# WIND-TUNNEL MODEL STUDY OF DIFFUSION - COALPLEX PROJECT

by

R. N. Meroney*
J. E. Cermak*
D. Hill**
J. A. Garrison***

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AE & CI Limited
Carlton Centre
Johannesburg, South Africa

Fluid Dynamics and Diffusion Laboratory
Department of Civil Engineering
College of Engineering
Colorado State University
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*Co-principal investigators, Colorado State University
**Representative AE & CI, South Africa
***Research Engineer, Colorado State University



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## ABSTRACT

Measurements were made in the meteorological wind tunnel of the concentration of gas at selected sampling ports on a 1:500 scale model for selected emission locations above and at the surface upwind of a large industrial complex emitting substantial generated heat. The data obtained include time exposure, still photographs and color motion pictures of smoke from the selected sources. Maps of nondimensional concentrations at 4100 meters downwind in a vertical distribution of sampling positions are included in a table.

The effects of wind speed, source emission rate and surface heat generation are evaluated for both neutral and stable density stratification.

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LIST OF SYMBOLS

| Symbol | Definition | |
|---|---|---|
| $A$ | Area of the projection of a building | $(L^2)$ |
| $C_p$ | Specific heat capacity | $(L^2T^{-2}\theta^{-1})$ |
| $D$ | Stack diameter | $(L)$ |
| $Fr$ | Froude number $\frac{V^2}{g\frac{\Delta\rho}{\rho}D}$ | $(-)$ |
| $g$ | Gravitational constant | $(L/T^2)$ |
| $H$ | Stack height, or effective building height | $(L)$ |
| $\Delta H$ | Plume rise | $(L)$ |
| $k$ | Von Karman constant | $(-)$ |
| $L_{MO}$ | Monin-Obukhov stability length | $(L)$ |
| $L$ | Reference length $D_s/H_s$ | |
| $M$ | Molecular weight | $(-)$ |
| $q$ | Source flow rate | $(L^3/T)$ |
| $Q$ | Source strength | (Curies/T) |
| $R$ | Exhaust velocity ratio $V_S/V_H$ | $(-)$ |
| $Re$ | Reynolds number $\frac{VL}{\nu}$ | $(-)$ |
| $Ri$ | Richardson number $\frac{g\Delta TH}{T\ V^2}$ | $(-)$ |
| $T$ | Temperature | $(\theta)$ |
| $\Delta T, \Delta\theta$ | Temperature difference across some reference distance or layer | $(\theta)$ |
| $U_*$ | Friction velocity | $(L/T)$ |
| $V$ | Mean velocity at some reference height | $(L/T)$ |
| $x,y,z$ | General coordinates--downwind, lateral, upwind | $(L)$ |
| $z_o$ | Surface roughness parameter | $(L)$ |

LIST OF SYMBOLS (continued)

| Symbol | Definition | |
|---|---|---|
| **Greek Symbols** | | |
| $\chi$ | Local concentration | (Curies/$L^2$) |
| $\tau$ | Sampling time | (T) |
| $\theta$ | Potential temperature | ($\theta$) |
| $\sigma$ | Standard deviation of either plume dispersion or wind angle fluctuations | (L)<br>(-) |
| $\nu$ | Kinematic viscosity | ($L^2$/T) |
| $\delta$ | Boundary layer thickness | (L) |
| $\gamma$ | Specific weight | M/($T^2L^2$) |
| $\rho$ | Density | (M/$L^3$) |
| $\Omega$ | Angular velocity | (1/T) |
| $\mu$ | Dynamic viscosity | M/(TL) |
| **Subscripts** | | |
| a | Free stream | |
| s | Stack | |
| m | Model | |
| p | Prototype | |
| max | Maximum | |

## 1.0 INTRODUCTION

Questions involving environmental quality, priority of land use, and public safety have created and will continue to create difficulties in finding acceptable sites for industrial complexes.

In many cases noxious or potentially dangerous effluents are not only released from tall stacks but from line or area sources at ground level associated with building ventilators, storage vessels, or conveyor belts. Normally the degree of concern associated with such situations would be evaluated by handbook, tables, and prescribed procedures for atmospheric dispersion. Frequently, however, these results appear conservative in that they do not consider effects of wind shear, aerodynamically induced mixing due to flow over buildings, or additional dispersion encouraged by the presence of distributed industrial heating or thermal plumes.

A recent case in point concerns the construction of a chemical complex in the vicinity of a highly industrialized area. One possible scenario of effluent release sees transport in stable stratification conditions across this region to a reception location where high effluent concentrations would be a disadvantage. Classical plume transport theory suggests the gases arrive undiluted; yet the release of up to 1300 megawatts of heat near the surface cannot be included into the dispersion picture by any known analytical means. Such complicated situations have in the past yielded to interpretation by laboratory experiment in Meteorological Wind-Tunnel facilities.

### 1.1 Verification of Laboratory Simulation

A primary factor in determing whether these gaseous products are to be a nuisance is the stack design. Under certain conditions it may be necessary to make a release in meteorologically unfavorable situations. Hence, it is necessary to design gas exhaust systems such that adequate dispersion of gaseous materials will occur under any realistic meteorological condition.

It has been a traditional design technique to release the various gases through the top of a tall stack located near the plant or power station, where the stack is at least two and one-half times taller than nearby buildings. Calculation of peak and mean ground concentrations of these gases are then based on some semiempirical model which relates the release rate from an elevated point source to the concentration at some point downwind. Mathematical models have been suggested by Sutton (1947), Hay and Pasquill (1962), Roberts and Cramer (1957). These mathematical models require the assumptions of plane homogeneous atmospheric turbulence and constant mean lateral and mean vertical velocities. These assumptions are satisfied for a point release over a flat undisturbed terrain.

In addition, considerable effort has been made to determine the effects of vertical stack velocity and gas buoyancy on the effective stack release height. Recently Carson and Moses (1967) have reviewed over 15 plume rise formulas constructed to calculate effective stack heights for conditions where there are no effects from local terrain or buildings. They concluded that no available plume rise equation can be expected to accurately predict short-term plume rise. More recent results produced by Briggs (1969) are more optimistic concerning isolated plumes suggesting error bounds for plume rise of ±20 percent.

Often, it is necessary, due to aesthetics, cost, and public relation reasons, to utilize a short to medium height stack. In these cases plume dispersion is sufficiently modified by the presence of the local building structure, ground topography, or surface heating, that the only approach available is one of wind tunnel model tests (Moses, et al. (1964), Halitsky, et al. (1963)).

A number of wind tunnel studies have considered the effects of variations in a single building geometry on plume entrainment and dispersion (Halitsky (1963), Strom et al. (1957), Dickson et al. (1967), Jensen and Frank (1963)). These studies have permitted the speculation of pertinent scaling criteria for model studies of plume excursions near buildings. Model laws will be discussed in greater detail in Section 2.

Since each arrangement of plant and auxiliary buildings or terrain may have separate effects on the generation of mechanical turbulence and mean flow movement, any specific gas dispersion problem will require individual tests. Hence, there exist in the literature descriptions of a variety of different model studies on industrial plants (Halitsky et al. (1963), Kalinske (1945), Davies et al. (1964), Sherlock and Stalker (1940), Hohenleiten and Wolf (1942), Martin (1965), Meroney et al. (1967), Meroney et al. (1968), Cermak and Nayak (1973), etc.). These studies are significant in that their results have been essentially confirmed by either direct prototype measurements or the absence of the gases or dusts the study was directed to remove. Kalinske (1945), Davies and Moore (1964), Hohenleiten and Wolf (1942), and Martin (1965), incorporate such comparisons within their text. Halitsky et al. (1963) has recently been compared with prototype measurements at the National Reactor Testing Station in southeast Idaho (Dickson et al. (1967)). Agreement of the diffusion concentration results were very satisfactory. Martin (1965) favorably compared his wind tunnel study measurements about a model of the Ford Nuclear Reactor at the University of Michigan with prototype measurements.

Indeed, in comparison between calculations based on Sutton's equation, wind tunnel measurements, and field measurements Martin examined three different stratification conditions, two wind directions, and three wind speeds. The wind tunnel and field results were always within a factor of three whereas the analytical prediction for ground concentrations under predicted some cases by five to thirteen orders of magnitude!

Finally, Munn and Cole (1967) have taken diffusion measurements on a power station complex at the National Research Council, Ottawa, Canada, to confirm the general entrainment criteria suggested by the model studies of Davies and Moore (1964).

## 1.2 Purpose and Scope of Study

The purpose of this study then is to determine the concentrations of an effluent released into the atmosphere by one industrial plant complex which will arrive at air intakes of another plant located downwind. A small scale model of the plants was placed in a meteorological wind tunnel capable of simulating the appropriate meteorological conditions. Concentrations of the effluent at and near the downwind plant air intakes were determined by sampling concentrations of tracer gas (Krypton 85) released from sources at the upwind plant. Overall plume geometry and behavior were obtained by photographing smoke discharged from the modeled sources.

The general scope includes determination of how plume behavior is affected by stack location, height, and type, wind speed and thermal stratification of the atmosphere for plumes originating from plant vent stacks, containment vessel leaks, ventilator exhausts, conveyor belts, and storage areas. A wide range of meteorological conditions can be simulated in the meteorological wind tunnel of the Fluid Dynamics and Diffusion Laboratory (FDDL) at Colorado State University. The conditions simulated for this study included the adiabatic lapse rate (thermally neutral flow) and the ground based inversion (stably stratified) situation.

The general scope of the study included the following basic elements:

A. Construction of a 1:500 scale model of an industrialized area centered on a line passing through center of the source plant and the receptor plant air intakes which includes these plants and all intermediate structures.

B. Simulation of all significant sources at the source plant by use of area, line and elevated point emissions.

C. Simulation of all significant heat sources between the source and receptor plants and in the vicinity of the receptor plant.

D. Simulation of significant meteorological variables--one wind direction (from source plant to the receptor plant) and three thermal stratification (neutral, maximum attainable ground-based inversion and one ground-based inversion of intermediate strength).

E. Recording of plume behavior from the various sources by motion picture and still photography of smoke emissions from the simulated sources.

F. Measurement of mean concentration of a radioactive tracer gas (Krypton 85) at an array of points in a vertical plane normal to the mean wind direction and including the receptor plant air intakes for each individual source.

The modelling criteria necessary to simulate atmospheric motions over such a site are presented in Section 2. Details of the model construction and the experimental equipment are described in Section 3. Finally, Sections 4 and 5 discuss the results obtained and their significance.

This report is supplemented by a motion picture (in color) which shows the plume behavior for all stacks for all operating levels and meteorological conditions investigated during the course of this study (see Table 10 for motion picture sequences). A set of black-and-white photographs of each plume realization further supplements the material presented in this paper.

## 2.0 SIMULATION OF ATMOSPHERIC MOTION

The use of a wind tunnel for model tests of gas diffusion by the atmosphere is based upon the concept that nondimensional concentration coefficients will be the same at contiguous points in the model and the prototype and will not be a function of the length scale ratio. Concentration coefficients will only be independent of scale if the wind tunnel boundary layer is made similar to the atmospheric boundary layer by satisfying certain similarity criteria. These criteria are obtained by inspectional analysis of physical statements for conservation of mass, momentum and energy. Detailed discussions have been given by Halitsky (1963), Martin (1965), Cermak et al. (1966). Basically the model laws may be divided into requirements for geometric, dynamic, thermic and kinematic similarity. In addition, similarity of upwind flow characteristics and ground boundary conditions must be achieved.

For this industrial complex study, geometric similarity is satisfied by an undistorted model of length ratio 1:500. This scale was chosen to facilitate ease of measurements, provide a boundary layer equivalent to 300 meters for the atmosphere and minimize wind tunnel blockage. (The ratio of projected area to the area of the wind tunnel cross section should not exceed five percent. The model of the complex at a scale of 1:500 produced a blockage of about one percent in the Meteorological Wind Tunnel.)

### 2.1 Modeling the Neutral Atmosphere Case

When interest is focused on the vertical motion of plumes of heated gases emitted from stacks into a thermally neutral atmosphere the following variables are of primary significance:

$\rho_a$ = density of ambient air

$\Delta\gamma$ = $(\rho_a'-\rho_s)g$--difference in specific weight of ambient air and stack gas

$\Omega$ = local angular velocity component of earth

$\mu_a$ = dynamic viscosity of ambient air

$V_a$ = speed of ambient wind at stack height

$V_s$ = speed of stack gas emission

H = stack height

D = stack diameter

$\delta_a$ = thickness of planetary boundary layer

$z_o$ = roughness heights for upwind surface

Grouping the independent variables into dimensionless parameters with $\rho_a$, $V_a$ and H as reference variables yields the following parameters upon which the dependent quantities of interest must depend:

$$\frac{V_a}{H\Omega},\ \frac{\delta_a}{H},\ \frac{z_o}{H},\ \frac{D}{H},\ \frac{V_a\rho_a H}{\mu_a},\ \frac{\rho_s V_s^2}{\rho_a V_a^2},\ \frac{\rho_a V_a^2}{\Delta\gamma D},\ \frac{\Delta\gamma}{g\rho}$$

The laboratory boundary-layer-thickness parameter $\delta_a/H$ was made approximately equal to that for the atmosphere. A value for this ratio of at least five was established for the highest stacks. Equality of the effects of the surface parameter $z_o/H$ for model and prototype was achieved through geometrical scaling of the stacks and similarity of the upwind velocity profile. Likewise the stack parameter D/H was equal for model and prototype.

Dynamic similarity is achieved in a strict sense if a Reynolds number $\frac{\rho_a V_a H}{\mu_a}$ and a Rossby number $\frac{V_a}{H\Omega}$ for the model is equal to its counterpart for the atmosphere. The model Rossby number cannot be made equal to the atmospheric value. However, over the short distances considered (up to 15,000 ft or 4100 m), the Coriolis acceleration has little influence upon the flow. Accordingly, the standard practice is to relax the requirement of equal Rossby numbers.

Kinematic similarity requires the scaled equivalence of streamline movement of the air over prototype and model. It has been shown in Halitsky et al. (1963) that flow around geometrically similar sharp-edged buildings at ambient temperatures in a neutrally stratified atmosphere should be dynamically and kinematically similar when the approaching flow is kinematically similar. This approach depends upon producing flows in which the flow characteristics become independent of Reynolds number if a lower limit of the Reynolds number is exceeded. For example, the resistance coefficient for flow in a sufficiently rough pipe as shown in Schlicting (1960, p. 521) is constant for a Reynolds number larger than $2 \times 10^4$. This implies that surface or drag forces are directly proportional to the mean flow speed squared. In turn, this condition is the necessary condition for mean turbulence statistics such as root-mean square value and correlation coefficient of the turbulence velocity components to be equal for the model and the prototype flow.

Golden, as cited by Halitsky et al. (1963), found that for flow about a cube for Reynolds numbers above 11,000, there was no change in concentration measurements. The minimum Reynolds number encountered in the present study was ~15,000 based on the model scale of 0.3 mand a minimum velocity of 1 m/sec. Correlation tests of flow about the Rock of Gibraltar flow over Pt. Arguello, California, and flow over San Nicolas Island, California, may be cited as examples of large Reynolds number flows which have been modelled successfully in a wind tunnel (Field and Warden (1933), Cermak and Peterka (1966), Meroney and Cermak (1965)).

Building and building complexes produce nonuniform fields of flow which perturb the regular upstream atmospheric wind profiles. Around each building a boundary layer exists, where the velocity is zero at the surface but increases rapidly to a relatively constant value a short distance from the building wall. Outside of the boundary layer and downstream there exists a region of low velocities and pressures called the cavity. In this region circulations are such that flow may actually reverse with respect to the upstream winds. Surrounding the cavity but extending further downstream is a parabolic region called the wake in which the presence of the building is still evident in terms of deviations of velocity, turbulence, and pressure from conditions found in the upstream atmospheric boundary layer.

The formation of the wake and cavity regions are associated with a phenomena called boundary-layer separation. Under certain conditions the boundary layer actually detaches and enters the flow streaming about the building. This may occur at the corner of a sharp-edged building or on a curved surface if the pressure increases due to a decelerating flow field. The separated boundary layer forms a sheet which completely surrounds the cavity region which contains relatively stagnant fluid. The extent of the cavity region for the source building may be approximated by $5H \cong 150$ m. Based on the measurements of Evans (1957) the effect of alternate wind approach angles to an elongated rectangular complex may extend this to $6H \cong 180$ m.

The need for scaling of the atmospheric mean wind profile was demonstrated by Jensen (1963). Substitutions of a uniform velocity profile for a logarithmic profile results in threefold variation in the dimensionless pressure coefficient downstream of a model building. Such variance in the pressure fields indicates a strong effect of the upstream wind profile on the kinematic behavior of the fluid near the building complex. One of the few tunnels currently capable of generating a turbulent boundary layer thick enough for a 1:500 model scale is the Meteorological Wind Tunnel at Colorado State University. Other investigators have attempted to generate logarithmic profiles in short tunnels by inserting special grids upstream of the test section; however, this technique normally creates a nontypical turbulence field which decays rapidly downstream.

The length scale often used for scaling the velocity profile is the roughness height $z_o$. For flow over flat grassland the dynamic roughness $z_o$ varies from 1 to 2 cm. In a wind tunnel over a smooth surface the effective roughness length may be expected to behave as $0.141\ \nu/U^*$. Thus, for a scale of 1:500 the modeled roughness scale would be smaller than desired by an order of magnitude. In this study, however, suitable roughness was generated by spreading rice randomly on the ground surface. For neutral flow conditions the mean wind velocity profile may be simulated by a power law profile whose exponent, n, has a value in the range from 0.12 - 0.15 (Poll, 1972) i.e.,

$$\frac{u(z)}{u(z_1)} = \left(\frac{z}{z_1}\right)^n .$$

where $z_1$ is some reference height, say $z_1 = H$.

Equality of the parameter $\rho_a V_a^{\,2}/(\Delta\gamma D)$ for model and prototype normally assures one that the plume trajectory in that region dominated by buoyancy will be similar. Often this criteria results in $(V_a)_m$ being too small to satisfy the minimum Reynolds number requirement. In such cases the specific weight difference for the model $(\Delta\gamma)_m$ can be made larger than $(\Delta\gamma)_p$ to compensate for the effect of small geometric scale. Unfortunately when one reduces the model plume density there is the problem that its momentum flux relative to that of the surrounding air is too low if the efflux velocity, $V_s$, is scaled by the same factors as the surrounding air velocity, $V_a$.

Since the prototype plant vent stack, exhaust ventilators, or storage temperatures may be 250°, 200°, and 20°C, respectively, it is not practical to adjust model plume densities by increased temperature or use of helium-air mixtures. However, as most of the source heights are still undetermined a neutrally buoyant plume was emitted horizontally from a variable height stack to simulate final plume rise heights.

To summarize, the following scaling criteria were applied for the neutral boundary layer situation:

1/ $\quad Re = \dfrac{\rho_a V_a H}{\mu_a} > 11{,}000$

2/ $\quad H_p = H_m$

3/ Similar velocity and turbulence profiles upwind.

## 2.2 Modeling the Stratified Atmosphere Case

When air follows a trajectory over a cold surface, the lower layers of the atmosphere are cooled and an inversion develops to a depth of from 30 to 100 m. Yang and Meroney (1970) found that inversion stratification causes smaller transverse spread in a diffusing plume behind a simple model building. The stratification "freezes" the plume growth in the vertical direction once aerodynamic mixing has subsided.

When vertical motion of plumes takes place in an atmosphere with thermal stratification, additional requirements must be met to achieve similarity of the atmospheric motion. These requirements have been discussed previously by Cermak (1971), Yamada and Meroney (1971), and

SethuRaman and Cermak (1973). Similarity of the stably stratified flow approaching the power plant can be achieved by requiring equality of the bulk Richardson number

$$Ri = \frac{\Delta T}{\overline{T}} \frac{H}{V_a^2} g$$

for the laboratory flow and the atmosphere. In this expression, $\Delta T$ is the difference between mean temperature (potential temperature for the atmosphere) at the surface and at the height $H$, $\overline{T}$ is the average temperature over the layer of depth $H$ and $g$ is the acceleration due to gravitational attraction.

For a strongly stable stratified flow it is expected that the power-law coefficient for the velocity profile will increase in magnitude. Sutton reports measurements over an English airfield of coefficient values of 0.44, 0.59, 0.63, 0.62 and 0.77 when the temperature change over a 400 foot depth was 2-4, 4-6, 6-8, 8-10 and 10-12°F, respectively (Sutton, 1953). Panofsky, et al. (1961) have produced a nomogram from diabatic wind profile measurements for the power-law coefficient variation versus surface roughness, $z_o$, and stability length parameter, L, which suggests values for strongly stable situations between 0.25 and 0.6.

Large sources of rejected heat from industrial plants between the source plant and the receptor plant as well as cooling towers and power plants adjacent to the receptor plant have some influence on movement of air transporting gaseous products toward the receptor plant. The associated effect upon dispersion will be accounted for in the physical model by including simulated heat sources at the appropriate locations. Similarity will be achieved by maintaining geometrical similarity and requiring that (SethuRaman and Cermak, 1973)

$$Q_m = Q_p \left(\frac{T_m}{T_p}\right)\left(\frac{V_m}{V_p}\right)^3 \left(\frac{L_p}{L_m}\right)\left(\frac{A_m}{A_p}\right)$$

In this relationship, $Q$ is the heat flux to the atmosphere, $L$ is a reference length in the vertical, $A$ is a surface area heated, $T$ is the average ambient air temperature and $V$ is the ambient air speed (geostrophic wind speed in prototype).

Calculations indicate that the modeled head flux is very sensitive to velocity changes with background stability. Since the velocity near the wall increases rapidly as stability decreases it was not possible to simulate the full effects of surface heating for the intermediate stability. Indeed for a bulk Richardson number of approximately 0.5 heater capacities of the order of kilowatts would be required. This becomes clear during Runs 43-48 which were specifically made to examine the influence of the heat islands on a single release configuration. A second set of measurements, Runs 49-57, were made for the high stability situation to permit slight corrections of the modeled wall heat fluxes to reflect actual velocities measured during the first sequence of tests, Runs 1-42.

## 3.0 TEST APPARATUS

### 3.1 Wind Tunnel

The meteorological wind tunnel (MWT) shown in Figure 1 was used for this study. This wind tunnel, especially designed to study atmospheric flow phenomena, incorporates special features such as an adjustable ceiling, a rotating turntable, temperature controlled boundary walls, and a long test section to permit adequate reproduction of micrometeorological behavior. Mean wind speeds of 0 and 40 m/sec (0 to 90 mi/hr) in the MWT can be obtained. Boundary-layer thickness up to 1 meter can be developed "naturally" over the downstream 6 meters of the MWT test section. Thermal stratification in the MWT is provided by the heating and cooling systems in the section passage and the test section floor. The flexible test section roof on the MWT is adjustable in height to permit the longitudinal pressure gradient to be set at zero. From 2 to 12 m a set of 12 roll-bond aluminum panels were placed on the tunnel floor. These panels were connected to the facility refrigeration system and cooled to approximately 0°C. Fillets were installed in the bottom tunnel corners to cover the plumbing connections and reduce resulting wake turbulence. From 12 m to the end of the test section a permanently installed set of cooling panels were used to also lower the aluminum floor temperature to a level of 0°C. The free stream temperature was raised to a level near 65°C as prescribed by the Bulk Richardson number.

