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EPA COMPLEX TERRAIN MODEL DEVELOPMENT
Description of a Computer Data Base from Small Hill Impaction Study No. 1 Cinder Cone Butte, Idaho

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RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

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Description of a Computer Data Base
from Small Hill Impaction Study No. 1
Cinder Cone Butte, Idaho

by

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ABSTRACT

As part of the U.S. Environmental Protection Agency's effort to develop and demonstrate a reliable model of atmospheric dispersion for pollutant emmissions in irregular mountainous terrain, the Complex Terrain Model Development Program was initiated. The first phase, a comprehensive tracer field study, was carried out on Cinder Cone Butte, Idaho, during the autumn of 1980. Eighteen quantitative tracer experiments were conducted, each lasting 8 hr at night or early morning. The main tracer gas was sulfur hexafluoride; a second tracer, Freon 13B1 was used in ten of the eighteen experiments. Averaged meteorological data were recorded from six towers near and on the slopes on the hill. Data consisted of direct and derived measures of temperature, wind, turbulence, solar and net radiation, and nephelometer coefficent of scattering. Hourly wind profiles were obtained from pilot balloon observations; tethersonde observations recorded profiles of wind and temperature.

Tracer gas concentrations were detected by a network of approximately 100 samplers located on the slopes of the hill. The system used to collect the data, the operational procedures used to run the system, and its performance record are described. Tables of tracer gas release data have been included to assist in any modeling effort. All meteorological and

tracer concentration data have been edited and recorded on magnetic tape and are now available, upon request, at the National Computer Center, Research Triangle Park, North Carolina, either as copies or by interactive computer access.

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LIST OF SYMBOLS AND ABBREVIATIONS

SYMBOL

b_{scat}	Scattering coefficient - Nephelometer
C	Concentration
Fr	Froude number
g	Acceleration caused by gravity
h	Hill height
H	Height of the plume centerline above the ground over flat terrain
H_c	Critical dividing streamline height
IX, IY, IZ	Turbulence intensities alongwind, crosswind, and vertical
N	Brunt-Vaisala frequency
Q	Tracer emission rate
r, θ, z	CCB polar coordinate system coordinates
σ_θ	Standard deviation of horizontal wind direction
σ_w	Standard deviation of vertical velocity fluctuations
σ_u	Standard deviation of alongwind velocity fluctuations
σ_v	Standard deviation of crosswind velocity fluctuations
T_o	Average temperature
u_s	Wind speed at source
U, u	Uniform wind speed of flow approaching hill

LIST OF SYMBOLS AND ABBREVIATIONS (Continued)

z_i	Mixed layer height
z_r	Plume release height

ABBREVIATION

AFB	Air Force Base
AID	Analytical Instrument Development, Inc.
CCB	Cinder Cone Butte
CTMD	Complex Terrain Model Development Program
ECL	Executive Control Language
EPA	U.S. Environmental Protection Agency
ERT	Environmental Research & Technology, Inc.
FAA	Federal Aviation Administration
FMF	Fluid Modeling Facility
GC	Gas chromatograph
MSL	Mean Sea Level
MST	Mountain Standard Time
NOAA	National Oceanic and Atmospheric Administration
NRTS	National Reactor Testing Station
ppb	Parts per billion by volume

LIST OF SYMBOLS AND ABBREVIATIONS (Continued)

ppt	Parts per trillion by volume
RTD	Resistance Thermometric Device
SHIS	Small Hill Impaction Study
TRC	TRC Environmental Consultants, Inc.
WPL	Wave Propagation Laboratory

ACKNOWLEDGEMENTS

This report is partly composed of excerpts from publications and documents produced by Environmental Research and Technology, Inc. (ERT) the prime contractor for the Complex Terrain Model Development project, who compiled the computer data base of magnetic tapes. As referenced in the text, the First Milestone Report - 1981 by Lavery et al. (1982), was another important source, as was the Quality Assurance Project Report for Small Hill Impaction Study No. 1 by Greene and Heisler (1982). Section 7 of this report is a reproduction of a document by Strimaitis and DiCristofaro of ERT describing a special Modelers' Data Base they developed from data acquired at Cinder Cone Butte. The magnetic tape files containing observed and computed values derived to assist any modeling effort were included in the computer data base and made accessible along with all other tape files.

All credit for creation of the computer data base and documentation of the effort must go to the scientists and investigators at ERT. The purpose of this report was to condense available documentation into one volume that would serve as a convenient handbook for any investigators who might acquire and use this valuable computer data base.

SECTION 1

INTRODUCTION

1.1 EPA PROGRAM

The extensive development of energy resources, especially in the mountainous terrain of the western United States, has generated concern about the resulting impact on air quality (as well as on water and land). Even in relatively simple situtations, it has been difficult to produce reliable calculations of atmospheric transport and diffusion. In complex terrain, mathematical modeling is confounded because the physical processes are more complicated and meteorological measurements are less "representative" than in level terrain settings. Responding to this fundamental problem, the U.S. Environmental Protection Agency (EPA) has embarked upon the Complex Terrain Model Development (CTMD) Program, a major program to develop and demonstrate reliable models of atmospheric dispersion for emissions in mountainous terrain.

An early step in the development of this program was the convening of a workshop on problems in modeling atmospheric dispersion over complex terrain. In concert with recommendations of the workshop report (Hovind et al., 1979), EPA's CTMD Program involves a coordinated effort in mathematical model development, field experimentation, and scaled physical modeling. The Program's basic objective is the production of practical models with demonstrated reliability. Initially the CTMD Program has focused on the problem of stable plume impaction/interaction with elevated terrain. This phenomenon was singled out because of the likelihood of relatively high concentrations and because models that are in use have been challenged extensively. The approach has been to study stable plume interactions first in relatively simple terrain settings and subsequently in more complex situations.

EPA's prime contractor for carrying out the CTMD program is Environmental Research and Technology, Inc. (ERT). Significant contributions are also being provided by EPA's Fluid Modeling Facility (FMF) and by the National Oceanographic and Atmospheric Administration's Wave Propogation Laboratory (WPL) through their sophisticated measurement capabilities. A comprehensive tracer field study was carried out on Cinder Cone Butte (CCB), near Boise, Idaho, during the autumn of 1980 (Small Hill Impaction Study No. 1, SHIS #1). Based on those data, several models of plume impaction have been tested and some relatively new modeling concepts have been introduced (Lavery et al., 1982; Strimaitis et al., 1983).

1.2 OBJECTIVE

The purpose of this report is to describe the data that were collected in the tracer field study on CCB and to publicize their availability. These data offer a wealth of information for model development/testing, which is continuing in the EPA Program. This report is based on three other reports which provide further details and trace the history and refinement of the data. The first two are program milestone reports (Lavery et al., 1982; Strimaitis et al., 1983), while the third is a very thorough report on quality assurance (Greene and Heisler, 1982). In spite of the publication dates, these documents were written in the order mentioned above. They should be consulted for details beyond those provided here.

This report describes the setting of CCB, the experimental approach, and the following data archived on magnetic tape in seven sets of data files:

- Tower (six) wind and temperature measurements (unaltered but flagged), solar and net radiation at one location, and nephelometer data;
- Tower wind data refined by applied quality assurance procedures;
- Tracer gas concentrations and release data;
- Winds based on pilot balloon data;
- Winds, temperatures, and moisture measured from tethersondes;
- Winds, temperatures, and moisture measured from balloon-borne minisondes; and
- The modelers' archive of derived wind and temperature values at tracer release locations and measured tracer concentrations (tracer values in this file differ from those in data file 3; here averages are taken of colocated samplers, reanalyzed samples, and 10-min samples during a given hour).

In the first set of data files, the nephelometer measurements were taken at three locations near the top of CCB. These data (5-min averages of backscatter) are listed with Tower B data. A preliminary evaluation of these measurements indicates that they are qualitatively useful for determining when and where plume impact occurs. Although lidar measurements (by WPL) and extensive photography were made of the oil fog plumes, those data are not available for publication at this time. Pertinent scaled physical modeling studies by EPA's FMF are being published as they become available.

SECTION 2

FIELD STUDY AT CINDER CONE BUTTE

2.1 GEOGRAPHIC AND METEOROLOGICAL SETTINGS

Cinder Cone Butte is an isolated small hill in the Snake River Valley, located about 50 km SSE of Boise and 25 km NW of Mountain Home Air Force Base, Idaho. Near CCB the main axis of the valley is SE-NW. Mountains begin to rise sharply at roughly 20 km NE and SW of CCB. Immediately east of CCB some summer farming is done for potatoes, sugar beets, and grain. The butte is on the eastern boundary of a National Guard training range. The soil is mostly sandy and rocky with some grass as tall as 0.5 m and sparse scrub brush that rarely reaches 2 m.

Figure 1 illustrates the topography of CCB. Contours are shown in 10-m intervals. The base (zero) contour is at an elevation of 945 m (3100 ft) above sea level. Both rectangular and polar coordinates, with origins at the center of CCB, have been used. Cinder Cone Butte is a two-peaked, roughly axisymmetrical hill, about 95 m high. The nearly circular base is about 1 km in diameter. The upper part of the butte has slopes that are generally around 25 degrees. There are several roads near the base of CCB and one to the top to service a permanent FAA tower on the northern peak. Several photographs of CCB are presented in the report by Lavery et al. (1982).

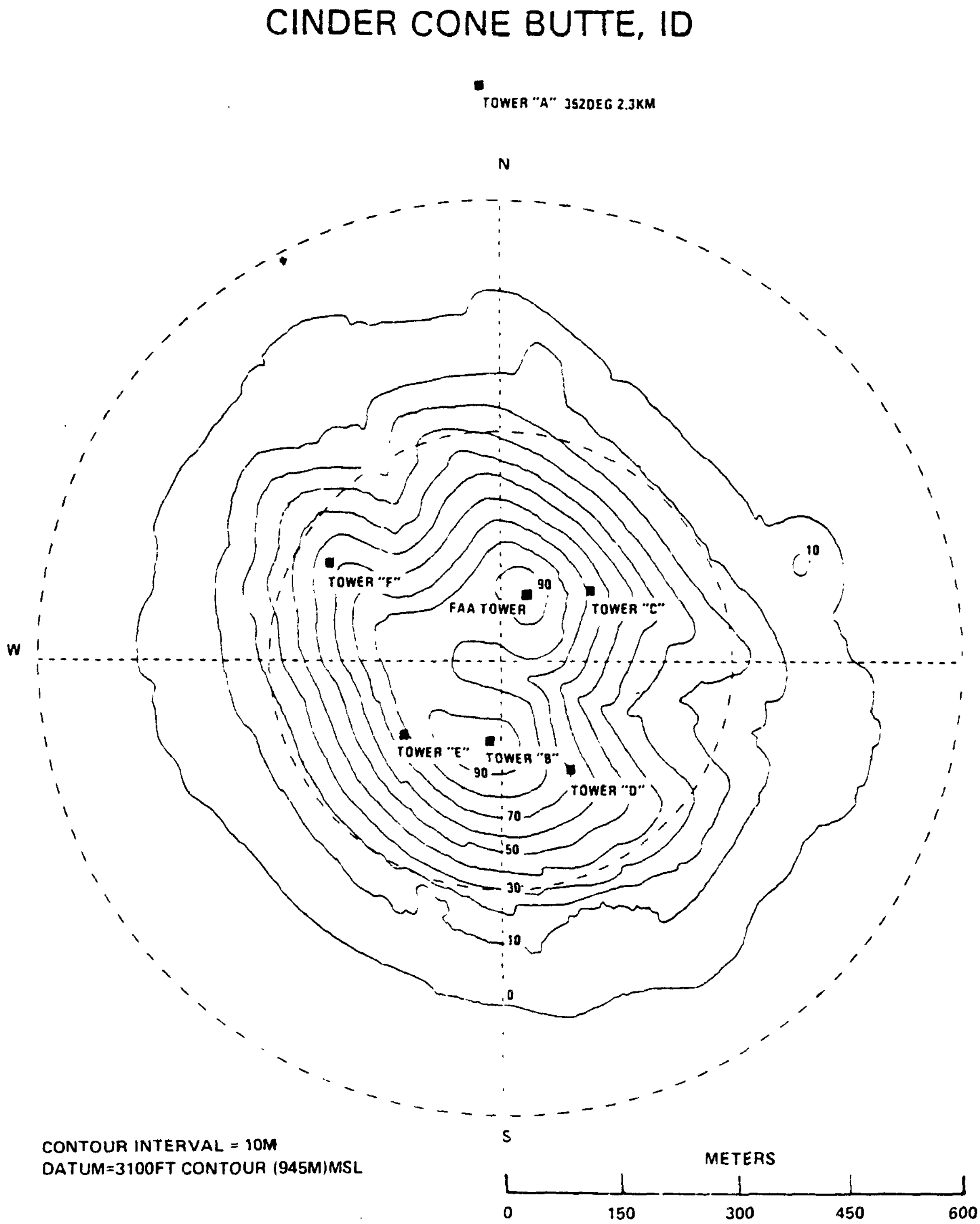

Figure 1. Topography of Cinder Cone Butte

General meteorological information indicated a high frequency throughout the year of nights with marked temperature inversions. The autumn season was targeted for the field study in order to operate during longer nights but before the normal onset of winter storms. Summaries of hourly wind observations from nearby Mountain Home AFB indicated predominant surface air flow from either the southeast or northwest, along the valley's axis.

