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An Algorithm to Estimate Field Concentrations Under Nonsteady Meteorological Conditions from Wind Tunnel Experiments

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ABSTRACT

AN ALGORITHM TO ESTIMATE FIELD CONCENTRATIONS
UNDER NONSTEADY METEOROLOGICAL CONDITIONS
FROM WIND-TUNNEL EXPERIMENTS

Highest concentrations at ground level are often produced from surface sources with stable atmospheric conditions and near calm winds. This report describes a weighted data methodology developed to predict surface concentrations from stationary wind-tunnel measurements and actual meteorological wind fields. Field measurements made downwind of the Rancho Seco Nuclear Power Station in 1975 have been compared against a set of wind-tunnel measurements around a 1:500 scale model of the same facilities. The weighted data algorithm was realistic in both predicting centerline concentration values as well as the horizontal spread of the plume.

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1.0 INTRODUCTION

In recent years safety considerations with respect to surface concentrations in the event of postulated radioactive releases have played a major role in the design and operation of nuclear power plants. Pollutant concentrations are often greatest under conditions of low windspeed, temperature inversions, and erratic wind direction often modified by building wake effects. The common method to calculate dispersion fields assumes the material is transported in a mean wind direction, at the mean wind speed, unmodified by building wake effects and intermittent shifts of wind direction or speed. Wind direction sometimes shifts over the entire compass during the course of an hour period and wind speed may vary by an order of magnitude during low wind speed conditions (Start et al., 1977).

This study is part of an overall research program developed by the Office of Nuclear Regulatory Research to empirically determine the effects of containment buildings on the atmospheric flow field during different stabilities and over a variety of terrains (Abbey, 1976). This program has consisted of two field studies and two wind tunnel studies. The first field study was carried out at the EOCR complex located in the Idaho National Engineering Laboratory. The corresponding wind tunnel study was conducted in the Meteorological Wind Tunnel of the Fluid Dynamics and Diffusion Laboratory at Colorado State University (Hatcher et al., 1978). The second field study was conducted at the Rancho Seco Nuclear Power Station in 1975 (Start et al., 1977). Corresponding wind tunnel study was reported by Allwine et al. (1980). The development of a simple algorithm to estimate field concentrations under nonsteady meteorological conditions from wind-tunnel data and the subsequent comparison of the Rancho Seco field data with the time-weighted wind-tunnel data are the subject of this report.

An algorithm to predict surface concentrations from a limited set of wind-tunnel measurements and detailed meteorological data is presented in Chapter 2. In Chapter 3 a brief summary of the field and wind-tunnel measurement programs for the Rancho Seco Nuclear Power Station are discussed. The measured and estimated field concentrations are compared in Chapter 4.

2.0 RELATING WIND TUNNEL TO FIELD MEASUREMENTS

It is well known that the sample averaging time has a definite effect in the measured concentrations. The average maximum concentrations of gases dispersing in the atmosphere tends to decrease with increasing sampling time (Hino, 1968). This is not the case in wind-tunnel model tests. The model test results generally correspond to short-time-averaged field measurements taken over not more than 3 to 10 minutes.

Briefly, what is involved is associated with the eddy scale sizes detected in the atmosphere. Since the motion of the airflow in the surface layer is limited in the vertical directions in the presence of the ground, the magnitude of the eddy size in the longitudinal or transverse direction may be much greater than that in the vertical direction. Thus, the meandering behavior or the gustiness effect may cause a large transverse dispersion in the atmosphere. Since the larger eddy motion is not generally produced in a wind tunnel, some adjustment must be made for comparison to field measurements.

Fortunately, the energy spectrum of wind gusts in the atmosphere generally shows a null, or near null, in the frequency range of 1 to 10 cycles per hour. This spectral gap (low energy region) first noted by Van der Hoven (1957) separating weather from turbulence is a very fortunate occurrence, both from an analytical and a fluid modeling viewpoint. It is possible to separate the energy spectrum into two parts and to deal with the phenomena associated with each part separately. The high-frequency portion, related to the roughness of the surface, differential surface heating, small topographical features, and the turbulence around buildings is well simulated in a wind tunnel (Cermak, 1975). The low frequency portion related to meandering and wind-speed variations, directional fluctuations, passage of weather systems, seasonal and annual changes, etc., cannot be simulated in a wind tunnel.

2.1 Averaging Time Methods

At moderate to high wind speeds situations corresponding to a stationary weather system there may exist only two to four statistically independent periods during the da (Corotis, 1977). This suggests an autocorrelation time constant from 3.5 to 7 hours.

Data taken during such an "independent" period will not show expressively large shifts in wind speed or direction, and concentration values may be simply related to averaging time.

This phenomenon, often known as the gustiness effect, was first considered by Inoue (1952). He reported that a smoke cloud width increases at a rate proportional to the 1/2 power of the observation time. Ogura (1952) developed a mathematical model which suggested a -1/2 power variation of the maximum concentration with time. Hino (1968) performed a large scale study for a time range from ten minutes to five hours. The study which involved releasing tracer materials from high stacks of thermal electric power stations also gives support to the -1/2 power law. Hino (1968) also found that atmospheric instability has only small effect on the exponent of the power law, i.e., $C \sim \tau^{-1/2}$. The applicable range of the -1/2 law is greater for unstable than for neutral stratification.

An alternative -1/5 power law was proposed by Nonhebel (1960). Hino (1968) suggested, however, that the applicable time range for this law is less than ten minutes. Other exponents for the peak to mean concentration ratio from -0.65 to -0.35 depending on meteorological conditions have been recommended by the ASME Committee on Air Pollution Control. Hinds (1967) measured the peak to mean concentration ratios in a building wake. Data indicated the -1/2 law can also be used satisfactorily to predict the dispersion in the wake flow.

More recently, Brun et al. (1973) reviewed all prior experiments for peak to mean variations with averaging time. Although they report values of the power law coefficient which vary from 0.12 to 0.86 depending upon stratification and averaging time, they conclude a value of 0.5 is most appropriate when transposing the 0.25 to one hour averaging times.

Applying Hino's (1968) minutes one-half power law,

$$C_p = C_m\left(\frac{t_p}{t_m}\right)^{-1/2} \tag{1}$$

where C_p is prototype concentration, C_m is model concentration, t_p is prototype sampling time, and t_m is model equivalent field sampling time, we have for this study,

$$C_p = C_m\left(\frac{60}{10}\right)^{-1/2} = 0.4 \ C_m. \tag{2}$$

This means that the wind tunnel measurements overpredict prototype concentrations by a factor of two and one-half for typical near-nuetral, as defined by $\Delta T/\Delta z$, flow conditions.

2.2 Gaussian Segmented-Plume Methods

During low wind speed or changing weather pattern situations the assumption of small deviations in mean wind speed and direction are not generally valid. In such cases the hour-average surface concentration are uniquely related to the actual history of meteorological conditions which exist during the given hour. It is suggested that one-hour average concentration distribution may be obtained by taking the time-weighted average of concentrations at each sample point for each combination of observed atmospheric wind speed, wind direction and stability during a two minute interval.

Sagendorf and Dickson (1974) compared the results of diffusion tests conducted under stable conditions with windspeeds less than 2 m/sec against a "segmented plume" version of the classical Gaussian distribution model. Each test time period was divided into 2 minute increments and separate calculations were made for each interval. Concentrations received at each sampler location were summed to determine the total concentration, the stability class for each case was determined from the average temperature gradient measured over the test period, and the vertical standard deviation, σ_z, was determined from Turner (1968). The lateral standard deviation, σ_y, was obtained from each 2-minute interval from the expression

$$\sigma_y = a\sigma_\theta x^b$$

where $a = 0.017$, $b = 0.87$, σ_θ was the 2-minute standard deviation in horizontal wind direction in degrees, and the other dimensions are meters. The model assumed that a plume segment would continue in the direction it started, even though there is expected to be an influence of subsequent shifts in wind direction.

The "segmented plume" Gaussian model showed considerable improvement over the Pasquill-Gifford method when compared to the data of Sagendorf and Dickson (1974). The model reproduced rather fine details as noted in Figure 1. The "segmented plume" model was the most realistic in both predicting centerline values as well as the horizontal spread of the plume as compared with P-G method.

2.3 Time-Weighted Laboratory Measurement Algorithm

Laboratory measurements of dispersion can effectively simulate a number of combinations of wind direction, wind speed, and thermal stratification conditions. This matrix must be large enough to reasonably reproduce the range of expected situations. The measured concentration fields may also be combined in a manner which reflects the influence of gustiness, meandering, and thermal structure utilizing proposed algorithm.

Halitsky (1969) proceeded in this spirit when he compared roof-top concentration patterns detected during field experiments with patterns obtained by weighting wind tunnel measurements made over a model placed at a series of wind orientations. The weighted laboratory data reproduced the magnitude and distribuiton of concentrations quite well as shown in Figure 2.

2.3.1 General Formulation

The concentration, C, measured at some sample location r and ϕ will be a function of source strength Q, speed U, wind direction orientation θ, and thermal stratification Ri. The time average value of a fluctuating concentration over a time interval T may then be expressed as

$$\overline{C}(r,\phi) = \frac{1}{T} \int_{t}^{t+T} C(Q(t),\ U(t),\ \theta(t),\ Ri(t);\ r,\phi)\ dt \qquad (3)$$

Alternatively given a constant source strength one might construct a value for $\overline{C}$ by utilizing the joint probability distribution of U, θ and Ri over the test period. Let the joint probability distribution be p(U,θ,Ri), then

$$\overline{C}(r,\phi) = \int_{Ri} \int_{\theta} \int_{U} p(U,\theta,Ri)C(U,\theta,Ri;r,\phi)\ dUd\theta dRi \qquad (4)$$

In the above formulations it is assumed that:

- Concentration wind tunnel data are continuously available for a combination of wind speed, direction, and stability.
- Mean wind and temperature characteristics are available from the field site at any instant during the test period.
- Meteorological data available from a single site near field release are characteristic of the flow over the entire site.
- The meteorological characteristics are quasi-steady over a period longer than the time it takes a particle to travel from the release point to a sample position. This implies that directional changes of the trajectory of an air parcel between the release point and the sample location are insignificant.

2.3.2 Segmented Time Approximation

Similarity theory suggests that for nonbuoyant plumes the dimensionless concentration coefficient, K, for equivalent field and laboratory conditions should be equal. The coefficient is defined as

$$K \equiv \frac{CUA}{Q} \qquad (5)$$

where U, A, and Q are characteristic velocity, area, and source scales; hence,

$$K_f = K_m \qquad (6)$$

and

$$C_f = \left(\frac{Q_f}{U_f A_f}\right) K_m \qquad (7)$$

where f and m subscripts indicate field and model situations respectively. Note that it is unnecessary to run laboratory tests for all source strength and velocity combinations since a single normalized concentration parameter defines such conditions. Frequently, however, field or laboratory data are reported with different characteristic length scales or velocity reference height. In such cases the comparison algorithm must incorporate scale and velocity profile adjustments.

Given a field test for every 2-minute average combination of the variables θ and Ri, one may represent an hour average version of Equation (7) by the sum

$$\overline{C}_f(r,\phi) = \sum_{i=1}^{30} \frac{(Q_f)_i}{(U_f)_i A_f} (K_m)_i \qquad (8)$$

or

$$\overline{\chi}_f(r,\phi) \equiv \frac{\overline{C}_f(r,\phi)\overline{U}_f}{\overline{Q}_f} = \sum_{i=1}^{30} \frac{(Q_f)_i}{\overline{Q}_f} \frac{\overline{U}_f}{(U_f)_i} \frac{(K_m(r,\phi))_i}{A_f} \qquad (9)$$

where the overbar represents one hour average value.

It is not economically feasible to run a laboratory test for every potential combination of Q, U, θ, and Ri; hence, there is usually a finite number of discrete conditions among which data must be interpolated. An approximation has been prepared to estimate mean average concentration based on the summation of such a discrete data set available from wind tunnel measurements.

Typically laboratory data may be available for a matrix of various thermal stratification conditions and for number of wind directions. An interpolation method is proposed to estimate $(K_m)_i$ for the nonincremental two-minute average values of $(\theta_f)_i$ and $(Ri_f)_i$. The following notation is introduced:

$$(K_m(r,\phi))_i = \sum_{j=1}^{NS} \sum_{k=1}^{NW} W_{ijk} K_{jk}(r,\phi) \qquad (10)$$

where K_{jk} is a set of model dimensionless concentration data for a specific member of the thermal stratification and wind orientation model test matrix,

W_{ijk} is a weight function varying in magnitude from 0 to 1.0,

NS Number of stratifications for which the wind tunnel study was performed,

NW Number of wind directions for which the wind tunnel study was performed.

The determination of the weight factors for the ith interval of a given hour period is accomplished in three steps. First the influence of wind orientation and stratification are assumed linearly independent; thus

$$W_{ijk} = WS_{ij}\, WW_{ik} \qquad (11)$$

where WS and WW are contributions due to stratification and orientation respectively.

The stability effects are estimated in the second step by a simple linear interpolation on bulk Richardson number, that is

a) if $(Ri_f)_i < (Ri_m)_1$, then $WS_{i1} = 1.0$

$WS_{ij} = 0.0, \quad j \neq 1$

b) if $(Ri_m)_j \leq (Ri_f)_i \leq (Ri_m)_{j+1}$, then

$$WS_{ij} = \frac{(Ri_m)_{j+1} - (Ri_f)_i}{(Ri_m)_{j+1} - (Ri_f)_j}$$

$$WS_{i,j+1} = \frac{(Ri_f)_i - (Ri_m)_j}{(Ri_m)_{j+1} - (Ri_m)_j}$$

otherwise

$WS_{ij} = 0.0,$

c) if $(Ri_m)_{NS} < (Ri_f)_i$, then $WS_{i,NS} = 1.0$

$WS_{i,j} = 0.0 \;, \quad j \neq NS$

Although the adequacy of linear interpolation may be questionable, it does not appear a more sophisticated interpolation scheme is appropriate at this time. Among those stratification classification schemes proposed for predictive schemes the bulk Richardson number was judged by Hanna et al. (1977) and Weber et al. (1977)

The wind orientation weight factor is also estimated by simple linear interpolation. That is

if $(\theta_m)_k \leq (\theta_f)_i \leq (\theta_m)_{k+1}$ then

$$WW_{i,k} = \frac{(\theta_m)_{k+1} - (\theta_f)_i}{(\theta_m)_{k+1} - (\theta_m)_k}$$

$$WW_{i,k+1} = \frac{(\theta_f)_i - (\theta_m)_k}{(\theta_m)_{k+1} - (\theta_m)_k}$$

Otherwise

$WW_{i,k} = 0.0$

The recommended interpolation scheme is not yet adequate to completely account for wind direction variation. It is proposed to assign a revised bearing to the wind tunnel data. The concentration at grid point r,ϕ is given the value of the model concentration of the grid point closest to $r,\phi - (\theta_f)_i + (\theta_m)_k$. This device prevents the appearance of lobed surface concentration contours, which result when one simply superimposes orientation unmodified data.

If the velocity reference height stipulated for field measurements is Z_f, whereas the equivalent reference height utilized for reference velocities for model data is Z_m, then a correction factor, f_j, must be applied to laboratory results based on the laboratory measured velocity profiles.

Hence

$$f_j \equiv \left(\frac{Z_f}{Z_m} \right)^{p_j} \qquad (12)$$

where p_j is the power-law coefficient determined by the site characteristics. Hence, when equations (11) and (12) are incorporated into equation (10) gives,

$$(K_m(r,\phi))_i = \sum_{j=1}^{NS} f_j WS_{ij} \sum_{k=1}^{NW} WW_{ik} K_{jk}(r,\phi-(\theta_f)_i + (\theta_m)_k) \qquad (13)$$

The final laboratory-weighting algorithm proposed herein incorporated Equation (13) into Equation (9) such that

$$\overline{\chi}_f(r,\phi) = \sum_{i=1}^{30} \frac{(Q_f)_i}{\overline{Q}} \frac{\overline{U}_f}{(U_f)_i} \frac{1}{A_f} \sum_{j=1}^{NS} f_j WS_{ij} \sum_{k=1}^{NW} WW_{ik} K_{jk}(r,\phi-(\theta_f)_i + (\theta_m)_k) \qquad (14)$$

Equation (14) presented above is the basis for the computer program RANSEC presented in Appendix A.

3.0 FIELD AND WIND TUNNEL EXPERIMENTS

3.1 Field Experiments

A series of 23 tests were conducted at the Rancho Seco Nuclear Power Station by Start et al. (1977). During each test period two tracer gases were released from the Rancho Seco facility; gas samples were taken at distances of up to 800 m downwind, and meteorological conditions were recorded at a nearby meteorological tower. A topographical plan of the study site indicating sampler locations and the meteorological tower is presented in Figure 3. The release and sampler locations are given on a more detailed plan view in Figure 4.

The sampling grid for this study consisted of four circular arcs centered on the reactor containment vessel with radii of 100, 200, 400, and 800 m. Samplers were spaced every six degrees starting from the north and were numbered clockwise. Nineteen additional samplers were placed around the base and on the roof of several of the buildings. No samples were taken at the corresponding nineteen locations of the wind tunnel study, hence, these positions were not considered in the present report.

Meteorological data (wind speed, direction, temperature) were obtained from instruments mounted on a 46 meter tower just within the 400 meter arc. Sensors to measure temperatures, horizontal wind velocities, and horizontal and vertical wind angles were mounted at heights of 4, 10, 16, 32, and 46 m. One-hour average values of the meteorological data were reported by Start et al. (1977). Meteorological data averaged over successive two-minute increments during the one-hour test periods are contained in Appendix D. The latter information was used to define the meteorological condition utilized during construction of time-weighted concentration averages from the wind tunnel data. For each 2-minute interval, bulk Richardson numbers were calculated based on measurements taken at the 4 and 46 m levels. The wind direction data sometimes show substantial variation of the wind direction with height; nevertheless, the characteristic wind direction selected was the one measured at the release height.

3.2 Wind Tunnel Experiments

Wind tunnel diffusion tests were conducted on a 1:500 scale model of the Rancho Seco Nuclear Power Station. The experiments were performed in the Meteorological Wind Tunnel located in the Fluid Dynamics and Diffusion Laboratory at Colorado State University (Allwine et al., 1980).

Three atmospheric stabilities, characteristic of the 1975 Rancho Seco field study, were simulated. Tracer gases were released under each of these stability conditions at the corresponding field-study release points for eight different wind directions. Ground-level concentrations were measured on a model sampling grid identical to the four circular areas as that given in Figure 4.

Wind tunnel concentration data are tabulated by Allwine et al. (1980) in a nondimensional form as

$$K_m = \frac{CUA}{Q} \qquad (15)$$

where C is the concentration (gm/m^3),

U is the upwind velocity at the release height (m/sec),

A is the characteristic area of the building (m^2),

Q is emission rate (gm/sec)

The weighted wind tunnel concentration data in this report are presented as

$$\chi = \frac{\overline{CU}}{\overline{Q}} \ (m^{-2})$$

which correspond to the convention for wind and source strength normalized field-concentration data provided by Start et al. (1977).

4.0 RESULTS

The algorithm developed in Section 2.3.2 has been incorporated into computer program RANSEC to predict one hour average concentrations at the Rancho Seco Nuclear Power Station. Wind-tunnel measurements of concentration fields downwind of a 1:500 scale model of the Rancho Seco facility were combined with 2-minute interval meteorological records taken during the field tests to produce a series of synthesized 1-hour average concentration data. The algorithm predicted data are then compared with the measured test data.

Figures 5 to 24 contain the results of the weighted laboratory data calculations. This model shows considerable improvement over direct comparison of 1-hour average field data to 10-minute equivalent laboratory measurements. The weighted algorithm is generally more realistic in predicting centerline values as well as the horizontal spread of the plume. The weighted average method is generally conserative as compared with the field data. Notice the fine details the model produces in Figures 13, 19, 20, and 23. The model calculations also show that the comparison with the field data was better for auxiliary building release.

There are, however, some marked dissimilarities between the synthesized and measured values. The measured profiles display considerable variations. At a number of bearing angles the measured values drop suddenly to zero. The synthesized plumes are generally smoother, displaying a monotonically increasing magnitude to a maximum followed by a monotonically decreasing variation to zero.

During field run 11:G5 (Start et al., 1977), the measured concentrations displayed in Figure 7 did not decay significantly from the 100 m to the 800 m. The synthesized profiles display the characteristic decay of maximum concentration with downwind distance.

It was observed that the mean wind direction at 4 m height for each 2-minute interval did not change much during the field tests, e.g., test 15:G5. However, for the same test run the standard deviation for wind direction for each 2-minute interval was large. This resulted in a 1-hr average concentration distribution that spread over the entire compass. In such cases, a modified methodology was utilized to improve the comparison between field and wind tunnel algorithm test. For the test 15:G5, the mean wind direction at 10 m height for each 2-minute interval was varying; hence the use of this wind direction would result in larger plume spread compared to that predicted with wind direction at 4 m height. The modified results of the algorithm were calculated and are shown in Figure 25. Comparing the results of Figure 25 with Figure 17, it can be concluded that the use of wind direction at 10 m height yields a better comparison with the field data at 100 m and overestimations are reduced at other arcs.

The maximum ground level concentration coefficients, $\frac{CU}{Q}\ m^{-2}$ for tests 7:G5, 12:G5, 14:G5, 15:G5, 17:G5, 18:G5, 17:G17, 18:G17, 7:A, 12:A, 14:A, 15:A are presented in Table 1. Table 1 records $\frac{CU}{Q}\ m^{-2}$ as measured by Start et al. (1977), as presented by Start et al. (1977) using Pasquill-Gifford methods, as presented in Slade (1968), as measured by Allwine et al. (1980) in the wind tunnel and as per algorithm in columns a, b, c, d, and e, respectively. The table also compares each method with field measurements. Considering the ratios b/a, c/a, d/a, and e/a it is evident that in general overall prediction using the algorithm described in the previous chapter yields better predicted values.

Using flow visualization techniques Start et al. (1977) observed during the stable runs that oil fog smoke released in the building wake cavity is drawn upward along the lee edge of the structure and streams away from the buildings as if released from a vertical elongated source. Depending upon the amount of stable layering of the atmosphere, the oil fog plume may be contained to greater or lesser extent within particular layers. Oil fog released in the building cavity zone tends to remain well above the ground surface. This resulted in lower concentration during field tests 18:G5 and 18:G17 ($Ri_b = \infty$). However, layering effects cannot be modeled in the laboratory measurements and the averages in Table 1 data were calculated excluding these two runs. It is evident that the Pasquill-Gifford method overpredicts the measured field concentration by approximately 100 times on an average. The laboratory data overpredicts the measured field concentration by 6.6 times, whereas the use of the algorithm reduced the overprediction to 2.5 times.

