1981

Reprinted from JOURNAL OF APPLIED METEOROLOGY, Vol. 20, No. 8, August 1981
American Meteorological Society
Printed in U. S. A.

An Algorithm to Estimate Field Concentrations in the Wake of a Power Plant Complex under Nonsteady Meteorological Conditions from Wind-Tunnel Experiments

K. M. KOTHARI, R. N. MERONEY AND R. J. B. BOUWMEESTER

An Algorithm to Estimate Field Concentrations in the Wake of a Power Plant Complex under Nonsteady Meteorological Conditions from Wind-Tunnel Experiments

K. M. KOTHARI, R. N. MERONEY AND R. J. B. BOUWMEESTER[1]

Fluid Mechanics and Wind Engineering Program, Civil Engineering Department, Colorado State University, Fort Collins, CO 80523

(Manuscript received 20 March 1980, in final form 24 April 1981)

ABSTRACT

Highest concentrations of pollutant at ground level are often produced from surface sources with stable or unstable atmospheric conditions and near calm erratic winds. This paper 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. On the average the wind-tunnel data combined with the weighting algorithm was some 40 times more accurate in predicting field data than the conventional Pasquill-Gifford formulas.

1. Introduction

In recent years safety considerations with respect to surface concentrations in the event of an unscheduled radioactive release have played a major role in the design and operation of nuclear power plants. Pollutant concentrations are often greatest under conditions of low wind speed, temperature inversions, and erratic wind direction as 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 and wind speed may vary by an order of magnitude during low wind speed conditions. The development of a simple algorithm to estimate field concentrations under nonsteady meteorological conditions from wind-tunnel data and the subsequent comparison with field data are the subject of this paper. This paper utilizes the field concentration measurements performed by Start *et al.* (1977) and compares them against the wind-tunnel measurements of Allwine *et al.* (1978) using the algorithm.

It is well known that the sample averaging time has a definite effect on the measured concentrations. The average maximum concentrations of gases dispersing in the atmosphere tend to decrease with increasing sampling time. 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 3–10 min.

Briefly, the difference is associated with the relative eddy scale sizes detected in the atmosphere versus the laboratory. Since the motion of the airflow in the surface layer is limited in the vertical directions by 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, a meandering behavior or a gustiness effect may cause a large transverse dispersion in the atmosphere. Since these large lateral eddy motions are 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 1–10 cph (cycles per hour). This spectral gap (low energy region) first noted by van der Hoven (1957) separates weather from turbulence. It 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. The low-frequency portion, related to meandering and wind-speed variations, directional fluctuations, passage of

[1] Present affiliation: Civil Engineering Department, Michigan State University, East Lansing, MI 48823.

0021-8952/81/080934-10$06.50

weather systems, seasonal and annual changes, etc., cannot be simulated in a wind tunnel.

2. Algorithm development

a. 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 a day (Corotis, 1977). Data taken during such an "independent" period will not show exceptionally large shifts in wind speed or direction; hence concentration values may be simply related to averaging time.

This phenomenon, often known as the gustiness effect, was first considered by Inoue (Hino, 1968). He reported that a smoke cloud width will increase at a rate proportional to the ½ power of the observation time. Ogura (1959) developed a mathematical model which suggested a −½ power variation of the maximum concentration with time. Hino (1968) performed a large-scale study for a time range from 10 min to 5 h. The study which involved releasing tracer materials from high stacks of thermal electric power stations also gives support to the −½ power law.

b. 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 a 1 h 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 2 min interval.

Sagendorf and Dickson (1974) compared the results of diffusion tests conducted under stable conditions with wind speeds less than 2 m s^{-1} against a "segmented plume" version of the classical Gaussian distribution model. Each test time period was divided into small 2 min 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 the appropriate Turner Workbook curve. The lateral standard deviation σ_y was obtained from each 2 min interval from

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

where $a = 0.017$, $b = 0.87$, σ_θ was the 2 min standard deviation in horizontal wind direction (deg), and the other dimensions are metric.

The "segmented plume" Gaussian model showed considerable improvement over the conventional Gaussian methods when compared to the data of Sagendorf and Dickson.

c. Time-weighted laboratory measurement algorithm

Laboratory measurements of dispersion are generally scheduled for 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; however, the number must remain finite to be economical. It is proposed that the measured concentration fields may also be combined in a time-weighted manner which reflects the influence of gustiness, meandering and thermal structure.

