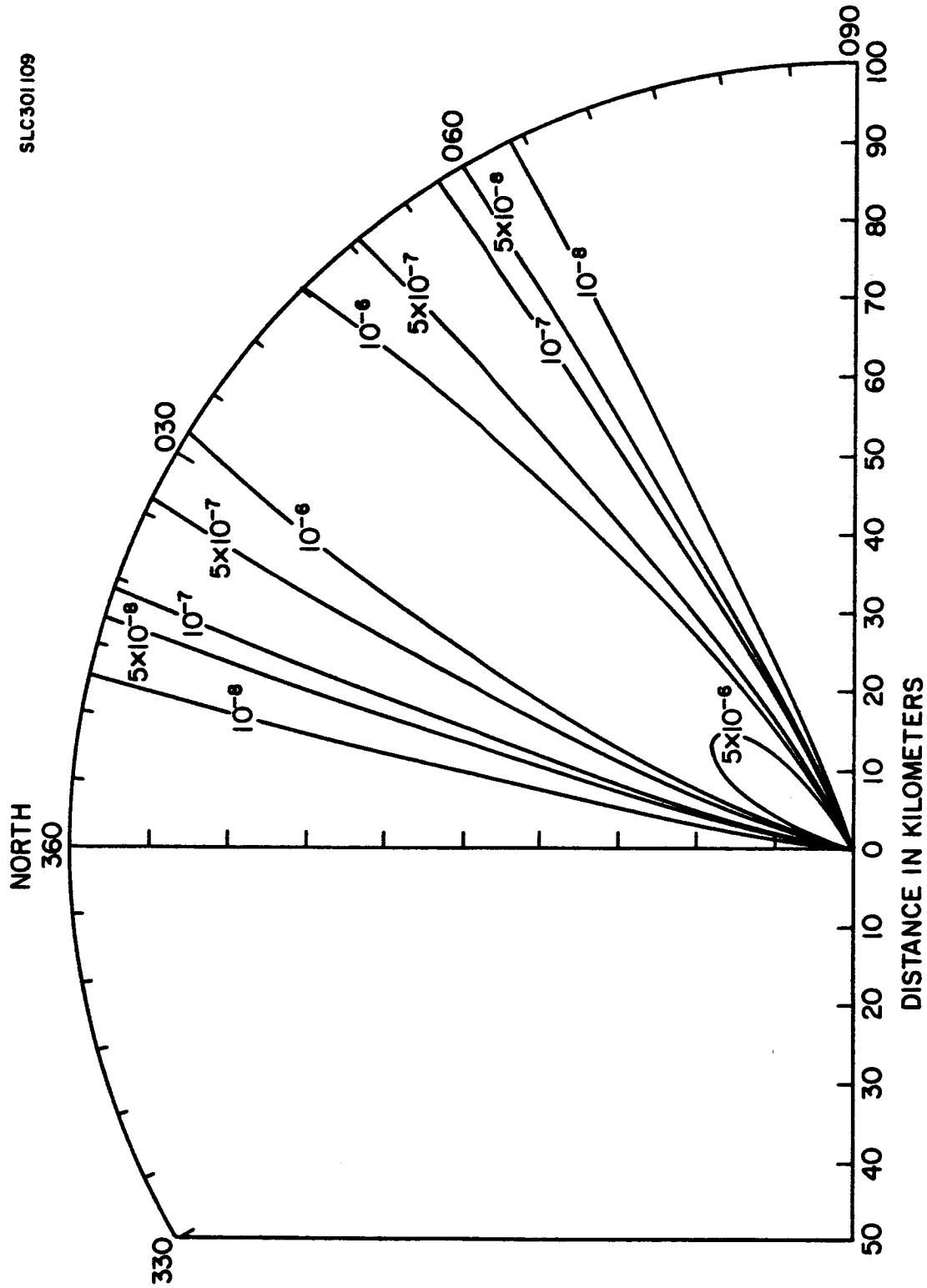


FIGURE E-59. Ground-level concentration isopleths in grams per cubic meter for a large surface spill, 0515 GMT, 12 May 1967.

