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Continued Analysis And Derivation Of A Method To Model Pit Retention

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CONTINUED ANALYSIS AND DERIVATION OF A METHOD TO MODEL PIT RETENTION

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TABLE OF CONTENTS

1.0 SUMMARY AND PURPOSE

This report continues the analysis of pit retention meteorology and predictive escape fraction equations begun in EPA's "Dispersion of Airborne Particulates in Surface Coal Mines" (EPA, 1985). The purpose of this work, which is described in this report, was three-fold:

- Examine the existing meteorological and smoke release data base to determine the relationship between in-pit and out-of-pit sigma-theta and alphabetic stability class in order to identify trends and other systematic behavior.
- Incorporate other physical or meteorological parameters (particularly wind speed) into the original Winges escape fraction equation. Refinements to the basic equation are to be tested against the existing field data.
- Prepare and document a computer algorithm to predict escape fraction for use in the ISC model.

The analysis of the meteorological data in and out of the pit yields an important finding: the sigma-theta (standard deviation of horizontal wind direction) inside the pit is almost always greater than the sigma-theta value measured simultaneously outside the pit. This indicates that the horizontal turbulence in the pit is greater than outside, and it is suspected that the enhanced in-pit sigma-thetas are induced by mechanical turbulence as air passes over, and in the wake of, the mine pit wall. The degree to which the in-pit sigma-theta exceeds that out-of-pit[1] increases with wind speed, but is not related to Pasquill-Gifford stability class.

Both the in-pit and out-of-pit sigma-thetas appear to provide a reasonably good measure of alphabetic stability class, when computed over a one-hour time period. The alphabetic stability classes measured in and out of the mine pits are identical to, or only one class removed from, the Pasquill-Gifford stability class for roughly 80% of the data base hours.

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1. As measured by the ratio of out-of-pit sigma theta divided by in-pit sigma-theta.

In an effort to incorporate other physical and meteorological parameters (especially wind speed) into the original Winges escape fraction equation, four alternative modifications to the Winges equation were derived. The alternative escape fraction equations differ in simplifying assumptions and in complexity:

ALTERNATIVE 1: CONSTANT-K LINEAR MODEL. The derivation of this equation assumes a constant value of eddy diffusivity with pit depth, and assumes that eddy diffusivity varies linearly with wind speed.

ALTERNATIVE 2: CONSTANT-K DETAILED MODEL. Like the previous derivation, the alternative 2 escape fraction equation assumes that vertical diffusivity is constant with pit depth. However the influence of both wind speed and stability class on diffusivity is taken into account by introducing the Monin-Obukhov length as a measure of stability.

ALTERNATIVE 3: VARIABLE-K LINEAR MODEL. The derivation of this equation recognizes that eddy diffusivity is not constant with pit depth.

ALTERNATIVE 4: VARIABLE-K DETAILED MODEL. The most complicated of the four alternatives, this derivation uses variable eddy diffusivity with pit depth, and incorporates Monin-Obukhov length as a measure of stability. An involved numerical solution is required to compute escape fraction with this alternative.

The four alternative escape fraction equations were evaluated by comparing values of escape fraction computed from the alternative equations with values of escape fraction inferred from the smoke release data. In general, the alternative equations predicted smaller escape fractions than did the original Winges equation. Furthermore, all of the alternative equations exhibit a much greater change in escape fraction with wind speed than does the original Winges equation, and the increase in predicted escape fractions with wind speed matches the trend observed in the smoke release data. In this sense, the introduction of wind speed into the Winges equation is successful.

However, the overall conclusion drawn from examining all of the alternative equations' predicted escape fractions is that they do not perform as well as would be liked. The correlation coefficients between predicted escape fractions and those inferred from the smoke release data are never greater than 0.39, and attempts at optimizing the agreement by introducing linear coefficients into the alternative escape fraction equations show very little improvement. Discrepancies between analytically predicted escape fractions and those inferred from the smoke release data are attributed to two factors. First, it must be remembered that the smoke release data do not provide a direct measure of escape fraction, and it is possible that some differences in measured and predicted escape fractions are due to misinterpretation of the smoke data. Second, the original Winges equation, and all of the alternative equations, assume that dust is removed from the mine pits by dispersion rather than by convection. This suggests that the Winges equations may be better predictors of escape fraction during stable conditions than during unstable or neutral conditions. A re-examination (and possibly re-interpretation) of the smoke release data gathered during stable conditions may be warranted, particularly since it is the stable atmospheres that induce peak concentrations downwind of surface mines.

Each of the four alternative escape fraction equations was coded into a FORTRAN algorithm, and tested in the ISC model with input data from a hypothetical surface coal mine. Run times for the four different algorithms were recorded during the tests. As expected, the equations using the more detailed analysis technique required more computer processing time. The two techniques based on the linear model (Alternatives 1 and 3) required approximately the same processing time as the original version of ISCST. Alternative 2 (Constant-K, detailed model) increased the run time by roughly a factor of 1.5, while Alternative 4 (Variable-K, detailed model) increased the run time by roughly a factor of 5.

2.0 BACKGROUND

Pit retention is the term used to describe the tendency for particulate matter released inside a surface mine pit to remain inside the pit. The pit retention phenomenon is important because most air quality models that are used to simulate particulate dispersion from surface mines treat these emissions as if they occurred at grade level, and ignore the possibility that a portion of the particulate matter may be trapped inside the pit, or that the characteristics of the dust plume may be altered by the presence of the pit.

Two years ago the U.S. EPA's Office of Air Quality Planning and Standards initiated a comprehensive study of the pit retention phenomenon (EPA, 1985). This investigation began with a data collection field study at four Western surface coal mines. Meteorological parameters were measured simultaneously in and out of the mine pits for a total duration of approximately 300 hours. In addition, a smoke release program was conducted to provide data concerning air motion within the pits. At each of the four mines, smoke generators at the bottoms of the pits were used to release discrete 10-second puffs of diesel fuel smoke. An observer positioned at the top of the pit filmed each smoke release on a video cassette recorder (VCR). Roughly 800 such smoke release experiments were conducted at the four mines, and the VCR observations were synchronized with the in-pit and out-of-pit meteorological measurements.

These field data were later reduced and interpreted in order to investigate relationships between meteorological variables and the behavior of the smoke puffs. For each smoke release experiment, the time from initial smoke release until the smoke puff exited the pit, or until the smoke puff was no longer visible, was determined by viewing the VCR tape. This time was used to define a discrete smoke release "episode". All of the data determined by analyzing the VCR tapes, were organized into episodes. Meteorological data (wind speeds, wind directions, temperatures, etc.) were averaged over the episode duration for analysis, along with subjectively determined variables (characteristic flow pattern and location of plume exit), and elapsed time duration of the smoke release episode. This information formed the data base for subsequent analysis.

2.1 SUMMARY OF PREVIOUS DATA ANALYSIS

Several different kinds of analyses were made with the data base, as discussed in "Dispersion of Airborne Particulates in Surface Coal Mines" (EPA, 1985). A comparison of winds in and out of the pits during smoke releases showed that in-pit wind speeds are, on the average, 25% less than the out-of-pit wind speeds, and wind speeds both in and out of the pit were positively correlated. Wind direction in and out of the pits, however, was not correlated, so that a knowledge of wind direction at the top of the pit (ie., at grade level) cannot predict wind direction within the pit.

The smoke puff observations by themselves did not provide a quantitative measure of particulate pit retention.(1) Consequently, a part of the data analysis was devoted to inferring escape fraction from the smoke puff observations by using two independent methods --- one based on a simple settling model, the other based on the source depletion particle deposition model. Both methods relied on assumed particle size distributions: one for particles smaller than 30 microns aerodynamic diameter (called the universal distribution), and one for particles up to 130 microns aerodynamic diameter (called the EDS distribution). It was found that the value of escape fraction inferred from both the settling and the deposition models is greater for unstable and neutral atmospheric conditions, as shown in Table 2.1 This suggests that stable atmospheres may suppress vertical motion causing particulate matter to be retained in the mine pits. In a similar manner, the

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1. A quantitative measure of pit retention is expressed by the escape fraction, ε , which is equal to the total mass of particulate that escapes from the pit, divided by the mass of particulate emitted within the pit.

TABLE 2.1
ESCAPE FRACTION SHOWN BY STABILITY

PARTICLE SIZE DISTRIBUTION	STABILITY(1)	SETTLING MODEL	DEPOSITION MODEL	WINGES EQUATION
UNIVERSAL	UNSTABLE	1.00	0.93	0.99
	NEUTRAL	1.00	0.81	0.92
	STABLE	1.00	0.58	0.58
EDS	UNSTABLE	0.81	0.59	0.90
	NEUTRAL	0.90	0.36	0.59
	STABLE	0.70	0.21	0.20

1. "A" stability class used for unstable; "D" used for neutral; "F" used for stable.

values of escape fraction determined by the settling and deposition models were grouped by National Weather Service wind speed class, as shown in Table 2.2. This analysis indicates that the escape fraction increases with increasing wind speed, as would be expected --- higher wind speeds tend to remove more particulate matter from the pits.

TABLE 2.2
ESCAPE FRACTION BY WIND SPEED

DISTRIBUTION	WIND SPEED (CLASS)	EXIT VELOCITY (SETTLING)	SOURCE DEPLETION (DEPOSITION)	WINGES EQUATION
UNIVERSAL	1	1.00	0.78	0.90
	2	1.00	0.84	0.91
	3	1.00	0.86	0.95
	4	1.00	0.88	0.95
	5	1.00	0.88	0.96
EDS	1	0.75	0.35	0.70
	2	0.85	0.46	0.70
	3	0.96	0.43	0.73
	4	0.96	0.43	0.69
	5	0.99	0.43	0.76

Two analytical expressions which predict escape fraction from meteorological and mine pit parameters were tested. The Winges equation (Winges, 1981), which expresses escape fraction as a function of pit depth, vertical diffusivity, and deposition velocity, was found to be superior:

$$\varepsilon = \frac{1}{1 + \left(\frac{V_d}{K_z}\right) H}$$

where ε is the escape fraction

V_d is the larger of deposition or settling velocity, m/s

K_z is vertical diffusivity, m^2/sec

H is pit depth, m.

The Winges equation was applied independently to each of the smoke release episodes, and the average values of predicted escape fraction were grouped by Pasquill-Gifford stability class and by wind speed. These predicted escape fractions are shown in Tables 2.1 and 2.2, where they are compared with the escape fractions inferred from the measured field data. Reasonably good agreement is indicated between the escape fractions inferred from the settling and deposition models and those predicted by the Winges equation when the data are grouped by stability class. The values of the Winges escape fraction decrease as the atmosphere becomes more stable, just as the measured values do.

When the data are grouped according to wind speed, as in Table 2.2, the agreement between escape fraction inferred from the field data, and escape fraction predicted by the Winges equation, is not especially good. One reason for this may be that the Winges equation does not include wind speed explicitly in estimating escape fraction. This suggests that the performance of the Winges equation may be improved by incorporating wind speed into the equation.

2.2 OVERVIEW OF CURRENT DATA ANALYSIS

The findings from the previous analyses (EPA, 1985) suggest two kinds of follow-on investigations. First, the moderate success of the Winges equation in predicting escape fractions inferred from the field data leads to a question of whether the Winges equation can be improved. In particular, can the agreement between predicted and inferred escape fractions be improved by introducing new variables (eg., wind speed), or by modifying the equation to take into account more accurate representations of dispersion. These questions are explored in Chapter 4 of this report.

The second follow-on investigation concerns the meteorological data collected in and out of the pits. EPA's analysis in January 1985 looked at meteorological conditions that were coincident with smoke puff releases, and were averaged over a time period equal to the episode duration of the smoke puff release. This meant that the values of sigma-theta measured in and out of the pits were converted to alphabetic stability class over time periods equal to the smoke puff episodes, which were generally between 30 seconds to ten minutes in duration. The equivalent alphabetic stability class for these short sampling times was predominantly "D", and as a consequence, further analyses of sigma-theta stability class were not performed. In this present report the values of sigma-theta stability class are recomputed over fifteen minute and one-hour time intervals, as described in the "Guideline on Air Quality Models (Revised)" (EPA, 1984). The details and findings of this investigation are discussed in Chapter 3.

3.0 SIGMA-THETA DATA ANALYSIS

The use of sigma-theta as a measure of atmospheric stability is especially attractive in the analysis of the field data because this is the only turbulence parameter that was measured independently and simultaneously inside and outside the pit.(1) In addition, the recent "Guideline on Air Quality Models (Revised)" (EPA, 1984) recommends the use of sigma-theta as an acceptable measure of stability class, and provides a uniform method to convert short-term values of sigma-theta to one-hour stability classes. Because a majority of the alphabetic stability classes computed previously were Category "D", there was some question about the accuracy of the field data itself. A quality assurance audit of the instrumentation and the software used to measure sigma-theta was made.

3.1 SIGMA-THETA AUDIT

Air Sciences, Inc., the company responsible for collecting the field data, was asked to perform an audit of the wind direction and wind speed instrumentation and the software in the data logger that were used to collect the 1983 field data. Their findings are included in Appendix A of this report. In summary, there were two separate causes of error discovered in the collection and calculation of sigma-theta values:

- POLLING FREQUENCY. The data logger used to interrogate the wind direction sensor was programmed to poll once every 10 seconds, and then compute a one-minute standard deviation from these six samples. This is a low polling frequency. The effect of the low polling frequency would be to introduce random errors in computed one-minute values of sigma-theta. That is, some values of sigma-theta would be artificially too big, and some values would be too small, but over

1. Sigma w, the standard deviation of vertical wind speed, was only measured out of the pit (EPA, 1985).

a large number of computed sigma-thetas the random errors would cancel one another. The effect of this error would tend to diminish with the number of computed sigma-theta values, and it would be expected that over a full one-hour time interval the error inherent in individual one-minute sigma-theta values would cancel out. Consequently, the polling frequency error is not important in one-hour sigma-theta values.

- COMPUTATION OF STANDARD DEVIATION. In computing sigma-theta, the software used in the data logger employed an equation for sample variance(1), as opposed to population variance. The difference in variance computed with the two equations is insignificant for a large number of samples, but when the number of samples, n, is small, the difference can be significant (Mendenhall, 1968):

> "...It can be shown that for small samples (n small) the sample variance tends to underestimate [sigma squared], and that the formula
>
> $$s^2 = \frac{\sum_{i=1}^{n}(y_i - \bar{y})^2}{n-1}$$
>
> provides better estimates."

The error introduced in this manner is systematic, and can be corrected very easily by multiplying the individual one-minute sigma-theta values by 1.1, which is derived as follows:

$$\text{sigma}_{\text{corrected}} = (6/5)^{1/2}\ \text{sigma}_{\text{one-minute}}$$

$$= 1.1\ \text{sigma}_{\text{one-minute}}$$

where $\text{sigma}_{\text{corrected}}$ = corrected value of sigma-theta

$\text{sigma}_{\text{one-minute}}$ = value of sigma-theta from field data

(6/5) = ratio of n and n-1

1. Variance is standard deviation squared.

The conclusion from the instrumentation and software audit is that sigma-theta values computed from the field data will be accurate if 1) the averaging time for computation of overall sigma-theta is increased so that random errors will cancel, and 2) individual one-minute sigma-theta values are multiplied by 1.1 before processing.

3.2 DATA AVERAGING

When the instrument and data logger software audit was completed, the field data were averaged into discrete, consecutive, one-hour time intervals. The one-hour averaging time was chosen since this is the standard time interval used for dispersion model input, and because the "Guideline on Air Quality Models (Revised)" (EPA, 1984) relates alphabetic stability classes to one-hour sigma-theta values. The field data base was that submitted at the conclusion of the field data gathering effort (Hittman and Air Sciences, 1983), except that spurious, illegible characters introduced into the data base during transcription from cassette to magnetic tape had been removed. The period of record for the field data base is shown in Table 3.1, by mine.

TABLE 3.1
FIELD DATA PERIOD OF RECORD IN 1983

MINE	PERIOD OF RECORD
YAMPA	JUNE 28 (1000 - 1400 HRS) JUNE 29 (0800 - 1400 HRS) JUNE 30 (0800) - JULY 2 (0700)
CABALLO	JULY 11 (1200)- JULY 16 (0200)
SPRING CREEK	JULY 19 (0700) - JULY 22 (1000)
ROSEBUD	AUGUST 1 (1100) - AUGUST 5 (1000)

One-hour averages of wind speed (in and out of the pit) and wind direction (in and out of the pit) were computed by scalar averaging and unit vector averaging, respectively.

The one-hour averages of sigma-theta in and out of the pit were computed as follows. First, individual sigma-theta values were multiplied by 1.1 to correct for the error in the data logger software. Next, fifteen consecutive one-minute values of sigma-theta were summed and averaged by the root-mean-squared (rms) method for each quarter hour within a fixed one-hour time period. Finally, the four consecutive 15 minute averages of sigma-theta were combined into an hourly sigma-theta value with the equation

$$\text{sigma}_{\text{1-hour}} = \left(\frac{\text{sigma}_{15}^{2} + \text{sigma}_{15}^{2} + \text{sigma}_{15}^{2} + \text{sigma}_{15}^{2}}{4} \right)^{1/2}$$

where $\text{sigma}_{\text{1 hour}}$ is one-hour average sigma theta

sigma_{15} is fifteen minute sigma-theta

This procedure has been recommended to compute average sigma-theta values in order to minimize wind direction meander effects (EPA, 1984).

Hourly daytime stability classes were computed using sigma-theta classifications and wind speed criteria shown in Table 9-2 and hourly nightime stabilities were computed using Table 9-3 criteria (EPA, 1984). Both of these methodologies eliminate unrealistic occurrences of stable and unstable conditions that would not occur with the Pasquill-Gifford stability typing scheme. For each hour of data, two independent sigma-theta stabilities (one in the pit, one outside the pit) were calculated.

The Pasquill-Gifford (P-G) stability class was determined from cloud cover and ceiling recorded in the field observer's logs, combined with average out-of-pit wind speed during each hour. The procedures used to compute P-G stability class were those used by the National Climatic Data Center (NCDC) in deriving STAR distributions.

The final parameter computed was the ratio of the hourly average sigma-theta measured out of the pit, divided by the sigma-theta measured in the pit. This ratio of sigma-theta values is a dimensionless variable that indicates whether turbulence (as measured by sigma-theta) is greater in or out of the pit. Values of sigma-theta ratio smaller than 1.0 indicate greater turbulence in the pit than out of the pit.

The processed hourly data averages are included in Appendix B of this report. Each data record (one horizontal line) shows a one-hour average of the meteorological parameters. Data fields filled with 999s indicate missing or invalid data.

The one-hour averaged data base shown in Appendix B is different from the data base used previously (EPA, 1985) to examine escape fractions in this respect: the data base in Appendix B presents one-hour averages of meteorological variables, as opposed to averages computed over the smoke puff release episode time.

3.3 METEOROLOGICAL DATA ANALYSIS

It is seen from the one-hour meteorological data in Appendix B that the value of sigma-theta outside the pit is almost always smaller than sigma-theta inside the pit. This is indicated by the value of the parameter RAT (ratio of the hourly sigma-theta out of the pit, divided by the hourly sigma-theta in the pit) which is almost always less than 1.0. In fact, of the 247 valid hourly observations during which both sigma-theta (out) and sigma-theta (in) were present, only 21 of the observations[(1)] indicate that the sigma-theta ratio is greater than 1.0. This indicates that the horizontal

1. The first measured value of sigma-theta ratios on Julian day 181, at time 8:59, was discarded from the data set. This is the first reading of a new measurement run, and it appears to be erroneous. The subsequent value of sigma-theta in the pit at time 9:59 was flagged as incorrect by Air Sciences, Inc.

wind direction fluctuation inside the pit is greater than outside the pit, which is as expected. The in-pit wind sensor responds to the mechanical turbulence caused by airflow over the edge of the pit, and by the wake created downwind of the pit walls. The out-of-pit sensor is not subject to these wake effects since it is located above the mechanically induced pit turbulence region. It should be remembered that sigma-theta does not necessarily measure vertical mixing, and it would be a mistake to conclude that pollutants inside the pit would be more thoroughly dispersed vertically than those outside the pit.

To examine the relationship of sigma-thetas in and out of the mine pits, all data were segregated into groups defined by values of sigma-theta ratio less than and greater than 1.0. The average wind speeds in and out of the mine pits, segregated by sigma-theta ratios, are shown in Table 3.2.

TABLE 3.2
AVERAGE WIND SPEED (kts.) OUT AND IN PIT
GROUPED BY SIGMA-THETA RATIOS

WIND SPEED LOCATION	SIGMA-THETA RATIO < 1.0	SIGMA-THETA RATIO > 1.0
OUT	7.99	4.62
IN	5.71	4.12

Table 3.2 shows that when the ratio of sigma-thetas is less than 1.0 (ie., when sigma-theta out of the pit is less than in the pit) that wind speeds are appreciably larger than when the sigma-theta ratio is greater than 1.0. The relationship of sigma-theta ratios with wind speed can be seen by listing average values of sigma-theta ratio with wind speed categories, in Table 3.3. It is evident that the ratio of in-pit and out-of-pit sigma-thetas depends strongly on wind speed. Values of the ratio decrease with increasing wind speed.

TABLE 3.3
COMPARISON OF WIND SPEED AND
SIGMA-THETA RATIO

OUT OF PIT WIND SPEED (kts.)	SIGMA-THETA RATIO
0 - 3	0.80
4 - 6	0.66
7 - 10	0.60
11 - 16	0.52
17 - 21	0.35
GREATER THAN 21	0.40

The relationship in Table 3.3 could be caused by either 1) increased turbulence in the pit with greater wind speeds, or 2) decreased turbulence out of the pit with greater wind speeds. Examining the sigma-theta values in and out of the pit as a function of wind speeds, suggests that the second explanation is correct.

TABLE 3.4
SIGMA-THETA OUT AND IN PITS
AS A FUNCTION OF WIND SPEED

OUT OF PIT WIND SPEED (kts.)	SIGMA-THETA OUT (deg)	SIGMA-THETA IN (deg)
0 - 3	14.0	19.5
4 - 6	13.9	21.7
7 - 10	13.4	23.7
11 - 16	10.2	20.2
17 - 21	8.3	24.8
GREATER THAN 21	7.2	17.8

The values of sigma-theta out of the pit decrease with increasing wind speed, as seen in Table 3.4. This means that the horizontal fluctuations of wind direction decrease with greater wind speed out of the pit, as would be expected, since higher wind speeds tend to increase wind direction persistence. Inside the pit, however, mechanical turbulence of the pit itself dominates the flow, and horizontal wind directions are more nearly constant regardless of wind speed.

Table 3.5 shows the number of occurrences of alphabetic stability class determined by the Pasquill-Gifford method versus those indicated by sigma-theta in the pit. If the two methods agreed perfectly, then all of the values in Table 3.5 would lie along a line drawn from the upper left of the Table to the lower right. When grouped by general stability category (ie, unstable, neutral, and stable) the agreement is fairly good. For any given value of Pasquill-Gifford stability class, the sigma-theta stability class in the pit tends to be slightly more unstable. Similarly, the comparison of Pasquill-Gifford stability with out-of-pit sigma-theta stability (shown in Table 3.6) exhibits similar general agreement, with the sigma-theta method showing more neutral stability ("D" class) than the Pasquill-Gifford method. Finally, a comparison of sigma-theta stabilities in and out of the pits shown in Table 3.7 indicates that stabilities inside the pit are, by and large, more diverse than stabilities outside the pit. While there are 136 occurrences of neutral ("D") stability measured out of the pit, there are only 55 measured in the pit.

TABLE 3.5
NUMBER OF OCCURRENCES OF STABILITY CLASS
DETERMINED BY PASQUILL-GIFFORD AND
SIGMA-THETA MEASURED IN-PIT

PASQUILL-GIFFORD	SIGMA-THETA IN-PIT					
	A	B	C	D	E	F
A	2	0	0	0	0	0
B	31	9	5	4	0	0
C	30	21	8	7	0	0
D	3	10	2	24	1	0
E	0	0	0	10	6	10
F	0	0	0	11	19	38

TABLE 3.6
NUMBER OF OCCURRENCES OF STABILITY CLASS
DETERMINED BY PASQUILL-GIFFORD AND
SIGMA-THETA MEASURED OUT-OF-PIT

PASQUILL-GIFFORD	SIGMA-THETA OUT-OF-PIT					
	A	B	C	D	E	F
A	0	4	1	1	0	0
B	13	19	22	11	0	0
C	1	7	26	36	0	0
D	0	0	0	42	0	0
E	0	0	0	24	7	0
F	0	0	0	41	32	18

TABLE 3.7
NUMBER OF OCCURRENCES OF STABILITY CLASS
DETERMINED BY SIGMA-THETA OUT-OF-PIT
AND SIGMA-THETA MEASURED IN-PIT

SIGMA THETA IN-PIT	SIGMA-THETA OUT-OF-PIT					
	A	B	C	D	E	F
A	12	14	20	18	0	0
B	0	2	13	24	0	0
C	0	1	6	8	0	0
D	1	0	1	45	7	1
E	0	0	0	17	5	4
F	0	0	0	24	17	7

In general, however, the agreement between all three stability typing schemes (Pasquill-Gifford, sigma-theta in the pit, and sigma-theta out of the pit) is reasonably good. Table 3.8 shows the number of hours in which the various stability classes differ by 0, 1, 2, 3, 4, or 5 categories. Table 3.8 shows that the Pasquill-Gifford method and the sigma-theta in-pit yield the same alphabetic category 87 hours out of a possible 251 hours, and they differ by one category 106 hours. From this, it can be seen that stability class determined by the Pasquill-Gifford method and by measuring sigma-theta in the pit are within one stability category for (87 + 106/251 = .77) 77% of the valid data hours. Similarly, the P-G and the sigma-theta (out-of-pit) stabilities agree within one stability class 82% of the hours, and sigma-theta stabilities in and out of the pit agree within one stability class 64% of the time.

TABLE 3.8
DIFFERENCES IN STABILITY CLASSES

CLASSES DIFFER BY	P-G & SIGMA-THETA IN-PIT	P-G & SIGMA-THETA OUT OF PIT	SIGMA-THETA IN & OUT OF PIT
0	87	112	77
1	106	138	82
2	55	54	69
3	3	1	19
4	0	0	0
5	0	0	0
TOTALS	251	305	247

This good agreement between sigma-theta and Pasquill-Gifford stabilites seemingly contradicts the poor agreement between sigma-theta and P-G stability detected in the previous examination of smoke release episode stabilities (EPA, 1985) in which the majority of the sigma-theta stability classes were found to be "D" class. The most likely reason for poor agreement between sigma-theta stabilities and P-G stabilities in the previous investigation is that the data sampling times in the smoke release data were limited to the episode duration, which varied from one minute to, at most, 20 minutes. Over these short time periods the horizontal wind direction fluctuations are small.

4.0 ANALYSIS OF ESCAPE FRACTION EQUATIONS

In the previous report (EPA, 1985), TRC evaluated two equations for computing the escape fraction. The evaluation data were the inferred escape fractions from the video-tape interpretations. The comparison of the data with the available formula indicated that the equation developed by Winges offered promise. This section details the efforts to extend the original Winges formula.

The original Winges equation was based on a theoretical analysis of diffusion of particles from an open depression in the ground. The derivation of the equation will be presented later in this document, but a general discussion of the overall technique and assumptions is pertinent here. The diffusion of particles from a sub-surface depression can be treated as a steady-state process, such that three phenomena are in constant mass-balance: the emission of dust in the pit, the deposition of dust on the surfaces of the pit and the flux of dust out of the pit.

The mass-balance approach was augmented by the key assumption that the transport of material within the pit could be completely characterized by the diffusion process -- that is, that the mean properties of the wind do not result in any transport of the material out of the pit, rather only the random motions of the wind are responsible for dust loss to the atmosphere. This assumption may be paraphrased as saying that there is no vertical wind within the pit, but there is vertical turbulent diffusion. It is important to emphasize that the concern here is only with vertical motion of the air since the emissions are assumed to occur within a cut from a flat surface and vertical motion is necessary for the escape of particles.

The key parameters are those that concern the vertical diffusion of particles from the pit. In the original Winges equation a simple gradient transfer approach was taken in which the vertical flux was assumed to be proportional to the gradient of concentration of dust within each vertical layer in the pit and the proportionality constant, called the eddy diffusivity, was assumed to be a constant for all heights. This approach, which will be called the Constant-K approach, yielded a simple equation for computation of the escape fraction. For implementation of the above equation, a value of the eddy diffusivity was taken from the literature. Evidence from Draxler (1979) suggests that different eddy diffusivities should be used for different stabilities.

In addition to the experimental evidence offered by TRC, there is ample evidence from the scientific literature that the eddy diffusivity, and hence the escape fraction, is related to the wind speed (Draxler, 1979). The purpose of the current investigation is to determine if wind speed could be incorporated into the previous equation. The logical place to incorporate the wind speed into the earlier formula is through the characterization of diffusion (the eddy diffusivity). Horizontal wind speed influences the vertical diffusion near a surface because a considerable portion of the turbulence near the surface results from frictional shearing caused by the wind as it passes over the surface. If the wind exerts more force on the surface (as a result of greater wind speeds), then it can be expected to create more turbulence.

The current report addresses two general avenues for incorporation of the effect of wind speed on pit retention and within each of these avenues there are options. All of these techniques are presented rather than presenting a single method in the interest of completeness. Later in this chapter, all of the newly-developed techniques will be compared with the experimental data. In addition to a comparison with the experimental data as interpreted in the earlier study, this report also offers a new interpretation of the video tape data. Without detailed experimental data it is not possible to determine if the more complex techniques result in greater accuracy.

4.1 DERIVATION OF THE CANDIDATE ESCAPE FRACTION EQUATIONS

As stated earlier, the original Winges equation was based on the assumption that the eddy diffusivity is a constant throughout the pit. The assumption of a constant eddy diffusivity is based in large part on the lack of understanding of what the dispersion behavior inside a pit really is. It is likely that the flow and turbulence patterns inside a pit are highly complex and not easily represented. Most research on turbulence characteristics are for flow over uniform flat surfaces or simple geometric shapes. Even the few studies which have been performed on shapes similar to a mine pit would not be expected to generalize to all orientations or configurations. Thus, the simple assumption of a horizontally well mixed volume of air with a single value of the eddy diffusivity was used in the original Winges equation because the actual behavior of the eddy diffusivity in the pit is unknown.