Halitsky (1969) proceeded in this spirit when he compared rooftop 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 distribution of concentrations quite well.

1) General formulation

It is generally accepted that 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

$$\bar{C}(r, \phi) = T^{-1} \times \int_t^{t+T} C[Q(t), U(t), \theta(t), \mathrm{Ri}(t); r, \phi]dt. \quad (1)$$

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

$$\bar{C}(r, \phi) = \int_U \int_\theta \int_{\mathrm{Ri}} p(U, \theta, \mathrm{Ri}) \times C(U, \theta, \mathrm{Ri}; r, \phi)dUd\theta d\,\mathrm{Ri}. \quad (2)$$

In the above formulations the following is assumed:

- Concentration wind-tunnel data are continuously available for any 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 T.

• Meteorological data available from a single site near the proposed 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) SEGMENTED TIME APPROXIMATION

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

$$K \equiv \frac{CUA}{Q}, \tag{3}$$

where U, A and Q are characteristic velocity, area and source scales. Prior laboratory experience confirms that these parameters are indeed equal when sampling times are less than 10 min; hence,

$$K_f = K_m, \tag{4}$$

$$C_f = \left(\frac{Q_f}{U_f A_f}\right) K_m, \tag{5}$$

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 min average combination of the variables θ and Ri, one may represent an hour average version of Eq. (1) by the sum

$$\bar{C}_f(r, \phi) = \sum_{i=1}^{30} \frac{(Q_f)_i}{(U_f)_i A_f} (K_m)_i \tag{6}$$

or

$$\bar{\chi}_f(r, \phi) \equiv \frac{\bar{C}_f(r, \phi)\bar{U}_f}{\bar{Q}_f}$$

$$= \sum_{i=1}^{30} \frac{(Q_f)_i}{\bar{Q}_f} \frac{\bar{U}_f}{(U_f)_i} \frac{[K_m(r, \phi)]_i}{A_f}, \tag{7}$$

where the overbar represents an hour average value.

Unfortunately it is not economically credible to run a laboratory test for every potential combination of Q, U, θ and Ri; hence, there is always 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.

Typically, laboratory data may be available for a matrix of 1 to NS thermal stratification conditions for each of 1 to NW wind orientations. An interpolation method is proposed to estimate $(K_m)_i$ for the nonincremental 2 min average values of $(\theta_f)_i$ and $(\mathrm{Ri}_f)_i$. The following notation is introduced:

$$[K_m(r, \phi)]_i = \sum_{j=1}^{NS} \sum_{k=1}^{NW} W_{ijk} K_{jk}(r, \phi), \tag{8}$$

where K_{jk} is a set of model concentration data measured for a specific member of the thermal stratification and wind orientation model test matrix, and W_{ijk} is a weight function varying in magnitude from 0 to 1.0.

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

$$W_{ijk} = WS_{ij} WW_{ik}, \tag{9}$$

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, if

(a) $(\mathrm{Ri}_f)_i < (\mathrm{Ri}_m)_1$,

then

$$WS_{i1} = 1.0,$$
$$WS_{ij} = 0.0, \quad j \neq 1,$$

(b) $(\mathrm{Ri}_m)_j \leq (\mathrm{Ri}_f)_i \leq (\mathrm{Ri}_m)_{j+1}$,

then

$$WS_{ij} = \frac{(\mathrm{Ri}_m)_{j+1} - (\mathrm{Ri}_f)_i}{(\mathrm{Ri}_m)_{j+1} - (\mathrm{Ri}_f)_j}$$

$$WS_{i(j+1)} = \frac{(\mathrm{Ri}_f)_i - (\mathrm{Ri}_m)_j}{(\mathrm{Ri}_m)_{j+1} - (\mathrm{Ri}_m)_j},$$

otherwise

$$WS_{ij} = 0.0,$$

(c) $(\mathrm{Ri}_m)_{\mathrm{NS}} < (\mathrm{Ri}_f)_i$,

then

$$WS_{i(\mathrm{NS})} = 1.0,$$
$$WS_{ij} = 0.0, \quad j \neq \mathrm{NS}.$$

Although the adequacy of such linear interpolation may be questionable, it does not appear that 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) to be reasonably reliable.