If the physical modeling is expected to be a useful means to predict concentrations in the field, there must be a high linear relationship between measurements in the laboratory and field. The best estimate of the population correlation coefficients is the sample correlation coefficient commonly calculated as:

$$r = \frac{n\Sigma xy - \Sigma x\Sigma y}{[n\Sigma x^2 - (\Sigma x)^2]^{1/2}[n\Sigma y^2 - (\Sigma y)^2]^{1/2}} . \tag{16}$$

For the present case x and y represent wind-tunnel algorithm calculated data and field data respectively. The correlation coefficient r always lies between -1 and +1. If, and only if, all points lie on the regression line, than $r = \pm 1$. If $r = 0$, the regression line does not explain anything about the variation of y. The square of the correlation coefficient, r^2, explains how much of the variance can be attributed to the actual data variabilities and how much noise.

If it is assumed that there are only two variables of interest, an "independent" variable x, and a "dependent" variable y, then the equation of the sample regression line of y on x is:

$$y = a + b\,x \tag{17}$$

Note that coefficients a and b are defined in the normal least squares manner for a two variable linear regression; that is:

$$b = \frac{n\Sigma xy - \Sigma x\Sigma y}{n\Sigma x^2 - (\Sigma x)^2} , \tag{18}$$

$$a = \frac{\Sigma y - b\Sigma x}{n}$$

Figure 26 presents scatter diagram of the field data (y) versus wind-tunnel data using algorithm (x). The correlation coefficient r was 0.48 and $y = 15 + 0.68\,x$ using all data of Table 1. However, with two runs 18:G5 and 18:G17 excluded, the correlation coefficient r was 0.82 and $y = -64 + 1.64\,x$. The correlation coefficient of 0.82 indicates that 65% of the spread can be explained by the data. The wind-tunnel results can be said to be in fair agreement with the field data when the proposed algorithm is used to adjust the wind tunnel data.

It is recommended to use the method in future when comparing unidirectional laboratory or numerical models against field observations measured over one hour or longer. This method can be used together with wind-tunnel data and field meteorological data to evaluate the dispersion characteristics before construction of a plant.

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APPENDIX A

PROGRAM RANSEC

```
      PROGRAM RANSEC(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,NPARAM)
      COMMON /WT/ NW,NS,WDR(8),RIB(3),IGP(8,3,99),CWT(8,3,99),NCC(8,3)
      COMMON /FD/ L,WD,U,RI,IGF(240),CF(240),TEST(9),TDT(18),US(9),SKPL(
     19),FF
      COMMON /LO/ NG,ND,G,D,NARC,IAD(4)
      COMMON /PLT/ X(60,4,2),C(60,4,2),NP(4,2)
      COMMON /TXT/ AX(3),AY(3),A(4),NX,NY,NA(4),AIX(3),NIA,R(4)
      DIMENSION WW(8),WWW(3),W(8,3),I1(2),I2(2),NPL(4)
      DATA AX,AY,A,NX,NY,NA,AIX,NIA,I1,I2,NPL /
     110HBEARING (D,10HEGREES)    ,10H          ,
     210HCONCENTRAT,10HION (1/M*M,10H)          ,
     310HARC 100 M ,10HARC 200 M ,10HARC 400 M ,10HARC 800 M ,
     417,21,4*9,
     510HCORRELATIO,10HN COEFFICI,10HENT IS     ,27,
     6100,100*0,100,1,2,3,4/
      DATA NP /8*60/
      DATA X0,XI,DX,Y0,YI,DY /0.,6.,60.,-7.,6.,1./
      DATA NG,ND,G,D,NARC,IAD /60,6,60.,6.,4,100,200,400,800/
      DO 200 IRUN=1,1
      DO 10 I=1,NG
      IB=I*ND
      DO 10 J=1,NARC
      DO 10 K=1,2
      X(I,J,K)=IB
      C(I,J,K)=0.
10    CONTINUE
      READ(5,5)NI
      S=NI
      CALL WTDATA
      DO 100 L=1,NI
      CALL FDDATA
      IF(WD.LT.WDR(1))WD=WD+360.
      CALL WEIGH(NW,WDR,WD,WW)
      CALL WEIGH(NS,RIB,RI,WWW)
      IWD=(WD+D/2.)/D+NG/2
      DO 20 I=1,NW
      DO 20 J=1,NS
20    W(I,J)=WW(I)*WWW(J)/S
      DO 30 I=1,NW
      IWTD=(WDR(I)+D/2.)/D+NG/2
      DO 30 J=1,NS
      NC=NCC(I,J)
      DO 30 N=1,NC
      IA=IGP(I,J,N)/NG
      IB=IGP(I,J,N)-IA*NG-IWTD+IWD+NG
      IT=IB/NG
      IB=IB-IT*NG
```

```
 30   C(IB,IA,1)=C(IB,IA,1)+W(I,J)*CWT(I,J,N)/U
100   CONTINUE
      WRITE(6,1)TEST,US,TDT,US,SKPL,SKPL
      WRITE(6,2)
      WRITE(6,3)
      I=1
      DO 60 M=1,NARC
      IIGP=NG*M
      DO 60 K=1,NG
      N=IIGP+K
      IF(N.NE.IGF(I))GOTO 40
      C(K,M,2)=CF(I)
      I=I+1
      GOTO 50
 40   IF(C(K,M,1).EQ.0.)GOTO 60
 50   CONTINUE
      C(K,M,1)=C(K,M,1)*FF
      WRITE(6,4)N,IAD(M),X(K,M,1),C(K,M,2),C(K,M,1)
 60   CONTINUE
      CALL PLOTS(0,0,0)
      CALL PLT(NARC,NPL,2,I1,3,0,X0,XI,DX,Y0,YI,DY)
200   CONTINUE
      CALL PLOT(0.,0.,999)
  1   FORMAT(1H1////(10X,9A10))
  2   FORMAT(10X,90HCOMPARISON BETWEEN FIELD CONCENTRATIONS AND ESTIMATE
     1D CONCENTRATIONS FROM WIND-TUNNEL DATA//)
  3   FORMAT(10X,91H    GRID POINT          ARC            BEARING    FIELD C
     1ONCENTRATION    ESTIMATED CONCENTRATION/31X,
     261H(M)         (DEGREES)          (1/M*M)                    (1/M*M)/)
  4   FORMAT(10X,I9,I15,F14.0,E21.3,E24.3)
  5   FORMAT(I5)
      END
```

```
      SUBROUTINE WEIGH(N,RT,R,W)
      DIMENSION RT(1),W(1)
      N1=N-1
      DO 10 I=1,N1
      IF(R.LE.RT(I+1).AND.R.GE.RT(I))GOTO 20
      W(I)=0.
10    CONTINUE
      IF(R.LT.RT(1))W(1)=1.
      IF(R.LT.RT(1))W(N)=0.
      IF(R.GT.RT(N))W(N)=1.
      RETURN
20    W(I+1)=(R-RT(I))/(RT(I+1)-RT(I))
      W(I)=1.-W(I+1)
      IF(I.EQ.N1)RETURN
      I1=I+2
      DO 30 I=I1,N
30    W(I)=0.
      RETURN
      END
```

```
      SUBROUTINE WTDATA
      COMMON /WT/ NW,NS,WDR(8),RIB(3),IGP(8,3,99),CWT(8,3,99),NCC(8,3)
      COMMON /WO/ IR,IS,IWD,RP,IG(40),C(40),NPW
      COMMON /LO/ NG,ND,G,D,NARC,IAD(4)
      DIMENSION NQ(4),NA1(4),NA2(4),P(3)
      DATA RIB,P,FH,WTH/-.32,.0,.35,.10,.16,.35,46.,52./
      READ(5,4)NW,NS
      DO 100 I=1,NW
      DO 100 J=1,NS
      READ(5,5)IR,IS,IWD,RH,RP
      WDR(I)=IWD
      READ(5,1)NPW
      READ(5,2)(IG(N),N=1,NPW)
      READ(5,3)(C(N),N=1,NPW)
      DO 70 N=1,NPW
70    IF(IG(N).LT.0)IG(N)=-IG(N)
      CALL WTOUT
      FW=(FH/WTH)**P(J)
      IF(FW.EQ.1.)GOTO 90
      DO 80 N=1,NPW
80    C(N)=C(N)*FW
90    CONTINUE
      N1=NPW-1
      L=1
      DO 20 N=1,N1
      IF((L+1)*NG.GE.IG(N).AND.(L+1)*NG.LT.IG(N+1))GOTO 10
      GOTO 20
10    NQ(L)=1
      IF(IG(N).LT.IG(N-1))NQ(L)=-1
      IF(IG(N)-IG(N-1).EQ.59)NQ(L)=-1
      IF(IG(N)-IG(N-1).EQ.-59)NQ(L)=1
      NA2(L)=N
      L=L+1
20    CONTINUE
      NQ(L)=1
      IF(IG(NPW).LT.IG(N1))NQ(L)=-1
      NA2(L)=NPW
      NA1(1)=1
      DO 30 K=2,L
```

```
30     NA1(K)=NA2(K-1)+1
       NC=1
       DO 40 K=1,L
       N1=NA1(K)
       N2=NA2(K)-1
       NL=NQ(K)
       DO 60 N=N1,N2
       M=N
       IF(NL.EQ.-1)M=N2+N1-N+1
       NN=IG(M+NL)-IG(M)-1
       IGP(I,J,NC)=IG(M)
       CWT(I,J,NC)=C(M)
       NC=NC+1
       IF(NN.EQ.0.OR.IABS(NN).EQ.NG)GOTO 60
       SN=NN+1
       DO 50 II=1,NN
       IGP(I,J,NC)=IG(M)+II
       CWT(I,J,NC)=C(M)+(C(M+NL)-C(M))/SN*II
       NC=NC+1
50     CONTINUE
60     CONTINUE
       IGP(I,J,NC)=IG(M+NL)
       CWT(I,J,NC)=C(M+NL)
       NC=NC+1
40     CONTINUE
       NCC(I,J)=NC-1
100    CONTINUE
       RETURN
1      FORMAT(I5)
2      FORMAT(20I4)
3      FORMAT(10F8.4)
4      FORMAT(2I5)
5      FORMAT(3I5,F5.2,A4)
       END
```

```
      [illegible]E WTOUT
      [illegible]/WO/ IR,IS,IWD,RP,IG(40),C(40),NPW
      [illegible]ON /LO/ NG,ND,G,D,NARC,IAD(4)
      DIMENSION S(2,3),IARC(40),IB(40)
      DATA S /10HSLIGHTLY U,10HNSTABLE    ,10HNEUTRAL   ,10H
     110HMODERATELY,10H STABLE    /
      WRITE(6,1)IR,S(1,IS+2),S(2,IS+2),IWD,RP
      IE=0
      DO 50 I=1,NPW
      IA=(IG(I)-1)/NG
      IARC(I)=IAD(IA)
      IB(I)=(IG(I)-IA*NG)*ND-IWD-180
      IF(IB(I).LT.0)IB(I)=IB(I)+360
   50 CONTINUE
      WRITE(6,2)(IG(I),IARC(I),IE,IB(I),C(I),I=1,NPW)
      RETURN
    1 FORMAT(1H1////10X,30HCONCENTRATION DATA FOR RUN NO.,I3/12X,
     111HSTABILITY, ,2A10/12X,15HWIND DIRECTION,,I4,5H DEG./12X,
     214HRELEASE POINT,,A4///)
    2 FORMAT(13X,61HSAMPLER        ARC       ELEV.     DEGREES OFF        CONC
     1ENTRATION/12X,61HGRID POINT     (M)         (M)       CENTERLINE
     3 COEFFICIENT//(12X,I6,I11,I9,I12,F20.4))
      END
```

```
      SUBROUTINE FDDATA
      COMMON /FD/ L,WD,U,RI,IGF(240),CF(240),TEST(9),TDT(18),US(9),SKPL(
     19),FF
      DATA TEST(9),TDT(9),TDT(18),SKPL,US /12*10H          ,
     19*10H---------- /
      IF (L.NE.1)GOTO 10
      READ(5,1)(TEST(I),I=1,8),(TDT(I),I=1,8),(TDT(I+9),I=1,8)
      READ(5,2)RH,HU,UM,AF,Z1,Z2
      FF=UM/AF
      READ(5,3)NP
      READ(5,4)(IGF(I),I=1,NP)
      READ(5,5)(CF(I),I=1,NP)
      IGF(NP+1)=1
      CF(NP+1)=0.
      WRITE(6,6)TEST,SKPL,US,TDT,US
      WRITE(6,7)Z1,Z2,Z1,Z2,HU,RH
10    CONTINUE
      READ(5,8)IT,T1,T2,W1,W2,U1,U2
      U2=U2*.4470
      U1=U1*.4470
      U=U2
      WD=W2
      IF(RH.EQ.4.)WD=W1
      CALL MOOB(T1,T2,U1,U2,Z1,Z2,RI,OL)
      IF(OL.EQ.10H  INFINITY.OR.OL.EQ.10H          .OR.OL.EQ.10H  NO CON
     1V.)GOTO 30
      WRITE(6,9)IT,T1,T2,U1,U2,U,WD,RI,OL
      GOTO 40
30    WRITE(6,11)IT,T1,T2,U1,U2,U,WD,RI,OL
40    CONTINUE
      RETURN
 1    FORMAT(8A10)
 2    FORMAT(6F10.4)
 3    FORMAT(I5)
 4    FORMAT(20I4)
 5    FORMAT(8F10.3)
 6    FORMAT(1H1////(10X,9A10))
 7    FORMAT(//41X,28HMETEOROLOGICAL DATA(TOWER 2)//10X,
     189H   TIME        TEMP.      TEMP.       VEL.        VEL.        VEL.     WI
     2ND DIR.    BULK      MONIN /10X,
     389H                (F)         (F)        (M/S)       (M/S)       (M/S)    (D
     4EGREES) RICHARDSON OBUKHOV/10X,
     5F16.0,1HM,F9.0,1HM,F9.0,1HM,F9.0,1HM,F9.0,1HM,F9.0,23HM          NUMBE
     6R    LENGTH/)
 8    FORMAT(I10,6F10.4)
 9    FORMAT(10X,I7,2F10.1,3F10.1,F11.1,F10.3,F10.2)
11    FORMAT(10X,I7,2F10.1,3F10.1,F11.1,F10.3,A10)
      END
```

```
      SUBROUTINE MOOB(T1,T2,U1,U2,Z1,Z2,R,L)
      REAL LLMT,LTEMP,L
      TDIFF=T2-T1
      UDIFF=U2-U1
      ZDIFF=Z2-Z1
      ZM=ZDIFF/ALOG(Z2/Z1)
      ULMT=(.000525*ZM+.0000023R*ZM*ZM)/(1.+.00001125*ZM*ZM)
      LLMT=-.004933*ZM*SQRT((100.+ZM)/(100.+.6*ZM))
      QOTNT=ZDIFF/UDIFF
      R=19.6*(TDIFF/ZDIFF+.0098)*QOTNT*QOTNT/(T1+T2)
      IF(R.LT.LLMT)GOTO 30
      IF(R.GT..214)GOTO 40
      IF(R.GT.ULMT)GOTO 20
      L=10H  INFINITY
      RETURN
20    A=(4.7-.37/R)*ZM
      B=(22.09-4.7/R)*ZM*ZM
      L=-A-ABS(A)/A*SQRT(A*A-B)
      IF(L.LT.0.)L=B/L
      RETURN
40    L=10H
      RETURN
30    A=-.5476/R/R
      B=-15*A
      L=3.-SQRT(9.-A/3.)
      FL=L*(L*(L-9.)+A)+B
      DO 50 I=1,35
      FL=L*(L*(L-9.)+A)+B
      DEN=L*(3.*L-18.)+A
      IF(DEN.NE.0.)GOTO 70
      L=10H  NO CONV.
      RETURN
70    CONTINUE
      LTEMP=L-FL/DEN
      IF(ABS(L-LTEMP).LT..000001)GOTO 60
50    L=LTEMP
      L=10H  NO CONV.
      RETURN
60    L=L*ZM
      RETURN
      END
```

```
      SUBROUTINE PLT(N,NPL,ID,IS,IG,IAT,X0,XI,DX,Y0,YI,DY)
      COMMON /TXT/ AX(3),AY(3),A(4),NX,NY,NA(4),AIX(3),NIA,R(4)
      DIMENSION XP(4),YP(4),XG(60),YG(60),IS(2),NPL(4)
      DATA XP,YP/1.25,3.5,-3.5,3.5,6.5,0.0,-4.5,0.0/
      DATA XAL,YAL/2.8,3.5/
      DATA H /.075/
      DATA LM1,LM2/-21846,-30584/
      IF(N.NE.1)GOTO 10
      XAL=6.
      YAL=6.
10    CONTINUE
      FX=XAL/XI
      FY=YAL/YI
      F=AMIN1(FX,FY)
      CALL FACTOR(F)
      G=H/F
      IX=XI
      IY=YI
      IF(IG.EQ.0)GOTO 20
      K=1
      DO 30 I=1,IX
      Z=1.
      DO 30 J=1,9
      XG(K)=DX*(ALOG10(Z+1)-ALOG10(Z))
      K=K+1
30    Z=Z+1.
      K=1
      DO 40 I=1,IY
      Z=1.
      DO 40 J=1,9
      YG(K)=DY*(ALOG10(Z+1)-ALOG10(Z))
      K=K+1
40    Z=Z+1.
20    CONTINUE
      DO 100 J=1,N
      I=NPL(J)
      XPI=XP(J)/F
      YPI=YP(J)/F
      IF(N.EQ.1)YPI=2.5/F
      CALL PLOT(XPI,YPI,-3)
      XS=(XI-NA(I)*G)/2.
      YS=YI+1.5*(1+IAT)*G
      CALL SYMBOL(XS,YS,G,A(I),0.,NA(I))
      IF(IAT.EQ.0)GOTO 60
      XS=(XI-(NIA+5)*G)/2.
      YS=YI+1.5*G
      CALL SYMBOL(XS,YS,G,AIX,0.,NIA)
      CALL NUMBER(999.,999.,G,R(I),0.,2)
```

```
 60   CONTINUE
      DO 50 L=1,ID
 50   CALL DTPLT(I,IS(L),IG,L,X0,DX,Y0,DY)
      CALL AXIS(0.,0.,AX,-NX,XI,0.,X0,DX)
      CALL AXIS(0.,0.,AY,NY,YI,90.,Y0,DY)
      IF(IG.EQ.0)GOTO 100
      CALL GRID(0.,0.,IX,1.,IY,1.,LM1)
      LX=IX*9+1000
      LY=IY*9+1000
      IF(IG.EQ.1.OR.IG.EQ.2)CALL GRID(0.,0.,LX,XG,1.YI,LM2)
      IF(IG.EQ.1.OR.IG.EQ.3)CALL GRID(0.,0.,1,XI,LY,YG,LM2)
100   CONTINUE
      CALL PLOT(0.,0.,-999)
      RETURN
      END
```

```
      SUBROUTINE DTPLT(I,IS,IG,ID,X0,DX,Y0,DY)
      COMMON /PLT/ X(60,4,2),Y(60,4,2),NP(4,2)
      DIMENSION XX(62),YY(62)
      M=NP(I,ID)
      XX(M+1)=X0
      XX(M+2)=DX
      YY(M+1)=Y0
      YY(M+2)=DY
      DO 50 J=1,M
      XX(J)=X(J,I,ID)
50    YY(J)=Y(J,I,ID)
      IF(IG.EQ.0)GOTO 10
      IF(IG.EQ.3)GOTO 20
      X10=10.**X0
      DO 30 J=1,M
      IF(XX(J).LT.X10)XX(J)=X10
30    XX(J)=ALOG10(XX(J))
      IF(IG.EQ.2)GOTO 10
20    CONTINUE
      Y10=10.**Y0
      DO 40 J=1,M
      IF(YY(J).LT.Y10)YY(J)=Y10
40    YY(J)=ALOG10(YY(J))
10    CONTINUE
      IF(IS.LE.-100)GOTO 60
      LT=-1
      IF(IS.EQ.100)LT=0
      CALL LINE(XX,YY,M,1,LT,IS)
      GOTO 70
60    IF(IS.EQ.-100)D=.5
      IF(IS.EQ.-101)D=-.5
      CALL CURVE(XX,YY,M,D)
70    RETURN
      END
```

APPENDIX B

DESCRIPTION OF VARIABLES

APPENDIX B

DESCRIPTION OF VARIABLES

1. SAMPLE LOCATIONS

Block/LO/

All variables relate to grid point locations.

NG number of grid points along an arc

ND number of degrees between grid points

G = NG

D = ND

NARC number of arcs

IAD distance from center to arc

2. WIND-TUNNEL EXPERIMENTS

All variables relate to wind-tunnel data.

Block/WT/

NW number of wind directions considered

NS number of stabilities considered

WDR wind directions (degrees)

RIB Bulk Richardson numbers

IGP (i,j,k) grid points

$i \leq$ number of wind directions (NW)

$j \leq$ number of stabilities (NS)

$k \leq$ number of grid points in the area of interest [NCC(i,j)]

CWT (i,j,k) measured and interpolated concentration at IGP

NCC (i,j) number of concentrations evaluated at all grid points in the area of interest

Other variables related to wind-tunnel data.