4.1.1 THE ORIGINAL WINGES EQUATION

The derivation of the original Winges equation is not in the open literature and may not be available to some readers. The fraction of material which escapes the pit may be represented by the following equation:

$$\varepsilon = \frac{F}{E} \qquad (1)$$

where: ε = escape fraction (dimensionless)
F = flux of material from the pit (g/sec-m^2)
E = emission rate within the pit (g/sec-m^2)

By a simple mass balance argument, the dust emitted in the pit must either be deposited on the internal surfaces of the pit or transported as a flux out of the pit. Mathematically this is represented by:

$$E = F + D \qquad (2)$$

where: D = deposition in the pit (g/sec-m^2)

The original Winges equation attempted to treat a very simplified dispersion scenario, and a number of assumptions were made to simplify the mathematical solution. These include:

1. All emissions occur at the bottom of the pit.

2. The only mechanism for transport of material out of the pit is turbulent diffusion. This assumption, discussed earlier, means that vertical wind speeds will be ignored.

3. The vertical flux of material is constant with height. This must occur if the flow is in steady-state, otherwise concentrations would be building-up inside the pit.

4. The turbulence within the pit is constant throughout the pit. This is the constant eddy diffusivity assumption.

5. Deposition occurs at the bottom of the pit and is proportional to the concentration at the bottom of the pit. The assumption of deposition being proportional to concentration at the ground is well supported in the literature (see for example, Chamberlain and Chadwick, 1953). The proportionality constant has the units of a velocity and is termed the "deposition velocity".

6. Concentrations directly above the pit, resulting from pit emissions, fall to zero at some height above the pit. This condition is necessary as a boundary condition for the differential equations to be solved. It is a reasonable assumption, since emissions that are mixed to the top of the pit would be carried away by the prevailing wind, so that the wind would provide a constant supply of "clean" air at the top of the pit. The original Winges equation used the assumption that concentrations fall to zero at the top of the pit, because it turns out that this results in the greatest percentage of material being lost and thus may be viewed as a conservative assumption. This assumption is generalized here to simply say that concentrations must fall to zero at some height above the bottom of the pit, H, and that height may be specified by the user. To be conservative, the user may select a value of H equal to the depth of the pit so that the zero height is the top of the pit and thereby maximize the escape of emissions.

The gradient transfer approach for dealing with turbulent diffusion is to model the turbulent behavior using equations that match laminar flow. In laminar flow the flux of material across any surface resulting from diffusion is proportional to the concentration gradient between the two bodies of fluid on either side of the surface. The proportionality constant is called diffusivity. The turbulent motions called eddys result in far more transfer of material than the laminar diffusion process. However, it is still the gradient in concentration between two bodies of fluid that results in transfer of material, since the eddy motions result in exchange of fluid across the boundary. Thus, the concept evolved of assuming the diffusion to be proportional to the concentration gradient, but here a much larger proportionality constant, called the "eddy diffusivity" was used (Bird et al., 1960).

There is a large difference between a laminar diffusivity and an eddy diffusivity. The laminar diffusivity is a function of the physical properties of the fluid, such as its viscosity and temperature. The eddy diffusivity is a property of the flow, and for a given fluid and temperature can vary widely depending on the energy of motion of the fluid and the shearing forces and other phenomena. For these purposes here, it is assumed the vertical motion of particles emitted in the pit can be represented by a gradient transfer equation:

$$F = -K\frac{\partial \chi}{\partial z} \qquad (3)$$

where: K = eddy diffusivity (m^2/sec)
χ = concentration (g/m^3)
z = vertical dimension (m)

The general approach in the Constant-K Model is to assume that the eddy diffusivity, K, is a constant with respect to height of the pit. This constant assumption allows easy integration of equation (3) as follows:

$$\chi = -\frac{F}{K} z + C \qquad (4)$$

where: C = constant of integration

It is necessary to evaluate the constant of integration with a boundary condition, and for this purpose, we use the assumption that concentration falls to zero at some height above the surface, H. This is accomplished as follows:

$$0 = -\frac{F}{K} H + C \qquad (5)$$

$$C = \frac{F}{K} H \qquad (6)$$

where: H = height at which $\chi = 0$ (m)

Now, equation (4) becomes:

$$\chi = \frac{F}{K}(H - z) \tag{7}$$

The above equation can be used to evaluate the term "D" in equation (2) with one additional assumption. The deposition at the surface must be proportional to the concentration at the surface. Mathematically this can be represented as (Chamberlain, 1953):

$$D = \chi_{z_0} u_d \tag{8}$$

where: χ_{z_0} = concentration at the surface (g/m^3)
u_d = deposition velocity (m/sec)

Equation (7) allows one to compute the concentration at the surface as follows:

$$\chi_{z_0} = \frac{F}{K}(H - z_0) \tag{9}$$

where: z_0 = some small height, usually called the roughness height (further detail provided later) (m)

Reforming equation (1) and substituting from above as follows:

$$\varepsilon = \frac{F}{F + D} \tag{10}$$

$$\varepsilon = \frac{1}{1 + \frac{D}{F}} \tag{11}$$

$$\varepsilon = \frac{1}{1 + \frac{u_d}{K}(H - z_0)} \tag{12}$$

Since the roughness height is usually very small when compared to H, it is possible to ignore the roughness height and express the equation as follows:

$$\varepsilon = \frac{1}{1 + \frac{u_d}{K}(H)} \tag{13}$$

The above equation is the one used previously (EPA, 1985) in the evaluation of the alternate pit retention formulae and referred to as the original Winges equation.

4.1.2 ALTERNATIVE 1 -- CONSTANT-K USING LINEAR MODEL

The simplest method of incorporating the wind speed into the above formula is to keep the assumption of a constant eddy diffusivity and calculate the value of the eddy diffusivity to be used as a function of the wind speed. This report investigates two general methods for computation of the eddy diffusivity as a function of wind speed. The first of these is based on an assumed linear relationship between wind speed and eddy diffusivity. The second, which will be presented later, involves a more detailed approach for characterizing the eddy diffusivity. The linear assumption results from a number of other assumptions about the relationship between turbulence and wind speed and the derivation of this relationship is presented in the following paragraphs.

The wind speed will generally be measured outside of the pit at some reference height. It is well known that the wind speed in the lower layers of the atmospheric boundary layer increases with height above the surface (Turner, 1970). The shape of the wind speed profile, as it is called, is reflective of the momentum balance of the flow at the surface. In one simplified analysis, the wind speed profile is characterized by two parameters, and these are usually expressed in a logarithmic equation known as the logarithmic profile (Monin and Yaglom, 1971).

$$u = \frac{u_*}{k} \ln\left(\frac{z}{z_0}\right) \qquad (14)$$

where: u = wind speed (m/sec)
u_* = friction velocity (m/sec)
k = von Karman constant, usually assumed to be 0.35

The two parameters, friction velocity and roughness height, will be used extensively in the analysis throughout this document, and need further explanation. The wind moving over the surface of the earth creates a shear stress at the surface. This shear stress, when divided by the density of the air to reduce it to its kinematic properties, has the units of a velocity squared, and when the square root is taken the result is called the friction velocity. The friction velocity, then, may be thought of as a measure of the shear stress exerted by the wind on the surface of the earth. The surface roughness height is a measure of the surface protrusions which create drag on the wind as it passes. The greater the surface area offered by these protrusions, the greater the drag, and the more gradual the increase of the wind speed with height.

The shear stress at the surface is a way of expressing the transfer of momentum by turbulent motion to the surface of the earth (Monin and Yaglom, 1971). The process of the transfer of momentum in turbulent flows is very similar to the process of the transfer of particles, thus it is useful to examine the momentum transfer process as reflected in the wind speed profile to see what it says about the particulate diffusion process. As with the diffusion of particles, a gradient transfer representation can also be used for the transfer of momentum. In the momentum transfer case, the gradient is of the wind speed rather than the concentration of particles The proportionality constant here is customarily called the kinematic eddy viscosity instead of the eddy diffusivity as used for the diffusion of particles earlier.

However, the mechanism for momentum transport is exactly the same as the mechanism for turbulent transfer of gasses and particles, and consequantly, researchers have used the eddy viscosity as a measure of the eddy diffusivity. The mathematical characterization of this process is as follows (Monin and Yaglom, 1971):

$$u_*^2 = - K_\nu \frac{\partial u}{\partial z} \qquad (15)$$

where: K_ν = kinematic eddy viscosity (m^2/sec)

Differentiate the wind speed profile (equation 14), to develop the following:

$$\frac{\partial u}{\partial z} = \frac{u_*}{k} \frac{1}{z} \qquad (16)$$

Substituting and reforming, obtain the following:

$$u_*^2 = - \frac{K_\nu u_*}{kz} \qquad (17)$$

$$K_\nu = - u_* kz \qquad (18)$$

As stated earlier, the wind speed will be measured at some reference height, and consequently, one can compute the resulting eddy viscosity at the same reference height by reforming the logarithmic profile to solve for the friction velocity and substituting the resulting equation into the above equation for the eddy viscosity. This is shown in the next few equations:

$$u_* = \frac{uk}{\ln(\frac{z_{ref}}{z_0})} \qquad (19)$$

where: z_{ref} = reference height of wind speed measurement (m)

$$K_\nu = \frac{uk^2}{\ln(\frac{z_{ref}}{z_0})} z_{ref} \qquad (20)$$

Inserting the solution for the eddy vicosity in place of the eddy diffusivity in equation (13) for the escape fraction yields a solution:

$$\varepsilon = \cfrac{1}{1 = \cfrac{u_d \ln(\frac{z_{ref}}{z_0}) H}{uk^2 z_{ref}}} \qquad (21)$$

4.1.3 ALTERNATIVE 2 -- CONSTANT-K USING A MORE DETAILED MODEL

A major shortcoming of the previous approach is that, while it incorporates wind speed in the equation, it has lost the capability to include stability. The original Winges equation allowed the user to select eddy diffusivities based on stability, if desired. The equation in Alternative 1 has used a simplified measure of the turbulence in the atmosphere to substitute for the eddy diffusivity. A problem arises because the logarithmic profile, while a reasonable approximation to the wind speed profile in uniform flow over a flat plate, ignores the effect of the temperature structure of the atmosphere in enhancing or inhibiting vertical mixing. Temperature structure can have a significant effect on the vertical mixing of both mass and momentum, and the atmospheric stability is an often-used concept to characterize this influence.

There is an alternative approach to the one presented in section 4.1.2. It involves considerably more detail and will be presented but not derived here. It is fundamentally different than the previous approach in that it is an empirical approach rather than a theoretical approach. It uses a parameter called the Monin-Obukhov length to characterize the stability aspects of the flow. The Monin-Obukhov length characterization of temperature structure influences on dispersion is viewed as an improvement over the previous stability classification scheme by the meteorological community.

The eddy diffusivity is computed using the following formula (Draxler, 1979):

$$K = \frac{ku_* z}{\phi_h} \qquad (22)$$

where: ϕ_h = normalized temperature profile

The normalized temperature profile may be computed by one of two formulas and uses the Monin-Obukhov length L. In fact, it is necessary to compute the Monin-Obukhov length first because the choice of formulas to use for the normalized temperature profile is made with the quantity Z/L (also used as a measure of the stability). If the stability is unstable ($Z/L < 0$) then the following formula is used for the normalized temperature profile:

$$\phi_h = \frac{0.74}{(1 - 9\frac{z}{L})^{\frac{1}{2}}} \tag{23}$$

If the stability is stable or neutral ($Z/L \geq 0$) then the following formula is used for the normalized temperature profile:

$$\phi_h = 0.74 + 5\frac{z}{L} \tag{24}$$

The computation of the Monin-Obukhov length is complicated. First, one must compute the Bulk Richardson Number, B, using the following equation:

$$B = \frac{gz^2}{T}\frac{\Delta\Theta}{u^2} \tag{25}$$

where: g = gravitational acceleration ($9.81\ m/sec^2$)
T = ambient temperature (^oK)
$\Delta\Theta$ = potential temperature gradient ($^oK/m$)

Then the Richardson Number itself, Ri, is calculated from the Bulk Richardson using the following equation:

$$B = \frac{Ri}{\left\{\frac{\ln(\frac{z_{ref}}{z_o}) - \psi_m}{\phi_m}\right\}^2} \tag{26}$$

where: ψ_m and ϕ_m are defined below

For stable and neutral conditions:

$$\phi_m = \frac{1}{(1 - 5Ri)} \tag{27}$$

$$\psi_m = \frac{-5Ri}{(1 - 5Ri)} \tag{28}$$

While during unstable conditions:

$$\phi_m = \frac{1}{(1 - 15Ri)^{1.4}} \tag{29}$$

$$\psi_m = \ln\left(\frac{z_{ref}}{z_0}\right) - \left\{\ln\left(\frac{(\zeta-1)(\zeta_0+1)}{(\zeta+1)(\zeta_0-1)}\right) + 2(\tan^{-1}\zeta - \tan^{-1}\zeta_0)\right\} \tag{30}$$

$$\zeta = (1 - 15Ri)^{1/4} \tag{31}$$

$$\zeta_0 = \left(1 - 15Ri\frac{z_0}{z_{ref}}\right)^{1/4} \tag{32}$$

It will be noted that equation (26) cannot be solved directly for the Richardson Number. In fact, solution of the equation is a tedious numerical process. A computer algorithm for the solution of this complicated set of equations is included in Appendix C. Alternative numerical solution techniques may be an improvement and should be investigated. Once the Richardson Number has been computed, the Monin-Obukhov length is computed by one of two formulas. If the Richardson Number is less than zero, the following formula applies:

$$\frac{z}{L} = Ri \tag{33}$$

If the Richardson Number is greater than or equal to zero, the following formula applies:

$$\frac{z}{L} = \frac{Ri}{(1 - 5Ri)} \tag{34}$$

The friction velocity is also computed using an empirical equation of the form:

$$u_* = \frac{ku}{\ln\left(\frac{z_{ref}}{z_0}\right) - \psi_m} \tag{35}$$

Once the eddy diffusivity is computed using the above analysis, it is again assumed to be a constant within the pit and escape fraction is computed using equation (13), which has been repeated here for convenience.

$$\varepsilon = \frac{1}{1 + \frac{u_d}{K}(H)} \tag{13}$$

4.1.4 ALTERNATIVE 3 -- VARIABLE-K USING LINEAR MODEL

The previous two sections presented alternate methods of extending the earlier equation to include wind speed, while at the same time maintaining the assumption that the eddy diffusivity is a constant throughout the pit. It will be noted that both of the alternatives presented thus far require the input of height in the computation of the eddy diffusivity. Section 4.1.2 used the reference height of the wind speed monitor as the height to input when computing the eddy diffusivity. Since the equations imply that eddy diffusivity is a function of height, it seems logical to investigate the implications on the escape fraction if the eddy diffusivity is input into the current analysis as a function of height.

As with the Constant-K methods, the Variable-K methods will investigate two separate options for characterization of the eddy diffusivity: the linear model and the more complex model, using the Monin-Obukhov length.

Equation (20) shows how the eddy viscosity can be calculated using the linear model. The eddy viscosity is then assumed to be equivalent to the eddy diffusivity based on the similarity of mass and momentum transfer processess (Bird, et al, 1960). The height used to compute the eddy diffusivity appears in two places in equation (20). To generalize the equation for application at all heights, the z_{ref} is replaced in one of the occurrences by z. Equation (20) then becomes:

$$K_{\nu} = \frac{uk^2}{\ln(\frac{z_{ref}}{z_0})} z \qquad (36)$$

It should be noted that z_{ref} was not replaced by z in the logarithmic term because the friction velocity is still a constant established by a single measurement of u at a reference height (using equation 19 which was then substituted into equation 18 to produce equation 36). The variable relationship for the eddy diffusivity in equation (36) is then substituted into equation (3) to develop a new relationship for the vertical flux:

$$F = - \frac{uk^2}{\ln(\frac{z_{ref}}{z_0})} z \frac{\partial \chi}{\partial z} \qquad (37)$$

It is important to note that the vertical flux is still a constant, as required by the steady-state assumption. Therefore, the integration of equation (37) is still possible to develop a relationship for calculating concentration as a function of height. The details of the integration are as follows:

$$\partial\chi = - \frac{F \ln(\frac{z_{ref}}{z_0})}{uk^2} \frac{1}{z} \partial z \qquad (38)$$

$$\int_{z_0}^{H} \partial\chi = - \frac{F \ln(\frac{z_{ref}}{z_0})}{uk^2} \int_{z_0}^{H} (\frac{1}{z}) \partial z \qquad (39)$$

$$\chi|_{z=H} - \chi|_{z=z_0} = - \frac{F \ln(\frac{z_{ref}}{z_0})}{uk^2} \ln(\frac{H}{z_0}) \qquad (40)$$

Since $\chi|_{z=H} = 0$

$$\chi_{z_0} = \frac{F \ln(\frac{z_{ref}}{z_0})}{uk^2} \ln(\frac{H}{z_0}) \qquad (41)$$

The deposition at the surface is computed using equations (8) and (41) as follows:

$$D = u_d \chi_{z_0} = \frac{u_d F \ln(\frac{z_{ref}}{z_0})}{uk^2} \ln(\frac{H}{z_0}) \qquad (42)$$

Finally, the escape fraction is computed from equations (11) and (42) as follows:

$$\varepsilon = \frac{1}{1 + \frac{u_d \ln(\frac{z_{ref}}{z_0})}{uk^2} \ln(\frac{H}{z_0})} \qquad (43)$$

The above equation can be used much as equation (21) is used.

4.1.5 ALTERNATIVE 4 -- VARIABLE-K USING THE MORE DETAILED MODEL

Similar to the Constant-K models, equation (43) fails to allow the escape fraction to be computed as a function of stability. It is possible to overcome this limitation by using the more complex technique for computing the eddy diffusivity as a function of the Monin-Obukhov length. The more complex technique also reveals eddy diffusivity to be a function of height. As with the Linear Model, for the more detailed approach in Section 4.1.3, this report recommended using the reference height of the wind speed monitor to compute the constant eddy diffusivity to be used in the escape fraction computation. It is possible to generalize this process by allowing the eddy diffusivity to vary with height in the computation of the escape fraction. The following equation illustrates the generalization of equation (3):

$$F = - K(z)\frac{\partial \chi}{\partial z} \qquad (44)$$

Equation (44) can be integrated over the range of z from the roughness height to H as follows:

$$\partial \chi = - \frac{F}{K(z)} \partial z \qquad (45)$$

$$\int_{z_0}^{H} \partial \chi = - F \int_{z_0}^{H} \left(\frac{1}{K(z)}\right) \partial z \qquad (46)$$

$$\chi|_{z=H} - \chi|_{z=z_0} = - F \int_{z_0}^{H} \left(\frac{1}{K(z)}\right) \partial z \qquad (47)$$

Since the concentration is zero at z=H, the following relationship is developed for the concentration at the roughness height:

$$\chi_{z_0} = F \int_{z_0}^{H} \left(\frac{1}{K(z)}\right) \partial z \qquad (48)$$

Substituting equation (48) in equation (8) and the result into equation (11) yields the following expression for the escape fraction:

$$\varepsilon = \frac{1}{1 + u_d \int_{z_0}^{H} \left(\frac{1}{K(z)}\right) \partial z} \tag{49}$$

The integral of the inverse of the eddy diffusivity can be evaluated numerically, by dividing the vertical extent of the pit (from the roughness height to H) into a series of finite elements and computing the eddy diffusivity at each height using the procedures outlines in equations (22) through (35). The process is not as complicated as it appears. The Richardson Number, Ri, the Monin-Obukhov length, L, and the friction velocity, u_* need only be computed once with the height of the wind speed monitor, z_{ref}, being used for z in all places in equations (25) through (35). Only when computing the eddy diffusivity itself and the normalized temperature profile in equations (22) through (24) should the actual height in the pit be used. Once the eddy diffusivities are computed at each height, the inverse of each is taken, and multiplied by the depth of each finite vertical element. Finally, the resulting values are summed to calculate the integral in equation (49).

4.2 EVALUATION OF CANDIDATE EQUATIONS WITH EXPERIMENTAL DATA

4.2.1 EVALUATION DATA

The only data available for the evaluation of the theoretical escape fraction equations presented in the previous section are the video tape recordings of the smoke releases documented in the earlier report. The major problem with using the smoke release data to evaluate the escape fraction for mining dust is that the particle size distribution for the smoke particles and the mining dust are very different. In fact, the density and size of the smoke particles are sufficiently small to behave virtually like a gas, for which no pit retention would be expected.

The video tapes do, however, give some information on the residence times of the smoke in the pit. From these residence times it is possible to infer some information about the pit retention behavior of actual mining dust. In the earlier work (EPA, 1985) the escape fraction was inferred from the measurement data using two separate techniques. The first involved the computation of an escape velocity by dividing the vertical depth of the smoke release by the residence time. For any fugitive dust source particles of all different sizes would be released. Each particle would have a different gravitational settling velocity and a deposition velocity. The particles were grouped into classes dependant on size and a characteristic gravitational settling velocity and deposition velocity were assumed for each class. The escape velocity was then compared to the larger of the two characteristic velocities (gravitational settling or deposition) for each class. If the escape velocity was larger, all particles in the size class were assumed to escape. If the escape velocity was smaller, all particles in the size class were assumed to be retained.

Two separate particle size distributions were evaluated with the above technique, and an overall escape fraction was computed for each distribution. One particle size distribution came from the PEDCo and TRC 1982 study of coal mines (PEDCo and TRC, 1982). The second size distribution came from a similar study conducted by TRC for the mining industry (Shearer, et al, 1981). The PEDCo/TRC study of size distributions considered only particulate matter smaller than 30 microns, while the TRC mining industry study looked at particles as large as 130 microns.

The second technique for computation of the escape fraction developed in the earlier study involved using an additional theoretical expression. It computed the escape fraction from the source depletion equation developed by Van der Hoven (1968) and the meteorological data collected for each smoke release.

The escape fraction was calculated using each of the above techniques and each of the two particle size distributions for all of the roughly 800 smoke releases. The results of this analysis have been reported in the earlier study.

One observation in the course of the earlier study was that escape fraction computed using the first of the two techniques above (using the escape velocity) revealed little or no pit retention for virtually all cases analyzed. This conclusion disagrees with that of the source depletion analysis. Since the video tape data do not measure escape fraction directly, but rather require the user to infer the escape fraction from the measure of the escape velocity, one effort which was undertaken in the current study was to re-evaluate the data extracted from the video tapes to determine if there were other interpretations which could be used to infer the escape fraction.

The end result is that an alternate interpretation of the data was developed. The escape fractions computed by this new technique provided a different yardstick by which the various escape fraction equations could be evaluated. The derivation of the new technique will be presented in the following paragraphs.

It is necessary to compute how a fugitive dust particle would behave if exposed to the conditions that the smoke puff was exposed to. It is assumed that the residence time in the pit would be unaffected by the change from a smoke puff to a fugitive dust puff, but during the residence time, many of the fugitive dust particles would be deposited on the surface and walls of the pit. Those particles which do not deposit during the residence time are assumed to escape. For a puff of fugitive dust, the rate of deposition is constantly changing as is the concentration within the puff. However, if a mathematical characterization of the rate of deposition over time can be established, the total deposition during the puff's residence in the pit can be computed by integrating the deposition rate over time from the release time to the exit time. This analysis is performed with four equations. Generally, the techniques used to calculate the escape fraction here are the same as equation (1). However, in equation (1) the concern was for a continuous release.

Here the concern is for an instantaneous release. Consequently, the flux term in equation (1) has been replaced by a term representing the amount of material which escapes after a certain residence time in the pit, R.

$$\varepsilon = \frac{E - DEPO(t)\big|_R}{E} \qquad (50)$$

where: E = amount emitted in pit
DEPO(t) = amount deposited on the surface from the release time through t
R = residence time (evaluate DEPO(t) at t=R)

The function DEPO(t) is the total deposition in the pit from the time of release of the smoke puff until some time, t, later (but not later than the residence time, R). The term DEPO is evaluated at t=R in the equation above to determine the total deposition that occurs from the time of release until the puff exits the pit. The function DEPO(t) is defined as follows:

$$DEPO(t) = \int_0^t D(t)WL\,dt \qquad (51)$$

where: D(t) = the average deposition rate over the area of the pit in g/m^2-sec at any time t
W = the width of the pit
L = the length of the pit

Note that the deposition rate, D(t), is a different function than DEPO(t). D(t) is the instantaneous value of the deposition rate at any point in time. As discussed earlier for equation (8), the deposition is assumed to be proportional to the concentration at the surface for uniformly sized particles and in the absence of any change in the meteorological conditions or surface conditions. The concentration is also continuously changing variable in the puff analysis, so a mathematical representation of this proportionality, similar to equation (8), is as follows:

$$D(t) = \chi(t)u_d \tag{52}$$

where: $\chi(t)$ = average concentration in the pit at any time t

u_d = deposition velocity (m/sec)

Finally, define the concentration as a function of time by simply dividing the remaining suspended emissions (amount emitted minus amount deposited from release time until some later time, t) by the dimensions of the pit. This assumes the emissions are well mixed throughout the pit. It is represented as:

$$\chi(t) = \frac{E - DEPO(t)}{HWL} \tag{53}$$

where: H = depth of the pit

The above system of four equations can be solved by first substituting equation (53) into equation (52) as follows:

$$D(t) = \frac{u_d E - u_d DEPO(t)}{HWL} \tag{54}$$

$$D(t) = \frac{u_d E}{HWL} - \frac{u_d DEPO(t)}{HWL} \tag{55}$$

Now, equation (51) is substituted into equation (55) and the result is:

$$D(t) = \frac{u_d E}{HWL} - \frac{u_d}{HWL}\int_0^t D(t)WL\ dt \tag{56}$$

$$D(t) = \frac{u_d E}{HWL} - \frac{u_d}{H}\int_0^t D(t)\ dt \tag{57}$$

$$D(t) + \frac{u_d}{H}\int_0^t D(t)\ dt = \frac{u_d E}{HWL} \tag{58}$$

Equation (58) is an integral expression which is solved by the following expression for D(t):

$$D(t) = \frac{u_d E}{HWL} e^{-\frac{u_d}{H}t} \qquad (59)$$

Now use equations (51) and (59) to evaluate the function DEPO(t):

$$DEPO(t) = \int_0^t \frac{u_d E}{H} e^{-\frac{u_d}{H}t} dt \qquad (60)$$

$$DEPO(t) = \frac{u_d E}{H} \int_0^t e^{-\frac{u_d}{H}t} dt \qquad (61)$$

$$DEPO(t) = \frac{u_d E}{H} \left(- \frac{H}{u_d} e^{-\frac{u_d}{H}t} + \frac{H}{u_d}\right) \qquad (62)$$

$$DEPO(t) = -E e^{-\frac{u_d}{H}t} + E \qquad (63)$$

Finally, evaluate the escape fraction by substituting equation (63) into equation (50) as follows:

$$\varepsilon = \frac{E + E e^{-\frac{u_d}{H}(R)} - E}{E} \qquad (64)$$

$$\varepsilon = e^{-\frac{u_d}{H}(R)} \qquad (65)$$

Using equation (65), which will be called the residence time analysis technique, the escape fraction was computed for each of the roughly 800 smoke releases and for each of the two particle size distributions. This established an additional measurement interpretation for evaluation of the theoretical escape fractions.

4.2.2 COMPARISON OF THE CANDIDATE EQUATIONS WITH THE EVALUATION DATA

There are three different evaluation data sets: one based on the escape velocity, one based on the source depletion equation, and one based on the residence time analysis. For each of these evaluation data sets, the escape fraction has been computed for two different particle size distributions: the Universal Size Distribution from the PEDCo/TRC Study of 1982 and the Emission Factor Development Study (EDS) size distribution.

For each of the smoke releases a Pasquill-Gifford stability class determined in the original study (EPA, 1985) was used here. Most of the parameters needed by the candidate escape fraction equations were available from the original data. It was necessary to specify some of the additional parameters needed by the candidate equations presented earlier. Table 4.1 illustrates the values of the various parameters assumed in this analysis.

TABLE 4.1

PARAMETERS USED IN THE ESCAPE FRACTION COMPUTATIONS

PARAMETER	VALUE
Potential Temperature Gradient ($^{o}K/m$)	
Stability A	-0.010
Stability B	-0.007
Stability C	-0.005
Stability D	0.000
Stability E	0.020
Stability F	0.035
Reference Height for Wind Monitor	10 m
Surface Roughness Height	0.03 m

As depicted in Table 4.2, all of the candidate escape fraction equations exhibit smaller escape fractions for stable conditions than for unstable and neutral conditions, as would be expected. Alternative 2, based on equations (22)-(35) and using equation (13) to compute the escape fraction, demonstrates somewhat better agreement with escape fractions inferred from the source depletion model than do the other alternatives.

TABLE 4.2
ESCAPE FRACTIONS BY STABILITY CLASS[a]

Universal Size Distribution

Equation	A	B	C	D	F
Evaluation Data:					
Escape Velocity	1.00	1.00	1.00	1.00	1.00
Source Depletion	0.93	0.88	0.86	0.81	0.58
Residence Time	0.94	0.94	0.96	0.95	0.91
Theoretical Formulae:					
Original Winges	0.99	0.98	0.96	0.92	0.58
Alternative 1	0.40	0.45	0.58	0.65	0.35
Alternative 2	0.85	0.75	0.70	0.70	0.11
Alternative 3	0.22	0.28	0.42	0.48	0.24
Alternative 4	0.78	0.70	0.66	0.65	0.11

EDS Size Distribution

Equation	A	B	C	D	F
Evaluation Data:					
Escape Velocity	0.81	0.85	0.93	0.90	0.70
Source Depletion	0.59	0.46	0.43	0.36	0.21
Residence Time	0.59	0.63	0.70	0.68	0.51
Theoretical Formulae:					
Original Winges	0.90	0.84	0.73	0.59	0.20
Alternative 1	0.23	0.25	0.37	0.44	0.17
Alternative 2	0.47	0.34	0.30	0.30	0.03
Alternative 3	0.10	0.13	0.22	0.27	0.11
Alternative 4	0.38	0.28	0.26	0.25	0.02

[a] Escape fractions were not computed for P-G stability E due to the infrequent occurrence of this stability class (EPA, 1985).

A similar comparison, stratified by wind speed instead of stability is shown in Table 4.3. All of the candidate escape fraction equations show a much greater change in escape fraction with wind speed than does the original Winges equation. The increase in predicted escape fraction with wind speed matches the trend observed in the evaluation data. In this sense, the introduction of wind speed into the escape fraction computation is successful.

However, the overall conclusion made from examining all of the candidate equations' predicted escape fractions, stratified by both wind speed and stability class, is that none of the candidate escape fraction equations match the evaluation data very closely.

The reasons for the discrepancies are not known; however, it is likely that a number of effects contribute to the error in prediction. Included among these effects are the assumption that there is no vertical component to the wind. It is possible that the vertical component of the wind is responsible for considerably more direct transport of the smoke puff out of the pit than turbulent diffusion. Another source of error is the interpretation of the measurement data. Although the computation of the escape fraction in the evaluation data sets is based on the measurement of residence time for a smoke plume, it may not be possible to infer one from the other. Only by actual measurement of particulate release data could such a quantification be made.