### 3.2 Model

The model consisted of the industrial complexes, the stacks, and the source and receptor buildings constructed from styrofoam or aluminum to a linear scale of 1:500 (see Figs. 2a & 2b). A scale of 1:500

permitted simulation of a 1,000 meter wide strip from the source to the receptor building. The basic flat prairie land topography was reproduced by fixing the model directly to the smooth wind tunnel floor surface and distributing small rice grains (typical diameter 0.2 cm) to represent surface roughness. Buildings which are not heat sources were constructed of styrofoam blocks while those with strong heat rejection were made of aluminum blocks. Heating for the heat sources was provided by area electrical heaters placed upon the wind-tunnel floor. The heaters were isolated thermally from the aluminum wind-tunnel floor by a sheet of asbestos insulation. In some cases as noted in Table 3, the actual heater size available was larger than the estimated heat release region. As a conservative estimate of the effect of the industrial heat release the modeled heat flux was set assuming the areas scaled geometrically. The model was located on the MWT floor at 14 m from the entrance. Location of sampling points and source release points are identified in Figure 3, 4a and 4b.

Metered quantities of gas were allowed to flow from each stack line or area source to simulate the source release in the prototype. Fischer-Porter Flowrator settings were adjusted for pressure, temperature, and molecular weight effects as necessary. When a visible plume was required the gas was bubbled through titanium tetrachloride before emission. When a traceable plume was required a high pressure mixture of Krypton-85 and air was used in place of the compressed air.

### 3.3 Flow Visualization Techniques

Smoke was used to define plume behavior over the power plant complex. The smoke was produced by passing the air mixture through a container of titanium tetrachloride located outside the wind tunnel and transported through the tunnel wall by means of a tygon tube terminating at the stack inlet within the model complex. The plume was illuminated with arc-lamp beams. A visible record was obtained by means of pictures taken with a Speed Graphic camera utilizing Polaroid film for immediate examination. Additional still pictures were obtained with a Hasselblad camera. Stills were taken with camera speeds of one second to identify mean plume boundaries. A complete series of color motion pictures were also taken with a Bolex motion picture camera. Complete sets of these still pictures and motion picture sequences were provided to the sponsor as a separate part of this final report.

### 3.4 Wind and Temperature Profile Measurements

Low speed velocity measurements in a thermally stratified flow field are extremely difficult to make by conventional techniques. For example, a Pitot static tube is suitable for a higher velocity (~100 cm/sec), hot-wire techniques are very sensitive to ambient temperature changes, and a laser doppler velocimeter method was not available for immediate application.

A smoke wire method has been utilized to investigate flow field during thermal stratification. It has been perfected for practical use at the Engineering Research Center, Colorado State University. Figure 5 shows a smoke wire with attached instruments for velocity measurements. The advantage of the smoke wire method is an instantaneous visualization of the velocity profile.

The principle of the technique is to follow photographically a white smoke emitted from a wire when light oil is vaporized. In Figure A is a nichrome wire which is heated electrically, thus vaporizing an oil coating. Oil is dropped down by gravity through an oil outlet B. B is connected to an oil reservoir C and an air bag D which is kept outside of the wind tunnel. Squeezing the air bag pushes the oil in the reservoir through the outlet. To measure velocity profiles quantitatively, several auxiliary devices are necessary: a strobe, a strobe delay system, an electronic counter, a trigger circuit, and a camera. A trigger circuit is connected to the smoke wire, to a strobe through a delay unit, and to an electronic counter. When a start button on the front panel of the trigger unit is pushed, a high voltage (~1500 volts) is applied to the nichrome wire, vaporizing the oil coating. A white smoke is released instantaneously and is carried along by the ambient wind. A typical time-delay photograph is included in Figure 5. The actual velocity profile can be deduced from the picture by use of the recorded time difference between the moment of firing the wire and the moment of the strobe picture.

Measurement of temperature was made with a miniature thermister (Fennal glass coated bead) system constructed by Yellowsprings, Corp. (YSI Model 42 SC). Thermocouples mounted in the MWT aluminum floor were used to monitor boundary temperatures. Table 4 lists all the instrumentation and materials employed in this study.

## 3.5 Gas Tracer Technique

After the flow in a tunnel was stabilized, a mixture of Kr-85 of predetermined concentration was released from model stacks at a required rate. Samples of air were withdrawn from the sample points and analyzed. The flow rate of Kr-85 mixture was controlled by a pressure regulator at the supply cylinder outlet and monitored by Fischer and Porter precision flow meters. Source concentration was 1.086 $\mu c_i$/cc of Kr-85, a beta emitter (half lifetime = 10.3 years). The sampling and detection systems are shown in Figure 5b and described by Cermak and Nayak (1973).

3.5.1 Analysis of Data

Krypton-85 is a radioactive noble gas with a half life of 10.6 years. The gas decays by emission of beta particles with small amounts of gamma rays. The gas has many advantages over the other tracers used in wind tunnel dispersion studies. It is diluted with air about a million times before use, and as such, has properties very similar to those of air. Its detection procedure is fairly simple and direct.

The procedure for analyzing the concentration data was as follows:

1) Counts of the pulses generated in the G.M. tubes and displayed by the ultra scaler counter were recorded for each sample location

2) These counts were transformed into concentration values by the following steps:□

$$\text{Cpm}^* = \text{Cpm} - \text{Background (Cpm)}$$

$$\chi(\mu\mu\ \text{Curie/cc}) = \text{Cpm}^* \times \text{Counting Yield (p Curie/cc/Cpm)}$$

3) For counts over 1,000 a dead time correction△ had to be applied to the readings, and in this case the correction is

$$\text{Cpm}^* = \text{Cpm} - \text{Background}$$

$$\text{Cpm}^* = \frac{\text{Cpm}^*}{1 - 2.00 \times 10^{-6} \times \text{Cpm}^*}$$

$$\chi(\text{p Curie/cc}) = \text{Cpm}^* \times \text{Counting Yield.}$$

4) Average concentration values were determined for the known probe position and then displayed at the proper locations.

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□ p Curie: pico curie ($10^{-12}$ curie)

△ The time taken for the positive space charge to move sufficiently far from the anode for further pulses to occur.

5) The concentration parameter $\chi$ V/Q was then computed at all locations. A sample computation is shown below:

$$q = 600 \text{ cc/min} = 10 \text{ cc/sec}$$

$$Q_{total} = 1.8\ \mu \text{ Curie/cc} \times 10 \text{ cc/sec}$$

$$= 18.0\ \mu \text{ Curie/sec}$$

Let $V = 2$ fps = 60.96 cm/sec, and $\chi = 80$ p Curie/cc. Then

$$\frac{\chi V}{Q} = \frac{80 \times 10^{-6} \times 60.96}{18} \times 10^{4} = 2.71 \text{ m}^{-2}$$
$$(= .25 \text{ ft}^{-2})$$

6) So far the values of the concentration parameter apply to the model and it is desirable to express these values in terms of the field. At the present time there is no set procedure for accomplishing this transformation. The simplest and most straightforward procedure is to make this transformation using the scaling factor of the model. Since

$$1 \text{ m}|_m = 500 \text{ m}|_p,$$

one can write

$$\frac{\chi V}{Q}\Big|_p (\text{m}^{-2}) = \frac{1}{500^2} \times \frac{\chi V}{Q}\Big|_m (\text{m}^{-2})$$

or in terms of the above example,

$$\frac{\chi V}{Q}\Big|_p (\text{ft}^{-2}) = \frac{1}{200^2} \times .25 = 6.25 \times 10^{-6} (\text{ft}^{-2})$$

or

$$\left(\frac{\chi V}{Q}\Big|_p (\text{m}^{-2}) = \frac{1}{500^2} \times 2.71 = 1.084 \times 10^{-5} (\text{m}^{-2})\right)$$

This sample scaling of the concentration parameter from model to field appears to give reasonable results.

### 3.5.2 Errors in Concentration Measurements

Where data is obtained with a scaler counter, the apparent activity of a radioactive source is found by subtracting the background rate from the observed sample-plus-background rate. The background rate is measured separately and has an uncertainty of its own due to random radioactive sources.

If the background is present, the standard deviation in the net counting rate $\sigma_{R_s}$ for a sample is

$$\sigma_{R_s} = \left(\frac{R_{s+b}}{t_s} + \frac{R_b}{t_b}\right)^{1/2}$$

where $R_{s+b}$ is the observed sample-plus-background rate, $R_b$ is the background rate, $t_s$ and $t_b$ are the measurement time for the sample and background, respectively. The standard deviation in the sample rate depends, then, upon both the time for sample measurement and that for background-rate measurement. When $R_{s+b}$ is large in comparison with $R_b$, a long background measurement is not needed to make the error contribution from the background rate negligible. On the other hand, when $R_{s+b}$ is comparable to $R_b$, both $t_s$ and $t_b$ must be very long for small values of $\sigma_{R_s}$. In the present experiments, an effort was made to keep the probable errors in concentration measurements within 10 percent. For this reason the sample counting time and background counting time were manipulated with this end in view. More detailed information on errors in radioactivity measurements can be found in Yang and Meroney (1970).

### 3.5.3 Test Results: Concentration Measurements

Since the conventional point-source diffusion equations cannot be used for predicting diffusion near objects which cause the wind to be nonuniform and nonhomogeneous in velocity and turbulence, it is necessary to calculate gaseous concentrations on the basis of experimental data. It is convenient to report dilution results in terms of a nondimensional factor independent of model to prototype scale.

In Cermak et al. (1966) and Halitsky (1963) the problem of similarity for diffusion plumes is discussed in detail. It is suggested that concentration measurements be transformed to K-isopleths by the formula

$$K = \frac{\chi}{Q/AV_a}$$

where

$\chi$ = sample volume concentration

$A$ = frontally projected area of plant complex

$V_a$ = mean wind velocity at some references height

$Q$ = gas source release rate

This expression is specifically suitable for measurements within the near-wake and cavity region. Data reported herein, however, represent measurements made at equivalent distances of 4100 m from the source plant.

Concentration measurements were made at this downwind distance in the vertical and horizontal planes. Count rates were corrected to concentration in picocuries and compensation was made for Geiger Mueller tube dead time. Since measurements were made at a variety of wind velocities, and source positions, the ground level concentration data has been reported in terms of the ratio $V_a\chi/Q$ which has units of length squared.

For dispersion in a homogeneous flow this should produce similarity for various $V_a$ and Q values. The significance of all results is discussed in the following section.

When interpreting model diffusion measurements it is important to remember that there can be considerable difference between the instantaneous concentration in a plume and the average concentration due to horizontal meandering. The average dilution factors near a building complex will correlate well with wind tunnel dilution factors since the mechanical turbulence of the wake and cavity region dominate the dispersion. In the wind tunnel a plume does not generally meander due to the absence of large scale eddies. Thus, it is found that field measurements of peak concentrations which effectively eliminate horizontal meandering, should correlate with the wind tunnel data (Hino (1968)). In order to compare downwind measurements of dispersion to predict average field concentrations it is necessary to use data on peak-to-mean concentration ratio as gathered by Singer, et al. (1953, 1963). Their data is correlated in terms of the gustiness categories suggested by Pasquill for a variety of terrain conditions. It is possible to determine the frequency of different gustiness categories for a specific site. Direct use of wind tunnel data at points removed from the building cavity region may underestimate the dilution capacity of a site by a factor of four unless these adjustments are considered (Martin (1965)).

An equivalent technique has also been suggested by Hino (1968) who argues the relationship between the maximum of time-mean ground concentration $\chi_{max}$ and the sampling time is $\chi_{max} \sim \tau^{-1/2}$. Field experiments may be compared with wind tunnel data by the formula:

$$(\chi_a)_p = \frac{(\chi_a)_m\, Q_p\, V_p^{-1} h_p^{-2}}{Q_m\, V_m^{-1}\, h_m^{-2}} \quad (\frac{\tau_p}{\tau_m})^{-1/2}$$

where $\chi_a$ is the maximum axial concentration, $Q$ discharge rate of gases from a stack, $V$ wind speed, $h$ effective height of stack, $\tau$ sampling time, and subscripts $p$ and $m$ represent values for a prototype and model respectively. One may assume that $\tau_m$ corresponds to three to five minutes in the atmosphere for the wind tunnel experiment. Pasquill's suggested values for the standard deviations $\sigma_z$ and $\sigma_y$ correspond to 10 minute averages (Turner (1969)). Hence tunnel concentrations could be high by a factor of 1.7 if a 10 minute average is desired, or by a factor of 21.9 if a 24 hour average is desired.

An examination of Singer's results for peak-to-mean concentration ratios suggests the ratio is a function of both stability and boundary surface roughness. Hence for a variation of stratification from unstable to moderately stable the peak/mean concentration ratio may be nearly equal though the sampling time might vary from 30 minutes to three minutes respectively and the power law coefficient in Hino's equation above would vary from -0.6 to -0.3. It is not likely that a decisive interpretation of the effects of plume meandering will be available in the near future; hence, the conservative assumption is often recommended that the wind tunnel measurements correspond to a 30 minute averaging time and, when correcting results to other sampling periods, a power law coefficient of -1/2 be utilized. (A five minute wind tunnel equivalent sampling time results in 24 hour equivalent concentrations 50 percent smaller.)

An alternative approach is to follow the ideas of Gifford (1959) who developed a theory which may be regarded as predictory fluctuation probabilities due to meandering alone. Gifford proposed that the mean concentration at a point is a function of the relative diffusion due to smaller scale eddies which distribute the effluent about an instantaneous mean and the larger scale transport of the entire plume due to meandering caused by larger eddies which moves the center line position of the mean about.

The distribution about the mean and the distribution of the disc centers are assumed of Gaussian form. Following Gifford's reasoning, it is expected that the mean value of $\chi/Q$ averaged over time $\tau$ might be written as

$$\frac{\chi_\tau}{Q} = (2\pi U)^{-1}\left(\sigma_{y_i}^{2} + \overline{D_y^{2}}\right)^{-1/2}\left(\sigma_{z_i}^{2} + \overline{D_z^{2}}\right)^{-1/2} \cdot$$

$$\exp\left[-\frac{y^2}{2(\sigma_{y_i}^{2}+\overline{D_y^{2}})}\right]\left[\exp -\frac{(z-h)^2}{2(\sigma_{z_i}^{2}+D_z^{2})} + \exp -\frac{(z+h)^2}{2(\sigma_{z_i}^{2}+D_z^{2})}\right]$$

where $\sigma_{y_i}^{2}$ and $\sigma_{z_i}^{2}$ are standard deviations of the instataneous plume (as measured in wind tunnel) and $\overline{D_y^{2}}$ and $\overline{D_z^{2}}$ are the standard deviations of the instantaneous plume center line from the $x$ axis over an averaging time $\tau$.

Gifford (1960) subsequently recommended that the dependence of the ratio of peak to average concentrations can be established by formulas such as:

$$\frac{\chi\,\text{peak}}{\chi_\tau} = \frac{\left(\sigma_{y_i}^{2}+\overline{D}_y^{2}\right)^{1/2}\left(\sigma_{z_i}^{2}+\overline{D_z^{2}}\right)^{1/2}}{\left(\sigma_{y_i}^{2}\sigma_{z_i}^{2}\right)^{1/2}} \cdot$$

$$\exp\left[\frac{y^2}{2(\sigma_{y_i}^{2}+\overline{D_y^{2}})}\right] \cdot$$

$$\left\{\exp\left[\frac{(z-h)^2}{2(\sigma_{z_i}^{\ 2}+\overline{D_z^{\ 2}})}\right] + \exp\left[\frac{(z+h)^2}{2(\sigma_{z_i}^{\ 2}+\overline{D_z^{\ 2}})}\right]\right\}$$

$$2\left\{\exp\left(\frac{-h^2}{\sigma_{z_i}^{\ 2}}\right)\right\}$$

Again $\chi_{peak_i}$, $\sigma_{y_i}$, and $\sigma_{z_1}$ are related to the wind tunnel measurement. $\overline{D_z^{\ 2}}$ and $\overline{D_y^{\ 2}}$ must be related to field information such as $\sigma_\theta$ and $\sigma_\phi$ obtained at the site (see Pasquill; 1974, p. 185ff).

# 4.0 TEST PROGRAM AND RESULTS

## 4.1 Test Program

The test program consisted of (1) a qualitative study of the flow field over the industrial complex by visual observation of the smoke plume trajectory released from the sources; and (2) a quantitative study of gas concentrations produced by the release of Kr-85 from the various sources. The test conditions are summarized in Tables 1 and 2. The test program was accomplished in two parts: Phase A involved neutral stratification and Phase B involved stable stratification.

Angular locations of the approach winds are referred to in terms of angles from a nominal north which is shown in Figure 2. Vertical traverse coordinates are measured from the nominal site center shown in the same figure. Unless otherwise noted, the term wind velocity refers to the velocity upstream at a reference height of 1 m. However, a velocity at any reference height is available by referring to the velocity profiles (Figures 6, 7, and 8).

## 4.2 Phase A: Neutral Stratification

### 4.2.1 Test Results: Characteristics of Flow

All the experiments were carried out in the MWT over the range of conditions shown in Tables 2 and 3. The atmospheric boundary layer was modeled to produce a velocity profile equivalent to flow over the open prairie. Figure 6 shows the development of the velocity profile over the model. The profile is conditioned by the building complex as the wind passes over the plant. No comparison of model velocity data with that in the prototype is possible because the latter is not available over a range of height. However, as the model velocity profiles reproduce a power-law behavior with exponents of 0.15 it is expected that the prototype flow effects over the plant complex are adequately represented by the model.

4.2.2 Test Results: Visualization

The visualization test results consist of photographs, sketches, and movie sequences showing the general nature of airflow and diffusion in the vicinity of the complex. A general understanding of wake and cavity flows is necessary for an interpretation of the plume behavior. Complete sets of still photographs supplement this report. Color motion pictures have been arranged into titled sequences, and the sets available are summarized in Table 7.

Turbulent diffusion of gaseous effluents released from a series of area, line, and point sources over the source area were studied. In each case atmospheric and aerodynamic turbulence distributed the visual tracer over several hundred meters vertically and laterally before the plume reached the receptor area. Slight differences could be observed in the initial plume behavior for area, line, and point sources as noted in Figure 11; however, no visual differentiation between source location or type was apparent at the receptor plant.

4.2.3 Test Results: Concentration Measurements

Turbulent diffusion of the gaseous effluent released for some twelve test cases as noted in Table 2 were studied. Krypton-85 concentrations at ground level and in a vertical plane were measured at 4500 m downwind as noted in Figure 4a and 4b. Twenty-five samples were evaluated for each case as noted in the test matrix. All concentration data have been converted to prototype scale levels as explained in Section 3.5.1. The data is recorded herein in dimensional form as $\chi V/Q(m^{-2})$ where $\chi$ is the concentration over the assumed equivalent averaging time for laboratory measurements, Q is the source strength, and V is the nominal mean wind velocity at a 300 m reference height.

The results for various sources are presented in Table 8. The coordinates z and y shown in the tables are explained in Figures 4a and 4b. To convert this information to a prototype situation requires an estimate of the velocity at a specified reference height in the prototype and model situation and correction for the effects of desired averaging time.

For the neutral case there are no large maximum concentrations apparent in the plane surveyed. The plumes are all mixed over several 100 meters in depth and lateral extent.

### 4.3 Phase B: Stable Stratification

#### 4.3.1 Test Results: Characteristics of the Flow

All experiments were carried out in the MWT over the range of conditions shown in Tables 2 and 3. The atmospheric boundary layer was modeled to produce a velocity and temperature profile equivalent to flow over an open prairie. Figures 7 and 9 and Figures 8 and 10 show the initial upwind profiles of velocity and temperature for the fully stable and half stable cases respectively. Velocity profiles reduced from repetitive smoke wire realizations over a short time interval were very similar displaying a maximum standard deviation based on the velocity at reference height of only 0.05. Turbulence was essentially absent at surface level as evidenced by the behavior of smoke plumes released over the cooled model surface. For the highly stable case studied the power-law velocity coefficient for the lower equivalent 100 m of the modeled boundary layer was .36, the less stably stratified region above fit a coefficient of .58. The less stable flow case had a power-law coefficient of 0.285. As may be expected for high Richardson numbers the temperature and velocity profiles are not similar. Indeed, since for high positive Richardson numbers ($Ri > 0.15$) the turbulent Prandtl number ($K_M/K_H$) becomes large, the transport of vertical heat flux nearly ceases whereas momentum is still transferred by gravity wave effects. Since all turbulence is suppressed it is doubtful whether a further increase in bulk Richardson number will have significant influence on scalar transport once a critical Richardson number of about 0.25 is exceeded. A bulk Richardson number evaluated over the height from cold surface to 100 m has the value of $Ri_B = 1.18$ for the full stable case and 0.41 for the half stable case.

### 4.3.2 Test Results: Visualization

Stable stratification tended to inhibit vertical growth of the aerodynamic building wake downwind of the source complex. As a result area sources and line sources initially mixed to the height of the source building wake region, but subsequent growth in the vertical was very slow. As the plume passed over or near heated regions the plume was deflected upward momentarily if the heat rate was small or some additional entrainment of clean air occurred if the heat rate for the given region was higher. Thermal turbulence induced by the heated regions did not persist very long, however, and the flow quickly relaminarized once out of the influence of the heated area.

If one compared plumes growth rate with and without the influence of added industrially produced heat one found a significant but not large increase in the size of the plume at the receptor building for the heated cases. Figure 12 displays typical area and line source behavior under stable stratification. As one can note in the bottom plate near ground releases do not mix much above an equivalent height of 50 meters. Elevated releases are not influenced by the building wake effects; hence they usually remain intact over the entire 4100 meter travel distance to the receptor area. Fortunately these elevated releases do not descend and will be left above receptor building intakes.

4.3.3 Test Results: Concentration Measurements

Twenty-five sample locations were prepared at the distance of 4100 meters as before. Measurements of Krypton-85 activity at these locations have been converted to $\chi V/Q$ ($m^{-2}$) prototype per the earlier discussions. The results for two stratification conditions and the various sources are presented in Table 8.

Under stable stratification conditions the plumes emitted remained essentially intact after initial mixing behind the source buildings. As a result of this the concentrations in the receptor plane are an order of magnitude higher than for neutral flows. The lateral and vertical plume scales are generally small and of the same order as the initial source complex wake.

A range of surface heating rates and flow stratification conditions were examined to determine their independent and combined influence. At eighty percent of the predicted modeled heat flux for a bulk Richardson number of ~ 1.2 (Runs 7-18, 31-40) most plumes were deflected toward the rising columns of air forming to the north. At one hundred percent of the predicted heat flux and a slightly lower stability ($Ri_B \approx 1.0$)(Runs 49-57) the plumes did not spread as much laterally; however, since increased vertical mixing occurred in most cases, the resultant concentrations were the same magnitude.

As mentioned in Section 2.2, it was not possible to simulate the total heating rates for the intermediate stability ($Ri_B \sim 0.5$); thus, for a heating rate only one percent of that considered appropriate, the plumes were undeflected and concentrations measured were the same or more for a high stability case with surface heating.

A set of tests (Runs 43-48) were performed for a single release configuration for high and intermediate stabilities with and without surface heating. The results of this sequence of tests indicate highest concentration occur for high stability flow fields without surface heating. Surface heating decreased concentrations by from 0-15 percent for the high stable case. Little change could be found in the results for intermediate stability since heating rates were effectively very low.

## 5.0 CONCLUSIONS

This investigation was undertaken to determine the dispersion of exhaust gases released from various stacks, valves, ventilators, or leaks located near an industrial plant. The primary aim of the study was to determine gas dilution magnitudes, the influence of certain flow field stability, surface heat release, source-height variations, and to provide data for selecting appropriate plant location and source to release configurations. Concentration data for the various test configurations recorded in Table 2 and 3 are found in Table 8.