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

$$(\theta_m)_k \leqslant (\theta_f)_i \leqslant (\theta_m)_{k+1},$$

then

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

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

otherwise

$$WW_{ik} = 0.0.$$

Of course, the recommended interpolation scheme is not yet adequate to fully 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 must be applied to laboratory results based on the laboratory measured velocity profiles. Hence

$$f_j \equiv \left(\frac{Z_f}{Z_m}\right)^{p_j}, \tag{10}$$

where p_j is the velocity profile power-law coefficient. Then incorporating the weight factors, the rotation and the reference height corrections in Eq. (8) produces

$$[K_m(r, \phi)]_i = \sum_{j=1}^{NS} f_j WS_{ij} \sum_{k=1}^{NW} WW_{ik} K_{jk} \times [r, \theta - (\theta_f)_i + (\theta_m)_k]. \tag{11}$$

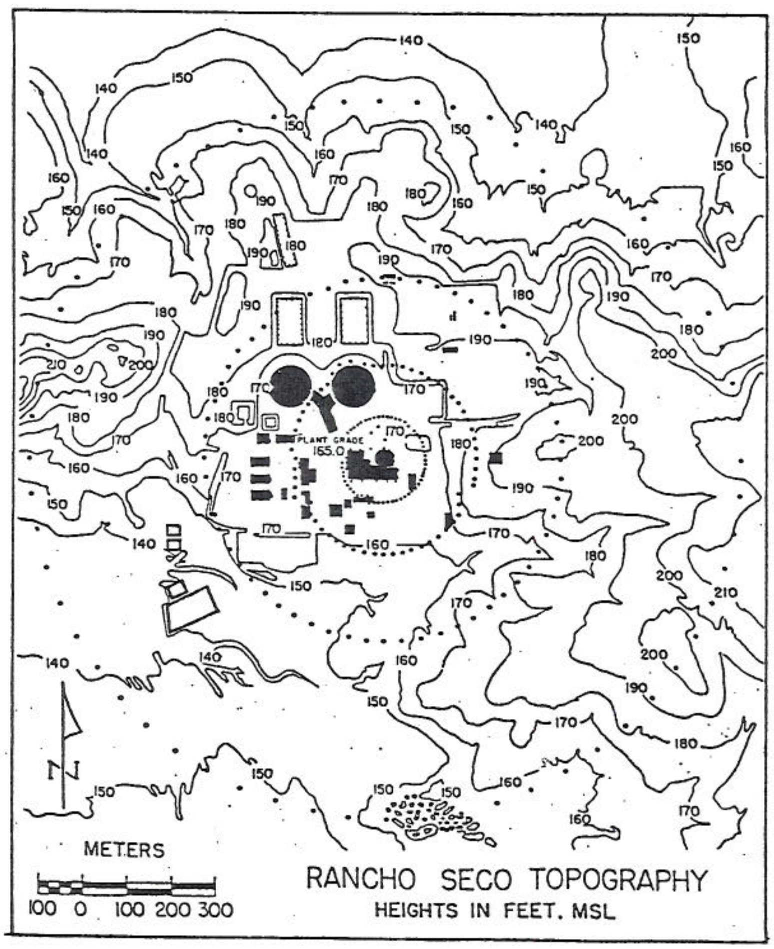


FIG. 1. Rancho Seco topography.