TABLE E-12

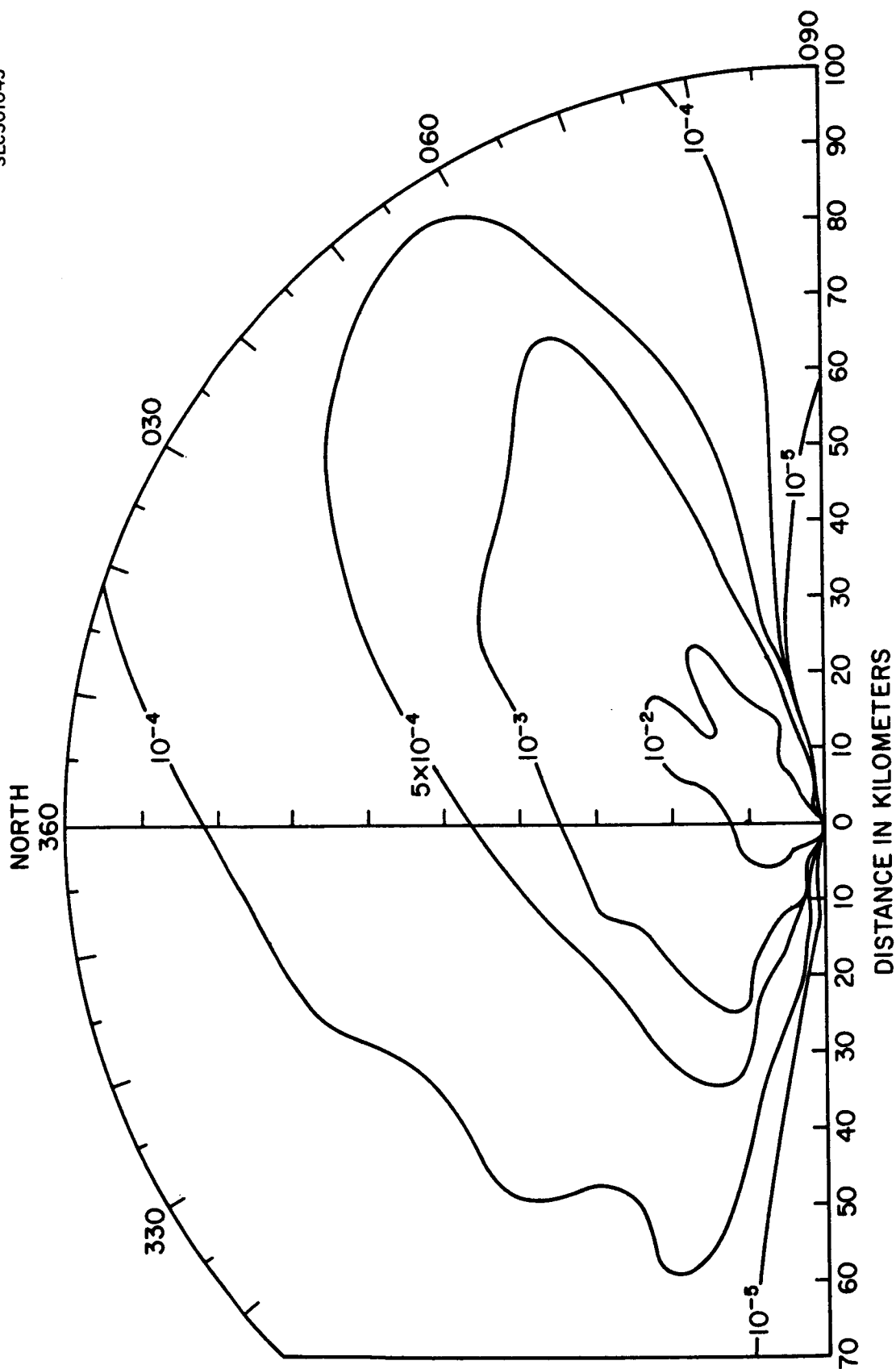
PROGRAM INPUTS

Example Problem: Deposition by Gravitational Settling for Pre-Cold
Front Situation, 2315GMT, 27 November 1966

MODEL NO. 7				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Source Inputs			
Q_K (g sec ⁻¹)	5×10^5	5×10^5	5×10^5	5×10^5
$\sigma_{yo}\{K\}$ (m)	290	150	100	75
$\sigma_{zo}\{K\}$ (m)	-	-	-	-
$\sigma_{xo}\{K\}$ (m)	-	-	-	-
$\tau_K = T_K$ (sec)	25	11	9.3	9.0
H_K (m)	-			
k	-			

TABLE E-12 (Continued)

MODEL NO. 7				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	5	0	0	0
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)		5	0	0
τ_{oK} (sec)	600	600	600	600
σ_{ETK} (deg)	4	0	0	0
σ_{EBK} (deg)		4	0	0
α_K	1	1	1	1
β_K	1	1	1	1
$\bar{u}_{TK}$ (m sec ⁻¹)	6.70	7.73	10.8	20.6
$\bar{u}_{BK}$ (m sec ⁻¹)		6.70	7.73	10.8
θ_{TK} (deg)	231	258	229	256
θ_{BK} (deg)	160	231	258	229
z_{TK} (m)	853	1829	3048	5000
z_{BK} (m)	2	853	1829	3048
Λ (sec ⁻¹)	-			
z_{lim} (m)	-			
t_1 (sec)	-			
t^* (sec)	-			



E-90

FIGURE E-60. Isopleths of ground-level deposition in grams per square meter due to gravitational settling for a normal launch, 2315 GMT, 27 November 1966.

This orientation of the axis of maximum deposition is due to the veering of the azimuth wind direction from south-southeast to west-southwest between the surface and higher layers. Thus, material emitted in the higher layers is transported by the wind in those layers to the east-northeast and is deposited at long downwind distances. Material emitted in the surface layers is deposited nearer the source along a more north-northwesterly axis.

E. 6 EXAMPLE OF A CHANGE IN LAYER STRUCTURE AND DEPOSITION DUE TO PRECIPITATION SCAVENGING

This example illustrates the use of the computer program for the multi-layer diffusion model to calculate ground-level deposition due to precipitation scavenging after a change in layer structure occurs. The time of change in layer structure t^* is set equal to 3000 seconds after launch. The meteorological and source inputs for the calculation of the concentration and dosage fields prior to the change in layer structure are given in Table E-4.

At time t^* , the wind direction near the surface becomes southwesterly and the lowest two layers are combined in a single layer as a cold front approaches Kennedy Space Center. Also, at the same time as the change in layer structure occurs, rain is assumed to begin falling through the new layer in the general area surrounding Kennedy Space Center. The turbulence structure in Layer 3 (Table E-4) is also changed and clouds are assumed to have formed in the layer. The source and meteorological inputs, reflecting the above changes in layer structure, that must be supplied to the computer program are given in Table E-13. With the exception of τ_K , the source parameters for the calculation of concentration, dosage, and deposition due to precipitation scavenging under the new structure regime are calculated internally in the program. In the new surface layer (Layer 1 in Table E-13), τ_K has been assigned the average of the values of τ_K in Layers 1 and 2 in Table E-4. In the new Layer 2 (Table E-13), the value of τ_K is the same as for Layer 3 in Table E-4.

TABLE E-13

PROGRAM INPUTS

Example Problem: Deposition by Precipitation Scavenging with Change in
 Layer Structure for Pre-Cold Front Situation,
 2315 GMT, 27 November 1966

MODEL NO. 5, 6				
	Layer 1	Layer 2	Layer 3	Layer 4
Parameter	Source Inputs			
Q_K				
$\sigma_{yo}\{K\}$ (m)				
$\sigma_{zo}\{K\}$ (m)				
$\sigma_{xo}\{K\}$ (m)				
τ_K (sec)	18	10		
H_K (m)				
k				

TABLE E-13 (Continued)