2.2 EXPERIMENTAL DESIGN

The field study was designed so that tracer releases from a platform lifted by a large crane would impact on or interact with CCB. Sixty sequential bag samplers were deployed over the butte to collect up to twelve 1-h samples each during each experiment. Twenty samplers were programmed to collect 10-min samples. Seventy of these samplers were in fixed locations and ten were moved according to meteorological conditions. In addition, a small number of samplers were used for background determination, for colocation, and for vertical sampling at two or three levels on four 6-m "reflection" masts (operated during experiments 203 to 218). Except for 3- or 6-m levels on masts, the sampler intakes were nominally at 1 m above local ground.

During Phase I, September 16 to 27, 1980, ten "shakedown" and strictly visualization experiments were conducted. During Phase II, October 16 to November 12, 1980, eighteen quantitative tracer experiments (numbers 201 to

218) were carried out. Each lasted 8 h and was conducted at night or early morning. The main tracer was sulfur-hexafluoride (SF_6). An oil fog, for visualization of the plume, was generated within 1 m (horizontally) of the SF_6 release point. A second tracer, Freon 13B1 (CF_3Br) was released simultaneously at a different elevation (usually lower) in nine experiments (numbers 208, 210, 211, and 213 to 218). The tracer gas concentrations in the bags were measured by gas chromatography. The lowest quantifiable limits of detection were 20 parts per trillion (ppt) of SF_6 and 220 ppt of Freon. More than 14,000 bag samples (1-h and 10-min) were analyzed. In cases where it was clearly demonstrated that the tracer gas(es) did not reach the bag samplers, most of those bags were not analyzed. In one tracer experiment (number 212) the wind was so variable that it was not possible to align the release system upwind of the sampler array. The visible oil fog plume was never observed to hit the hill. No concentrations of SF_6 were above 5 ppt, indicating a lack of background contamination. No meteorological data are included in the files for experiment 212. The tracer release and analysis procedures and quality assurance program are discussed extensively in the three documents mentioned previously and in other appropriate sections of this report.

A lidar (operated by WPL) took backscatter measurements through vertical sections of the oil fog plume but those data are not included in the archive described here. Nephelometer measurements were collected at three locations near the top of CCB. These data (5-min averages) are qualitatively useful for determining plume impact. An attempt was made to collect nephelometer data from instruments hung from a crane, but the data were not usable and are not included in the archive.

The arrangement of the meteorological monitoring equipment is shown in Figure 1. There were six towers. Tower A, 150 m tall, was instrumented at eight levels with a resistance thermometric device, at five of those levels with triaxial propeller anemometers, and at three of the latter levels with cup-and-vane wind instruments. Fast-response thermistors were operated at two levels for determining standard deviations of temperature. Tower A was located 2 km north of CCB, where scaled modeling studies at EPA's FMF had shown it to be outside the region of flow disturbed by the butte in the frequent stable southeasterly or northwesterly flows. A pyranometer and a net radiometer were located 40 m WSW of the tower base.

Tower B, 30 m tall, was located on top of the south knoll of CCB. It was instrumented at three levels with resistance thermometric devices and triaxial propellers and also at the two upper levels with cup-and-vane instruments.

Towers C through F, 10 m tall, were located on CCB near the 70-m contour, except F was about 10 m lower. Each was instrumented at two levels with resistance thermometric devices and triaxial propellers and also at the upper level with cup-and-vane instruments. The sampling frequency for all tower-mounted meteorological instruments was 4 Hz, which was used in real time to calculate 5-min and 1-h average values for automatic storage in the computer and display at the command post. Differences in the operating characteristics of the two wind systems and refinement of the measurements are discussed in detail in the quality assurance document mentioned earlier (Greene and Heisler, 1982). The base of the FAA tower was used to install a nephelometer instrument.

A tethersonde was operated at one of two sites (depending on wind direction) located about 1.3 km NW and SE from the butte center; the sondes were released from the more upwind of the two sites. Ascent and descent measurements were made of temperature, pressure, wind direction and speed, and moisture, normally at 1-h intervals during tracer releases. When winds were too fast to operate the tethersonde or the tethersonde system was inoperable, data were obtained from minisondes tracked by theodolite. In addition, double-theodolite pibals were taken at hourly intervals between tethersonde soundings.

Temperature and wind instruments 1 m above ground were deployed at five locations along the east-facing draw on CCB in order to document low-level drainage winds. However, the records and some instruments were stolen from the site and have not been recovered.

In addition to the lidar, the WPL also operated a frequency-modulated, continuous-wave radar to determine winds aloft and two monostatic acoustic sounders to determine stability structure aloft. However, these data are not yet available.

Further details on the CCB data archive are given in other appropriate sections of this report and in the reports by Lavery et al. (1982), Strimaitis et al. (1983), and Greene and Heisler (1982).

SECTION 3

TOWER METEOROLOGICAL DATA

3.1 FIXED METEOROLOGICAL NETWORK

Six meteorological towers, designated A through F, were deployed at the CCB site as shown in Figure 2 (Lavery et al., 1982). Tower A, the 150-m "profile" tower, was located about 2 km north of the butte, where tow-tank experiments at EPA's FMF had shown it would be outside the region of flow disturbed by the butte in the predominantly NW and ESE nocturnal winds of the Snake River Basin. Tower B, 30 m high, was located on the top of the south peak of the butte. Towers C through F were 10 m high, based within the 62- to 78-m contours (see Figure 1), and deployed approximately at 90 degree intervals from the center of the butte.

Meteorological data are identified in the computer data base by a code of four to six characters, the first of which identifies the tower, A through F, the second and third the level on the tower, and the remainder the type of data. Because the heights of the nine instrument levels on Tower A extend to 100 m and beyond, the levels are coded as simple identifiers, L0 to L8. For the other towers, the level codes are the level heights in meters above the tower base. Table 1 (Lavery et al., 1982)

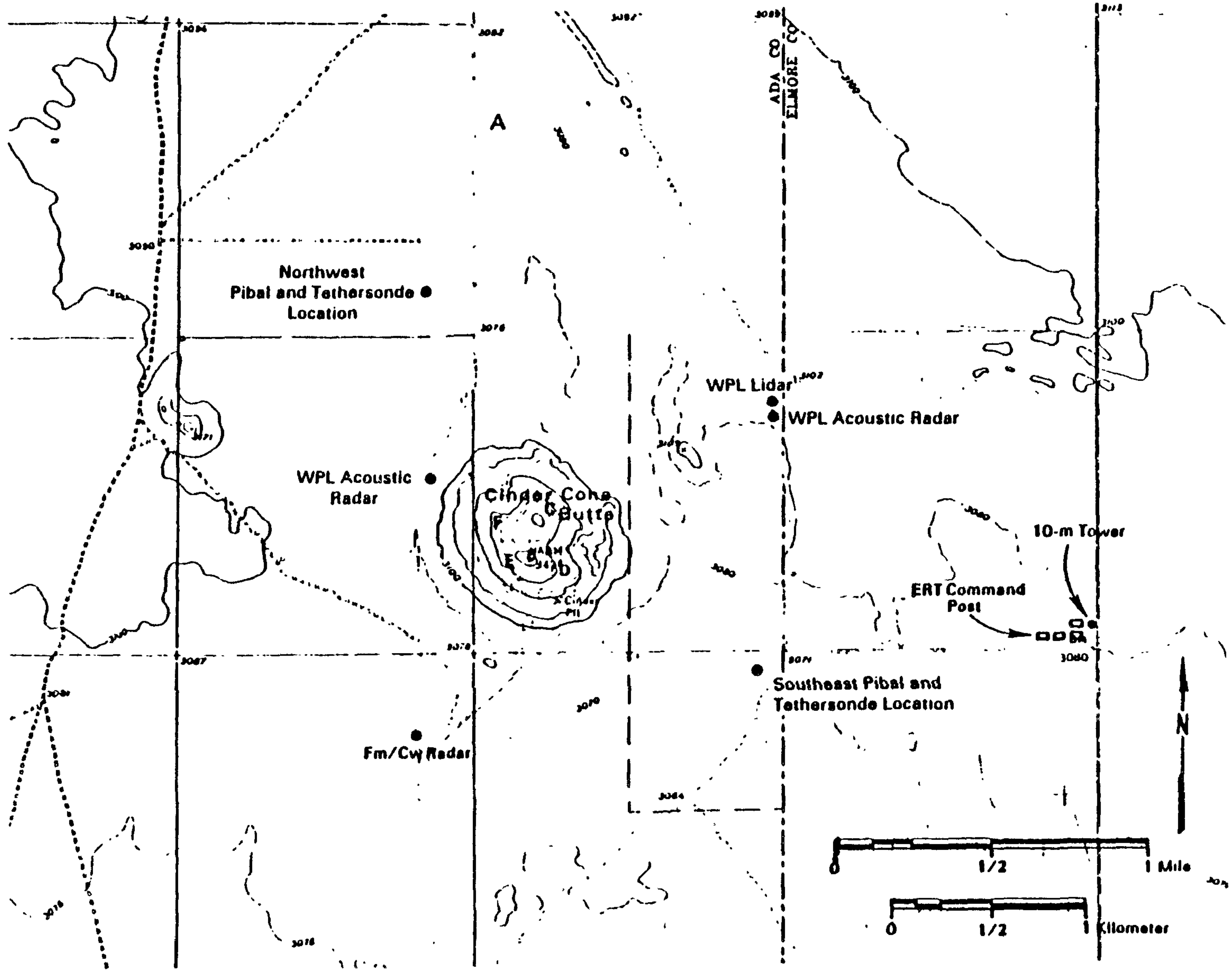

Figure 2. Field experiment layout. A is the 150-m tower; B is the 30-m tower, C, D, E, are 10-m towers.

illustrates the arrangement of instrumentation on each tower, and Table 2 (Lavery et al., 1982) identifies the codes used for each type of meteorological data measured.

Tower A was a Unarco-Rohn Model 80 with a Tower Systems elevator that lifted the instrument booms to 10, 40, 80 and 150 m. It was instrumented with temperature sensors at eight levels and wind sensors at five levels. A net radiometer and pyranometer were located about 1 m above the ground and roughly 40 m WSW of the tower base. The tower was surrounded by fairly sparse prairie grass about 50 cm high except near its base, where the grass had been trodden down by people and vehicles during installation and maintenance.

There were two temperature sensors on Tower A at both the 10- and 150-m levels. One was a standard platinum resistance thermometric device (RTD), giving temperature differences from the 2-m level, and one fast response thermistor bead, installed for the purpose of calculating the standard deviation of temperature. Both sensors at either level were mounted in the same aspirated shield. All aspirators were installed with the intake end facing north.

Tower B, a Unarco-Rohn Model 55 on top of the butte, was instrumented with wind and temperature sensors at the 2-, 10-, and 30-m levels. The area around its base was fairly smooth, soft rock and soil without vegetation. Very sparse grass, 10 to 20 cm long, and small stones covered the slopes of the hill away from this tower.