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FIGURES

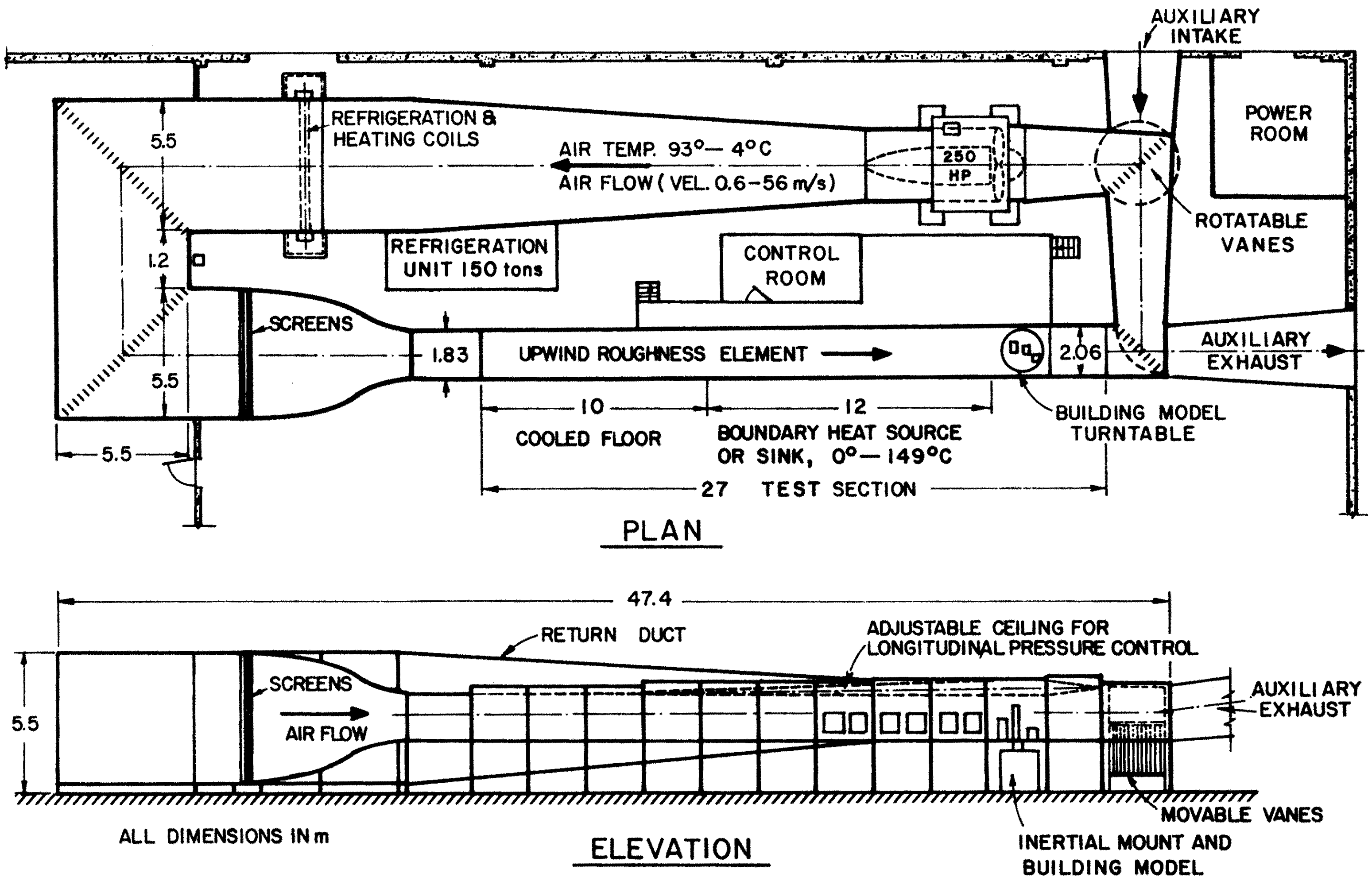



FIG. 1. METEOROLOGICAL WIND TUNNEL (Completed in 1963)
FLUID DYNAMICS & DIFFUSION LABORATORY
COLORADO STATE UNIVERSITY

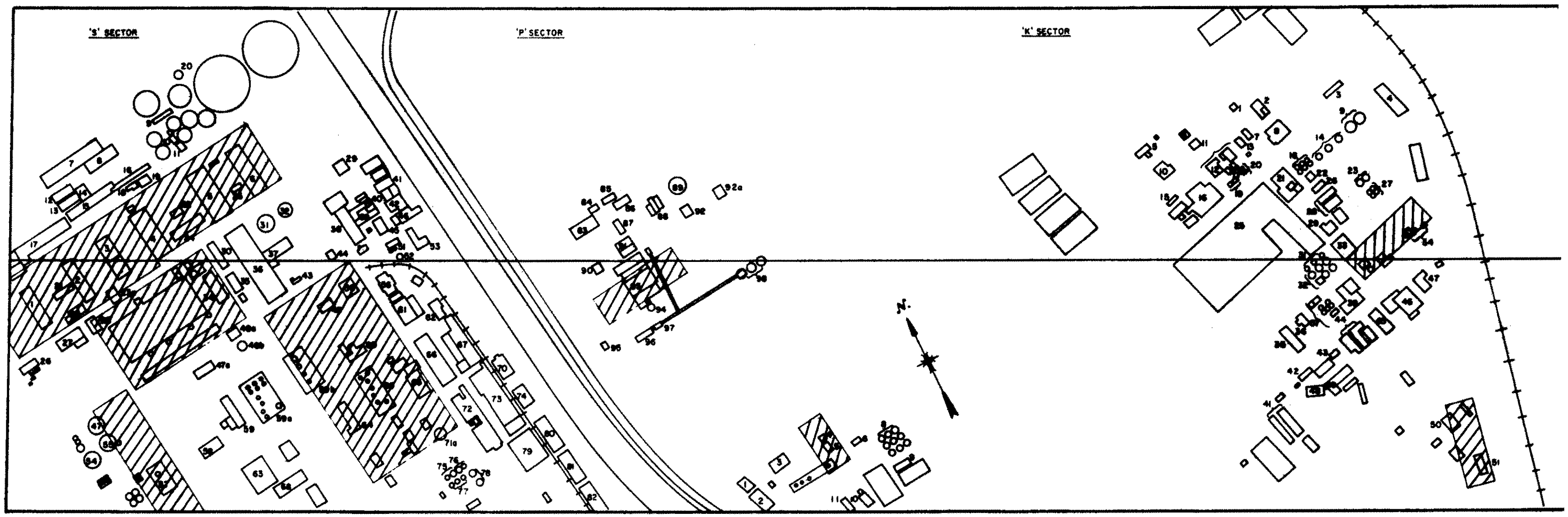



Figure 2a. Industrial Complex Modelled - (See Table 1 for key to buildings and Table 3 for surface heater description.)

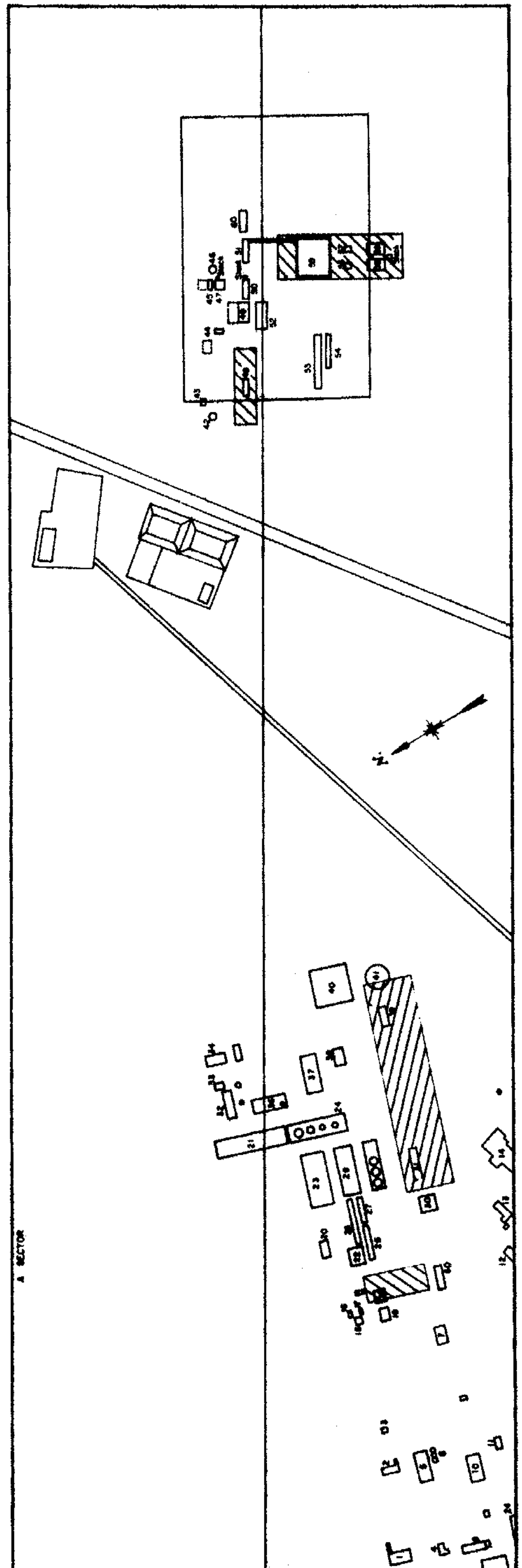
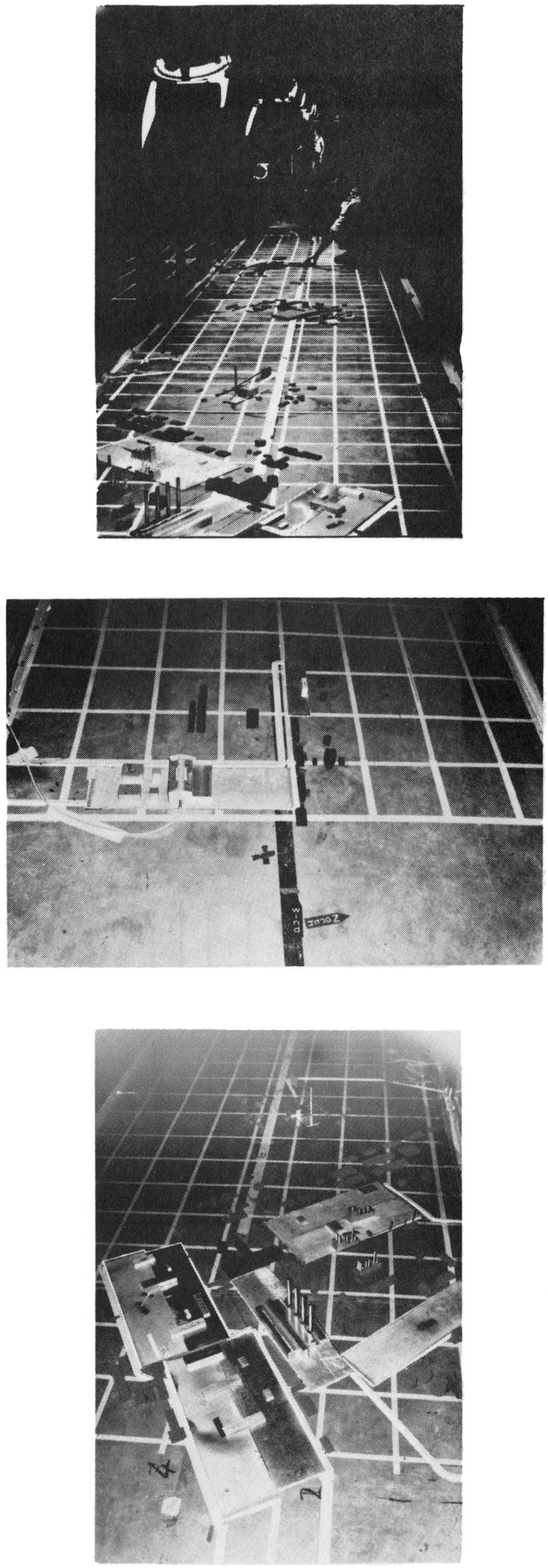


Figure 2b. Industrial Complex Modelled (Continued)



Total area

Source area

Receptor area

Figure 2c. Industrial Area Model

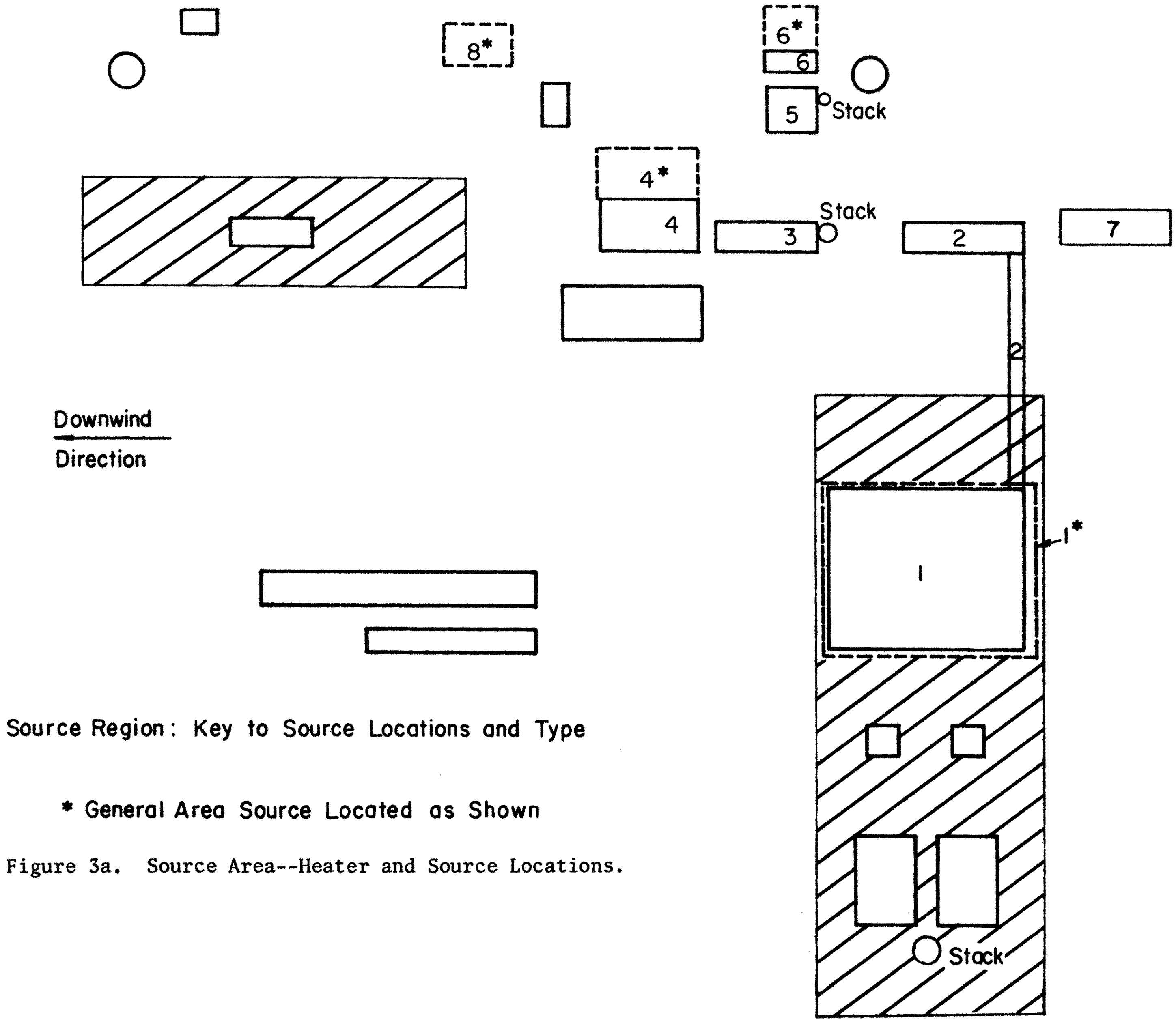



Figure 3a. Source Area--Heater and Source Locations.

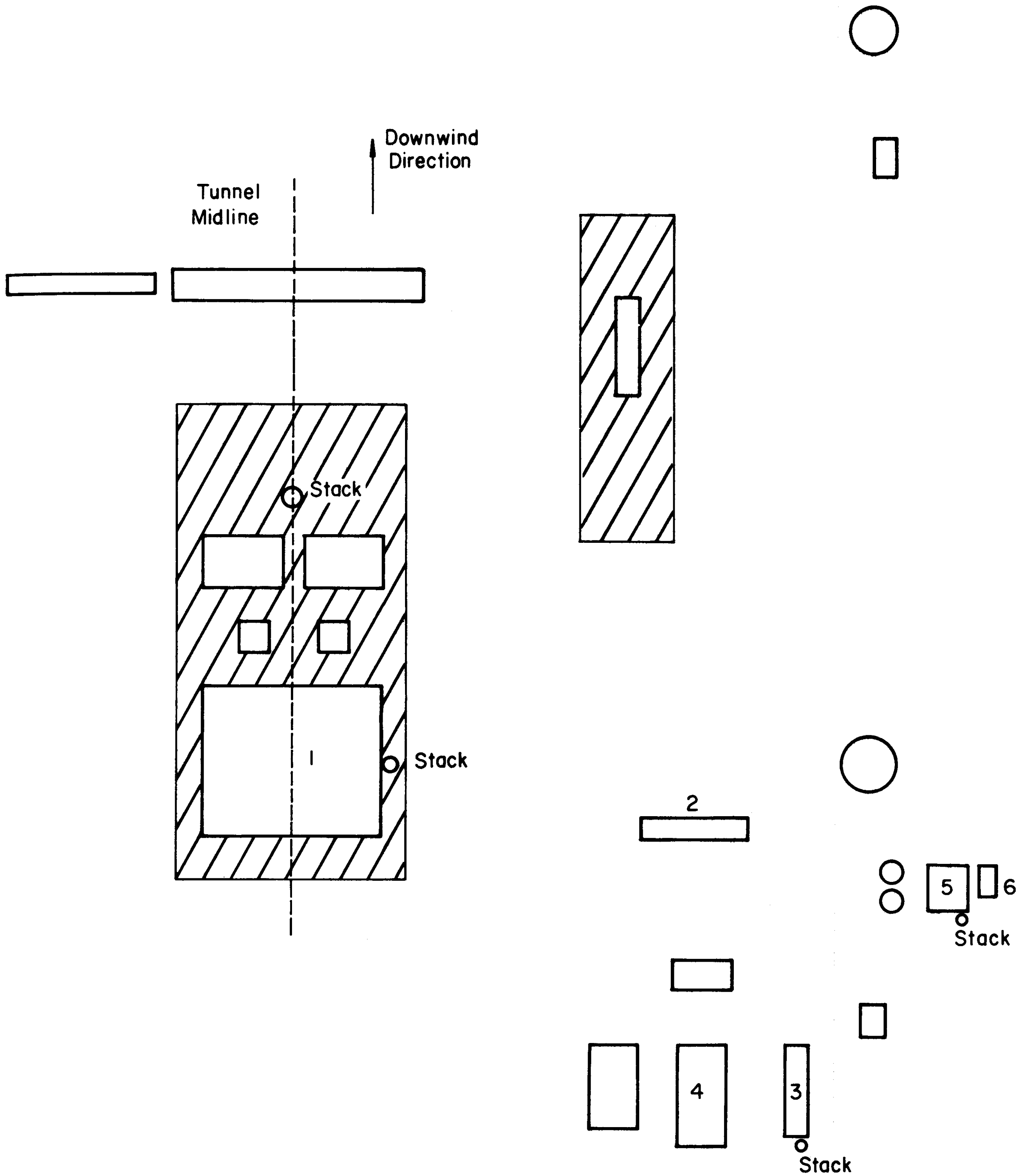



Figure 3b. Plant Reorientation A.

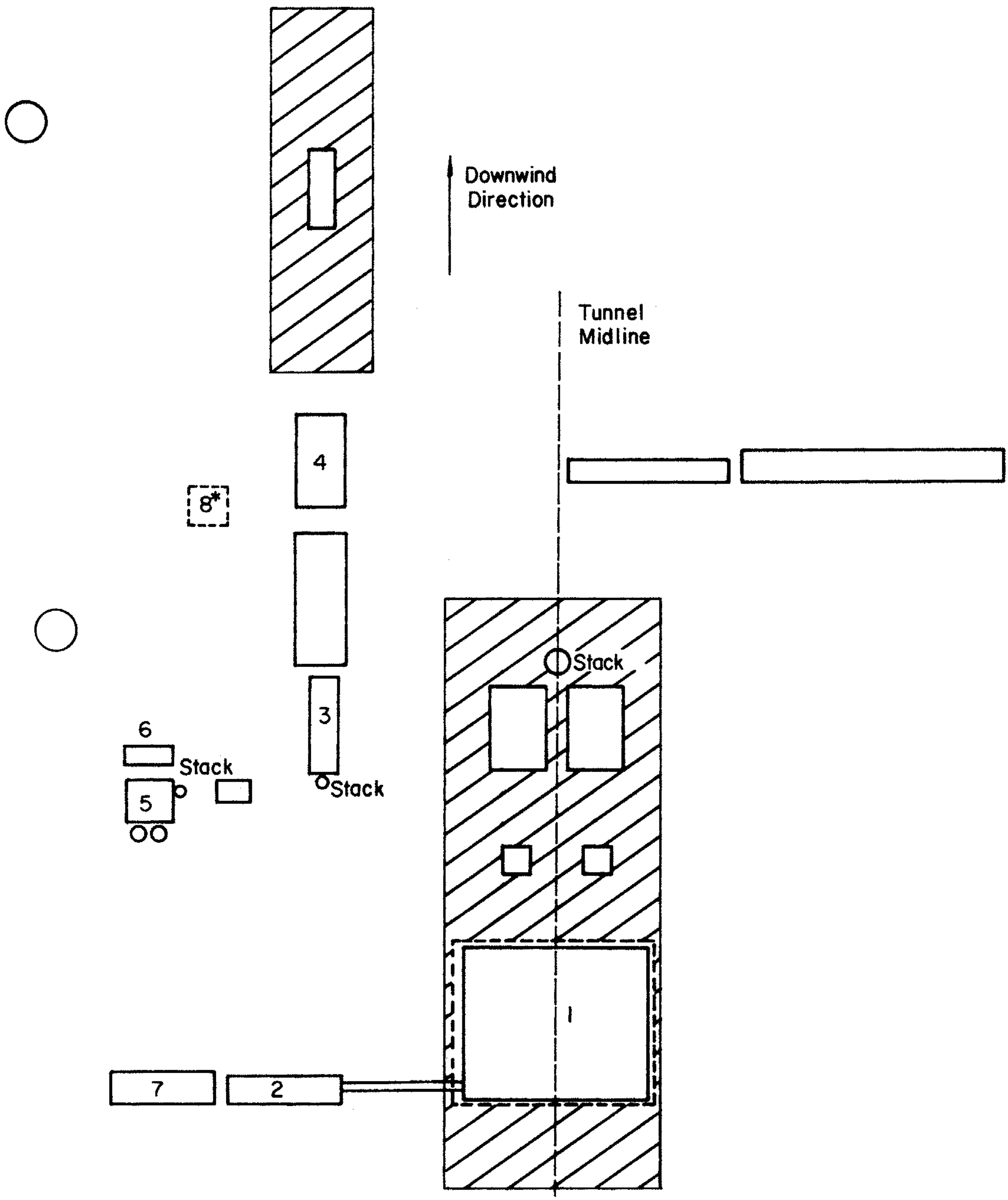



Figure 3c. Plant Reorientation B.