Subroutine WTDATA

P   upwind power-law coefficients for all stabilities (sequence: unstable, neutral, stable)

RHWT   equivalent wind-tunnel reference height (m)

RHF   field reference height (m)

IR   run number

IS   stability: IS = -1, unstable; IS = 0, neutral; IS = 1, stable

IWD   wind direction (degrees)

RP   release point identification

NPW   number of concentration measurements for this run

IG   grid point number

C   measured concentration at IG

Subroutine WTDATA

HR   ratio of field reference height to wind-tunnel reference height

FW   wind-tunnel data factor

Subroutine WTOUT

S   stability identification

IARC   distance in field from center to grid point (m)

IB   bearing (degrees)

IE   elevation of field release height (m)

3. FIELD EXPERIMENTS

All variables relate to field data

Block /FD/

L   L-th interval ($L \leq NI$)

NI   number of intervals

WD   wind direction at release height (RH)(degrees)

U   velocity at reference height (HU)(mph)

RI bulk Richardson number

IGF grid point numbers where (non-zero) field concentrations were measured

CF concentration at grid point number IGF

TEST text: identification of test

TDT tect: average meteorological characteristics during test period

FF field-data factor

Subroutine FDDATA

RH release height (m)

HU reference height (m)

UM mean upwind velocity at release height (m/sec)

AF characteristic area (m^2)

Z1 lower elevation for bulk Richardson number evaluation (m)

Z2 upper elevation for bulk Richardson number evaluation (m)

NP number of concentration measurements

IT starting time of L-th interval

T1 temperature at Z1 (°F)

T2 temperature at Z2 (°F)

U1 wind velocity at Z1 (m/sec)

U2 wind velocity at Z2 (m/sec)

Ri bulk Richardson number

OL Monin-Obukhov length parameter

Subroutine MOOB

ZM matching height (m)

R bulk Richardson number

L Monin-Obukhov length parameter

4. EVALUATION OF ESTIMATED CONCENTRATIONS

Main Program

IWD grid point number downwind of center minus arc number times NS (for field test interval)

WWW array containing weight factors to include stability effects

WW array containing weight factors to include wind direction effects

W two-dimensional array containing weight factors. (sum of all array elements = 1/S)

S number of (field data) = NI

IWTD grid point number downwind of center minus arc number times NG (for wind-tunnel run)

NI number of intervals (field data)(= S)

Subroutine WEIGH

N number of wind-tunnel runs; NS or NW

RT array with wind-tunnel value; Ri_m or θ_m

W array with calculated weight

R field value; Ri_f or θ_f

5. RESULTS

Block /PLT/

All variables relate to plotting subroutine PLT.

X(i,j,k) beating

i grid point number minus arc number times NG

j arc number

k has no significance; X(i,j,1) = X(i,j,2)

C(i,j,k) concentrations

i,j see specification under X

k k = 1: estimated concentration
k = 2: field concentration

NP(j,k) number of grid points per arc (= NG)

j,k see specification under X

Block /TXT/

Variables contain information for plot labeling and identification

AX X-axis label for concentration profile along arc

AY Y-axis label for concentration profile along arc

A header for each plot

NX number of characters of X-axis label

NY number of characters of Y-axis label

NA number of characters for headers

AIX additional text under header

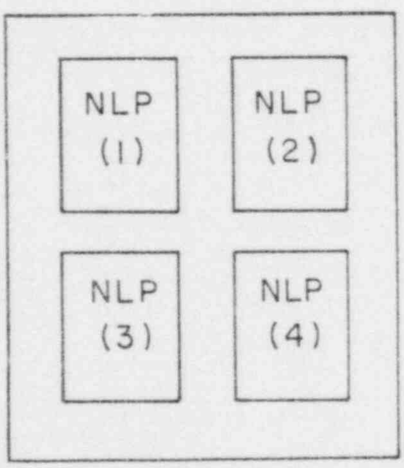
NIA number of characters of additional text

R number plotted after additional text

Subroutine PLT

N number of plots per page $N \leq 4$

NPL array that defines arrangement of plots



ID number of data sets to be plotted $ID \leq 2$

IS display of data set IS = 0-13 each data point plotted
IS = 100 data points connected by lines
IS = -100 curved-line interpolation
IS = -101 curved-broken-line interpolation

IG	IG = 0 lin-lin plot = 1 log-log plot = 2 log-lin plot = 3 lin-log plot
IAT	IAT = 0 no additional text under header IAT = 1 additional text under header
XO	X-value at "origin"
X1	number of intervals along X-axis
DX	increments between subsequent tic marks along X-axis
YO	Y-value at "origin"
Y1	number of intervals along Y-axis
DY	increments between subsequent tic marks along Y-axis
XP	horizontal distance of origin from last defined origin (inches)
YP	vertical distance of origin from last defined origin (inches)
XG	array required for grid generation
YG	array required for grid generation
xal	X-axis length (inches)
YAL	Y-axis length (inches)
H	character height (inches)
LM1	line-type specification for fine grid
LM2	line-type specification for fine grid

APPENDIX C

INPUT TO PROGRAM RANSEC

APPENDIX C

INPUT TO PROGRAM RANSEC

Two data sets are required for program RANSEC: Wind-tunnel data and field data.

I. Wind-tunnel Data — Format

Card 1: NW, NS — 2I5

NW: number of wind directions for which concentrations were measured

NS: number of stabilities per wind direction for which concentrations were measured

The next cards are repeated for each run. The number of runs is equal to NW times NS.

Card 2: IR, IS, IWD, RH, RP — 3I5, F5.2, A4

IR: run number

IS: stability identification
IS = -1 unstable
IS = 0 neutral
IS = 1 stable

IWD: wind direction (degrees)[Δ]

RH: equivalent full-scale release height (m)

RP: release point identification

Card 3: NPW — I5

NPW: number of concentrati n measurements for run IR

Cards 4,...: IG(i), i = 1, NPW — 20I4

IG: grid point number[ΔΔ]

Cards following: C(i), i = 1, NPW — 10F8.4

C: measured concentration (dimensionless) at corresponding grid point, IG

Δsee next page under (a)
ΔΔsee next page under (b)

a) The sequence of runs is such that IWD increases after all stabilities have been read in; sequence of stabilities is such that IS increases; for example, -1, 0, 1 or -1, 0, or 0, 1.

Example:

39	-1	315	4.	G5

followed by other cards for run 39

40	0	315	4.	G5
41	1	315	4.	G5
42	-1	360	4.	G5
43	0	360	4.	G5
44	1	360	4.	G5
45	-1	405	4.	G5

etc.

Note that the values of IWD increase!

b) The sequence of a set of grid point numbers along an arc should be either clockwise or counterclockwise with the following precaution. For example subsequent grid point numbers along an arc may have the following sequences:
68 64 120 118 116
Here ABS ((64-68) - (120-64)) = 60 ~ NG - 1,
and hence the grid point numbers should be changed to
68 61 120 118 116.
By doing this the concentration value of grid point number 64 has been moved to next grid point 61.

II. Field Data — Format

Card 1: NI — I5

NI number of intervals during test

Card 2: TEST (i), i = 1,8 — 8A10

TEST: identification of test

Cards 3 and 3: TDT(i), i = 1,16 — 8A10

TDT: average meteorological characteristics during the entire test period

Field Data		Format
Card 5:	RH, HU, UM, AF, Z1, Z2	6F10.4
	RH: release height (m)	
	HU: reference height (m)	
	UM: mean velocity at release height (m/sec)	
	AF: characteristic area (m^2)	
	Z1: lower elevation for bulk Richardson number evaluation	
	Z2: upper elevation for bulk Richardson number evaluation	
Card 6:	NP	I5
	NP: number of concentration measurements	
Card 7: IGF:	IGF(i), i= 1, NP	20I4
	IGF: grid point number	
Cards following:	CF(i), i = 1, NP	8E10.3
	CF: measures concentration at corresponding grid point IGF($1/m^2$)	
NI cards following:	IT, T1, T2, U1, U2, U, WD	I5 6F10.4
	IT: starting time of interval	
	T1: temperature at Z1 (F)	
	T2: temperature at Z2 (F)	
	U1: velocity at Z1 (mph)	
	U2: velocity at Z2 (mph)	
	U : velocity at reference height (mph)	
	WD: wind direction at release height (degrees)	

APPENDIX D

METEOROLOGICAL DATA

TEST 7

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
124145	71.6	69.1	340.9	320.2	3.8	4.8
124336	71.1	69.1	339.4	308.7	3.6	4.8
124526	70.9	69.0	339.2	317.9	3.4	4.0
124718	70.9	69.1	333.4	309.1	3.1	4.3
124909	71.4	69.4	345.8	327.1	4.7	6.2
125059	71.4	69.4	342.6	316.9	4.3	4.6
125250	71.5	69.6	353.4	332.0	4.2	4.8
125441	71.8	69.9	341.9	328.5	3.6	4.7
125632	72.1	70.0	342.1	327.2	4.8	6.7
125823	72.2	69.9	353.0	340.6	3.8	4.6
130014	72.4	70.3	349.7	320.0	6.2	7.5
130205	72.4	70.4	351.8	337.0	4.5	5.8
130356	72.7	70.6	338.5	311.6	4.0	5.2
130546	72.5	70.4	333.4	308.3	4.7	5.7
130737	72.3	70.3	330.1	302.5	4.8	5.7
130928	72.0	70.1	332.5	308.6	4.2	6.3
131119	72.1	70.3	333.4	311.1	6.1	6.9
131310	72.3	70.4	340.0	318.5	4.7	6.3
131502	72.4	70.4	344.7	329.6	3.6	4.6
131653	72.5	70.6	338.5	320.3	5.9	7.6
131844	72.8	70.7	347.4	336.9	5.1	6.2
132034	72.9	70.5	347.2	339.6	4.7	6.3
132226	73.0	70.5	340.5	320.8	4.2	5.4
132418	73.2	70.9	341.0	321.8	5.5	6.5
132608	72.9	70.6	341.1	318.6	3.8	4.9
132759	73.0	70.8	339.8	314.5	4.4	6.4
132951	73.1	70.9	339.9	318.9	6.1	7.7
133141	73.1	70.9	341.4	321.0	5.0	6.3
133332	73.1	70.8	336.4	320.1	3.5	5.0
133524	73.2	71.1	337.2	315.2	5.9	7.5
133715	73.1	71.1	339.6	323.8	5.8	7.1
133906	73.0	70.9	346.2	331.2	6.4	7.2
134057	73.1	71.0	341.3	323.5	5.1	6.8
134250	73.3	70.9	336.1	315.9	4.7	6.3

TEST 11

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
80801	49.9	50.6	300.2	325.2	2.6	6.5
80959	49.8	50.1	316.5	331.4	3.2	6.2
81157	49.7	50.0	312.1	328.4	2.8	6.5
81355	49.5	50.1	306.7	318.0	2.8	7.5
81553	49.6	50.0	305.5	319.5	3.1	7.0
81750	49.7	49.9	278.6	316.4	2.6	6.3
81948	49.8	49.9	286.6	316.5	2.6	6.4
82146	49.9	50.0	292.8	315.3	2.4	6.4
82344	49.9	50.2	307.2	316.9	2.5	6.2
82541	50.3	50.3	301.4	314.3	2.9	6.3
82739	50.5	50.5	299.3	312.9	3.2	6.6
82937	50.9	50.6	294.6	316.4	3.4	6.8
83135	51.0	50.6	308.6	321.6	3.6	6.6
83332	51.3	50.7	312.1	323.4	3.9	6.7
83530	51.7	50.8	310.5	320.8	3.8	5.8
83728	51.6	50.7	309.3	321.9	3.7	5.7
83926	51.7	50.9	309.1	320.1	3.4	5.7
84123	51.9	50.9	309.7	315.6	3.7	6.0
84346	52.4	51.2	303.6	317.7	3.6	5.5
84543	52.5	51.3	308.5	316.9	3.4	5.5
84741	53.2	51.6	308.2	315.7	3.4	6.1
84939	53.4	51.8	298.4	312.1	4.0	6.3
85137	53.5	52.0	305.5	314.4	4.6	6.5
85334	53.9	52.2	304.8	315.9	4.6	6.3
85532	53.8	52.3	306.6	309.8	4.9	6.6
85730	54.0	52.3	322.5	321.3	5.3	6.7
85927	54.1	52.5	324.1	325.6	4.7	6.6
90125	54.4	52.7	318.3	320.6	4.8	6.9
90323	54.3	52.7	318.3	320.1	4.8	6.7
90520	54.7	52.9	320.3	328.0	5.1	6.3
90718	54.8	53.0	326.1	329.2	5.0	6.8
90917	54.6	53.1	328.8	328.7	5.4	7.0
91116	55.2	53.1	322.0	323.2	4.9	6.2

TEST 12

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
60559	42.2	42.3	347.0	341.1	1.4	3.1
60759	42.2	42.3	345.7	327.5	1.7	3.3
60956	42.5	42.3	342.0	327.7	1.5	3.1
61156	42.6	42.3	336.1	334.3	1.9	2.9
61353	42.7	42.4	349.5	339.7	1.6	3.8
61549	42.8	42.4	349.4	339.0	1.9	3.4
61745	42.7	42.3	341.1	329.3	1.5	3.6
61941	42.6	42.3	345.4	334.1	1.5	3.6
62137	42.4	42.4	344.8	336.3	2.0	4.5
62333	42.5	42.4	344.2	337.9	1.6	3.8
62531	42.5	42.4	346.8	336.6	1.6	3.6
62730	42.4	42.3	344.6	342.1	1.2	2.5
62930	42.1	42.1	344.2	344.9	1.1	3.3
63129	42.4	42.1	341.3	343.6	1.6	3.8
63330	42.5	42.1	347.5	340.0	1.9	4.6
63531	42.1	42.2	348.2	348.6	1.2	4.7
63732	41.6	42.2	354.6	351.9	1.2	4.6
63933	41.6	42.0	3.0	.6	1.0	3.2
64129	41.4	41.8	11.9	5.6	1.1	2.1
64324	41.4	41.5	15.0	1.5	.9	2.2
64521	41.3	41.4	19.8	1.9	.8	1.7
64717	41.1	41.4	353.4	359.2	.9	1.6
64913	41.5	41.4	5.4	360.0	1.0	2.3
65109	41.8	41.5	1.2	3.6	.9	2.0
65306	41.9	41.7	347.2	356.2	.4	2.3
65506	42.0	41.8	343.9	355.6	.4	2.4
65708	41.9	41.9	341.2	356.1	.5	2.8
65911	42.3	42.0	348.0	354.3	.8	3.3
70114	42.1	42.1	352.5	356.7	.9	2.9
70317	42.3	42.1	345.6	353.3	1.1	3.1

TEST 14

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
234702	49.0	56.1	92.1	124.8	.8	3.0
234903	48.4	56.0	90.0	119.5	1.0	2.8
235104	47.8	56.0	82.4	119.9	1.1	3.0
235306	47.6	55.9	80.7	119.4	1.1	3.2
235507	47.7	55.7	89.7	121.8	1.3	3.1
235708	48.0	55.6	86.1	120.6	1.3	3.2
235907	48.4	55.5	89.6	122.5	1.4	3.3
106	48.6	55.4	76.8	109.3	1.3	3.3
304	48.3	55.1	77.7	103.9	1.2	3.5
503	48.3	55.1	65.2	102.6	1.4	3.8
703	48.6	55.0	66.7	105.4	1.3	4.0
859	48.6	55.0	89.4	114.4	1.3	4.2
1058	48.9	55.0	107.6	118.5	1.3	4.3
1257	49.1	55.0	104.7	118.6	1.1	4.4
1456	49.1	55.1	112.0	120.4	1.0	4.3
1655	49.1	55.3	124.8	122.4	.9	4.2
1852	49.2	55.7	133.2	122.0	1.0	4.0
2050	49.5	55.8	129.1	122.1	1.4	4.2
2248	49.9	55.8	133.6	119.6	1.2	4.2
2446	49.9	55.7	137.3	123.3	.8	4.2
2644	50.0	55.7	139.2	123.2	.7	4.2
2843	49.8	55.9	139.2	124.3	.7	4.2
3043	49.8	55.8	139.2	130.9	.8	4.3
3243	49.9	56.0	150.7	124.9	1.3	4.0
3448	49.9	56.1	146.8	126.8	1.1	4.1
3648	50.0	56.3	146.7	123.9	1.1	4.2
3851	49.8	56.3	148.4	125.5	.8	4.0
4053	49.7	56.4	148.7	124.7	.4	3.9
4257	49.7	56.4	148.0	124.2	.4	3.8
4457	49.9	56.5	147.4	129.0	.6	4.0
4654	50.1	56.4	148.6	125.9	.6	4.2
4854	49.9	56.2	146.9	126.6	.6	4.4

TEST 15

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
170705	59.9	60.1	303.7	310.4	1.7	2.6
170906	60.7	60.0	308.4	312.1	2.0	2.7
171106	61.0	60.1	311.6	311.2	1.9	2.7
171309	61.1	60.1	318.4	321.3	1.6	2.6
171511	60.9	60.2	329.3	323.8	2.0	2.3
171713	61.0	60.1	322.4	318.0	1.9	2.4
171914	61.1	60.0	321.6	320.6	1.8	2.4
172117	61.1	60.1	315.1	317.1	1.5	2.4
172318	61.0	60.0	292.6	311.2	1.2	1.8
172521	60.2	60.1	297.5	339.6	.6	1.5
172723	59.6	60.0	295.1	352.5	.3	1.3
172929	59.9	59.9	293.6	352.8	.5	1.1
173134	59.8	59.9	296.3	351.3	.6	1.2
173338	59.7	59.9	304.2	341.0	.7	1.3
173541	59.7	59.9	294.2	345.5	.6	1.3
173746	59.7	59.9	296.1	5.0	.5	1.3
173951	60.0	59.9	292.6	25.6	.8	.8
174154	60.2	59.9	310.3	29.5	.6	1.5
174357	60.2	59.8	330.3	26.7	.8	1.6
174600	60.3	59.7	351.6	26.3	.7	1.7
174759	60.3	59.9	10.6	30.9	1.1	1.7
174958	60.2	59.8	26.8	28.2	1.3	1.8
175156	60.2	59.8	31.2	29.6	1.3	2.0
175353	60.2	59.7	34.1	39.2	1.2	1.9
175550	60.1	59.8	41.8	46.8	1.2	1.9
175748	60.1	59.8	55.9	49.0	1.3	2.0
175946	60.1	59.7	62.1	56.3	1.2	2.0
180145	60.4	59.8	61.5	53.6	1.3	1.9
180342	60.2	59.7	59.8	52.4	1.3	1.7
180539	59.9	59.9	58.9	46.0	1.2	1.7
180737	60.1	59.8	59.0	56.4	.8	1.3

TEST 17

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
220220	43.6	52.1	47.5	39.2	2.0	3.0
220413	43.7	52.1	55.2	47.0	2.3	3.2
220607	43.7	52.2	56.6	45.5	2.4	3.3
220801	43.8	52.4	54.3	43.8	2.0	3.3
220953	43.3	52.2	52.0	42.9	2.1	3.2
221147	43.2	51.8	49.2	52.4	2.0	3.3
221339	42.8	51.0	48.2	53.9	1.8	3.2
221532	42.8	50.8	58.6	54.8	2.0	3.0
221724	43.2	50.7	63.5	56.0	2.2	2.7
221917	43.1	50.9	63.4	59.1	2.4	2.8
222109	43.3	51.2	62.8	58.9	2.6	2.8
222300	43.5	51.1	53.5	53.5	2.2	2.7
222452	43.4	51.4	55.8	58.0	2.0	3.1
222643	43.3	52.0	58.2	63.5	2.1	3.0
222835	43.4	52.3	51.4	59.1	1.9	3.0
223026	43.1	52.3	35.8	52.9	1.7	2.8
223217	42.9	52.1	30.6	53.2	1.7	2.5
223408	42.9	52.1	41.3	54.6	1.7	2.6
223600	43.0	52.4	36.4	50.4	1.7	2.5
223750	42.9	52.1	32.4	48.1	1.9	2.5
223941	42.5	52.0	44.4	44.1	2.1	2.5
224132	42.6	51.7	42.3	37.6	2.1	2.4
224323	42.5	50.9	44.3	46.2	2.1	2.7
224513	42.5	49.9	48.9	49.2	2.2	3.3
224704	42.7	49.6	51.2	55.9	2.0	3.4
224918	43.1	49.8	59.2	61.5	1.7	3.0
225110	43.2	50.3	59.2	62.2	1.9	3.4
225302	43.7	50.7	59.7	57.5	2.2	3.9
225453	44.1	51.2	63.0	57.4	2.2	4.4
225644	44.1	51.8	60.7	59.2	2.3	4.3
225837	44.0	52.1	60.2	60.9	2.1	4.6
230028	43.9	52.2	61.3	61.5	2.0	4.8

POOR ORIGINAL

TEST 18

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
180918	58.5	61.3	250.1	186.0	.7	.5
181123	58.5	61.2	250.1	186.1	.5	.8
181329	58.4	61.2	250.6	289.1	.5	.9
181532	58.5	61.2	250.6	294.0	.5	1.0
181735	57.9	61.2	250.3	290.5	.6	.9
181940	56.8	61.1	250.1	292.5	.6	.8
182141	56.1	61.0	250.4	270.7	.7	.9
182347	56.0	61.1	250.6	272.0	.8	1.0
182554	56.0	61.1	250.4	272.3	.9	1.0
182759	55.6	61.1	250.2	268.3	.8	1.1
183005	55.1	60.9	250.3	266.9	.5	1.0
183208	54.4	60.9	250.3	273.8	.6	.8
183412	54.7	60.7	250.3	270.2	.4	.8
183614	55.3	60.8	250.1	241.7	.3	.7
183815	56.1	60.7	251.0	237.3	.3	.6
184016	56.2	60.7	250.3	236.5	.3	.5
184217	56.0	60.7	250.6	237.5	.3	.6
184419	56.0	60.5	250.3	237.7	.3	.7
184623	55.6	60.5	250.2	237.3	.4	.8
184827	55.3	60.4	250.3	241.0	.6	.9
185032	55.7	60.3	250.7	286.2	.4	.8
185235	55.2	60.2	250.6	278.5	.3	.8
185435	56.1	60.4	250.4	240.0	.6	.8
185639	56.5	60.4	250.4	233.5	.6	.7
185843	56.2	60.4	250.1	217.8	.7	.8
190047	56.4	60.5	250.5	218.6	.8	.8
190250	56.9	60.4	250.4	213.5	.8	.8
190457	57.0	60.4	250.1	182.9	.9	.7
190704	57.0	60.5	250.3	171.2	.8	.7
190910	56.9	60.4	250.4	197.2	.8	.6
191111	56.7	60.5	250.4	207.1	.8	.5