The other four towers, C through F, were identically instrumented Unarco-Rohn Model 45's; wind and temperature sensors were mounted at 2- and

TABLE 1A. TOWER INSTRUMENTATION AND MEASURES

Site	Instrument*	Direct Measures**	Derived Measures+
Tower A			
Level 0 (1 m)	Pyranometer	Insolation	
	Net radiometer	Net radiation	
Level 1 (2 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	Cup-and-vane	UX, VX	SP, DR
	RTD	T	
Level 2 (10 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	Cup-and-vane	UX, VX, MS, MD, SD	SP, DR
	RTD	TD	TC
	Fast bead thermistor	T, ST	
Level 3 (20 m)	RTD	T	
Level 4 (40 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	RTD	TD	TC
Level 5 (60 m)	RTD	T	
Level 6 (80 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	RTD	TD	TC
Level 7 (100 m)	RTD	T	
Level 8 (150 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	Cup-and-vane	UX, VX	SP, DR
	RTD	TD	TC
	Fast bead thermistor	T, ST	

(continued)

TABLE 1A. (Continued)

Site	Instrument*	Direct Measures**	Derived Measures+
Tower B			
Level 2 (2 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	RTD	T	
Level 10 (10 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	Cup-and-vane	UX, VX	SP, DR
	RTD	TD	TC
Level 30 (30 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	Cup-and-vane	UX, VX	SP, DR
	RTD	TD	TC
(1.5 m)	Nephelometer	ANEPH	
Towers C, D, E, F			
Level 2 (2 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	RTD	T	
Level 10 (10 m)	Triaxial props	U, V, W, IX, IY, IZ	WS, WD
	Cup-and-vane	UX, VX	SP, DR
	RTD	TD	TC
Tower D			
(1.5 m)	Nephelometer	CNEPH	
FAA Tower (north peak)			
(1.5 m)	Nephelometer	BNEPH	

(continued)

TABLE 1A. (Continued)

*All temperature sensors were mounted in aspirated radiation shields; an RTD is a Resistance Thermometric Device.

**"Direct" measures are those calculated by the data station microprocessors from the outputs of the instrument translators. The turbulence data (IX, IY, IZ, SD, ST) were calculated for both 5-min and 1-h data periods. All direct measures were updated once per min by the data stations. UX and VX are the westerly and southerly components of the wind calculated from the cup-and-vane outputs at the 4 Hz sampling frequency.

+"Derived" measures are those calculated by the data collector computer from the 5-min averages provided by the data stations. These derived measures comprise 5-min average values of the measures indicated as well as 1-h averages of all direct and derived measures except the turbulence data, 1-h averages of which were calculated by the data stations.

Tower elevations - datum = 944.9 m MSL

Tower A	=	-03.5 m
Tower B	=	98.0 m
Tower C	=	69.0 m
Tower D	=	69.4 m
Tower E	=	78.8 m
Tower F	=	61.8 m
FAA Tower	=	94.9 m

TABLE 1B. CLIMATRONICS INSTRUMENTS USED FOR TOWER INSTRUMENTATION

Type	Model no.
UVW component anemometer - Triaxial props (23 cm styrofoam propellers)	WC-13
Cup-and-vane windset	F460
Platinum resistance thermometric device - RTD	100826
Fast response bead thermistor probe	100093-4
Motor aspirated temperature probe	TS-10
Solar radiation sensor - pyranometer	1000484
Net radiation sensor - net radiometer	100881

TABLE 2. IDENTIFICATION OF MEASUREMENT CODES

Code	Units	Instrument	Measurement
SR	ly/min	pyranometer	solar radiation
NR	ly/min	net radiometer	net radiation
U, V, W	m/s	propellers	westerly, southerly, vertical wind components
WS	m/s	propellers	vector resultant wind speed
WD	degrees	propellers	vector resultant wind direction
IX, IY, IZ	percent	propellers	alongwind, crosswind, and vertical intensity of turbulence
UX, VX	m/s	cup-and-vane	westerly and southerly wind components
SP	m/s	cup-and-vane	vector resultant wind speed
DR	degrees	cup-and-vane	vector resultant wind direction
T	°C	RTD	dry bulb temperature
TD	°C	RTD	temperature difference from 2-m level
TC	°C	T & TD	calculated temperature
TF	°C	bead thermistor	dry bulb temperature

(continued)

TABLE 2. (Continued)

Code	Units	Instrument	Measurement
ST	°C	bead thermistor	standard deviation of dry bulb temperature
MS	m/s	cups	scalar mean wind speed
MD	degrees	vane	scalar mean wind direction
SD	degrees	vane	standard deviation of wind direction
ANEPH, BNEPH, CNEPH	b_{SCAT}, m^{-1}	nephelometer	scattering coefficient

10 m. Tower C, to the NE of the butte's center, was based on a steep slope covered with sparse, short grass, small stones and soil. Tower D was to the SE of the center of the butte and located approximately 20 m north of the crest of the ridge coming down from Tower B. Here the grass was somewhat longer (20 to 30 cm) and thicker than it was around the other towers on the butte, particularly on the steep slope NE of this tower. The ground around Tower E, on the other hand, was nearly free of vegetation except for some sagebrush and large rocks up to 0.5 m in diameter and half that in height. Tower F sat on a small, fairly level spot on the ridge to the S of the NW draw. The ground around it was quite variable, mostly short sagebrush below it and to the N on the slope of the draw, with short grass and small rocks in other directions.

Because the sites of the four 10-m towers were sloped, and the different wind instruments at the 10-m level were separated from one another by crossarms, the heights of the sensors above the ground must be regarded as "nominal".

Sites were established for three nephelometer instruments to detect the impact of the oil-fog plume on CCB. Nephelometer-A was located at the base of Tower B on the south peak, nephelometer-B on the north peak near the FAA Tower, and nephelometer-C at the base of Tower D. All instrument sample intakes were approximately 1.5 m above the ground. Data were recorded as a scattering coefficient (b_{scat}) and placed in Tower B data tape files.

Certain of the measures in the CCB data base require explanation. With the exception of measurements made at 10 m on Tower A, all wind speeds and directions are horizontal vector resultant values whether derived from triaxial propeller anemometers or from cup-and-vane sets. These measures are derived from the propellers simply by averaging the u (westerly) and v (southerly) component values from the respective propellers. The measurements from the cup-and-vane sets were resolved into westerly and southerly components as the data were taken at the 4-Hz sampling frequency. Only at the 10-m level on Tower A were the cup mean speed (MS) and vane mean direction (MD) recorded in the traditional, single-sensor fashion. Standard deviation of vane direction (SD) was also calculated only for this site.

The other measures requiring explanation are the intensities of turbulence, IX, IY, and IZ, respectively, the alongwind, crosswind, and vertical intensities. These are approximately $\sigma u/\bar{U}$, $\sigma v/\bar{U}$, and $\sigma w/\bar{U}$, where $\bar{U}$ is the mean horizontal wind speed. The CCB measures, however, are calculated from the signals of the propeller anemometers by means of the following algorithms:

$$IX = \{\frac{1}{N} [\frac{(\Sigma u)^2 \Sigma u^2 + (\Sigma v)^2 \Sigma v^2 + 2\Sigma u \Sigma v \Sigma uv}{(\Sigma u)^2 + (\Sigma v)^2} - \frac{(\Sigma u)^2 + (\Sigma v)^2}{N}]\}^{\frac{1}{2}} \div \bar{U}$$

$$IY = \{\frac{1}{N} [\Sigma u^2 + \Sigma v^2 - \frac{(\Sigma u)^2 \Sigma u^2 + (\Sigma v)^2 \Sigma v^2 + 2\Sigma u \Sigma v \Sigma uv}{(\Sigma u)^2 + (\Sigma v)^2}]\}^{\frac{1}{2}} \div \bar{U}$$

$$IZ = \{\frac{\Sigma w^2 - (\Sigma w)^2}{N}\}^{\frac{1}{2}} \div \bar{U},$$

where $U = \frac{[(\Sigma u)^2 + (\Sigma v)^2]^{\frac{1}{2}}}{N}$ is the vector resultant mean wind speed, N is the number of samples in the calculations, and u, v, and w are the instantaneous wind component speeds from the triaxial propeller anemometers.

3.1.1 Data Acquisition System

Each of the 89 instrument transmitters in the fixed meteorological network was sampled four times a second. This sampling was done by nine microprocessors (ERT Data Station Model No. DS-00) installed with the instrument translators and power supplies in the two shelters provided, one to the west of the 150-m tower and one between the two peaks of the butte, which served the five shorter towers. The microprocessors converted the 0- to 5- volt instrument outputs to digital values, calculated the intensities of turbulence and standard deviations of temperature and wind direction, resolved the cup-and-vane data into westerly and southerly components, and made 5-min averages of 142 measurements. All calculations were updated once per minute by the microprocessors.

The 5-min data were collected by a minicomputer located in ERT's base trailer approximately 3 km E of the butte. This data collector was a Data General Nova 3 equipped with two disk drives, a tape drive, and a Digital Equipment Corporation Decwriter as interactive console. The data collector polled each microprocessor channel every 5 min for the 5-min data and every hour for the turbulence quantities. It did parity and range checks on the data received (flagging faulty data), resolved the vector component wind data into speeds and directions, calculated temperatures at elevated tower locations by adding ΔT's to 2-m T's, wrote a selected subset of 5-min data on the console for experiment control, accumulated hour averages of the 142 measurements provided by the microprocessors, and wrote the data to disk. On the hour it also requested the 1-h turbulence quantities from the microprocessors and made the same calculations from its accumulated hour averages that it did from each 5-min scan of data.

The scan of the microprocessors' 142 channels took longer than 1 min so that all the data associated with a particular time are not necessarily representative of the same 5-min period. Consequently a calculated temperature (TC) may sometimes not equal the sum of the 2-m temperature (T) and the temperature difference (TD) because the T value was requested again by the data collector just before the calculation of the higher level TC.

At least once per hour (every 20 minutes during the later experiments) the Data General M-600 at ERT's office in Concord, MA, requested the 5-min data (and 1-h data if appropriate) from the Nova and wrote it to disk for archive.

The microprocessors in the instrument shelters and the data collector in the trailer communicated via cables. The microprocessors transmitted their data as integers between 0 and 1,023. The resolution of the transmitted data was therefore slightly better than 0.1% of full range. The range and resolution of each of the measurements is listed in Table 3 (Lavery et al., 1982). The data collector and the computer in Concord communicated via telephone line. Figure 3 (Lavery et al., 1982) is a schematic of the data acquisition system.

3.1.2 Quality Assurance Plan

ERT's quality assurance plan (Greene and Heisler, 1982) for the fixed meteorological measurements was based on careful, documented calibration of the instruments before installation; a calibration check shortly before Phase 2, the complete tracer experiments that started in the middle of October; a calibration check at take-down in mid-November; and the performance audit by TRC. Additional automatic quality control (QC) checks for parity and range were done by the data collector computer in real time (see Section 3.1.1 above).