(Nos. adjacent to sampling point
position refers to sample number.)

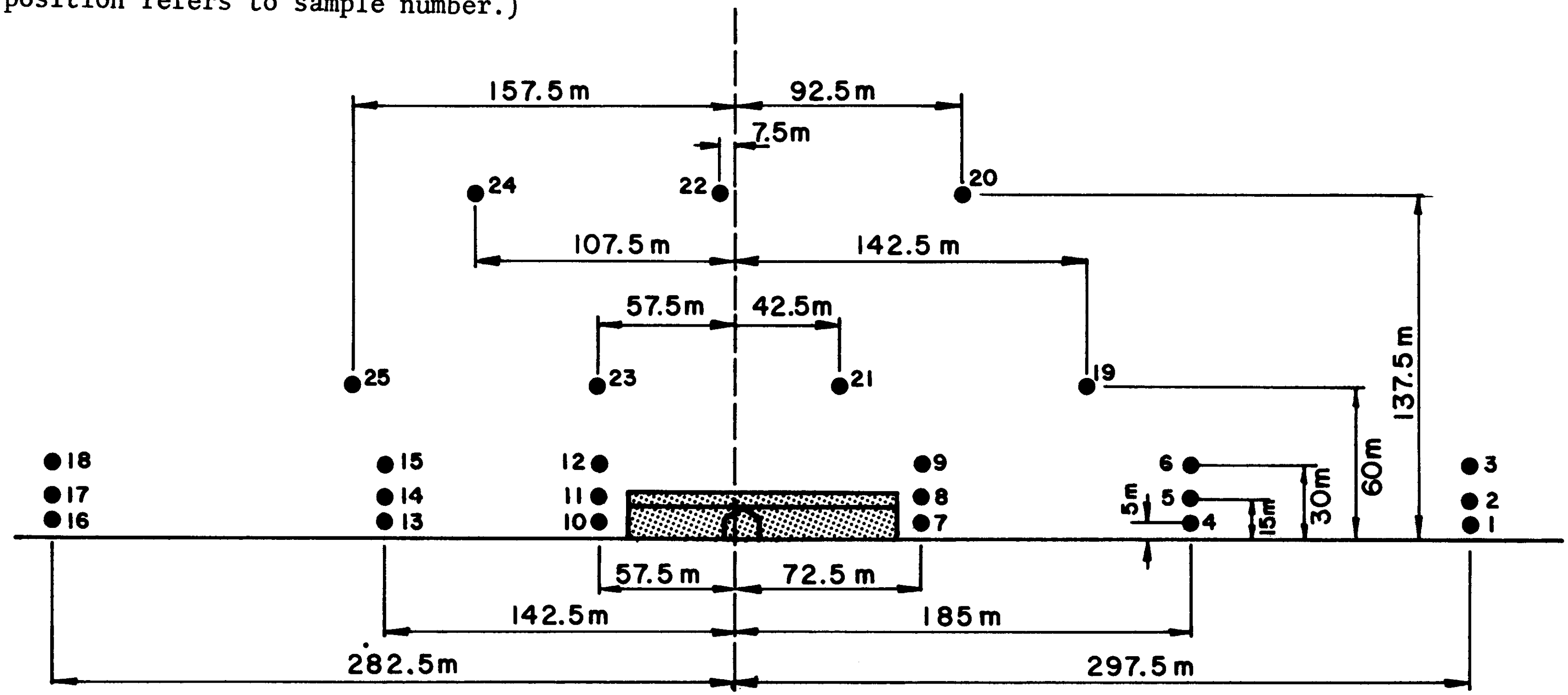



Figure 4a. Sampling Points as Laid Out in Tunnel. Perpendicular Vertical Plane 4.095 km Downwind of Western Edge of Present Position of Furnace Bldg. (Looking W)

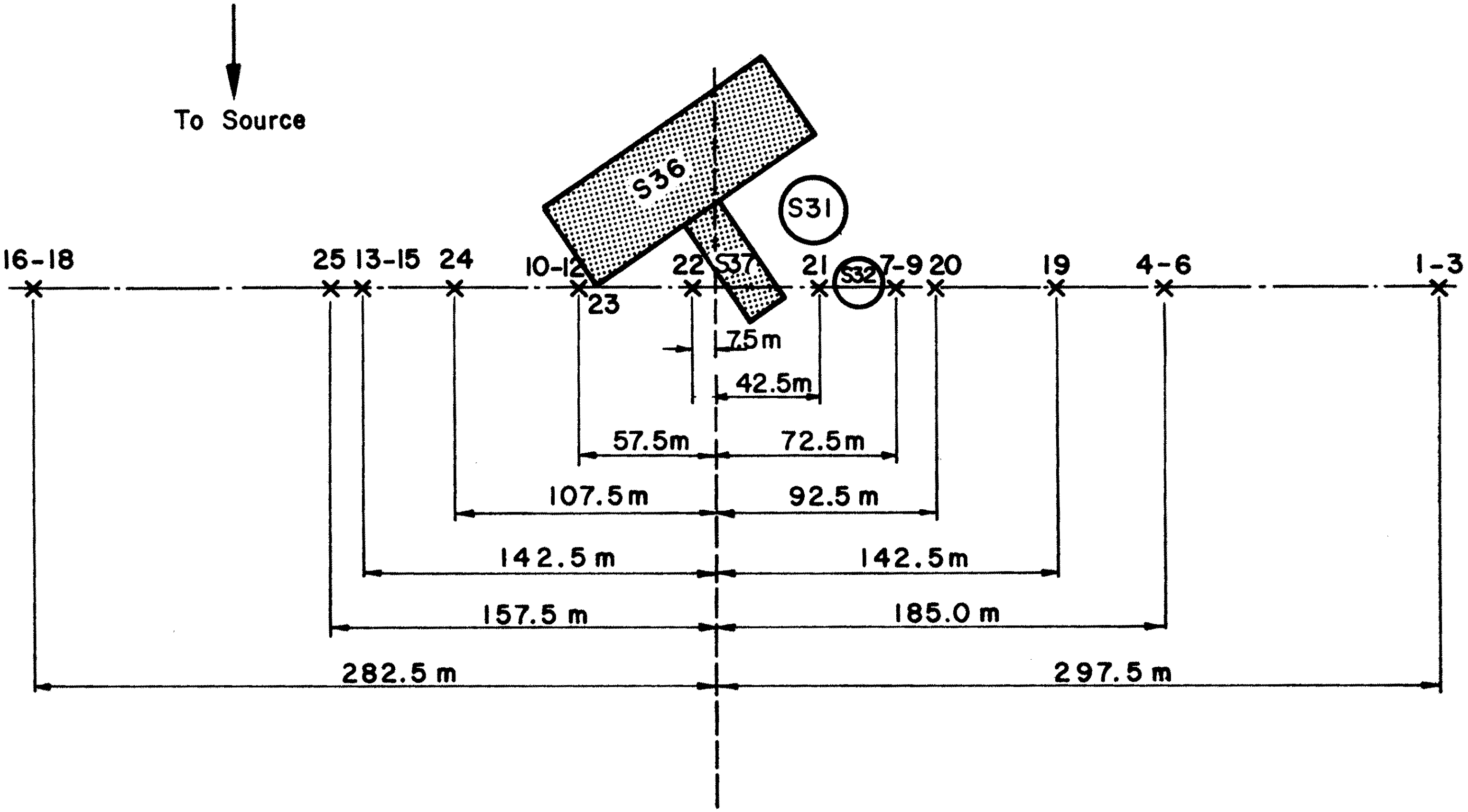



Figure 4b. Sampling Points as Laid Out in Tunnel. Plan View.

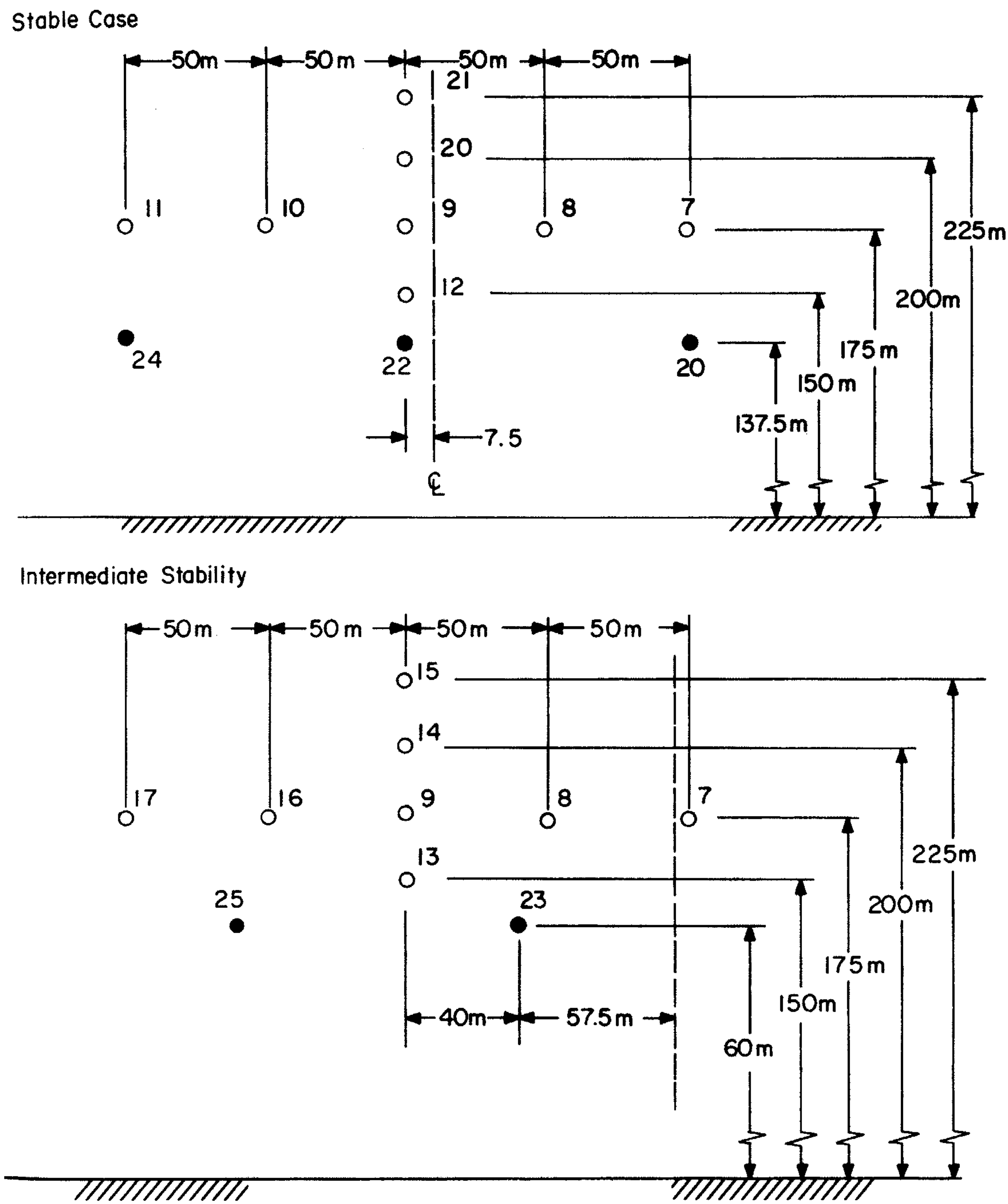
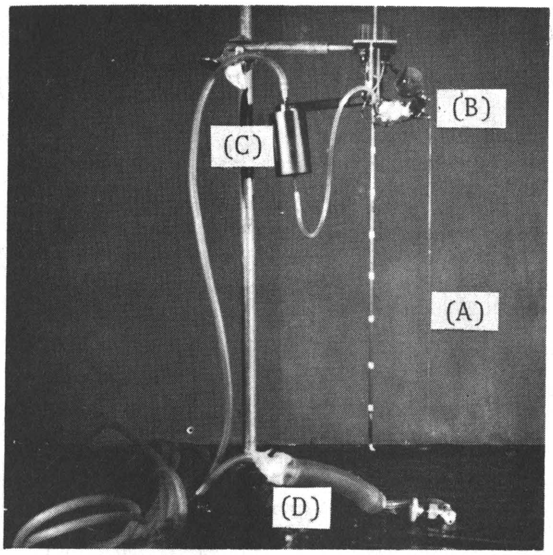
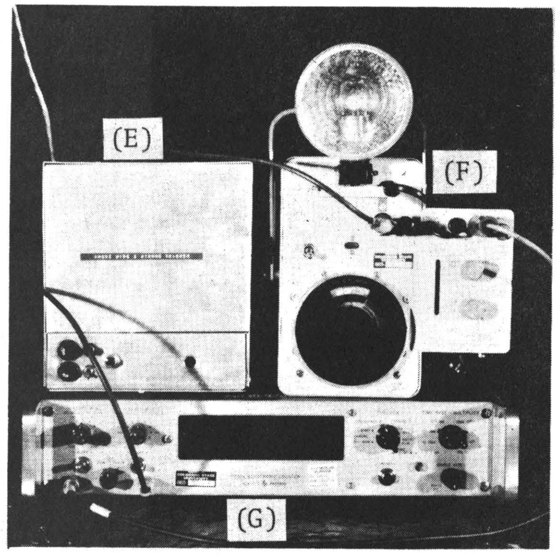



Figure 4c. Sampling Points as Laid Out in Wind Tunnel: Relocated Sample Positions Building 1: Stack Releases




(A) Nichrome Wire

(B) Oil Outlet

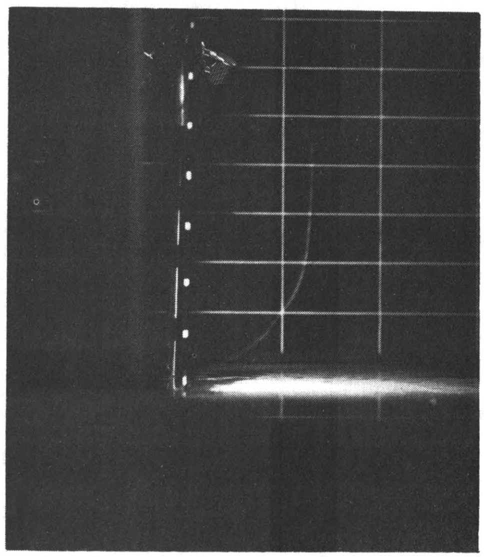
(C) Oil Reservoir

(D) Air Bag

(E) Trigger Circuit

(F) Strobe System

(G) Electronic Counter



A Typical Velocity Profile (Neutral Case)

Figure 5a. Smoke Wire and Attached Instruments for Velocity Measurements. A Typical Velocity Profile is included.

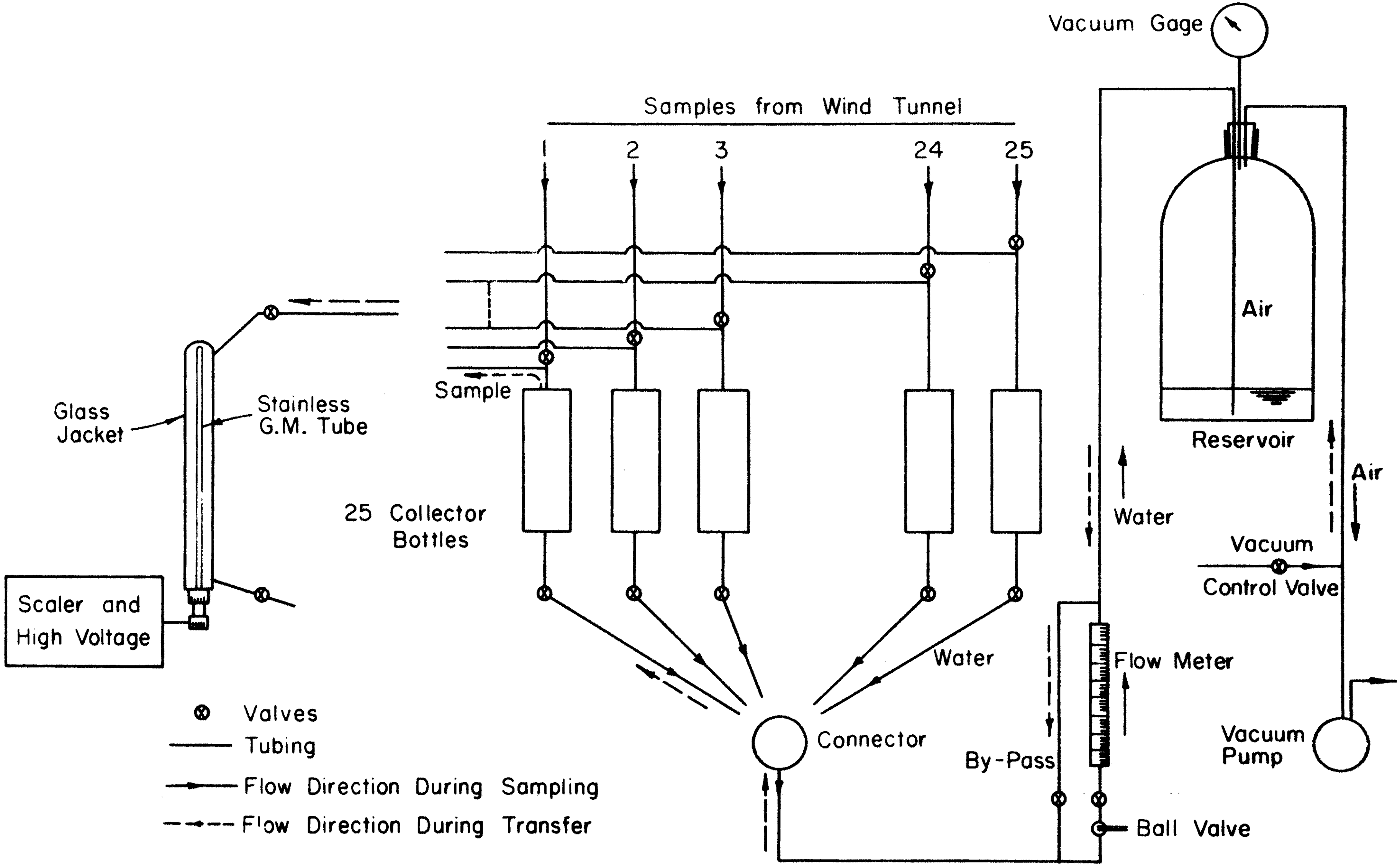
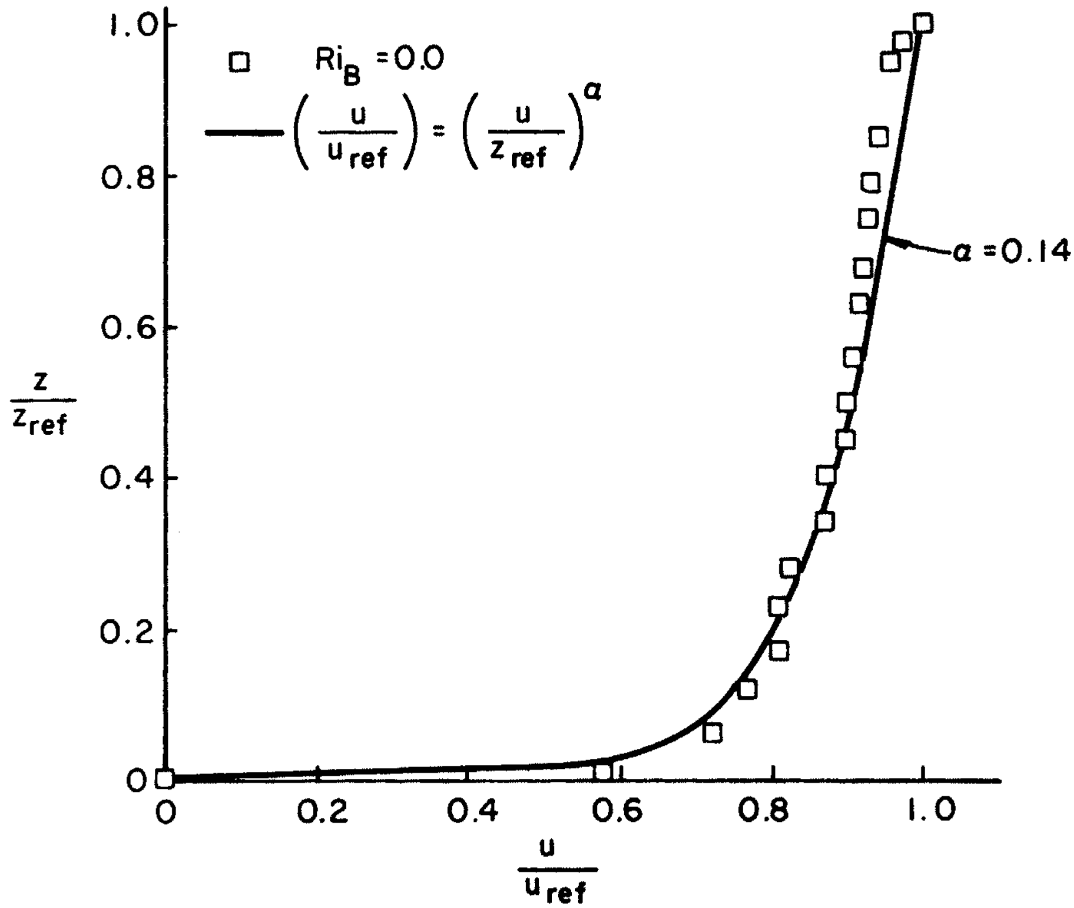