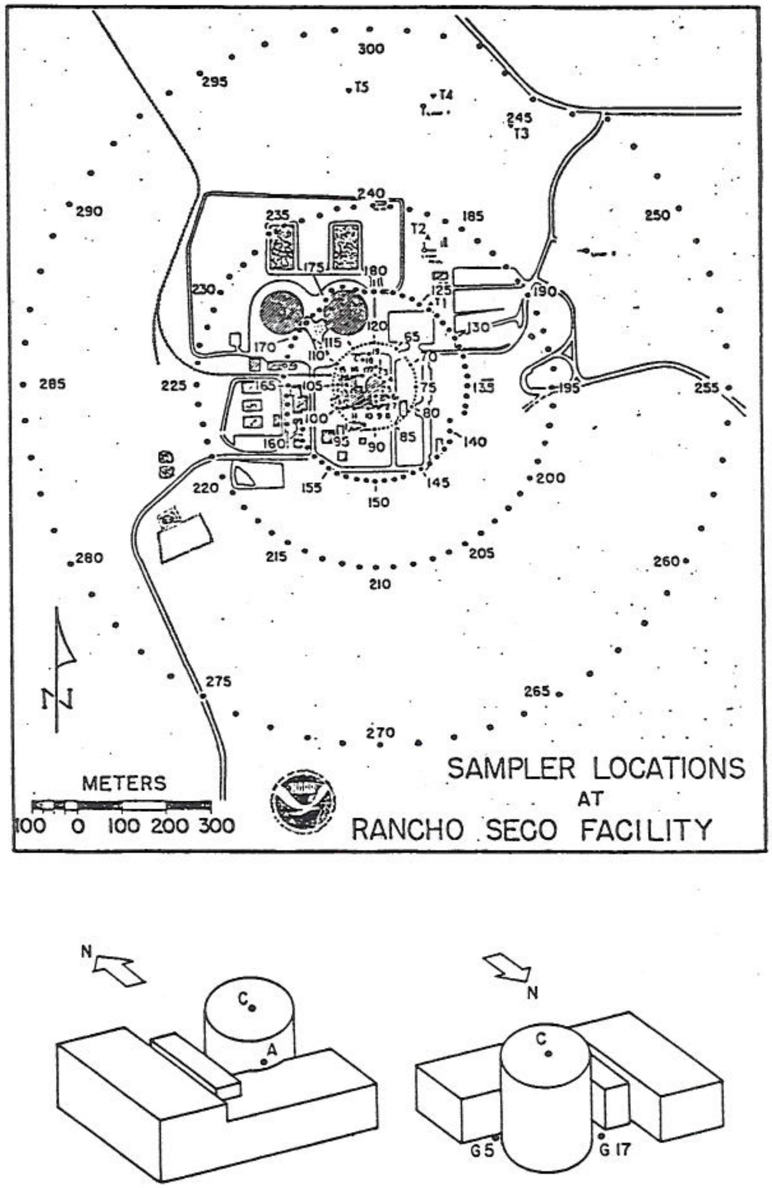


FIG. 2. Prototype sampler locations and release point identification.

The final laboratory-weighting algorithm proposed herein incorporates Eq. (11) into Eq. (7) such that

$$\bar{\chi}_f(r, \phi) = \sum_{i=1}^{30} \frac{(Q_f)_i}{\bar{Q}} \frac{\bar{U}_f}{(U_f)_i} \frac{1}{A_f} \sum_{j=1}^{\mathrm{NS}} f_j WS_{ij} \times \sum_{k=1}^{\mathrm{NW}} WW_{ik} K_{jk}(r, \phi - (\theta_f)_i + (\theta_m)_k). \quad (12)$$

Eq. (12) presented above is the basis for a computer program to calculate 1 h mean field concentration using wind-tunnel data. The details of the program are described by Bouwmeester *et al.* (1979).

3. Field and wind-tunnel experiments

a. Field experiments

A series of 23 tests was conducted at the Rancho Seco Nuclear Power Station in the Fall of 1975. 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 Fig. 1. The release and sampler locations are given on a more detailed plan view as Fig. 2.

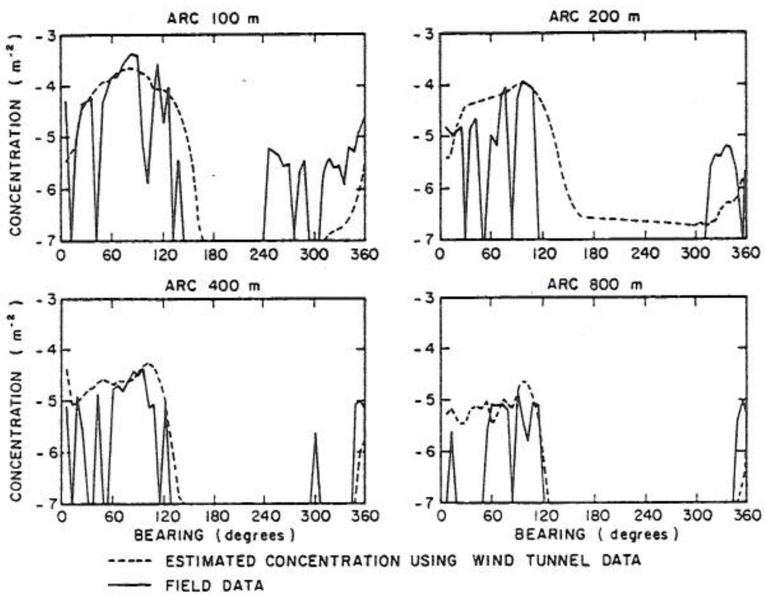


FIG. 3. Comparison of CUQ^{-1} (powers of 10) for test 21:G5. Tracer was released at surface position G5 under NRC stability category G. Mean tower wind at release height was from 262° at 2.3 m s^{-1}.