TEST 21

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
212417	57.5	63.0	178.0	158.7	2.6	4.8
212625	58.2	62.9	179.3	159.4	2.2	5.1
212834	58.0	62.7	193.1	172.5	2.5	4.4
213042	58.8	61.9	232.9	217.0	2.4	2.9
213248	57.2	60.2	250.1	240.3	3.0	2.8
213452	56.9	59.2	235.5	222.6	2.7	3.3
213656	57.8	59.3	214.1	206.1	2.1	3.4
213900	57.6	59.1	224.3	216.9	2.1	3.0
214106	57.3	58.4	253.0	244.6	2.2	2.6
214310	56.2	58.3	260.8	243.2	2.6	2.4
214514	55.7	58.0	269.8	261.5	3.2	3.0
214716	54.7	57.7	273.3	259.2	3.7	4.0
214920	54.2	58.0	274.4	260.7	3.7	3.7
215122	53.6	59.1	278.4	258.2	3.1	3.5
215325	53.3	59.4	273.6	265.9	2.8	3.4
215528	53.2	58.3	283.6	273.8	3.2	4.1
215731	52.9	58.8	285.3	279.2	3.2	4.5
215932	52.8	56.6	282.2	281.1	3.8	8.0
220135	53.1	56.7	278.0	277.9	3.0	6.1
220336	53.4	57.1	280.7	282.5	2.8	5.5
220537	53.7	57.7	278.9	281.4	2.4	5.0
220738	53.9	58.0	280.9	286.6	2.3	6.0
220939	54.3	57.8	296.5	293.4	2.4	6.7
221139	54.6	57.5	286.8	290.7	2.2	6.2
221338	54.9	57.1	286.3	287.0	2.1	6.7
221538	54.6	57.1	290.5	285.9	2.5	6.9
221740	54.9	56.9	283.2	283.6	2.7	7.2
221941	54.9	56.9	276.4	278.0	2.7	7.1
222142	55.3	56.9	271.4	275.8	2.9	7.7
222344	55.1	57.2	272.1	273.1	3.2	8.5
222547	55.9	57.4	272.8	272.5	3.4	8.6

TEST 22

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
151933	58.8	57.8	44.7	40.4	2.3	2.9
152120	58.7	87.9	38.1	36.6	2.1	2.6
152307	58.8	58.0	24.0	29.5	1.9	2.5
152453	58.9	58.1	32.3	28.5	2.5	3.4
152641	59.2	58.2	30.9	31.6	2.5	3.7
152828	59.2	58.5	32.6	36.3	2.2	3.1
153016	59.8	58.8	48.4	45.6	2.5	3.1
153204	60.0	59.1	44.2	43.5	2.5	3.0
153350	60.4	59.3	43.8	39.3	1.8	2.7
153537	60.6	59.6	30.7	28.4	2.5	3.0
153724	60.5	59.6	24.6	22.4	2.4	3.0
153911	59.9	59.5	22.5	23.2	2.6	2.9
154058	59.4	59.5	23.5	25.8	1.7	2.4
154245	59.1	59.5	15.6	20.3	2.0	2.6
154432	59.0	59.4	16.8	16.3	1.7	2.1
154620	58.8	59.5	28.1	30.1	1.9	2.3
154806	59.3	59.5	28.4	25.8	2.0	2.5
154953	59.0	59.6	29.8	27.0	2.3	2.5
155139	59.0	59.4	24.7	17.4	1.7	2.1
155326	59.3	59.0	10.5	5.8	1.4	1.9
155515	59.3	58.8	15.4	.6	1.3	2.1
155704	59.4	58.8	15.3	20.9	1.7	2.9
155851	59.5	58.7	6.7	22.4	2.0	2.5
160041	59.6	58.6	34.2	19.3	1.1	2.4
160229	59.6	58.7	14.9	26.5	1.6	2.5
160416	59.5	58.8	21.6	20.5	2.2	3.3
160602	59.6	58.8	18.1	19.5	2.4	2.7
160749	59.6	58.8	13.7	15.6	1.5	2.5
160937	59.6	58.8	10.8	1.9	1.6	3.0
161125	59.5	58.8	6.7	10.9	2.1	3.4
161314	59.7	58.9	3.7	13.2	2.5	3.4
161503	59.4	58.9	12.0	6.5	1.9	3.3
161652	59.3	58.9	12.2	20.5	1.6	2.7
161841	59.5	58.9	355.3	13.9	1.3	2.8
162030	59.5	58.7	352.2	359.9	1.8	2.6
162220	59.3	58.8	345.4	6.9	2.4	3.2

TEST 23

METEOROLOGICAL DATA (TOWER 2)

TIME	TEMP (F) 4M	TEMP (F) 46M	WIND DIR (DEGREES) 4M	WIND DIR (DEGREES) 16M	VEL (M/S) 4M	VEL (M/S) 46M
191258	53.5	56.8	306.1	4.5	.9	3.3
191458	53.3	56.8	305.7	9.6	.8	3.2
191657	53.1	56.7	304.8	14.8	.8	3.2
191856	52.7	56.7	305.7	17.1	.8	3.3
192054	52.6	56.7	306.3	7.9	1.0	3.5
192252	53.0	56.6	306.1	9.2	1.0	3.8
192451	52.7	56.6	308.4	5.2	1.0	3.9
192650	52.9	56.6	306.6	7.9	1.0	4.0
192848	52.9	56.7	305.2	12.9	1.0	4.2
193047	53.0	56.6	305.3	14.7	1.0	4.1
193246	52.9	56.7	307.4	7.6	1.1	4.3
193447	52.9	56.7	305.6	359.6	1.3	4.4
193645	53.5	56.6	307.7	346.6	1.3	4.4
193844	53.9	56.5	306.9	354.8	1.3	4.2
194042	54.3	56.4	304.8	350.8	1.3	4.4
194241	54.0	56.5	309.9	355.0	1.4	4.4
194438	53.9	56.4	320.9	348.8	1.4	4.3
194636	53.7	54.6	320.5	348.6	1.4	4.2
194836	53.3	54.1	320.5	1.0	1.3	3.8
195034	52.6	55.8	320.5	9.9	1.2	3.5
195233	51.7	55.4	345.1	355.3	.8	3.1
195430	50.9	54.6	27.0	17.9	.9	2.5
195626	50.1	54.3	46.7	11.9	1.5	2.4
195820	50.2	54.0	49.8	3.5	1.6	2.1
200016	50.4	53.9	47.8	5.1	1.3	2.2
200212	51.2	54.1	28.7	14.4	.6	2.1
200409	51.9	54.2	38.5	1.6	.4	2.1
200608	52.0	54.5	59.9	356.0	.4	2.5
200806	52.5	54.4	76.2	343.7	.4	2.4
201003	53.0	54.2	40.8	351.5	.9	2.3
201201	53.0	54.1	89.0	350.3	.4	2.5

IMAGE EVALUATION
TEST TARGET (MT-3)

6"

MICROCOPY RESOLUTION TEST CHART

IMAGE EVALUATION
TEST TARGET (MT-3)

6"

MICROCOPY RESOLUTION TEST CHART

FIGURES

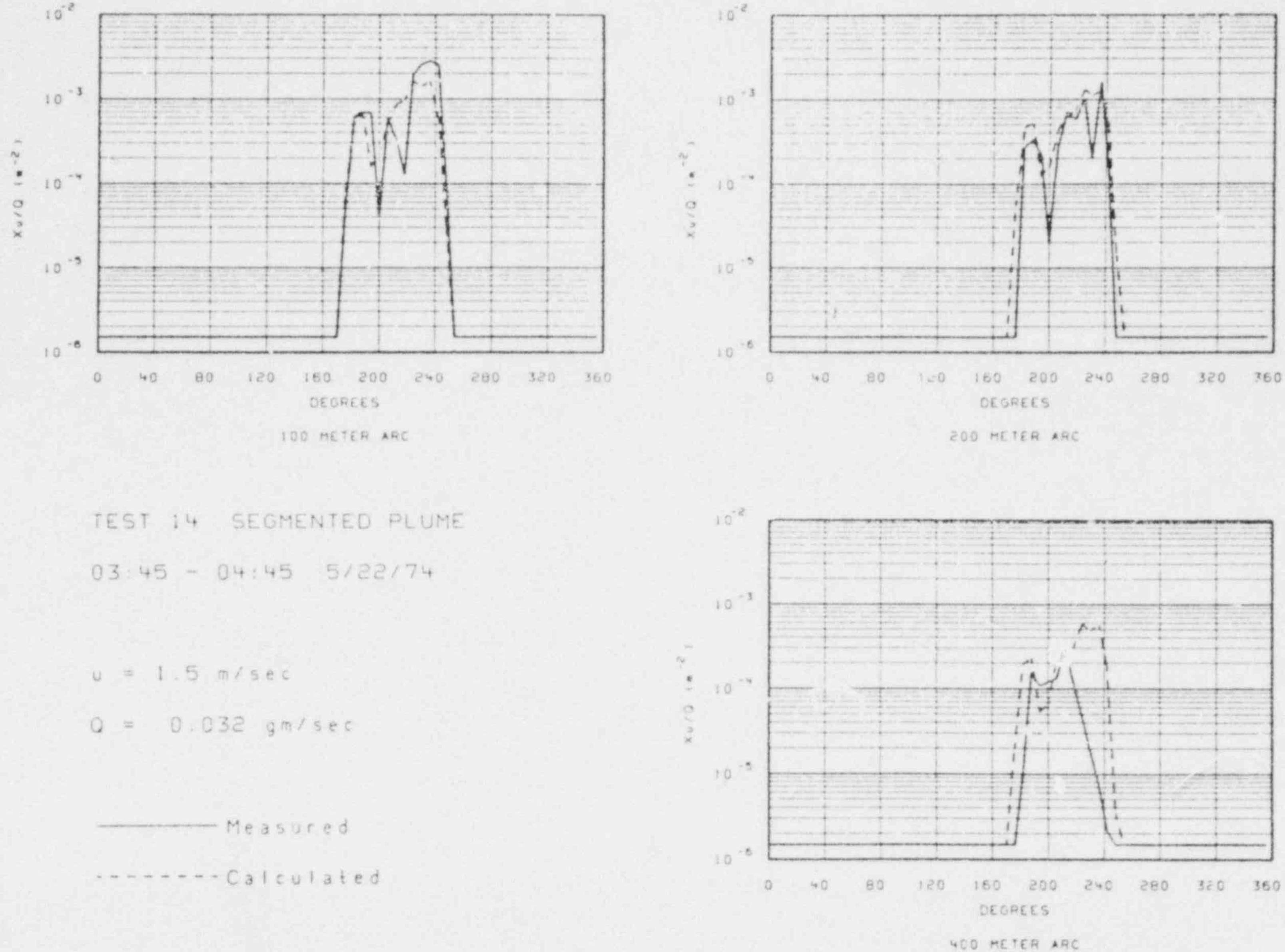
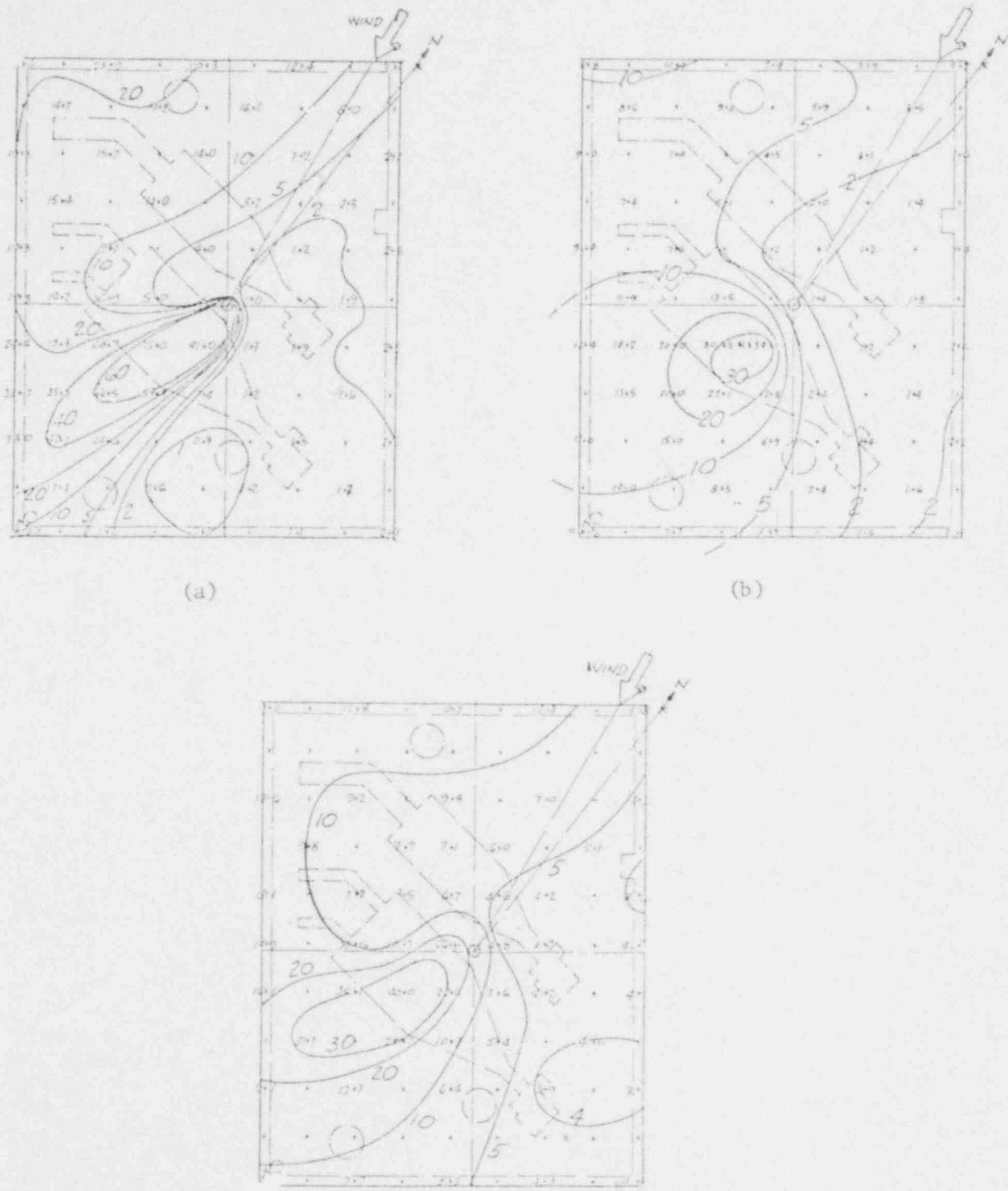


Figure 1. Comparison of Field Conce.itration with Gaussian Segmented-Plume Method (Sagendorf and Dickson, 1974)



(a) (b)

(c)

Figure 2. Concentration Distributions for Test Building Roof Release
(a) Low Turbulence Case, (b) High Turbulence Case,
(c) Mathematically Oscillated Wind Field (Halitsky 1969)