Additional attempts were made to examine the degree of agreement of the candidate equations with the evaluation data using linear regression. It is not possible to perform a linear regression for one of the evaluation data sets (the escape velocity techniques with the Universal Size Distribution) because this technique yielded a value of 1.0 for the escape fraction in every one of the puff releases experiments. Linear regressions were performed, however, for the residence time evaluation data set and for the escape velocity evaluation data set using the EDS particle size distribution. The results of the linear regression using the escape velocity evaluation data set (with the EDS particle size distribution) are depicted in Table 4.4. As the table shows, the observed and predicted comparisons in all cases revealed a

TABLE 4.3

ESCAPE FRACTIONS BY WIND SPEED CLASS[a]

Universal Size Distribution

Equation	Wind Speed Category 1	2	3	4	5
Evaluation Data:	1.00	1.00	1.00	1.00	
Escape Velocity	1.00	1.00	1.00	1.00	1.00
Source Depletion	0.78	0.84	0.86	0.88	0.88
Residence Time	0.92	0.94	0.97	0.97	0.97
Theoretical Formulae:					
Original Winges	0.90	0.91	0.95	0.95	0.96
Alternative 1	0.33	0.49	0.59	0.72	0.80
Alternative 2	0.65	0.61	0.68	0.78	0.85
Alternative 3	0.20	0.32	0.43	0.54	0.61
Alternative 4	0.61	0.56	0.64	0.72	0.77

EDS size Distribution

Equation	Wind Speed Category 1	2	3	4	5
Evaluation Data:					
Escape Velocity	0.75	0.83	0.96	0.96	0.99
Source Depletion	0.35	0.46	0.43	0.43	0.43
Residence Time	0.54	0.62	0.73	0.73	0.76
Theoretical Formulae:					
Original Winges	0.70	0.70	0.73	0.69	0.76
Alternative 1	0.16	0.27	0.36	0.53	0.66
Alternative 2	0.31	0.25	0.27	0.36	0.45
Alternative 3	0.08	0.15	0.22	0.31	0.38
Alternative 4	0.27	0.20	0.24	0.30	0.34

[a] Wind speed categories are those used by the National Climatic Data Center, defined as follows:

Category 1:	0 - 3 knots
2:	4 - 6
3:	7 -10
4:	11 -16
5:	17 -21
6:	above 21

TABLE 4.4
LINEAR REGRESSION RESULTS FOR THE ESCAPE VELOCITY
EVALUATION DATA SET AND THE EDS PARTICLE SIZE DISTRIBUTION

	Regression Parameters		
	a	b	r^2
Original Winges Equation	0.73	0.17	0.03
Alternative 1	0.65	0.53	0.23
Alternative 2	0.76	0.29	0.04
Alternative 3	0.59	1.02	0.39
Alternative 4	0.67	0.68	0.11

very low correlation. This implies that it will be extremely difficult to improve the prediction accuracy by adjustment of the theoretical formulae with arbitrary constants.

Similarly, linear regressions were performed with the residence time evaluation data set and each of the candidate equations for both the Universal and the EDS size distributions. The results are depicted in Table 4.5. As with the earlier table, the agreement between measured and predicted is not encouraging.

TABLE 4.5
LINEAR REGRESSION RESULTS FOR THE
RESIDENCE TIME EVALUATION DATA SET

Universal Size Distribution

	Regression Parameters		
	a	b	r^2
Original Winges Equation	0.86	0.10	0.11
Alternative 1	0.90	0.09	0.22
Alternative 2	0.92	0.04	0.07
Alternative 3	0.90	1.15	0.34
Alternative 4	0.91	0.06	0.11

EDS Size Distribution

	Regression Parameters		
	a	b	r^2
Original Winges Equation	0.57	0.12	0.03
Alternative 1	0.52	0.41	0.22
Alternative 2	0.63	0.07	0.00
Alternative 3	0.48	0.94	0.39
Alternative 4	0.59	0.26	0.03

5.0 ESCAPE FRACTION ALGORITHM FOR ISC

The previous sections have detailed the development of four separate equations for computing the escape fraction as a function of commonly measurable parameters. This chapter discusses the adaptation of these equations into one of the standard air pollution models, the Industrial Source Complex Model (ISC). Subroutines are developed for each of the four techniques in the previous section for incorporation into the ISC Short-Term Model (ISCST). In addition, it was necessary to make certain changes to the main section of the program and two existing subroutines, INCHK and MODEL.

Appendix C contains a listing of the complete program as modified for this purpose. The version of the ISCST Model that is shown in Appendix C is identical to the version currently available from the National Technical Information Service (NTIS) in the UNAMAP series, with a few changes. These changes are listed as follows:

1. The version of ISCST in Appendix C has been adapted to run on an IBM-PC Computer. The changes necessary to accomplish this were very minor. OPEN statements were added and the character strings were explicitly declared. Also, all quotation marks were changed to apostrophes.

2. A new subroutine called ESCAPE for computation of the escape fraction was added. In Appendix C there are four separate versions of this subroutine corresponding to the four separate techniques developed for the escape fraction computation in the previous chapter.

3. The addition of the subroutine ESCAPE required several new user inputs which were added to the ISCST main program and the subroutines INCHK and MODEL through the addition of a new COMMON block called DEPO. The new paremeters were deposition velocity array (a separate deposition velocity for each source and each particle size group within each source - very similar to the way gravitational settling velocities are included in the original code), the reference height, ZREF, the surface roughness height, ZO, and a pit depth for each source (incorporated in one of the previously unused storage spaces in the SOURCE array). Changes were made to the ISCST program to allow for user input of these variables. ZREF and ZO were added to the end of the card group 2, card number 2. The pit depth is read for each source at the end of card group 6, card number 1 (after the building height) and the deposition velocities are read as a new card appearing after card group 6, card number 4.

4. The call to the new subroutine was added to the MODEL subroutine at two places: in the loop over particle size classes for the concentration calculation and in the loop over particle size classes in the deposition calculation. The subroutine ESCAPE returns the values of the escape fraction, ESCP, which is then used to reduce the vertical distribution function, V.

Using each separate version of the new subroutine, ESCAPE, four separate versions of a compiled and linked ISCST Model were made and tested with a sample data set to verify that they were operational. Appendix D presents the sample outputs for each of these test data sets. The input file is also shown in Appendix D. The same input file is used for all four versions of the model.

Run times for the four different versions of the model were recorded during the tests. While the absolute values of the runtime is not of interest here, the relative times are significant. As might be expected, the equations using the more detailed analysis technique required more computer processing time. The two techniques based on the linear model (alternatives 1 and 3) required approximately the same processing time as the original version of ISCST. Alternative 2 (Constant-K, detailed model) increased the run time by roughly a factor of 1.5, while Alternative 4 (Variable-K, detailed model) increased the run time by roughly a factor of 5.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

A number of conclusions can be formulated based on the foregoing analysis. Some of these conclusions have been stated in the previous report (EPA, 1985) and will be restated here for completeness. Other conclusions presented here have not been previously stated and will be discussed in more detail.

It is clear from the analysis of stabilities discussed in chapter 3.0 that the standard deviation of the wind direction measured inside the pit is always larger than that measured outside the pit. This suggests that the horizontal turbulence is greater inside the pit than outside, and a reasonable explanation for this would be that sensors inside the pit respond to mechanical turbulence caused by airflow over, and in the wake of, the pit wall. Outside the pit this mechanically induced turbulence is absent. It must be remembered that the measurement of sigma-theta in the pit says nothing about vertical turbulence inside or outside the pit.

Another observation concerning the stabilities calculated from the standard deviation of the wind direction is that they agree well with the stabilities estimated from the Pasquill-Gifford method which uses cloud cover and ceiling height. The stabilities computed in and out of the pits are either identical, or only one class different from, the P-G stability for about 80% of the data hours.

Four new equations were developed for the computation of the escape fraction as a function of commonly measured parameters. When compared to escape fractions inferred from the smoke release data, none of these new equations were seen to provide accurate predictions of the escape fraction over the full range of stability classes and wind speeds. There are many reasons for this descrepancy between measured and predicted values, but it is important to reiterate that the smoke release experiments did not measure all of the important quantities which define the escape fraction in and out of the pit.

Another possible reason for the discrepancy between measured and predicted escape fractions is that none of the techniques used to calculate the escape fraction considered the vertical motion of the wind (called convection). It is clear from the smoke release video tapes that in many of the experiments, the smoke was moved from the pit by convection of the air rather than by dispersion. In all four of the escape fraction analysis techniques developed here, an essential assumption is that the only mechanism for transfer of material from the pit to the external air is by dispersion -- convection is ignored.

The question of the influence of stability is very important. The smoke release data imply that during unstable and neutral conditions a large percentage of the dust emitted in the pit escapes. The various theoretical escape fraction equations disagree with the inferred escape fractions from the smoke releases for unstable and neutral conditions. It is likely that for these conditions, the escape fractions inferred from the measurement data are more accurate than the theoretically calculated escape fractions, because the vertical motion of the air may be quite significant for the unstable and neutral conditions and the theoretical formulae do not consider such motion while the residence time extracted from the video tapes is influenced by the vertical winds. Although analysis of vertical wind speeds might be instructive in these instances, characterization of the chaotic flow in the pit would be extremely difficult.

For stable cases, however, the situation is quite different. Here again the smoke release data infer that a large percentage of the emitted dust escapes the pit, but all the theoretical formulae conclude that only a small fraction of the emitted dust escapes. For stable conditions one would expect very little vertical motion of the air, thus the primary mechanism for vertical transport should be dispersion, and in fact that is precisely the assumption made in the development of the candidate equations. While confidence increases in the candidate equations for stable conditions, confidence in the experimental data, and in particular in the ability to infer the escape fraction from the smoke release video tapes, decreases for the stable cases. The reason for this is that in both the interpretations of the smoke release data (the escape velocity evaluation data set and the residence time evaluation data set) the escape fraction is computed from the ratio of the pit depth to the residence time -- a quantity called the escape velocity. Vertical motion is implicit in both evaluations, when in fact for stable conditions, there may be no vertical motion at all, and the residence time of the puff in the pit may be as long as the stable conditions persist. Material will leave the pit, but the mechanism is by dispersion, not by a vertical escape velocity. The centerpoint of the puff (the point of maximum concentration) remains in the pit. The smoke release video tapes did not allow for such long residence times, and in fact the residence time in many cases where the puff appeared to disperse in the pit without any vertical motion was arbitrarily defined based on the time when the camera was turned off, or when the puff was no longer visible.

Focus on the stable cases here is appropriate because they are the most important cases to consider. Computer modeling studies done for permitting of surface mining operations typically predict the peak concentrations under stable, low-wind-speed conditions. The inferred escape fractions fróm the smoke release data imply that a large percentage of the dust escapes the pit during these conditions, while the four candidate equations predict low escape percentages. Since the ability to infer the escape fraction from the smoke release data is the least reliable for the stable conditions, and since the assumptions made to develop the theoretical formulae are most representative of the stable conditions, we conclude that the theoretical formulae are likely to be more correct for these stable conditions than the escape fractions inferred from the smoke releases.

Selecting between the four theoretical formulae for calculation of the escape fraction is not an easy task. None of the equations work particularly well for unstable and neutral conditions, and for the most important conditions, the stable conditions, the evaluation data are suspect and do not provide reliable selection criteria. In all the techniques the escape fraction is defined by the amount of mixing in the pit which allows emissions at the surface of the pit to be mixed upward to where the external flow of wind can carry them away. The amount of mixing is characterized by the eddy diffusivity. For the two models based on the linear model, the amount of mixing is determined from the shearing of the wind speed profile caused by the surface drag of the earth -- a reasonable assumption for small scale dispersion over a uniform flat plat in the open boundary layer. The other two techniques, called the more detailed models, allow consideration of the stability of the atmosphere as it affects the vertical mixing in the pit.

It is our conclusion, therefore, that one of the more detailed techniques (Alternatives 2 and 4) should offer improved prediction accuracy for the escape fraction for stable conditions. It is also evident from the data evaluation that for particles smaller than 30 microns (the universal particle size distribution) there is little difference between Alternative 2 and Alternative 4 (Constant-K vs Variable-K). We conclude that Alternative 2 is the most reasonable method to use for the escape fraction computation for stable conditions for several reasons. There is no basis on which to postulate a relationship for the eddy diffusivity with height within a mining pit and the assumption of a constant value is the simplest assumption which can be made. Also, the Variable-K method (Alternative 4) significantly increases the computation time when used in the ISC Model, without providing significantly different values than the Constant-K method (Alternative 2).

6.2 RECOMMENDATIONS FOR FUTURE WORK

The attempt to develop a characterization for the escape fraction for mining pits is made difficult by the complexity of the dispersion scenario and the difficulty in collecting meaningful data. In the course of our work, we have identified a number of shortcomings in the data and the analysis techniques and we have considered numerous methods for overcoming these shortcomings. However, we believe that our recommendations should be guided by the practical applications of the analysis techniques that are to be developed. Consequently, we will not attempt to provide recommendations for the resolution of every uncertainty we have identified in the course of our study.

While it would be interesting to determine the vertical motions inside mining pits that result in the escape of dust via vertical winds during neutral and unstable conditions, it is very likely that such motions are too complicated to be predicted and simulated in an operational air quality model. The ultimate use of the air quality model is for permitting purposes, and the most important consideration is the conditions which produce the peak impacts. Invariably it is stable low-wind speed conditions that result in the peak concentrations. We will therefore not recommend such studies as wind tunnel investigations of the flow in and around mining pits, because such studies cannot yet adequately reproduce all atmospheric stability classes. We would also not recommend further equation development to take vertical wind velocities into account, since velocities are likely to be highly dependent on site specific conditions, which would not be known prior to a mine's construction, and ultimately it is not such vertical wind conditions which lead to peak impacts as predicted by the air quality model.

Since we have developed several equations for prediction of the escape fraction, which are hoped to work best for the stable conditions of most concern, our primary recommendation concerns the need to develop a data base for the escape fraction during stable conditions which can be used to evaluate the theoretical formulas. One of the fundamental problems with the smoke release data was that they were collected entirely during daylight hours, when stable conditions rarely exist. The best technique for measuring the escape velocity would be the use of dual tracer experiments where a tracer gas is emitted simultaneously with a tracer particle, such as zinc-sulfide. By measuring the relative concentrations of the two tracers downwind, the amount deposited can be determined and the escape fraction readily determined. There are problems with such techniques, because re-entrainment of the tracer particles from previous experiments could contaminate later experiments, thus restricting the number of experiments which could be run at a single mining operation. The dual tracers could be run at night, however, when the stable conditions are most persistent. We have not attempted to estimate costs for such a program but it is assumed that such a program would be a relatively high cost option.

An alternative program which would be less costly, and would not suffer the problems associated with the re-entrainment of tracer particles is to perform a series of experiments with a single tracer gas such as sulfur-hexafluoride. The single tracer experiments could still be run at night when the stable conditions persist, and would provide a direct measure of the ground-level concentration from pollutants emitted at the surface of the pit. While such tracer gases would not undergo deposition, the knowledge of ground-level concentrations at a grid of points throughout the pit as a function of time after release would allow us to fully quantify the dispersion process in the pit. With some assumptions concerning the deposition velocities, the deposition rates of particles on the surface of the pit could be inferred (with much greater accuracy than the smoke releases) and the escape fraction determined. The disadvantage to this technique is that it would require measurement of the tracer concentration at a large number of locations in the pit and it would still involve assumptions concerning the deposition velocities, which would be directly measured in the dual-tracer experiments described earlier. The single tracer program would be significantly cheaper than the dual tracer program, because the sampling equipment for tracer gases is typically low-cost gas syringes which can be analyzed in a remote laboratory with a gas chromatograph.

Another option for establishing a data base for evaluation of the escape fraction equations during stable conditions is to re-evaluate the video-tape recordings. Although the bulk of the experiments were in unstable or neutral conditions, there were roughly 60 experiments during stable conditions. At the time the original viewing of these tapes was performed, the viewers did not know the stability. If given the opportunity to examine these tapes again, the limited number of tapes and the knowledge of the stability class might allow the evaluator to more accurately determine the residence time in the pit. The particular items desired would be the trajectory of the puff and the amount of surface contact experienced by the puff. Also those cases where the puff stayed in the pit and dispersed will be evaluated using a much longer residence time than previously used. It is possible that by reviewing the tapes a more accurate representation of the escape fraction for the stable cases can be established. If a new data base for evaluation of the escape fraction equations can be developed, the equations can be evaluated with the same technique used in the current study.

A final option for future work would be a very simple investigation to determine a "ballpark" estimate of the magnitude of pit retention. Using existing hi-vol data and meteorological data already collected in the vicinity of surface mines, a comparison can be made of actual measured concentrations just downwind of a pit ($C_{measured}$), and modeled concentrations determined from the ISCST model ($C_{modeled}$), which idealizes the terrain as flat and unaffected by the presence of the pit. Emission rates could be estimated from AP-42, Supplement 14 fugitive dust factors, and a representative background concentration (perhaps from an upwind hi-vol) would be subtracted from the measured concentrations. Any departure in the value of ($C_{measured}/C_{modeled}$) from 1.0 would be due to errors in the emission factors, or to errors in the model. If a long time period is considered -- perhaps by examining annual average concentrations -- then random errors in the model and emission factors will cancel out. Difference in the value of ($C_{measured}/C_{modeled}$) from unity would be due to systematic errors, such as pit retention or plume perturbation caused by the pit. In the absence of systematic errors in the emission factors or in idealizing the dust plume, the ratio of ($C_{measured}/C_{modeled}$) would be just equal to the escape fraction for the particle size distribution collected by the hi-vols. This approach would be a "first-cut" at estimating the magnitude of pit retention. Of course, it would offer no insight into the physical mechanisms that control dispersion from the pit, but it would provide an evaluation of the performance of the emission factors and the ISC dispersion model. A study of this sort, using existing data, would cost from $10,000 to $20,000.

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APPENDIX A

AIR SCIENCES AUDIT REPORT

AIR SCIENCES INC.
12687 West Cedar Drive
Lakewood, Colorado 80228
303/988-2960

April 17, 1985
Project No. 5-2

TRC Environmental Consultants, Inc.
7002 South Revere Parkway
Englewood, CO 80112

Attn: Mr. Cliff Cole
Senior Project Manager

RE: Sigma theta audit for TRC project 2990-V82

Gentlemen:

Air Sciences has performed an audit of the wind direction standard deviation signal generated for EPA in the summer of 1983. The audit included an electronic evaluation of the speed and direction circuits used in generating the input for the sigma calculation, and a checking of the software aspects of the calculation. The audit confirms the data as approximately correct as presented in the August 1983 report to EPA.

The direction deviation was calculated on-site by a Campbell Scientific CR-21 data logger taking instantaneous wind speed and direction data from the meteorological sensors. Samples of speed and direction data were taken every ten seconds and from these one minute averages were calculated. Thus, six instantaneous values make up each minute calculation. Note that wind speed and direction vector average was also calculated by the data logger as one-minute averages and any electronic error arising from the sensors, signal conditioning or logger input programming would also affect the wind speed and direction vector averages which were provided in the 1983 report to EPA.

There are several points in the signal conditioning and calculation process where error could arise and a list of them is given below.

1 calibration error in direction sensor
2 excess friction in speed sensor
3 calibration error in electronic conditioning for direction
4 calibration error in electronic conditioning for speed
5 improper matching of the output of conditioning cards to input of logging unit

6 incorrect algorithm built into the digital processing unit
7 incorrect field programming of inputs
8 incorrect field programming of outputs
9 error in transferring data from field tapes to archive tape

Each of these nine items has been investigated as a part of the audit.

1-4 The speed sensor, direction sensor, signal conditioning circuitry, and data logger in the pit were identical to those out of the pit. All calibrations and alterations made to the in-pit sensors and circuits were made also to the out-of-pit sensors. The sensors and signal conditioning circuits from the out-of-pit station have not been used since the 1983 study. These components were recalibrated as a part of this audit and the calibrations compared with their 1983 calibrations. The in-pit sensors are not available, but because of the similarity of the in-pit and out-of-pit systems, we consider a thorough study of the out-of-pit sensors sufficient to demonstrate the condition of the in-pit system also. The calibration documentation is attached. The comparison shows that the components are still in calibration. The checking of the friction of the speed sensor is not documented on the forms. It was checked by touch of an experienced technician and no excessive friction was detected.

5 The speed and direction conditioning card outputs were checked and found to be in the range of 0 to 1 VDC as was earlier assumed. The conditioning cards had been altered in 1983 to produce an instantaneous signal output rather than an averaged signal. This alteration was checked and found to be correct. The logger units were programmed to accept 0 to 1 VDC inputs as designated by the input program No. 1 (as shown on the logger documentation form, input programming section). Logger program No. 1 scales the data to engineering units by a linear equation. That equation requires a slope and an intercept. Note from the programming list that after the input program number the slope and intercept are given. Slope for speed is 50 mph/VDC and for direction is 540 degrees/VDC. The intercepts are both zero by default since they were not programmed in. Thus, the logger was receiving the data in the proper units and performing the proper scaling.

6 The wind direction standard deviation calculational algorithm is attached. It is a numerical procedure for estimating direction standard deviation with listed error of less than 1 percent for deviations less than 40 degrees, which is well within the precision of the measurement. Because direction is a circular function rather than a scalar, the exact mathematical formulation is lengthy and the algorithm in the data logger is only an

approximation. It is based on the assumption that there is no correlation of speed deviation with direction deviation (page B-9). This assumption has been experimentally verified under certain conditions as stated with the algorithm explanation. It is possible that with 10-second scans making up the rather short one-minute averages in the EPA program that this assumption may lead to some error, but we suspect that with several minutes of data averaged together random error of the type we are addressing will cancel.

The standard deviation routine calculates a variance by dividing by (N) rather than (N-1). This introduces an error (underestimate) of about 10 percent in the EPA application where the standard deviation was composed of only six values.

7-8 The programming of inputs and outputs has been documented in the report to EPA. These steps have been verified with the programming manual and found to be correct. Whether these steps were followed in the field cannot be checked, but since the speed, direction and deviation data appears to be consistent among sites we assume that no mistakes were made in the field.

9 Data were collected in the field on cassette tapes and transferred to other magnetic media in the office. It is conceivable that in this transferral process a column of field data could have been truncated. The data is logged in engineering units in the field and this truncation would not have affected the location of the decimal point. The data transferral program (a trivial program) cannot be located and rechecked, but the data has been studied and truncation error is not apparent. Only truncation of the left column would be of concern to us and if the left-most column were truncated it could only be the hundreds column. Most sigma data is in the range of 0 to 40 degrees, well below the hundred level.

These steps complete the Air Sciences audit of the sigma theta calculation. We will be happy to answer questions that should arise from this audit.

Sincerely,

Rodger G. Steen

Rodger G. Steen
Principal

AIR SCIENCES INC.

APPENDIX B

HOURLY METEOROLOGICAL DATA BASE

In this Appendix, hourly averaged values of the parameters defined in Table B2.1 are shown for each hour of the meteorological data base.

TABLE B2.1
DEFINITION OF VARIABLES

NAME	MEANING
DAY	JULIAN DAY ON WHICH DATA WERE RECORDED
NTIME	TIME AT END OF HOURLY AVERAGE (HHMM)
WDOUT	OUT-OF-PIT AVERAGE WIND DIRECTION
WSOUT	OUT-OF-PIT AVERAGE WIND SPEED (mph)
SGOUT	OUT-OF-PIT AVERAGE SIGMA-THETA (deg)
ISGOUT	OUT-OF-PIT SIGMA-THETA STABILITY CLASS
WDIN	IN-PIT AVERAGE WIND DIRECTION
WSIN	IN-PIT AVERAGE WIND SPEED
SGIN	IN-PIT AVERAGE SIGMA-THETA (deg)
ISGIN	IN-PIT SIGMA-THETA STABILITY CLASS
RAT	SGOUT/SGIN
IPG	PASQUILL-GIFFORD STABILITY CLASS
IWS	WIND SPEED CLASS

DAY			NTIME	WDOUT (DEG)	WSOUT (MPH)	SGOUT (DEG)	ISGOUT	WDIN (DEG)	WSIN (MPH)	SGIN (DEG)	ISGIN	RAT	IPG
179	10	59	1059	164.3	5.1	20.91	2	257.9	4.1	32.31	1	.65	2
179	11	59	1159	15.6	6.2	16.12	3	48.8	7.5	18.52	2	.87	2
179	12	59	1259	11.7	6.3	12.12	4	57.2	6.6	26.03	1	.47	1
179	13	59	1359	349.9	7.2	11.01	4	51.2	7.2	32.48	1	.34	2
180	8	59	859	15.3	3.3	16.59	3	37.5	3.2	29.85	1	.56	2
180	9	59	959	351.2	3.2	15.84	3	67.7	3.5	38.93	1	.41	2
180	10	59	1059	354.4	3.5	16.58	3	43.7	4.1	18.15	2	.91	2
180	11	59	1159	359.0	4.1	13.99	3	34.6	4.2	25.28	1	.55	2
180	12	59	1259	329.2	6.4	16.44	3	74.7	5.9	43.26	1	.38	2
180	13	59	1359	320.8	10.8	12.52	3	71.5	8.8	32.97	1	.38	2
181	8	59	859	257.3	4.3	27.37	1	330.6	3.2	2.91	4	9.42	3
181	9	59	959	288.5	9.0	21.32	2	318.3	3.6	999.90	9	9.99	3
181	10	59	1059	268.6	15.0	11.33	4	228.9	11.2	29.07	1	.39	4
181	11	59	1159	273.8	16.0	10.15	4	226.6	10.8	19.77	2	.51	4
181	12	59	1259	273.4	17.3	9.80	4	224.6	13.2	20.31	2	.48	3
181	13	59	1359	272.3	13.7	11.50	4	234.8	10.9	22.68	1	.51	3
181	14	59	1459	280.1	14.3	11.49	4	226.1	11.5	21.67	2	.53	3
181	15	59	1559	275.7	17.0	9.50	4	222.8	12.5	19.51	2	.49	4
181	16	59	1659	280.6	15.6	8.94	4	215.3	12.6	19.66	2	.45	4
181	17	59	1759	266.5	11.6	10.58	4	228.2	9.1	19.11	2	.55	3
181	18	59	1859	253.5	11.6	9.42	4	238.4	8.6	15.43	3	.61	4
181	19	59	1959	223.2	6.9	7.20	5	253.8	5.7	15.54	4	.46	6
181	20	59	2059	196.9	6.0	10.99	4	253.7	4.6	21.51	6	.51	6
181	21	59	2159	199.7	8.8	5.83	5	247.2	4.9	21.76	6	.27	5
181	22	59	2259	203.5	12.5	4.88	4	270.7	8.3	13.51	4	.36	4
181	23	59	2359	203.2	14.5	5.12	4	274.8	10.4	10.13	4	.51	4
182	0	59	59	209.3	15.4	5.58	4	271.7	12.3	9.44	4	.59	4
182	1	59	159	206.0	14.0	5.77	4	270.7	10.8	11.82	4	.49	4
182	2	59	259	96.7	3.3	21.12	6	312.0	5.5	25.20	6	.84	6
182	3	59	359	139.0	2.9	16.77	5	176.2	1.7	29.78	6	.56	6
182	4	59	459	154.7	4.0	16.92	5	175.3	2.0	31.74	6	.53	6
182	5	59	559	239.4	3.7	22.76	6	285.2	8.3	18.41	4	1.24	6
182	6	59	659	218.6	5.0	23.33	6	265.8	4.7	30.37	6	.77	6
182	7	59	759	320.9	2.1	23.66	1	303.8	4.4	26.62	1	.89	2
182	8	59	859	277.6	2.6	30.88	1	334.5	4.2	31.20	1	.99	2
182	9	59	959	224.6	4.3	27.09	1	10.7	4.5	29.35	1	.92	2
182	10	59	1059	341.8	5.5	23.86	1	123.9	6.7	36.09	1	.66	2
182	11	59	1159	286.5	10.1	13.19	3	224.7	8.5	27.37	1	.48	3
182	12	59	1259	257.6	17.2	10.39	4	234.9	12.8	16.02	3	.65	3
182	13	59	1359	248.8	17.3	11.25	4	241.3	13.3	15.54	3	.72	3
182	14	59	1459	231.0	13.7	11.94	4	262.6	11.3	19.44	2	.61	3
182	15	59	1559	212.8	13.1	14.10	3	276.8	10.8	21.68	2	.65	3
182	16	59	1659	261.1	12.3	12.12	4	237.3	9.7	19.48	2	.62	3
182	17	59	1759	247.6	8.8	12.73	3	241.0	7.2	20.25	2	.63	3
182	18	59	1859	245.9	8.6	9.80	4	241.5	7.9	14.25	3	.69	3
182	19	59	1959	220.3	10.7	9.53	4	263.7	8.4	15.35	4	.62	5
182	20	59	2059	182.0	5.9	11.67	4	280.8	4.0	23.14	6	.50	6
182	21	59	2159	139.5	4.9	11.78	4	179.9	2.2	25.74	6	.46	6
182	22	59	2259	191.6	6.0	17.95	5	242.5	3.3	26.43	6	.68	6
182	23	59	2359	203.6	9.4	14.22	4	265.0	6.6	21.62	5	.66	5
183	0	59	59	200.9	11.4	7.19	4	280.8	10.1	11.63	4	.62	5
183	1	59	159	190.3	9.3	15.10	4	254.7	5.7	30.46	6	.50	5
183	2	59	259	200.4	9.7	13.24	4	244.0	4.6	33.18	6	.40	5
183	3	59	359	221.9	13.9	8.66	4	246.4	9.4	15.50	4	.56	4
183	4	59	459	214.4	15.4	8.00	4	262.9	10.7	15.67	4	.51	4
183	5	59	559	216.7	15.1	7.39	4	257.5	10.6	12.60	4	.59	4
183	6	59	659	223.7	13.9	9.14	4	247.7	9.1	46.77	4	.20	4