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 6° starting from the north and were numbered clockwise. Meteorological data were obtained from instrumentation mounted on a 46 m tower just within the 400 m 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 2 min increments during the 1 h test periods also were supplied by Start directly to the authors. This data has been reproduced in Bouwmeester *et al.* (1979). The latter information was used to define the meteorological condition utilized during construction of time-

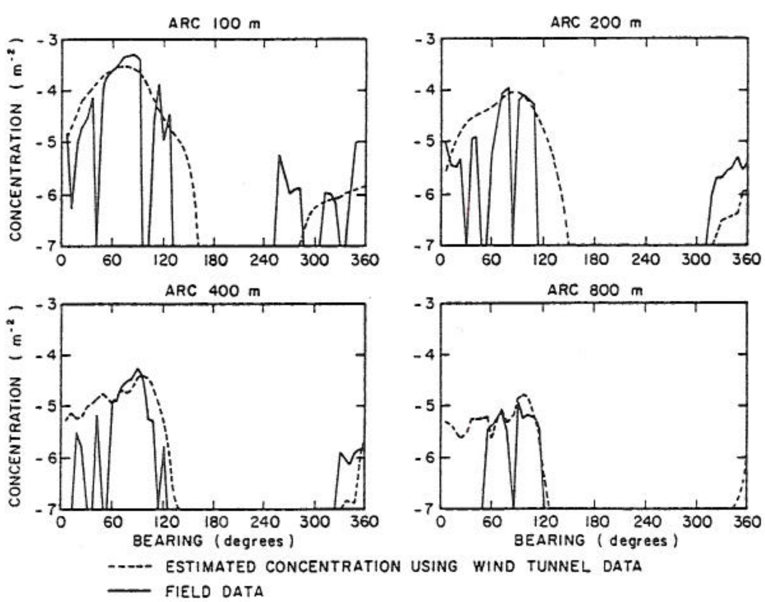
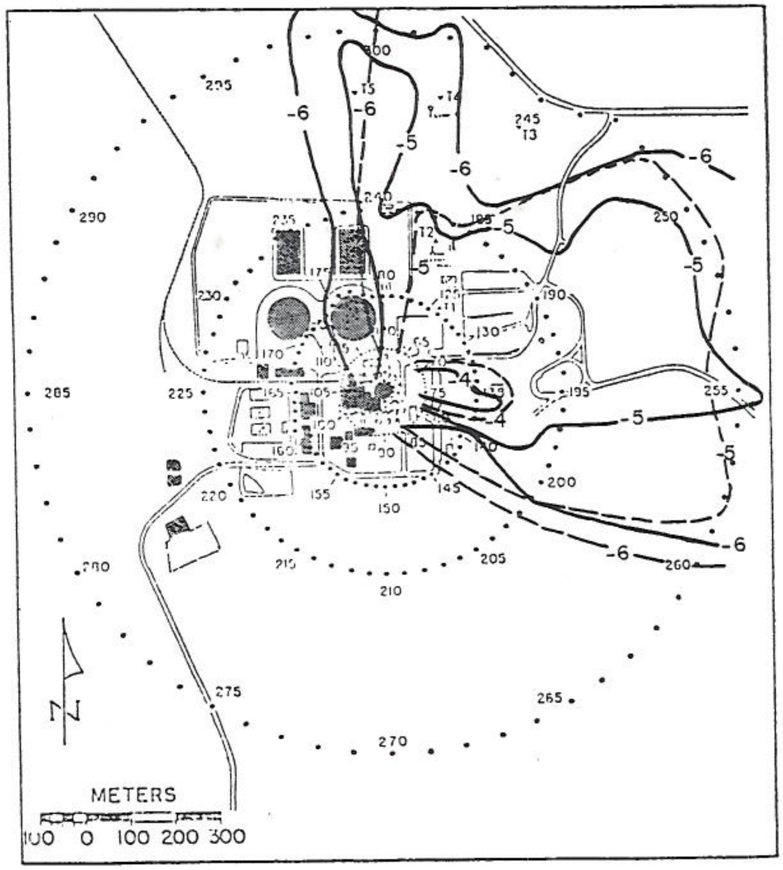


FIG. 4. Comparison of CUQ^{-1} (powers of 10) for test 21:G17. Tracer was released at surface position G17 under NRC stability category G. Mean tower wind at release height was from 262° at 2.3 m s^{-1}.