MODEL NO. 5, 6				
Parameter	Layer 1	Layer 2	Layer 3	Layer 4
	Meteorological Inputs			
$\sigma_{AR}\{\tau_{oR}\}$ (deg)	8			
σ_{ER} (deg)	4.5			
$\bar{u}_R$ (m sec ⁻¹)	4.1			
z_R (m)	18			
$\sigma_{ATK}\{\tau_{oK}\}$ (deg)	4	0		
$\sigma_{ABK}\{\tau_{oK}\}$ (deg)		4		
τ_{oK} (sec)	600	600		
σ_{ETK} (deg)	2	0		
σ_{EBK} (deg)		2		
α_K	1	1		
β_K	1	1		
$\bar{u}_{TK}$ (m sec ⁻¹)	7.73	10.8		
$\bar{u}_{BK}$ (m sec ⁻¹)		7.73		
θ_{TK} (deg)	258	229		
θ_{BK} (deg)	230	258		
z_{TK} (m)	1829	3048		
z_{BK} (m)	2	1829		
Λ (sec ⁻¹)	10 ⁻³			
z_{lim} (m)	1829			
t_1 (sec)	3000			
t^* (sec)	3000			

Ground-level dosage isopleths calculated by the program are shown in Figure E-61. The isopleth pattern reflects the change in wind direction in the surface layer from southerly to southwesterly. Figure E-62 shows ground-level deposition isopleths due to precipitation scavenging. The lobe of the pattern at distances between 20 and 40 kilometers east of the source is due to washout of material contained in the second layer prior to the change in layer structure. The isopleth for 10^{-1} grams per square meter indicates the approximate location, just after precipitation started, of material originally contained in the surface layer.

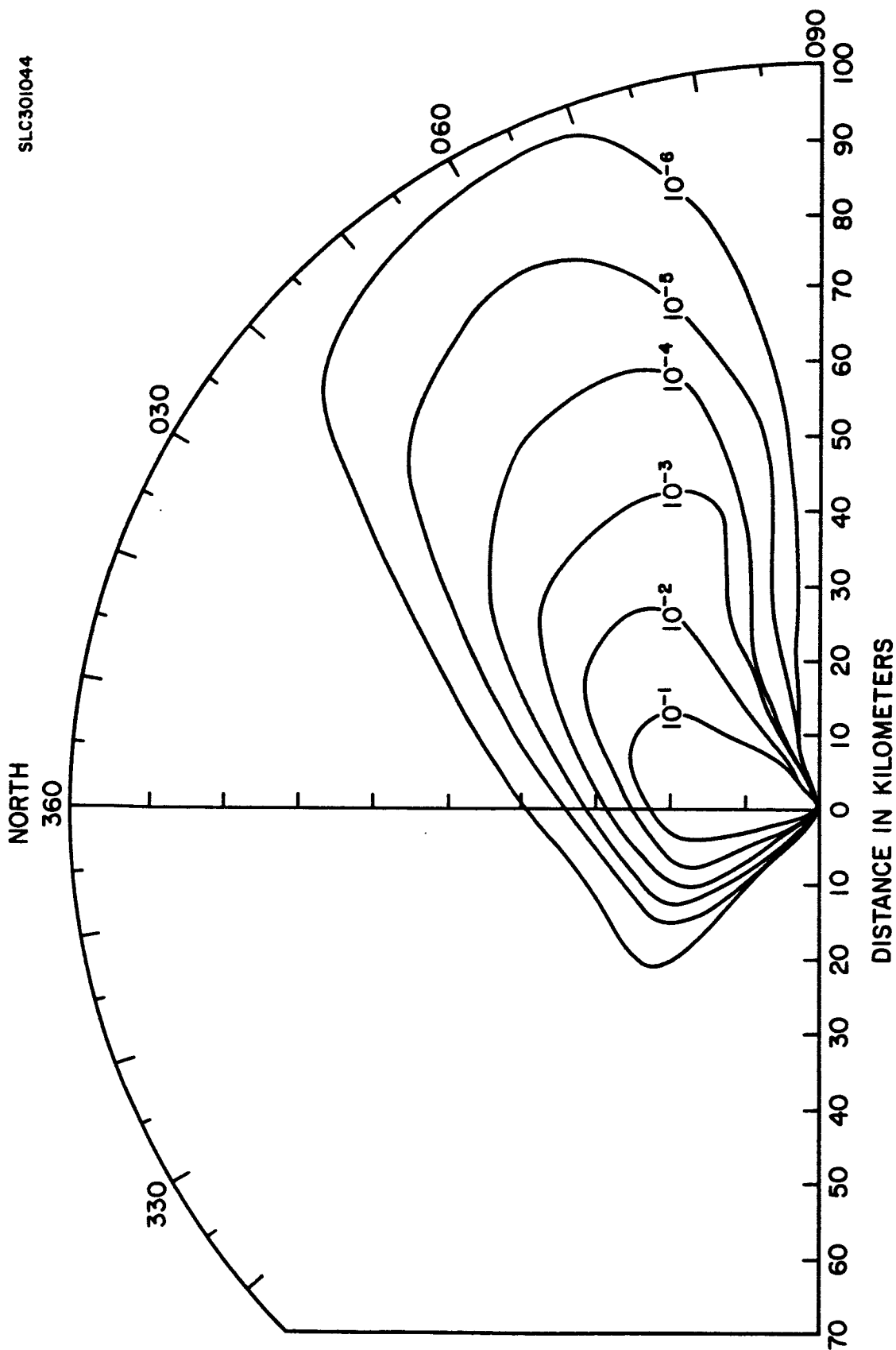


FIGURE E-61. Ground-level dosage isopleths in grams seconds per cubic meter for a normal launch, 2315 GMT, 27 November 1966, with a change in layer structure and the start of precipitation occurring 50 minutes after launch.