DAY			NTIME	WDOUT (DEG)	WSOUT (MPH)	SGOUT (DEG)	ISGOUT	WDIN (DEG)	WSIN (MPH)	SGIN (DEG)	ISGIN	RAT	IPG	IW
192	12	59	1259	203.4	6.7	21.93	2	332.3	5.4	999.90	9	9.99	2	2
192	13	59	1359	158.2	8.6	19.29	2	209.9	5.9	31.40	1	.61	2	3
192	14	59	1459	183.5	7.7	24.45	1	174.8	5.6	31.79	1	.77	2	3
192	15	59	1559	174.8	8.3	23.57	1	213.1	6.0	29.49	1	.80	2	3
192	16	59	1659	209.6	8.0	16.84	3	251.6	6.5	25.56	1	.66	2	3
192	18	59	1859	221.1	5.1	17.17	3	272.5	4.4	22.85	1	.75	3	2
192	19	59	1959	322.4	4.2	9.11	4	302.8	3.9	13.16	5	.69	6	2
192	20	59	2059	27.0	5.0	7.10	5	22.3	3.7	13.62	5	.52	6	2
192	21	59	2159	22.5	4.4	20.51	6	286.1	2.6	15.89	5	1.29	6	2
192	23	59	2359	152.1	4.1	9.90	4	132.0	2.0	24.87	6	.40	6	2
193	0	59	59	169.2	5.8	9.75	4	180.3	3.0	31.94	6	.31	6	2
193	1	59	159	186.4	5.3	11.12	4	241.3	1.6	30.64	6	.36	6	2
193	2	59	259	162.8	5.6	6.46	5	136.2	2.0	29.27	6	.22	6	2
193	3	59	359	180.0	4.4	5.70	5	191.5	2.2	17.70	6	.32	6	2
193	4	59	459	152.2	3.6	6.66	5	194.6	2.0	15.73	5	.42	6	1
193	5	59	559	130.4	2.7	6.48	5	269.4	1.1	13.23	5	.49	6	1
193	6	59	659	136.9	5.5	5.45	5	209.9	1.8	21.05	6	.26	6	2
193	7	59	759	150.7	6.2	8.45	4	148.7	3.3	31.47	1	.27	3	2
193	8	59	859	161.5	9.6	7.68	4	186.8	5.1	31.25	1	.25	3	3
193	9	59	959	181.8	10.0	12.96	3	200.6	7.2	19.06	2	.68	3	3
193	10	59	1059	193.6	10.4	11.54	4	205.9	7.4	23.85	1	.48	3	3
193	11	59	1159	226.9	14.4	12.27	4	235.3	10.3	20.59	2	.60	4	4
193	12	59	1259	234.8	16.6	10.46	4	248.8	11.5	21.77	2	.48	3	4
193	13	59	1359	231.3	14.3	11.70	4	232.5	10.5	19.38	2	.60	3	4
193	14	59	1459	216.3	13.5	11.65	4	221.2	9.7	24.98	1	.47	3	4
193	15	59	1559	201.0	12.8	11.78	4	205.0	8.9	23.49	1	.50	3	4
193	16	59	1659	207.0	13.0	11.48	4	225.1	9.0	24.86	1	.46	3	4
193	17	59	1759	212.4	13.3	10.69	4	232.1	9.7	21.18	2	.50	4	4
193	18	59	1859	215.4	13.4	10.05	4	233.1	8.0	24.90	1	.40	4	4
193	19	59	1959	210.9	10.3	7.81	4	244.2	5.3	29.83	6	.26	5	3
193	20	59	2059	188.5	5.0	5.69	5	234.9	1.9	26.26	6	.22	6	2
193	21	59	2159	150.0	5.4	4.48	5	237.3	1.1	10.33	4	.43	6	2
193	22	59	2259	168.0	4.7	10.09	4	267.0	1.6	14.71	5	.69	6	2
193	23	59	2359	113.8	2.5	17.81	6	279.2	1.2	17.02	5	1.05	6	1
194	0	59	59	144.2	1.8	13.30	5	271.3	1.0	13.17	5	1.01	6	1
194	1	59	159	150.5	3.9	12.47	4	174.6	1.1	14.08	5	.89	6	1
194	2	59	259	151.7	2.2	19.70	6	184.6	1.3	16.72	5	1.18	6	1
194	3	59	359	296.5	1.9	16.31	5	290.2	1.3	15.43	5	1.06	6	1
194	4	59	459	311.5	2.6	8.71	4	286.5	1.9	12.38	4	.70	6	1
194	5	59	559	315.4	3.0	8.06	4	319.2	3.0	10.54	4	.76	6	1
194	6	59	659	330.3	3.0	8.75	4	333.1	2.6	10.47	4	.84	6	1
194	7	59	759	132.9	4.1	6.92	4	38.7	1.5	23.54	1	.29	3	2
194	8	59	859	86.2	3.4	19.39	2	51.7	2.2	26.33	1	.74	2	1
194	9	59	959	337.0	8.0	9.69	4	314.9	5.6	21.95	2	.44	2	3
194	10	59	1059	330.9	9.0	11.24	4	337.4	6.5	21.83	2	.51	3	3
194	11	59	1159	326.0	10.8	9.73	4	338.1	7.0	22.46	2	.43	3	3
194	12	59	1259	334.5	9.7	13.84	3	322.6	7.0	23.75	1	.58	2	3
194	13	59	1359	351.5	7.5	19.29	2	332.5	6.4	999.90	9	9.99	2	2
194	14	59	1459	347.3	7.2	18.16	2	999.0	999.0	999.90	9	9.99	2	2
194	15	59	1559	265.3	6.9	18.40	2	999.0	999.0	999.90	9	9.99	2	2
194	16	59	1659	342.6	6.0	19.23	2	999.0	999.0	999.90	9	9.99	2	2
194	17	59	1759	1.3	5.2	13.42	3	999.0	999.0	999.90	9	9.99	2	2
194	18	59	1859	7.5	4.6	9.93	4	999.0	999.0	999.90	9	9.99	3	2
194	19	59	1959	21.3	4.6	6.10	5	999.0	999.0	999.90	9	9.99	6	2
194	20	59	2059	42.2	7.4	2.06	5	999.0	999.0	999.90	9	9.99	6	2
194	21	59	2159	69.4	8.6	3.83	5	999.0	999.0	999.90	9	9.99	5	3
194	22	59	2259	100.0	5.7	5.59	5	999.0	999.0	999.90	9	9.99	6	2
194	23	59	2359	141.7	2.6	18.54	6	999.0	999.0	999.90	9	9.99	6	1

DAY			NTIME	WDOUT (DEG)	WSOUT (MPH)	SGOUT (DEG)	ISGOUT	WDIN (DEG)	WSIN (MPH)	SGIN (DEG)	ISGIN	RAT	IPG
195	0	59	59	158.4	3.2	12.19	4	999.0	999.0	999.90	9	9.99	6
195	1	59	159	310.5	3.2	17.35	5	999.0	999.0	999.90	9	9.99	6
195	2	59	259	317.7	3.6	3.00	6	999.0	999.0	999.90	9	9.99	6
195	3	59	359	305.7	2.4	10.62	4	999.0	999.0	999.90	9	9.99	6
195	4	59	459	319.3	3.2	3.21	6	999.0	999.0	999.90	9	9.99	6
195	5	59	559	325.0	2.7	3.60	6	327.0	2.6	999.90	9	9.99	6
195	6	59	659	301.3	1.4	10.67	4	241.1	1.4	999.90	9	9.99	6
195	7	59	759	146.9	5.5	6.00	4	52.7	2.2	999.90	9	9.99	3
195	8	59	859	151.4	7.9	7.24	4	163.4	3.9	999.90	9	9.99	3
195	9	59	959	157.0	8.6	9.44	4	165.7	6.0	999.90	9	9.99	2
195	11	59	1159	157.2	9.5	15.49	3	177.8	7.3	999.90	9	9.99	3
195	12	59	1259	160.9	9.7	13.43	3	153.9	6.4	34.70	1	.39	2
195	13	59	1359	147.3	11.8	11.85	4	143.7	7.2	29.05	1	.41	3
195	14	59	1459	132.9	11.1	16.20	3	125.0	6.9	30.47	1	.53	3
195	15	59	1559	191.8	9.6	16.20	3	206.9	6.1	30.88	1	.52	3
195	16	59	1659	197.8	11.1	14.40	3	224.0	7.4	25.07	1	.57	3
195	17	59	1759	207.1	9.7	12.77	3	234.3	7.2	24.30	1	.53	3
195	18	59	1859	198.8	9.0	10.59	4	224.8	6.5	20.93	2	.51	3
195	19	59	1959	229.5	10.6	8.84	4	255.1	8.0	17.75	4	.50	5
195	20	59	2059	209.8	5.6	9.65	4	264.3	2.9	21.53	6	.45	6
195	22	59	2259	226.8	19.1	8.38	4	237.9	12.3	29.74	4	.28	4
195	23	59	2359	332.2	32.3	6.41	4	326.2	20.2	17.64	4	.36	4
196	0	59	59	332.2	24.3	7.96	4	323.7	14.8	17.90	4	.44	4
196	1	59	159	333.8	23.5	8.27	4	327.0	13.9	18.95	4	.44	4
196	2	59	259	345.6	21.5	8.18	4	340.7	10.2	25.60	4	.32	4
196	3	59	359	331.3	16.8	7.32	4	325.4	10.5	16.01	4	.46	4
196	4	59	459	335.6	17.4	7.57	4	332.0	10.0	19.60	4	.39	4
196	5	59	559	343.6	18.8	7.56	4	344.5	9.5	23.75	4	.32	4
196	6	59	659	341.7	16.1	7.43	4	333.6	9.7	19.49	4	.38	4
196	7	59	759	335.6	17.5	7.52	4	327.6	12.3	15.65	3	.48	4
196	8	59	859	340.4	17.5	7.20	4	339.2	10.5	21.18	2	.34	4
196	9	59	959	357.0	16.2	8.63	4	11.9	8.6	25.00	1	.35	4
196	10	59	1059	8.1	16.3	8.71	4	37.5	10.7	19.69	2	.44	4
196	11	59	1159	346.0	14.9	9.22	4	349.0	9.6	20.66	2	.45	4
196	12	59	1259	332.1	15.5	9.27	4	324.8	11.1	15.72	3	.59	3
196	13	59	1359	343.8	16.7	8.11	4	349.5	10.0	23.60	1	.34	3
196	14	59	1459	349.0	12.6	11.32	4	345.2	8.3	23.53	1	.48	3
196	15	59	1559	8.6	11.7	13.38	3	30.1	7.9	22.50	1	.59	3
196	16	59	1659	323.4	6.1	17.54	2	331.5	5.2	23.65	1	.74	2
196	18	59	1859	79.8	6.7	7.90	4	91.8	4.8	19.55	2	.40	3
196	19	59	1959	121.3	16.4	5.72	4	113.1	11.7	15.66	4	.37	4
196	20	59	2059	140.5	8.5	6.62	5	137.5	4.2	28.65	6	.23	5
196	21	59	2159	188.6	7.0	8.69	4	225.0	4.4	18.72	6	.46	6
196	23	59	2359	315.9	8.1	7.22	5	302.0	5.6	14.74	4	.49	5
197	0	59	59	319.4	9.6	6.91	5	323.7	14.8	17.90	4	.39	5
197	1	59	159	347.2	4.7	7.02	5	327.0	13.9	18.95	4	.37	6
200	7	59	759	116.6	5.4	999.90	9	94.8	2.5	11.38	4	9.99	3
200	10	59	1059	116.0	9.9	999.90	9	134.3	4.6	25.43	1	9.99	3
200	11	59	1159	106.5	10.2	999.90	9	91.4	4.9	20.55	2	9.99	3
200	12	59	1259	153.3	11.3	999.90	9	102.6	5.8	23.21	1	9.99	3
200	13	59	1359	131.7	5.7	21.46	2	33.1	4.5	27.65	1	.78	1
200	14	59	1459	144.1	7.2	25.35	1	89.2	5.7	22.50	1	1.13	2
200	15	59	1559	130.1	7.8	22.46	2	110.8	6.4	21.83	2	1.03	2
200	16	59	1659	108.8	8.1	17.10	3	125.9	6.2	22.60	1	.76	2
200	17	59	1759	118.2	10.3	12.71	3	110.9	9.1	11.79	4	1.08	3
200	19	59	1959	212.0	14.9	9.47	4	323.8	7.5	19.35	4	.49	4
200	22	59	2259	226.9	5.0	12.77	5	303.4	4.1	18.42	6	.69	6

DAY			NTIME	WDOUT (DEG)	WSOUT (MPH)	SGOUT (DEG)	ISGOUT	WDIN (DEG)	WSIN (MPH)	SGIN (DEG)	ISGIN	RAT	IFG	IWS
201	1	59	159	281.9	6.6	9.22	4	274.8	4.4	17.80	6	.52	6	2
201	2	59	259	280.3	6.2	7.95	4	273.1	3.8	22.16	6	.36	6	2
201	3	59	359	323.0	3.8	18.78	6	119.1	3.9	15.71	5	1.20	6	1
201	4	59	459	358.0	3.9	12.32	4	142.8	3.0	16.92	5	.73	6	1
201	6	59	659	279.3	4.2	9.66	4	290.9	3.4	16.25	5	.59	6	2
201	7	59	759	258.5	3.2	8.46	4	322.0	2.2	14.01	3	.60	2	1
201	8	59	859	106.1	2.3	11.80	4	113.7	2.1	12.84	3	.92	2	1
201	9	59	959	153.8	4.6	14.26	3	99.7	4.1	16.43	3	.87	2	2
201	10	59	1059	66.2	3.0	9.33	4	106.4	3.0	11.64	4	.80	2	1
201	11	59	1159	11.9	2.3	17.20	3	142.9	1.8	24.21	1	.71	2	1
201	12	59	1259	90.4	2.8	13.10	3	122.6	2.8	999.90	9	9.99	1	1
201	13	59	1359	23.8	3.6	20.71	2	999.0	999.0	999.90	9	9.99	1	1
201	14	59	1459	102.7	8.6	8.04	4	106.8	8.7	999.90	9	9.99	2	3
201	15	59	1559	101.3	14.0	6.27	4	109.9	11.3	9.69	4	.65	4	4
201	16	59	1659	107.2	10.7	7.66	4	109.6	9.0	6.94	4	1.10	3	3
201	17	59	1759	116.8	6.0	10.21	4	103.6	4.9	11.57	4	.88	2	2
201	18	59	1859	112.6	6.5	9.26	4	108.0	6.4	8.69	4	1.07	3	2
201	19	59	1959	134.4	7.5	5.93	5	111.9	4.9	10.62	4	.56	5	2
201	20	59	2059	266.3	15.8	9.96	4	286.1	11.6	18.83	4	.53	4	4
202	0	59	59	306.9	7.4	10.88	4	293.8	4.2	10.46	4	1.04	6	2
202	1	59	159	265.2	4.7	20.58	6	266.3	3.3	21.56	6	.95	6	2
202	2	59	259	290.6	5.1	13.37	5	281.2	5.3	8.13	4	1.64	6	2
202	4	59	459	277.5	6.5	7.96	4	274.7	6.6	7.87	4	1.01	6	2
202	5	59	559	284.0	6.1	9.81	4	279.5	5.2	17.18	5	.57	6	2
202	6	59	659	278.0	5.1	8.98	4	97.0	2.6	15.63	5	.57	6	2
202	7	59	759	60.5	3.5	10.45	4	108.7	4.3	5.33	4	1.96	2	1
202	8	59	859	94.6	3.8	11.75	4	108.1	3.6	11.43	4	1.03	2	1
202	9	59	959	102.2	6.0	15.11	3	106.7	5.9	13.79	3	1.10	2	2
202	10	59	1059	107.2	5.5	23.64	1	136.4	5.6	999.90	9	9.99	2	2
202	11	59	1159	97.4	6.0	20.79	2	270.0	6.6	999.90	9	9.99	2	2
202	12	59	1259	107.3	7.6	20.52	2	999.0	999.0	999.90	9	9.99	2	3
202	13	59	1359	105.1	10.3	15.16	3	999.0	999.0	999.90	9	9.99	2	3
202	14	59	1459	103.0	9.7	18.87	2	999.0	999.0	999.90	9	9.99	2	3
202	15	59	1559	127.8	10.5	13.35	3	999.0	999.0	999.90	9	9.99	3	3
202	16	59	1659	95.0	8.1	16.32	3	999.0	999.0	999.90	9	9.99	2	3
202	17	59	1759	106.8	7.0	18.73	2	999.0	999.0	999.90	9	9.99	2	2
202	19	59	1959	83.7	9.2	7.23	5	999.0	999.0	999.90	9	9.99	5	3
202	21	59	2159	32.8	3.1	24.15	6	999.0	999.0	999.90	9	9.99	6	1
202	23	59	2359	270.8	4.6	7.57	5	999.0	999.0	999.90	9	9.99	6	2
203	1	59	159	281.9	3.4	12.79	5	999.0	999.0	999.90	9	9.99	6	1
203	3	59	359	271.1	6.2	3.87	5	999.0	999.0	999.90	9	9.99	6	2
203	5	59	559	269.8	4.8	5.87	5	266.4	3.0	19.78	6	.30	6	2
203	6	59	659	282.5	5.5	8.76	4	288.3	4.2	11.67	4	.75	6	2
203	7	59	759	353.1	2.0	14.60	3	121.3	1.9	19.63	2	.74	2	1
203	8	59	859	307.7	7.0	14.66	3	276.8	6.0	13.81	3	1.06	3	2
203	9	59	959	299.5	6.4	11.71	4	281.7	6.4	18.20	2	.64	2	2

DAY			NTIME	WDOUT (DEG)	WSOUT (MPH)	SGOUT (DEG)	ISGOUT	WDIN (DEG)	WSIN (MPH)	SGIN (DEG)	ISGIN	RAT	IPG
213	11	59	1159	999.0	999.0	999.90	9	352.8	13.2	24.69	1	9.99	9
213	12	59	1259	999.0	999.0	999.90	9	345.7	11.6	21.46	2	9.99	9
213	14	59	1459	246.3	13.7	18.02	4	341.1	12.9	24.56	1	.73	3
213	15	59	1559	153.0	15.0	8.46	4	105.4	8.8	20.47	2	.41	4
213	16	59	1659	150.2	12.9	8.59	4	114.5	9.6	10.74	4	.80	3
213	17	59	1759	151.7	11.4	9.09	4	115.5	9.1	10.94	4	.83	3
213	18	59	1859	249.9	8.7	18.14	2	47.5	7.3	23.72	1	.76	3
213	19	59	1959	227.9	7.9	14.72	4	7.3	5.3	27.45	6	.54	5
213	20	59	2059	186.1	7.2	13.68	4	95.3	3.2	38.09	6	.36	6
213	21	59	2159	218.4	10.8	17.63	4	346.5	4.8	29.65	6	.59	5
213	22	59	2259	234.1	11.6	13.41	4	345.8	7.8	15.60	4	.86	5
213	23	59	2359	215.4	12.6	15.15	4	337.7	8.7	17.97	4	.84	4
214	0	59	59	216.0	13.7	14.45	4	355.5	7.8	28.42	5	.51	4
214	1	59	159	228.6	11.7	15.34	4	1.6	8.9	21.80	4	.70	5
214	2	59	259	232.0	11.2	13.30	4	358.4	7.4	24.71	5	.54	5
214	3	59	359	231.1	10.6	13.75	4	357.4	7.6	23.23	5	.59	5
214	4	59	459	227.4	9.3	15.01	4	357.2	7.3	20.03	4	.75	5
214	5	59	559	229.9	10.6	11.70	4	1.9	7.1	21.40	4	.55	5
214	6	59	659	240.1	9.0	14.92	4	359.1	6.2	21.57	5	.69	5
214	7	59	759	244.4	10.4	15.38	3	349.3	8.3	18.16	2	.85	3
214	8	59	859	246.6	10.1	17.48	3	353.0	8.7	23.39	1	.75	3
214	9	59	959	270.8	11.2	16.91	3	357.8	8.4	29.35	1	.58	3
214	10	59	1059	264.0	10.6	17.83	2	351.6	8.5	25.96	1	.69	3
214	11	59	1159	297.8	11.2	12.70	3	316.7	9.4	14.47	3	.88	3
214	12	59	1259	283.3	13.6	15.08	4	335.5	10.7	22.11	2	.68	3
214	13	59	1359	271.8	13.3	18.73	2	344.9	11.0	23.12	1	.81	3
214	14	59	1459	286.9	12.1	15.76	3	331.4	9.7	25.66	1	.61	3
214	15	59	1559	290.9	11.3	13.33	3	320.4	9.2	20.16	2	.66	3
214	16	59	1659	280.7	8.6	14.33	3	332.7	7.1	22.14	2	.65	3
214	17	59	1759	199.1	9.1	11.50	4	94.0	5.2	31.57	1	.36	3
214	18	59	1859	163.8	19.0	11.29	4	111.9	11.7	18.41	2	.61	4
214	19	59	1959	164.2	17.6	8.89	4	114.4	9.5	18.67	4	.48	4
214	20	59	2059	174.2	14.3	14.54	4	108.4	8.2	30.31	4	.48	4
214	21	59	2159	195.4	11.1	19.40	4	83.7	4.9	41.81	6	.46	5
214	22	59	2259	182.7	10.6	14.53	4	112.7	6.7	35.44	5	.41	5
214	23	59	2359	203.4	7.1	15.21	4	74.9	4.2	37.12	6	.41	6
215	0	59	59	308.0	4.4	8.67	4	305.9	3.7	13.44	5	.65	6
215	1	59	159	274.0	6.2	10.20	4	315.7	4.0	13.50	5	.76	6
215	2	59	259	227.8	3.6	13.76	5	257.1	2.0	21.06	6	.65	6
215	3	59	359	207.9	3.5	22.58	6	204.9	2.9	19.49	6	1.16	6
215	4	59	459	202.4	5.7	23.12	6	126.7	3.9	35.26	6	.66	6
215	5	59	559	223.8	4.8	26.72	6	128.9	4.4	28.48	6	.94	6
215	6	59	659	230.5	3.7	22.28	6	123.2	2.9	29.66	6	.75	6
215	7	59	759	276.1	6.1	17.67	2	354.7	4.6	17.45	3	1.01	3
215	8	59	859	266.7	7.7	18.36	2	4.8	6.8	24.77	1	.74	3
215	9	59	959	237.7	11.3	15.51	3	354.4	10.0	21.76	2	.71	3
215	10	59	1059	266.6	8.8	18.25	2	353.6	7.0	33.23	1	.55	3
215	11	59	1159	259.9	8.1	20.06	2	356.1	6.5	25.56	1	.78	2
215	12	59	1259	246.2	7.5	23.24	1	.1	6.4	29.42	1	.79	2
215	13	59	1359	251.9	6.8	20.09	2	346.1	5.7	25.87	1	.78	2
215	14	59	1459	228.2	6.4	21.91	2	359.2	5.5	30.34	1	.72	2
215	15	59	1559	187.1	7.4	24.15	1	90.2	5.2	32.21	1	.75	2
215	16	59	1659	204.5	5.5	25.60	1	80.0	4.7	29.61	1	.86	2
215	17	59	1759	173.3	6.4	18.33	2	96.4	4.8	23.94	1	.77	2
215	18	59	1859	145.4	7.0	12.57	3	131.2	5.3	16.14	3	.78	3
215	19	59	1959	154.6	8.7	9.26	4	129.0	5.4	21.30	6	.43	5
215	20	59	2059	156.1	11.7	6.19	4	120.7	5.9	21.84	5	.28	5
215	21	59	2159	164.9	9.2	8.64	4	117.0	5.1	27.08	6	.32	5
215	22	59	2259	214.7	6.4	17.70	5	299.1	3.7	27.73	6	.64	6
215	23	59	2359	112.3	4.8	11.80	4	159.2	3.4	21.57	6	.55	6

DAY			NTIME	WDOUT (DEG)	WSOUT (MPH)	SGOUT (DEG)	ISGOUT	WDIN (DEG)	WSIN (MPH)	SGIN (DEG)	ISGIN	RAT	IFG	IWS
216	0	59	59	130.4	3.6	13.01	5	124.6	2.5	22.13	6	.59	6	1
216	1	59	159	45.6	2.2	6.97	5	108.6	2.1	18.74	6	.37	6	1
216	2	59	259	170.7	3.4	14.82	5	301.7	2.4	23.95	6	.62	6	1
216	3	59	359	161.9	2.5	10.65	4	58.5	2.5	20.09	6	.53	6	1
216	4	59	459	200.3	2.3	11.84	4	36.0	2.0	17.91	6	.66	6	1
216	5	59	559	185.4	1.9	9.94	4	92.7	1.7	16.86	5	.59	6	1
216	6	59	659	259.3	4.2	13.12	5	333.2	2.7	23.53	6	.56	6	2
216	8	59	859	350.1	2.8	14.12	3	296.4	2.3	22.22	2	.64	2	1
216	9	59	959	262.0	5.0	19.85	2	356.2	4.4	20.53	2	.97	2	2
216	10	59	1059	272.1	5.9	26.82	1	355.2	5.2	27.39	1	.98	2	2
216	11	59	1159	310.5	5.4	23.58	1	323.6	4.4	29.97	1	.79	2	2
216	12	59	1259	336.2	6.2	18.88	2	278.6	6.8	999.90	9	9.99	1	2
216	13	59	1359	64.2	4.9	21.88	2	999.0	999.0	999.90	9	9.99	1	2
216	14	59	1459	136.9	8.3	14.12	3	999.0	999.0	999.90	9	9.99	2	3
216	15	59	1559	163.8	10.9	14.21	3	999.0	999.0	999.90	9	9.99	3	3
216	16	59	1659	93.0	12.7	13.06	3	999.0	999.0	999.90	9	9.99	3	4
216	17	59	1759	96.5	17.5	10.19	4	999.0	999.0	999.90	9	9.99	4	4
216	18	59	1859	114.5	12.8	8.02	4	999.0	999.0	999.90	9	9.99	4	4
216	19	59	1959	157.0	10.4	8.65	4	999.0	999.0	999.90	9	9.99	5	3
216	20	59	2059	207.7	4.9	11.55	4	999.0	999.0	999.90	9	9.99	6	2
216	21	59	2159	127.6	3.4	7.69	4	999.0	999.0	999.90	9	9.99	6	1
216	22	59	2259	280.4	3.2	9.93	4	999.0	999.0	999.90	9	9.99	6	1
216	23	59	2359	282.4	11.4	11.71	4	999.0	999.0	999.90	9	9.99	5	3
217	0	59	59	271.6	8.7	10.35	4	999.0	999.0	999.90	9	9.99	5	3
217	1	59	159	246.7	5.8	13.59	4	999.0	999.0	999.90	9	9.99	6	2
217	2	59	259	90.6	5.9	13.63	4	999.0	999.0	999.90	9	9.99	6	2
217	3	59	359	99.6	4.0	11.82	4	999.0	999.0	999.90	9	9.99	6	1
217	4	59	459	144.8	2.9	13.21	5	999.0	999.0	999.90	9	9.99	6	1
217	5	59	559	196.0	2.7	21.64	6	999.0	999.0	999.90	9	9.99	6	1
217	6	59	659	273.1	3.4	11.24	4	317.6	1.5	23.37	6	.48	6	1
217	7	59	759	293.6	3.4	14.23	3	33.3	2.0	16.29	3	.87	2	1
217	8	59	859	285.6	6.6	14.04	3	337.7	5.8	17.97	2	.78	3	2
217	9	59	959	277.4	8.1	16.49	3	343.0	6.8	18.74	2	.88	2	3

APPENDIX C

FORTRAN LISTING OF MODIFIED ISCST PROGRAM

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      PROGRAM ISCSTE
C***********************************************************************
C   THE FOLLOWING LINE OF CODE HAS BEEN ALTERED TO RUN ON IBM-PC
      CHARACTER*4 TITLE,IQUN,ICHIUN,CONDEP                              S0106000
C***********************************************************************
      COMMON QF(43500)                                                  S0106010
      DIMENSION IZERO(161),IQF(1)                                       S0106020
      COMMON /LOGIX/ ISW(40),NSOURC,NXPNTS,NYPNTS,NXWYPT,NGROUP,        S0106030
     1 NSOGRP(150),IDSOR(200),IPERD,NPNTS,NAVG,NHOURS,NDAYS,NTDAY,LINE, S0106040
     2 IO,IN,TITLE(15),IQUN(3),ICHIUN(7),CONDEP(6),LIMIT,I13            S0106050
C***********************************************************************
C   THE FOLLOWING LINE OF CODE HAS BEEN ADDED TO COMPUTE ESCAPE FRACTION
      COMMON/DEPO/UD(200,20),ZREF,ZO                                    TRC 001
C***********************************************************************
      EQUIVALENCE (ISW,IZERO),(QF,IQF)                                  S0106060
C     SET MAXIMUM LIMIT FOR "QF" ARRAY.  MUST AGREE WITH VALUE USED TO  S0106070
C     DIMENSION "QF".                                                   S0106080
      LIMIT = 43500                                                     S0106090
C***********************************************************************
C   THE FOLLOWING LINE OF CODE HAS BEEN ADDED TO RUN ON IBM-PC
      OPEN (6,FILE='LPT1:')
C***********************************************************************
      WRITE (6,5432)
 5432 FORMAT ('1',21X,'ISCST   (VERSION 80339)'/
     1 22X,'AN AIR QUALIT/ DISPERSION MODEL IN'/
     2 22X,'SECTION 3. MODELS PROPOSED SEP80 FOR 81 GUIDELINES.'/
     3 22X,'IN UNAMAP (VERSION 4) DEC 80'/
     4 22X,'SOURCE% FILE 16 ON UNAMAP MAGNETIC TAPE FROM NTIS.')
C     CLEAR "QF" ARRAY AND "LOGIX" BLOCK.                               S0106100
      DO 10  I = 1,LIMIT                                                S0106110
   10 QF(I) = 0.0                                                       S0106120
      DO 20  I = 1,161                                                  S0106130
   20 IZERO(I) = 0                                                      S0106140
C     SET INPUT AND OUTPUT LOGICAL UNIT NUMBERS.                        S0106150
      IN = 5                                                            S0106160
      IO = 6                                                            S0106170
C***********************************************************************
C   THE FOLLOWING LINE OF CODE HAS BEEN ADDED TO RUN ON IBM-PC
      OPEN (5,FILE='ISCIN')
C***********************************************************************
C     INPUT TITLE.                                                      S0106180
      READ(IN,9001) (TITLE(I),I=1,15)                                   S0106190
C     INPUT LOGIC OPTIONS.                                              S0106200
      READ(IN,9002) (ISW(I),I=1,40)                                     S0106210
C     INPUT SOURCE & RECEPTOR SIZE VALUES.                              S0106220
C***********************************************************************
C   THE FOLLOWING LINES OF CODE HAVE BEEN ALTERED TO COMPUTE ESCAPE FRACTION
      READ(IN,9003) NSOURC,NXPNTS,NYPNTS,NXWYPT,NGROUP,IPERD,NHOURS,    S0106230
     1 NDAYS,ZREF,ZO                                                    S0106240
C***********************************************************************
C     DETERMINE NUMBER OF TIME PERIODS TO BE CALCULATED.                S0106250
      NAVG = 0                                                          S0106260
      DO 30  I = 7,14                                                   S0106270
      IF (ISW(I) .LE. 0) GOTO 30                                        S0106280
      NAVG = NAVG + 1                                                   S0106290
   30 CONTINUE                                                          S0106300
C     CALCULATE TOTAL NUMBER OF RECEPTORS.                              S0106310
      NPNTS = NXPNTS*NYPNTS + NXWYPT                                    S0106320
      NGROPS = NGROUP                                                   S0106330
      IF(NGROUP .LE. 0) NGROPS = 1                                      S0106340
      NN = NAVG*NPNTS*NGROPS                                            S0106350
C     CALCULATE INDICES FOR STORAGE ALLOCATION.                         S0106360
      I1 = NPNTS + NPNTS + 1                                            S0106370
      I2 = I1 + NN                                                      S0106380
      I3 = I2                                                           S0106390
      IF(ISW(15) .EQ. 1) I3 = I2 + NPNTS*NGROPS                         S0106400
      I4 = I3                                                           S0106410
      I5 = I3                                                           S0106420
      IF(NXPNTS .EQ. 0 .OR. NYPNTS .EQ. 0) GOTO 40                      S0106430
      I4 = I3 + NXPNTS                                                  S0106440
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      I5 = I4 + NYPNTS
   40 I6 = I5
      I7 = I5
      IF(NXWYPT .EQ. 0) GOTO 50
      I6 = I5 + NXWYPT
      I7 = I6 + NXWYPT
   50 I8 = I7
      IF(ISW(4) .NE. 0) I8 = I7 + NPNTS
      I9 = I8
      IF(ISW(17) .NE. 0) I9 = I8 + 4*NN
      I10 = I9
      I11 = I10
      I12 = I10
      IF(ISW(18) .LE. 0) GOTO 60
      I10 = I9 + 150*NAVG*NGROPS
      I11 = I10 + 50*NAVG*NGROPS
      I12 = I11 + NAVG*NGROPS
   60 I13 = I12 + 215*NSOURC - 1
C     DETERMINE IF CALCULATED STORAGE ALLOCATION EXCEEDS LIMIT.
      IF(I13 .LE. LIMIT) GOTO 70
      WRITE(IO,9004) I13,LIMIT
      STOP
C     CALL INPUT ROUTINE.
   70 CALL INCHK(QF(1),QF(I1),QF(I2),QF(I3),QF(I4),QF(I5),QF(I6),QF(I7),
     1 QF(I8),QF(I9),IQF(I10),IQF(I11),QF(I12))
C     CALL MODEL ROUTINE.
      CALL MODEL(QF(1),QF(I1),QF(I2),QF(I3),QF(I4),QF(I5),QF(I6),QF(I7),
     1 QF(I8),QF(I9),IQF(I10),IQF(I11),QF(I12))
      STOP
 9001 FORMAT(15A4)
 9002 FORMAT(40I2)
C***********************************************************************
C   THE FOLLOWING LINE OF CODE HAS BEEN ALTERED TO COMPUTE ESCAPE FRACTION
 9003 FORMAT(8I6,2F10.0)
C***********************************************************************
 9004 FORMAT('1',58H   ***ERROR***  CALCULATED STORAGE ALLOCATION LIMIT 
     1EQUALS,I6,/52H AND EXCEEDS THE MAXIMUM STORAGE ALLOCATION LIMIT OF
     2,I6,/16H RUN TERMINATED.)
      END
```