- - - - - Estimated concentration using wind-tunnel data.

———— Field concentration.

FIG. 5. Comparison of concentration isopleths CUQ^{-1} (powers of 10) for test 21:G5. Tracer was released at surface position G5 under NRC stability category G. Mean tower wind at release height was from 262° at 2.3 m s^{-1}.

weighted concentration averages from the wind-tunnel data. For each 2 min 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 was selected at the release height.

b. 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.

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 Fig. 2.

Wind-tunnel concentration data are tabulated by Allwine *et al.* (1978) in a nondimensional form as

$$K_m = \frac{CUA}{Q},$$

where C is the concentration (g m^{-3}), U the upwind velocity at the release height (m s^{-1}), A the characteristic area (m^2) and Q the emission rate (g s^{-1}).

The weighted wind-tunnel concentration data in this paper, however, are presented as

$$\chi = \frac{\bar{C}\bar{U}}{\bar{Q}} \, [m^{-2}]$$

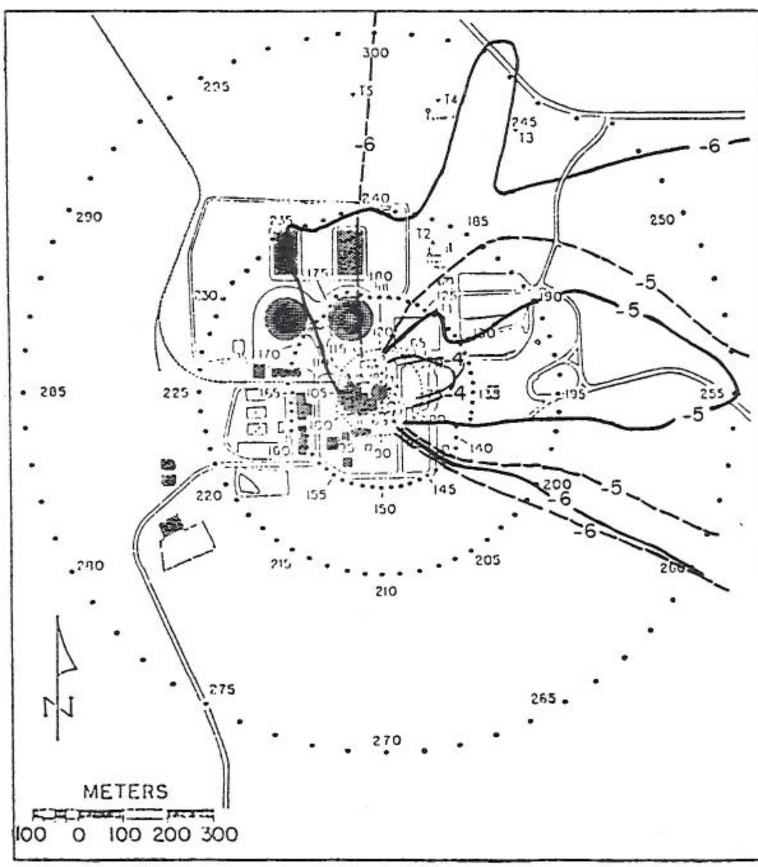
which corresponds to the convention for wind and source strength normalized field-concentration data provided by Start *et al.* (1977).

4. Results

The algorithm developed in Section 2c2 has been incorporated into a computer program to predict hourly average concentrations as measured at the Rancho Seco facility 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 min interval meteorological records taken during the field tests to produce a series of synthesized 1 h average concentration data.

Figs. 3 and 4 show the results of the weighted laboratory data calculations. In Figs. 5 and 6 the comparison of field and algorithm calculated concentration isopleths are shown. Similar results also were obtained for other tests and are described by Bouwmeester *et al.* (1979). This model shows considerable improvement over direct comparison of 1 h average field data to 10 min equivalent laboratory measurements. The weighting algorithm is generally more realistic in predicting centerline values as well as the horizontal spread of the plume. The weighted-average method is generally conservative as compared with the field data. Notice the fine details the model produces in Figs. 3–6.