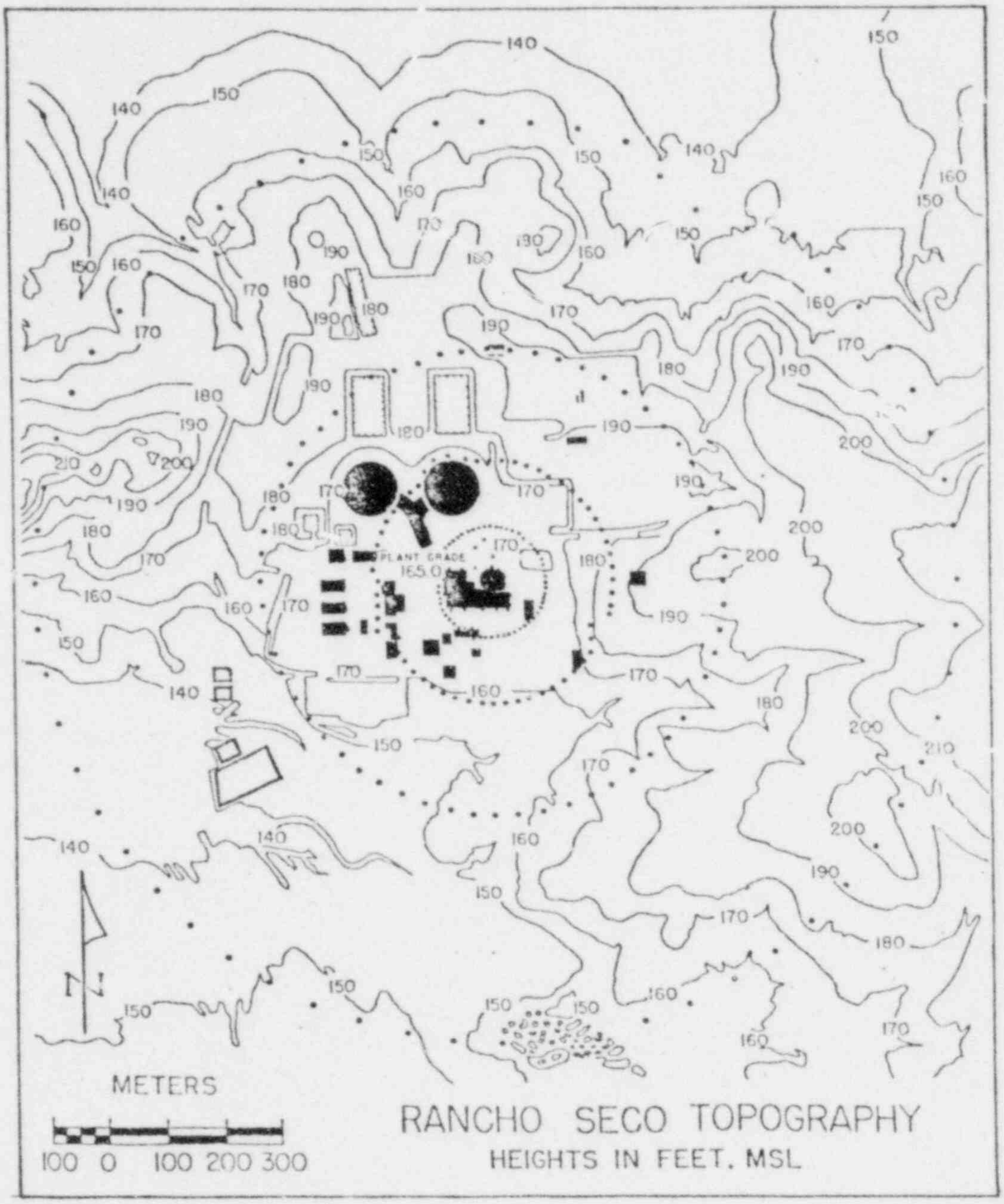


Figure 3. Rancho Seco Topography

POOR ORIGINAL

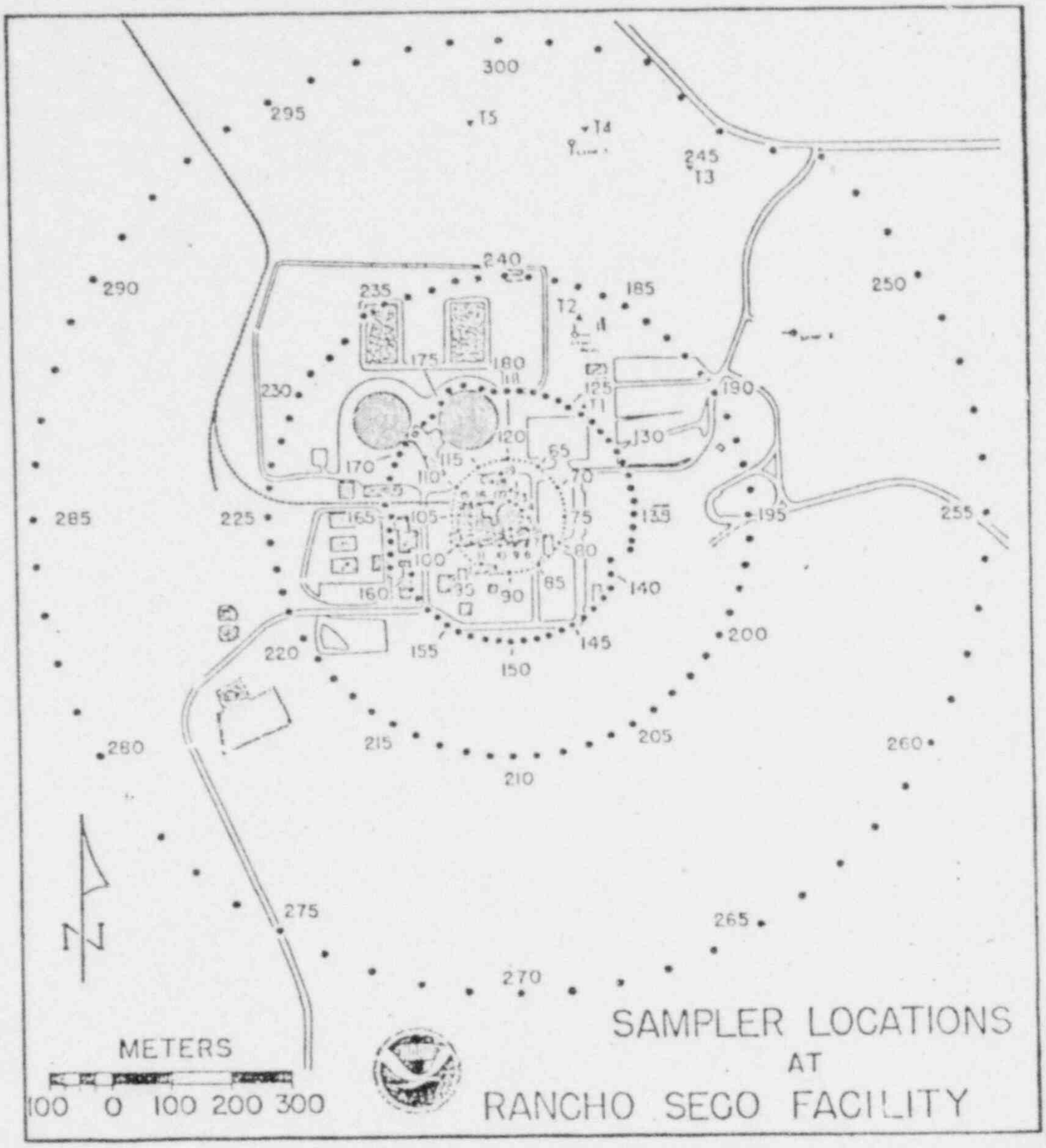


Figure 4. Prototype Sampler Locations

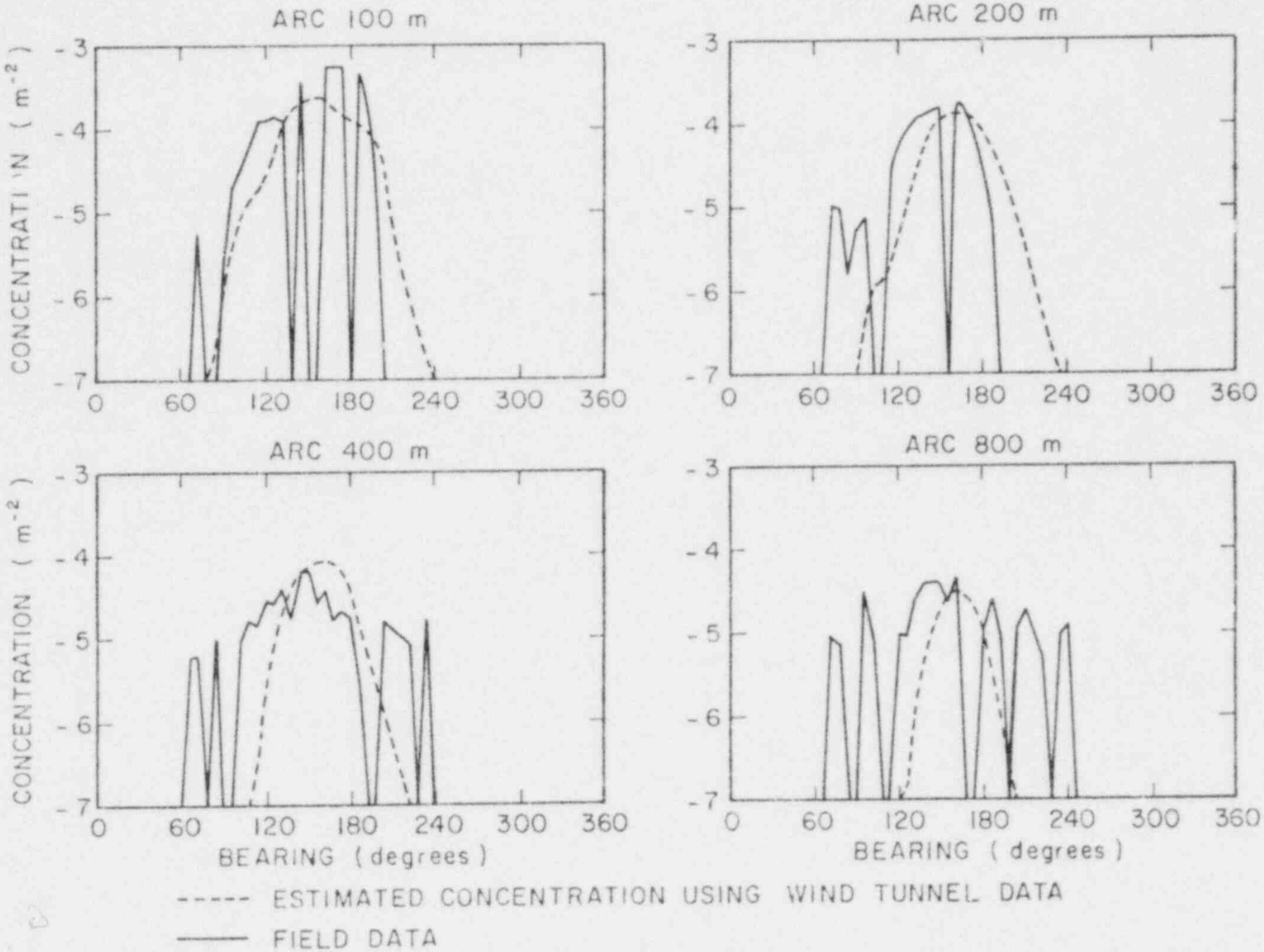


Figure 5. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 7:G5

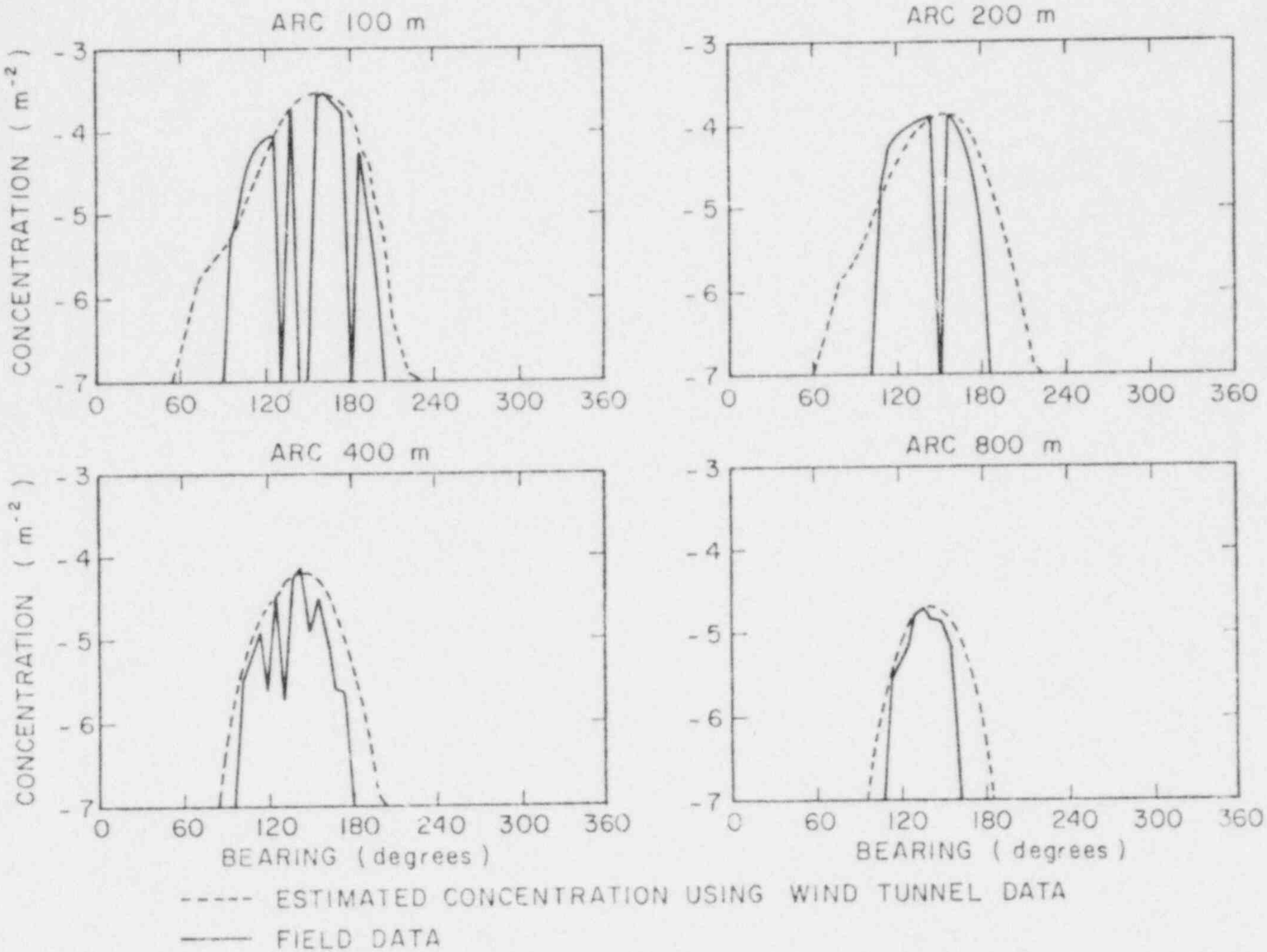


Figure 6. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 7A

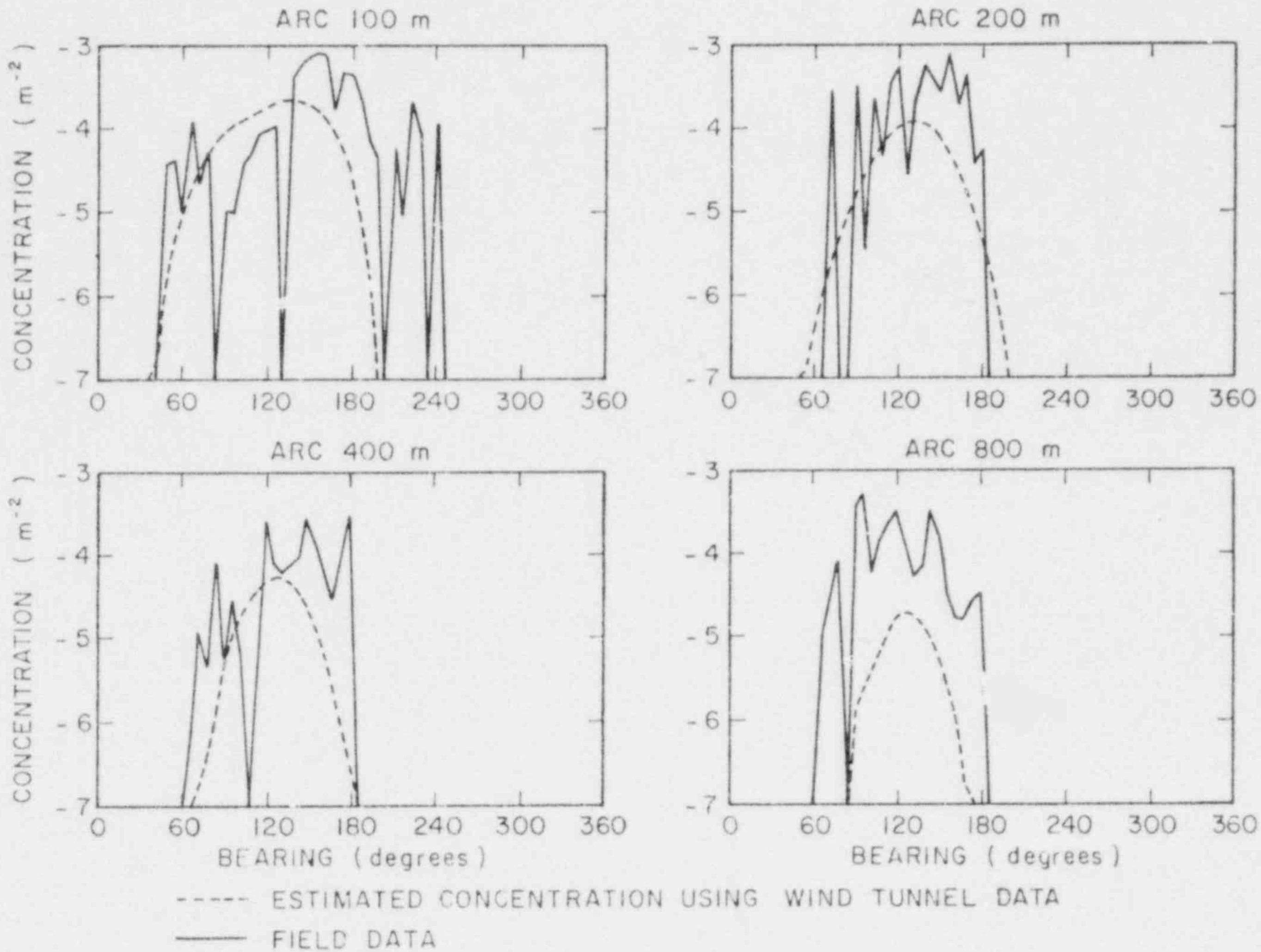


Figure 7. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 11:G5

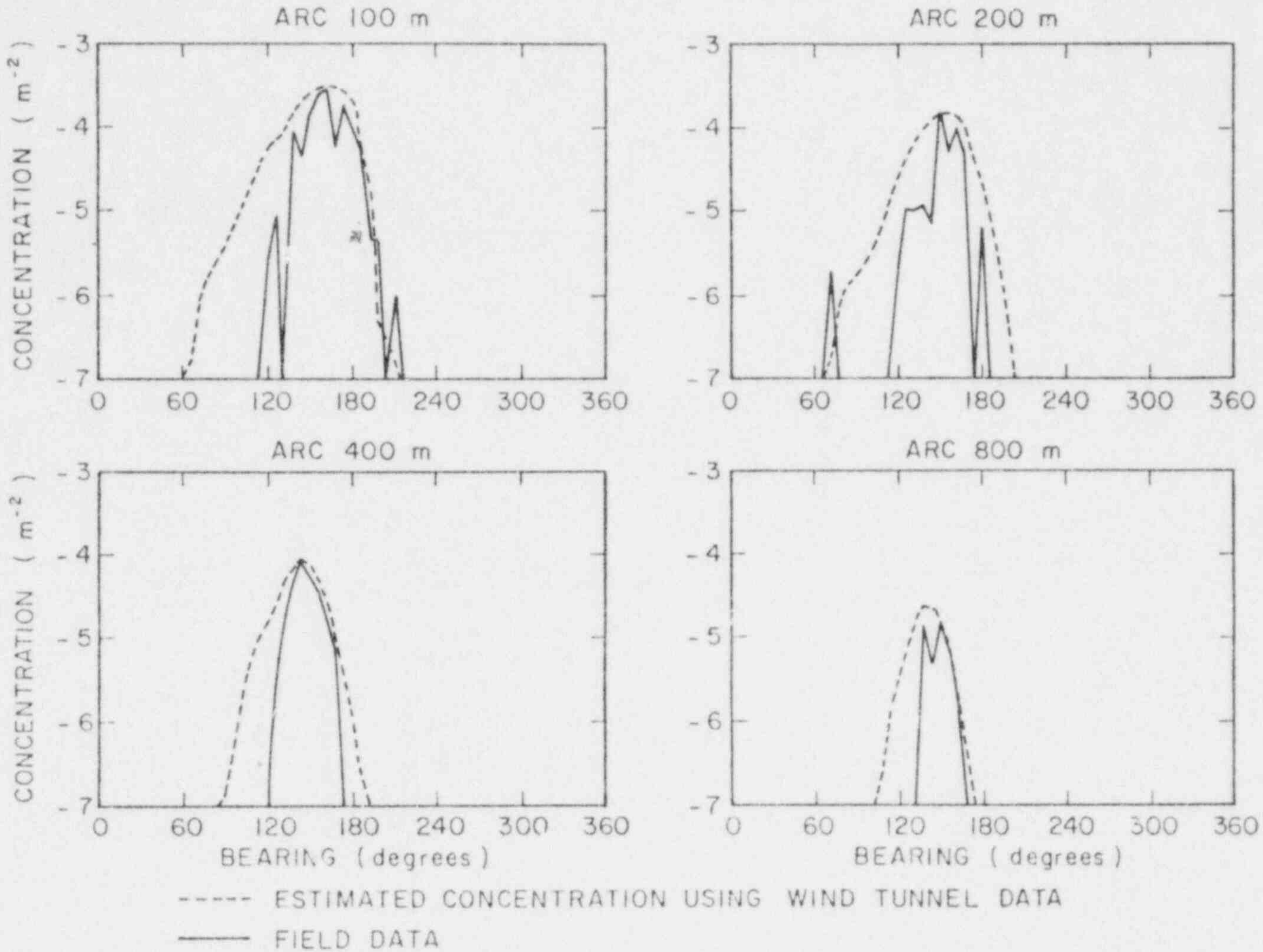


Figure 8. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 11A

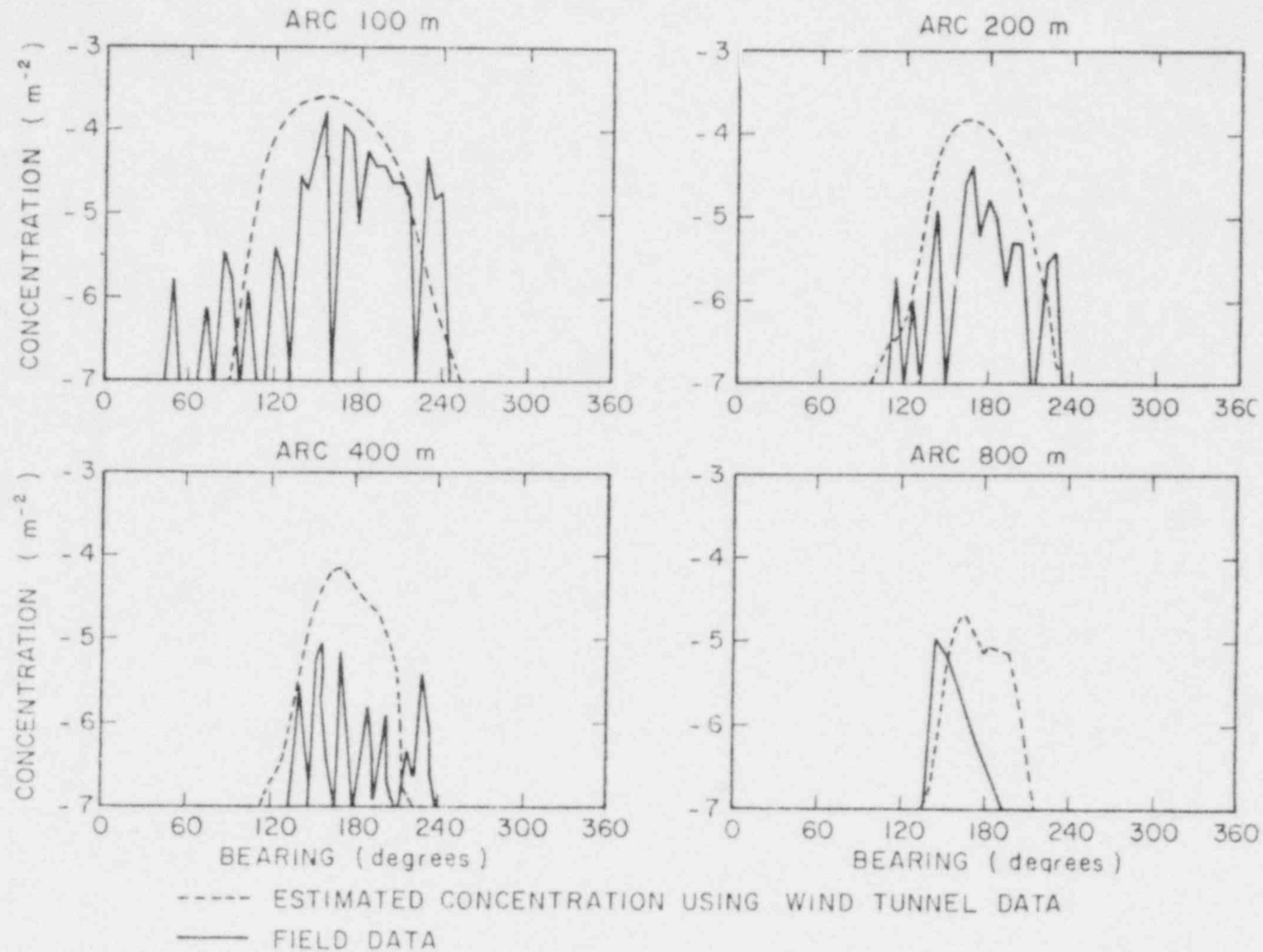


Figure 9. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 12:G5

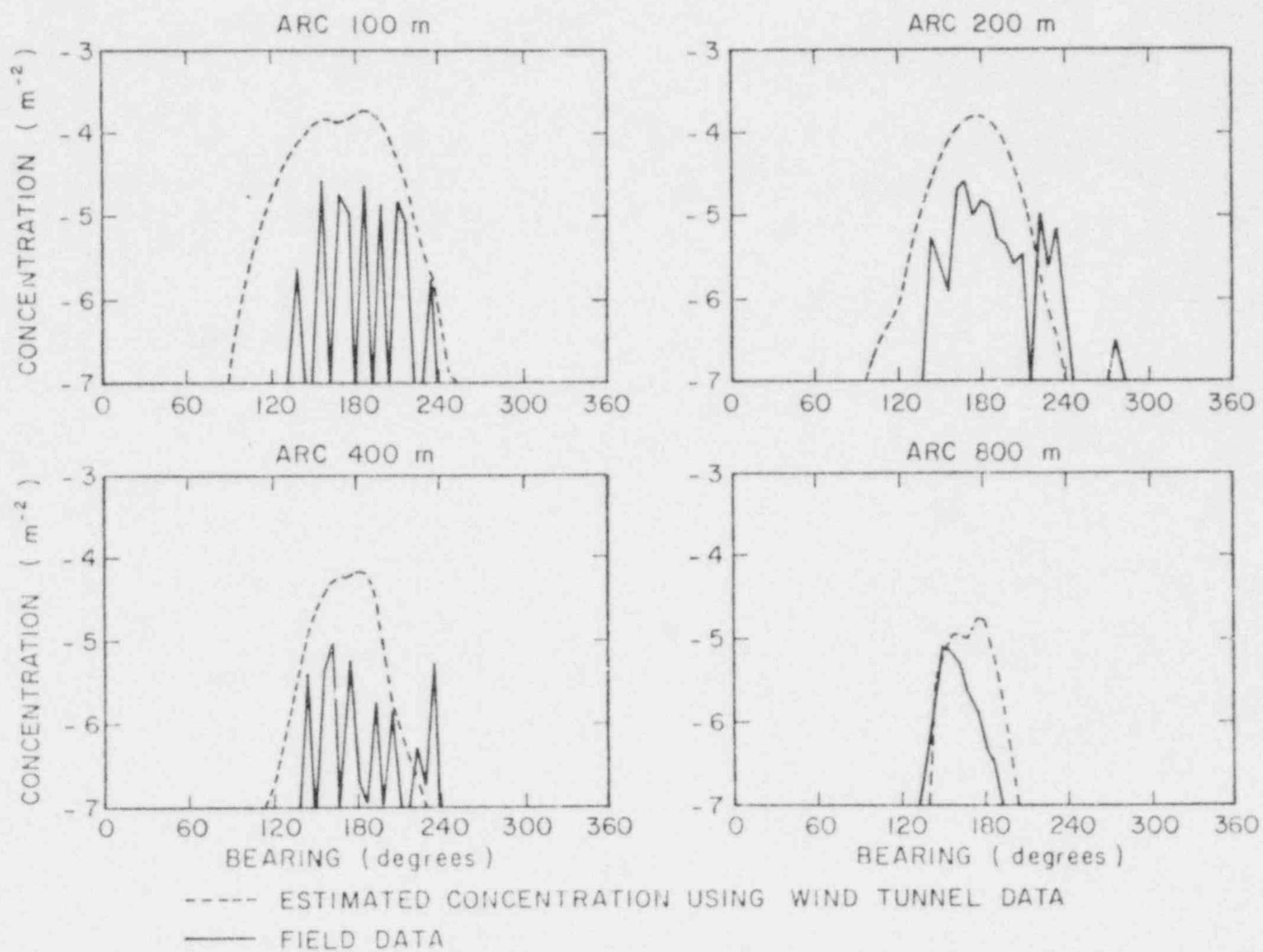


Figure 10. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 12A

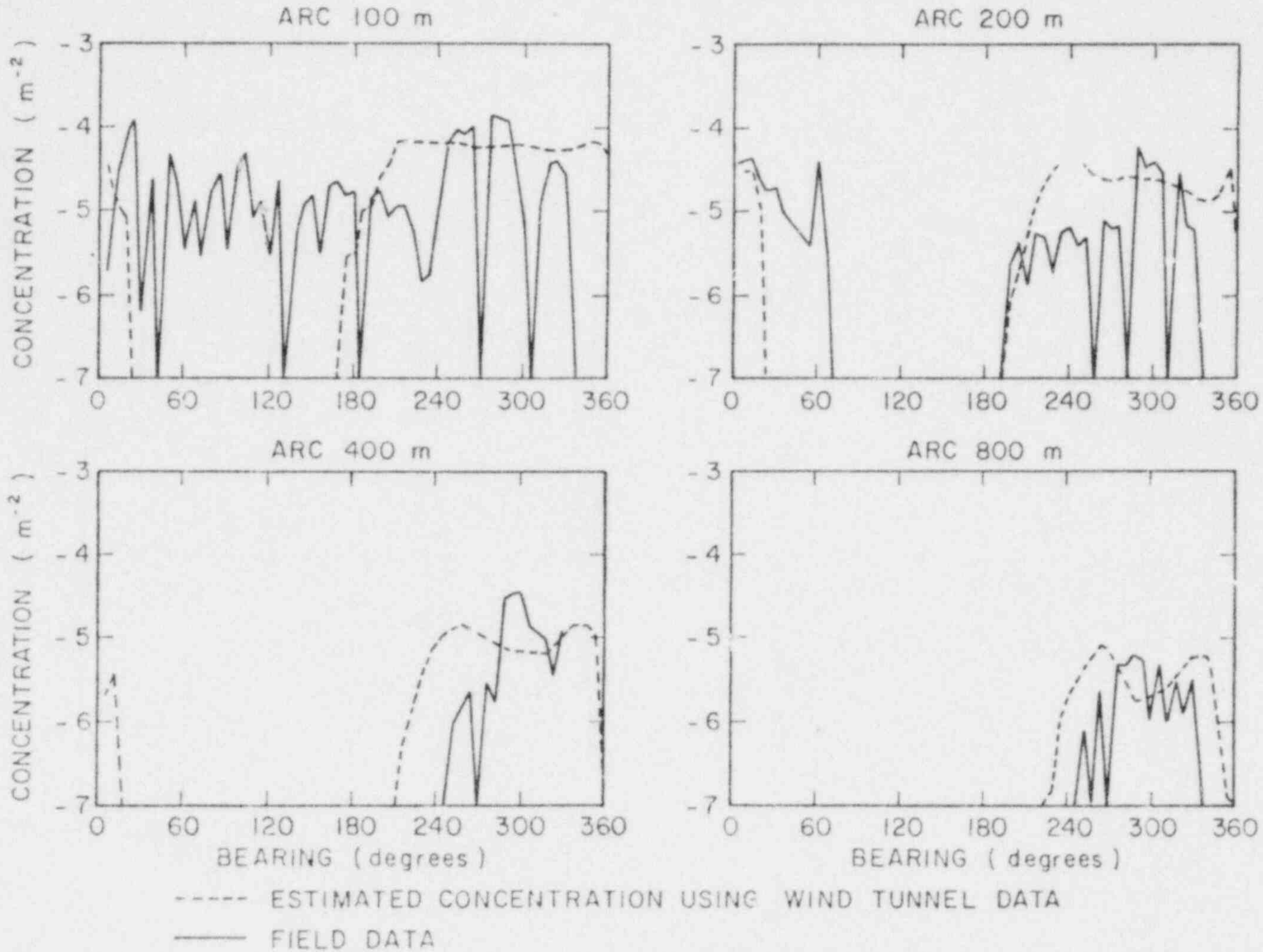


Figure 11. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 14:G5

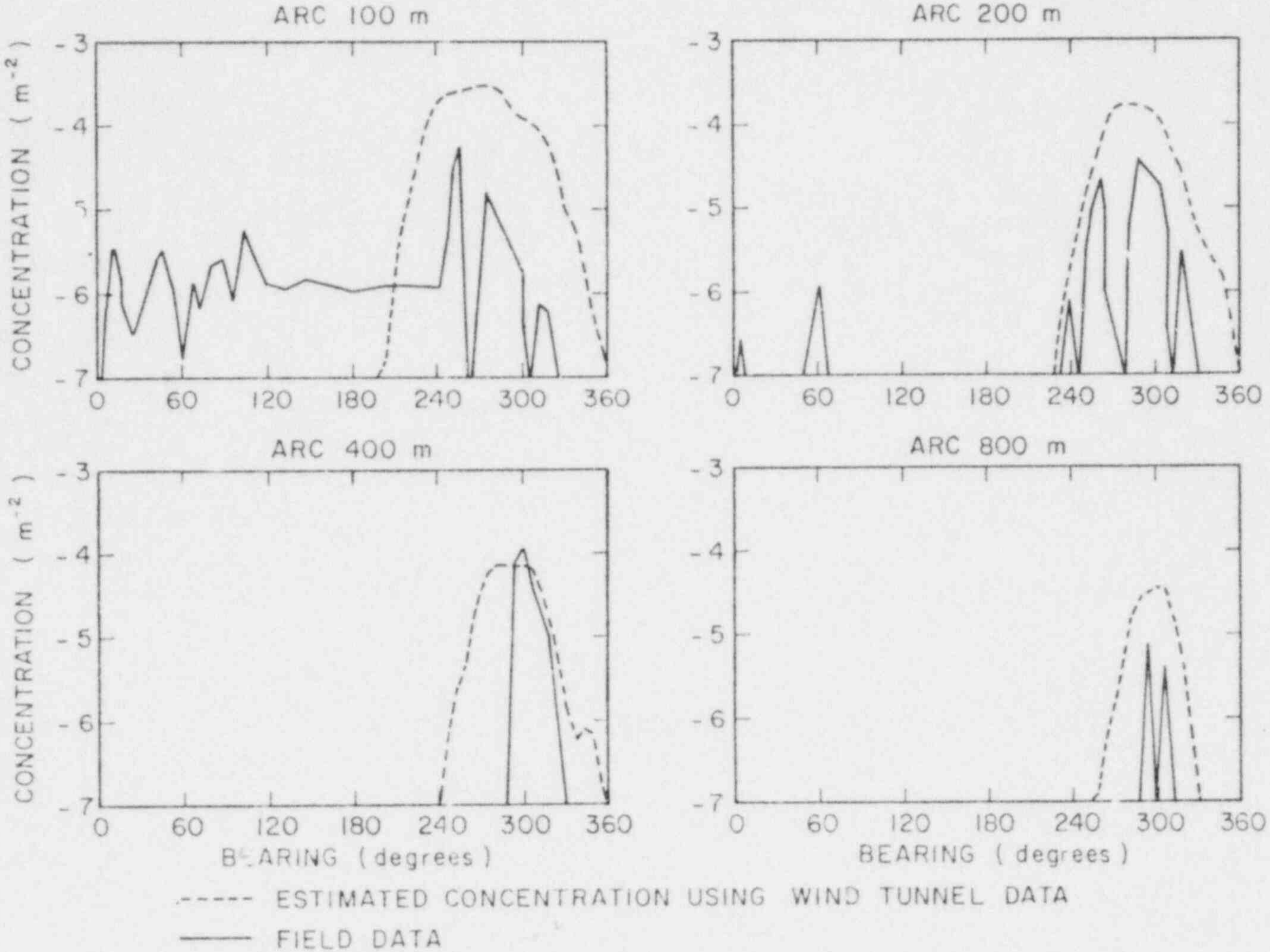


Figure 12. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 14A

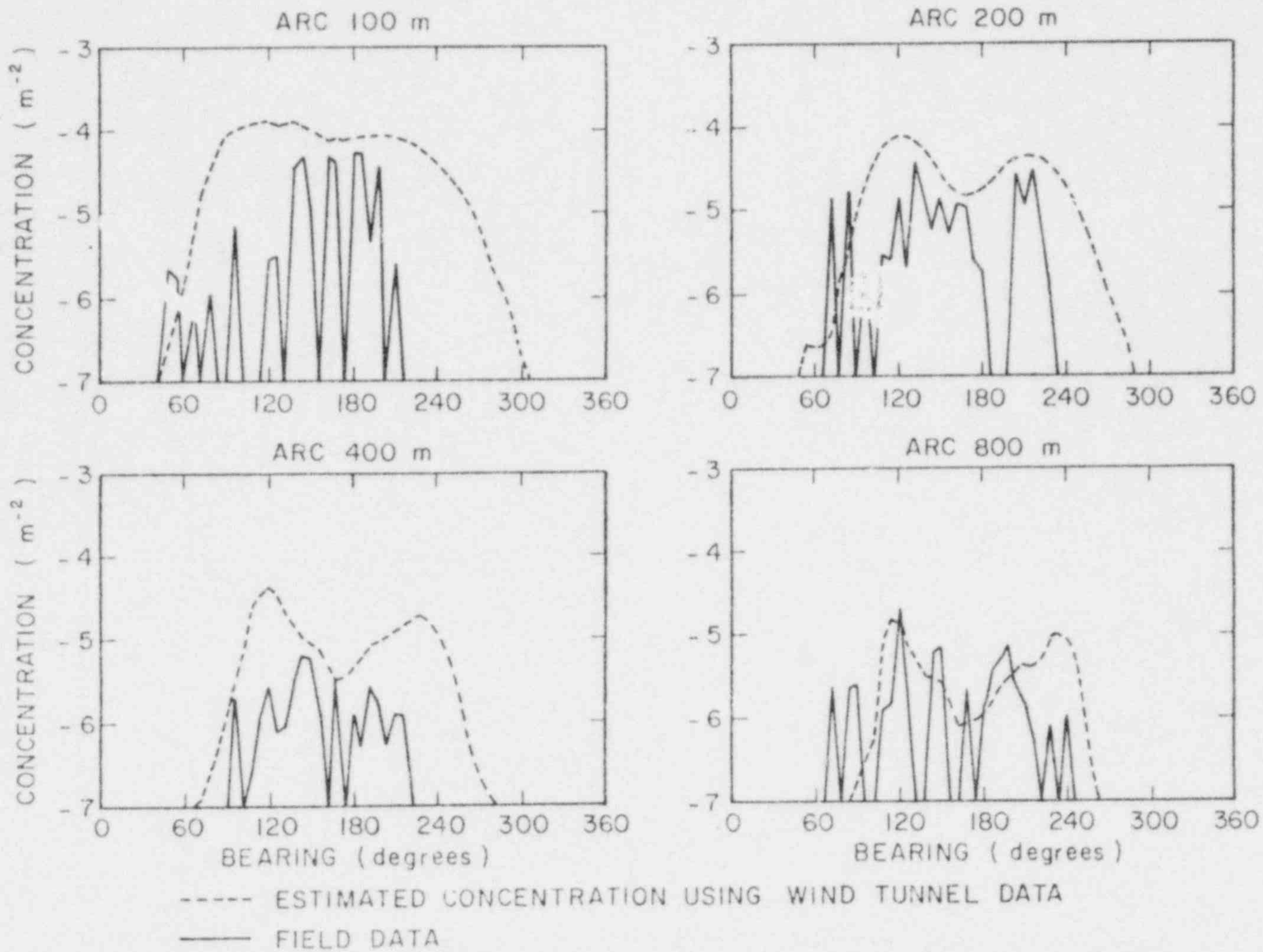


Figure 13. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 15:G5

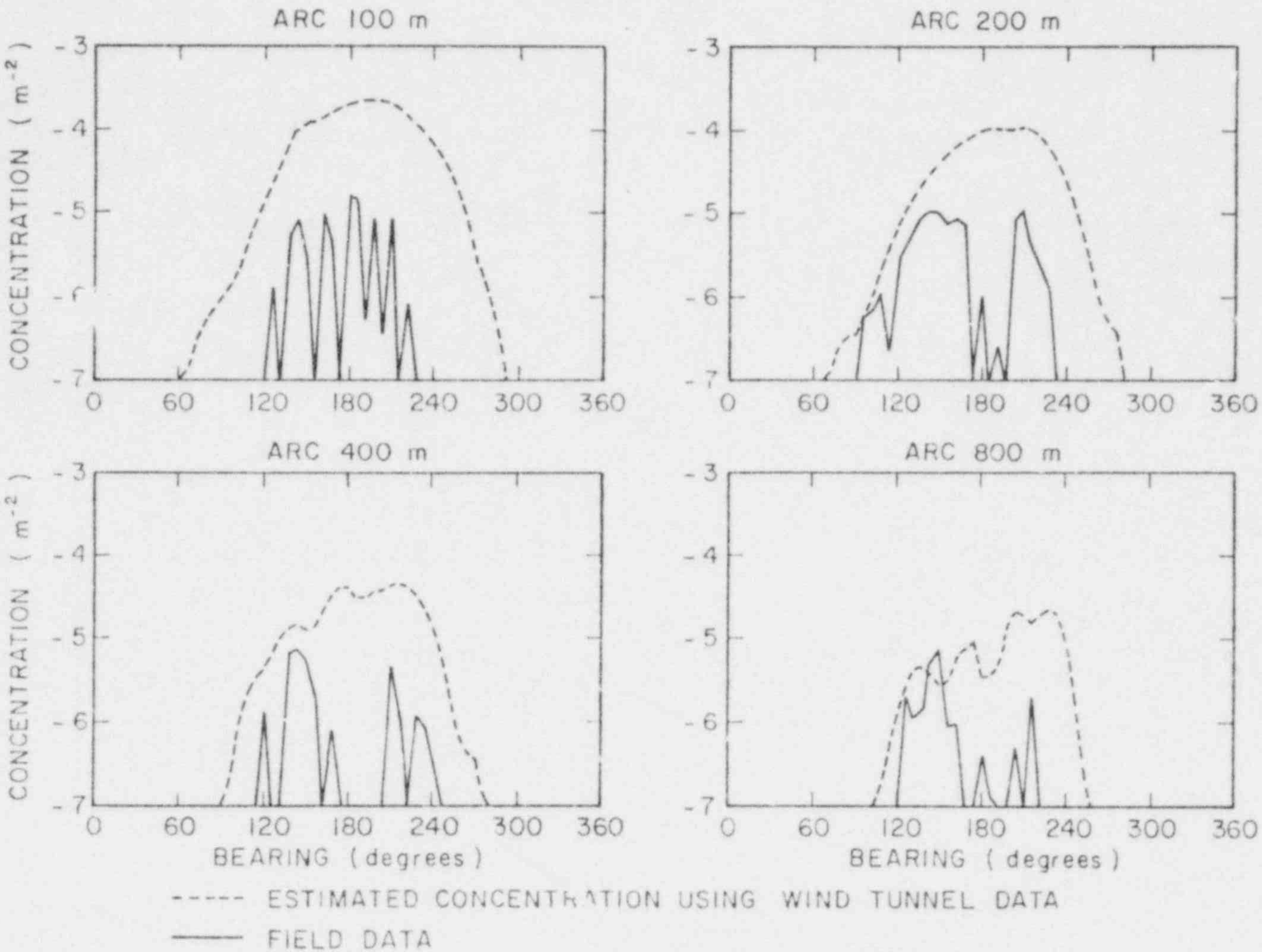


Figure 14. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 15A

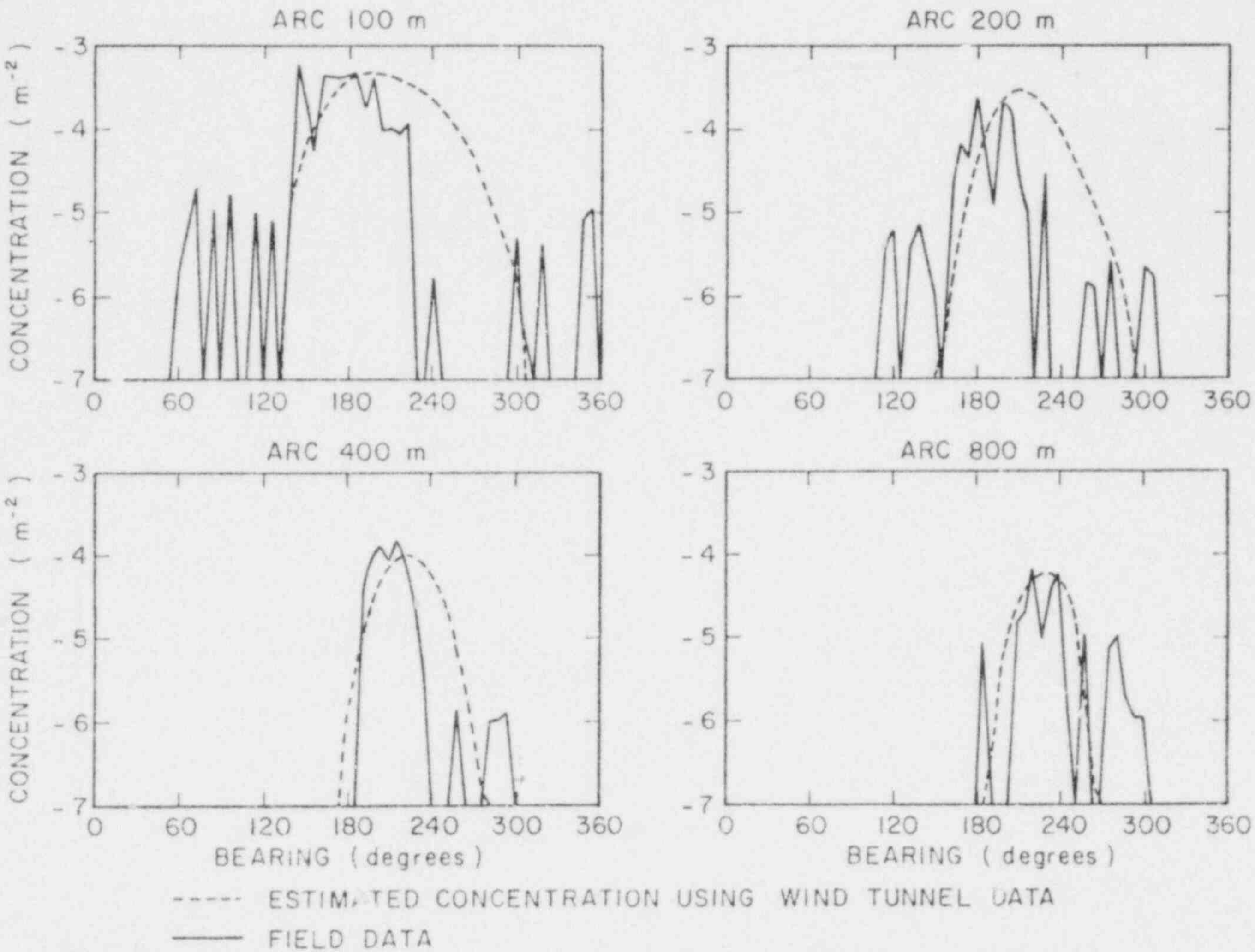


Figure 15. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 17:G5

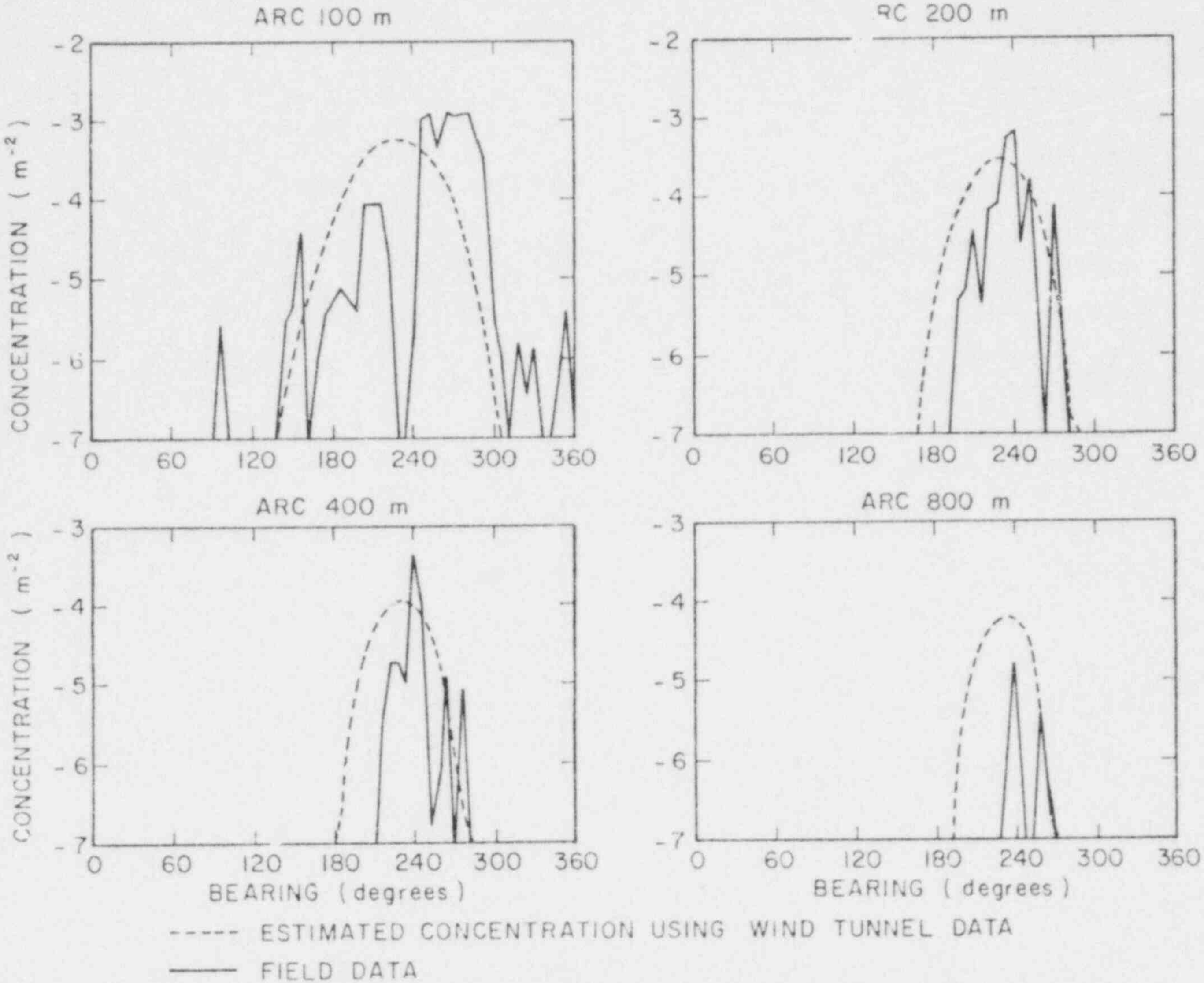


Figure 16. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 17:G17

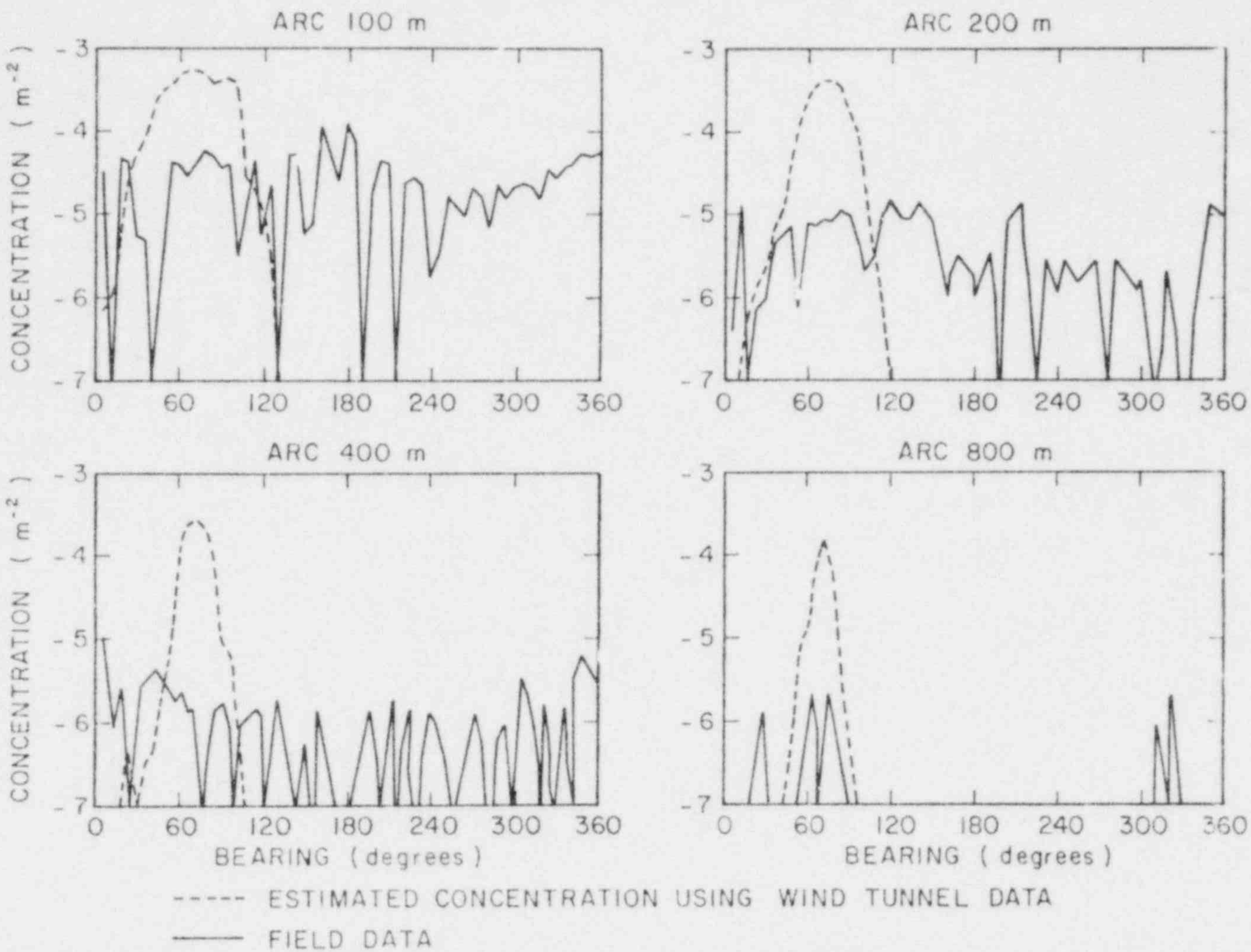


Figure 17. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 18:G5

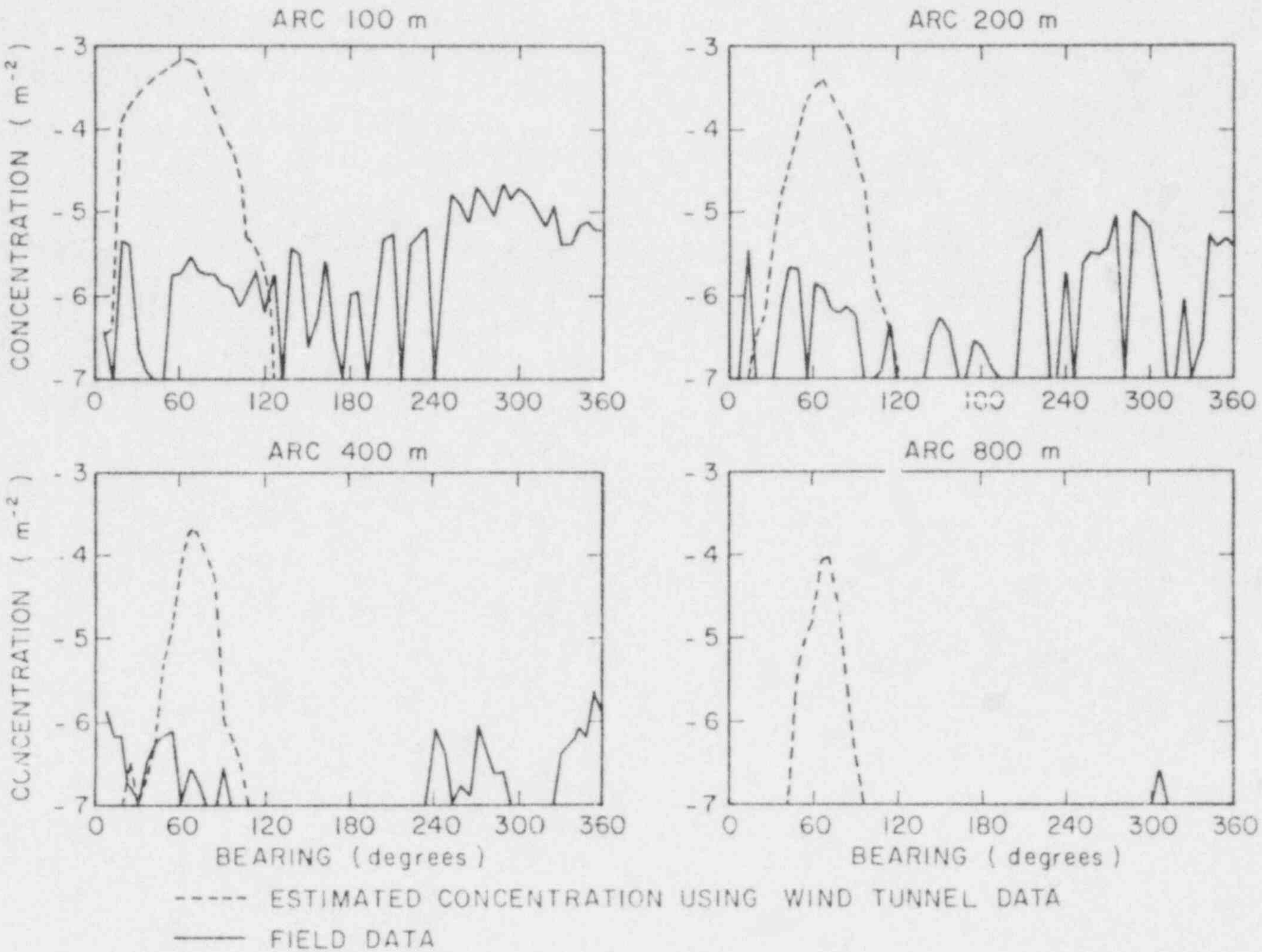


Figure 18. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 18:G17

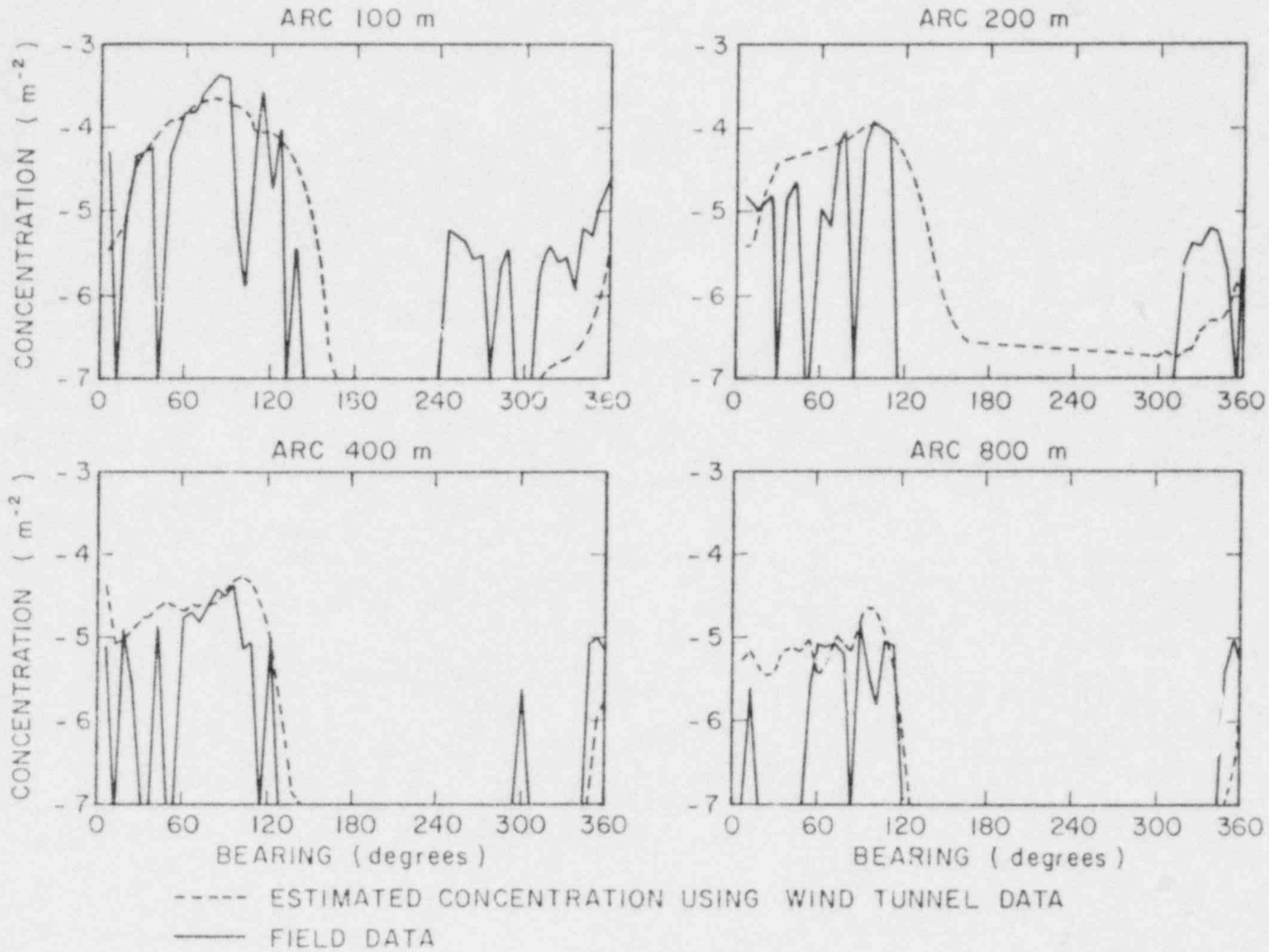