The instruments could not be completely checked out and calibrated, as planned in the ERT laboratory in Ft. Collins prior to installation because the period between receipt of the instruments from the manufacturer and startup was too brief. The field calibration done at installation, however, incorporated most of the laboratory procedures. The output of the cup and propeller anemometers was checked when spun with a synchronous motor and when held stationary, the bearings of the vanes and anemometers were checked

TABLE 3. MEASUREMENT RANGE AND RESOLUTION DUE TO INTEGER COMMUNICATION

Code	Measurement	Range	Resolution
SR	solar radiation	0.0 to 2.0 ly/min	.0019 ly/min
NR	net radiation	-0.5 to 2.0 ly/min	.0024 ly/min
U, V	horizontal wind components (props)	-25 to +25 m/s	.049 m/s
W	vertical wind component (prop)	-10 to +10 m/s	.020 m/s
IX, IY	horizontal turbulence intensities	0 to 100 percent	.098 percent
IZ	vertical turbulence intensity	0 to 40 percent	.039 percent
UX, VX	horizontal wind components (C&V)	-50 to +50 m/s	.098 m/s
T	dry bulb temperature	-30 to +50°C	.078°C
TD	temperature difference	-5 to +15°C	.020°C
TF	fast response temperature	-30 to +50°C	.078°C
ST	standard deviation of temperature	0 to 16°C	.016°C
MS	scalar mean wind speed	0 to 50 m/s	.049 m/s
MD	scalar mean wind direction	0 to 540 degrees	.528 degrees
SD	standard deviation of vane direction	0 to 108 degrees	.016 degrees

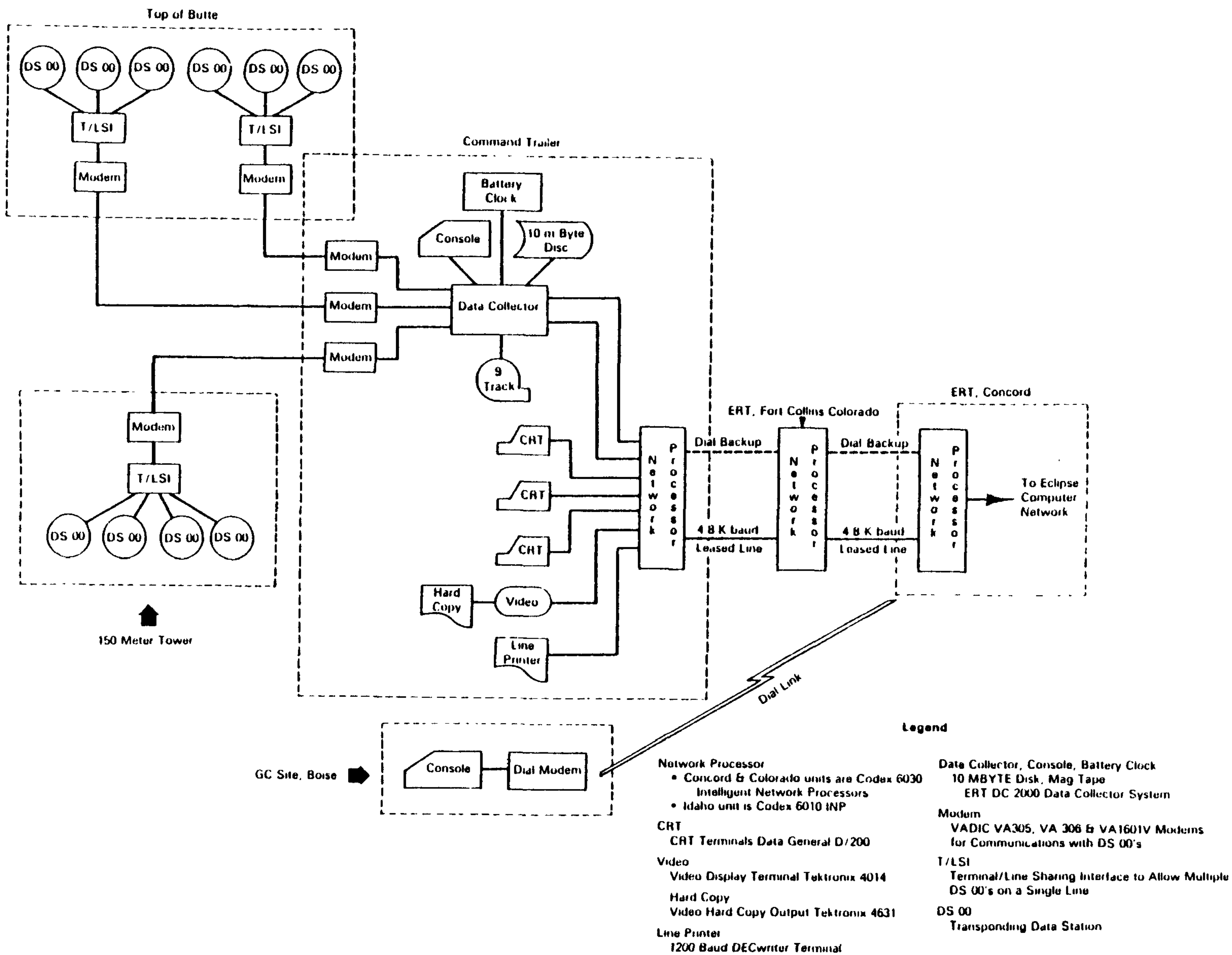

Figure 3. Data collection system configuration.

for proper performance, and vane output was checked when pointed towards and away from known landmarks. Temperature sensors were immersed in cold and warm stirred water baths whose temperatures were measured with NBS-traceable precision thermometers. All instrument translator cards were tuned to give correct output voltages at various calibration points.

3.1.3 Data Editing

ERT has performed two types of editing on the data from the fixed meteorological network. The first was an examination of each 5-min value to flag data that were identified as incorrectly transmitted to the data collector or that were taken from a malfunctioning sensor. The second editing process was correction of the data for consistent and significant calibration errors, for misorientation of wind sets to true north as determined by TRC's audit, for instrument response characteristics, and for effects of tower wakes.

The first data editing, or validation, was largely necessitated by two types of equipment failures. Shielded cable had been specified by ERT for the data links from the microprocessors in the instrument shelters to the data collector, but it could not be obtained from vendors in time for the startup of the experiments, and unshielded cable was used. This resulted in frequent communication errors in spite of parity checks done on both the data requests from the data collector and the data transmissions from the microprocessors. The second type of equipment failure was a loss of response of a UVW component propeller. Sometimes a propeller would stop turning almost completely, in which case the fault was easy to identify.

More frequently, however, the failure was more subtle - a slight "stiffening" of the instrument identified by an unusually low ratio of crosswind intensity of turbulence, IY, to alongwind intensity of turbulence, IX, or by changes in the relative values of U or V components with respect to an adjacent cup-and-vane set in similar conditions of wind speed and direction but separated by an hour or more.

The communication problems resulting from the unshielded cable caused two major types of errors. The first type was a miscommunication from a data station to the data collector that was not always picked up by the parity checking on the transmission. Such an error resulted in a value that looked peculiar in the time series of values for the measure affected. From the redundant wind measurements (both cup-and-vane and UVW propellers), errors of this type could be fairly easily verified for wind speed and direction except at the 40- and 80-m levels of Tower A, where propellers were alone and vertically separated by 30 m or more from the nearest source of data for comparison. Because of the strong thermal layering during many experiments, it was often unfeasible to verify a communications "hit" by comparison to these levels, and the determination that a value was suspect or in error depended entirely on whether it was unreasonable or out of place in the time series. Calculated temperatures at 10 m and 150 m could be validated by comparison with the values from the fast-response thermistors at these sites. Temperatures and temperature differences at other heights on Tower A were validated by comparison with temperatures above and below the height being validated.

Fortunately, few errors of communication from the data stations to the data collector resulted in values that were in the range of possible values. Most were recognized as faulty by the data collector and identified by an "M" flag.

A more difficult communication problem occurred in the data requests from the data collector to the data stations. A request for a wind component might, for example, be received as a request for a temperature, and the temperature would therefore be returned to the data collector and put into the data base as the wind value. All measured values were transmitted to the data collector as integers (called "counts") between 0 and 1,023 inclusively. The data collector converted them to proper engineering units by interpolation in the range of the measure. A temperature transmitted in error as a wind component would therefore not appear in the data base as the value of temperature that was sent but rather as the value of the wind component appropriate to the number of counts corresponding to the temperature. Consequently, one could look through all the data for the 5-min scan in which the suspect value occurred for another measure value that had the same associated counts. If such a measure was found, the suspect value was regarded as bad.

To expedite the time-consuming error check through all measurements taken during the experiments, the 5-min data were retrieved from the data base in time-series files for each experiment. In general, each of these files included all the 5-min measures for one level on a tower; there are 19 files per experiment in this "edit" format. A set of data flags for identifying the quality of the data was established as follows:

" " (blank): Both the editor and the data system concur that the value is valid.

"M" (missing): Both the editor and the data system concur the value is invalid.

"U" (unavailable): The value is unavailable because of data collector or data station failure.

"B" (bad): The editor believes the value is invalid but the data system did not catch the error; this flag is therefore associated either with instrument malfunction or communication problems.

"R" (restored): The editor believes the value is valid although the data system had flagged it "M".

"C" (calculated): The editor calculated a derived measure (WD, WS, SP, DR, TC), usually from "R" flagged values; the only exceptions are nonzero solar radiation values in a string of zeros at night, for which a 0.000 was inserted and flagged "C".

"S" (suspect): The editor believes the data are somewhat in error but cannot confirm either an instrument malfunction or communication failure.

"L" (at limit): The measure is at the upper limit of its range and the "true" value exceeds that shown. The instrument ranges were not themselves exceeded during the experiment, and this flag is necessary only for the turbulence data (IX, IY, IZ, SD) in very light and variable winds.

No data have been estimated and inserted into the data base.

In this validation editing, ERT tried to maintain a balance between the premise that all data are potentially valid and the premise that no data are above suspicion. Consequently, if no instrument failure or communications error could be verified, a value was regarded as valid unless it appeared to be unreasonable with respect to comparable values adjoining it in time and space. This is generally not a difficult judgement to make, but in some situations a value may look peculiar but not completely unreasonable and might indicate a significant phenomenon. Such data are left unflagged if they will not be misleading and are flagged "S" if they are substantially removed from the general trend.

The different characteristics of propeller wind sets and cup-and-vane systems are well demonstrated in the CCB data. In general, the vector resultant wind speed (WS) from the propellers was less than the vector resultant wind speed (SP) from a cup-and-vane set at the same location. The ratio of WS to SP decreased from 0.8 to 0.9 in high-speed smooth flows down to 0.5 or less in light and variable winds. In near-calm conditions, the props were observed to be more responsive to gentle puffs than the vanes, so that a 5-min wind direction (WD) and wind speed (WS) resolved from the props might be 175° at 0.2 m/sec, whereas the corresponding cup-and-vane direction and speed might be 245° at 0.5 m/sec. Both these pairs of wind measurements may appear in the validated data without any error flag because there was no indication of instrument malfunction or communication error. The differences between the measurements are attributable to the differences in the instruments.

Similarly, the response of propeller sensors is direction-dependent. Often the difference between WD and DR at the site changed markedly when WD passed through a cardinal direction such as 0°, 45°, 90°, or 135°. Again, the measures were both retained as valid in the data base.

The differences between the speeds and directions from the two kinds of instruments show general consistency with the differences anticipated as a result of the departure of the UVW systems from the cosine response curve, as discussed by Horst (1973). Furthermore, the horizontal intensities of turbulence IX and IY tend to become more nearly equal when the average angle of attack of the wind is approximately equal on both propellers (i.e., directions near 45°, 135°, 225°, 315°), whereas IX tends to exceed IY when the average angles of attack are substantially different (i.e., directions near 0°, 90°, 180°, 270°). This consistency suggested that the quality of the UVW data might significantly improve if corrections were applied similar to those described by Horst (1973), which were derived from comparisons of R. M. Young propeller data and sonic anemometer data. Although ERT was unable to find any similar comparative analysis of data for the Climatronics system, corrections for noncosine response were applied to all data from wind component propeller sensors, and a separate file of wind data was produced.

3.1.4 Periods Of Data Collection

Table 4 illustrates the dates and times of the experiments and the concurrent periods of meteorological tower data collection. No meteorological tower data collected during experiment 212, November 11, 1980, 1700 to 2400 MST have been included in the data base because the tracer gas never hit the sampler array on the butte.

TABLE 4. PERIODS OF METEOROLOGICAL DATA COLLECTION

Experiment no.	1980 Date	Experiment hours (MST)	Stability
201	10/16	1700 to 2300	E
202	10/17	1700 to 2300	E
203	10/20	0000 to 0800	E to F
204	10/21	0000 to 0800	E to F
205	10/23	0000 to 0800	E
206	10/24	0000 to 0800	E
207	10/25	0000 to 0800	E to F
208	10/27	1700 to 0100	E to F
209	10/28	1700 to 0100	F
210	10/30	0000 to 0740	E to F
211	10/31	0000 to 0800	E to F
213	11/04	0000 to 0800	E to F
214	11/05	0200 to 1000	E to F
215	11/06	0000 to 0600	E to F
216	11/09	0000 to 0700	E to F
217	11/10	0200 to 1000	E to F
218	11/12	0200 to 1000	E

NOTE: NO DATA COLLECTED FOR EXPERIMENT 212.