The maximum ground-level concentration coefficients CUQ^{-1} for tests 7:G5, 12:G5, 14:G5, 15:G5, 17:G5, 18:G5, 17:G17, 18:G17, 7:A, 12:A, 14:A and 15:A are presented in Table 1. Table 1 records measured field data by Start *et al.* (1977), Pasquill-Gifford (PG) calculated values as presented by Start *et al.* (1977), PG values from Slade (1968), wind-tunnel measured values by Allwine *et al.* (1978), and algorithm values in columns a, b, c, d and e, respectively. The table also compares each method with



- - - - - Estimated concentration using wind-tunnel data.

———— Field concentration.

FIG. 6. Comparison of concentration isopleths CUQ^{-1} (powers of 10) for test 21:G17. Tracer was released at surface position G17 under NRC stability category G. Mean tower wind at release height was from 262° at 2.3 m s^{-1}.

TABLE 1. Comparison of field data with various prediction techniques.

Case$_f$ (Case$_m$)	Release location	U (m s^{-1})	$\bar{\theta}_f$ ($\bar{\theta}_m$)	Ri$_f$ (Ri$_m$)	PG$_f$* (PG$_m$) [NRC$_f$]	Arc (m)	$CUQ^{-1} \times 10^6$ m^{-2} a	b	c	d	e	b/a	c/a	d/a	e/a
7	G5	4.6	342	−1.35	A	100	608	833	4000	395	250	1.37	6.58	0.65	0.41
(17)			(360)	(−0.32)	(C)	200	182	21.4	1000	179	140	1.18	5.49	0.98	0.77
					[A]	400	71.5	46.5	270	130	80	0.65	3.78	1.82	1.12
						800	47.7	6.7	70	63	33	0.14	1.47	1.32	0.70
12	G5	1.3	349	0.0	D	100	159	14561	9000	336	230	91.6	56.60	2.11	1.44
(1)			(360)	(0.0)	(D)	200	45.1	4366	1270	175	140	96.8	28.16	3.88	3.10
					[E]	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	0.96
14	G5	0.9	109	0.64	F	100	146	—	52000	726	70	—	356.16	4.97	0.48
(12)			(90)	(0.35)	(E)	200	64.5	10158	12000	463	40	157.49	186.05	7.18	0.62
					[G]	400	34.4	3057	3500	153	13	88.87	101.74	4.45	0.38
						800	6.8	963	980	123	8	141.62	144.12	18.09	1.18
15	G5	0.8	339	−0.66	A-B	100	54.7	—	4000	395	120	—	73.13	7.22	2.19
(17)			(360)	(−0.32)	(C)	200	39.5	2438	1000	178	80	61.72	25.32	4.50	2.02
					[D]	400	6.3	712	270	130	42	113.02	42.86	20.63	6.67
						800	18.6	216	70	62.7	17	11.61	3.76	3.37	0.91
17	G5	2.0	50	8.23	G	100	653	—	52000	880	470	—	79.63	1.35	0.72
(11)			(45)	(0.35)	(E)	200	270	10160	12000	550	295	37.63	44.44	2.04	1.09
					[G]	400	156	3052	3500	257	102	19.56	22.43	1.65	0.65
						800	66	962	980	170	62	14.58	14.85	2.58	0.94
18	G5	0.7	251	∞	G	100	127	—	52000	690	540	—	409.45	5.43	4.25
(16)			(270)	(0.35)	(E)	200	19.8	10157	12000	431	420	512.96	606.06	21.76	21.21
					[F]	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	G17	2.0	50	8.23	G	100	1250	32637	52000	1000	580	26.11	41.60	0.80	0.47
(11)			(45)	(0.35)	(E)	200	702	10157	12000	658	300	14.47	17.09	0.94	0.43
					[G]	400	451	3053	3500	318	120	6.77	7.76	0.71	0.27
						800	21.2	985	980	177	68	46.46	46.22	8.35	3.21
18	G17	0.7	251	∞	G	100	23	32637	52000	1012	750	1419	2260	44.0	32.61
(16)			(270)	(0.35)	(E)	200	10.6	10161	12000	476	410	958	1132	44.91	38.67
					[F]	400	2.1	3051	3500	218	200	1452	1667	103.81	95.24
						800	0.3	945	980	99	96	3150	3266	330.0	320.0
7	A	5.1	322	−1.35	A	100	286	835	4000	456	300	2.92	13.99	1.59	1.05
(24)			(360)	(−0.32)	(C)	200	136	215	1000	188	125	1.58	7.35	1.38	0.92
					[A]	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	A	1.7	345	0.0	D	100	28.2	14562	9000	513	200	516	319.15	18.19	7.09
(1)			(360)	(0.0)	(D)	200	27.9	4366	1270	301	150	156.49	45.52	10.79	5.38
					[E]	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	A	2.3	121	0.64	F	100	54.4	32585	52000	635	300	599	955	11.67	5.51
(13)			(135)	(0.35)	(E)	200	42.6	10160	12000	444	190	238	282	10.42	4.46
					[G]	400	125	3053	3500	168	72	24	28	1.34	0.58
						800	7.64	962	980	59	36	399	128	7.72	4.71
15	A	1.3	357	−0.66	A-B	100	17	8443	4000	284	122	496	235	16.71	7.17
(17)			(360)	(−0.32)	(C)	200	11.5	2438	1000	275	102	212	86.9	23.91	8.87
					[D]	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 of all data												275	284	18.5	14.1
Average without test 18:G17 and 18:G5												107.8	90.6	6.6	2.5