Figure 19. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 21:G5

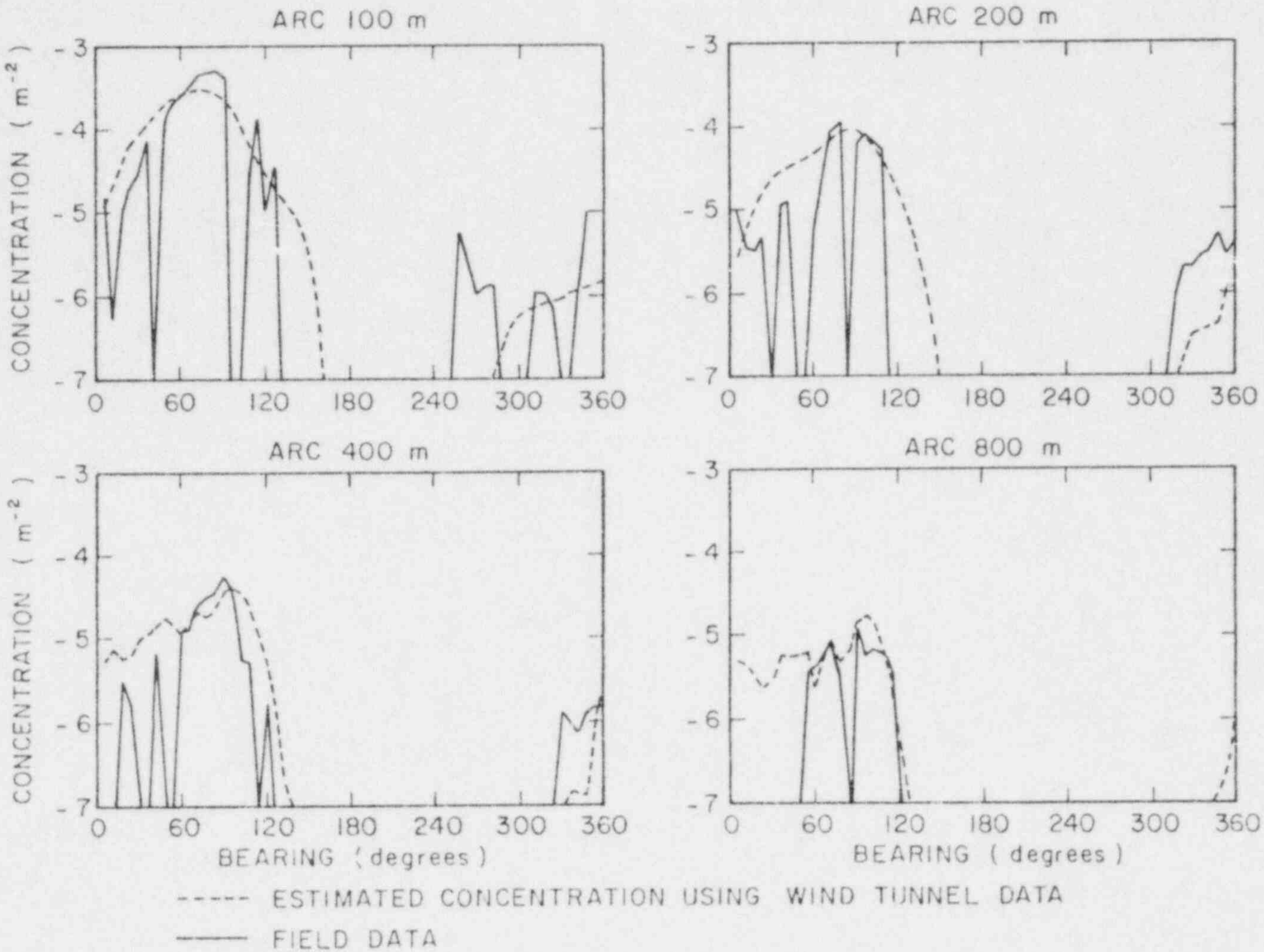


Figure 20. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 21:G17

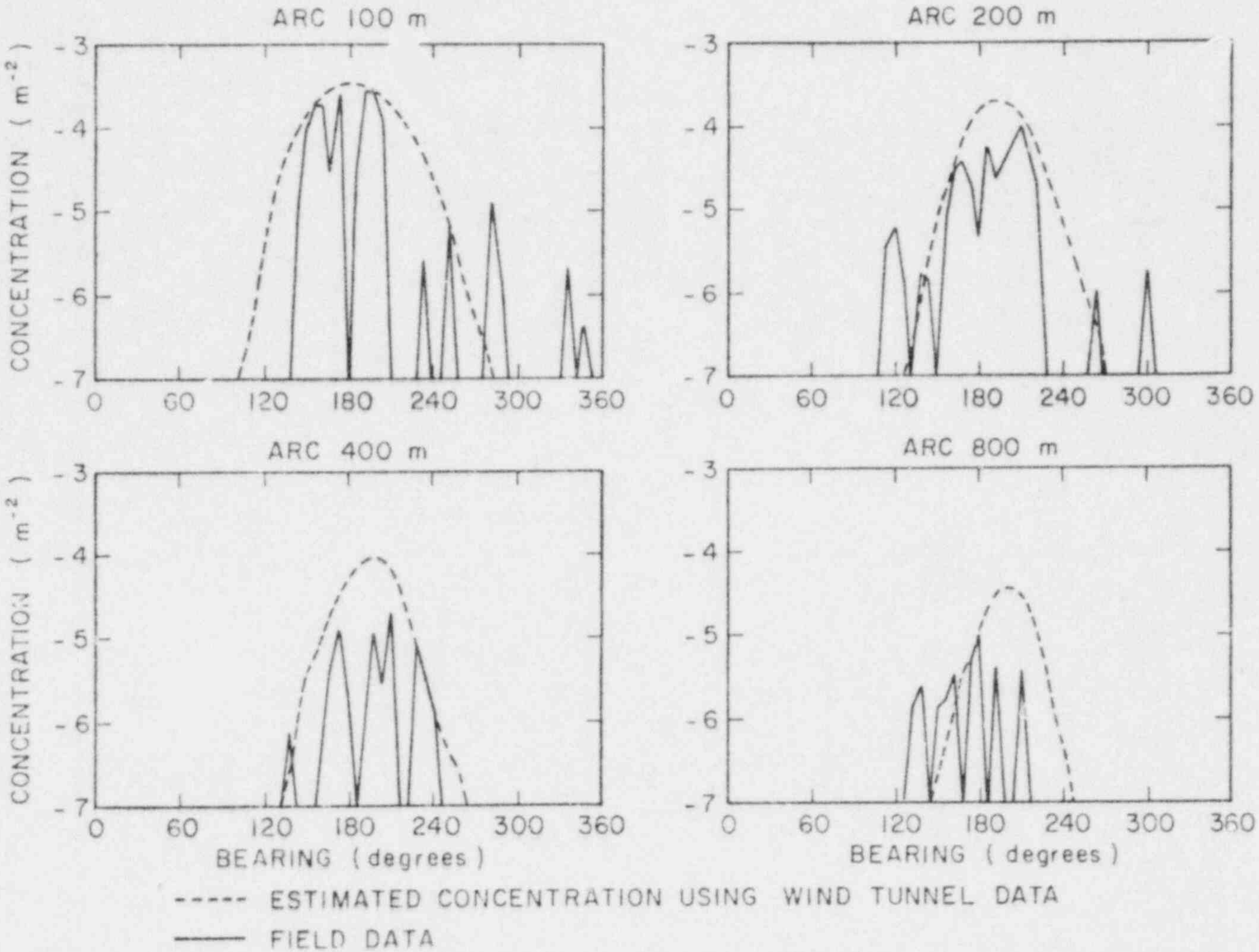


Figure 21. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 22:G5

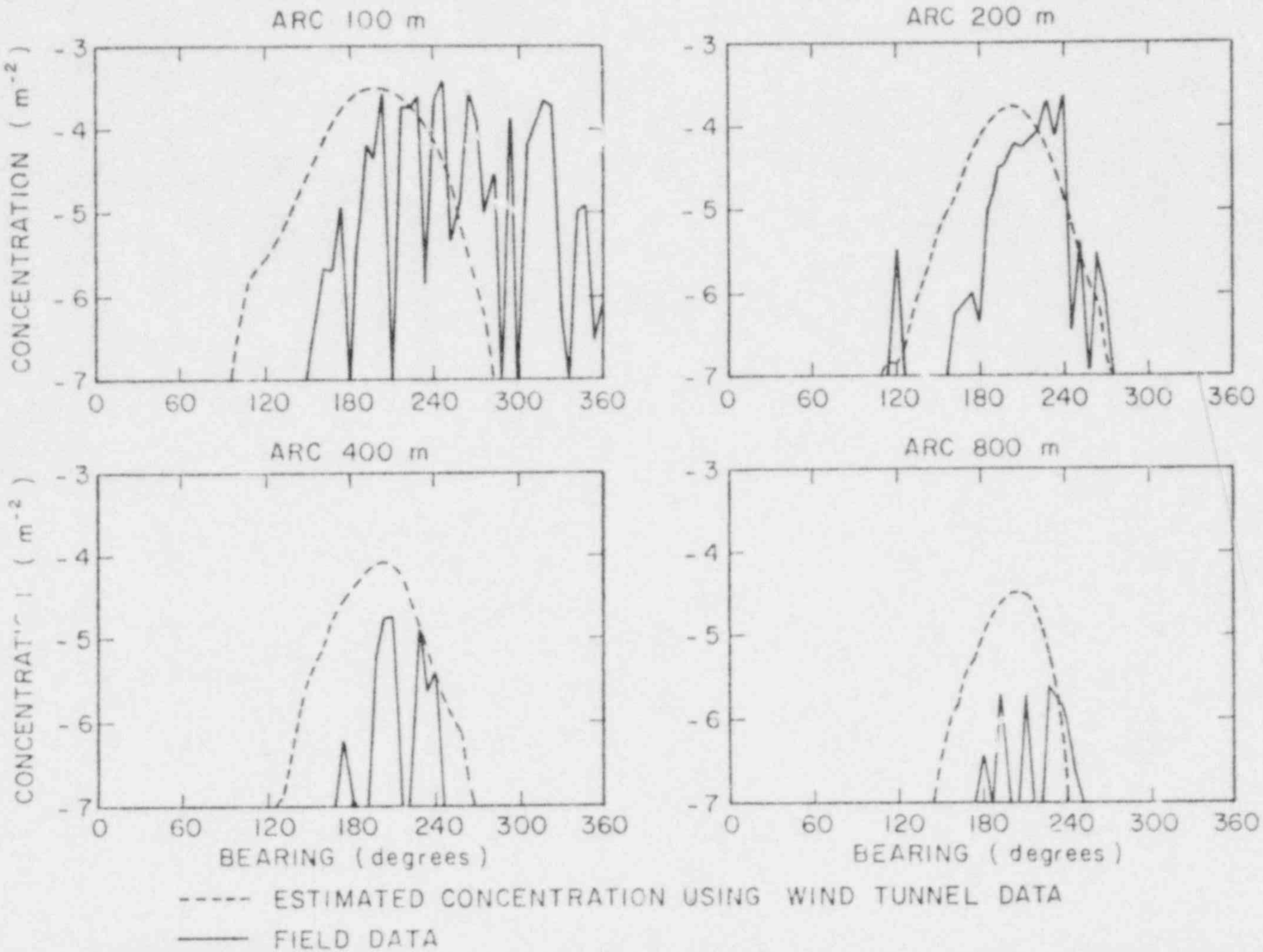


Figure 22. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 22:G17

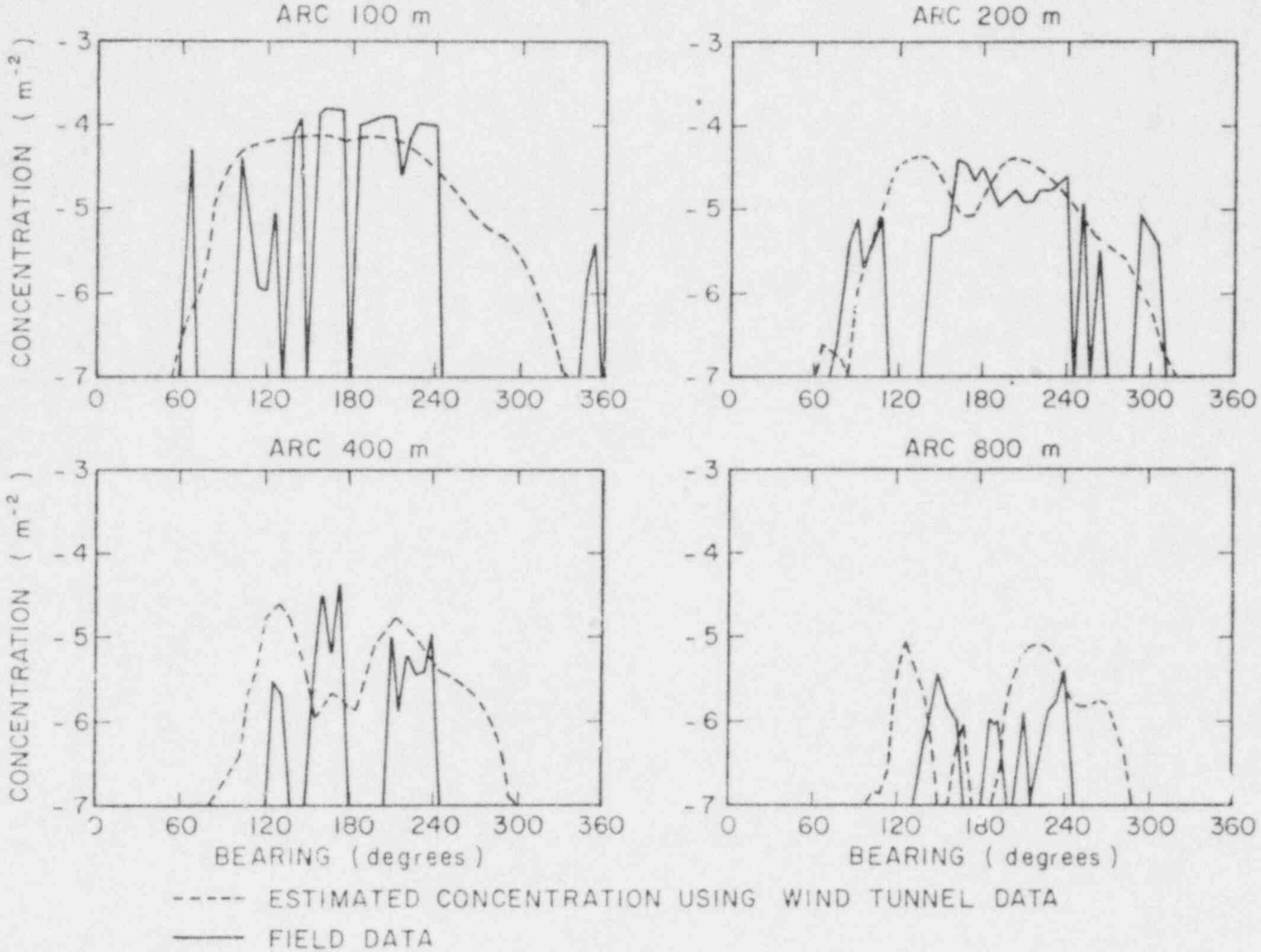


Figure 23. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 23:G5

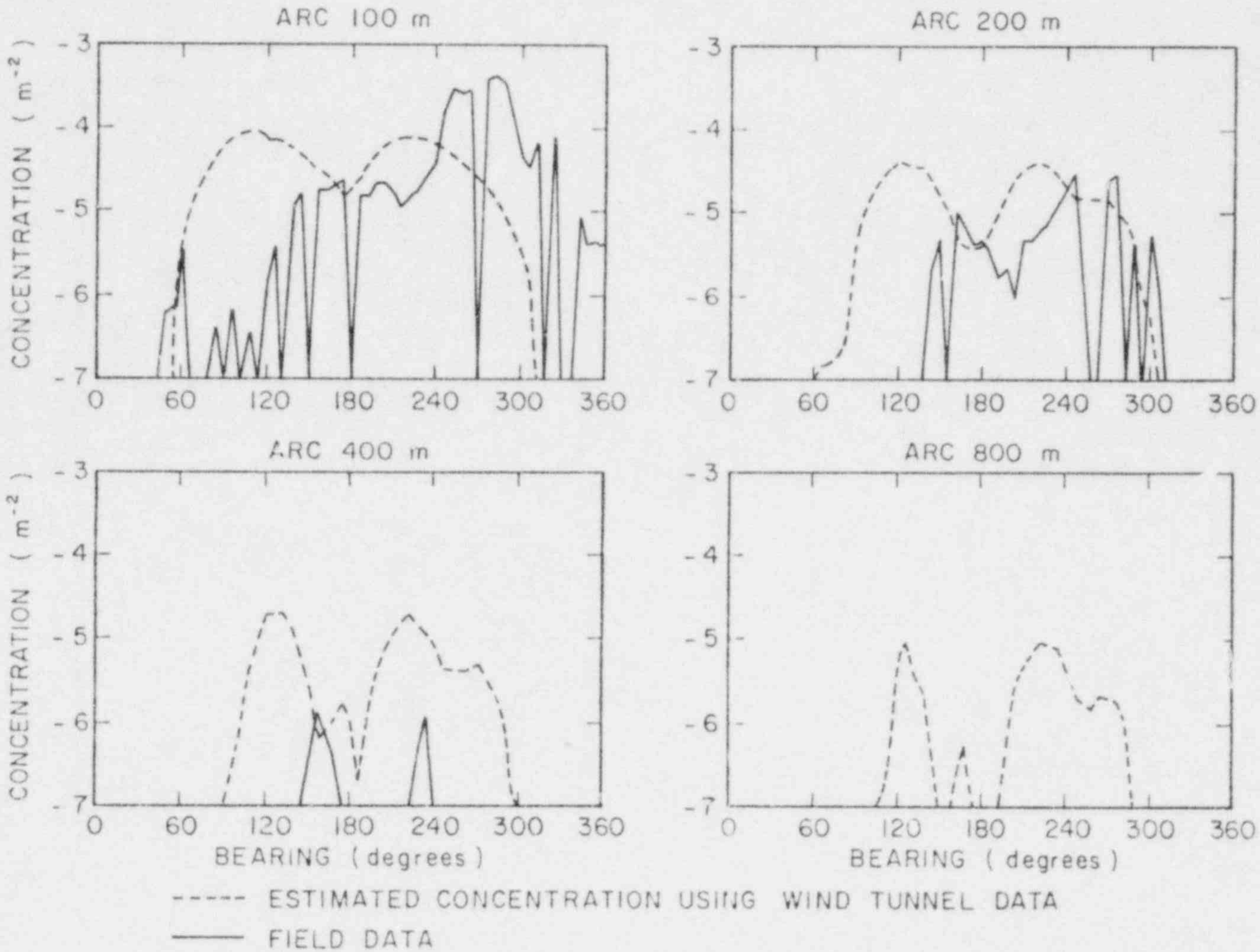


Figure 24. Comparison of $\frac{CU}{Q}$ (powers of ten) for Test 23:G17

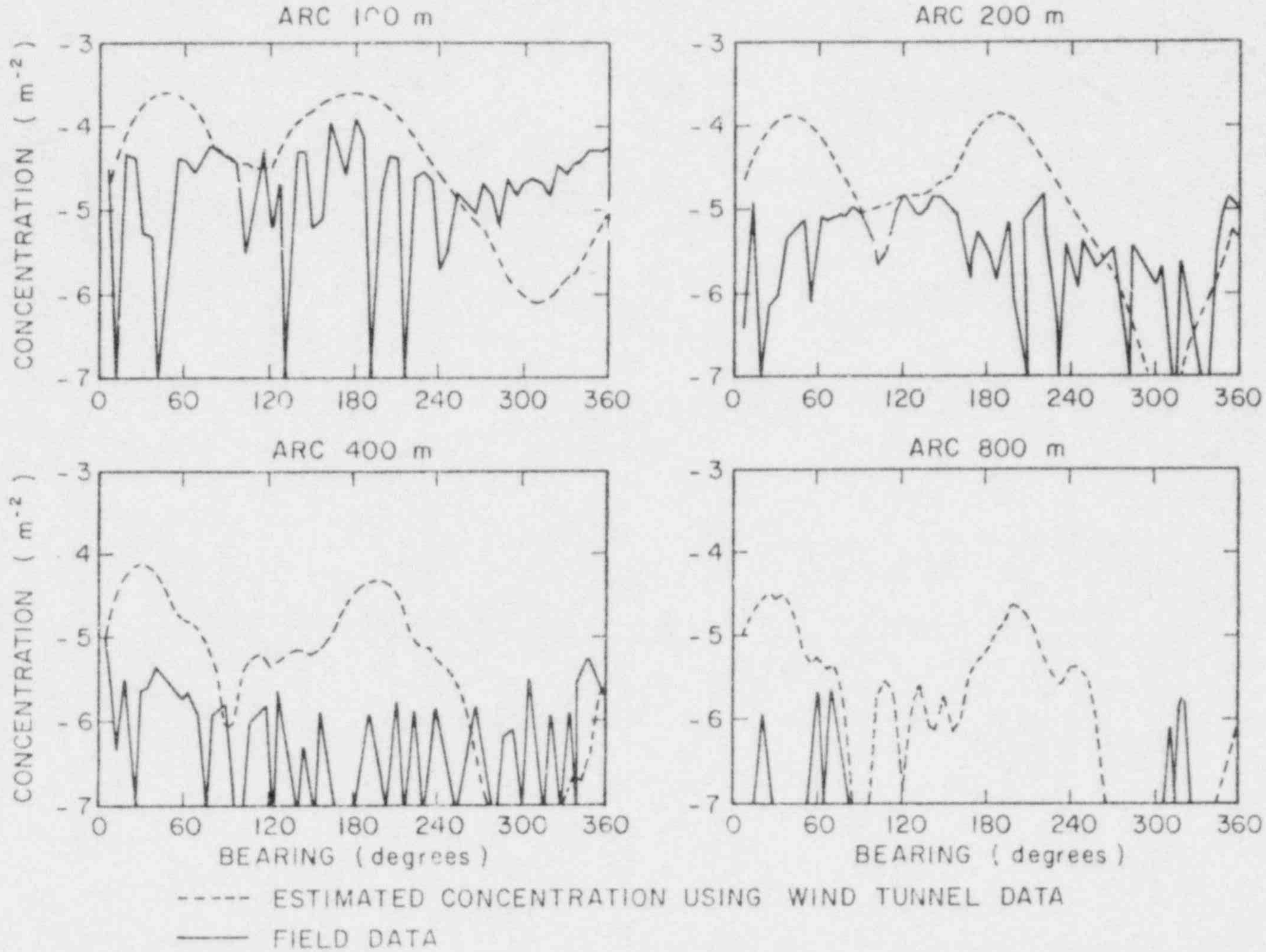


Figure 25. Comparison of $\frac{CU}{Q}$ (power of ten) for Test 18:[illegible] using field wind direction at 10 m height

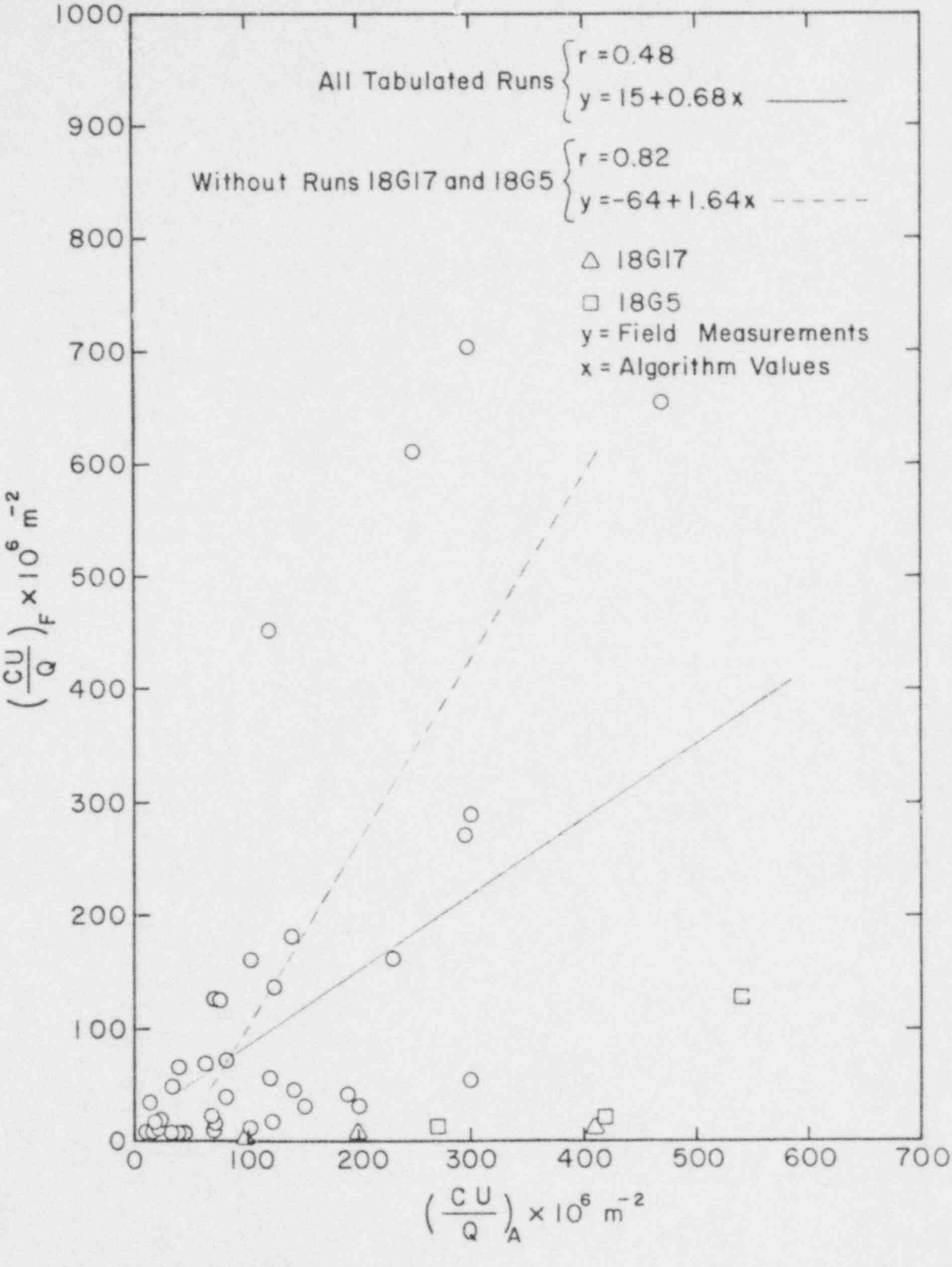


Figure 26. Comparison of $(\frac{CU}{Q})_F$ versus $(\frac{CU}{Q})_A$

TABLES

TABLE 1. Comparison of Field Data With Various Prediction Techniques

$Case_f$ ($Case_m$)	Release Location	U m/sec	$\bar{\theta}°_f$ ($\bar{\theta}°_m$)	Ri_f (Ri_m)	$P\text{-}G_f$ ($P\text{-}G_m$) [NRC_f]	Arc m	$\frac{C U}{Q} \times 10^6\ m^{-2}$ a	b	c	d	e	$\frac{b}{a}$	$\frac{c}{a}$	$\frac{d}{a}$	$\frac{e}{a}$
7 (17)	G5	4.6	342 (360)	-1.35 (-0.32)	A (C) [A]	100	608	833	4000	395	250	1.37	6.58	0.65	0.41
						200	182	21.4	1000	179	160	1.18	5.49	0.98	[illegible]
						400	71.5	46.5	270	130	80	0.65	3.78	1.82	[illegible]
						800	47.7	6.7	70	63	33	0.14	1.47	1.32	0.70
12 (1)	G5	1.3	349 (360)	0.0 (0.0)	D (D) [E]	100	159	14561	9000	336	230	91.6	56.60	2.11	1.44
						200	45.1	4366	1270	175	140	96.8	28.10	3.88	3.10
						400	16.2	1324	725	123	70	81.7	44.75	7.59	4.32
						800	20.9	427	215	48.1	20	20.4	10.29	2.30	[illegible]
14 (12)	G5	0.9	109 (90)	0.64 (0.35)	F (E) [G]	100	146	--	52000	726	70	--	356.16	4.97	0.48