3.2 TOWER METEOROLOGICAL DATA TAPE FILES

Data are stored at the National Computer Center, Environmental Research Center, Research Triangle Park, North Carolina on Sperry UNIVAC 1100/83 systems magnetic tape, nine track, odd parity, ASCII-quarter word mode, density 6250 BPI, tape number 004700. Record length is 132 characters, and the block size is 1320 words or 40 records per block. Each file has three blocks. UNIVAC users may assign the tape, @ASG,T CCB,U9S//////Q,004700 using

UNIVAC Executive Control Language (ECL). Upon request, copies can be furnished and translated into formats acceptable to any computer using nine track tape drives.

3.2.1 Meteorological Data Tape File Index

Two sets of meteorological data files are recorded on tape number 004700. The first set of files, numbers 1 to 323, are edited but uncorrected data; data editing procedures and flags were performed as described. Table 5 illustrates how individual tape files are related to tower sites, record types, and experiment number in the first set of files.

The second set of files, numbers 324 to 612, are derived from the same wind speed and direction observations as set number one, except that the data have been corrected to account for audited misalignment of wind sets, for consistent errors in instrument calibration, for noncosine response of the wind component propeller sensors, and for the effect of tower wakes on wind speeds.

Wind speed and directions from the Climatronics F460 cup-and-vane anemometers were corrected for erroneous calibration, misalignment to true north, and mean nonlinearity in vane response. Wind speeds and directions derived from the UVW propeller anemometers were corrected for noncosine response, misalignment to true north, and consistent calibration errors that were greater than the resolution of the measurement provided by the data acquisition system. In addition, corrections were applied to wind speeds derived from both types of wind instruments to account for tower wakes. These corrections result in substantially improved correspondence between speed and direction data from the two types of wind sets.

TABLE 5. METEOROLOGICAL DATA SET NO. 1: EDITED DATA WITH UNCORRECTED WIND DATA - TAPE FILE NUMBERS

Experiment no.	Record type																			
	Tower A 150 m							Tower B 30 m				Tower C 10 m		Tower D 10 m		Tower E 10 m		Tower F 10 m	
	1	2	3	4	5	6	7	1	2	3	4	1	2	1	2	1	2	1	2
201	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
202	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
203	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
204	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
205	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
206	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114
207	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133
208	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152
209	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171
210	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190
211	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209
213	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228
214	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247
215	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266
216	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285
217	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304
218	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323

No corrections were made to the temperature data because of inconsistencies between results of two independent audits. The differences between audit or calibration values and output measurements were quite small for most of the temperature sensors. All but two indicated errors were less than 0.2 °C in magnitude, and it appeared that the magnitude of the errors was close to the resolution of the auditing procedures.

No corrections were made to the turbulence intensity data. Certainly these data are in error because of the response characteristics of the propeller sensors, but no satisfactory justifiable corrections were found to apply. In most cases, the intensity of turbulence data is probably too low.

Other errors that remain in the corrected data are the effects of the wake of one instrument on another and the effects of tower wakes on turbulence measurements and wind direction. Installation of propeller sensors on the north side of the towers resulted in a region between 90° and 125° in which the propeller speed was about 40% of cup anemometer speed. Data users should be advised to give precedence where possible to wind measurements from instruments that are clearly out of the wakes. A comprehensive discussion of this problem is presented in Greene (1982).

The second set of meteorological data files, numbers 324 to 612, contains a corrected version of wind data that are in the first set of tape files. Since no corrections were applied to temperature data, record type 1 from Tower A and record type 4 from Tower B were omitted from the second set of files. Table 6 illustrates the relationship of files to experiments.

TABLE 6. METEOROLOGICAL DATA SET NO. 2: EDITED DATA WITH CORRECTED WIND DATA - TAPE FILE NUMBERS

Experiment no.	Record type																			
	Tower A 150 m							Tower B 30 m				Tower C 10 m		Tower D 10 m		Tower E 10 m		Tower F 10 m	
	1	2	3	4	5	6	7	1	2	3	4	1	2	1	2	1	2	1	2
201		324	325	326	327	328	329	330	331	332		333	334	335	336	337	338	339	340
202		341	342	343	344	345	346	347	348	349		350	351	352	353	354	356	357	358
203		358	359	360	361	362	363	364	365	366		367	368	369	370	371	372	373	374
204		375	376	377	378	379	380	381	382	383		384	385	386	387	388	389	390	391
205		392	393	394	395	396	397	398	399	400		401	402	403	404	405	406	407	408
206		409	410	411	412	413	414	415	416	417		418	419	420	421	422	423	424	425
207		426	427	428	429	430	431	432	433	434		435	436	437	438	439	440	441	442
208		443	444	445	446	447	448	449	450	451		452	453	454	455	456	457	458	459
209		460	461	462	463	464	465	466	467	468		469	470	471	472	473	474	475	476
210		477	478	479	480	481	482	483	484	485		486	487	488	489	490	491	492	493
211		494	495	496	497	498	499	500	501	502		503	504	505	506	507	508	509	510
213		511	512	513	514	515	516	517	518	519		520	521	522	523	524	525	526	527
214		528	529	530	531	532	533	534	535	536		537	538	539	540	541	542	543	544
215		545	546	547	548	549	550	551	552	553		554	555	556	557	558	559	560	561
216		562	563	564	565	566	567	568	569	570		571	572	573	574	575	576	577	578
217		579	580	581	582	583	584	585	586	587		588	589	590	591	592	593	594	595
218		596	597	598	599	600	601	602	603	604		605	606	607	608	609	610	611	612

3.2.2 Tape Data Records

The first record of the first block of each file contains alphabetic ASCII characters of column headings for the data fields in the records that follow. This first record may be considered to have a FORTRAN statement, format (132A1). Column headings are coded in four or five characters, such as AL2TD, where the first three characters are tower and level identifiers, and the last one or two identify the meterological data. Here the "A" identifies Tower A, "L2" identifies level 2 (10 m), and the "TD" specifies the meteorological data, the value of temperature difference between the 10-m level and the 2-m level reference temperature. Table 7 lists the codes for towers, levels, and meteorological measurements.

All data records following the first record have data fields arranged as illustrated in Table 7.

TABLE 7. DATA RECORDS FORMAT

Position	Contents		FORTRAN format
1 to 4	Year	1980	I4
6 to 8	Day (Julian)	290 to 315	I3
10 to 11	Hour (MST)	00 to 23	I2
13 to 16	Seconds	0, 300, 600, 1500, 1800, 2100, 2400, 2700, 3000, 3300	I4
17 to 24	Meteorological data		F8.3
25	Data quality flag		A1
26 to 132	Meteorological data & data flag fields		F8.3, A1

3.2.3 Data Record Types

Meteorological data acquired during each experiment was classified into 19 separate files, of 13 different record types, according to tower, level and data type.

Table 8 classifies the record types of the first set of files, numbers 1 to 323, edited but uncorrected data.

TABLE 8. METEOROLOGICAL RECORD TYPES

Type	No. of data fields	Meteorological data	Data codes
		Tower A	
1	12	Temperature profile, 2 to 150 m	T, TD, TC
2	9	Solar radiation, fast response temperature, cup-and-vane wind statistics	NR, SR, TF, ST, MS, MD, SD
3	12	Wind data, 2-m level	U, V, W, WS, WD, IX, IY, IZ, UX, VX, SP, DR
4	12	Wind data, 10-m level	U, V, W, WS, WD, IX, IY, IZ, UX, VX, SP, DR
5	12	Wind data, 150-m level	U, V, W, WS, WD, IX, IY, IZ, UX, VX, SP, DR
6	8	Wind data, 40-m level	U, V, W, WS, WD, IX, IY, IZ
7	8	Wind data, 80-m level	U, V, W, WS, WD, IX, IY, IZ

(continued)

TABLE 8. (Continued)

Type	No. of data fields	Meteorological data	Data codes
		Tower B	
1	8	Wind data, 2-m level	U, V, W, WS, WD, IX, IY, IZ
2	12	Wind data, 10-m level	U, V, W, WS, WD, IX, IY, IZ, UX, VX, SP, DR
3	12	Wind data, 30-m level	U, V, W, WS, WD, IX, IY, IZ, UX, VX, SP, DR
4	8	Temperature profile, 2 to 30 m	T, TD, TC, ANEPH, BNEPH, CNEPH
		Tower C, D, E, F	
1	11	Temperature profile, 2 to 10 m & Wind data, 2-m level	U, V, W, WS, WD, IX, IY, IZ, T, TD, TC
2	12	Wind data, 10-m level	U, V, W, WS, WD, IX, IY, IZ, UX, VX, SP, DR

For the second set of files, numbers 324 to 612, corrected wind data, only 17 separate files were required for each experiment since no temperature data were corrected, thus record type 1 from Tower A and record type 4 for Tower B were omitted. Otherwise, the classification of files by record type is the same as in the first set of files as shown in Table 8.

Table 9 is a printout of the first five records from the first seven files from the first set of meteorological data files, numbers 1 to 323. It illustrates how the first alphabetic record of each file identifies with headings of the meteorological data that follows in the data records in the remainder of the file. The seven files shown represent the seven different record types used to record data from Tower A.

Table 10 is a printout of the first five records from the first seven files from the second set of meteorological data files, numbers 324 to 612. Since temperature profile data were omitted from this set of files, only six record types were used for Tower A, and the seventh file shown is wind data from Tower B. If wind data are required from Cinder Cone Butte, only the second set of files should be used if ERT's corrections are considered satisfactory. The first set of files, edited but uncorrected data, are available for application of other corrections and for comparative purposes. Only the temperature profile data are considered reliable.

Further refinements of propeller anemometer data may be possible when results of more wind tunnel studies are analyzed and when comparisons are made between propeller and sonic anemometer data from colocated systems operated at Small Hill Impaction Study No. 2 at Hogback Ridge, New Mexico during 1982.

TABLE 9. METEOROLOGICAL DATA SET NO. 1: SAMPLE PRINTOUT - EDITED DATA WITH UNCORRECTED WIND DATA

FILE NO.= 1

YR	JDY	HH	SEC	AL1T	AL2TD	AL2TC	AL3T	AL4TD	AL4TC	AL5T	AL6TD	AL6TC	AL7T	AL8TD	AL8TC
1980	290	17	0	10.743	-.171	10.572	10.430	-.601	10.142	9.961	-.992	9.985	9.570	-1.696	9.047
1980	290	17	300	-30.000U	-5.000U	.000U	-30.000U	-5.000U	.000U	-30.000U	-5.000U	.000U	-30.000U	-5.000U	.000U
1980	290	17	600	10.587	-.073	10.513	10.352	-.425	10.161	9.961	-.816	9.770	9.570	-1.520	9.066
1980	290	17	900	10.508	-.034	10.474	10.352	-.347	10.161	9.961	-.718	9.790	9.570	-1.42[illegible]	9.086

FILE NO.= 2

YR	JDY	HH	SEC	AL0NR	AL0SR	AL2TF	AL2ST	AL8TF	AL8ST	AL2MS	AL2MD	AL2SD
1980	290	17	0	.013	.205	10.508	.016	9.101	.031	6.061	311.965	5.067
1980	290	17	300	-.500U	.000U	-30.000U	.000U	-30.000U	.000U	.000U	.000U	.000U
1980	290	17	600	-.016	.166	10.352	.000	9.022	.000	6.500	316.188	4.328
1980	290	17	900	-.033	.145	10.352	.016	9.022	.016	5.621	310.381	4.751

FILE NO.= 3

YR	JDY	HH	SEC	AL1U	AL1V	AL1W	AL1WS	AL1WD	AL1IX	AL1IY	AL1IZ	AL1UX	AL1VX	AL1SP	AL1DR
1980	290	17	0	2.908	-2.077	.088	3.574	305.538	19.550	18.768	4.418	3.568	-2.981	4.650	309.883
1980	290	17	300	-25.000U	-25.000U	-10.000U	.000U	.000U	.000U	.000U	.000U	-50.000U	-50.000U	.000U	.000U
1980	290	17	600	2.713	-2.517	.108	3.701	312.854C	14.467	18.671	3.793	3.275	-3.470	4.771	316.656C
1980	290	17	900	-25.000M	-1.833	.127	.000M	.000M	19.062	17.986	4.262	3.372	-2.786	4.374	309.560