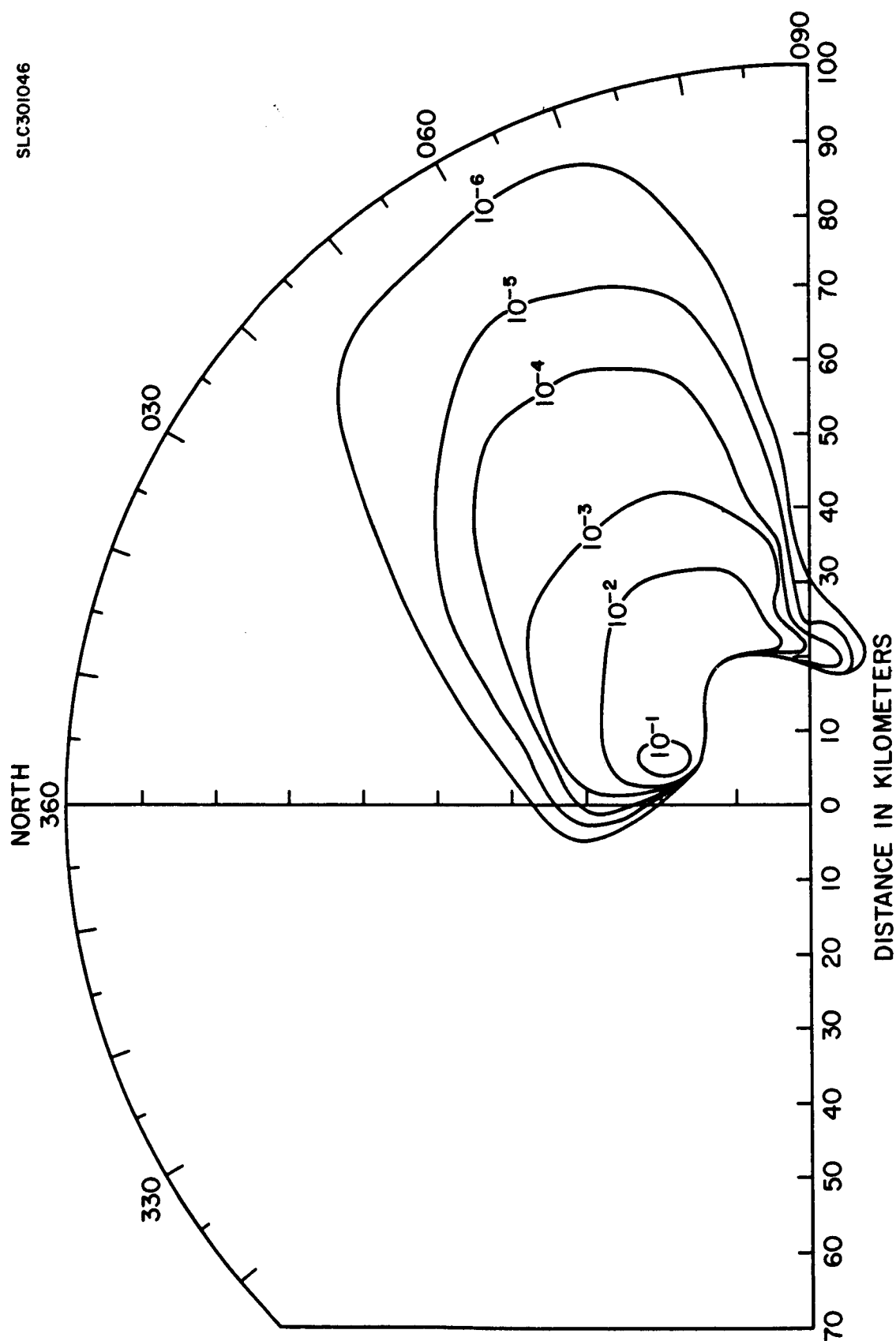


FIGURE E-62. Ground-level deposition isopleths in grams per square meter due to precipitation scavenging, 2315 GMT, 27 November 1966; precipitation starts 50 minutes after launch.

APPENDIX F

NOMOGRAMS FOR CALCULATING σ_A , σ_E AND p AND EXAMPLE CALCULATIONS

F.1 NOMOGRAMS FOR CALCULATING σ_A , σ_E AND p

Three nomograms for calculating the meteorological inputs σ_E , σ_A and p to the multi-layer diffusion model from values of σ_A and σ_E at a reference height and from wind speeds at layer boundaries are presented in Figures F-1 through F-3.

Figure F-1 is used to calculate ratios or products.

Figure F-2 is used for calculations based on the wind speed power-law relationship.

$$\frac{\bar{U} \text{ (upper)}}{\bar{U} \text{ (lower)}} = \left\{ \frac{Z \text{ (upper)}}{Z \text{ (lower)}} \right\}^p$$

Figure F-3 is used for the calculation of σ_E under unstable thermal stratification from the expression

$$\frac{\sigma_E \text{ (upper)}}{\sigma_E \text{ (lower)}} = \left\{ \frac{Z \text{ (upper)}}{Z \text{ (lower)}} \right\}^{0.3-p} \quad 0 < p < 0.3$$

The use of these nomograms is illustrated below by calculating model input values for Layers 1 and 2 of the example case described in Section E.1.1 for 27 November 1966, 2315 GMT.

F.2 EXAMPLE CALCULATIONS

F.2.1 Selection of Nomogram Inputs

The wind speed at the reference height of 18 meters is interpolated

from a log-log plot of the radiosonde data as 8.4 knots. Figure 4-4 shows that the sounding was taken about 45 minutes after transition time, and slightly stable conditions are postulated near the ground. The temperature profile indicates an adiabatic lapse rate between 870 and 2,800 feet (Layer 2) and that a surface inversion is being established below 870 feet (Layer 1). It is postulated that vertical mixing is still taking place in Layer 2. For a wind speed of 8.4 knots (4.3 meters per second) and slight stability ($\Delta T \approx 0.4^\circ\text{C}$), Figures 4-2 and 4-3 give values of about 8 and 4.5 degrees, respectively, for σ_A and σ_E at the reference height of 18 meters. Wind speeds at 870 and 2,800 feet are 12 and 13 knots, respectively. According to the relationships given in Section 4.2, σ_A and σ_E are assumed to vary as Z^{-p} within Layer 1. For illustrative purposes it is assumed that σ_E varies as $Z^{0.3-p}$ within Layer 2, although Layer 2 is in the process of becoming decoupled from the surface as the surface temperature inversion in Layer 1 develops.

F.2.2 Use of the Nomograms

The use of the nomograms to determine model inputs is illustrated by Figures F-4, F-5, and F-6. Figure F-4 uses the wind speeds at 59 feet (18 meters) and 870 feet to calculate $\sigma_A = 5.6$ degrees and $\sigma_E = 3.2$ degrees at 870 feet from the reference values at 18 meters. Figure F-5 uses the wind speed and height ratios at the upper and lower boundaries of Layer 2 to calculate p for the layer. Figure F-6 uses the value of p determined for Layer 2, the height ratio of the boundaries, and the value of σ_E at the lower boundary to calculate σ_E at the upper boundary.