						200	64.5	10158	12000	461	40	157.49	186.05	7.18	0.62
						400	34.4	3057	3500	153	17	88.87	101.74	4.45	[illegible]
						800	6.8	963	960	123	8	141.62	144.12	18.09	1.18
15 (17)	G5	0.8	339 (360)	-0.66 (-0.32)	A-B (C) [D]	100	54.7	--	4000	395	120	--	73.12	7.22	2.19
						200	39.5	2438	1000	178	80	61.72	25.32	4.50	2.02
						400	6.3	712	270	130	42	113.02	42.86	20.63	6.67
						800	18.7	216	70	62.7	17	11.61	3.76	3.37	0.91
17 (11)	G5	2.0	50 (45)	8.23 (0.35)	G (E) [G]	100	641	--	52000	880	470	--	79.63	1.35	[illegible]
						200	270	10169	12000	550	215	37.63	44.44	2.04	[illegible]
						400	156	3052	3500	257	103	19.56	22.43	1.65	0.65
						800	68	962	980	170	62	14.55	14.55	2.55	0.94
18 (16)	G5	0.7	251 (270)	∞ (0.35)	G (E) [F]	100	127	--	52000	690	540	--	409.45	5.43	4.25
						200	19.8	10152	12000	431	420	512.96	606.06	21.76	21.21
						400	12.5	3053	3500	255	270	244.24	280	20.40	21.60
						800	2.5	962	980	137	115	385	392	54.80	46.00
17 (11)	G17	2.0	50 (45)	8.23 (0.35)	G (E) [G]	100	1250	32637	52000	1000	480	26.11	41.60	0.80	0.42
						200	702	10157	12000	658	309	14.47	17.09	0.94	0.43
						400	451	3053	3500	418	120	6.77	7.76	0.93	0.27
						800	21.2	985	980	177	68	46.46	46.22	8.35	3.21
18 (16)	G17	0.7	251 (270)	∞ (0.35)	G (E) [F]	100	23	32637	52000	1012	750	1419	2260	44.0	32.61
						200	10.6	10161	12000	470	410	958	1132	44.34	38.67
						400	2.1	3051	3500	218	200	1452	1667	103.81	95.24
						800	3.3	945	980	99	96	3150	[illegible]	330.0	[illegible]
7 (24)	A	5.1	322 (360)	-1.35 (-0.32)	A (C) [A]	100	286	835	4000	456	300	2.92	13.99	1.59	1.05
						200	136	215	1000	188	125	1.58	7.35	1.38	[illegible]
						400	68.7	46.7	270	85	63	0.70	3.93	1.24	0.92
						800	20.2	6.7	70	32	20	0.33	3.47	1.58	0.99
12 (1)	A	1.7	345 (360)	0.0 (0.0)	D (D) [E]	100	28.2	14562	9000	513	200	516	319.15	18.19	7.09
						200	27.9	4366	1270	301	150	156.49	45.52	10.79	5.38