FILE NO.= 4

YR	JDY	HH	SEC	AL2U	AL2V	AL2W	AL2WS	AL2WD	AL2IX	AL2IY	AL2IZ	AL2UX	AL2VX	AL2SP	AL2DR
1980	290	17	0	3.690	-2.810	.381	4.638	307.293	11.535	14.370	4.184	4.643	-3.959	6.102	310.452
1980	290	17	300	-25.000U	-25.000U	-10.000U	.000U	.000U	.000U	.000U	.000U	-50.000U	-50.000U	.000U	.000U
1980	290	17	600	3.544	-3.250	.323	4.808	312.528	19.355	13.001	3.832	4.448	-4.545	6.359C	315.618C
1980	290	17	900	3.641	-2.566	.381	4.455	305.172	13.099	13.001	4.066	4.448	-3.861	5.890	310.962

FILE NO.= 5

YR	JDY	HH	SEC	AL8U	AL8V	AL8W	AL8WS	AL8WD	AL8IX	AL8IY	AL8IZ	AL8UX	AL8VX	AL8SP	AL8DR
1980	290	17	0	4.668	-4.081	.186	6.200	311.165	6.549	9.580	6.178	5.718	-5.816	8.157	315.486
1980	290	17	300	-25.000U	-25.000U	-10.000U	.000U	.000U	.000U	.000U	.000U	-50.000U	-50.000U	.000U	.000U
1980	290	17	600	4.863	-3.788	.049	6.164C	311.162C	5.865	7.625	5.513	5.816	-5.425	7.953C	313.008C
1980	290	17	900	5.108	-3.886	.108	6.418	307.263	5.572	8.211	6.686	6.109	-5.621	8.302	312.614

FILE NO.= 6

YR	JDY	HH	SEC	AL4U	AL4V	AL4W	AL4WS	AL4WD	AL4IX	AL4IY	AL4IZ
1980	290	17	0	4.326	-3.935	.108	5.847	312.290	6.158	9.384	3.558
1980	290	17	300	-25.000U	-25.000U	-10.000U	.000U	.000U	.000U	.000U	.000U
1980	290	17	600	3.935	-25.000M	.068	.000U	.000U	7.331	7.918	3.675
1980	290	17	900	4.472	-3.788	.244	5.861	310.264	9.286	9.677	4.809

FILE NO.= 7

YR	JDY	HH	SEC	AL6U	AL6V	AL6W	AL6WS	AL6WD	AL6IX	AL6IY	AL6IZ
1980	290	17	0	5.156	-3.739	.186	6.369	305.947	6.843	10.948	4.770
1980	290	17	300	-25.000U	-25.000U	-10.000U	.000U	.000U	.000U	.000U	.000U
1980	290	17	600	5.010	-3.739	.147	6.251C	306.734C	6.158	5.670	3.910
1980	290	17	900	5.547	-3.592	.205	6.609	302.926	7.820	5.083	3.675

TABLE 10. METEOROLOGICAL DATA SET NO. 2: SAMPLE PRINTOUT - EDITED DATA WITH CORRECTED WIND DATA

FILE NO.=324

YR	JDY	HH	SEC	AL0NR	AL0SR	AL2TF	AL2ST	AL8TF	AL8ST	AL2MS	AL2MD	AL2SD
1980	290	17	0	.013	.205	10.508	.016	9.101	.031	5.895	309.965	5.067
1980	290	17	300	-.500U	.000U	-30.000U	.000U	-30.000U	.000U	-.214U	358.000U	.000U
1980	290	17	600	-.016	.166	10.352	.000	9.022	.000	6.338	314.188	4.328
1980	290	17	900	-.033	.145	10.352	.016	9.022	.016	5.452	308.381	4.751

FILE NO.=325

YR	JDY	HH	SEC	AL1U	AL1V	AL1W	AL1WS	AL1WD	AL1IX	AL1IY	AL1IZ	AL1UX	AL1VX	AL1SP	AL1DR
1980	290	17	0	3.867	-2.420	.088	4.561	302.041	19.550	18.768	4.418	3.798	-2.363	4.473	301.883
1980	290	17	300	.000U	.000U	-10.000U	.000U	232.727U	.000U	.000U	.000U	-.030U	.212U	-.214U	352.000U
1980	290	17	600	3.737	-2.880	.108	4.719	307.623C	14.467	18.671	3.793	3.588	-2.870	4.595	308.656C
1980	290	17	900	.000M	.000M	.127	.000M	232.727M	19.062	17.986	4.262	3.575	-2.196	4.195	301.560

FILE NO.=326

YR	JDY	HH	SEC	AL2U	AL2V	AL2W	AL2WS	AL2WD	AL2IX	AL2IY	AL2IZ	AL2UX	AL2VX	AL2SP	AL2DR
1980	290	17	0	4.645	-3.678	.381	5.925	308.375	11.535	14.370	4.184	4.649	-3.692	5.937	308.452
1980	290	17	300	.000U	.000U	-10.000U	.000U	237.727U	.000U	.000U	.000U	-.007U	.214U	-.214U	358.000U
1980	290	17	600	4.530	-4.133	.323	6.132	312.373	19.355	13.001	3.832	4.486C	-4.274C	6.196C	313.618C
1980	290	17	900	4.554	-3.402	.381	5.684	306.762	13.099	13.001	4.066	4.450	-3.599	5.723	308.962

FILE NO.=327

YR	JDY	HH	SEC	AL8U	AL8V	AL8W	AL8WS	AL8WD	AL8IX	AL8IY	AL8IZ	AL8UX	AL8VX	AL8SP	AL8DR
1980	290	17	0	5.565	-5.629	.186	7.916	315.328	6.549	9.580	6.178	5.810	-5.511	8.008	313.486
1980	290	17	300	.000U	.000U	-10.000U	.000U	241.727U	.000U	.000U	.000U	-.007U	.214U	-.214U	358.000U
1980	290	17	600	5.533C	-5.596C	.049	7.870C	315.326C	5.865	7.625	5.513	5.888C	-5.120C	7.803C	311.008C
1980	290	17	900	6.059	-5.523	.108	8.199	312.353	5.572	8.211	6.686	6.190	-5.308	8.154	310.614

FILE NO.=328

YR	JDY	HH	SEC	AL4U	AL4V	AL4W	AL4WS	AL4WD	AL4IX	AL4IY	AL4IZ
1980	290	17	0	5.526	-5.009	.108	7.459	312.190	6.158	9.384	3.558
1980	290	17	300	.000U	.000U	-10.000U	.000U	237.727U	.000U	.000U	.000U
1980	290	17	600	.000U	.000U	.068	.000U	237.727U	7.331	7.918	3.675
1980	290	17	900	5.681	-4.876	.244	7.486	310.639	9.286	9.677	4.809

FILE NO.=329

YR	JDY	HH	SEC	AL6U	AL6V	AL6W	AL6WS	AL6WD	AL6IX	AL6IY	AL6IZ
1980	290	17	0	6.009	-5.478	.186	8.131	312.352	6.843	10.948	4.770
1980	290	17	300	.000U	.000U	-10.000U	.000U	242.727U	.000U	.000U	.000U
1980	290	17	600	5.844C	-5.440C	.147	7.984C	312.950C	6.158	5.670	3.910
1980	290	17	900	6.438	-5.412	.205	8.411	310.051	7.820	5.083	3.675

FILE NO.=330

YR	JDY	HH	SEC	B02U	B02V	B02W	B02WS	B02WD	B02IX	B02IY	B02IZ
1980	290	17	0	5.168C	-6.943C	.147	8.655C	323.340C	11.535	6.549	2.424
1980	290	17	300	.000U	.000U	-10.000U	.000U	226.558U	.000U	.000U	.000U
1980	290	17	600	4.929C	-6.004C	.127	7.768C	320.619C	11.632	7.527	2.542
1980	290	17	900	5.425	-6.542	.147	8.499	320.334	11.730	8.700	2.424

SECTION 4

TRACER GAS DATA

4.1 TRACER GAS RELEASE SYSTEM

Two tracer gases, SF_6 and Freon, were released at different heights from the boom of a mobile crane. The mobility of the release system resulted in a higher number of successful hours per test (normally six or seven hours out of eight) in which significant tracer concentrations were recorded on the hill. In only one experiment (212) were the wind patterns so variable that it was not possible to align the release system upwind of the hill.

The SF_6 and Freon tracer gases were stored in individual compressed gas cylinders kept at ground level; flexible Tygon tubing, approximately 100 m long, led from the gas cylinders to different release heights on the crane boom. For the first nine experiments (201 to 209), the tracer release tube was attached to the smoke generator platform at the smoke release height but from 0.5 m to 1 m away, horizontally. For the last nine experiments (210 to 218), the tracer release tube was on a separate pulley system independent of the smoke generator platform and about 1 m away, horizontally, from the smoke release. The gas flow was monitored by separate rotameters on the SF_6

and Freon cylinders, and each cylinder's weight loss was monitored by a separate electronic digital scale.

Because of the difficulty in calibrating rotameters with 100 m of tubing attached, the rotameters were used simply to monitor a constant tracer flow rate; the weight loss of the cylinders (as recorded by the digital scale) was used to determine the emission rate of each tracer. The scales could be read accurately only to the nearest 0.05 lb, and because the SF_6 flow rate was initially as low as 0.06 g/sec (0.5 lb/h), the possible uncertainty in the hourly emission rate determination could be up to 10%. This problem was alleviated in the later experiments by increasing the SF_6 flow rate to about 0.18 g/sec (1.5 lb/h), thus reducing the emission rate uncertainty to about 3%. Table 11 presents the average tracer release rates in each experiment; release rates ranged from 0.06 g/sec to 0.20 g/sec for SF_6 and from 0.86 g/sec to 0.98 g/sec for Freon.* Table 11 (Greene and Heisler, 1982) also identifies locations of tracer release points. Release point range (r) and azimuth (Θ) are determined with respect to the center of CCB. Elevation at release point (z) is determined with respect to CCB datum (3100 ft. or 944.9-m MSL), and the height of release (Ht) is determined with respect to local ground elevation.

4.2 TRACER GAS SAMPLING SYSTEM

Tracer sampling was accomplished by means of approximately 100 individual battery-operated samplers capable of either 10-min or 1-h sequential operation. Each sampler contained 12 individual pumps, each of

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*In analysis by electron-capture gas chromatography, Freon is about 20 times less sensitive than SF_6.