In Figures F-4 through F-6, the number in parentheses is the height in feet to which the quantity refers. The symbol $\bar{U}$ refers to the wind speed. The symbol R denotes one of the ratio scales shown as ordinates in Figures F-2 and F-3; the subscript used with R indicates the specific scale to which reference is made:

- $R_{\bar{U}}$ = ratio of wind speeds
- R_{σ} = ratio of standard deviations of elevation
- R_Z = ratio of heights

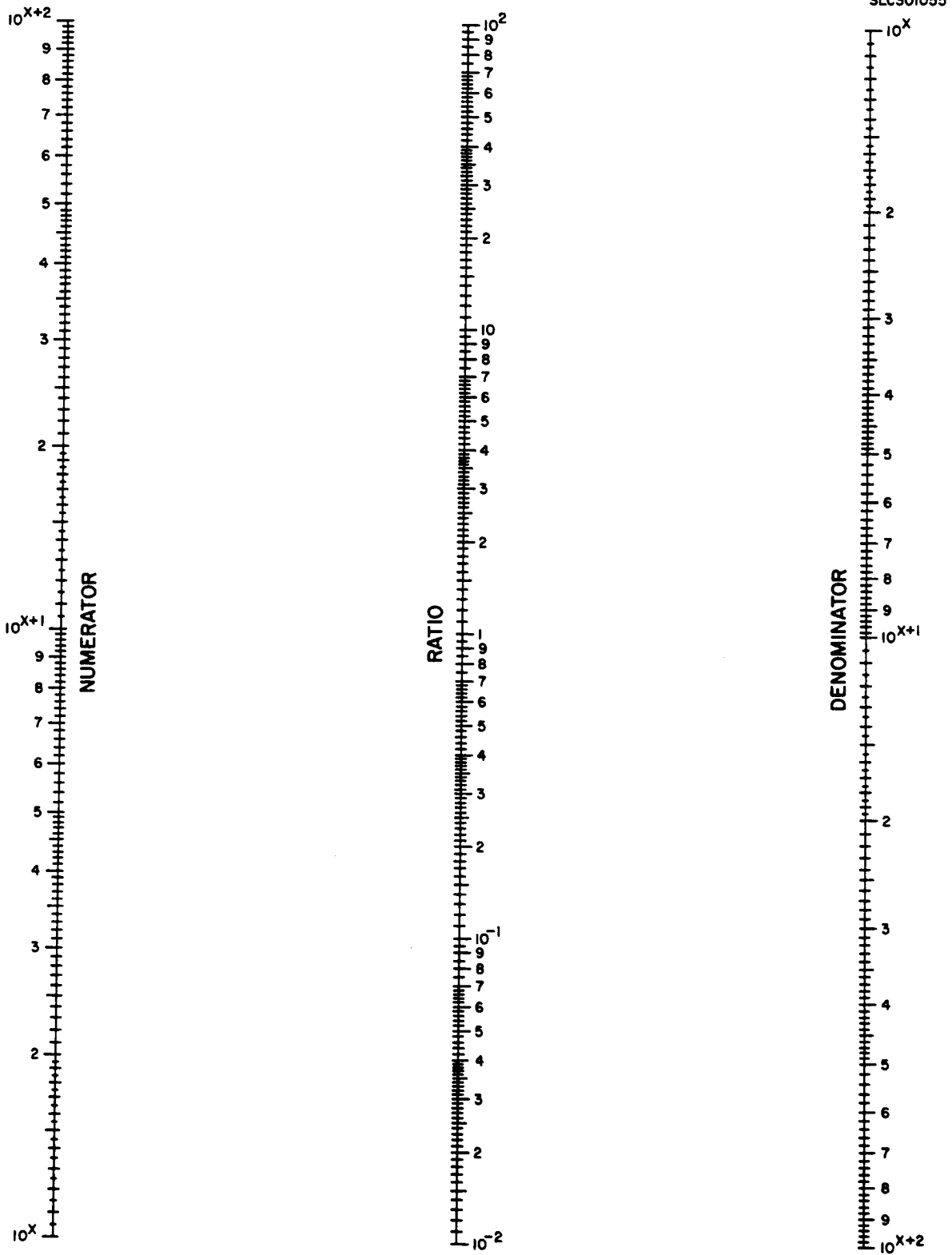


FIGURE F-1. Nomogram for calculating ratios or products.