Figure 5b. Tracer-gas Sampling and Analysis System




$z_{ref}$ = 300 m in prototype

= 0.6 m in model

$u_{ref}, T_{ref}$ = Evaluated at $z_{ref}$

Figure 6. Normalized Average Velocity Profile - Neutral Case

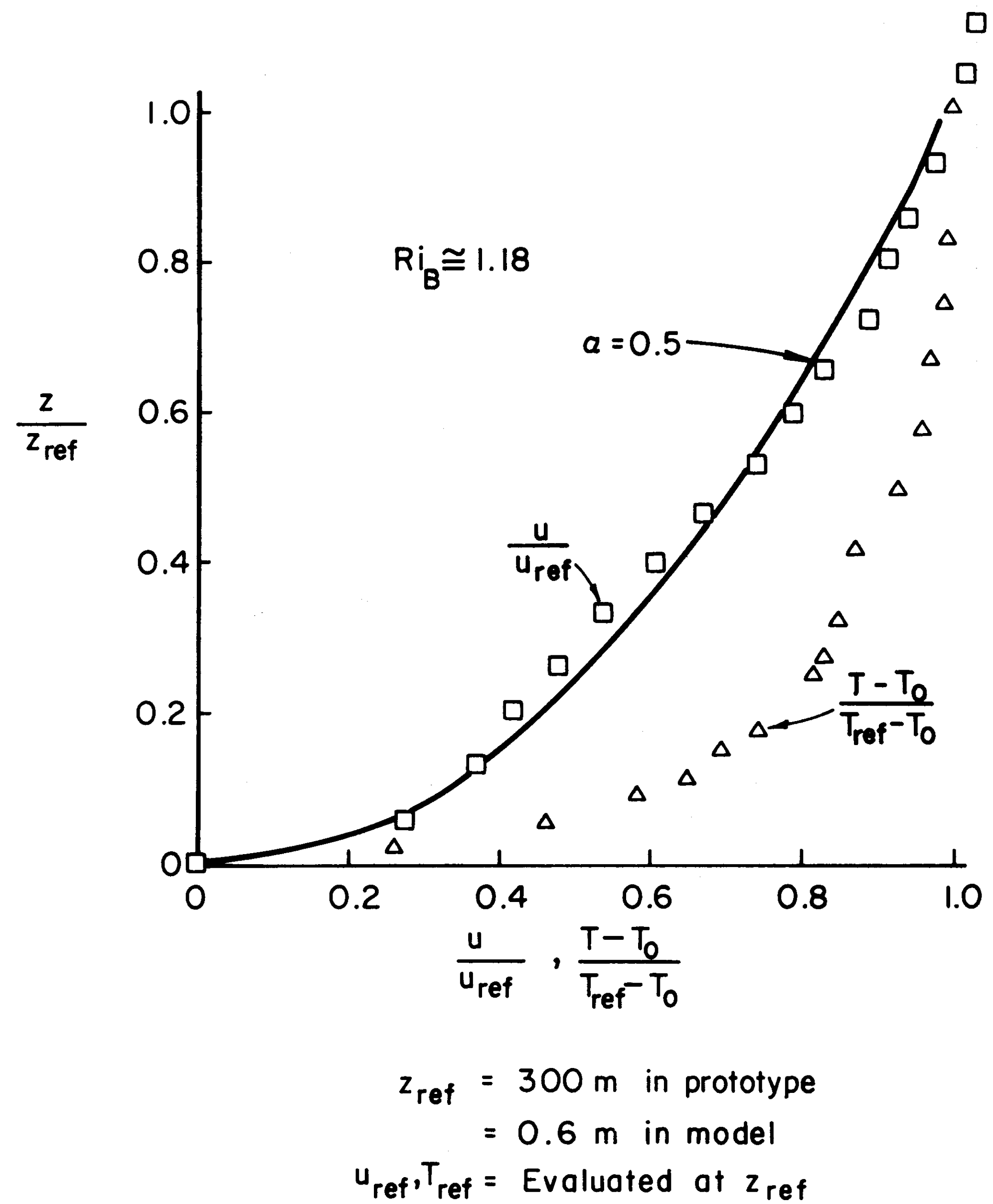



Figure 7. Normalized Average Velocity and Temperature Profiles - Stable Case

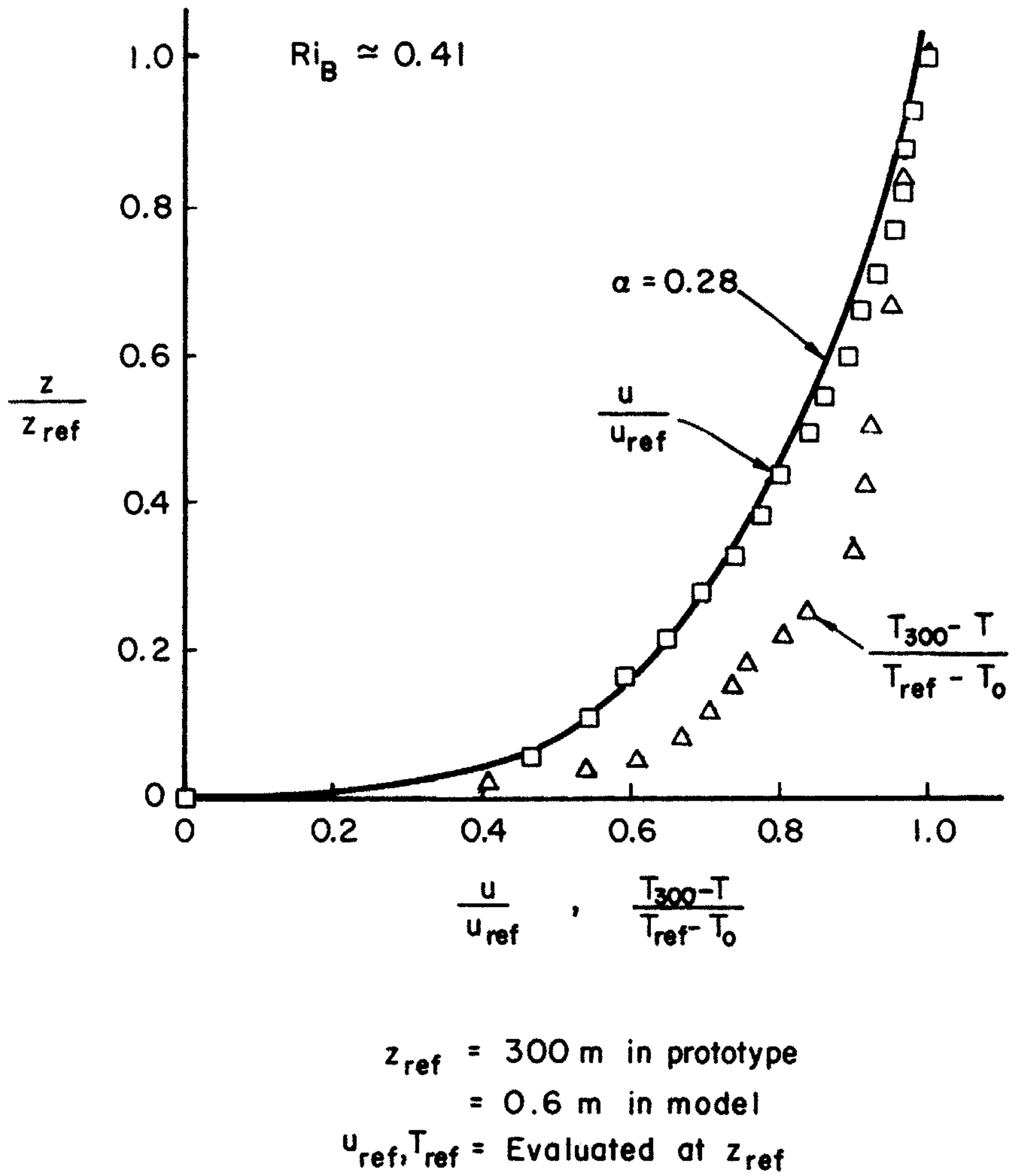



Figure 8. Normalized Average Velocity & Temperature Profiles - Intermediate Stable Case

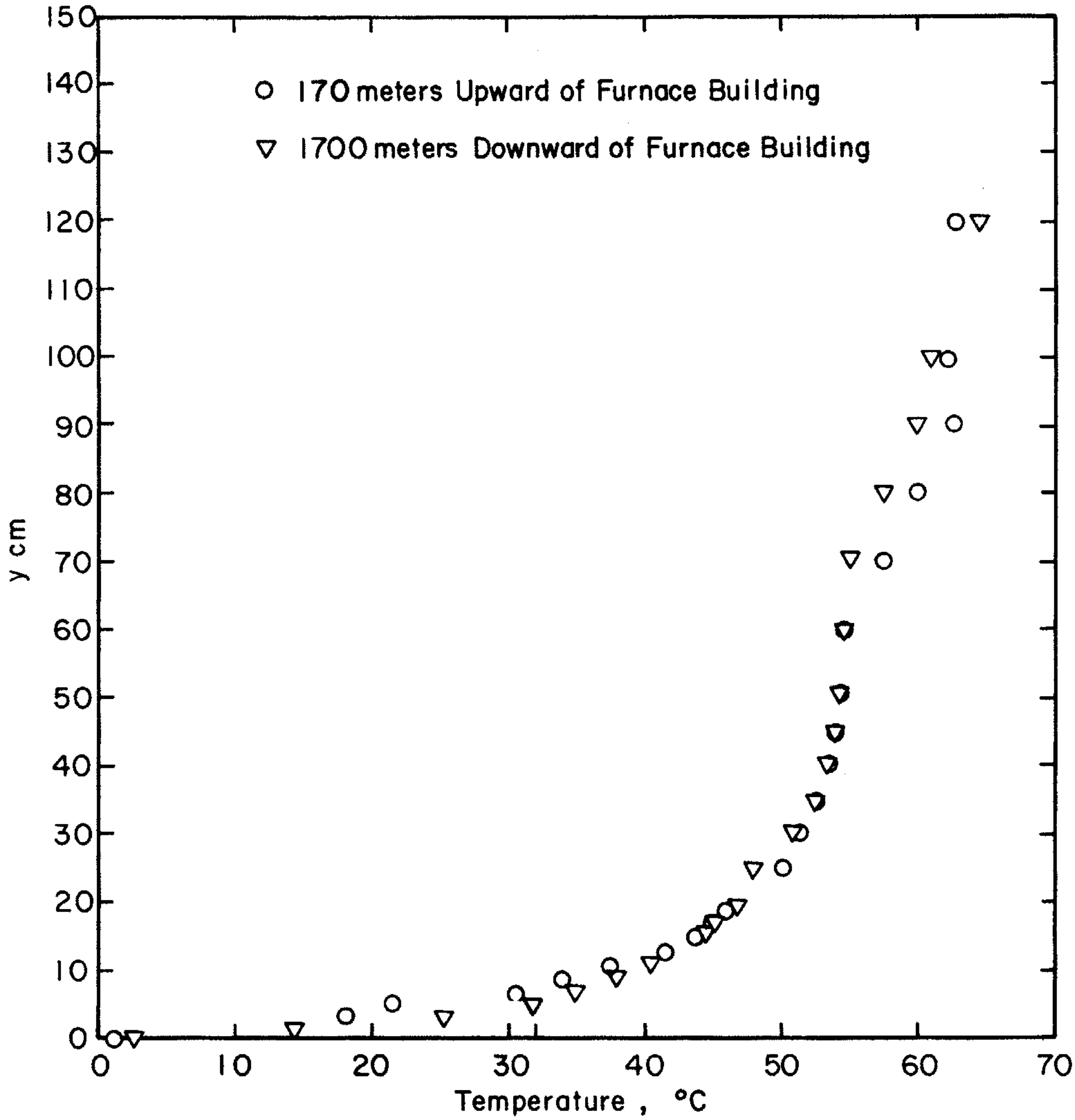



Figure 9. Vertical Temperature Profiles Measured in Wind Tunnel for Maximum Stability Case

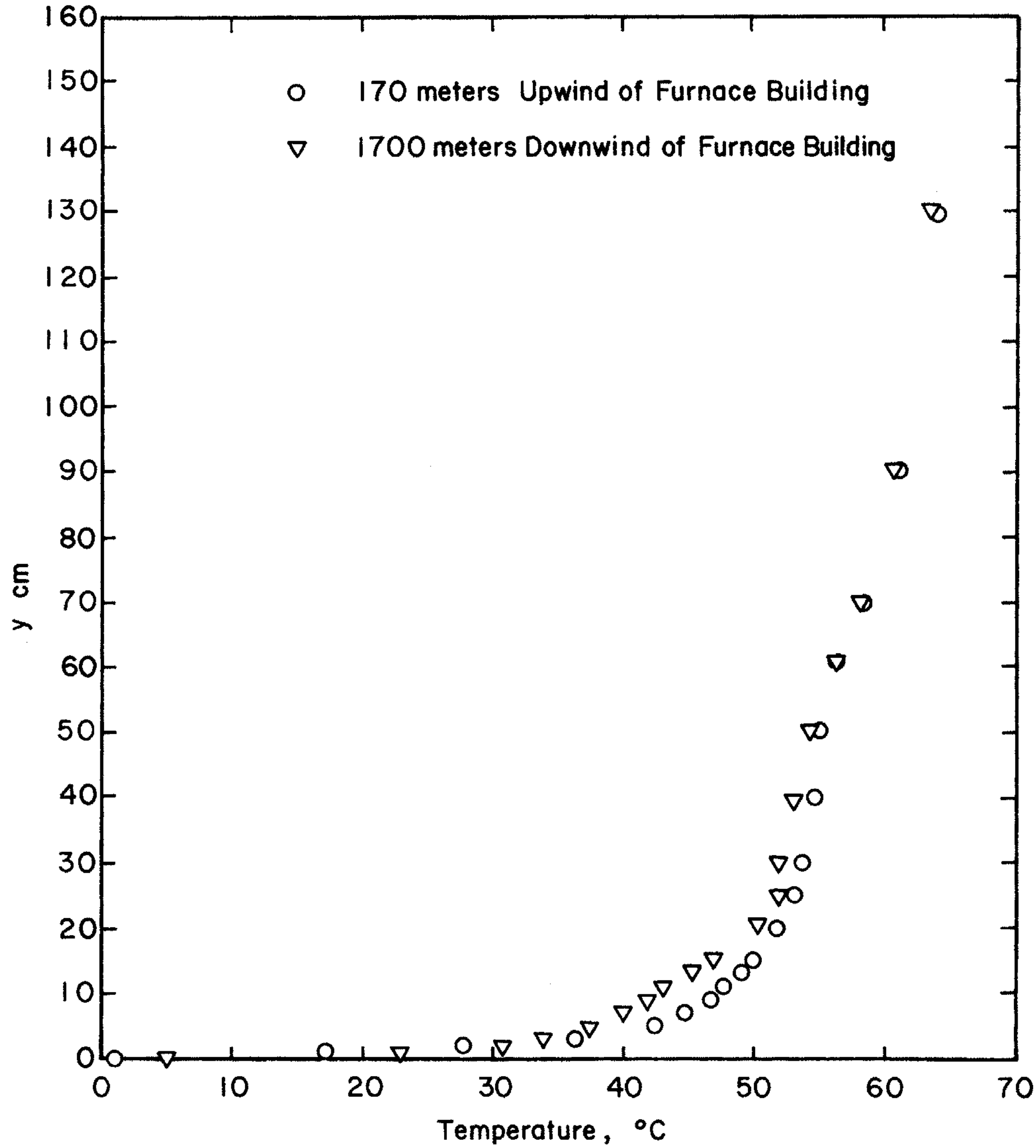



Figure 10. Vertical Temperature Profiles Measured in Wind Tunnel for Intermediate Stability Case

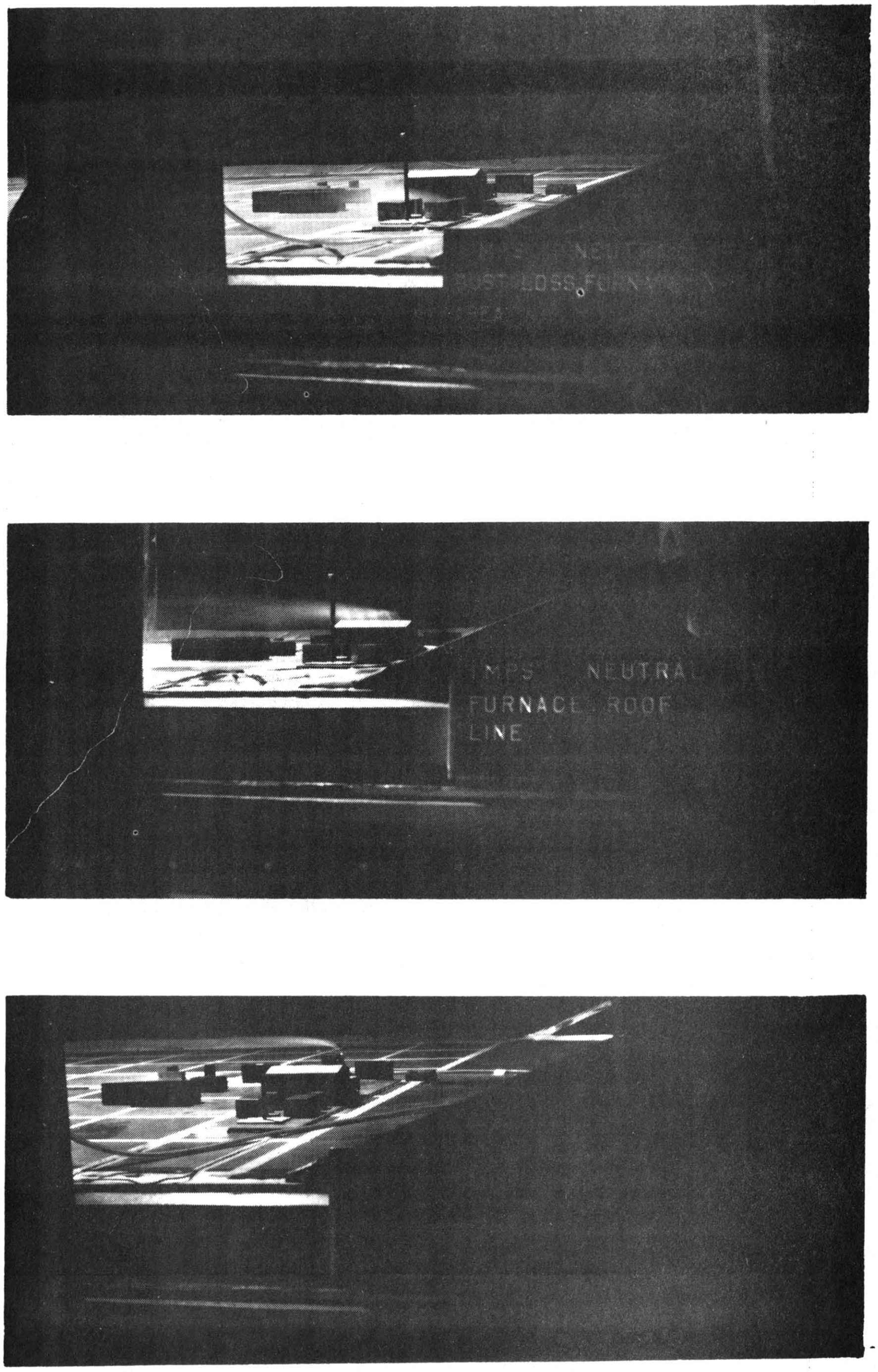



Figure 11. Typical Appearance Source Region: Area, Line, and Point Releases 8 Neutral Stability

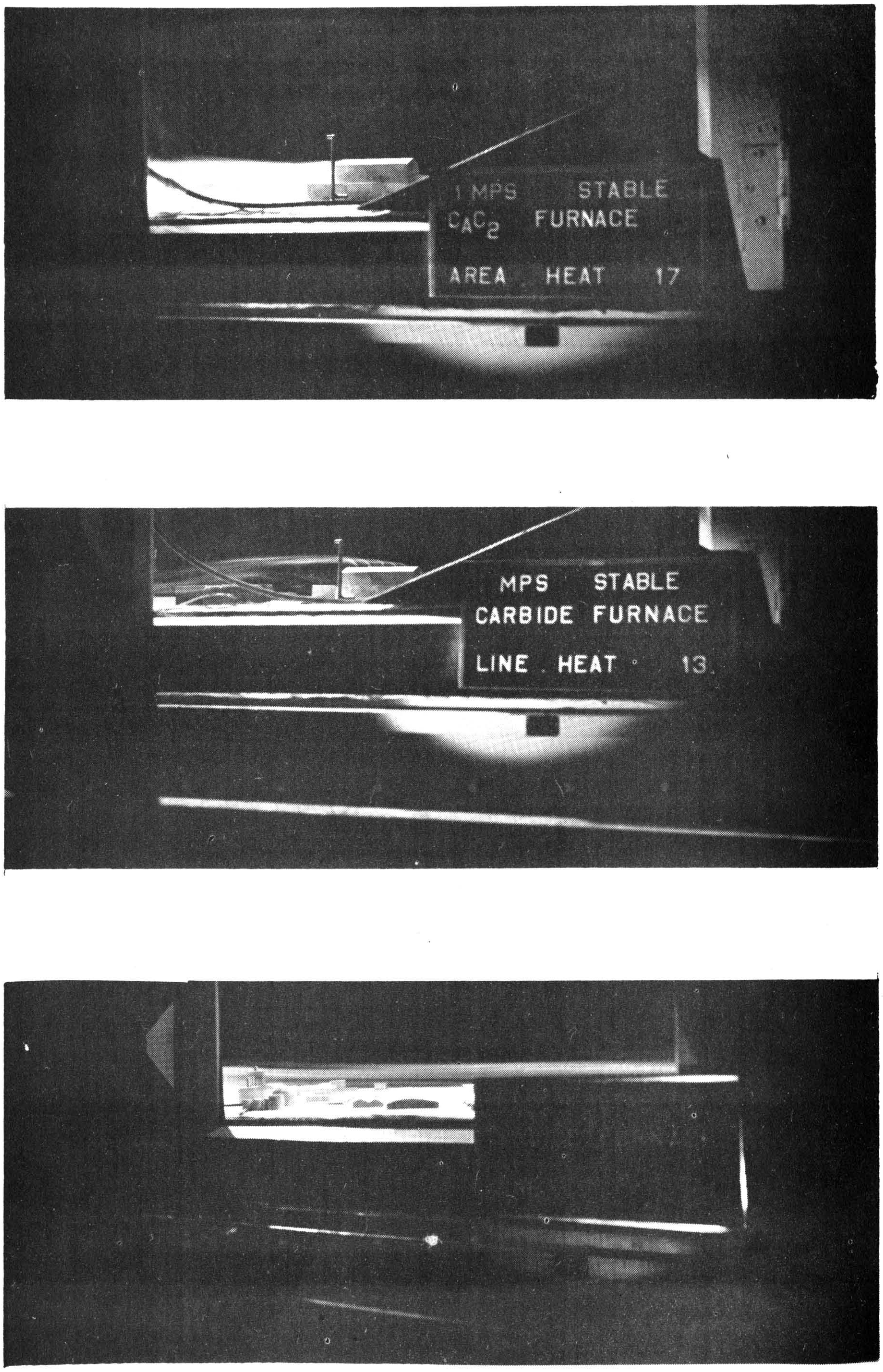



Figure 12. Typical Appearance Source and Receptor Regions: Stable Stratification

# TABLES

TABLE 1

Index

| | | |
|---|---|---|
| 'S' Sector | 1-82 | Refinery |
| 'P' Sector | 83-98 | Power Plant |
| | 1-11 | Chemical Plant |
| 'K' Sector | 1-49 | Rubber Factory |
| | 50-51 | Fertilizer Plant |
| 'A' Sector | 1-14 | Chemical Plant |
| | 15-57 | New Chemical Plant |
| | (42-55) | (Source Area) |

Source Index

| Source Number | Figure 2a,b Building Number |
|---|---|
| 1 | 54 |
| 2 | 40 |
| 3 | 48 |
| 4 | 47 |
| 5 | 45 |
| 6 | 44 |
| 7 | 50 |
| 8 | --(near 43) |

TABLE 2

Test Order

Stability: Neutral & stable & intermediate stable

Wind Speed: @ 300 m equiv = ~1; ~1.5 m/sec

Heaters to be on in all cases

| Run No. | Unit | Source Type | Height of Release |
|---|---|---|---|
| 1 | Building 2 | Line | 35 m |
| 2 | " 2 | " | 0-20 m |
| 3 | " 5 | " | 26 m |
| 4 | " 4 | Area | 0 |
| 5 | " 1 | " | 0 |
| 6 | " 8 | " | 0 |
| 7 | " 6 | " | 0 |
| 8 | " 7 | Line | 10 m |
| 9 | " 1 | Stack | 112-415 m |
| 10 | " 5 | " | 30-38 m |
| 11 | " 3 | " | 93-225 m |
| 12 | " 1<br>Reorientate | Area & Line | 0,35 m |

TABLE 3

Field and Model Heat Releases

| Building No. | $Q_p$ (MW) | $\sim A_p$ ($m^2$) | $Q_{m_1}$ (w) | $Q_{m_2}$ (w) | $\sim A_m$ ($m^2$) | $A_m$ actual ($m^2$) |
|---|---|---|---|---|---|---|
| S1-6 S22-25 | 695 | 52,000 | 2516 | 3294 | 0.208 | 0.416 |
| S33-34 | 55.6 | 24,200 | 201 | 264 | 0.097 | 0.104 |
| S57 | 111 | 5,000 | 402 | 526 | 0.020 | 0.104 |
| S49,50,60 69,65 | 30.6 | 24,000 | 111 | 145 | 0.096 | 0.104 |
| S59a,b | 222 | 28,800 | 804 | 1052 | 0.115 | 0.104 |
| P91,93,94 | 13.9 | 6,000 | 50 | 65.9 | 0.024 | 0.024 |
| P4,5 | 2.17 | 800 | 7.86 | 10.3 | 0.0032 | 0.009 |
| K6 | 1.86 | 400 | 6.73 | 8.8 | 0.0016 | 0.005 |
| K2,8 | 3.08 | 2,940 | 11.2 | 14.6 | 0.0012 | 0.024 |
| K30 | 2.28 | 1,200 | 8.25 | 10.8 | 0.0048 | 0.003 |
| K39 | 6.06 | 1,200 | 21.9 | 28.7 | 0.0048 | 0.024 |
| K51 | 23.4 | 800 | 84.7 | 111 | 0.0032 | 0.024 |
| A19 | 9.3 | 900 | 33.7 | 44 | 0.0036 | 0.012 |
| A32,33,36 | 4.2 | 10,500 | 15.2 | 19.9 | 0.042 | 0.024 |
| A57 | 21 | 800 | 76 | 99.5 | 0.0032 | 0.012 |
| A31 | 28 | 800 | 101.4 | 133 | 0.0032 | 0.052 |
| A39 | 2 | 800 | 7.24 | 9.5 | 0.0032 | 0.052 |
| A45 | 9.3 | 800 | 33.7 | 44 | 0.032 | 0.024 |
| A51-55 | 35 | 15,000 | 126.7 | 166 | 0.060 | 0.104 |

Calculated from:

$$Q_m = Q_p \frac{T_p}{T_m} \left(\frac{V_m}{V_p}\right)^3 \frac{L_m}{L_p}$$

Q - heat released
T - temperature
V - velocity
L - characteristic length

p - prototype
m - model

Taking $(T_p/T_m) = 1$
$V_m$ = 0.18 m/sec,
$V_p$ = 1.5 m/sec for $Q_{m_1}$
$U_m$ = 0.20 m/y,
$V_p$ = 1.5 m/y for $Q_{m_2}$

$Q_{m_1}$ - Used throughout for Runs 1-48 is at 75 percent of average predicted surface heat flux for high stability case and is at ~ 1 percent of predicted surface heat flux for lower stability case.