TABLE 11. TRACER RELEASE DATA

Experiment	Date 1980	Julian Day	Time (MST)	Exp. Hrs.	R (m)	θ (deg)	Z (m)	SF_6 Ht(m)	SF_6 Q(g/s)	Freon Ht(m)	Freon Q(g/s)	Fogger Ht(m)
201	10/16	290	1646-1900	1-2	991	316.5	-7.0	30	.090 ± 2.0%			30
			2009-2200	4-5	952	311.5	-7.0	30	.088 ± 2.1%			30
			2216-2302	6	952	311.5	-7.0	30	.087 ± 4.0%			30
202	10/17	291	1716-1800	1	1015	319.0	-7.0	50	.080 ± 5.3%			50
			1800-1859	2	1015	319.0	-7.0	50	.082 ± 1.1%			50
			1900-2100	3-4	1015	319.0	-7.0	20	.082 ± 0.5%			20
			2111-2200	5	1015	319.0	-7.0	30	.086 ± 5.7%			30
			2209-2300	6	1015	319.0	-7.0	40	.088 ± 4.6%			40
203	10/20	294	0051-0300	2-3	1424	115.4	-8.8	30	.082 ± 7%			30
			0414-0505	5	850	137.3	-9.6	59	.086 ± 8%			59
			0505-0600	6	850	137.3	-9.6	30	.086 ± 8%			30
			0623-0810	7-8	640	129.2	-7.0	50	.071 ± 20%			50
204	10/21	295	0001-0150	1-2	1036	4.5	-6.8	30	.094 ± 9%			30
			0311-0349	4	1010	103.3	-5.0	30	.089 ± 9%			30
			0435-0800	5-8	960	130.6	-9.3	30	.085 ± 8.7%			30
205	10/23	297	0058-0141	2	1008	102.9	-5.0	40	.063 ± 8.3%			40
			0216-0349	3-4	1155	120.1	-8.9	40	.083 ± 2.7%			40
			0403-0455	5	1155	120.1	-8.9	50	.087 ± 7.7%			50
			0501-0542	6	1155	120.1	-8.9	30	.092 ± 9.8%			30
			0614-0800	7-8	748	138.5	-9.0	30	.080 ± 2.4%			30
206	10/24	298	0108-0150	2	735	137.5	-8.9	46	.033 ± 8.7%			46
			0207-0259	3	596	123.6	-5.5	46	.038 ± 10%			46
			0301-0400	4	596	123.6	-5.5	35	.039 ± 3.4%			35
			0417-0753	5-8	596	123.6	-5.5	35	.062 ± 1.0%			35
207	10/25	299	0113-0353	2-4	830	138.9	-9.5	30	.159 ± 1.4%			30
			0700-0737	8	1007	102.8	-5.0	30	.164 ± 4.5%			30
208	10/27	301	1920-2000	3	897	300.1	-7.0	30	.173 ± 4.2%	20	.978 ± 13%	30
			2000-2100	4	897	300.1	-7.0	30	.173 ± 4.2%	20	.850 ± 7.4%	30
			2216-2305	6	1069	338.3	-6.9	30	.203 ± 7.7%	20	1.050 ± 8.0%	30
			0004-0100	8	888	296.6	-7.0	30	.168 ± 5.6%	30	.997 ± 6.9%	30
209	10/28	302	1654-1759	1	986	315.9	-7.0	40	.156 ± 5.9%			40
			1811-1900	2	986	315.9	-7.0	40	.175 ± 7.7%			40
			1900-2000	3	986	315.9	-7.0	40	.184 ± 4.9%			40
			2212-0000	6-7	999	100.9	-4.7	40	.160 ± 1.5%			40
			0000-0100	8	999	100.9	-4.7	40	.160 ± 1.5%			30

(continued)

TABLE 11. TRACER RELEASE DATA (continued)

Experiment	Date 1980	Julian Day	Time (MST)	Exp. Hrs.	R (m)	θ (deg)	Z (m)	SF_6 Ht(m)	SF_6 Q(g/s)	Freon Ht(m)	Freon Q(g/s)	Fogger Ht(m)
210	10/30	304	0003-0045	1	1007	102.8	-5.0	30	.180 ± 8%	45	.990 ± 9.1%	40
			0122-0345	2-4	1084	113.7	-7.2	57	.169 ± 6.3%	30	.926 ± 2.0%	57
			0400-0441	5	1084	113.7	-7.2	58	.184 ± 8%	30	.926 ± 2.0%	58
			0505-0700	6-7	1086	122.2	-8.2	58	.178 ± 7.4%	30	.986 ± 3.3%	58
			0713-0740	8	1086	122.2	-8.2	40	.168 ± 8%	40	Unknown	40
211	10/31	305	0000-0200	1-2	1001	101.4	-4.7	30	.179 ± 5.1%	20	Unknown	30
			0200-0245	3	1001	101.4	-4.7	30	.179 ± 5.1%	20	1.008 ± 8.4%	30
			0310-0400	4	1155	120.1	-8.9	20	.175 ± 3.9%	58	.941 ± 3.6%	58
			0400-0500	5	1155	120.1	-8.9	20	.175 ± 3.9%	58	.941 ± 3.6%	58 (0400-0436)
												45 (0436-0444)
												20 (0444-0500)
			0500-0600	6	1155	120.1	-8.9	20	.175 ± 3.9%	58	.941 ± 3.6%	20 (0500-0526)
												40 (0526-0545)
			0600-0655	7	1155	120.1	-8.9	20	.175 ± 3.9%	58	.941 ± 3.6%	58 (0545-0655)
			0714-0800	8	1033	126.8	-8.4	20	.164 ± 10%	58	.986 ± 8.4%	58
213	11/4	309	0110-0145	2	1018	341.4	-9.0	40	.173 ± 25%			40
			0214-0345	3-4	1007	102.8	-5.0	30	.194 ± 11%	58	.934 ± 4.5%	30 (0211-0226)
												58 (0226-0300)
												50 (0300-0304)
												40 (0304-0311)
												30 (0311-0355)
			0411-0800	5-8	1063	111.4	-6.8	30	.202 ± 3.3%	58	.966 ± 1.7%	30 (0410-0445)
												58 (0445-0610)
												30 (0610-0649)
												58 (0653-0735)
												30 (0735-0800)
214	11/5	310	0302-0357	2	786	142.7	-9.2	17	.170 ± 3.2%	47	.928 ± 5.0%	47
			0408-0451	3	786	142.7	-9.2	24	.170 ± 4.2%	49	.967 ± 5%	47
			0516-0600	4	886	134.3	-9.2	24	.175 ± 1.8%	49	.945 ± 5%	Unknown
			0600-0635	5	886	134.3	-9.2	24	.175 ± 1.8%	?	Unknown	47
			0635-0656	5	886	134.3	-9.2	24	.175 ± 1.8%	49	1.001 ± 5%	24
			0740-0859	6-7	540	113.2	-2.0	24	.160 ± 2.4%	49	.957 ± 5%	47
			0909-1000	8	600	124.2	-5.5	24	.159 ± 3.8%	49	.889 ± 5%	47
215	11/6	311	0017-0240	1-3	1018	127.4	-8.7	30	.177 ± 1.2%	58	.951 ± 2.8%	57 (0017-0156)
												30 (0156-0235)
			0306-0355	4	1033	107.2	-6.1	30	.190 ± 3.2%			30
			0409-0500	5	1078	113.0	-7.0	30	.227 ± 2.6%	58	.957 ± 2.5%	30 (0419-0425)
			0500-0645	6-7	1078	113.0	-7.0	30	.231 ± 1.4%	58	.957 ± 2.5%	57 (0427-0530)
												30 (0531-0628)
												57 (0638-0644)
216	11/9	314	0001-0200	1-2	1075	112.7	-7.0	30	.188 ± 1.2%	50	.949 ± 1.7%	50 (0000-0110)
												30 (0110-0150)
			0200-0300	3	1075	112.7	-7.0	30	.180 ± 3.8%	50	.949 ± 1.7%	50 (0253-0300)

(continued)

TABLE 11. TRACER RELEASE DATA (continued)

Experiment	Date 1980	Julian Day	Time (MST)	Exp. Hrs.	R (m)	θ (deg)	Z (m)	SF_6 Ht(m)	SF_6 Q(g/s)	Freon Ht(m)	Freon Q(g/s)	Fogger Ht(m)
			0304-0358	4	1075	112.7	-7.0	30	.161 ± 3.4%	50	.949 ± 1.7%	50 (0300-0335) 30 (0336-0400)
			0408-0545	5-6	1075	112.7	-7.0	37	.158 ± 2.0%	57	.974 ± 4.0%	30 (0400-0410) 50 (0410-0457)
			0609-0745	7-8	1307	79.8	-7.0	30	.191 ± 1.6%			30
217	11/10	315	0156-0400	1-2	1157	330.9	-7.0	30	.168 ± 3.0%			30
			0400-0500	3	1157	330.9	-7.0	25	.159 ± 3.2%			25
			0603-0800	5-6	1153	331.3	-7.0	40	.163 ± 1.4%	15	.977 ± 1.6%	40 (0600-0625) 15 (0628-0651) 30 (0703-0800)
			0800-1000	7-8	1153	331.3	-7.0	40	.139 ± 2.0%	15	.977 ± 1.6%	40 (0803-0809) 30 (0809-0952)
218	11/12	317	0151-0245	1	881	295.2	-7.0	30	.164 ± 3.4%			30
			0259-0553	2-4	1119	327.3	-7.0	30	.156 ± 1.2%	45	.831 ± 2.7%	30 (0258-0546)
			0606-0800	5-6	1026	320.0	-7.0	30	.155 ± 1.0%	45	.860 ± 3.9%	30 (0640-0724) 45 (0724-0800)
			0800-1000	7-8	1026	320.0	-7.0	15	.146 ± 1.8%	30	.898 ± 3.5%	45 (0800-0820) 30 (0826-1000)

which intermittently** filled a Tedlar bag over the time period of interest. Thus, each sampler could take sequential 1-h samples over a 12-h period or sequential 10-min samples over a 2-h period. Normally, 1-l bags were used for both hourly and 10-min samples. Except for samples taken from reflection masts (described below), all samples were taken at 1 m above ground level.

Figure 4 (Lavery et al., 1982) shows the locations of the 70 fixed samplers and also the 10 movable samplers that were placed on either the NW or SE side of the hill, depending on the prevailing wind direction. Of these 80 samplers, typically 60 were used for 1-h average samples and 20 were used for 10-min average samples. Another 20 samplers were used for reflection masts, for background ambient air samples, and for colocated samplers. Table 12 presents the locations of samplers with regard to range and azimuth and Cartesian coordinates using the center of CCB as origin. Elevations of samplers are also presented with regard to a datum of 944.9-m MSL.

The design of a reflection mast is shown in Figure 5 (Lavery et al., 1982). Air samples were drawn in from 3 m and 6 m (in addition to the normal 1-m height) and also at an uphill site equal in elevation to the 6-m height. The purpose of this sampling strategy was to determine if tracer concentrations would "reflect" off the surface as predicted by some disperson models. Four of these reflection masts were used during Cases 203 to 218. Normally, the 3-m height was sampled on only one of the reflection masts; the other masts were sampled at 6 m and 1 m, in addition to the uphill site.

**For a 1-h average sample, a pump sampled intermittently for about 1 sec every 15 sec.

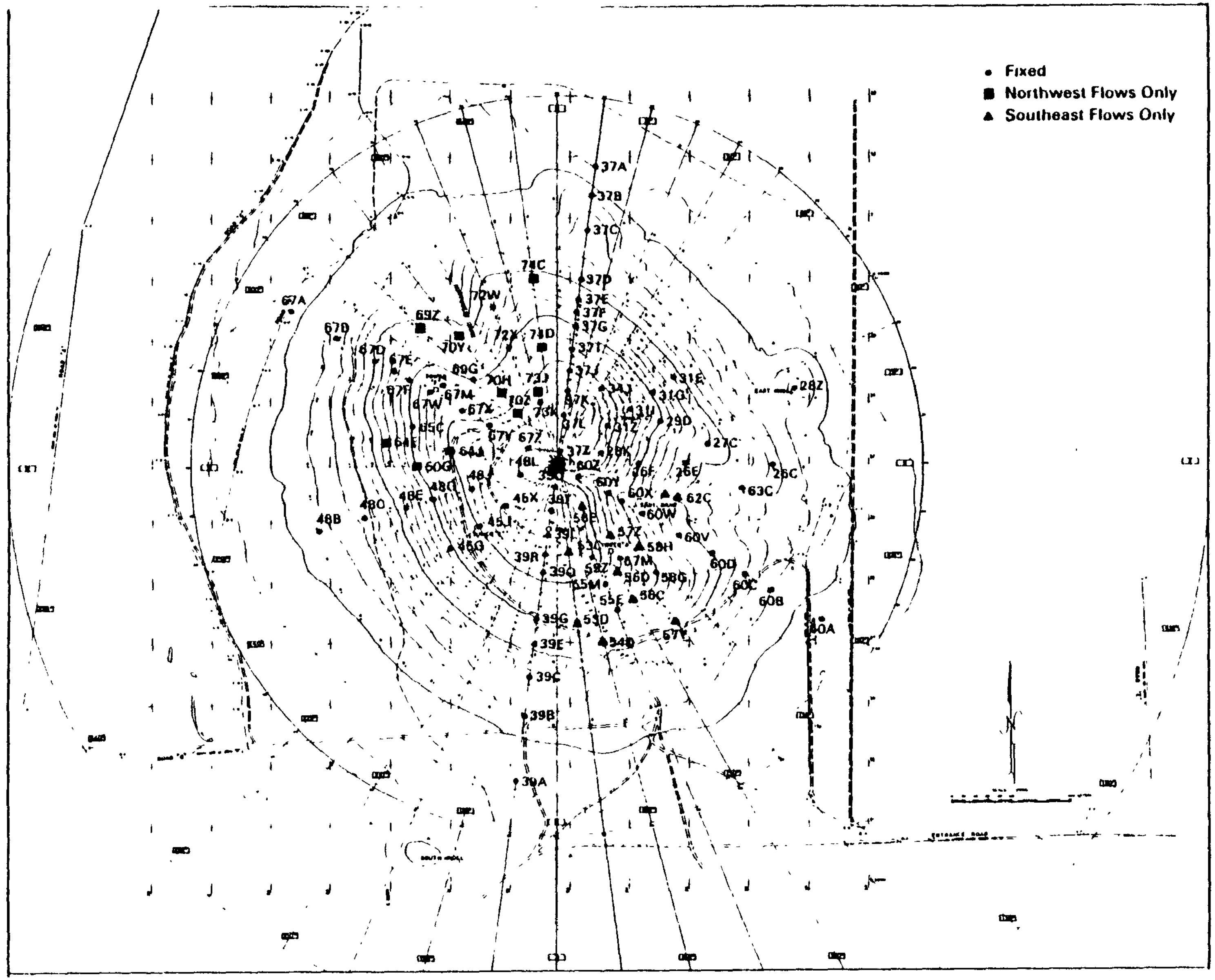

Figure 4. Tracer gas sampler locations.