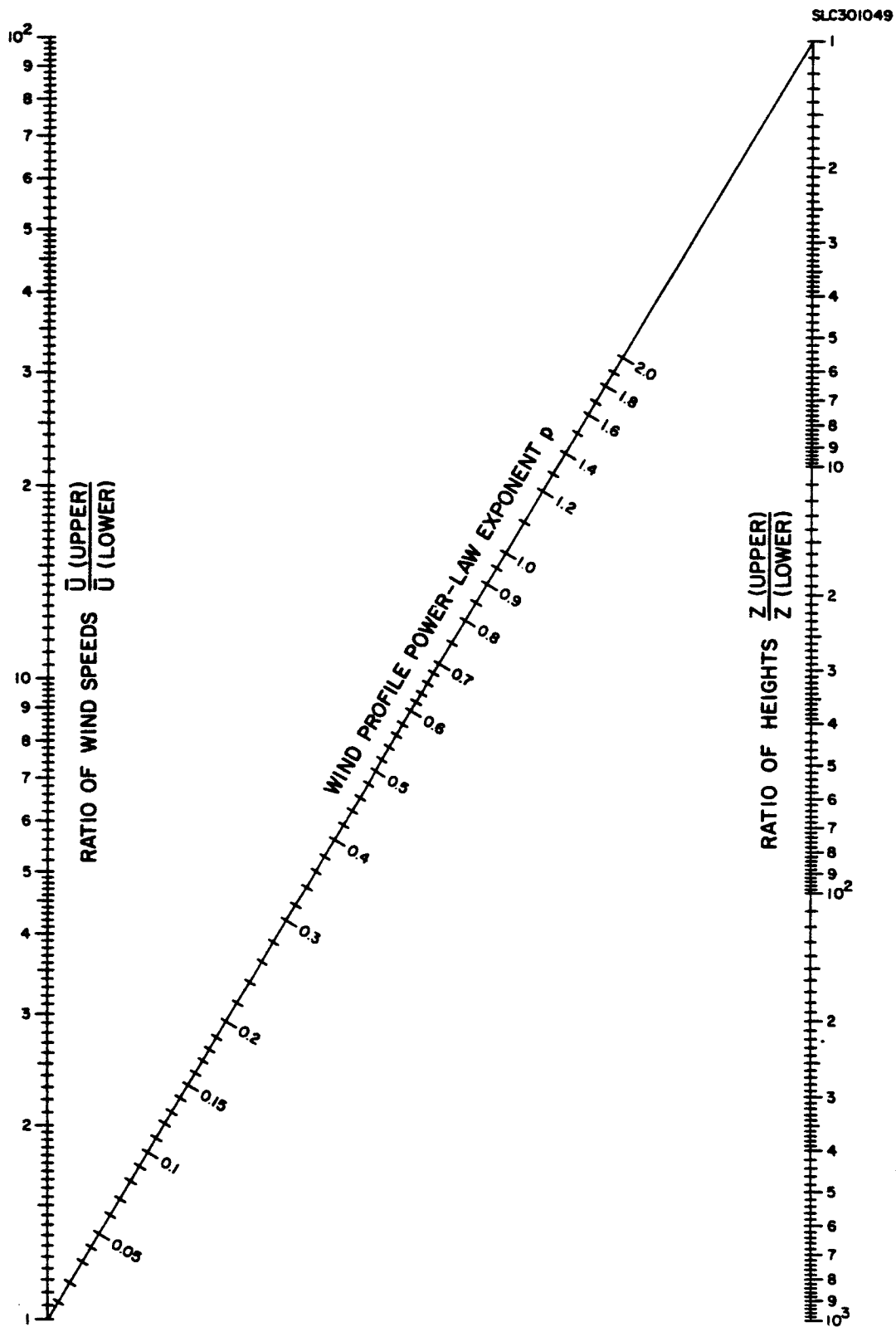


FIGURE F-2. Nomogram for calculating the wind-profile exponent p .

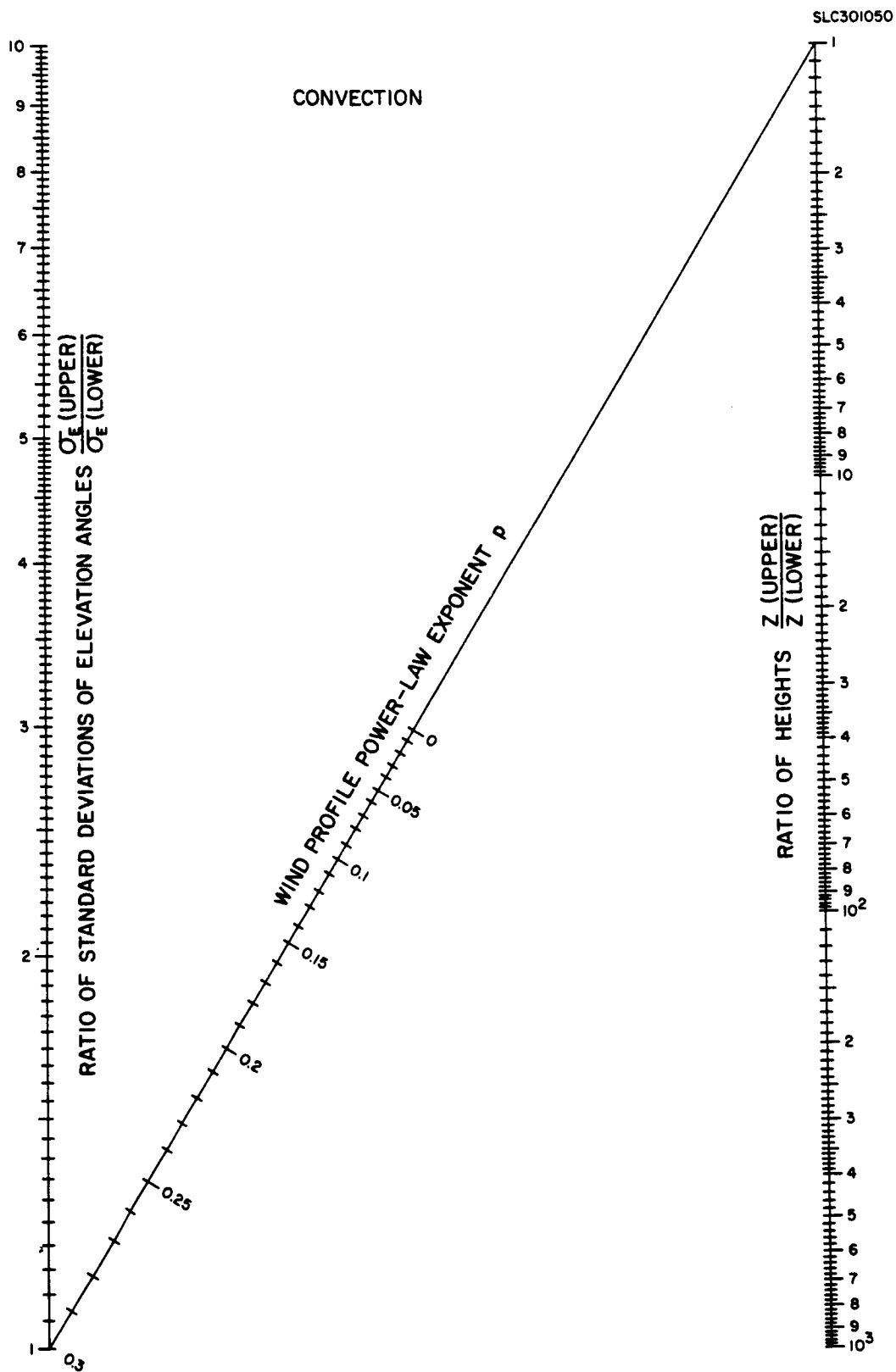


FIGURE F-3. Nomogram for calculating σ_E under unstable thermal stratification.