```
      SUBROUTINE MODEL(CALC,CHIAV,CHIAN,GRIDX,GRIDY,XDIS,YDIS,GRIDZ,
     1 CHIMAX,CHI50,IPNT,ICOUNT,SOURCE)
C                     SUBROUTINE MODEL  (VERSION 80339), PART OF ISCST.
C     THIS ROUTINE CONTAINS THE MODEL EQUATIONS FOR CALCULATING GROUND-
C     LEVEL CONCENTRATION OR DEPOSITION INCLUDING THE PLUME RISE
C     EQUATIONS.  THIS ROUTINE ALSO CONTROLS THE CALCULATION AND OUTPUT
C     OF ALL TABLES THE PROGRAM PRODUCES.
C
      INTEGER QFLG,QFLGS
C***********************************************************************
C   THE FOLLOWING LINE OF CODE ADDED TO RUN ON IBM-PC
      CHARACTER*4 TITLE,IQUN,ICHIUN,CONDEP
C***********************************************************************
      LOGICAL FZERO,WAKE,POLAR,DONE,SGZDON,IFLAG(8),ISW24
      COMMON /LOGIX/ ISW(40),NSOURC,NXPNTS,NYPNTS,NXWYPT,NGROUP,
     1 NSOGRP(150),IDSOR(200),IPERD,NPNTS,NAVG,NHOURS,NDAYS,NTDAY,LINF,
     2 IO,IN,TITLE(15),IQUN(3),ICHIUN(7),CONDEP(6),LIMIT,MIMIT
      COMMON /MET/ IDAY(366),ISTAB(24),AWS(24),TEMP(24),AFV(24),
     1 AFVR(24),HLH(24,2),P(24),DTHDZ(24),DECAY(24),PDEF(6,6),
     2 DTHDEF(6,6),GAM1I,GAM2I,ZR,DDECAY,IMET,ITAP,TK,UCATS(5)
C***********************************************************************
C   THE FOLLOWING LINE OF CODE ADDED TO COMPUTE ESCAPE FRACTION
      COMMON/DEPO/UD(200,20),ZREF,ZO                                   TRC 002
C***********************************************************************
      DIMENSION CALC(1),CHIAV(1),CHIAN(1),GRIDX(1),GRIDY(1),XDIS(1),
     1 YDIS(1),GRIDZ(1),CHIMAX(1),CHI50(150,1),IPNT(50,1),ICOUNT(1),
     2 SOURCE(215,1)
      DIMENSION COSNUM(360),SINNUM(451),RLH(48),SASIGZ(36),SBSIGZ(36),
     1 SP(6),SQ(6),SC(6),SD(6),KAVG(8),MSTAB(24),IMOS(11),ISEAS(12)
      EQUIVALENCE (COSNUM(1),SINNUM(91)),(ISW20,ISW(40)),(VS,SIGYO,XO),
     1 (TS,SIGZO),(POLAR,DONE),(ISW(23),QFLGS)
      DATA SASIGZ / 158.08,170.22,179.52,217.41,258.89,346.75,2*453.85,
     1 90.673,98.483,109.3,61.141,34.459,32.093,32.093,33.504,36.65,
     2 44.053,23.331,21.628,21.628,22.534,24.703,26.97,35.42,47.618,
     3 15.209,14.457,13.953,13.953,14.823,16.187,17.836,22.651,27.074,
     4 34.219 /
      DATA SBSIGZ / 1.0542,1.0932,1.1262,1.2644,1.4094,1.7283,2*2.1166,
     1 .93198,.98332,1.0971,.91465,.86974,.81066,.64403,.60486,.56589,
     2 .51179,.81956,.75660,.63077,.57154,.50527,.46713,.37615,.29592,
     3 .81558,.78407,.68465,.63227,.54503,.46490,.41507,.32681,.27436,
     4 .21716 /
      DATA SC,SD / 24.1667,18.333,12.5,8.333,6.25,4.1667,2.5334,1.8096,
     1 1.0857,.72382,.54287,.36191 /, SP,SQ / .004781486,.006474168,
     2 .009684292,.014649868,.019584802,.029481132,1.1235955,1.1086475,
     3 1.0905125,1.0881393,1.0857763,1.0881393 /
      DATA KAVG / 1,2,3,4,6,8,12,24 /
      DATA IMOS / 32,61,92,122,153,183,214,245,275,306,336 /
      DATA ISEAS / 1,1,2,2,2,3,3,3,4,4,4,1 /
C
C***  INITIALIZE.
C
      ISW24 = ISW(24) .EQ. 1
C     INITIALIZE COSNUM & SINNUM ARRAYS WITH COSINE & SINE VALUES OF
C     INTEGER WIND DIRECTIONS.
      DO 10  I = 1,451
      A1 = I
   10 SINNUM(I) = SIN(A1*.017453293)
C     IF MAX 50 TABLES ARE NOT COMPUTED, ICOUNT & IPNT DO NOT EXIST.
      IF(ISW(18) .LE. 0) GOTO 30
C     INITIALIZE POINTER ARRAY & COUNTER FOR MAXIMUM FIFTY TABLES.
      I1 = NAVG
      IF(NGROUP .GT. 0) I1 = I1*NGROUP
      DO 20  I = 1,I1
      ICOUNT(I) = 0
      DO 20  J = 1,50
   20 IPNT(J,I) = J
C     CALCULATE VIRTUAL DISTANCES FOR ALL SOURCES AND STABILITY
C     CATEGORIES.  ALSO CHECK SOURCE-RECEPTOR DISTANCES.
```

```
   30 LINE = 100
      DO 310 I = 1,NSOURC
      ITYPE = SOURCE(1,I)
      IWAK = ITYPE/8192
      ITYPE = ITYPE - (ITYPE/16)*16
      IF(ITYPE-1) 40 ,110,140
   40 HB = SOURCE(11,I)
      HW = SOURCE(12,I)
      IF(HB .LE. 0.0 .AND. HW .LE. 0.0) GOTO 190
      H = HB
      IF(HW .LT. HB) H = HW
      DO 50  J = 1,36
   50 SOURCE(81+J,I) = (1.2*H/SASIGZ(J))**(1./SBSIGZ(J)) - .01*H
      IF(HW .GE. HB) GOTO 70
      DO 60  J = 1,6
   60 SOURCE(75+J,I) = (.85*HW*SP(J))**SQ(J) - .01*HW
      GOTO 160
   70 IF(HW .GT. 5.*HB) GOTO 90
      DO 80  J = 1,6
   80 SOURCE(75+J,I) = ((.35*HW+.5*HB)*SP(J))**SQ(J) - .01*HB
      GOTO 160
   90 H = .85*HB
      IF(IWAK .EQ. 1) H = 2.25*HB
      DO 100 J = 1,6
  100 SOURCE(75+J,I) = (H*SP(J))**SQ(J) - .01*HB
      GOTO 160
  110 SIGYO = SOURCE(9,I)
      SIGZO = SOURCE(8,I)
      DO 120 J = 1,6
  120 IF(SIGYO .GT. 0.0) SOURCE(75+J,I) = (SIGYO*SP(J))**SQ(J)
      DO 130 J = 1,36
  130 IF(SIGZO .GT. 0.0) SOURCE(81+J,I) = (SIGZO/SASIGZ(J))**
     1                                     (1./SBSIGZ(J))
      GOTO 160
  140 XO = SOURCE(9,I)
      DO 150 J = 1,36
  150 SOURCE(81+J,I) = .001*XO
C     NO VIRTUAL DISTANCFS CAN BE LESS THAN ZERO.
  160 DO 170 J = 1,6
  170 IF(SOURCE(75+J,I) .LT. 0.0) SOURCE(75+J,I) = 0.0
      DO 180 J = 1,36
  180 IF(SOURCE(81+J,I) .LT. 0.0) SOURCE(81+J,I) = 0.0
  190 A1 = 99.99
      IF(ITYPE-1) 200  ,210  ,220
  200 XOP = 0.0
      H = HB
      IF(HW .LT. HB) H = HW
      A1 = 3.*H
      IF(A1 .LT. 99.99) A1 = 99.99
      GOTO 230
  210 XOP = 2.15*SIGYO
      GOTO 230
  220 XOP = .5641896*SOURCE(9,I)
  230 NSO = SOURCE(2,I)
      XS = SOURCE(4,I)
      YS = SOURCE(5,I)
      IF(NXPNTS .EQ. 0 .OR. NYPNTS .EQ. 0) GOTO 270
      POLAR = .FALSE.
      IF(ISW(2) .EQ. 2 .OR. ISW(2) .EQ. 4) POLAR = .TRUE.
      DO 260   J = 1,NYPNTS
      YR = GRIDY(J)
      I1 = YR
      DO 260   K = 1,NXPNTS
      XR = GRIDX(K)
      IF(.NOT.POLAR) GOTO 240
      YR = XR*COSNUM(I1)
      XR = XR*SINNUM(I1)
  240 A3 = YR - YS
      XR = XR - XS
```

```
      A2 = SQRT(XR*XR + A3*A3) - XOP
      IF(A2 .GE. A1) GOTO 260
      IF(LINE .LT. 57) GOTO 250
      WRITE(IO,9011)
      WRITE(IO,9005) TITLE
      WRITE(IO,9002) CONDEP
      LINE = 16
  250 WRITE(IO,9003) NSO,GRIDX(K),GRIDY(J),A2
      LINE = LINE + 1
  260 CONTINUE
  270 IF(NXWYPT .EQ. 0) GOTO 310
      POLAR = .FALSE.
      IF(ISW(3) .EQ. 2) POLAR = .TRUE.
      DO 300   J = 1,NXWYPT
      YR = YDIS(J)
      XR = XDIS(J)
      IF(.NOT.POLAR) GOTO 280
      I1 = YR
      YR = XR*COSNUM(I1)
      XR = XR*SINNUM(I1)
  280 YR = YR - YS
      XR = XR - XS
      A2 = SQRT(XR*XR + YR*YR) - XOP
      IF(A2 .GE. A1) GOTO 300
      IF(LINE .LT. 57) GOTO 290
      WRITE(IO,9005) TITLE
      WRITE(IO,9002) CONDEP
      LINE = 16
  290 WRITE(IO,9003) NSO,XDIS(J),YDIS(J),A2
      LINE = LINE + 1
  300 CONTINUE
  310 CONTINUE
C     INITIALIZE NUMBER DAYS, HOURS & HOURS PER DAY. SET MIXING HEIGHT
C     INDEX.
      NTDAY = 0
      IF(ISW(19) .GT. 1) GOTO 320
      NHOURS = 24
  320 IHM = 1
      IF(ISW(20) .GT. 0) IHM = 2
C
C***  BEGIN LOOP OVER DAYS OF METEOROLOGICAL DATA.
C
      DO 1690 IDY = 1,NDAYS
      WRITE(*,*) ' STARTED DAY NO.',IDY
      IF(ISW(19) .EQ. 1) GOTO 380
C     INPUT A DAY OF CARD MET DATA.
      DO 370 I = 1,NHOURS
      READ(IMET,9004) JDAY,AFV(I),AWS(I),HLH(I,1),TEMP(I),DTHDZ(I),
     1 ISTAB(I),P(I),DECAY(I)
      IF(ISTAB(I) .GT. 6) ISTAB(I) = 6
      AFVR(I) = AFV(I)
      IF(JDAY .LT. 1) JDAY = 1
      IF(I.EQ.1) JDY=JDAY
      IF(ISW(21) .EQ. 3 .AND. ISW(22) .EQ. 3) GOTO 350
C     COMPUTE WIND SPEED CATEGORY IN ORDER TO LOAD DEFAULT VALUE FOR
C     P OR DTHDZ.
      IST = ISTAB(I)
      DO 330 J = 1,5
      ISP = J
      IF(UCATS(J) .GE. AWS(I)) GOTO 340
  330 CONTINUE
      ISP = 6
  340 IF(ISW(21) .NE. 3) P(I) = PDEF(ISP,IST)
      IF(ISW(22) .NE. 3) DTHDZ(I) = DTHDEF(ISP,IST)
  350 IF(ISW(6) .NE. 2) GOTO 370
      IF(I .GT. 1) GOTO 360
      WRITE(IO,9001) JDAY
```

```
      WRITE(IO,9005) TITLE
      WRITE(IO,9007) JDAY
      WRITE(IO,9006)
  360 WRITE(IO,9008) I,AFV(I),AWS(I),HLH(I,1),TEMP(I),DTHDZ(I),
     1 ISTAB(I),P(I),DECAY(I)
  370 CONTINUE
      LINE = 0
      GOTO 480
C     INPUT PRE-PROCESSED MET DATA.
  380 IF(IDAY(IDY) .GT. 0) GOTO 410
      I1 = IDY + 1
      IF(IDAY(I1) .GT. 0) GOTO 390
      READ(IMET) ISTAB
      GOTO 1690
  390 READ(IMET) JYR,IMO,DAY,ISTAB
      LSTAB = ISTAB(1)
      IF(LSTAB .GT. 6) LSTAB = 6
      DO 400 I = 2,24
      IF(ISTAB(I) .GT. 6) ISTAB(I) = 6
      KSTT = ISTAB(I) - LSTAB
      IF(KSTT .GT. 1) ISTAB(I) = LSTAB + 1
      IF(KSTT .LT. -1) ISTAB(I) = LSTAB - 1
  400 LSTAB = ISTAB(I)
      GOTO 1690
  410 READ(IMET) JYR,IMO,DAY,ISTAB,AWS,TEMP,AFV,AFVR,HLH
C     REARRANGE MIXING HEIGHTS.
      DO 420 I = 1,2
      DO 420 J = 1,24
      K = (24*(I-1)) + J
  420 RLH(K) = HLH(J,I)
      DO 430 I = 1,48,2
      J = .5*I + 1
  430 HLH(J,1) = RLH(I)
      DO 440 I = 2,49,2
      J = .5*I
  440 HLH(J,2) = RLH(I)
      IF(IDY .EQ. 1) LSTAB = ISTAB(1)
      IF(LSTAB .GT. 6) LSTAB = 6
C     DO NOT ALLOW STABILITY TO VARY RAPIDLY & ADJUST FOR URBAN MODES.
      DO 460 I = 1,24
      IF(ISTAB(I) .GT. 6) ISTAB(I) = 6
      MSTAB(I) = ISTAB(I)
      KSTT = ISTAB(I) - LSTAB
      IF(KSTT .GT. 1) ISTAB(I) = LSTAB + 1
      IF(KSTT .LT. -1) ISTAB(I) = LSTAB - 1
      IF(ISW(20) .EQ. 0) GOTO 460
      IF(ISW(20) .EQ. 1) GOTO 450
      IF(ISTAB(I) .EQ. 6) ISTAB(I) = ISTAB(I) - 1
      GOTO 460
  450 IF(ISTAB(I) .GT. 4) ISTAB(I) = 4
  460 LSTAB = ISTAB(I)
      IF(ISW(6) .NE. 2) GOTO 480
      WRITE(IO,9001) IDY
      WRITE(IO,9005) TITLE
      WRITE(IO,9007) IDY
      WRITE(IO,9009)
      DO 470 I = 1,24
  470 WRITE(IO,9010) I,AFV(I),AFVR(I),AWS(I),HLH(I,IHM),TEMP(I),
     1 MSTAB(I),ISTAB(I)
      LINE = 0
  480 CONTINUE
C     SET JULIAN DAY.
      IF(ISW(19) .EQ. 1) JDY = IDY
C     FETCH SEASON & MONTH.
      IF(ISW(19) .EQ. 1) GOTO 500
      DO 490 I = 1,11
      IMO = I
      IF(IMOS(I) .GT. JDY) GOTO 500
```

```
  490 CONTINUE                                                          S0302630
      IMO = 12                                                          S0302640
  500 CONTINUE                                                          S0302650
      ISEA = ISEAS(IMO)                                                 S0302660
C                                                                       S0302670
C***  BEGIN LOOP OVER MET DATA FOR EACH HOUR.                           S0302680
C                                                                       S0302690
      DO 1670 IHR = 1,NHOURS                                            S0302700
      IST = ISTAB(IHR)                                                  S0302710
C     IF URBAN MODE 2, ADJUST STABILITY FOR CALCULATION OF SIGY & SIGZ. S0302720
      ISTUM2 = IST                                                      S0302730
      IF(ISW(20) .EQ. 2) ISTUM2 = IST - 1                               S0302740
      IF(ISTUM2 .LT. 1) ISTUM2 = 1                                      S0302750
      UBAR = AWS(IHR)                                                   S0302760
      FV = AFV(IHR)                                                     S0302770
      FVR = AFVR(IHR)                                                   S0302780
      HM = HLH(IHR,IHM)                                                 S0302790
C     SET MIXING HEIGHT TO 10000.0 SO THAT ONLY FIRST TERM OF VERTICAL  S0302800
C     EQUATION IS COMPUTED (RURAL MODE, E & F STABILITIES ONLY).        S0302810
      IF(ISW(20) .EQ. 0 .AND. IST .GT. 4) HM = 10000.0                  S0302820
      TA = TEMP(IHR)                                                    S0302830
      IF(HM .GT. 0.0) HMI = 1./HM                                       S0302840
C     COMPUTE WIND SPEED CATEGORY FOR THIS HOUR.                        S0302850
      DO 510 I = 1,5                                                    S0302860
      ISP = I                                                           S0302870
      IF(UCATS(I) .GE. UBAR) GOTO 520                                   S0302880
  510 CONTINUE                                                          S0302890
      ISP = 6                                                           S0302900
  520 IF(ISW(19) .EQ. 2) GOTO 530                                       S0302910
      PP = PDEF(ISP,IST)                                                S0302920
      DTH = DTHDEF(ISP,IST)                                             S0302930
      DECAY(IHR) = DDECAY                                               S0302940
      GOTO 540                                                          S0302950
  530 PP = P(IHR)                                                       S0302960
      DTH = DTHDZ(IHR)                                                  S0302970
  540 CONTINUE                                                          S0302980
C     CLEAR CALCULATION ARRAY FOR SOURCE SUMMATIONS.                    S0302990
      NPNTS2 = NPNTS + NPNTS                                            S0303000
      DO 550 I = 1,NPNTS2                                               S0303010
  550 CALC(I) = 0.0                                                     S0303020
C     SET IFLAG FOR DAILY TABLES IF HOUR/TIME PERIOD = INTEGER MULTIPLE.S0303030
      DO 560  I = 1,8                                                   S0303040
      IF(ISW(I+6) .NE. 1) GOTO 560                                      S0303050
      IFLAG(I) = .FALSE.                                                S0303060
      IF(MOD(IHR,KAVG(I)) .EQ. 0) IFLAG(I) = .TRUE.                     S0303070
  560 CONTINUE                                                          S0303080
      IF(HM .LE. 0.0) GOTO 1490                                         S0303090
C     COMPUTE X & Y SCALARS OF RANDOM FLOW VECTOR.                      S0303100
      FVRCOS = (FVR+180.)*.017453293                                    S0303110
      FVRSIN = SIN(FVRCOS)                                              S0303120
      FVRCOS = COS(FVRCOS)                                              S0303130
C                                                                       S0303140
C***  BEGIN LOOP OVER SOURCES.                                          S0303150
C                                                                       S0303160
      DO 1480 IS = 1,NSOURC                                             S0303170
C     CLEAR CALCULATION ARRAY FOR EACH SOURCE.                          S0303180
      DO 570 I = 1,NPNTS                                                S0303190
  570 CALC(I) = 0.0                                                     S0303200
      HS = SOURCE(7,IS)                                                 S0303210
      IF(HS .GT. HM) GOTO 1480                                          S0303220
      ITYPE = SOURCE(1,IS)                                              S0303230
      XS = SOURCE(4,IS)                                                 S0303240
      YS = SOURCE(5,IS)                                                 S0303250
      ZS = SOURCE(6,IS)                                                 S0303260
      VS = SOURCE(9,IS)                                                 S0303270
      HB = SOURCE(11,IS)                                                S0303280
      HW = SOURCE(12,IS)                                                S0303290
      D = SOURCE(10,IS)                                                 S0303300
```