$Q_{m_2}$ - Used throughout for Runs 49-57 is at 100 percent of average predicted surface heat flux for high stability case.

TABLE 4

Instrumentation and Materials Employed

| | | |
|---|---|---|
| Camera | movie: | Bolex 16 mm camera lens |
| | still: | Speed Graphic Camera 4" x 5" & Hasselblad 2" x 3" |
| Film | movie: | Extachrome - 7242, ASA 125 - Forced developed ASA 500 |
| | still: | Tri-X-Pan-4164 Kodak film, Polaroid |
| Exposure | movie: | f-1.9, 18 frames per second |
| | still: | f = 8-11, t = 1/30 sec or 1 sec |
| Flow meters | 1) | Fischer & Porter Co. Precision flow rator No. B4-21-10 float B SVT-45 |
| | 2) | Fischer & Porter Co. Precision flow rator No. FP1/4-09-G-G3/4 / 4 / 61 |
| | 3) | Fischer & Porter Co. Precision flow rator No. 2F-1/4-20-5/70 |
| Counters | 1) | Ultra scaler - model 192A by Nuclear Chicago |
| | 2) | Ortec timer model 482, Sclaer model - 484 power supply model 446, amplifier model 485, ratemeter model 441 |
| Sampling Panels | 1) | Made at Colorado State University, 25 sample point capacity as shown in Fig. 5b |
| | 2) | Radioactive gas samplers<br>a) Nooo14-68-A-0493-0001-65234<br>b) Nooo14-68-A-0493-0001-65227 |
| Thermistor | | Fennel Glass coated bead #GB33L1, time constant in air ~2 sec |
| Thermometer | | Yellow Springs Corp., YS1 Model 42 SC, Tele - Thermometer range - 40°C ~150°C. |
| Smoke Wire Apparatus | 1) | Voltage Supply & Control - made at Colorado State University |
| | 2) | 50 $Mh_z$ Universa Counter - Hewlett-Packard 5302A |
| | 3) | Strobotac - General Radio Co., Type 1531 |

TABLE 5

Vertical Velocity Profiles Measured in Wind Tunnel

| Neutral Stability | | High Stability $Ri_B \cong 1.18$ | | Intermediate Stability $Ri_B \approx .41$ | |
|---|---|---|---|---|---|
| Z (cm) | U (m/sec) | Z (cm) | U (m/sec) | Z (cm) | U (m/sec) |
| 1.13 | 0.5066 | 3.98 | 0.301 | 3.73 | 0.826 |
| 3.39 | 0.635 | 7.95 | 0.394 | 7.46 | 0.963 |
| 6.77 | 0.673 | 11.93 | 0.447 | 11.20 | 1.061 |
| 10.16 | 0.710 | 15.90 | 0.511 | 14.93 | 1.155 |
| 13.55 | 0.710 | 19.88 | 0.574 | 18.66 | 1.244 |
| 16.93 | 0.722 | 23.85 | 0.649 | 22.39 | 1.319 |
| 20.32 | 0.763 | 27.83 | 0.713 | 26.13 | 1.379 |
| 23.71 | 0.763 | 31.81 | 0.787 | 29.86 | 1.428 |
| 27.09 | 0.784 | 35.78 | 0.842 | 33.59 | 1.498 |
| 30.48 | 0.789 | 39.76 | 0.885 | 37.32 | 1.534 |
| 33.87 | 0.795 | 43.73 | 0.945 | 41.06 | 1.590 |
| 37.25 | 0.804 | 47.71 | 0.973 | 44.79 | 1.634 |
| 40.64 | 0.807 | 51.68 | 1.003 | 48.52 | 1.665 |
| 44.03 | 0.809 | 55.66 | 1.037 | 52.25 | 1.696 |
| 47.41 | 0.815 | 59.63 | 1.063 | 55.48 | 1.718 |
| 50.80 | 0.822 | 63.61 | 1.079 | 59.72 | 1.730 |
| 54.19 | 0.834 | 67.59 | 1.094 | 63.45 | 1.742 |
| 57.57 | 0.843 | | | 68.42 | 1.78 |
| 59.83 | 0.877 | | | | |

Average standard deviation

| Neutral Stability | High Stability | Intermediate Stability |
|---|---|---|
| 0.049 | .032 | 0.060 |

Average % variation

| Neutral Stability | High Stability | Intermediate Stability |
|---|---|---|
| 6.55% | 4.4% | 4.4% |

TABLE 5 (continued)

Actual Freestream Velocities Based on Smoke Wire Unit Measurements

| Run No. | $\overline{U}_{ref}$(m/s) | Run No. | $\overline{U}_{ref}$(m/s) |
|---|---|---|---|
| 1 | 0.915 | 29 | 1.014 |
| 2 | " | 30 | " |
| 3 | " | 31 | 1.027 |
| 4 | " | 32 | " |
| 5 | " | 33 | " |
| 6 | " | 34 | 1.096 |
| 7 | 0.970 | 35 | 1.129 |
| 8 | " | 36 | " |
| 9 | " | 37 | 1.082 |
| 10 | 1.062 | 38 | " |
| 11 | " | 39 | " |
| 12 | " | 40 | " |
| 13 | " | 41 | 1.625 |
| 14 | " | 42 | 1.190 |
| 15 | 1.022 | 43 | 1.135 |
| 16 | " | 44 | 1.585 |
| 17 | " | 45 | " |
| 18 | " | 46 | 1.135 |
| 19 | 1.603 | 47 | 1.29 |
| 20 | " | 48 | " |
| 21 | " | 49 | 1.145 |
| 22 | 1.603 | 50 | " |
| 23 | " | 51 | " |
| 24 | 1.780 | 52 | " |
| 25 | " | 53 | " |
| 26 | " | 54 | " |
| 27 | " | 55 | " |
| 28 | 1.014 | 56 | " |
| | | 57 | " |

TABLE 6

Vertical Temperature Profiles Measured in Wind Tunnel
for Maximum Stability Case

| $Y_{cm}$ | 170 m upstream Furnace Building Temp °C | 1700 m downstream of Furnace Building Temp °C |
|---|---|---|
| 0 | 1 | 2.5 |
| 1 | 14 | 14.5 |
| 3 | 18.1 | 25.4 |
| 5 | 21.5 | 31.8 |
| 7 | 30.5 | 35.0 |
| 9 | 34 | 38.0 |
| 11 | 37-38 | 40.3-40.8 |
| 15 | 43-44 | 44.5-44.7 |
| 17 | 45 | 45.5-45.7 |
| 19 | 46 | 46.5-47 |
| 25 | 50 | 48 |
| 30 | 51-52 | 51 |
| 35 | 52-53 | 52.5 |
| 40 | 53-54 | 53.5 |
| 45 | 54 | 54.1 |
| 50 | 54.3 | 54.2 |
| 60 | 54.9-55 | 54.9 |
| 70 | 56-59 | 55.1 |
| 80 | 60 | 57-58 |
| 90 | 62-63 | 60 |
| 100 | 62.2-62.3 | 61 |
| 130 | 62.8 | 64.5 |

for Lower Stability Case

| $Y_{cm}$ | 170 m upstream Furnace Building Temp °C | 1700 m downstream of Furnace Building Temp °C |
|---|---|---|
| 0 | 2.3 | 5.1 |
| 1 | 16.9-17.6 | 23.1-23.3 |
| 2 | 27.5-28.0 | 30.8-31.0 |
| 3 | 36.0-36.5 | 34.0 |
| 5 | 42.6 | 37.6 |
| 7 | 44.8-44.9 | 40.0-40.2 |
| 9 | 46.8 | 41.8 |
| 11 | 47.5-47.9 | 43.0 |
| 13 | 49.1 | 45.3 |
| 15 | 49.9-50.0 | 47.1 |
| 20 | 51.8-52.0 | 50.6 |
| 25 | 53.1 | 52.1 |
| 30 | 53.9 | 52.0 |
| 40 | 54.8 | 53.1 |
| 50 | 55.4 | 54.7 |
| 60 | 56.2 | 56.4 |
| 70 | 59.3 | 57.0-59.5 |
| 90 | 61.2 | 61.0 |
| 130 | 64.0 | 63.- |

TABLE 7

Velocity and Temperature Profiles Heat Island Test--
High Stability Case

$Ri_B = 1.07$

| Velocity Profile | | Temperature Profile | |
|---|---|---|---|
| z (cm) | u (m/sec) | z (cm) | T (°C) |
| 3.69 | 0.363 | 0 | 3.0 |
| 7.37 | 0.522 | 1.75 | 18.5 |
| 11.06 | 0.593 | 2.5 | 24.6 |
| 14.75 | 0.667 | 3.0 | 29.8 |
| 18.44 | 0.733 | 6.3 | 40.7 |
| 22.12 | 0.852 | 9.0 | 44.1 |
| 25.81 | 0.913 | 12.7 | 47.0 |
| 29.50 | 0.957 | 16.0 | 48.5 |
| 33.18 | 1.017 | 28.9 | 52.2 |
| 36.87 | 1.057 | 42.3 | 54.6 |
| 40.56 | 1.098 | 55.5 | 54.9 |
| 44.25 | 1.128 | 65.0 | 55.9 |
| 47.93 | 1.120 | 71.5 | 57.9 |
| 51.62 | 1.130 | 85.2 | 63.0 |
| 55.31 | 1.147 | 112.0 | 66.0 |
| 58.99 | 1.127 | | |
| 62.68 | 1.115 | | |
| 66.37 | 1.135 | | |

Average standard deviation = 0.0455

Average percent variation = 5.5

TABLE 7 (continued)

Velocity and Temperature Profiles Heat Island Test--
Low Stability Case, Wind Varied

$Ri_B = 0.54$

| Velocity Profile z (cm) | Velocity Profile u (m/sec) | Temperature Profile z (cm) | Temperature Profile T (°C) |
|---|---|---|---|
| 3.69 | 0.856 | 0 | 4.5 |
| 7.37 | 0.998 | 0.75 | 25.0 |
| 11.06 | 1.140 | 1.5 | 28.8 |
| 14.75 | 1.213 | 2.3 | 33.7 |
| 18.4 | 1.264 | 2.7 | 36.1 |
| 22.12 | 1.313 | 6.1 | 40.5 |
| 25.81 | 1.366 | 9.5 | 44.3 |
| 29.50 | 1.414 | 16.1 | 49.0 |
| 33.18 | 1.469 | 22.7 | 51.8 |
| 36.87 | 1.521 | 36.1 | 54.0 |
| 40.56 | 1.540 | 49.5 | 54.8 |
| 44.25 | 1.545 | 56.1 | 55.1 |
| 47.93 | 1.549 | 65.4 | 58.6 |
| 51.62 | 1.550 | 78.5 | 62.0 |
| 55.31 | 1.574 | 91.8 | 63.1 |
| 58.99 | 1.585 | 112.0 | 64.7 |

Average standard deviation = 0.0555

Average percent variation = 4.1

TABLE 7 (continued)

Velocity and Temperature Profiles Heat Island Test--
Low Stability Case, Temperature Varied

$Ri_B = 0.49$

| Velocity Profile | | Temperature Profile | |
|---|---|---|---|
| z (cm) | u (m/sec) | z (cm) | T (°C) |
| 3.69 | 0.671 | 0 | 1.5 |
| 7.37 | 0.851 | 1.7 | 9.1 |
| 11.06 | 1.000 | 2.6 | 13.1 |
| 14.75 | 1.087 | 3.5 | 15.1 |
| 18.4 | 1.129 | 10.0 | 21.5 |
| 22.12 | 1.136 | 16.6 | 24.5 |
| 25.81 | 1.147 | 29.7 | 25.5 |
| 29.50 | 1.157 | 43.2 | 26.5 |
| 33.18 | 1.175 | 56.4 | 28.6 |
| 36.87 | 1.184 | 65.8 | 30.9 |
| 40.56 | 1.203 | 72.5 | 32.1 |
| 44.25 | 1.216 | 92.5 | 35.5 |
| 47.93 | 1.225 | 112.8 | 37.1 |
| 51.31 | 1.242 | | |
| 55.31 | 1.255 | | |
| 58.99 | 1.270 | | |
| 62.68 | 1.290 | | |
| 66.37 | 1.289 | | |

Average standard deviation = 0.0355

Average percent variation = 3.1

TABLE 8

Concentration Results

$\frac{\chi V}{Q}$ $(m^{-2})$

V - measured at reference height equivalent to 300 m.

Locator Table for Concentration Data

| Building Unit | Building Configuration | Type Source Line | Type Source Area | Type Source Stack |
|---|---|---|---|---|
| 1 | Regular | 8-1 | 8-2 | 8-3 |
| 2 | " | 8-4 | - | - |
| 3 | " | - | - | 8-5 |
| 4 | " | 8-6 | 8-7 | - |
| 5 | " | - | - | 8-8 |
| 6 | " | - | 8-9 | - |
| 7 | " | 8-10 | - | - |
| 8 | " | - | 8-11 | - |
| 1 | Reoriented | 8-12 | 8-12 | - |
| 1 | Layout A | 8-13 | 8-14 | 8-15 |
| 2 | " | 8-16 | - | - |
| 4 | " | - | 8-17 | - |
| 5 | " | 8-18 | | - |
| 1 | Layout B | - | 8-19 | - |
| 2 | " | 8-20 | - | - |
| General Stack 115 m | Regular | - | - | 8-21 |
| General Stack 175 m | " | - | - | 8-22 |
| 1 Changed Stability | " | - | 8-23 | - |
| Effect of Heat Islands and Stability | " | - | 8-24, 8-25, 8-26 | - |
| 1 | Regular | 8-27 | 8-28 | 8-29 |
| 2 | " | 8-30 | - | - |
| 4 | " | - | 8-31 | - |
| 5 | " | 8-32 | - | - |
| 6 | " | - | 8-33 | - |
| 7 | " | 8-34 | - | - |
| 8 | " | - | 8-35 | - |

Note: See Figures 4a & 4b for area and line source sampling point configurations. See Figure 4c for stack source sampling point configurations. If 0.0 is registered for all cases no test was performed for given stability.

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = LINE SOURCE HEIGHT = 35M

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = .96M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .272E-05 | .234E-04 | .755E-06 |
| 2 | 0. | .608E-04 | .104E-05 |
| 3 | .111E-05 | .114E-03 | 0. |
| 4 | .846E-05 | .778E-04 | 0. |
| 5 | .503E-06 | .150E-03 | .208E-05 |
| 6 | .485E-05 | .144E-03 | 0. |
| 7 | .574E-05 | .106E-03 | .244E-04 |
| 8 | .499E-05 | .937E-04 | .224E-04 |
| 9 | .513E-05 | .104E-03 | .395E-04 |
| 10 | .790E-05 | .994E-04 | .677E-04 |
| 11 | .946E-05 | .630E-04 | .885E-04 |
| 12 | .901E-05 | .547E-04 | .893E-04 |
| 13 | .148E-04 | .522E-04 | .143E-03 |
| 14 | .180E-04 | .555E-04 | .139E-03 |
| 15 | .112E-04 | .595E-04 | .120E-03 |
| 16 | .957E-05 | .781E-05 | .273E-04 |
| 17 | .108E-04 | .155E-04 | .593E-04 |
| 18 | 0. | .170E-04 | .554E-04 |
| 19 | .332E-05 | .332E-04 | .378E-05 |
| 20 | .236E-05 | .104E-05 | .156E-05 |
| 21 | .413E-05 | .672E-04 | .442E-04 |
| 22 | .430E-05 | 0. | .104E-05 |
| 23 | .825E-05 | .788E-04 | .474E-04 |
| 24 | .665E-05 | .121E-06 | .104E-05 |
| 25 | .146E-04 | .558E-04 | .346E-04 |
| | MAX CONC = .180E-04 | MAX CONC = .150E-03 | MAX CONC = .143E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = 1.04M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .912E-06 | .246E-05 |
| 2 | .457E-06 | 0. | 0. |
| 3 | .604E-06 | .228E-06 | .944E-06 |
| 4 | .254E-05 | .503E-05 | .416E-05 |
| 5 | .154E-05 | .249E-04 | .178E-04 |
| 6 | .721E-05 | .193E-04 | .190E-04 |
| 7 | 0. | .265E-04 | .905E-04 |
| 8 | 0. | .103E-03 | .510E-04 |
| 9 | .453E-05 | .177E-03 | .709E-04 |
| 10 | .119E-04 | .815E-04 | .849E-04 |
| 11 | .112E-04 | .115E-03 | .943E-04 |
| 12 | .763E-05 | .131E-03 | .799E-04 |
| 13 | .133E-04 | .102E-03 | .123E-03 |
| 14 | .119E-04 | .956E-04 | .130E-03 |
| 15 | .966E-05 | .833E-04 | .813E-04 |
| 16 | .887E-05 | .247E-04 | .190E-04 |
| 17 | .856E-05 | .342E-04 | .467E-04 |
| 18 | .832E-05 | .410E-04 | .346E-04 |
| 19 | .206E-05 | .176E-04 | .134E-04 |
| 20 | .250E-05 | 0. | .260E-05 |
| 21 | .624E-05 | .647E-04 | .493E-04 |
| 22 | .444E-05 | 0. | .182E-05 |
| 23 | .103E-04 | .106E-03 | .319E-04 |
| 24 | .832E-05 | 0. | 0. |
| 25 | .121E-04 | .413E-04 | .661E-05 |
| | MAX CONC = .133E-04 | MAX CONC = .177E-03 | MAX CONC = .130E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = STACK SOURCE HEIGHT = 137M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = .99M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. |
| 7 | 0. | .580E-05 | .115E-04 |
| 8 | 0. | .220E-04 | .182E-04 |
| 9 | 0. | .433E-04 | .159E-04 |
| 10 | 0. | .424E-04 | 0. |
| 11 | 0. | .321E-04 | 0. |
| 12 | 0. | .582E-04 | .520E-05 |
| 13 | 0. | 0. | .200E-04 |
| 14 | 0. | 0. | .101E-04 |
| 15 | 0. | 0. | .189E-05 |
| 16 | 0. | 0. | 0. |
| 17 | 0. | 0. | .774E-05 |
| 18 | 0. | 0. | .143E-04 |
| 19 | 0. | 0. | .246E-05 |
| 20 | 0. | .994E-05 | 0. |
| 21 | 0. | .164E-05 | .283E-05 |
| 22 | 0. | .369E-04 | .148E-04 |
| 23 | 0. | .109E-05 | .144E-04 |
| 24 | 0. | .768E-05 | .330E-04 |
| 25 | 0. | 0. | .888E-05 |
| | MAX CONC = 0. | MAX CONC = .582E-04 | MAX CONC = .330E-04 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 2 TYPE = LINE SOURCE HEIGHT = 0-20M

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = .96M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .267E-05 | .279E-04 | .111E-04 |
| 2 | .268E-05 | .306E-04 | 0. |
| 3 | .265E-05 | .371E-04 | .453E-05 |
| 4 | .423E-05 | .521E-04 | .122E-04 |
| 5 | .538E-05 | .106E-03 | .149E-04 |
| 6 | .451E-05 | .805E-04 | .359E-04 |
| 7 | .109E-04 | .770E-04 | .656E-04 |
| 8 | .887E-05 | .109E-03 | .734E-04 |
| 9 | .116E-04 | .998E-04 | .112E-03 |
| 10 | .157E-04 | .950E-04 | .106E-03 |
| 11 | .179E-04 | .898E-04 | .118E-03 |
| 12 | .180E-04 | .757E-04 | .914E-04 |
| 13 | .138E-04 | .689E-04 | .144E-03 |
| 14 | .134E-04 | .694E-04 | .122E-03 |
| 15 | .131E-04 | .710E-04 | .936E-04 |
| 16 | .634E-05 | .142E-04 | .247E-04 |
| 17 | .594E-05 | .244E-04 | .550E-04 |
| 18 | .610E-05 | .279E-04 | .445E-04 |
| 19 | .624E-05 | .162E-04 | .200E-04 |
| 20 | .887E-05 | .203E-05 | .182E-05 |
| 21 | .141E-04 | .246E-04 | .401E-04 |
| 22 | .114E-04 | .145E-05 | .286E-05 |
| 23 | .157E-04 | .324E-04 | .221E-04 |
| 24 | .860E-05 | .624E-06 | 0. |
| 25 | .107E-04 | .293E-04 | .104E-04 |
| | MAX CONC = .180E-04 | MAX CONC = .109E-03 | MAX CONC = .144E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 3 TYPE = STACK SOURCE HEIGHT = 38M