* Pasquill-Gifford stability condition.
a. Measured by Start *et al.* (1977).
b. PG from Start *et al.* (1977).
c. PG no building from Slade (1968).
d. Measured by Allwine *et al.* (1978).
e. Calculated by algorithm.
f. Field condition.
m. Model condition.

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 section yields better predicted values.

Start *et al.* (1977) observed during the stable runs in flow visualization that in some cases 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 ($Ri_b = \infty$). Unfortunately, layering effects were not modeled in the laboratory measurements and the averages in Table 1 data were calculated excluding these two runs. It is evident that the PG method overpredicts the measured field concentration by ~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. Thus is concluded that the weighted algorithm method is 40 times (ratio b/e in Table 1) more accurate than the conventional Pasquill-Gifford formulas.

Acknowledgments. This research was conducted under Contract AT(49-24)-0366 with the U.S. Nuclear Regulatory Commission and the financial support received is gratefully acknowledged.

REFERENCES

Allwine, K. J., R. N. Meroney and J. A. Peterka, 1978: Rancho Seco building wake effects on atmospheric diffusion: Simulation in a meteorological wind tunnel. U.S. Nuclear Regulatory Commission Report NUREG/CR-1286, 176 pp.

Bouwmeester, R. J. B., K. M. Kothari and R. N. Meroney, 1979: An algorithm to estimate field concentrations under nonsteady meteorological conditions from wind-tunnel experiments. U.S. Nuclear Regulatory Commission Report NUREG/CR-1474, 85 pp.

Corotis, R. B., 1977: Stochastic modelling of site wind characteristics. Northwestern University Report RLO/2342-77/2, 143 pp.

Halitsky, J., 1969: Validation of scaling procedures for wind tunnel model testing of diffusion near buildings. New York University Report No. TR-69-8, 204 pp.

Hanna, S. R., G. A. Briggs, J. Deardorff, B. A. Egan, F. A. Gifford and F. Pasquill, 1977: AMS workshop on stability classification schemes and sigma curves—Summary of recommendations. *Bull. Amer. Meteor. Soc.* **58**, 1305–1309.

Hino, M., 1968: Maximum ground level concentration and sampling time. *Atmos. Environ.*, **2**, 149–165.

Ogura, Y., 1959: Diffusion from a continuous source in relation to a finite observation interval. *Advances in Geophysics*, Vol. 6, Academic Press, 149–159.

Sagendorf, J. F., and C. R. Dickson, 1974: Diffusion under low wind-speed inversion conditions. NOAA Tech. Memo. ERL-ARC-52, 89 pp.

Slade, D. H., Ed., 1968: *Meteorology and Atomic Energy*. U.S. Atomic Energy Commission, Division of Technical Information, 445 pp.

Start, G. E., J. H. Cote, C. R. Dickson, N. R. Ricks, G. R. Ackerman and J. F. Sagendorf, 1977: Rancho Seco building wake effects on atmospheric diffusion. U.S. Nuclear Regulatory Commission Report NUREG/CR-0454 185 pp.

van der Hoven, I., 1957: Power spectrum of horizontal wind speed in the frequency range from 0.0007 to 900 cycles per hour. *J. Meteor.*, **14**, 160–164.