```
      TS = SOURCE(8,IS)
      NSO = SOURCE(2,IS)
      IWAK = ITYPE/8192
      QFLG = ITYPE/512 - (ITYPE/8192)*16
      NVS = ITYPE/16 - (ITYPE/512)*32
      ITYPE = ITYPE - (ITYPE/16)*16
      XY = SOURCE(ISTUM2+75,IS)
      FZERO = .FALSE.
      XMAX = 0.0
C     RETRIEVE SOURCE EMISSIONS RATE (IF ANY).
      QTK = 1.0
      IF(QFLG .LE. 0 .AND. QFLGS .LE. 0) GOTO 640
      I1 = IS
      IF(QFLGS .LE. 0) GOTO 580
      I1 = 1
      QFLG = QFLGS
  580 I2 = ISEA
      GOTO (630,590 ,600 ,610 ,620 ) ,QFLG
  590 I2 = IMO
      GOTO 630
  600 I2 = IHR
      GOTO 630
  610 I2 = (IST-1)*6 + ISP
      GOTO 630
  620 I2 = (ISEA - 1)*24 + IHR
  630 QTK = SOURCE(I2+119,I1)
  640 QTK = SOURCE(3,IS)*TK*QTK
C     CALCULATE EFFECTIVE WIND SPEED.
      UBARS = UBAR
      IF(PP) 670,670,650
  650 IF(HS) 670,670,660
C     NOTE%   ZR IS IN RECIPROCAL FORM.
  660 A1 = HS
      IF(HS .LT. 10.0) A1 = AMIN1(10.0,1./ZR)
      UBARS = UBAR*(A1*ZR)**PP
  670 UBARI = 1./UBARS
C     BEGIN PLUME RISE CALCULATIONS FOR STACK-TYPE SOURCES.
      IF(ITYPE-1) 680,840,840
  680 WAKE = .FALSE.
      IF(VS) 690,690,700
C     CHECK FOR DOWNWASH STACK HEIGHT ADJUSTMENT, VS = 0.
  690 IF(ISW(25) .EQ. 2) HS = HS -3.*D
C     IF EXIT VELOCITY, VS, EQUALS 0 THEN DHA = 0.
      DHAWAK = HS
      IF(HS .LT. 2.5*HB .AND. HS .LT. HB+1.5*HW) WAKE = .TRUE.
      GOTO 840
  700 VSD = VS*D
C     CHECK FOR DOWNWASH STACK HEIGHT ADJUSTMENT, VS > 0.
      IF(ISW(25) .EQ. 2 .AND. VS .LT. 1.5*UBARS) HS = HS + (VS*UBARI
     1 -1.5)*(D+D)
      GAMJI = 1./(.33333333+UBARS/VS)
      GAMJI = GAMJI*GAMJI
      IF(DTH .LE. 0.0) GOTO 710
      S = 9.8*DTH/TA
      SI = 1./S
      SS = SQRT(S)
      SSI = 1./SS
  710 IF(TS-TA) 730,730,720
C     IF SOURCE TEMPERATURE = 0, SET EQUAL TO AMBIENT AIR TEMP.
  720 IF(TS) 730,730,740
  730 FM = VSD*VSD*.25
      F = 0.0
      FZERO = .TRUE.
      GOTO 770
  740 TOT = TA/TS
      FM = TOT*VSD*VSD*.25
      F = 2.45*VSD*D*(1.-TOT)
      IF(F .GT. 55.0) GOTO 750
```

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      FC = .0727*VSD**1.3333333                                        S0303990
      GOTO 760                                                         S0304000
  750 FC = .0141*VSD**1.6666667                                        S0304010
  760 IF(F .GT. FC) GOTO 770                                           S0304020
      FZERO = .TRUE.                                                   S0304030
      F = 0.0                                                          S0304040
  770 IF(HB .LE. 0.0) GOTO 800                                         S0304050
      IF(DTH .GT. 0.0) GOTO 780                                        S0304060
C     TEST FOR WAKE EFFECTS-CALCULATE XPLUME.                          S0304070
      DHA = 3.*FM*(HB+HB)*GAMJI*UBARI*UBARI                            S0304080
      DHAWAK = DHA**.33333333                                          S0304090
      GOTO 790                                                         S0304100
  780 DHA = 3.*FM*GAMJI*UBARI*SSI                                      S0304110
      IF(1.570796327*UBARS*SSI.GT.HB+HB) DHA = DHA*SIN(SS*(HB+HB)*UBARI)S0304115
      DHAWAK = DHA**.33333333                                          S0304120
      DHA1 = 3.*VSD*UBARI                                              S0304130
      IF(DHAWAK .GT. DHA1) DHAWAK = DHA1                               S0304140
  790 DHAWAK = HS + DHAWAK                                             S0304150
      IF(DHAWAK.LT.2.5*HB .AND. DHAWAK.LT.HB+1.5*HW) WAKE = .TRUE.     S0304160
  800 IF(DTH .GT. 0.0) GOTO 830                                        S0304180
      IF(FZERO) GOTO 820                                               S0304190
      IF(F .GT. 55.0) GOTO 810                                         S0304200
      XPLUME = 49.*F**.625                                             S0304210
      GOTO 840                                                         S0304220
  810 XPLUME = 119.*F**.4                                              S0304230
      GOTO 840                                                         S0304240
  820 XPLUME = 4.*D*UBARI*(VS+3.*UBARS)**2/VS                          S0304250
      GOTO 840                                                         S0304260
  830 XPLUME = 1.570796327*UBARS*SSI                                   S0304270
      IF(.NOT.FZERO) XPLUME = XPLUME + XPLUME                          S0304280
  840 CONTINUE                                                         S0304290
C     CHECK FOR FINAL PLUME RISE OPTION.                               S0304300
      IF(.NOT.ISW24) GOTO 880                                          S0304310
      IF(DTH .GT. 0.0) GOTO 850                                        S0304320
      DHA = 3.*FM*XPLUME*GAMJI*UBARI*UBARI                             S0304330
      IF(.NOT.FZERO) DHA = DHA + 1.5*F*XPLUME*XPLUME*GAM1I*UBARI**3    S0304340
      GOTO 870                                                         S0304350
  850 IF(FZERO) GOTO 860                                               S0304360
      DHA = 6.*F*GAM2I*UBARI*SI                                        S0304370
      GOTO 870                                                         S0304380
  860 DHA = 3.*FM*GAMJI*UBARI*SSI                                      S0304390
  870 DHA = DHA**.33333333                                             S0304400
  880 CONTINUE                                                         S0304410
C                                                                      S0304420
C***  BEGIN LOOP OVER RECEPTOR POINTS.                                 S0304430
C                                                                      S0304440
      IF(NXPNTS .NE. 0 .AND. NYPNTS .NE. 0) GOTO 900                   S0304450
  890 IF(NXWYPT .EQ. 0) GOTO 1400                                      S0304460
      GOTO 910                                                         S0304470
  900 J = 0                                                            S0304480
      POLAR = .FALSE.                                                  S0304490
      IF(ISW(2) .EQ. 2 .OR. ISW(2) .EQ. 4) POLAR = .TRUE.              S0304500
      NEXTR = 1                                                        S0304510
      GOTO 920                                                         S0304520
  910 I = 0                                                            S0304530
      NEXTR = 3                                                        S0304540
      POLAR = .FALSE.                                                  S0304550
      IF(ISW(3) .EQ. 2) POLAR = .TRUE.                                 S0304560
  920 CONTINUE                                                         S0304570
      IF(NEXTR-2) 930,950,970                                          S0304580
  930 J = J + 1                                                        S0304590
      IF(J. GT. NYPNTS) GOTO 890                                       S0304600
      YR = GRIDY(J)                                                    S0304610
      IF(.NOT.POLAR) GOTO 940                                          S0304620
      IYR = YR                                                         S0304630
      YRS = SINNUM(IYR)                                                S0304640
      YRC = COSNUM(IYR)                                                S0304650
  940 IJ = (J-1)*NXPNTS                                                S0304660
      I = 0                                                            S0304670
```

```
      NEXTR = 2
  950 I = I + 1
      IF(I .LE. NXPNTS) GOTO 960
      NEXTR = 1
      GOTO 920
  960 IJ = IJ + 1
      XR = GRIDX(I)
      GOTO 990
  970 I = I + 1
      IF(I .GT. NXWYPT) GOTO 1400
      YR = YDIS(I)
      IF(.NOT.POLAR) GOTO 980
      IYR = YR
      YRS = SINNUM(IYR)
      YRC = COSNUM(IYR)
  980 IJ = NXPNTS*NYPNTS + I
      XR = XDIS(I)
  990 CONTINUE
      IF(POLAR) GOTO 1000
      XR1 = XR -XS
      YR1 = YR - YS
      GOTO 1010
 1000 XR1 = XR*YRS - XS
      YR1 = XR*YRC - YS
C     CHECK IF TERRAIN ELEVATION IS LOWER THAN STACK HEIGHT.
 1010 IF(ISW(4).NE.1.OR.HS+ZS-GRIDZ(IJ).GT.0.0.OR.ITYPE.EQ.2) GOTO 1020
      IF(LINE .EQ. 0) WRITE(IO,9011)
      WRITE(IO,9012) NSO,XR,YR
      STOP
C     CALCULATE DOWNWIND DISTANCE, XBAR.
 1020 XBAR = -(XR1*FVRSIN + YR1*FVRCOS)
      IF(XBAR .LE. 0.0) GOTO 920
      IF(XMAX .LE. 0.0) GOTO 1030
      IF(XBAR .GT. XMAX .AND. ISW(4) .EQ. 0) GOTO 920
C     CALCULATE CROSSWIND DISTANCE.
 1030 YBAR = XR1*FVRCOS - YR1*FVRSIN
      XOP = 0.0
C     1./SQRT(3.14159265) = .5641896  (CALCULATE EFFECTIVE RADIUS.)
      IF(ITYPE .EQ. 2) XOP = .5641896*XO
      IF(ITYPE .EQ. 1) XOP = 2.15*SIGYO
      A1 = 3.*HB
      IF(HW .LT. HB) A1 = 3.*HW
      IF(A1 .LT. 99.99) A1 = 99.99
      IF((XBAR-XOP) .LT. 0.0) GOTO 920
      A2 = SQRT(XBAR*XBAR + YBAR*YBAR) - XOP
      IF(A2 .LT. A1) GOTO 920
      YP = XBAR*1.19175359
      IF(YBAR .GT. YP) GOTO 920
C     ADJUST XBAR TO DOWNWIND EDGE OF AREA SOURCE.
      IF(ITYPE .EQ. 2) XBAR = XBAR - XOP
C     RESUME PLUME RISE CALCULATIONS.
      H = HS
      IF(ITYPE .GT. 0) GOTO 1095
      IF(ISW24) GOTO 1090
      IF(VS .LE. 0.0) GOTO 1095
      IF(DTH .GT. 0.0) GOTO 1040
      XP = XPLUME
      IF(XBAR .LT. XPLUME) XP = XBAR
      DHA = 3.*FM*XP*UBARI*UBARI*GAMJI
      IF(.NOT.FZERO) DHA = DHA + 1.5*F*XP*XP*GAM1I*UBARI**3
      GOTO 1060
 1040 IF(FZERO) GOTO 1070
      IF(XBAR .LT. XPLUME) GOTO 1050
      DHA = 6.*F*GAM2I*UBARI*SI
      GOTO 1060
 1050 XP1 = SS*XBAR*UBARI
      DHA = 3.*FM*GAMJI*UBARI*SSI*SIN(XP1) + 3.*F*GAM2I*UBARI*SI*
     1      (1.-COS(XP1))
```

```
 1060 DHA = DHA**.33333333                                                  S0305360
      GOTO 1090                                                             S0305370
 1070 DHA = 3.*FM*GAMJI*UBARI*SSI                                           S0305380
      IF(XBAR .GE. XPLUME) GOTO 1080                                        S0305390
      XP1 = SS*XBAR*UBARI                                                   S0305400
      DHA = DHA*SIN(XP1)                                                    S0305410
 1080 DHA = DHA**.33333333                                                  S0305420
      DHA1 = 3.*VSD*UBARI                                                   S0305430
      IF(DHA .GT. DHA1) DHA = DHA1                                          S0305440
C     EFFECTIVE PLUME HEIGHT.                                               S0305450
 1090 H = HS + DHA                                                          S0305460
C     ADJUST H DUE TO TERRAIN                                               S0305470
 1095 IF(ISW(4).NE.1.OR.ISW(1).NE.1.OR.NVS.NE.0.OR.ITYPE.EQ.2) GOTO 1100S0305480
      A1 = ZS - GRIDZ(IJ)                                                   S0305490
      IF(A1 .GT. 0.0) GOTO 1100                                             S0305500
      H = H + A1                                                            S0305510
 1100 CONTINUE                                                              S0305520
      IF(H .LE. HM) GOTO 1110                                               S0305530
      XMAX = XBAR                                                           S0305540
C     IF POLAR & NEXTR=2 & NO TERRAIN, SKIP RINGS FOR THIS RADIAL.          S0305550
      IF(.NOT.POLAR .OR. NEXTR .NE. 2 .OR. ISW(4) .NE. 0) GOTO 920          S0305560
      NEXTR = 1                                                             S0305570
      GOTO 920                                                              S0305580
 1110 XBARK = .001*XBAR                                                     S0305590
      XBARY = XBARK                                                         S0305600
      XBARZ = XBARK                                                         S0305610
C     CALL SIGMAZ TO COMPUTE EFFECTIVE DOWNWIND DISTANCE INDEX, IXDIST.     S0305620
      I1 = 3                                                                S0305630
      IF(ITYPE .EQ. 0 .AND. .NOT.WAKE) I1 = 4                               S0305640
      CALL SIGMAZ(XBARK,SIGZ,BBAR,ISTUM2,IXDIST,I1,SASIGZ,SBSIGZ,           S0305650
     1 SOURCE(82,IS))                                                       S0305660
C     CALCULATE LATERAL AND VERTICAL SIGMAS.                                S0305670
      SGZDON = .FALSE.                                                      S0305680
      IF(ITYPE .GT. 0) GOTO 1130                                            S0305690
 1120 IF(.NOT.WAKE) GOTO 1190                                               S0305700
      A1 = HB                                                               S0305710
      IF(HW .LT. HB) A1 = HW                                                S0305720
      IF(XBAR .GE. 10.*A1) GOTO 1130                                        S0305730
      SGZDON = .TRUE.                                                       S0305740
      SIGZ = .7*A1 + .067*(XBAR-3.*A1)                                      S0305750
      IF(ISTUM2 .GT. 2) GOTO 1140                                           S0305760
      A3 = XBARK + SOURCE(IXDIST+81,IS)                                     S0305770
      CALL SIGMAZ(A3,A2,BBAR,ISTUM2,IXDIST,1,SASIGZ,SBSIGZ,DUMMY)           S0305780
      SIGZ = AMAX1(SIGZ,A2)                                                 S0305790
      GOTO 1140                                                             S0305800
 1130 XBARZ = XBARK + SOURCE(IXDIST+81,IS)                                  S0305810
 1140 IF(ITYPE .GT. 0) GOTO 1180                                            S0305820
      IF(DHAWAK .GT. 1.2*HB) GOTO 1190                                      S0305830
      IF(XBAR .GE. 10.*A1) GOTO 1180                                        S0305840
      IF(HW .LE. 5.*HB) GOTO 1160                                           S0305850
      IF(IWAK .EQ. 1) GOTO 1150                                             S0305860
      SIGY = .35*HB + .067*(XBAR-3.*HB)                                     S0305870
      GOTO 1170                                                             S0305880
 1150 SIGY = 1.75*HB + .067*(XBAR - 3.*HB)                                  S0305890
      GOTO 1170                                                             S0305900
 1160 SIGY = .35*HW + .067*(XBAR - 3.*A1)                                   S0305910
 1170 IF(ISTUM2 .GT. 2) GOTO 1200                                           S0305920
      A3 = XBARK + XY                                                       S0305930
      TH = .017453293*(SC(ISTUM2)-SD(ISTUM2)*ALOG(A3))                      S0305940
      A2 = 465.11628*A3*TAN(TH)                                             S0305950
      SIGY = AMAX1(SIGY,A2)                                                 S0305960
      GOTO 1200                                                             S0305970
 1180 XBARY = XBARK + XY                                                    S0305980
 1190 TH = .017453293*(SC(ISTUM2)-SD(ISTUM2)*ALOG(XBARY))                   S0305990
      SIGY = 465.11628*XBARY*TAN(TH)                                        S0306000
 1200 SIGYI = 1./SIGY                                                       S0306010
      IF(ITYPE .EQ. 2) GOTO 1210                                            S0306020
      A1 = .5*(YBAR*SIGYI)**2                                               S0306030
      IF(A1 .GT. 50.0) GOTO 920                                             S0306040
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 1210 IF(SGZDON) GOTO 1220                                                   S0306050
      CALL SIGMAZ(XBARZ,SIGZ,BBAR,ISTUM2,IXDIST,1,SASIGZ,SBSIGZ,DUMMY)      S0306060
      IF(SIGZ .GT. 5000. .AND. NVS .EQ. 0) SIGZ = 5000.                      S0306070
 1220 SIGZI = 1./SIGZ                                                        S0306080
C     CALCULATE DECAY TERM.                                                  S0306090
      XBARU = XBAR*UBARI                                                     S0306100
      DECAYT = 1.0                                                           S0306110
      IF(DECAY(IHR) .GT. 0.0) DECAYT = EXP(-DECAY(IHR)*XBARU)                S0306120
C     CHECK CONCENTRATION-DEPOSITION SWITCH.                                 S0306130
      IF(ISW(1) .EQ. 2) GOTO 1320                                            S0306140
C     CONCENTRATION EQUATION.                                                S0306150
C     CHECK FOR PARTICULATES WITH SETTLING VELOCITIES.                       S0306160
      IF(NVS .GT. 0) GOTO 1260                                               S0306170
      IF(SIGZ*HMI .LT. 1.6) GOTO 1240                                        S0306180
C     CALCULATE "BOX-MODEL" CONCENTRATION                                    S0306190
      IF(ITYPE .EQ. 2) GOTO 1230                                             S0306200
      CHI = QTK*UBARI*SIGYI*HMI*EXP(-A1)*DECAYT*.39894228                    S0306210
      GOTO 1390                                                              S0306220
 1230 A3 = .70710678*SIGYI                                                   S0306230
      A4 = (XOP+YBAR)*A3                                                     S0306240
      A5 = -(XOP-YBAR)*A3                                                    S0306250
      A3 = ERFX(A4,A5)                                                       S0306260
      CHI = QTK*XO*HMI*UBARI*A3*.5*DECAYT                                    S0306270
      GOTO 1390                                                              S0306280
C     CALCULATE VERTICAL TERM FOR ALL SOURCE TYPES W/O PARTICLE              S0306290
C     SETTLING VELOCITIES.                                                   S0306300
 1240 V = 0.0                                                                S0306310
      A2 = 0.0                                                               S0306320
 1250 VL = V                                                                 S0306330
      A2 = A2 + 2.0                                                          S0306340
      HMA2 = A2*HM                                                           S0306350
      A3 = (HMA2-H)*SIGZI                                                    S0306360
      A4 = (HMA2+H)*SIGZI                                                    S0306370
      A3 = -.5*A3*A3                                                         S0306380
      A4 = -.5*A4*A4                                                         S0306390
      A5 = 0.0                                                               S0306400
      IF(A3 .GT. -50.) A5 = EXP(A3)                                          S0306410
      A6 = 0.0                                                               S0306420
      IF(A4 .GT. -50.) A6 = EXP(A4)                                          S0306430
      V = V + A5 + A6                                                        S0306440
      IF(ABS(V-VL) .GT. 1.E-8) GOTO 1250                                     S0306450
      A2 = H*SIGZI                                                           S0306460
      V = EXP(-.5*A2*A2) + V                                                 S0306470
      GOTO 1300                                                              S0306480
C     CALCULATE VERTICAL TERM FOR ALL SOURCE TYPES WITH SETTLING             S0306490
C     VELOCITIES.                                                            S0306500
 1260 V = 0.0                                                                S0306510
      DO 1290 K=1,NVS                                                        S0306515
      SUM = 0.0                                                              S0306520
      SUM1 = 0.0                                                             S0306530
      JP70 = K + 35                                                          S0306550
      XBARUV = SOURCE(JP70,IS)*XBARU                                         S0306560
      JP70 = K + 55                                                          S0306570
      GAMMA = SOURCE(JP70,IS)                                                S0306580
      JP70 = K + 15                                                          S0306590
      PHI = SOURCE(JP70,IS)                                                  S0306600
      A2 = 0.0                                                               S0306610
      A3 = (-H+XBARUV)*SIGZI                                                 S0306620
      A5 = -.5*A3*A3                                                         S0306630
      IF(A5 .GT. -50.) SUM = EXP(A5)                                         S0306640
      IF(GAMMA .LE. 0.0) GOTO 1270                                           S0306650
      A4 = (H - XBARUV)*SIGZI                                                S0306660
      A5 = -.5*A4*A4                                                         S0306670
      IF(A5 .GT. -50.) SUM = SUM + EXP(A5)*GAMMA                             S0306680
      CALL VERT(H,HM,XBARUV,SIGZI,GAMMA,A2,SUM)                              S0306690
 1270 A2 = 2.0                                                               S0306700
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      A3 = (HM+HM-H+XBARUV)*SIGZI                                       S0306710
      A5 = -.5*A3*A3                                                    S0306720
      IF(A5 .GT. -50.) SUM1 = EXP(A5)                                   S0306730
C***********************************************************************
C   THE FOLLOWING LINE OF CODE ALTERED TO COMPUTE ESCAPE FRACTION
      IF(GAMMA .LE. 0.0) GOTO 1280                                      S0306740
C***********************************************************************
      A4 = (HM+HM+H-XBARUV)*SIGZI                                       S0306750
      A5 = -.5*A4*A4                                                    S0306760
      IF(A5 .GT. -50.) SUM1 = SUM1 + EXP(A5)*GAMMA                      S0306770
      CALL VERT(H,HM,XBARUV,SIGZI,GAMMA,A2,SUM1)                        S0306780
C***********************************************************************
C   THE FOLLOWING LINES OF CODE ALTERED/ADDED TO COMPUTE ESCAPE FRACTION
 1280 CALL ESCAPE(ZREF,ZO,TA,IST,UBAR,UD(IS,K),SOURCE(14,IS),ESCP)      TRC 003
      V = V + .5*PHI*(SUM+SUM1)*ESCP                                    S0306790
C***********************************************************************
 1290 CONTINUE                                                          S0306800
C     CALCULATE CONCENTRATON FOR ALL SOURCE TYPES WITH VERTICAL TERM.   S0306810
 1300 IF(ITYPE .EQ. 2) GOTO 1310                                        S0306820
      CHI = QTK*UBARI*SIGYI*SIGZI*EXP(-A1)*V*DECAYT*.31830989           S0306830
      GOTO 1390                                                         S0306840
 1310 A3 = .70710678*SIGYI                                              S0306850
      A4 = (XOP+YBAR)*A3                                                S0306860
      A5 = -(XOP-YBAR)*A3                                               S0306870
      A3 = ERFX(A4,A5)                                                  S0306880
      CHI = QTK*XO*SIGZI*UBARI*V*DECAYT*A3*.39894228                    S0306890
      GOTO 1390                                                         S0306900
C     BEGIN DEPOSITION CALCULATIONS.                                    S0306910
 1320 IF(NVS .GT. 0) GOTO 1330                                          S0306920
      IF(LINE .EQ. 0) WRITE(IO,9011)                                    S0306930
      WRITE(IO,9013) NSO                                                S0306940
      STOP                                                              S0306950
C     CALL SIGMAZ TO COMPUTE AVERAGE EFFECTIVE DOWNWIND DISTANCE, BBAR. S0306960
 1330 CALL SIGMAZ(XBARZ,SIGZ,BBAR,ISTUM2,IXDIST,2,SASIGZ,SBSIGZ,DUMMY)  S0306970
      V = 0.0                                                           S0306980
      DO 1370 K = 1,NVS                                                 S0306990
      JP70 = K + 55                                                     S0307000
      GAMMA = SOURCE(JP70,IS)                                           S0307010
      JP70 = K + 15                                                     S0307020
      PHI = SOURCE(JP70,IS)                                             S0307030
      JP70 = K + 35                                                     S0307040
      XBARUV = XBARU*SOURCE(JP70,IS)                                    S0307050
      A5 = (1.-BBAR)*XBARUV                                             S0307060
      GAM1 = 1.0                                                        S0307070
      GAM2 = GAMMA                                                      S0307080
      A2 = 0.0                                                          S0307090
      SUM = 0.0                                                         S0307100
 1340 SUML = SUM                                                        S0307110
      A2 = A2 + 2.                                                      S0307120
      HMA2 = A2*HM                                                      S0307130
      A3 = (HMA2-H+XBARUV)*SIGZI                                        S0307140
      A6 = 0.0                                                          S0307150
      A3 = -.5*A3*A3                                                    S0307160
      IF(A3 .GT. -50.) A6 = EXP(A3)*GAM1*(BBAR*(HMA2-H)-A5)             S0307170
      IF(GAMMA .GT. 0.0) GOTO 1350                                      S0307180
      SUM = A6                                                          S0307190
      GOTO 1360                                                         S0307200
 1350 A4 = (HMA2+H-XBARUV)*SIGZI                                        S0307210
      A7 = 0.0                                                          S0307220
      A4 = -.5*A4*A4                                                    S0307230
      IF(A4 .GT. -50.) A7 = EXP(A4)*GAM2*(BBAR*(HMA2+H)+A5)             S0307240
      SUM = SUM + A6 + A7                                               S0307250
      IF(ABS(SUM-SUML) .LT. 1.E-8) GOTO 1360                            S0307260
      GAM1 = GAM2                                                       S0307270
      GAM2 = GAM2*GAMMA                                                 S0307280
      GOTO 1340                                                         S0307290
 1360 A3 = (H-XBARUV)*SIGZI                                             S0307300
      A7 = -.5*A3*A3                                                    S0307310
      A3 = 0.0                                                          S0307320
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      IF(A7 .GT. -50.) A3 = (BBAR*H + AS)*EXP(A7)                       S0307330
C*****************************************************************************
C   THE FOLLOWING LINES OF CODE ALTERED/ ADDED TO COMPUTE ESCAPE FRACTION
      CALL ESCAPE(ZREF,ZO,TA,IST,UBAR,UD(IS,K),SOURCE(14,IS),ESCP)      TRC 004
      V = V + (1.-GAMMA)*PHI*(A3 + SUM)*ESCP                            S0307340
C*****************************************************************************
 1370 CONTINUE                                                          S0307350
C     FINISH DEPOSITION CALCULATIONS.                                   S0307360
      IF(ITYPE .EQ. 2) GOTO 1380                                        S0307370
      CHI = QTK*SIGYI*SIGZI/XBAR*EXP(-A1)*DECAYT*V*.15915494            S0307380
      GO TO 1390                                                        S0307385
 1380 CHI = QTK*XO*SIGZI/XBAR*DECAYT*V*ERFX((XOP+YBAR)*SIGYI*.70710678  S0307390
     1 ,-(XOP-YBAR)*SIGYI*.70710678)*.39894228                          S0307400
C     STORE CONCENTRATION OR DEPOSITION INTO CALC ARRAY.  GO GET        S0307410
C     NEXT RECEPTOR.                                                    S0307420
 1390 CALC(IJ) = CHI                                                    S0307430
      IJP = IJ + NPNTS                                                  S0307440
      CALC(IJP) = CALC(IJP) + CHI                                       S0307450
      GOTO 920                                                          S0307460
 1400 CONTINUE                                                          S0307470
      IF(NGROUP .EQ. 0) GOTO 1480                                       S0307480
      NSUM = 0                                                          S0307490
      DO 1470 IG = 1,NGROUP                                             S0307500
      NS = NSOGRP(IG)                                                   S0307510
      DO 1460 N = 1,NS                                                  S0307520
      NNSO = IDSOR(NSUM+1)                                              S0307530
      IF(NNSO .GT. 0) GOTO 1410                                         S0307540
      NNSO = -NNSO                                                      S0307550
      MNSO = IDSOR(NSUM) + 1                                            S0307560
      IF(NSO .LT. MNSO .OR. NSO .GT. NNSO) GOTO 1460                    S0307570
      GOTO 1420                                                         S0307580
 1410 IF(NNSO .NE. NSO) GOTO 1460                                       S0307590
C     LOAD THIS SOURCE CHI INTO APPROPRIATE CHIAV ARRAYS.               S0307600
 1420 IAVG = 0                                                          S0307610
      DO 1440 I = 1,8                                                   S0307620
      IF(ISW(I+6) .NE. 1) GOTO 1440                                     S0307630
      I1 = NPNTS*((IG-1)*NAVG + IAVG)                                   S0307640
      IAVG = IAVG + 1                                                   S0307650
      DO 1430 J = 1,NPNTS                                               S0307660
      IP7 = I1 + J                                                      S0307670
 1430 CHIAV(IP7) = CHIAV(IP7) + CALC(J)                                 S0307680
 1440 CONTINUE                                                          S0307690
      IF(ISW(15) .NE. 1) GOTO 1460                                      S0307700
C     LOAD SOURCE CHI FOR ANNUAL TABLE FOR THIS SOURCE GROUP.           S0307710
      I2 = (IG-1)*NPNTS                                                 S0307720
      DO 1450 J = 1,NPNTS                                               S0307730
      IP7 = I2 + J                                                      S0307740
 1450 CHIAN(IP7) = CHIAN(IP7) + CALC(J)                                 S0307750
 1460 NSUM = NSUM + 1                                                   S0307760
 1470 CONTINUE                                                          S0307770
C     GET NEXT SOURCE                                                   S0307780
 1480 CONTINUE                                                          S0307790
 1490 IF(NGROUP .GT. 0) GOTO 1520                                       S0307800
C     LOAD ALL SOURCE CHI"S INTO APPROPRIATE CHIAV ARRAYS.              S0307810
      IAVG = 0                                                          S0307820
      DO 1510 I = 1,8                                                   S0307830
      IF(ISW(I+6) .NE. 1) GOTO 1510                                     S0307840
      IP6 = IAVG*NPNTS                                                  S0307850
      IAVG = IAVG + 1                                                   S0307860
      DO 1500 J = 1,NPNTS                                               S0307870
      I2 = IP6 + J                                                      S0307880
      IP7 = NPNTS + J                                                   S0307890
 1500 CHIAV(I2) = CHIAV(I2) + CALC(IP7)                                 S0307900
 1510 CONTINUE                                                          S0307910
C                                                                       S0307920
C     BEGIN LOOP OVER ALL SOURCE GROUPS.                                S0307930
C                                                                       S0307940
 1520 NSUM = 1                                                          S0307950
```

```
      IG = 1
      IF(NGROUP .LE. 0) GOTO 1540
 1530 NS = NSOGRP(IG)
      ITO = NSUM + NS - 1
C
C     BEGIN LOOP OVER ALL TIME PERIODS FOR THIS HOUR.
C
 1540 IAVG = 0
      DO 1640  I = 1,8
C     FOR DAILY TABLES COMPUTE AVERAGES, WRITE TO TAPE & PRINT.
      IF(ISW(I+6) .NE. 1) GOTO 1640
      IAVG = IAVG + 1
      IF(.NOT.IFLAG(I)) GOTO 1640
      I1 = NPNTS*((IG-1)*NAVG + IAVG - 1)
      IF(KAVG(I) .EQ. 1.OR. ISW(1) .EQ. 2) GOTO 1560
      A1 = 1./KAVG(I)
      DO 1550 J = 1,NPNTS
      IP7 = I1 + J
 1550 CHIAV(IP7) = CHIAV(IP7)*A1
 1560 IF(ISW(5) .EQ. 1) WRITE(ITAP) IHR,JDY,IG,(CHIAV(I1+J),J=1,NPNTS)
      IF(IPERD .GT. 0 .AND. IPERD .NE. IHR/KAVG(I)) GOTO 1570
      IF(ISW(16) .NE. 1) GOTO 1570
      IP7 = I1 + 1
      CALL DYOUT(GRIDX,GRIDY,XDIS,YDIS,CHIAV(IP7),KAVG(I),JDY,IHR,1,
     1 NSUM,ITO,IG)
C     CALCULATE HIGHEST & SECOND HIGHEST TABLES IF DESIRED.
 1570 IF(ISW(17) .NE. 1) GOTO 1600
      NPNTS2 = NPNTS + NPNTS
      NPNTS3 = NPNTS2 + NPNTS
      IP4 = 4*I1
C     512 = 2**9  SHIFT HOUR VALUE & STORE WITH DAY.
      IHRT5 = 512*IHR
      DO 1590 J = 1,NPNTS
      JP4 = IP4 + J
      JP5 = I1 + J
      JP2 = JP4 + NPNTS2
      JP3 = JP4 + NPNTS3
      IF(CHIMAX(JP4) .GE. CHIAV(JP5)) GOTO 1580
      JP1 = JP4 + NPNTS
      CHIMAX(JP2) = CHIMAX(JP4)
      CHIMAX(JP4) = CHIAV(JP5)
      CHIMAX(JP3) = CHIMAX(JP1)
      CHIMAX(JP1) = JDY + IHRT5
      GOTO 1590
 1580 IF(CHIMAX(JP2) .GE. CHIAV(JP5)) GOTO 1590
      CHIMAX(JP2) = CHIAV(JP5)
      CHIMAX(JP3) = JDY + IHRT5
 1590 CONTINUE
C     CALCULATE 50 HIGHEST CONCENTRATIONS(DEPOSITIONS).
 1600 IF(ISW(18) .NE. 1) GOTO 1610
      IP7 = (IG-1)*NAVG
      IP6 = I1 + 1
      IP7 = IP7 + IAVG
      CALL MAX50(CHIAV(IP6),CHI50(1,IP7),IPNT(1,IP7),ICOUNT(IP7),
     1  IHR,JDY)
C     CLEAR "CHIAV" ARRAY FOR THIS SOURCE GROUP & APPROPRIATE TIME
C     PERIOD.
 1610 DO 1620 J = 1,NPNTS
 1620 CHIAV(I1+J) = 0.0
 1630 CONTINUE
 1640 CONTINUE
      IG = IG + 1
      IF(IG .GT. NGROUP) GOTO 1650
      NSUM = NSUM + NS
      GOTO 1530
C     STORE ANNUAL AVERAGE.
 1650 IF(ISW(15) .NE. 1 .OR. NGROUP .GT. 0) GOTO 1670
```

```
      DO 1660 I = 1,NPNTS                                               S0308630
      IP6 = I + NPNTS                                                   S0308640
 1660 CHIAN(I) = CHIAN(I) + CALC(IP6)                                   S0308650
C     END HOURLY LOOP.                                                  S0308660
 1670 CONTINUE                                                          S0308670
C     CLEAR DAILY AVERAGES ARRAY BEFORE GOING TO NEXT DAY.              S0308680
      NPNTS2 = NAVG*NPNTS                                               S0308690
      IF(NGROUP .GT. 0) NPNTS2 = NPNTS2*NGROUP                          S0308700
      DO 1680 I = 1,NPNTS2                                              S0308710
 1680 CHIAV(I) = 0.0                                                    S0308720
      NTDAY = NTDAY + 1                                                 S0308730
 1690 CONTINUE                                                          S0308740
C     END OF MET DATA.                                                  S0308750
      NDAYS = NTDAY                                                     S0308760
      NSUM = 1                                                          S0308770
      IG = 1                                                            S0308780
      IF(NGROUP .LE. 0) GOTO 1710                                       S0308790
 1700 NS = NSOGRP(IG)                                                   S0308800
      ITO = NSUM + NS - 1                                               S0308810
C     PRINT "N"-DAY TABLE                                               S0308820
 1710 IF(ISW(15) .NE. 1) GOTO 1730                                      S0308830
      NHTOT = NTDAY*24                                                  S0308840
      IF(ISW(19) .NE. 1) NHTOT = NDAYS*NHOURS                           S0308850
      HTOT = 1./FLOAT(NHTOT)                                            S0308860
      IF(ISW(1) .EQ. 2) HTOT = 1.0                                      S0308870
      I1 = (IG-1)*NPNTS + 1                                             S0308880
      I2 = I1 + NPNTS - 1                                               S0308890
      DO 1720 I = I1,I2                                                 S0308900
 1720 CHIAN(I) = CHIAN(I)*HTOT                                          S0308910
      CALL DYOUT(GRIDX,GRIDY,XDIS,YDIS,CHIAN(I1),75,IDY,IHR,1,NSUM,ITO, S0308920
     1 IG)                                                              S0308930
      IF(ISW(5) .EQ. 1) WRITE(ITAP) NHOURS,NTDAY,NGROUP,(CHIAN(I),      S0308940
     1 I=I1,I2)                                                         S0308950
C                                                                       S0308960
C     BEGIN LOOP OVER TIME PERIODS.                                     S0308970
 1730 IAVG = 0                                                          S0308980
      DO 1750 I = 1,8                                                   S0308990
      IF(ISW(I+6) .NE. 1) GOTO 1750                                     S0309000
      IAVG = IAVG + 1                                                   S0309010
C     PRINT HIGHEST & SECOND HIGHEST CONCENTRATION(DEPOSITION) TABLES.  S0309020
      IF(ISW(17) .NE. 1) GOTO 1740                                      S0309030
      IP6 = 4*NPNTS*((IG-1)*NAVG + IAVG - 1) + 1                        S0309040
      CALL DYOUT(GRIDX,GRIDY,XDIS,YDIS,CHIMAX(IP6),KAVG(I),IDY,IHR,2,   S0309050
     1 NSUM,ITO,IG)                                                     S0309060
      IP6 = IP6 + NPNTS + NPNTS                                         S0309070
      CALL DYOUT(GRIDX,GRIDY,XDIS,YDIS,CHIMAX(IP6),KAVG(I),IDY,IHR,3,   S0309080
     1 NSUM,ITO,IG)                                                     S0309090
C     PRINT MAXIMUM 50                                                  S0309100
 1740 IF(ISW(18) .NE. 1) GOTO 1750                                      S0309110
      IP6 = (IG-1)*NAVG + IAVG                                          S0309120
      CALL MAXOT(CHI50(1,IP6),GRIDX,GRIDY,XDIS,YDIS,IPNT(1,IP6),        S0309130
     1 ICOUNT(IP6),KAVG(I),NSUM,ITO,IG)                                 S0309140
 1750 CONTINUE                                                          S0309150
      IG = IG + 1                                                       S0309160
      IF(IG .GT. NGROUP) GOTO 1760                                      S0309170
      NSUM = NSUM + NS                                                  S0309180
      GOTO 1700                                                         S0309190
 1760 IF(ISW(5) .NE. 1) GOTO 1770                                       S0309200
      ENDFILE ITAP                                                      S0309210
      ENDFILE ITAP                                                      S0309220
 1770 RETURN                                                            S0309230
 9001 FORMAT('1',121X,9HMET. DATA/122X,3HDAY,I4)                        S0309240
 9002 FORMAT(31X,69H* SOURCE-RECEPTOR COMBINATIONS LESS THAN 100 METERS S0309250
     1OR THREE BUILDING/34X,25HHEIGHTS IN DISTANCE.  NO ,6A4,           S0309260
     2 16H IS CALCULATED *///46X,25H- - RECEPTOR LOCATION - -/51X,      S0309270
     3  1HX,8X,10HY (METERS),10X,8HDISTANCE/31X,6HSOURCE,11X,           S0309280
     4 23HOR RANGE   OR DIRECTION,9X,7HBETWEEN/31X,6HNUMBER,11X,        S0309290
     5 21H(METERS)     (DEGREES),11X,8H(METERS)/30X,30(2H- )/)          S0309300
```

```
9003 FORMAT(31X,I5,8X,2F13.1,7X,F10.2)                                  S0309310
9004 FORMAT(I8,5F8.0,I8,2F8.0)                                          S0309320
9005 FORMAT(32X,4H*** ,15A4,4H ***//)                                   S0309330
9006 FORMAT(//68X,10HPOT. TEMP./29X,4HFLOW,7X,15HWIND     MIXING,13X,  S0309340
    1 8HGRADIENT,17X,16HWIND       DECAY/28X,16HVECTOR    SPEED,5X,    S0309350
    264HHEIGHT    TEMP.    (DEG. K    STABILITY   PROFILE   COEFFICIENS0309360
    3T/20X,92HHOUR   (DEGREES)   (MPS)    (METERS)  (DEG. K)  PER METERS0309370
    4)   CATEGORY   EXPONENT   (PER SEC)/19X,47(2H -)/)                S0309380
9007 FORMAT(49X,29H* METEOROLOGICAL DATA FOR DAY,I4,2H *)              S0309390
9008 FORMAT(21X,I2,F11.1,F10.2,F11.1,F9.1,F12.4,I9,F13.4,E15.6)        S0309400
9009 FORMAT(//47X,6HRANDOM/38X,2(4HFLOW,6X),16H WIND     MIXING,15X,   S0309410
    1 19HINPUT      ADJUSTED/37X,2(6HVECTOR,4X),27H SPEED     HEIGHT   S0309420
    2  TEMP.,2(3X,9HSTABILITY)/29X,6HHOUR  ,2(10H (DEGREES)),3X,       S0309430
    3 30H(MPS)     (METERS)  (DEG. K)    ,2(8HCATEGORY,4X)/27X,40(2H -)/)S0309440
9010 FORMAT(30X,I2,F11.1,F10.1,F10.2,F11.1,F9.1,I9,I12)                S0309450
9011 FORMAT('1')                                                        S0309460
9012 FORMAT(10X,46H*** ERROR ***  PHYSICAL STACK HEIGHT OF SOURCE,I5/  S0309470
    1 10X,52HIS LOWER THAN THE TERRAIN ELEVATION FOR THE RECEPTOR/10X, S0309480
    1 12HLOCATED AT (,F 9.1,1H,,F 9.1,19H).  RUN TERMINATED.)          S0309490
9013 FORMAT(10X,25H***ERROR*** SOURCE NUMBER,I6,41H HAS NO GRAVITATIONAS0309500
    1L SETTLING CATEGORIES,/10X,52HWITH WHICH TO CALCULATE DEPOSITION. S0309510
    2 RUN TERMINATED.)                                                  S0309520
     END                                                                S0309530
```

```
C
      SUBROUTINE INCHK(CALC,CHIAV,CHIAN,GRIDX,GRIDY,XDIS,YDIS,GRIDZ,    S0200010
     1 CHIMAX,CHI50,IPNT,ICOUNT,SOURCE)                                 S0200020
C                    SUBROUTINE INCHK  (VERSION 80339), PART OF ISCST.
C     THIS ROUTINE READS THE REST OF THE INPUT VARIABLES AND PROVIDES   S0200030
C     DEFAULT VALUES IF REQUIRED.  ALSO TABLES LISTING THE INPUT VARI-  S0200040
C     ABLES ARE CONTROLLED BY THIS ROUTINE.                             S0200050
C                                                                       S0200060
C***********************************************************************
C   THE FOLLOWING LINES OF CODE ALTERED TO RUN ON IBM-PC
      CHARACTER*1 ATHRUF
      CHARACTER*4 TITLE,METER,SEASON,IBLANK,IQUN,ICHIUN,CONDEP
C***********************************************************************
      LOGICAL DONE                                                      S0200070
      INTEGER WAKE,QFLG,QFLGS                                           S0200080
      COMMON /LOGIX/ ISW(40),NSOURC,NXPNTS,NYPNTS,NXWYPT,NGROUP,        S0200090
     1 NSOGRP(150),IDSOR(200),IPERD,NPNTS,NAVG,NHOURS,NDAYS,NTDAY,LINE, S0200100
     2 IO,IN,TITLE(15),IQUN(3),ICHIUN(7),CONDEP(6),LIMIT,MIMIT          S0200110
      COMMON /MET/ IDAY(366),ISTAB(24),AWS(24),TEMP(24),AFV(24),        S0200120
     1 AFVR(24),HLH(24,2),P(24),DTHDZ(24),DECAY(24),PDEF(6,6),          S0200130
     2 DTHDEF(6,6),GAM1I,GAM2I,ZR,DDECAY,IMET,ITAP,TK,UCATS(5)          S0200140
C***********************************************************************
C   THE FOLLOWING LINE OF CODE ADDED TO COMPUTE ESCAPE FRACTION
      COMMON/DEPO/UD(200,20),ZREF,ZO                                    TRC 005
C***********************************************************************
      DIMENSION GRIDX(1),GRIDY(1),XDIS(1),YDIS(1),GRIDZ(1),SOURCE(215,1)S0200150
      DIMENSION METER(2),SEASON(2,4),ATHRUF(6),UCTDEF(5)                S0200160
      EQUIVALENCE (ISW(23),QFLGS)                                       S0200170
      DATA ATHRUF / 'A','B','C','D','E','F' /                           S0200180
      DATA UCTDEF / 1.54,3.09,5.14,8.23,10.8 /                          S0200190
      DATA METER /'(MET','ERS)'/                                        S0200200
      DATA SEASON /'WINT','ER  ','SPRI','NG  ','SUMM','ER  ','AUTU',    S0200210
     1 'MN  ' /                                                         S0200220
      DATA IBLANK /'    '/                                              S0200230
C     CHECK "ISW" AND SET DEFAULT VALUES.                               S0200240
C     DEFAULT TO CONCENTRATION ON RECTANGULAR GRID & DISCRETE POINTS.   S0200250
   10 IF(ISW(1) .LE. 0) ISW(1) = 1                                      S0200260
      IF(ISW(2) .LE. 0) ISW(2) = 1                                      S0200270
      IF(ISW(3) .LE. 0) ISW(3) = 1                                      S0200280
C     DEFAULT CARD MET PARAMETERS.                                      S0200290
      IF(NDAYS .LE. 0) NDAYS = 1                                        S0200300
C     DEFAULT TO PRE-PROCESSED MET DATA WITH RURAL OPTION.              S0200310
      IF(ISW(19) .LE. 0) ISW(19) = 1                                    S0200320
      IF(ISW(19) .EQ. 2) ISW(20) = 0                                    S0200330
C     DEFAULT TO PROGRAM"S WIND PROFILE EXPONENT AND VERTICAL POTENTIAL S0200340
C     TEMPERATURE GRADIENT VALUES.                                      S0200350
      IF(ISW(21) .LT. 1) ISW(21) = 1                                    S0200360
      IF(ISW(22) .LT. 1) ISW(22) = 1                                    S0200370
C     DEFAULT TO FINAL PLUME RISE FOR ALL RECEPTORS.                    S0200380
      IF(ISW(24) .LT. 1) ISW(24) = 1                                    S0200390
C     DEFAULT TO NO STACK DOWNWASH ADJUSTMENT.                          S0200400
      IF(ISW(25) .LT. 1) ISW(25) = 1                                    S0200410
C     READ GRID THEN DISCRETE POINTS                                    S0200420
      IF(NXPNTS .EQ. 0 .OR. NYPNTS .EQ. 0) GOTO 70                      S0200430
      IF(ISW(2) .NE. 3) READ(IN,9020) (GRIDX(I),I=1,NXPNTS)             S0200440
      IF(ISW(2) .LT. 3) READ(IN,9020) (GRIDY(I),I=1,NYPNTS)             S0200450
      IF(ISW(2) .NE. 3) GOTO 30                                         S0200460
C     GENERATE GRID, THEN READ DISCRETE POINTS.                         S0200470
      READ(IN,9020) GRIDX(1),DX                                         S0200480
      I2 = NXPNTS - 1                                                   S0200490
      DO 20  I = 1,I2                                                   S0200500
      I1 = I + 1                                                        S0200510
   20 GRIDX(I1) = GRIDX(I) + DX                                         S0200520
   30 IF(ISW(2) .LT. 3) GOTO 50                                         S0200530
      READ(IN,9020) GRIDY(1),DY                                         S0200540
      I2 = NYPNTS - 1                                                   S0200550
      DO 40  I = 1,I2                                                   S0200560
      I1 = I + 1                                                        S0200570
```

```
   40 GRIDY(I1) = GRIDY(I) + DY
   50 IF(ISW(2) .NE. 2 .AND. ISW(2) .NE. 4) GOTO 70
C     SET DEFAULT DIRECTION VALUES.
      DO 60 I = 1,NYPNTS
   60 IF(GRIDY(I) .LE. 0.0 .OR. GRIDY(I) .GT. 360.0) GRIDY(I) = 360.0
   70 IF(NXWYPT .EQ. 0) GOTO 90
      READ(IN,9020) (XDIS(I),I=1,NXWYPT)
      READ(IN,9020) (YDIS(I),I=1,NXWYPT)
      IF(ISW(3) .NE. 2) GOTO 90
C     SET DEFAULT DIRECTION VALUES.
      DO 80 I = 1,NXWYPT
   80 IF(YDIS(I) .LE. 0.0 .OR. YDIS(I) .GT. 360.0) YDIS(I) = 360.0
C     CHECK FOR TERRAIN HEIGHTS
   90 IF(ISW(4) .NE. 1) GOTO 125
      IF(NXPNTS .EQ. 0 .OR. NYPNTS .EQ. 0) GOTO 110
C     READ TERRAIN FOR GRID AND DISCRETE REC"S; READ NO OF SOURCE GROUPS
      DO 100  J = 1,NYPNTS
      I1 = (J-1)*NXPNTS
      I2 = I1 + NXPNTS
      I1 = I1 + 1
  100 READ(IN,9020) (GRIDZ(I),I=I1,I2)
  110 IF(NXWYPT .EQ. 0) GOTO 120
      I1 = NXPNTS*NYPNTS + 1
      READ(IN,9020) (GRIDZ(I),I=I1,NPNTS)
  120 DO 121 I=1,NPNTS
  121 GRIDZ(I) = GRIDZ(I) * .3048006
  125 IF(NGROUP .EQ. 0) GOTO 140
      READ(IN,9023) (NSOGRP(I),I=1,NGROUP)
      I1 = 0
      DO 130 I = 1,NGROUP
  130 I1 = I1 + NSOGRP(I)
      READ(IN,9024) (IDSOR(I),I=1,I1)
C     DEFAULT OR READ WIND PROFILE EXPONENTS, VERTICAL POTENTIAL
C     TEMPERATURE GRADIENTS.
  140 IF(ISW(21) .NE. 2) GOTO 160
      DO 150  J = 1,6
  150 READ(IN,9020)  (PDEF(I,J),I=1,6)
  160 IF(ISW(22) .NE. 2) GOTO 180
      DO 170  J = 1,6
  170 READ(IN,9020)  (DTHDEF(I,J),I=1,6)
C     ENTER QFLGS AND WIND SPEED CATEGORIES.
  180 READ(IN,9020) ZR,(UCATS(I),I=1,5)
      DO 190   I = 1,5
      IF(UCATS(I) .GT. 0.0) GOTO 190
      UCATS(I) = UCTDEF(I)
  190 CONTINUE
C     READ GENERAL INPUT VARIABLES & SET DEFAULT VALUES.
  200 READ(IN,9021) TK,BETA1,BETA2,DDECAY,(IQUN(I),I=1,3),
     1 (ICHIUN(I),I=1,7),IMET,ITAP
      IF(TK .LE. 0.0 .AND. ISW(1) .EQ. 1) TK = 1.E6
      IF(TK .LE. 0.0 .AND. ISW(1) .EQ. 2) TK = 1.0
      IF(BETA1 .LE. 0.0) BETA1 = .6
      IF(BETA2 .LE. 0.0) BETA2 = .6
      IF(IMET .LE. 0 .AND. ISW(19) .EQ. 1) IMET = 9
      IF(IMET .LE. 0 .AND. ISW(19) .EQ. 2) IMET = IN
      IF(ITAP .LE. 0) ITAP = 3
      IF(ZR .LE. 0.0) ZR = 10.0
      DO 210 I = 1,3
      IF(IQUN(I) .NE. IBLANK) GOTO 230
  210 CONTINUE
      IF(ISW(1) .EQ. 2) GOTO 220
      IQUN(1) = '(GRA'
      IQUN(2) = 'MS/S'
      IQUN(3) = 'EC) '
      GOTO 230
  220 IQUN(1) = '  (G'
      IQUN(2) = 'RAMS'
      IQUN(3) = ')   '
  230 DO 240 I = 1,7
```

```
      IF(ICHIUN(I) .NE. IBLANK) GOTO 260                                S0201270
  240 CONTINUE                                                          S0201280
      IF(ISW(1) .EQ. 2) GOTO 250                                        S0201290
      ICHIUN(1) = '(MIC'                                                S0201300
      ICHIUN(2) = 'ROGR'                                                S0201310
      ICHIUN(3) = 'AMS/'                                                S0201320
      ICHIUN(4) = 'CUBI'                                                S0201330
      ICHIUN(5) = 'C ME'                                                S0201340
      ICHIUN(6) = 'TER)'                                                S0201350
      ICHIUN(7) = '    '                                                S0201360
      GOTO 260                                                          S0201370
  250 ICHIUN(1) = '(GRA'                                                S0201380
      ICHIUN(2) = 'MS/S'                                                S0201390
      ICHIUN(3) = 'QUAR'                                                S0201400
      ICHIUN(4) = 'E ME'                                                S0201410
      ICHIUN(5) = 'TER '                                                S0201420
      ICHIUN(6) = '    '                                                S0201430
      ICHIUN(7) = '    '                                                S0201440
C     READ "DAY" ARRAY & MET IDENTIFICATION.                            S0201450
  260 IF(ISW(19) .NE. 1) GOTO 270                                       S0201460
      READ(IN,9022) (IDAY(I),I=1,366)                                   S0201470
      READ(IN,9024) ISS,ISY,IUS,IUY                                     S0201480
      NDAYS = 365                                                       S0201490
      IF(MOD(ISY,4) .EQ. 0) NDAYS = 366                                 S0201500
      READ(IMET) ISSI,ISYI,IUSI,IUYI                                    S0201510
      IF(ISS.EQ.ISSI.AND.ISY.EQ.ISYI.AND.IUS.EQ.IUSI.AND.IUY.EQ.IUYI)   S0201520
     1 GOTO 280                                                         S0201530
      WRITE(IO,9025) ISS,ISSI,ISY,ISYI,IUS,IUSI,IUY,IUYI                S0201540
      STOP                                                              S0201550
C     FOR CARD MET DATA SET RURAL-URBAN SWITCH TO RURAL.                S0201560
  270 ISW(20) = 0                                                       S0201570
  280 IF(NSOURC .GT. 0) GOTO 290                                        S0201580
      WRITE(IO,9026)                                                    S0201590
      STOP                                                              S0201600
C*                                                                      S0201610
C     READ SOURCE DATA.                                                 S0201620
C     MOST VARIABLES ARE READ DIRECTLY INTO THE "SOURCE" ARRAY WHICH    S0201630
C     HAS 215 STORAGE LOCATIONS ALLOCATED PER SOURCE.  STORAGE LOCATION S0201640
C     1 CONTAINS WAKE, QLFG, NVS & ITYPE PACKED INTO THE FIRST LOCATION.S0201650
C     STORAGE LOCATIONS 2-13 CONTAIN% NSO, Q, X, Y, ZS, HS, TS OR       S0201660
C     SIGZO, VS OR SIGYO OR XO, D, HB, BUILDING LENGTH, AND BUILDING    S0201670
C     WIDTH, RESPECTIVELY.  STORAGE LOCATIONS 16-35 CONTAIN PHI, 36-55  S0201680
C     CONTAIN SETTLING VELOCITIES AND 56-75 CONTAIN GAMMA.  STORAGE     S0201690
C     LOCATIONS 76-81 CONTAIN STABILITY-DEPENDENT LATERAL VIRTUAL       S0201700
C     DISTANCES AND LOCATIONS 82-117 CONTAIN STABILITY AND XBAR-        S0201710
C     DEPENDENT VERTICAL VIRTUAL DISTANCES BOTH OF WHICH ARE COMPUTED   S0201720
C     IN SUBROUTINE MODEL.  STORAGE LOCATIONS 120-215 CONTAIN Q         S0201730
C     ADJUSTMENT FACTORS AS A FUNCTION OF EITHER TIME OF DAY-SEASONAL ORS0201740
C     STABILITY-WIND SPEED VARIATIONS.  STORAGE LOCATIONS 14, 15, 118, &S0201750
C     119 ARE CURRENTLY NOT BEING USED.                                 S0201760
C                                                                       S0201770
  290 II = 1                                                            S0201780
  300 IF(II .GT. NSOURC) GOTO 320                                       S0201790
C***********************************************************************************
C   THE FOLLOWING LINES OF CODE ALTERED TO COMPUTE ESCAPE FRACTION
      READ(IN,9027) NSO,ITYPE,WAKE,NVS,QFLG,(SOURCE(I,II),I=3,13),      S0201800
     1 PITDEP(II)                                                       TRC 006
C***********************************************************************************
      IF(NVS .LE. 0) GOTO 310                                           S0201810
C     INPUT VARIABLES RELATED TO PARTICULATE SOURCES.                   S0201820
      READ(IN,9020) (SOURCE(15+I,II),I=1,NVS)                           S0201830
      READ(IN,9020) (SOURCE(35+I,II),I=1,NVS)                           S0201840
      READ(IN,9020) (SOURCE(55+I,II),I=1,NVS)                           S0201850
      READ(IN,9020) (UD(II,I),I=1,NVS)
  310 CONTINUE                                                          S0201860
C     PACK SOURCE VARIABLES WAKE, QFLG, NVS & ITYPE INTO FIRST LOCATION.S0201870
C     ALSO STORE SOURCE NUMBER.                                         S0201880
      SOURCE(1,II) = ITYPE + NVS*16 + QFLG*512 + WAKE*8192              S0201890
```

```
      SOURCE(2,II) = NSO
      II = II + 1
      GOTO 300
C     ENTER SOURCE EMISSION RATE SCALARS.
  320 II = 1
      IF(QFLGS .LT. 1 .OR. QFLGS .GT. 5) GOTO 330
      DONE = .TRUE.
      QFLG = QFLGS
      GOTO 350
  330 DONE = .FALSE.
  340 IF(II .GT. NSOURC) GOTO 430
      ITYPE = SOURCE(1,II)
      QFLG = ITYPE/512 - (ITYPE/8192)*16
      IF(QFLG .LT. 1 .OR. QFLG .GT. 5) GOTO 420
  350 J = 1
      I = 4
      GOTO (400,360,370,380,390), QFLG
  360 I = 12
      GOTO 400
  370 I = 24
      GOTO 400
  380 J = 6
      I = 6
      GOTO 400
  390 J = 4
      I = 24
  400 DO 410 I1 = 1,J
      IFR = (I1-1)*I + 120
      ITO = IFR + I - 1
  410 READ(IN,9020) (SOURCE(I2,II),I2=IFR,ITO)
      IF(DONE) GOTO 430
  420 II = II + 1
      GOTO 340
C     LIST ALL INPUT VARIABLES IF DESIRED.
  430 IF(ISW(6) .LE. 0) GOTO 820
      WRITE(IO,9029) (TITLE(I),I=1,15)
      WRITE(IO,9030) (ISW(I),I=1,14)
      WRITE(IO,9031) (ISW(I),I=15,25)
      WRITE(IO,9032) NSOURC,NGROUP,IPERD,NXPNTS,NYPNTS,NXWYPT
      IF(ISW(19) .EQ. 2) WRITE(IO,9033) NHOURS,NDAYS
      WRITE(IO,9034) TK,BETA1,BETA2,ZR,IMET
      IF(ISW(19) .NE. 1) GOTO 440
      WRITE(IO,9035) DDECAY,ISS,ISY,IUS,IUY
  440 CONTINUE
      IF(ISW(5) .GT. 0) WRITE(IO,9036) ITAP
      WRITE(IO,9056) LIMIT,MIMIT
      WRITE(IO,9029) (TITLE(I),I=1,15)
      LINE = 6
      IF(ISW(19) .NE. 1) GOTO 450
C     PRINT "DAY" ARRAY.
      LINE = 18
      WRITE(IO,9037) (IDAY(I),I=1,366)
  450 IF(NGROUP .EQ. 0) GOTO 470
C     PRINT SOURCE GROUP INFO.
      LINE = LINE + 12
      WRITE(IO,9057) (NSOGRP(I),I=1,NGROUP)
      I3 = 0
      DO 460 I = 1,NGROUP
  460 I3 = I3 + NSOGRP(I)
      WRITE(IO,9058) (IDSOR(I),I=1,I3)
C     PRINT UPPER BOUND OF FIRST 5 WIND SPEED CATEGORIES.
  470 LINE = LINE + 6
      WRITE(IO,9001) (UCATS(I),I=1,5)
      IF(ISW(19).EQ.2.AND.ISW(6).EQ.2) GOTO 530
      IF(ISW(21) .EQ. 3) GOTO 500
C     PRINT WIND PROFILE EXPONENTS.
      LINE = LINE + 12
      IF(LINE .LT. 57) GOTO 480
```

```
      LINE = 15
      WRITE(IO,9029) TITLE
  480 WRITE(IO,9059)
      WRITE(IO,9016) (I1,I1=1,6)
      DO 490  I = 1,6
  490 WRITE(IO,9017) ATHRUF(I),(PDEF(J,I),J=1,6)
  500 IF(ISW(22) .EQ. 3) GOTO 530
C     PRINT VERTICAL POTENTIAL TEMPERATURE GRADIENTS.
      LINE = LINE + 12
      IF(LINE .LT. 57) GOTO 510
      LINE = 15
      WRITE(IO,9029) TITLE
  510 WRITE(IO,9060)
      WRITE(IO,9016) (I1,I1=1,6)
      DO 520  I = 1,6
  520 WRITE(IO,9017) ATHRUF(I),(DTHDEF(J,I),J=1,6)
C     PRINT RECEPTOR INFO.
  530 IF(NXPNTS .EQ. 0 .OR. NYPNTS .EQ. 0) GOTO 550
      LINE = LINE + 20
      IF(LINE .LT. 57) GOTO 540
      LINE = 6
      WRITE(IO,9029) TITLE
  540 IF(ISW(2) .EQ. 1 .OR. ISW(2) .EQ. 3) WRITE(IO,9038)
      IF(ISW(2) .EQ. 2 .OR. ISW(2) .EQ. 4) WRITE(IO,9039)
      WRITE(IO,9040) (GRIDX(I),I=1,NXPNTS)
      IF(ISW(2) .EQ. 1 .OR. ISW(2) .EQ. 3) WRITE(IO,9041)
      IF(ISW(2) .EQ. 2 .OR. ISW(2) .EQ. 4) WRITE(IO,9042)
      WRITE(IO,9040) (GRIDY(I),I=1,NYPNTS)
  550 IF(NXWYPT .EQ. 0) GOTO 570
      LINE = LINE + 5 + NXWYPT/5
      IF(LINE .LT. 57) GOTO 560
      LINE = 6
      WRITE(IO,9029) TITLE
  560 IF(ISW(3) .EQ. 1) WRITE(IO,9043)
      IF(ISW(3) .EQ. 2) WRITE(IO,9044)
      WRITE(IO,9045) (XDIS(I),YDIS(I),I=1,NXWYPT)
C     PRINT TERRAIN HEIGHTS.
  570 IF(ISW(4) .NE. 1) GOTO 580
      CONDEP(3) = 'HGT '
      CALL DYOUT(GRIDX,GRIDY,XDIS,YDIS,GRIDZ,99,IDY,IHR,1,0,0,0)
C     PRINT OUT SOURCE INFO.
  580 CONTINUE
      LINE = 100
      I3 = 0
      DO 600 I = 1,NSOURC
      IF(LINE .LE. 56) GOTO 590
      WRITE(IO,9029) (TITLE(J),J=1,15)
      WRITE(IO,9046) ((IQUN(J),J=1,3),I2=1,2),(METER(1),METER(2),J=1,10)
      LINE = 18
  590 CONTINUE
      ITYPE = SOURCE(1,I)
C     GET WAKE OPTION, SOURCE NO., NVS & TYPE FROM FIRST WORD.
      NSO = SOURCE(2,I)
      WAKE = ITYPE/8192
      QFLG = ITYPE/512 - (ITYPE/8192)*16
      NVS = ITYPE/16 - (ITYPE/512)*32
      ITYPE = ITYPE - (ITYPE/16)*16
      IF(NVS .GT. 0) I3 = 1
      WRITE(IO,9047) NSO,ITYPE,WAKE,NVS,(SOURCE(J,I),J=3,13)
      LINE = LINE + 1
  600 CONTINUE
      IF(I3 .NE. 1) GOTO 630
C     PRINT OUT PARTICLE CATEGORY INFORMATION.
      LINE = 100
      DO 620 I = 1,NSOURC
      IF(LINE .LT. 43) GOTO 610
      WRITE(IO,9029) (TITLE(J),J=1,15)
      WRITE(IO,9049)
```

```
      LINE = 10
  610 CONTINUE
      ITYPE = SOURCE(1,I)
      NSO = SOURCE(2,I)
      NVS = ITYPE/16 - (ITYPE/512)*32
      IF(NVS .LE. 0) GOTO 620
      WRITE(IO,9050) NSO
      I2 = 15 + NVS
      WRITE(IO,9051)  (SOURCE(J,I),J=16,I2)
      I2 = 35 + NVS
      WRITE(IO,9052)  (SOURCE(J,I),J=36,I2)
      I2 = 55 + NVS
      WRITE(IO,9053) (SOURCE(J,I),J=56,I2)
      LINE = LINE + 14
  620 CONTINUE
C     PRINT SOURCE EMISSION RATE SCALARS.
  630 I = 1
      IF(QFLGS .LT. 1 .OR. QFLGS .GT. 5) GOTO 640
      DONE = .TRUE.
      QFLG = QFLGS
      LINE = 100
      GOTO 670
  640 DONE = .FALSE.
      J = 1
  650 IF(J .GT. 5) GOTO 820
      LINE = 100
      I = 1
  660 IF(I .GT. NSOURC) GOTO 810
      ITYPE = SOURCE(1,I)
      QFLG = ITYPE/512 - (ITYPE/8192)*16
      IF(QFLG .NE. J) GOTO 800
      NSO = SOURCE(2,I)
  670 GOTO (680,700,720,740,770), QFLG
  680 IF(LINE .LT. 54) GOTO 690
      WRITE(IO,9029) TITLE
      WRITE(IO,9002)
      IF(DONE) WRITE(IO,9003)
      WRITE(IO,9004) ((SEASON(I1,I2),I1=1,2),I2=1,4)
      LINE = 14
  690 IF(.NOT.DONE) WRITE(IO,9005) NSO
      WRITE(IO,9006) (SOURCE(I1,I),I1=120,123)
      IF(DONE) GOTO 820
      LINE = LINE + 3
      GOTO 800
  700 IF(LINE .LT. 54) GOTO 710
      WRITE(IO,9029) TITLE
      WRITE(IO,9007)
      IF(DONE) WRITE(IO,9003)
      WRITE(IO,9008)
      WRITE(IO,9013)
      LINE = 14
  710 IF(.NOT. DONE) WRITE(IO,9009) NSO
      WRITE(IO,9010) (SOURCE(I1,I),I1=120,131)
      IF(DONE) GOTO 820
      LINE = LINE + 3
      GOTO 800
  720 IF(LINE .LT. 50) GOTO 730
      WRITE(IO,9029) TITLE
      WRITE(IO,9011)
      IF(DONE) WRITE(IO,9003)
      WRITE(IO,9012)
      WRITE(IO,9013)
      LINE = 14
  730 IF(.NOT.DONE) WRITE(IO,9009) NSO
      WRITE(IO,9014) (I1,SOURCE(119+I1,I),I1=1,24)
      IF(DONE) GOTO 820
      LINE = LINE + 7
      GOTO 800
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  740 IF(LINE .LT. 49) GOTO 750
      WRITE(IO,9029) TITLE
      WRITE(IO,9015)
      IF(DONE) WRITE(IO,9003)
      WRITE(IO,9016) (I1,I1=1,6)
      WRITE(IO,9013)
      LINE = 16
  750 IF(.NOT.DONE) WRITE(IO,9009) NSO
      DO 760  I1 = 1,6
      IFR = (I1-1)*6 + 120
      ITO = IFR + 5
  760 WRITE(IO,9017) ATHRUF(I1),(SOURCE(I2,I),I2=IFR,ITO)
      IF(DONE) GOTO 820
      LINE = LINE + 8
      GOTO 800
  770 IF(LINE .LT. 37) GOTO 780
      WRITE(IO,9029) TITLE
      WRITE(IO,9018)
      IF(DONE) WRITE(IO,9003)
      WRITE(IO,9012)
      WRITE(IO,9013)
      LINE = 14
  780 IF(.NOT.DONE) WRITE(IO,9009) NSO
      DO 790  I1 = 1,4
      IFR = (I1-1)*24 + 119
      WRITE(IO,9019) SEASON(1,I1),SEASON(2,I1)
  790 WRITE(IO,9014) (I2,SOURCE(I2+IFR,I),I2=1,24)
      IF(DONE) GOTO 820
      LINE = LINE + 22
  800 I = I + 1
      GOTO 660
  810 J = J + 1
      GOTO 650
C     STORE RECIPROCAL SQUARED OF BETA1, BETA2 AS GAM1I, GAM2I AND STORE
C     RECIPROCAL OF ZR.
  820 CONTINUE
      GAM1I = 1./(BETA1*BETA1)
      GAM2I = 1./(BETA2*BETA2)
      ZR = 1./ZR
C     COMPUTE EFFECTIVE BUILDING WIDTH FOR ALL SOURCES & STORE IN
C     LOCATION 12 OF "SOURCE" ARRAY.  BUILDING LENGTH & WIDTH WILL NO
C     LONGER BE NEEDED.  ALSO, RELOCATE AREA SOURCE COORDINATES FROM
C     THE SOUTHWEST CORNER TO THE CENTER OF THE AREA SOURCE.
      DO 830 I = 1,NSOURC
C     2/SQRT(3.14159265) = 1.1283792
      SOURCE(12,I) = 1.1283792*SQRT(SOURCE(12,I)*SOURCE(13,I))
      ITYPE = SOURCE(1,I)
      IF(ITYPE-(ITYPE/16)*16 .NE. 2) GOTO 830
      A1 = .5*SOURCE(9,I)
      SOURCE(4,I) = SOURCE(4,I) + A1
      SOURCE(5,I) = SOURCE(5,I) + A1
  830 CONTINUE
C     SET HEADING.
      IF(ISW(1) .EQ. 1) GOTO 840
      CONDEP(1) = '  TO'
      CONDEP(2) = 'TAL '
      CONDEP(3) = 'DEPO'
      CONDEP(4) = 'SITI'
      CONDEP(5) = 'ON  '
      CONDEP(6) = '    '
      GOTO 850
  840 CONDEP(1) = 'AVER'
      CONDEP(2) = 'AGE '
      CONDEP(3) = 'CONC'
      CONDEP(4) = 'ENTR'
      CONDEP(5) = 'ATIO'
      CONDEP(6) = 'N   '
  850 CONTINUE
      RETURN
```