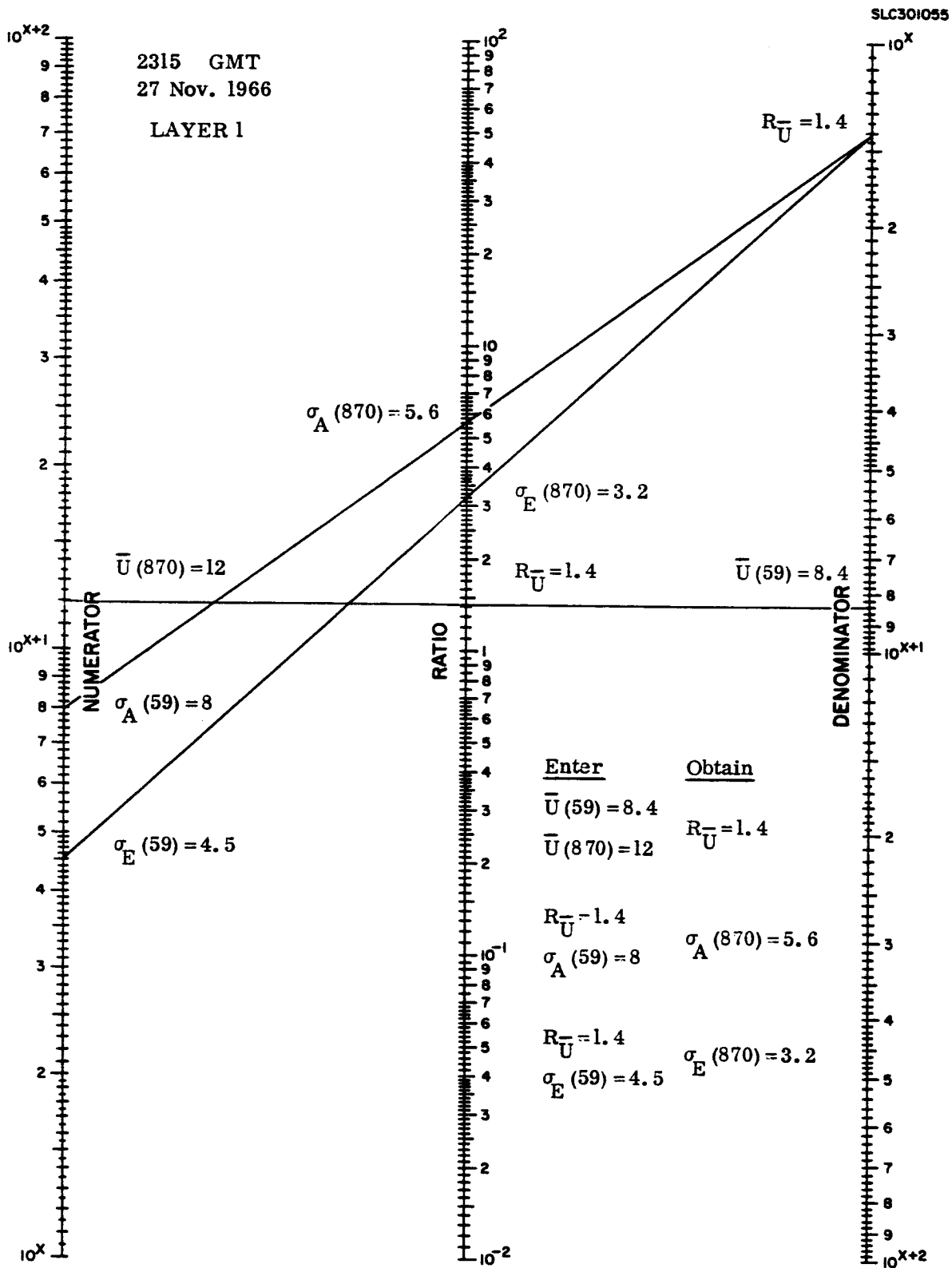


FIGURE F-4. Use of Figure F-1 to calculate σ_A and σ_E from the wind speed ratio when σ_A and σ_E are assumed to vary as Z^{-p} .