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = .99M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .916E-05 | .120E-05 | 0. |
| 2 | .804E-05 | .121E-05 | 0. |
| 3 | .926E-05 | .230E-05 | 0. |
| 4 | .316E-04 | .949E-05 | 0. |
| 5 | .307E-04 | .168E-04 | 0. |
| 6 | .323E-04 | .829E-05 | 0. |
| 7 | .433E-04 | .194E-04 | 0. |
| 8 | .334E-04 | .261E-04 | 0. |
| 9 | .393E-04 | .534E-04 | 0. |
| 10 | .284E-04 | .124E-04 | 0. |
| 11 | .273E-04 | .678E-05 | 0. |
| 12 | .258E-04 | .331E-05 | 0. |
| 13 | .120E-04 | .284E-05 | 0. |
| 14 | .115E-04 | .362E-05 | 0. |
| 15 | .976E-05 | .197E-05 | 0. |
| 16 | 0. | .136E-05 | 0. |
| 17 | .835E-06 | .131E-05 | 0. |
| 18 | .236E-06 | .271E-05 | 0. |
| 19 | .295E-04 | .116E-04 | 0. |
| 20 | .182E-04 | .105E-05 | 0. |
| 21 | .367E-04 | .160E-03 | 0. |
| 22 | .209E-04 | .151E-05 | 0. |
| 23 | .242E-04 | .499E-04 | 0. |
| 24 | .638E-05 | .196E-05 | 0. |
| 25 | .745E-05 | .284E-05 | 0. |
| | MAX CONC = .433E-04 | MAX CONC = .160E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 4 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = 1.04M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .526E-05 | .561E-04 | .127E-04 |
| 2 | .402E-05 | .745E-04 | .754E-05 |
| 3 | .725E-05 | .820E-04 | .121E-04 |
| 4 | .115E-04 | .978E-04 | .113E-03 |
| 5 | .123E-04 | .130E-03 | .186E-03 |
| 6 | .134E-04 | .109E-03 | .182E-03 |
| 7 | .146E-04 | .135E-03 | .168E-03 |
| 8 | .144E-04 | .134E-03 | .174E-03 |
| 9 | .165E-04 | .944E-04 | .968E-04 |
| 10 | .846E-05 | .141E-03 | .109E-03 |
| 11 | .103E-04 | .103E-03 | .741E-04 |
| 12 | .513E-05 | .681E-04 | .362E-04 |
| 13 | .339E-05 | .795E-04 | .340E-04 |
| 14 | .245E-05 | .862E-04 | .252E-04 |
| 15 | .372E-05 | .771E-04 | .215E-04 |
| 16 | .277E-06 | .182E-04 | .260E-06 |
| 17 | .151E-05 | .243E-04 | .359E-05 |
| 18 | .832E-06 | .234E-04 | 0. |
| 19 | .259E-05 | .523E-04 | .225E-04 |
| 20 | .100E-04 | 0. | 0. |
| 21 | .127E-04 | .420E-04 | .812E-05 |
| 22 | .624E-05 | 0. | 0. |
| 23 | 0. | .274E-04 | .434E-05 |
| 24 | .245E-05 | 0. | 0. |
| 25 | .393E-05 | .153E-04 | 0. |
| | MAX CONC = .165E-04 | MAX CONC = .141E-03 | MAX CONC = .186E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 5 TYPE = LINE SOURCE HEIGHT = 26M

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = .96M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .735E-05 | .852E-04 | .368E-04 |
| 2 | .513E-05 | .923E-04 | .494E-05 |
| 3 | .453E-05 | .762E-04 | .359E-05 |
| 4 | .116E-04 | .124E-03 | .166E-03 |
| 5 | .129E-04 | .131E-03 | .190E-03 |
| 6 | .108E-04 | .103E-03 | .206E-03 |
| 7 | .157E-04 | .140E-03 | .191E-03 |
| 8 | .143E-04 | .111E-03 | .185E-03 |
| 9 | 0. | .684E-04 | .109E-03 |
| 10 | .763E-05 | .131E-03 | .760E-04 |
| 11 | .654E-05 | .101E-03 | .644E-04 |
| 12 | .998E-05 | .444E-04 | .286E-04 |
| 13 | .396E-05 | .678E-04 | .249E-04 |
| 14 | .347E-05 | .703E-04 | .187E-04 |
| 15 | .372E-05 | .579E-04 | .174E-04 |
| 16 | .624E-06 | .154E-04 | .260E-05 |
| 17 | .171E-05 | .214E-04 | .302E-05 |
| 18 | .171E-05 | .241E-04 | 0. |
| 19 | .173E-04 | .189E-04 | .276E-04 |
| 20 | .107E-04 | .145E-06 | 0. |
| 21 | .130E-04 | .238E-04 | .963E-05 |
| 22 | .527E-05 | .871E-06 | 0. |
| 23 | .825E-05 | .151E-04 | .812E-05 |
| 24 | .298E-05 | 0. | 0. |
| 25 | .453E-05 | .149E-04 | .189E-06 |
| | MAX CONC = .173E-04 | MAX CONC = .140E-03 | MAX CONC = .206E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 5 TYPE = STACK SOURCE HEIGHT = 93M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = .99M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .272E-04 | 0. |
| 2 | 0. | .310E-04 | 0. |
| 3 | 0. | .492E-05 | 0. |
| 4 | 0. | .104E-03 | 0. |
| 5 | 0. | .126E-03 | 0. |
| 6 | 0. | .967E-04 | 0. |
| 7 | 0. | .175E-03 | 0. |
| 8 | 0. | .173E-03 | 0. |
| 9 | 0. | .149E-03 | 0. |
| 10 | 0. | .177E-03 | 0. |
| 11 | 0. | .152E-03 | 0. |
| 12 | 0. | .955E-04 | 0. |
| 13 | 0. | .864E-04 | 0. |
| 14 | 0. | .955E-04 | 0. |
| 15 | 0. | .798E-04 | 0. |
| 16 | 0. | .214E-04 | 0. |
| 17 | 0. | .336E-04 | 0. |
| 18 | 0. | .351E-04 | 0. |
| 19 | 0. | .233E-04 | 0. |
| 20 | 0. | .151E-05 | 0. |
| 21 | 0. | .456E-04 | 0. |
| 22 | 0. | .301E-06 | 0. |
| 23 | 0. | .240E-04 | 0. |
| 24 | 0. | .151E-06 | 0. |
| 25 | 0. | .162E-04 | 0. |

MAX CONC = 0. MAX CONC = .177E-03 MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 6 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = 1.04M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .231E-05 | .118E-04 | .240E-04 |
| 2 | .250E-05 | .355E-05 | .208E-04 |
| 3 | .242E-05 | 0. | .472E-05 |
| 4 | .416E-05 | .257E-04 | .961E-04 |
| 5 | .574E-05 | .179E-04 | .144E-03 |
| 6 | .984E-05 | .487E-05 | .133E-03 |
| 7 | .139E-04 | .593E-04 | .160E-03 |
| 8 | .129E-04 | .654E-04 | .153E-03 |
| 9 | .117E-04 | .581E-04 | .926E-04 |
| 10 | .151E-04 | .942E-04 | .643E-04 |
| 11 | .171E-04 | .962E-04 | .525E-04 |
| 12 | .177E-04 | .849E-04 | .252E-04 |
| 13 | .664E-05 | .109E-03 | .264E-04 |
| 14 | .998E-05 | .115E-03 | .148E-04 |
| 15 | .825E-05 | .106E-03 | .149E-04 |
| 16 | .347E-05 | .352E-04 | 0. |
| 17 | .272E-05 | .709E-04 | .208E-05 |
| 18 | .222E-05 | .774E-04 | 0. |
| 19 | .946E-05 | .126E-04 | .298E-04 |
| 20 | .144E-04 | 0. | 0. |
| 21 | .146E-04 | .380E-04 | .176E-04 |
| 22 | .182E-04 | .707E-06 | 0. |
| 23 | .122E-04 | .330E-04 | .737E-05 |
| 24 | .679E-05 | 0. | 0. |
| 25 | .725E-05 | .473E-04 | 0. |
| | MAX CONC = .182E-04 | MAX CONC = .115E-03 | MAX CONC = .160E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 7 TYPE = LINE SOURCE HEIGHT = 10M

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = 1.04M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .221E-05 | .183E-04 | .831E-05 |
| 2 | .180E-05 | .487E-05 | .109E-04 |
| 3 | .211E-05 | .593E-05 | .115E-04 |
| 4 | .485E-05 | .239E-04 | .455E-04 |
| 5 | .513E-05 | .102E-04 | .843E-04 |
| 6 | .527E-05 | .104E-04 | .968E-04 |
| 7 | .102E-04 | .573E-04 | .155E-03 |
| 8 | .929E-05 | .333E-04 | .141E-03 |
| 9 | .805E-05 | .127E-04 | .106E-03 |
| 10 | .162E-04 | .701E-04 | .103E-03 |
| 11 | .150E-04 | .700E-04 | .870E-04 |
| 12 | .173E-04 | .555E-04 | .432E-04 |
| 13 | .128E-04 | .788E-04 | .452E-04 |
| 14 | .107E-04 | .881E-04 | .375E-04 |
| 15 | .105E-04 | .770E-04 | .268E-04 |
| 16 | .430E-05 | .552E-04 | .234E-05 |
| 17 | .201E-05 | .867E-04 | .699E-05 |
| 18 | .291E-05 | .887E-04 | .598E-05 |
| 19 | .815E-05 | .825E-05 | .295E-04 |
| 20 | .114E-04 | .990E-06 | .520E-06 |
| 21 | .148E-04 | .250E-04 | .230E-04 |
| 22 | .144E-04 | 0. | .312E-05 |
| 23 | .153E-04 | .359E-04 | .168E-04 |
| 24 | .860E-05 | .209E-05 | 0. |
| 25 | .986E-05 | .493E-04 | .510E-05 |

MAX CONC = .173E-04 MAX CONC = .887E-04 MAX CONC = .155E-03

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = GENERAL AREA 8 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = .91M/S
HIGH STABILITY = 1.04M/S
LOW STABILITY = 1.72M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | .654E-05 | .793E-04 | .470E-04 |
| 2 | .860E-05 | .406E-04 | .281E-04 |
| 3 | .845E-05 | .445E-05 | .642E-05 |
| 4 | .214E-04 | .130E-03 | .149E-03 |
| 5 | .209E-04 | .952E-04 | .188E-03 |
| 6 | .416E-05 | .336E-04 | .127E-03 |
| 7 | .232E-04 | .177E-03 | .112E-03 |
| 8 | .223E-04 | .139E-03 | .158E-03 |
| 9 | .243E-04 | .848E-04 | .813E-04 |
| 10 | .749E-05 | .154E-03 | .966E-04 |
| 11 | .664E-05 | .167E-03 | .493E-04 |
| 12 | .721E-05 | .106E-03 | .239E-04 |
| 13 | .191E-05 | .123E-03 | .132E-04 |
| 14 | .832E-06 | .135E-03 | .989E-05 |
| 15 | .272E-05 | .912E-04 | .491E-05 |
| 16 | .319E-05 | .236E-04 | 0. |
| 17 | .201E-05 | .569E-04 | 0. |
| 18 | .263E-05 | .631E-04 | 0. |
| 19 | .197E-04 | .770E-05 | .162E-04 |
| 20 | .943E-05 | .196E-05 | 0. |
| 21 | .209E-04 | .269E-04 | .944E-05 |
| 22 | .901E-05 | 0. | 0. |
| 23 | .745E-05 | .186E-04 | .132E-05 |
| 24 | .194E-05 | 0. | 0. |
| 25 | .121E-05 | .205E-04 | .378E-06 |
| | MAX CONC = .243E-04 | MAX CONC = .177E-03 | MAX CONC = .188E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 REORIENT     TYPE = AREA AND LINE     SOURCE HEIGHT = GROUND LEVEL + 35M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = .99M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .186E-05 | 0. |
| 2 | 0. | .904E-06 | 0. |
| 3 | 0. | .820E-06 | 0. |
| 4 | 0. | .655E-05 | 0. |
| 5 | 0. | .175E-04 | 0. |
| 6 | 0. | .101E-04 | 0. |
| 7 | 0. | .286E-04 | 0. |
| 8 | 0. | .898E-04 | 0. |
| 9 | 0. | .138E-03 | 0. |
| 10 | 0. | .768E-04 | 0. |
| 11 | 0. | .125E-03 | 0. |
| 12 | 0. | .150E-03 | 0. |
| 13 | 0. | .113E-03 | 0. |
| 14 | 0. | .117E-03 | 0. |
| 15 | 0. | .105E-03 | 0. |
| 16 | 0. | .234E-04 | 0. |
| 17 | 0. | .387E-04 | 0. |
| 18 | 0. | .385E-04 | 0. |
| 19 | 0. | .487E-05 | 0. |
| 20 | 0. | .196E-05 | 0. |
| 21 | 0. | .268E-04 | 0. |
| 22 | 0. | .105E-05 | 0. |
| 23 | 0. | .955E-04 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .449E-04 | 0. |
| | MAX CONC = 0. | MAX CONC = .150E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

Note: Refer to Fig. 3a for Building 1 Position; however building was rotated 90° clockwise as seen from above.

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 LAYOUT A TYPE = LINE SOURCE HEIGHT = 35M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .653E-05 | 0. |
| 2 | 0. | .656E-05 | 0. |
| 3 | 0. | .288E-05 | 0. |
| 4 | 0. | .241E-04 | 0. |
| 5 | 0. | .936E-04 | 0. |
| 6 | 0. | .879E-04 | 0. |
| 7 | 0. | .846E-04 | 0. |
| 8 | 0. | .165E-03 | 0. |
| 9 | 0. | .158E-03 | 0. |
| 10 | 0. | .119E-03 | 0. |
| 11 | 0. | .112E-03 | 0. |
| 12 | 0. | .892E-04 | 0. |
| 13 | 0. | .634E-04 | 0. |
| 14 | 0. | .655E-04 | 0. |
| 15 | 0. | .712E-04 | 0. |
| 16 | 0. | .200E-04 | 0. |
| 17 | 0. | .219E-04 | 0. |
| 18 | 0. | .247E-04 | 0. |
| 19 | 0. | .168E-04 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .840E-04 | 0. |
| 22 | 0. | 0. | 0. |
| 23 | 0. | .605E-04 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .235E-04 | 0. |

MAX CONC = 0. MAX CONC = .165E-03 MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 LAYOUT A TYPE = STACK SOURCE HEIGHT = 60M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .175E-04 | 0. |
| 2 | 0. | .102E-04 | 0. |
| 3 | 0. | .133E-05 | 0. |
| 4 | 0. | .818E-04 | 0. |
| 5 | 0. | .168E-03 | 0. |
| 6 | 0. | .139E-03 | 0. |
| 7 | 0. | .161E-03 | 0. |
| 8 | 0. | .151E-03 | 0. |
| 9 | 0. | .108E-03 | 0. |
| 10 | 0. | .117E-03 | 0. |
| 11 | 0. | .530E-04 | 0. |
| 12 | 0. | .282E-04 | 0. |
| 13 | 0. | .221E-04 | 0. |
| 14 | 0. | .256E-04 | 0. |
| 15 | 0. | .234E-04 | 0. |
| 16 | 0. | .671E-05 | 0. |
| 17 | 0. | .753E-05 | 0. |
| 18 | 0. | .793E-05 | 0. |
| 19 | 0. | .116E-03 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .142E-03 | 0. |
| 22 | 0. | .152E-06 | 0. |
| 23 | 0. | .197E-04 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .410E-05 | 0. |

MAX CONC = 0. MAX CONC = .168E-03 MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 LAYOUT A        TYPE = AREA        SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .664E-06 | 0. |
| 2 | 0. | .457E-06 | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 0. | .133E-04 | 0. |
| 5 | 0. | .258E-04 | 0. |
| 6 | 0. | .137E-05 | 0. |
| 7 | 0. | .612E-04 | 0. |
| 8 | 0. | .818E-04 | 0. |
| 9 | 0. | .659E-04 | 0. |
| 10 | 0. | .110E-03 | 0. |
| 11 | 0. | .126E-03 | 0. |
| 12 | 0. | .121E-03 | 0. |
| 13 | 0. | .100E-03 | 0. |
| 14 | 0. | .933E-04 | 0. |
| 15 | 0. | .936E-04 | 0. |
| 16 | 0. | .122E-04 | 0. |
| 17 | 0. | .173E-04 | 0. |
| 18 | 0. | .214E-04 | 0. |
| 19 | 0. | .112E-04 | 0. |
| 20 | 0. | .610E-06 | 0. |
| 21 | 0. | .655E-04 | 0. |
| 22 | 0. | 0. | 0. |
| 23 | 0. | .860E-04 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .258E-04 | 0. |

MAX CONC = 0.        MAX CONC = .126E-03        MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 2 LAYOUT A TYPE = LINE SOURCE HEIGHT = 0-20M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .308E-04 | 0. |
| 2 | 0. | .656E-05 | 0. |
| 3 | 0. | .133E-05 | 0. |
| 4 | 0. | .681E-04 | 0. |
| 5 | 0. | .517E-04 | 0. |
| 6 | 0. | .702E-05 | 0. |
| 7 | 0. | .113E-03 | 0. |
| 8 | 0. | .108E-03 | 0. |
| 9 | 0. | .659E-04 | 0. |
| 10 | 0. | .103E-03 | 0. |
| 11 | 0. | .111E-03 | 0. |
| 12 | 0. | .876E-04 | 0. |
| 13 | 0. | .847E-04 | 0. |
| 14 | 0. | .696E-04 | 0. |
| 15 | 0. | .492E-04 | 0. |
| 16 | 0. | .226E-04 | 0. |
| 17 | 0. | .329E-04 | 0. |
| 18 | 0. | .299E-04 | 0. |
| 19 | 0. | .196E-04 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .674E-04 | 0. |
| 22 | 0. | 0. | 0. |
| 23 | 0. | .391E-04 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .116E-04 | 0. |

MAX CONC = 0. MAX CONC = .113E-03 MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 4 LAYOUT A          TYPE = AREA          SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .939E-04 | 0. |
| 2 | 0. | .824E-04 | 0. |
| 3 | 0. | .501E-04 | 0. |
| 4 | 0. | .771E-04 | 0. |
| 5 | 0. | .790E-04 | 0. |
| 6 | 0. | .714E-04 | 0. |
| 7 | 0. | .641E-04 | 0. |
| 8 | 0. | .589E-04 | 0. |
| 9 | 0. | .449E-04 | 0. |
| 10 | 0. | .529E-04 | 0. |
| 11 | 0. | .410E-04 | 0. |
| 12 | 0. | .244E-04 | 0. |
| 13 | 0. | .241E-04 | 0. |
| 14 | 0. | .235E-04 | 0. |
| 15 | 0. | .155E-04 | 0. |
| 16 | 0. | .381E-05 | 0. |
| 17 | 0. | .542E-05 | 0. |
| 18 | 0. | .641E-05 | 0. |
| 19 | 0. | .130E-04 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .143E-04 | 0. |
| 22 | 0. | .915E-06 | 0. |
| 23 | 0. | .531E-05 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .232E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .939E-04 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 5 LAYOUT A          TYPE = LINE          SOURCE HEIGHT = 26M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .145E-03 | 0. |
| 2 | 0. | .957E-04 | 0. |
| 3 | 0. | .240E-04 | 0. |
| 4 | 0. | .147E-03 | 0. |
| 5 | 0. | .155E-03 | 0. |
| 6 | 0. | .910E-04 | 0. |
| 7 | 0. | .134E-03 | 0. |
| 8 | 0. | .105E-03 | 0. |
| 9 | 0. | .908E-04 | 0. |
| 10 | 0. | .962E-04 | 0. |
| 11 | 0. | .749E-04 | 0. |
| 12 | 0. | .418E-04 | 0. |
| 13 | 0. | .514E-04 | 0. |
| 14 | 0. | .559E-04 | 0. |
| 15 | 0. | .387E-04 | 0. |
| 16 | 0. | .824E-05 | 0. |
| 17 | 0. | .111E-04 | 0. |
| 18 | 0. | .149E-04 | 0. |
| 19 | 0. | .165E-04 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .281E-04 | 0. |
| 22 | 0. | .107E-05 | 0. |
| 23 | 0. | .941E-05 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .742E-05 | 0. |

MAX CONC = 0.          MAX CONC = .155E-03          MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 LAYOUT B        TYPE = AREA        SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .731E-05 | 0. |
| 2 | 0. | .137E-05 | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 0. | .267E-04 | 0. |
| 5 | 0. | .430E-04 | 0. |
| 6 | 0. | .824E-05 | 0. |
| 7 | 0. | .738E-04 | 0. |
| 8 | 0. | .122E-03 | 0. |
| 9 | 0. | .110E-03 | 0. |
| 10 | 0. | .137E-03 | 0. |
| 11 | 0. | .137E-03 | 0. |
| 12 | 0. | .125E-03 | 0. |
| 13 | 0. | .897E-04 | 0. |
| 14 | 0. | .841E-04 | 0. |
| 15 | 0. | .787E-04 | 0. |
| 16 | 0. | .191E-04 | 0. |
| 17 | 0. | .256E-04 | 0. |
| 18 | 0. | .326E-04 | 0. |
| 19 | 0. | .841E-05 | 0. |
| 20 | 0. | .152E-06 | 0. |
| 21 | 0. | .532E-04 | 0. |
| 22 | 0. | .137E-05 | 0. |
| 23 | 0. | .724E-04 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .216F-04 | 0. |
| | MAX CONC = 0. | MAX CONC = .137E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 2 LAYOUT B          TYPE = LINE          SOURCE HEIGHT = 0-20M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .136E-04 | 0. |
| 2 | 0. | .108E-04 | 0. |
| 3 | 0. | .310E-05 | 0. |
| 4 | 0. | .378E-04 | 0. |
| 5 | 0. | .596E-04 | 0. |
| 6 | 0. | .366E-04 | 0. |
| 7 | 0. | .740E-04 | 0. |
| 8 | 0. | .120E-03 | 0. |
| 9 | 0. | .129E-03 | 0. |
| 10 | 0. | .104E-03 | 0. |
| 11 | 0. | .109E-03 | 0. |
| 12 | 0. | .890E-04 | 0. |
| 13 | 0. | .744E-04 | 0. |
| 14 | 0. | .757E-04 | 0. |
| 15 | 0. | .698E-04 | 0. |
| 16 | 0. | .151E-04 | 0. |
| 17 | 0. | .294E-04 | 0. |
| 18 | 0. | .346E-04 | 0. |
| 19 | 0. | .179E-04 | 0. |
| 20 | 0. | .305E-06 | 0. |
| 21 | 0. | .500E-04 | 0. |
| 22 | 0. | .107E-05 | 0. |
| 23 | 0. | .625E-04 | 0. |
| 24 | 0. | .229E-05 | 0. |
| 25 | 0. | .299E-04 | 0. |

MAX CONC = 0.          MAX CONC = .129E-03          MAX CONC = 0.