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 9001 FORMAT(/34X,64H*** UPPER BOUND OF FIRST THROUGH FIFTH WIND SPEED CS0204630
     1ATEGORIES ***/60X,12H(METERS/SEC)//46X,5(F7.2,1H,))              S0204640
 9002 FORMAT(39X,54H* SOURCE EMISSION RATE SCALARS WHICH VARY SEASONALLYS0204650
     1 *//)                                                             S0204660
 9003 FORMAT(56X,19H* FOR ALL SOURCES *//)                              S0204670
 9004 FORMAT(40X,4(2A4,7X)/20X,40(2H- )/)                               S0204680
 9005 FORMAT(/20X,12HSOURCE NO. =,I6)                                   S0204690
 9006 FORMAT(38X,4(E10.5,5X))                                           S0204700
 9007 FORMAT(41X,51H* SOURCE EMISSION RATE SCALARS WHICH VARY MONTHLY * S0204710
     1 //)                                                              S0204720
 9008 FORMAT(7X,51HJANUARY  FEBRUARY   MARCH     APRIL      MAY       , S0204730
     1 58HJUNE      JULY     AUGUST   SEPTEMBER  OCTOBER  NOVEMBER  ,   S0204740
     2  8HDECEMBER/)                                                    S0204750
 9009 FORMAT(/13H SOURCE NO. =,I6)                                      S0204760
 9010 FORMAT(5X,12E10.4)                                                S0204770
 9011 FORMAT(32X,68H* SOURCE EMISSION RATE SCALARS WHICH VARY FOR EACH HS0204780
     1OUR OF THE DAY *//)                                               S0204790
 9012 FORMAT(5X,6(14HHOUR    SCALAR,6X))                                S0204800
 9013 FORMAT(1X,65(2H- )/)                                              S0204810
 9014 FORMAT(4(5X,6(I3,3X,E10.5,4X)/))                                  S0204820
 9015 FORMAT(30X,73H* SOURCE EMISSION RATE SCALARS WHICH VARY WITH STABIS0204830
     1LITY AND WIND SPEED *//)                                          S0204840
 9016 FORMAT(16X,9HSTABILITY,29X,19HWIND SPEED CATEGORY/16X,8HCATEGORY, S0204850
     1 9X,6(I1,14X))                                                    S0204860
 9017 FORMAT(19X,A1,5X,6(5X,E10.5))                                     S0204870
 9018 FORMAT(32X,68H* SOURCE EMISSION RATE SCALARS WHICH VARY SEASONALLYS0204880
     1 AND DIURNALLY *//)                                               S0204890
 9019 FORMAT(59X,9HSEASON = ,2A4)                                       S0204900
 9020 FORMAT(8F10.0)                                                    S0204910
 9021 FORMAT(E8.0,3F8.0,3A4,7A4,2I2)                                    S0204920
 9022 FORMAT(80I1)                                                      S0204930
 9023 FORMAT(20I4)                                                      S0204940
 9024 FORMAT(13I6)                                                      S0204950
 9025 FORMAT('1',10X,63H*** ERROR ***  MET DATA REQUESTED DOES NOT MATCHS0204960
     1 MET DATA READ./10X,28H"REQUESTED/READ" VALUES ARE%/10X,          S0204970
     2 21HSURFACE STATION NO. =,I6,1H/,I6,23H YEAR OF SURFACE DATA =,I6,S0204980
     3 1H/,I6/10X,23HUPPER AIR STATION NO. =,I6,1H/,I6,                 S0204990
     4 25H YEAR OF UPPER AIR DATA =,I6,1H/,I6/10X,15HRUN TERMINATED.)   S0205000
 9026 FORMAT('1',10X,73H*** ERROR ***  NUMBER OF SOURCES TO BE READ EQUAS0205010
     1LS ZERO.  RUN TERMINATED.)                                        S0205020
C***********************************************************************
C   THE FOLLOWING LINE OF CODE ALTERED TO COMPUTE ESCAPE FRACTION
 9027 FORMAT(I5,2I1,I2,I1,E8.0,2F7.0,9F6.0)                             S0205030
C***********************************************************************
 9028 FORMAT(9X,I1,5F10.0)                                              S0205040
 9029 FORMAT('1'//32X,4H*** ,15A4,4H ***//)                             S0205050
 9030 FORMAT(18X,40HCALCULATE (CONCENTRATION=1,DEPOSITION=2),29X,       S0205060
     1 8HISW(1) =,I4/18X,55HRECEPTOR GRID SYSTEM (RECTANGULAR=1 OR 3, POS0205070
     2LAR=2 OR 4),14X,8HISW(2) =,I4/                                    S0205080
     3 18X,48HDISCRETE RECEPTOR SYSTEM (RECTANGULAR=1,POLAR=2),21X,     S0205090
     4 8HISW(3) =,I4/,18X,40HTERRAIN ELEVATIONS ARE READ (YES=1,NO=0),  S0205100
     5 29X,8HISW(4) =,I4/,18X,                                          S0205110
     6 45HCALCULATIONS ARE WRITTEN TO TAPE (YES=1,NO=0),24X,8HISW(5) =, S0205120
     7 I4/18X,                                                          S0205130
     8 48HLIST ALL INPUT DATA (NO=0,YES=1,MET DATA ALSO=2),21X,         S0205140
     9 8HISW(6) =,I4//18X,39HCOMPUTE AVERAGE CONCENTRATION (OR TOTAL,   S0205150
     0 12H DEPOSITION)/18X,32HWITH THE FOLLOWING TIME PERIODS%/20X,     S0205160
     1 19HHOURLY (YES=1,NO=0),48X,8HISW(7) =,I4/20X,                    S0205170
     2 19H2-HOUR (YES=1,NO=0),48X,8HISW(8) =,I4/20X,                    S0205180
     3 19H3-HOUR (YES=1,NO=0),48X,8HISW(9) =,I4/20X,                    S0205190
     4 19H4-HOUR (YES=1,NO=0),47X,9HISW(10) =,I4/20X,                   S0205200
     5 19H6-HOUR (YES=1,NO=0),47X,9HISW(11) =,I4/20X,                   S0205210
     6 19H8-HOUR (YES=1,NO=0),47X,9HISW(12) =,I4/20X,                   S0205220
     7 20H12-HOUR (YES=1,NO=0),46X,9HISW(13) =,I4/20X,                  S0205230
     8 20H24-HOUR (YES=1,NO=0),46X,9HISW(14) =,I4)                      S0205240
 9031 FORMAT(18X,35HPRINT "N"-DAY TABLE(S) (YES=1,NO=0),33X,            S0205250
     1 9HISW(15) =,I4//18X,58HPRINT THE FOLLOWING TYPES OF TABLES WHOSE S0205260
     2TIME PERIODS ARE/18X,36HSPECIFIED BY ISW(7) THROUGH ISW(14)%/20X, S0205270
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     3 25HDAILY TABLES (YES=1,NO=0),41X,9HISW(16) =,I4/20X,             S0205280
     4 44HHIGHEST & SECOND HIGHEST TABLES (YES=1,NO=0),22X,9HISW(17) =, S0205290
     5 I4/20X,30HMAXIMUM 50 TABLES (YES=1,NO=0),36X,9HISW(18) =,I4/18X, S0205300
     6 57HMETEOROLOGICAL DATA INPUT METHOD (PRE-PROCESSED=1,CARD=2),11X,S0205310
     7 9HISW(19) =,I4/18X,58HRURAL-URBAN OPTION (RURAL=0,URBAN MODE 1=1,S0205320
     8URBAN MODE 2=2),10X,9HISW(20) =,I4/18X,57HWIND PROFILE EXPONENT VAS0205330
     9LUES (DEFAULTS=1,USER ENTERS=2,3),11X,9HISW(21) =,I4/18X,         S0205340
     0 64HVERTICAL POT. TEMP. GRADIENT VALUES (DEFAULTS=1,USER ENTERS=2,S0205350
     13),4X,9HISW(22) =,I4/18X,49HSCALE EMISSION RATES FOR ALL SOURCES (S0205360
     2NO=0,YES>0),19X,9HISW(23) =,I4/18X,53HPROGRAM CALCULATES FINAL PLUS0205370
     3ME RISE ONLY (YES=1,NO=2),15X,9HISW(24) =,I4/18X,                 S0205380
     4 59HPROGRAM ADJUSTS ALL STACK HEIGHTS FOR DOWNWASH (YES=2,NO=1),  S0205390
     5  9X,9HISW(25) =,I4)                                              S0205400
 9032 FORMAT(/18X,23HNUMBER OF INPUT SOURCES,46X,8HNSOURC =,I4/18X,      S0205410
     1 40HNUMBER OF SOURCE GROUPS (=0,ALL SOURCES),29X,8HNGROUP =,I4/18XS0205420
     2,53HTIME PERIOD INTERVAL TO BE PRINTED (=0,ALL INTERVALS),17X,    S0205430
     3 7HIPERD =,I4/18X,31HNUMBER OF X (RANGE) GRID VALUES,38X,8HNXPNTS S0205440
     4=,I4/18X,31HNUMBER OF Y (THETA) GRID VALUES,38X,8HNYPNTS =,I4/18X,S0205450
     5 28HNUMBER OF DISCRETE RECEPTORS,41X,8HNXWYPT =,I4)               S0205460
 9033 FORMAT(18X,46HNUMBER OF HOURS PER DAY IN METEOROLOGICAL DATA,23X, S0205470
     1 8HNHOURS =,I4/18X,37HNUMBER OF DAYS OF METEOROLOGICAL DATA,32X,  S0205480
     2 8H NDAYS =,I4)                                                   S0205490
 9034 FORMAT(18X,44HSOURCE EMISSION RATE UNITS CONVERSION FACTOR,27X,   S0205500
     1 6H   TK =,E10.5/18X,47HENTRAINMENT COEFFICIENT FOR UNSTABLE ATMOSPS0205510
     2HERE,22X,8H BETA1 =,F5.3/18X,45HENTRAINMENT COEFFICIENT FOR STABLES0205520
     3 ATMOSPHERE,24X,8H BETA2 =,F5.3/,18X,                             S0205530
     4 52HHEIGHT ABOVE GROUND AT WHICH WIND SPEED WAS MEASURED,18X,     S0205540
     5 7H    ZR =,F7.2,8H  METERS/18X,                                  S0205550
     6 42HLOGICAL UNIT NUMBER OF METEOROLOGICAL DATA,29X,6HIMET =,I4)   S0205560
 9035 FORMAT(18X,52HDECAY COEFFICIENT FOR PHYSICAL OR CHEMICAL DEPLETIONS0205570
     1 ,18X,7HDECAY =,E12.6/18X,19HSURFACE STATION NO.,                 S0205580
     3 53X,5HISS =,I6/18X,20HYEAR OF SURFACE DATA,52X,5HISY =,I3/18X,   S0205590
     4 21HUPPER AIR STATION NO.,51X,5HIUS =,I6/18X,                     S0205600
     5 22HYEAR OF UPPER AIR DATA,50X,5HIUY =,I3)                        S0205610
 9036 FORMAT(18X,39HLOGICAL UNIT OF CALCULATION "SAVE" TAPE,30X,        S0205620
     1 8H ITAP  =,I4)                                                   S0205630
 9037 FORMAT(44X,43H*** METEOROLOGICAL DAYS TO BE PROCESSED ***/        S0205640
     1 63X,6H(IF=1)//8(11X,5(10I2,2X)/))                                S0205650
 9038 FORMAT(//42X,48H*** X-COORDINATES OF RECTANGULAR GRID SYSTEM ***/ S0205660
     1 62X,8H(METERS)/)                                                 S0205670
 9039 FORMAT(//47X,35H*** RANGES OF POLAR GRID SYSTEM ***/62X,          S0205680
     1 8H(METERS)/)                                                     S0205690
 9040 FORMAT(100(5X,10(F10.1,1H,)/))                                    S0205700
 9041 FORMAT(//42X,48H*** Y-COORDINATES OF RECTANGULAR GRID SYSTEM ***  S0205710
     1 /62X,8H(METERS)/)                                                S0205720
 9042 FORMAT(//45X,42H*** RADIAL ANGLES OF POLAR GRID SYSTEM ***/       S0205730
     1 /62X,9H(DEGREES)/)                                               S0205740
 9043 FORMAT(//47X,45H*** X,Y COORDINATES OF DISCRETE RECEPTORS ***/    S0205750
     1 62X,8H(METERS)/)                                                 S0205760
 9044 FORMAT(//39X,53H*** RANGE,THETA COORDINATES OF DISCRETE RECEPTORS S0205770
     1***/58X,16H(METERS,DEGREES)/)                                     S0205780
 9045 FORMAT(100(6X,5(1H(,F9.1,1H,,F9.1,4H),  )/))                      S0205790
 9046 FORMAT(55X,19H*** SOURCE DATA ***//21X,13HEMISSION RATE,38X,      S0205800
     1 5HTEMP.,4X,9HEXIT VEL./24X,8HTYPE=0,1,40X,2(6HTYPE=0,4X)/10X,    S0205810
     2 3HT W,8X,3A4,38X,18H(DEG.K);  (M/SEC);,12X,3(5HBLDG.,4X)/10X,    S0205820
     3 20HY A NUMBER    TYPE=2,25X,4HBASE,12X,53HVERT.DIM  HORZ.DIM DIAMS0205830
     4ETER  HEIGHT   LENGTH    WIDTH/3X,19HSOURCE P K  PART.  ,3A4,5X,  S0205840
     5 1HX,8X,43HY      ELEV.   HEIGHT   TYPE=1   TYPE=1,2  ,4(6HTYPE=0,S0205850
     6 3X)/3X,31HNUMBER E E  CATS. *PER METER**2,2(5(1X,2A4),1X)/       S0205860
     7 63(2H -)/)                                                       S0205870
 9047 FORMAT(I8,I3,I2,I5,3X,E11.5,2F10.1,F8.1,2F9.2,1X,5F9.2)           S0205880
 9048 FORMAT(I8,I3,I2,I5,3X,2A4,A3,1X,2F9.1,3F9.2,1X,5F9.2)             S0205890
 9049 FORMAT(50X,31H*** SOURCE PARTICULATE DATA ***//)                  S0205900
 9050 FORMAT(/10X,19H*** SOURCE NUMBER =,I6,4H ***)                     S0205910
 9051 FORMAT(/10X,15HMASS FRACTION =/2(10X,10(F7.5,1H,)/))              S0205920
 9052 FORMAT(/10X,31HSETTLING VELOCITY(METERS/SEC) =/2(10X,10(F7.4,1H,) S0205930
     1 /))                                                              S0205940
 9053 FORMAT(/10X,32HSURFACE REFLECTION COEFFICIENT =/2(10X,10(F7.5,1H, S0205950
     1 )/))                                                             S0205960
```