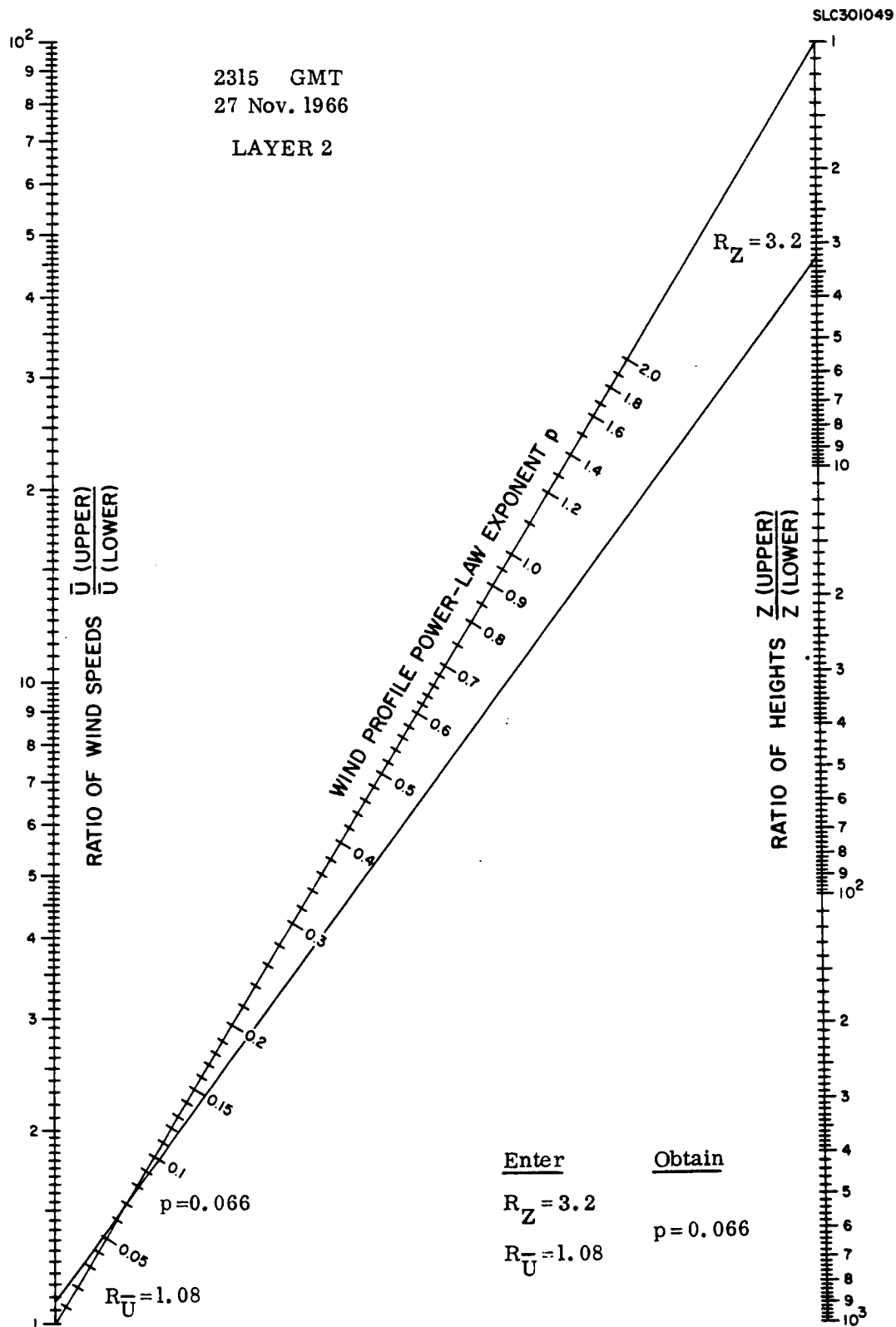


FIGURE F-5. Use of Figure F-2 to calculate the power-law exponent p .

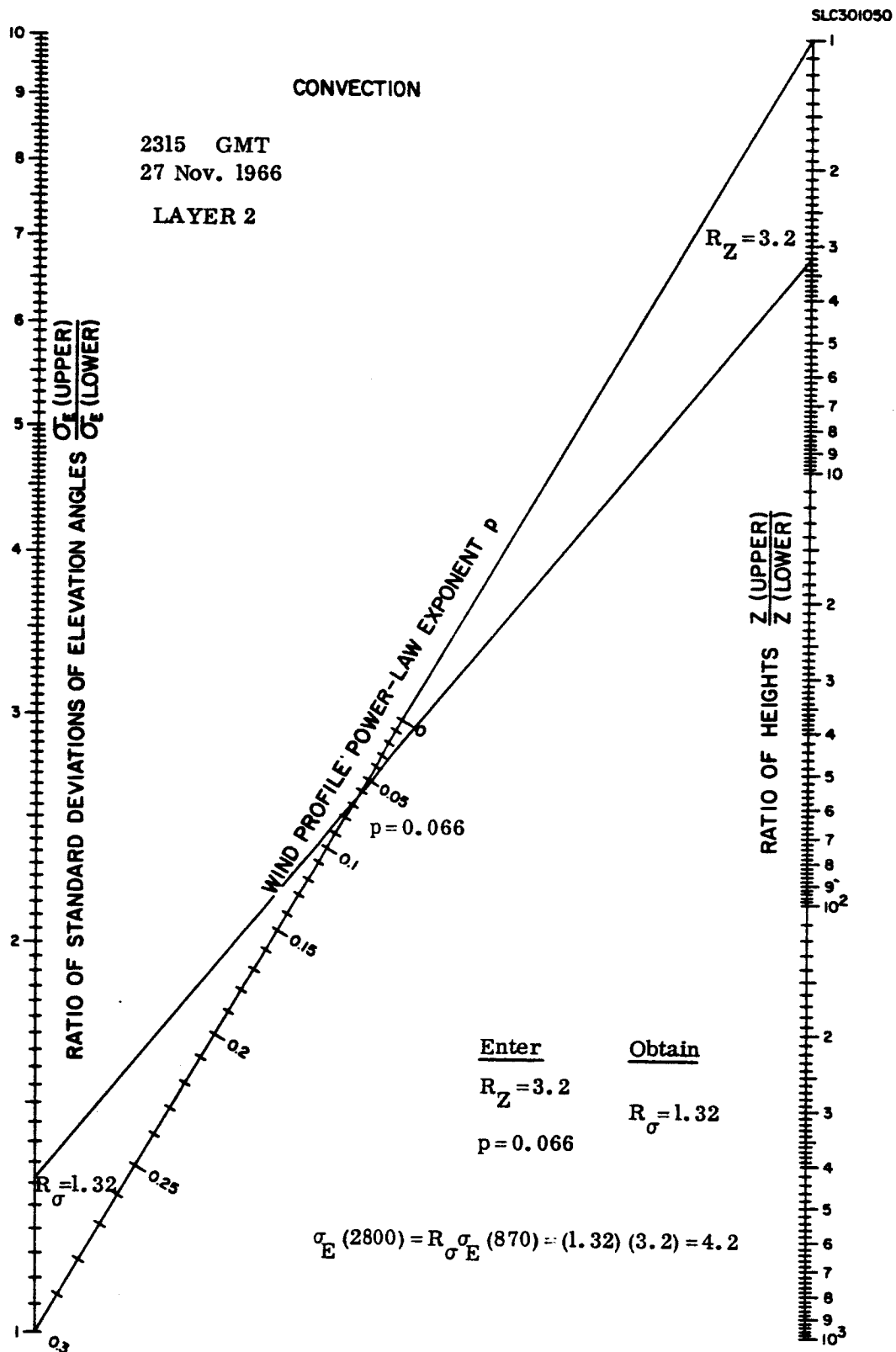


FIGURE F-6. Use of Figure F-3 to calculate σ_E when σ_E is assumed to vary as $Z^{0.3-p}$.