						400	9.7	1331	725	152	70	137.22	74.74	15.67	7.21
						800	8.4	425	215	60.6	19	50.59	25.59	7.21	2.26
14 (13)	A	2.3	131 (135)	0.64 (0.35)	F (E) [G]	100	54.4	32585	52000	635	300	599	955	11.67	5.51
						200	42.6	10160	12000	444	190	238	282	10.42	4.46
						400	125	3051	3500	168	72	24	28	1.34	0.58
						800	7.64	962	980	59	36	399	128	7.72	4.71
15 (17)	A	1.3	357 (360)	-0.66 (-0.32)	A-B (C) [D]	100	17	8443	4000	284	122	496	235	16.71	7.17
						200	11.5	2438	1000	275	102	212	86.9	23.91	8.87
						400	7.5	711	270	132	43	94.8	36.0	17.6	5.73
						800	7.6	216	70	54.1	20	28.42	9.21	7.12	2.63
											AVERAGE	275	284	18.5	14.1
							without tests 18:G5 and 18:G17,				AVERAGE	107.8	90.6	6.6	2.5

a--measured Start et al. (1977)
b--P-G from Start et al. (1977)
c--P-G no building from Slade (1968)
d--measured Allwine et al. (1980)
e--calculated by algorithm
f--field condition
m--model condition

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3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
R. J. B. Bouwmeester, K. M. Kothari, and R. N. Meroney

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Highest concentrations at ground level are often produced from surface sources with stable atmospheric conditions and near calm winds. This report describes a weighted data methodology developed to predict surface concentrations from stationary wind-tunnel measurements and actual meteorological wind fields. Field measurements made downwind of the Rancho Seco Nuclear Power Station in 19'5 have been compared against a set of wind-tunnel measurements around a 1:500 scale model of the same facilities. The weighted data algorithm was realistic in both predicting centerline concentration values as well as the horizontal spread of the plume.

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