```
9054 FORMAT(34X,27H* SEASONAL SOURCE STRENGTHS,3A4,                     S0205970
    1 26HFOR EACH HOUR OF THE DAY *//20H *** SOURCE NUMBER =,I5,4H ***)S0205980
9055 FORMAT(/4X,A4,A2/2(/4X,4HHOUR,I8,11I10/2X,8HSTRENGTH,12E10.4))    S0205990
9056 FORMAT(18X,22HALLOCATED DATA STORAGE,48X,7HLIMIT =,I6,6H WORDS/   S0206000
    1 18X,42HREQUIRED DATA STORAGE FOR THIS PROBLEM RUN,28X,            S0206010
    2  7HMIMIT =,I6,6H WORDS)                                           S0206020
9057 FORMAT('1',33X,65H*** NUMBER OF SOURCE NUMBERS REQUIRED TO DEFINE S0206030
    1SOURCE GROUPS ***/62X,8H(NSOGRP)//3(15X,20(I4,1H,)/))              S0206040
9058 FORMAT('1',43X,45H*** SOURCE NUMBERS DEFINING SOURCE GROUPS ***/  S0206050
    1 62X,7H(IDSOR)//8(15X,14(I6,1H,)/))                                S0206060
9059 FORMAT(//51X,30H*** WIND PROFILE EXPONENTS ***//)                 S0206070
9060 FORMAT(//42X,48H*** VERTICAL POTENTIAL TEMPERATURE GRADIENTS ***/ S0206080
    1 53X,26H(DEGREES KELVIN PER METER)//)                              S0206090
     END                                                                S0206100
```

ESCAPE FRACTION SUBROUTINE

ALTERNATIVE 1

CONSTANT-K, LINEAR MODEL

```
      SUBROUTINE ESCAPE(ZREF,ZO,TA,IS,U,UD,H,ESCP)
C   SUBROUTINE ESCAPE, ALTERNATIVE-1 CONSTANT-K LINEAR MODEL
      A5=ALOG(ZREF/ZO)
      A6=1./.123/ZREF
      A1=UD*A5*H/U*A6
      ESCP=1./(1.+A1)
      RETURN
      END
```

```
      SUBROUTINE ESCAPE(ZREF,ZO,TA,IS,U,UD,H,ESCP)
      DIMENSION DTDZ(6)
     DATA DTDZ/-.01,-.007,-.005,0.,.02,.035/
      A5=ALOG(ZREF/ZO)
      A6=1./.123/ZREF
      B=9.81*ZREF*ZREF*DTDZ(IS)/TA/U/U
      A1=ALOG(ZREF/ZO)
      IF(B.LT.O.) GOTO 1
      XH=0.05
      X=0.15
      FH=XH/((A1+.33333)/1.33333)**2-B
10    IF(X.EQ.0.2) X=0.19999999
      IF(X.LT.0.2) GOTO 12
      XTEST=-A1/5/(1-A1)
      IF(X.GE.XTEST)X=XTEST-.0001
12    F=X/(A1*(1.-5*X)+5*X)**2-B
      PH=1./(1.-5*X)
      PS=-5*X*PH
      IF(ABS(F).LT.0.0001) GOTO 100
      IF(X.EQ.XH) GOTO 100
      SL=(F-FH)/(X-XH)
      BINT=F-SL*X
      XNEW=-BINT/SL
      IF(ABS(XNEW-X).LT.0.0001) GOTO 100
      XH=X
      FH=F
      X=XNEW
      GOTO 10
1     XH=0.
      FH=-B
      X=-.05
20    IF(X.GE..06667) X=.06666
      IF(X.EQ.O.) X=0.0001
      PH=1.0/(1.0-15*X)**.25
      ZETA=(1.0-15*X)**.25
      ZETAO=(1.0-15*X*ZO/ZREF)**.25
      ARG1=ALOG((ZETA-1.0)*(ZETA+1.0)/((ZETA+1.0)*(ZETAO-1.0)))
      ARG2=2.0*(ATAN(ZETA)-ATAN(ZETAO))
      F=X/((A1-PS)/PH)**2-B
      IF(ABS(F).LT..0001) GOTO 100
      SL=(F-FH)/(X-XH)
      BINT=F-SL*X
      XNEW=-BINT/SL
      IF(ABS(XNEW-X).LT.0.0001) GOTO 100
      XH=X
      FH=F
      X=XNEW
      GOTO 20
100   IF(X.LT.O.) ZOL=X
      IF(X.GE.O.) ZOL=X/(1.0-5*X)
      USTAR=0.35*U/(A1-PS)
      IF(ZOL.LT.O.) PHH=0.74/(1.-9*ZOL)**.5
      IF(ZOL.GE.O.) PHH=.74+5*ZOL
      EDDY=.35*USTAR*ZREF/PHH
      ESCP=1.0/(1.0+UD*H/EDDY)
      RETURN
      END
```

ESCAPE FRACTION SUBROUTINE

ALTERNATIVE 3

VARIABLE-K, LINEAR MODEL

```
SUBROUTINE ESCAPE(ZREF,ZO,TA,IS,U,UD,H,ESCP)
A5=ALOG(ZREF/ZO)
A6=1./.123/ZREF
A1=UD*A5*ALOG(H/ZO)/U/.123
ESCP=1./(1.+A1)
RETURN
END
```

ESCAPE FRACTION SUBROUTINE

ALTERNATIVE 4

VARIABLE-K, DETAILED MODEL

```
      SUBROUTINE ESCAPE(ZREF,ZO,TA,IS,U,UD,H,ESCP)
      DIMENSION DTDZ(6)
     DATA DTDZ/-.01,-.007,-.005,0.,.02,.035/
      A5=ALOG(ZREF/ZO)
      A6=1./.123/ZREF
      DZ=H/10.
      TEDDY=0.
      DO 3 I=1,10
      Z=DZ*I-DZ/2
      CALL KCAL(ZREF,Z,ZO,TA,DTDZ(IS),U,UD,H,EDDY)
      TEDDY=TEDDY+1./EDDY*DZ
3    CONTINUE
      ESCP=1./(1.+UD*TEDDY)
      RETURN
      END
      SUBROUTINE KCAL(ZREF,Z,ZO,TA,DTDZ,U,UD,H,EDDY)
      B=9.81*ZREF*ZREF*DTDZ/TA/U/U
      A1=ALOG(ZREF/ZO)
      IF(B.LT.0.) GOTO 1
      XH=0.05
      X=0.15
      FH=XH/((A1+.33333)/1.33333)**2-B
10    IF(X.EQ.0.2) X=0.19999999
      IF(X.LT.0.2) GOTO 12
      XTEST=-A1/5/(1-A1)
      IF(X.GE.XTEST)X=XTEST-.0001
12    F=X/(A1*(1.-5*X)+5*X)**2-B
      PH=1./(1.-5*X)
      PS=-5*X*PH
      IF(ABS(F).LT.0.0001) GOTO 100
      IF(X.EQ.XH) GOTO 100
      SL=(F-FH)/(X-XH)
      BINT=F-SL*X
      XNEW=-BINT/SL
      IF(ABS(XNEW-X).LT.0.0001) GOTO 100
      XH=X
      FH=F
      X=XNEW
      GOTO 10
1     XH=0.
      FH=-B
      X=-.05
20    IF(X.GE..06667) X=.06666
      IF(X.EQ.0.) X=0.0001
      PH=1.0/(1.0-15*X)**.25
      ZETA=(1.0-15*X)**.25
      ZETAO=(1.0-15*X*ZO/ZREF)**.25
      ARG1=ALOG((ZETA-1.0)*(ZETA+1.0)/((ZETA+1.0)*(ZETAO-1.0)))
      ARG2=2.0*(ATAN(ZETA)-ATAN(ZETAO))
      F=X/((A1-PS)/PH)**2-B
      IF(ABS(F).LT..0001) GOTO 100
      SL=(F-FH)/(X-XH)
      BINT=F-SL*X
      XNEW=-BINT/SL
      IF(ABS(XNEW-X).LT.0.0001) GOTO 100
      XH=X
      FH=F
      X=XNEW
      GOTO 20
100   IF(X.LT.0.) ZOL=X
      IF(X.GE.0.) ZOL=X/(1.0-5*X)
      USTAR=0.35*U/(A1-PS)
      IF(ZOL.LT.0.) PHH=0.74/(1.-9*ZOL)**.5
      IF(ZOL.GE.0.) PHH=.74+5*ZOL
      EDDY=.35*USTAR*Z/PHH
      RETURN
      END
```

APPENDIX D

TEST RUNS AND SAMPLE INPUT FILE

SAMPLE INPUT FILE

```
TEST CASE FOR EPA PROJECT
 1 3 1 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 2 0 1 1 0 1 1
     2     2     5     0     0     0    24     1 10.0     .03
     6500.     1000.
     8000.     1000.


    120 30.0000032  8500.  8000.     0.     0.       811.0                    30.
     0.227     0.278     0.495
  0.000744  0.006694  0.018594
      1.00      0.82      0.73
      0.01      0.02      0.03
    220 30.0000032  8500.  9000.     0.     0.       811.0                    30.
     0.227     0.278     0.495
  0.000744  0.006694  0.018594
      1.00      0.82      0.73
      0.01      0.02      0.03
      1    263.      5.0   5000.    281.              5
      1    275.      3.5   5000.    281.              6
      1    258.      2.5   5000.    281.              6
      1    268.      3.5   5000.    281.              6
      1    268.      2.0   5000.    281.              6
      1    275.      5.0   5000.    281.              5
      1    281.      5.5   5000.    281.              4
      1    280.      4.5   5000.    281.              3
      1    264.      5.5   5000.    281.              3
      1    279.      5.5   5000.    281.              3
      1    265.      5.0   5000.    281.              3
      1    269.      8.0   5000.    281.              4
      1    267.      9.0   5000.    281.              4
      1    255.      9.0   5000.    281.              4
      1    281.      9.0   5000.    281.              4
      1    270.      5.0   5000.    281.              4
      1    261.      6.0   5000.    281.              4
      1    271.      5.0   5000.    281.              5
      1    272.      6.0   5000.    281.              4
      1    282.      8.0   5000.    281.              4
      1    261.      8.0   5000.    281.              4
      1    267.      7.0   5000.    281.              4
      1    276.      8.0   5000.    281.              4
      1    270.      5.0   5000.    281.              5
```

SAMPLE OUTPUT FILE

ALTERNATIVE 1

Constant-K, Linear Model

DAILY% 1
24-HR/PD 1
SGROUP# 1

*** TEST CASE FOR EPA PROJECT ***

* DAILY 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* ENDING WITH HOUR 24 FOR DAY 1 *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 5.36375 AND OCCURRED AT (7500.0, 9000.0) *

X-AXIS (METERS)

Y-AXIS / (METERS) /	6500.0	7500.0
12000.0 /	.00000	.00000
11000.0 /	.00004	.00000
10000.0 /	1.29845	1.07853
9000.0 /	4.33673	5.36375
8000.0 /	3.04080	4.28522

SAMPLE OUTPUT FILE

ALTERNATIVE 2

Constant-K, Detailed Model

DAILY% 1
24-HR/PD 1
SGROUP# 1

*** TEST CASE FOR EPA PROJECT ***

* DAILY 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER) *
* ENDING WITH HOUR 24 FOR DAY 1 *
* FROM ALL SOURCES *
* FOR THE RECEPTOR GRID *

* MAXIMUM VALUE EQUALS 4.24774 AND OCCURRED AT (7500.0, 9000.0) *

X-AXIS (METERS)

Y-AXIS (METERS) /	6500.0	7500.0
12000.0 /	.00000	.00000
11000.0 /	.00005	.00000
10000.0 /	1.20241	1.06225
9000.0 /	3.42940	4.24774
8000.0 /	2.22967	3.18549

SAMPLE OUTPUT FILE

ALTERNATIVE 3

Variable-K, Linear Model

```
                                                                                          DAILY%    1
                                                                                          24-HR/PD  1
                                                                                          SGROUP#   1
                         *** TEST CASE FOR EPA PROJECT                               ***

                         * DAILY 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER)      *
                                    * ENDING WITH HOUR 24 FOR DAY    1 *
                                         * FROM ALL SOURCES *
                                       * FOR THE RECEPTOR GRID *

                      * MAXIMUM VALUE EQUALS      3.59801 AND OCCURRED AT (    7500.0,    9000.0) *

    Y-AXIS   /                                             X-AXIS (METERS)
   (METERS)  /        6500.0        7500.0
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

    12000.0 /         .00000        .00000
    11000.0 /         .00003        .00000
    10000.0 /         .90017        .75939
     9000.0 /        2.91143       3.59801
     8000.0 /        2.01318       2.83861
```

SAMPLE OUTPUT FILE

ALTERNATIVE 4

Variable-K, Detailed Model

```
                                                                                              DAILY%    1
                                                                                              24-HR/PD  1
                                                                                              SGROUP#   1
                        *** TEST CASE FOR EPA PROJECT                                ***

                        * DAILY 24-HOUR AVERAGE CONCENTRATION (MICROGRAMS/CUBIC METER)      *
                                    * ENDING WITH HOUR 24 FOR DAY    1 *
                                         * FROM ALL SOURCES *
                                       * FOR THE RECEPTOR GRID *

                     * MAXIMUM VALUE EQUALS      3.66439 AND OCCURRED AT (     7500.0,     9000.0) *

   Y-AXIS   /                                          X-AXIS (METERS)
  (METERS)  /       6500.0       7500.0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

   12000.0 /        .00000       .00000
   11000.0 /        .00004       .00000
   10000.0 /       1.04998       .94175
    9000.0 /       2.94972      3.66439
    8000.0 /       1.90222      2.72264
```

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16. ABSTRACT

This report summarizes the results of a continuing effort to better understand the dispersion and transport of particulate matter released within surface coal mines. The report examines the relationship between critical meteorological parameters in an effort to refine an existing model algorithm to determine escape fraction. Methods to incorporate calculating particulate matter escape fraction into a regulatory air quality model are proposed and FORTRAN program listings of four alternatives are included.

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