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = GENERAL STACK TEST          TYPE = STACK          SOURCE HEIGHT = 115M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY =  1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .133E-05 | 0. |
| 2 | 0. | .320E-05 | 0. |
| 3 | 0. | .443E-06 | 0. |
| 4 | 0. | .148E-04 | 0. |
| 5 | 0. | .343E-05 | 0. |
| 6 | 0. | 0. | 0. |
| 7 | 0. | .223E-04 | 0. |
| 8 | 0. | .106E-03 | 0. |
| 9 | 0. | .124E-03 | 0. |
| 10 | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. |
| 13 | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. |
| 15 | 0. | 0. | 0. |
| 16 | 0. | 0. | 0. |
| 17 | 0. | 0. | 0. |
| 18 | 0. | 0. | 0. |
| 19 | 0. | .141E-04 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .111E-05 | 0. |
| 22 | 0. | 0. | 0. |
| 23 | 0. | .122E-05 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | .553E-06 | 0. |
| | MAX CONC = 0. | MAX CONC = .124E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = GENERAL STACK TEST TYPE = STACK SOURCE HEIGHT = 175M

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.01M/S
LOW STABILITY =

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .886E-06 | 0. |
| 2 | 0. | .166E-04 | 0. |
| 3 | 0. | .327E-04 | 0. |
| 4 | 0. | .737E-04 | 0. |
| 5 | 0. | .218E-04 | 0. |
| 6 | 0. | .366E-05 | 0. |
| 7 | 0. | .639E-04 | 0. |
| 8 | 0. | .850E-04 | 0. |
| 9 | 0. | .529E-04 | 0. |
| 10 | 0. | 0. | 0. |
| 11 | 0. | 0. | 0. |
| 12 | 0. | 0. | 0. |
| 13 | 0. | 0. | 0. |
| 14 | 0. | 0. | 0. |
| 15 | 0. | 0. | 0. |
| 16 | 0. | 0. | 0. |
| 17 | 0. | 0. | 0. |
| 18 | 0. | 0. | 0. |
| 19 | 0. | .553E-06 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | 0. | 0. |
| 22 | 0. | 0. | 0. |
| 23 | 0. | .996E-06 | 0. |
| 24 | 0. | 0. | 0. |
| 25 | 0. | 0. | 0. |
| | MAX CONC = 0. | MAX CONC = .850E-04 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 VHS TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL =
HIGH STABILITY = 1.19M/S
LOW STABILITY = 1.63M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .186E-04 | .232E-05 |
| 2 | 0. | .117E-04 | .296E-05 |
| 3 | 0. | .126E-04 | .250E-05 |
| 4 | 0. | .205E-04 | .419E-05 |
| 5 | 0. | .266E-04 | .102E-04 |
| 6 | 0. | .153E-04 | .175E-04 |
| 7 | 0. | .404E-04 | .345E-04 |
| 8 | 0. | .754E-04 | .439E-04 |
| 9 | 0. | .840E-04 | .522E-04 |
| 10 | 0. | .794E-04 | .959E-04 |
| 11 | 0. | .155E-03 | .109E-03 |
| 12 | 0. | .155E-03 | .860E-04 |
| 13 | 0. | .118E-03 | .112E-03 |
| 14 | 0. | .116E-03 | .101E-03 |
| 15 | 0. | .107E-03 | .931E-04 |
| 16 | 0. | .276E-04 | .345E-05 |
| 17 | 0. | .397E-04 | .930E-05 |
| 18 | 0. | .397E-04 | .616E-05 |
| 19 | 0. | .864E-05 | .608E-05 |
| 20 | 0. | 0. | .246E-06 |
| 21 | 0. | .149E-04 | .445E-04 |
| 22 | 0. | .270E-05 | 0. |
| 23 | 0. | .667E-04 | .483E-04 |
| 24 | 0. | .108E-05 | .123E-05 |
| 25 | 0. | .588E-04 | .166E-04 |
| | MAX CONC = 0. | MAX CONC = .155E-03 | MAX CONC = .112E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

| Freestream Temperature | T | ~ $Ri_B$ |
|---|---|---|
| High Stability | 81°C | 1.15 |
| Low Stability | 75°C | 0.55 |

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL HIGH STABILITY

FREESTREAM VELOCITY- HEAT OFF = 1.16M/S
HEAT ON = 1.16M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | HEAT OFF | HEAT ON |
|---|---|---|
| 1 | .171E-04 | .242E-05 |
| 2 | .211E-05 | .193E-05 |
| 3 | .191E-05 | .166E-05 |
| 4 | .249E-04 | .878E-05 |
| 5 | .637E-05 | .637E-05 |
| 6 | .527E-06 | .111E-04 |
| 7 | .583E-04 | .304E-04 |
| 8 | .307E-04 | .191E-04 |
| 9 | .119E-04 | .560E-04 |
| 10 | .847E-04 | .571E-04 |
| 11 | .998E-04 | .842E-04 |
| 12 | .951E-04 | .805E-04 |
| 13 | .130E-03 | .115E-03 |
| 14 | .146E-03 | .111E-03 |
| 15 | .125E-03 | .822E-04 |
| 16 | .130E-03 | .436E-04 |
| 17 | .136E-03 | .584E-04 |
| 18 | .889E-04 | .592E-04 |
| 19 | .175E-04 | .334E-04 |
| 20 | .492E-05 | .492E-05 |
| 21 | .584E-04 | .495E-04 |
| 22 | .404E-05 | .193E-05 |
| 23 | .526E-04 | .247E-04 |
| 24 | .246E-05 | .246E-05 |
| 25 | .318E-04 | .286E-04 |

MAX CONC = .146E-03 MAX CONC = .115E-03

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL LOW STABILITY, WIND

FREESTREAM VELOCITY- HEAT OFF = 1.62M/S
HEAT ON = 1.62M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | HEAT OFF | HEAT ON |
|---|---|---|
| 1 | .141E-04 | .125E-04 |
| 2 | .204E-04 | .216E-04 |
| 3 | .125E-04 | .130E-04 |
| 4 | .332E-04 | .315E-04 |
| 5 | .355E-04 | .443E-04 |
| 6 | .327E-04 | .423E-04 |
| 7 | .829E-04 | .840E-04 |
| 8 | .918E-04 | .940E-04 |
| 9 | .850E-04 | .916E-04 |
| 10 | .915E-04 | .112E-03 |
| 11 | .922E-04 | .106E-03 |
| 12 | .782E-04 | .888E-04 |
| 13 | .434E-04 | .906E-04 |
| 14 | .544E-04 | .740E-04 |
| 15 | .518E-04 | .382E-04 |
| 16 | .111E-04 | .492E-05 |
| 17 | .155E-04 | .104E-04 |
| 18 | .664E-05 | .885E-05 |
| 19 | .123E-04 | .170E-04 |
| 20 | .295E-05 | .197E-05 |
| 21 | .368E-04 | .346E-04 |
| 22 | .492E-05 | .492E-05 |
| 23 | .366E-04 | .468E-04 |
| 24 | .541E-05 | .565E-05 |
| 25 | .130E-04 | .134E-04 |
| | MAX CONC = .922E-04 | MAX CONC = .112E-03 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL LOW STABILITY, TEMP

FREESTREAM VELOCITY- HEAT OFF = 1.16M/S
HEAT ON = 1.16M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | HEAT OFF | HEAT ON |
|---|---|---|
| 1 | .268E-05 | .268E-05 |
| 2 | .702E-05 | .176E-05 |
| 3 | .204E-05 | .191E-05 |
| 4 | .207E-04 | .404E-05 |
| 5 | .222E-04 | .370E-05 |
| 6 | .126E-04 | .404E-05 |
| 7 | .591E-04 | .245E-04 |
| 8 | .531E-04 | .151E-04 |
| 9 | .505E-04 | .279E-04 |
| 10 | .770E-04 | .541E-04 |
| 11 | .704E-04 | .639E-04 |
| 12 | .580E-04 | .617E-04 |
| 13 | .550E-04 | .609E-04 |
| 14 | .415E-04 | .502E-04 |
| 15 | .339E-04 | .452E-04 |
| 16 | .146E-04 | .137E-04 |
| 17 | .113E-04 | .226E-04 |
| 18 | .492E-05 | .163E-04 |
| 19 | .880E-05 | .688E-05 |
| 20 | .123E-05 | .386E-05 |
| 21 | .449E-04 | .328E-04 |
| 22 | .123E-05 | .158E-05 |
| 23 | .316E-04 | .463E-04 |
| 24 | .878E-06 | .457E-05 |
| 25 | .119E-04 | .186E-04 |
| | MAX CONC = .770E-04 | MAX CONC = .639E-04 |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

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AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1      TYPE = LINE      SOURCE HEIGHT = 35M

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .123E-05 | 0. |
| 2 | 0. | .254E-05 | 0. |
| 3 | 0. | .185E-05 | 0. |
| 4 | 0. | .237E-05 | 0. |
| 5 | 0. | .320E-05 | 0. |
| 6 | 0. | .102E-05 | 0. |
| 7 | 0. | .825E-05 | 0. |
| 8 | 0. | .322E-05 | 0. |
| 9 | 0. | .308E-05 | 0. |
| 10 | 0. | .275E-04 | 0. |
| 11 | 0. | .431E-04 | 0. |
| 12 | 0. | .625E-04 | 0. |
| 13 | 0. | .111E-03 | 0. |
| 14 | 0. | .117E-03 | 0. |
| 15 | 0. | .143E-03 | 0. |
| 16 | 0. | .383E-04 | 0. |
| 17 | 0. | .387E-04 | 0. |
| 18 | 0. | .499E-04 | 0. |
| 19 | 0. | .345E-05 | 0. |
| 20 | 0. | .390E-05 | 0. |
| 21 | 0. | .110E-04 | 0. |
| 22 | 0. | .339E-05 | 0. |
| 23 | 0. | .828E-04 | 0. |
| 24 | 0. | .322E-05 | 0. |
| 25 | 0. | .874E-04 | 0. |
| | MAX CONC = 0. | MAX CONC = .143E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .209E-05 | 0. |
| 2 | 0. | .305E-05 | 0. |
| 3 | 0. | .148E-05 | 0. |
| 4 | 0. | .187E-05 | 0. |
| 5 | 0. | .283E-05 | 0. |
| 6 | 0. | .204E-05 | 0. |
| 7 | 0. | .132E-04 | 0. |
| 8 | 0. | .712E-05 | 0. |
| 9 | 0. | .492E-05 | 0. |
| 10 | 0. | .458E-04 | 0. |
| 11 | 0. | .694E-04 | 0. |
| 12 | 0. | .769E-04 | 0. |
| 13 | 0. | .130E-03 | 0. |
| 14 | 0. | .123E-03 | 0. |
| 15 | 0. | .128E-03 | 0. |
| 16 | 0. | .297E-04 | 0. |
| 17 | 0. | .384E-04 | 0. |
| 18 | 0. | .480E-04 | 0. |
| 19 | 0. | .320E-05 | 0. |
| 20 | 0. | .492E-05 | 0. |
| 21 | 0. | .203E-04 | 0. |
| 22 | 0. | .407E-05 | 0. |
| 23 | 0. | .742E-04 | 0. |
| 24 | 0. | .254E-05 | 0. |
| 25 | 0. | .685E-04 | 0. |
| | MAX CONC = 0. | MAX CONC = .130E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 1 TYPE = STACK SOURCE HEIGHT = 137M

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | 0. | 0. |
| 2 | 0. | 0. | 0. |
| 3 | 0. | 0. | 0. |
| 4 | 0. | 0. | 0. |
| 5 | 0. | 0. | 0. |
| 6 | 0. | 0. | 0. |
| 7 | 0. | 0. | 0. |
| 8 | 0. | 0. | 0. |
| 9 | 0. | 0. | 0. |
| 10 | 0. | .334E-04 | 0. |
| 11 | 0. | .429E-04 | 0. |
| 12 | 0. | .317E-04 | 0. |
| 13 | 0. | .222E-04 | 0. |
| 14 | 0. | .102E-04 | 0. |
| 15 | 0. | .145E-04 | 0. |
| 16 | 0. | .248E-04 | 0. |
| 17 | 0. | .249E-04 | 0. |
| 18 | 0. | .103E-04 | 0. |
| 19 | 0. | .209E-05 | 0. |
| 20 | 0. | .661E-05 | 0. |
| 21 | 0. | .382E-05 | 0. |
| 22 | 0. | .253E-04 | 0. |
| 23 | 0. | .283E-05 | 0. |
| 24 | 0. | .180E-04 | 0. |
| 25 | 0. | .320E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .429E-04 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 2 TYPE = LINE SOURCE HEIGHT = 0-20M

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .259E-05 | 0. |
| 2 | 0. | .220E-05 | 0. |
| 3 | 0. | .406E-05 | 0. |
| 4 | 0. | .424E-05 | 0. |
| 5 | 0. | .332E-05 | 0. |
| 6 | 0. | .373E-05 | 0. |
| 7 | 0. | .166E-04 | 0. |
| 8 | 0. | .865E-05 | 0. |
| 9 | 0. | .107E-04 | 0. |
| 10 | 0. | .512E-04 | 0. |
| 11 | 0. | .744E-04 | 0. |
| 12 | 0. | .893E-04 | 0. |
| 13 | 0. | .144E-03 | 0. |
| 14 | 0. | .132E-03 | 0. |
| 15 | 0. | .127E-03 | 0. |
| 16 | 0. | .339E-04 | 0. |
| 17 | 0. | .469E-04 | 0. |
| 18 | 0. | .521E-04 | 0. |
| 19 | 0. | .431E-05 | 0. |
| 20 | 0. | 0. | 0. |
| 21 | 0. | .370E-04 | 0. |
| 22 | 0. | .390E-05 | 0. |
| 23 | 0. | .820E-04 | 0. |
| 24 | 0. | .254E-05 | 0. |
| 25 | 0. | .619E-04 | 0. |
| | MAX CONC = 0. | MAX CONC = .144E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 4 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .603E-05 | 0. |
| 2 | 0. | .237E-05 | 0. |
| 3 | 0. | .985E-06 | 0. |
| 4 | 0. | .434E-04 | 0. |
| 5 | 0. | .148E-04 | 0. |
| 6 | 0. | .305E-05 | 0. |
| 7 | 0. | .136E-03 | 0. |
| 8 | 0. | .947E-04 | 0. |
| 9 | 0. | .805E-04 | 0. |
| 10 | 0. | .161E-03 | 0. |
| 11 | 0. | .153E-03 | 0. |
| 12 | 0. | .118E-03 | 0. |
| 13 | 0. | .118E-03 | 0. |
| 14 | 0. | .106E-03 | 0. |
| 15 | 0. | .563E-04 | 0. |
| 16 | 0. | .205E-04 | 0. |
| 17 | 0. | .239E-04 | 0. |
| 18 | 0. | .221E-04 | 0. |
| 19 | 0. | .249E-04 | 0. |
| 20 | 0. | .322E-05 | 0. |
| 21 | 0. | .669E-04 | 0. |
| 22 | 0. | .848E-06 | 0. |
| 23 | 0. | .374E-04 | 0. |
| 24 | 0. | .288E-05 | 0. |
| 25 | 0. | .554E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .161E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 5 TYPE = LINE SOURCE HEIGHT = 26M

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .579E-05 | 0. |
| 2 | 0. | .356E-05 | 0. |
| 3 | 0. | .308E-05 | 0. |
| 4 | 0. | .336E-04 | 0. |
| 5 | 0. | .102E-04 | 0. |
| 6 | 0. | .136E-04 | 0. |
| 7 | 0. | .130E-03 | 0. |
| 8 | 0. | .966E-04 | 0. |
| 9 | 0. | .126E-03 | 0. |
| 10 | 0. | .137E-03 | 0. |
| 11 | 0. | .129E-03 | 0. |
| 12 | 0. | .830E-04 | 0. |
| 13 | 0. | .841E-04 | 0. |
| 14 | 0. | .767E-04 | 0. |
| 15 | 0. | .315E-04 | 0. |
| 16 | 0. | 0. | 0. |
| 17 | 0. | .160E-04 | 0. |
| 18 | 0. | .202E-04 | 0. |
| 19 | 0. | .431E-04 | 0. |
| 20 | 0. | .187E-05 | 0. |
| 21 | 0. | .699E-04 | 0. |
| 22 | 0. | .170E-05 | 0. |
| 23 | 0. | .272E-04 | 0. |
| 24 | 0. | .119E-05 | 0. |
| 25 | 0. | .505E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .137E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 6 | TYPE = AREA | SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .686E-04 | 0. |
| 2 | 0. | .159E-04 | 0. |
| 3 | 0. | .271E-05 | 0. |
| 4 | 0. | .144E-03 | 0. |
| 5 | 0. | .919E-04 | 0. |
| 6 | 0. | .431E-04 | 0. |
| 7 | 0. | .216E-03 | 0. |
| 8 | 0. | .189E-03 | 0. |
| 9 | 0. | .123E-03 | 0. |
| 10 | 0. | .183E-03 | 0. |
| 11 | 0. | .128E-03 | 0. |
| 12 | 0. | .760E-04 | 0. |
| 13 | 0. | .788E-04 | 0. |
| 14 | 0. | .662E-04 | 0. |
| 15 | 0. | .331E-04 | 0. |
| 16 | 0. | .112E-04 | 0. |
| 17 | 0. | .150E-04 | 0. |
| 18 | 0. | .202E-04 | 0. |
| 19 | 0. | .246E-04 | 0. |
| 20 | 0. | .170E-05 | 0. |
| 21 | 0. | .246E-04 | 0. |
| 22 | 0. | .102E-05 | 0. |
| 23 | 0. | .170E-04 | 0. |
| 24 | 0. | .220E-05 | 0. |
| 25 | 0. | .308E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .216E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 7 TYPE = LINE SOURCE HEIGHT = 10M

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .135E-04 | 0. |
| 2 | 0. | .105E-04 | 0. |
| 3 | 0. | .542E-05 | 0. |
| 4 | 0. | .243E-04 | 0. |
| 5 | 0. | .214E-04 | 0. |
| 6 | 0. | .170E-04 | 0. |
| 7 | 0. | .904E-04 | 0. |
| 8 | 0. | .699E-04 | 0. |
| 9 | 0. | .108E-03 | 0. |
| 10 | 0. | .112E-03 | 0. |
| 11 | 0. | .115E-03 | 0. |
| 12 | 0. | .810E-04 | 0. |
| 13 | 0. | .969E-04 | 0. |
| 14 | 0. | .874E-04 | 0. |
| 15 | 0. | .509E-04 | 0. |
| 16 | 0. | .200E-04 | 0. |
| 17 | 0. | .255E-04 | 0. |
| 18 | 0. | .288E-04 | 0. |
| 19 | 0. | .313E-04 | 0. |
| 20 | 0. | .288E-05 | 0. |
| 21 | 0. | .477E-04 | 0. |
| 22 | 0. | .102E-05 | 0. |
| 23 | 0. | .271E-04 | 0. |
| 24 | 0. | .187E-05 | 0. |
| 25 | 0. | .874E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .115E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

AIR POLLUTION DIFFUSION STUDY FROM DIFFERENT TYPES AND HEIGHTS OF SOURCES
CONCENTRATION = RECIPROCAL METERS SQUARED

SOURCE UNIT = BUILDING 8 TYPE = AREA SOURCE HEIGHT = GROUND LEVEL

FREESTREAM VELOCITY- NEUTRAL = 0.00M/S
HIGH STABILITY = 1.12M/S
LOW STABILITY = 0.00M/S

TABLE OF CONCENTRATIONS (AS XV/Q)

| SAMPLE POINT | NEUTRAL CASE | HIGH STABILITY CASE | LOW STABILITY CASE |
|---|---|---|---|
| 1 | 0. | .257E-04 | 0. |
| 2 | 0. | .187E-05 | 0. |
| 3 | 0. | .135E-05 | 0. |
| 4 | 0. | .139E-03 | 0. |
| 5 | 0. | .746E-04 | 0. |
| 6 | 0. | .326E-04 | 0. |
| 7 | 0. | .274E-03 | 0. |
| 8 | 0. | .240E-03 | 0. |
| 9 | 0. | .137E-03 | 0. |
| 10 | 0. | .262E-03 | 0. |
| 11 | 0. | .184E-03 | 0. |
| 12 | 0. | .114E-03 | 0. |
| 13 | 0. | .131E-03 | 0. |
| 14 | 0. | .111E-03 | 0. |
| 15 | 0. | .463E-04 | 0. |
| 16 | 0. | .158E-04 | 0. |
| 17 | 0. | .229E-04 | 0. |
| 18 | 0. | .254E-04 | 0. |
| 19 | 0. | .117E-04 | 0. |
| 20 | 0. | .424E-05 | 0. |
| 21 | 0. | .874E-05 | 0. |
| 22 | 0. | .254E-05 | 0. |
| 23 | 0. | .251E-04 | 0. |
| 24 | 0. | .119E-05 | 0. |
| 25 | 0. | .271E-05 | 0. |
| | MAX CONC = 0. | MAX CONC = .274E-03 | MAX CONC = 0. |

FOR SAMPLING POINT LOCATIONS REFER TO TEXT

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TABLE 9

Run Numbers and Order

| Run No. | Source Building | Source Type | Stability |
|---|---|---|---|
| 1 | 1 | Line | Neutral |
| 2 | 2 | " | " |
| 3 | 5 | " | " |
| 4 | 4 | Area | " |
| 5 | 1 | " | " |
| 6 | 5 | Stack | " |
| 7 | 1 | Line | Stable |
| 8 | 2 | " | " |
| 9 | 5 | " | " |
| 10 | 4 | Area | " |
| 11 | 1 | " | " |
| 12 | 8 | " | " |
| 13 | 6 | " | " |
| 14 | 7 | Line | " |
| 15 | 1 | Stack | " |
| 16 | 5 | " | " |
| 17 | 3 | " | " |
| 18 | 1* | Area/Line | " |
| 19 | 1 | Line | Intermediate Stability |
| 20 | 2 | " | " |
| 21 | 5 | " | " |
| 22 | 4 | Area | " |
| 23 | 1 | " | " |
| 24 | 8 | " | " |
| 25 | 6 | " | " |
| 26 | 7 | Line | " |
| 27 | 1 | Stack | " |
| 28 | 8 | Area | Neutral |
| 29 | 6 | " | " |
| 30 | 7 | Line | " |
| 31 | 1 | " | Stable |
| 32 | 1 | Stack | " |
| 33 | 1 | Area | " |
| 34 | 2 | Line | " |
| 35 | 5 | " | " |
| 36 | 4 | Area | " |
| 37 | 2 | Line | " |
| 38 | 1 | Area | " |
| 39 | - | Stack | " |
| 40 | - | " | " |
| 41 | 1 | Area | High Stability |
| 42 | 1 | " | " |
| 43 | 1 | " | " |
| 44 | 1 | " | (Heat Island Tests) |
| 45 | 1 | " | " |
| 46 | 1 | " | " |
| 47 | 1 | " | " |
| 48 | 1 | " | " |
| 49 | 1 | Line | High Stability |
| 50 | 2 | Line | (Reruns) |
| 51 | 1 | Area | " |
| 52 | 5 | Line | " |
| 53 | 4 | " | " |
| 54 | 8 | " | " |
| 55 | 6 | " | " |
| 56 | 7 | " | " |
| 57 | 1 | Stack | " |

*Building reorientated

TABLE 10

Motion Picture Log

Only one wind direction of interest - ESE

| Sequence No. | Source Building | Source Type | Stability | Industrial Heat |
|---|---|---|---|---|
| 1 | $C_aC_2$ furnace | Line | Neutral | No |
| 2 | $C_aC_2$ conveying e storage | Line | " | " |
| 3 | $C_2H_2$ generation | Line | " | " |
| 4 | $C_aC_2$ gurnace | Area | " | " |
| 5 | Line hydrate system | Area | " | " |
| 6 | $C_aC_2$ drumming | Line | " | " |
| 7 | $C_2H_2$ purification plant | Area | " | " |
| 8 | Gosholdes, seals etc. (general) | Area | " | " |
| 9 | $C_aC_2$ furnace reorientated | Line/Area | " | " |
| 10 | Crushing plant | Stack | " | " |
| 11 | $C_aC_2$ furnace | Line | " | Yes |
| 12 | $C_aC_2$ furnace | Line | Stable | No |
| 13 | $C_aC_2$ furnace | Line | " | Yes |
| 14 | Line hydrate | Area | " | " |
| 15 | $C_aC_2$ conveying e storage | Line | " | " |
| 16 | $C_2H_2$ generation | Line | " | " |
| 17 | $C_aC_2$ furnace | Area | " | " |
| 18 | Gosholdes, seals etc. (general) | Area | " | " |
| 19 | $C_aC_2$ drumming | Line | " | " |
| 20 | $C_aC_2$ furnace | Stack | " | " |
| 21 | Crushing plant | Stack | " | " |
| 22 | Calcining plant | Stack | " | " |
| 23 | $C_aC_2$ furnace reorientated | Area/Line | " | " |