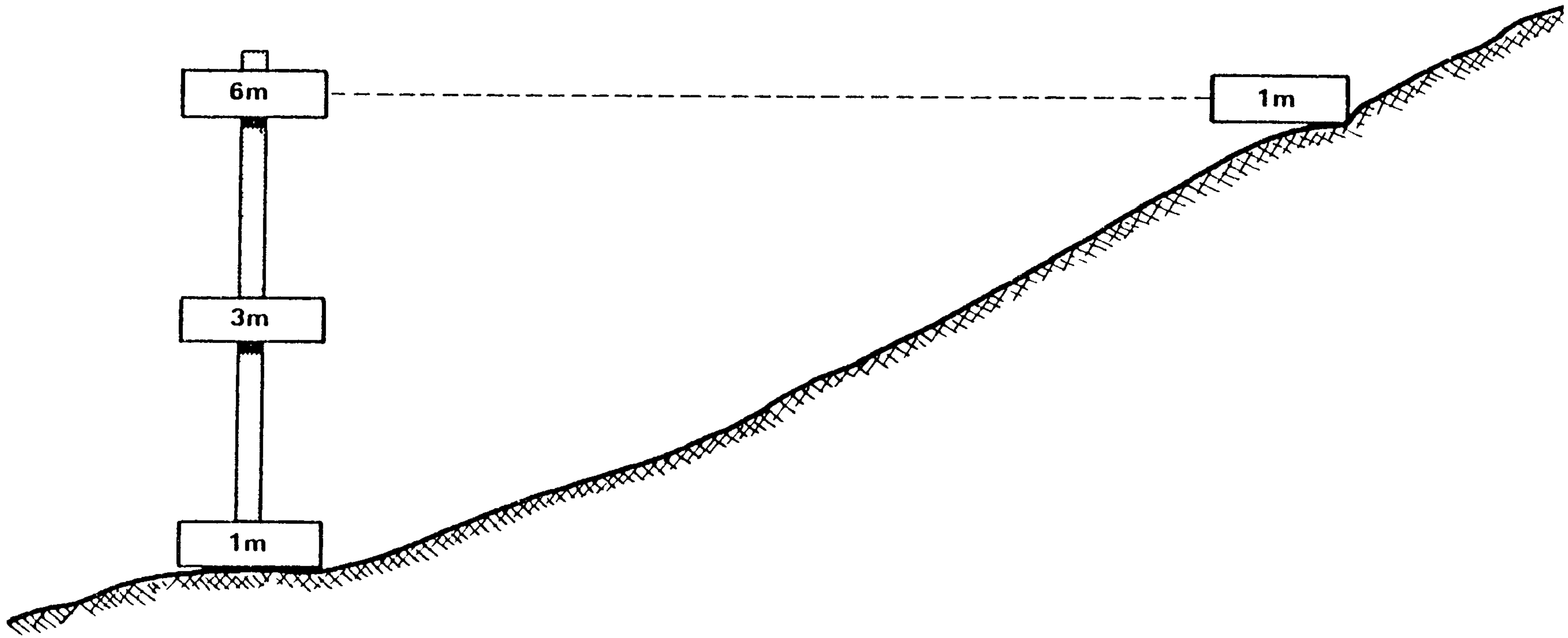

Figure 5. Reflection mast design.

TABLE 12. TRACER GAS SAMPLER NETWORK

Sampler Loc.	Θ deg.	R (m)	X (m)	Y (m)	Z (m)	Sampler loc.	Θ deg.	R (m)	X (m)	Y (m)	Z (m)
26C	90.	360.0	360.2	0.0	13.3	39B	187.	411.0	- 53.7	-407.8	3.8
26E	90.	208.0	208.3	0.0	31.2	39C	187.	348.0	- 45.5	-345.3	13.7
26F	90.	142.0	142.0	0.0	50.0	39E	187.	291.0	- 38.0	-288.3	32.9
27C	83.	260.0	257.8	33.9	30.0	39G	187.	251.0	- 32.8	-249.1	48.8
28K	75.	75.0	72.1	19.9	80.0	39L	187.	115.0	- 15.0	-114.0	99.0
28Z	71.	420.0	404.9	111.6	10.0	39Q	187.	180.0	- 23.5	-178.5	80.0
29D	68.	187.0	172.8	71.6	50.0	39R	187.	150.0	- 19.9	-149.1	90.0
31E	53.	246.0	195.1	149.7	27.4	39T	187.	77.0	- 9.9	- 76.1	90.0
31G	53.	200.0	159.0	122.0	46.9	39U	187.	31.0	- 4.9	- 37.1	80.0
31I*	53.	154.0	121.8	93.5	66.7	45G	232.	224.0	-177.4	-136.1	49.2
31Z	53.	107.0	85.1	64.9	80.0	45J	232.	158.0	-125.2	- 96.1	78.8
34J	30.	146.0	73.0	126.4	77.0	45X	232.	107.0	- 84.9	- 65.1	90.0
37A	8.	510.0	66.6	505.9	- 6.5	48B	255.	411.0	-396.7	-106.3	3.4
37B	8.	449.0	58.6	445.4	3.4	48C	255.	327.0	-315.8	- 84.6	13.2
37C	8.	391.0	51.0	387.7	11.8	48E	255.	258.0	-248.9	- 66.7	32.9
37D	8.	308.0	40.2	305.1	22.1	48G	255.	211.0	-204.1	- 54.7	32.3
37E	8.	275.0	35.9	272.8	31.9	48J	255.	150.0	-144.9	- 38.1	80.0
37F	8.	250.0	32.6	247.7	41.7	48L	255.	63.0	- 60.9	- 16.1	80.0
37G	8.	227.0	29.6	224.8	51.5	50G	270.	238.0	-238.0	0.0	50.0
37J	8.	154.0	20.1	152.5	81.1	53C	171.	139.0	21.7	-137.3	90.0
37K	8.	122.0	16.0	121.3	90.9	53D	173.	260.0	31.7	-258.1	50.0
37L	8.	81.0	10.6	80.6	92.0	54D	165.	301.0	77.9	-290.6	35.1
37T	8.	193.0	25.1	190.9	65.0	55E	158.	250.0	95.8	-231.3	53.0
37Z	8.	19.0	2.1	18.9	80.0	55M*	158.	204.0	74.8	-189.8	65.0
39A	187.	510.0	- 66.5	-505.2	- 3.5	55Z	159.	165.0	59.1	-154.0	80.0

(continued)

TABLE 12. TRACER GAS SAMPLER NETWORK (continued)

Sampler loc.	Θ (deg)	R (m)	X (m)	Y (m)	Z (m)	Sampler loc.	Θ (deg)	R (m)	X (m)	Y (m)	Z (m)
56C	150.	255.0	127.5	-220.8	50.0	67A	300.	510.0	-441.9	255.1	- 0.9
56D*	150.	198.0	99.0	-171.5	65.0	67B	300.	416.0	-359.9	207.8	8.9
56E	150.	86.0	43.0	- 74.5	80.0	67D	300.	343.0	-297.1	171.5	28.1
57M*	143.	165.0	100.4	-130.9	65.0	67E	300.	311.0	-269.6	155.7	38.1
57Y	143.	327.0	199.1	-259.4	30.0	67F	300.	284.0	-246.2	142.1	48.0
57Z	143.	140.0	91.4	-109.4	65.0	67M*	300.	230.0	-190.7	128.6	60.0
58G	137.	240.0	163.7	-175.5	50.0	67W*	300.	247.0	-213.9	123.5	60.0
58H	135.	185.0	137.9	-137.9	50.0	67X	300.	178.0	-153.9	89.9	70.0
60A	120.	510.0	441.5	-254.9	- 2.4	67Y	300.	130.0	-111.9	65.9	80.0
60B	120.	410.0	355.1	-205.0	5.7	67Z	300.	54.0	- 40.9	28.9	80.0
60C	120.	362.0	313.6	-181.1	15.3	69G	315.	200.0	-141.4	141.4	50.0
60D	120.	297.0	256.8	-148.3	25.3	69Z	315.	325.0	-229.8	229.8	30.0
60V	120.	235.0	204.1	-117.1	30.0	70H	322.	151.0	- 91.9	119.9	65.0
60W	120.	164.0	142.1	- 81.1	40.0	70Y	333.	275.0	-167.4	218.2	30.0
60X	120.	124.0	108.1	- 61.1	50.0	70Z	322.	108.0	- 65.9	85.9	80.0
60Y	120.	94.0	82.1	- 46.1	60.0	72W	338.	285.0	-109.1	263.3	30.0
60Z	120.	43.0	37.1	- 21.1	70.0	72X	338.	211.0	- 80.7	194.9	50.0
62C	105.	190.0	183.5	- 49.2	30.0	73J	345.	127.0	- 32.9	122.9	80.0
63C	98.	315.0	312.4	- 41.1	14.0	73K	345.	105.0	- 29.9	104.9	85.0
64E	277.0	282.0	279.9	36.8	35.8	74C	353.	310.0	- 40.5	307.3	30.0
64J	277.0	159.0	-157.4	20.7	83.4	74D	353	197.0	- 25.7	195.5	65.0
65C	285.0	252.0	-243.4	65.2	50.0	75Z = Recounted data					

*Reflection mast site

All distances, ranges, and angles relative to center of CCB
Datum; Z = Θ = 944.9-m MSL (3,100 ft contour)

Background air was sampled during each experiment by at least one sampler upwind of the tracer release point. At two locations during each test, an extra sampler was placed next to the normal sampler and set to sample at the same time. These colocated samplers were used to assess the variability in the sampling technique.

The mechanical reliability of the samplers was relatively poor, with a typical pump breakdown rate of about 20% during each test. During the earlier experiments, the mechanical breakdown problems, when combined with sampler crew mistakes in setting the sampler times, resulted in fairly low data capture for some of the experiments. However, as the sampler crew gained experience, the data capture during the later experiments was limited mainly by mechanical problems.

The sampling system design is proved to be a good compromise between total system flexibility and personnel endurance. For example, it was not possible to operate many more 10-min samplers because bags had to be manually changed by the sampler crew every two hours for each 10-min sampler. The utility of the reflection mast system cannot be properly assessed at present because a more detailed study of the results is necessary.

4.3 TRACER ANALYSIS SYSTEM

The analysis of the bag samples was done by means of chromatographic separation and electron capture detection at the NAWC gas analysis laboratory in Boise. Seven gas chromatographs (GCs) were originally used in the laboratory--three Baseline Industries units, three S^3 Inc. units, and one AID (Analytical Instrument Development, Inc.) unit. The output of all but the AID GC was evaluated by electronic integraters (with strip chart backup) to give the area under tracer gas peaks. The AID's output was recorded on a strip chart and evaluated by measuring peak height. The AID differed from the other GCs in that it operated with several attenuation factors ranging up to 64 x 10^3. It was the only instrument whose molecular sieve column could separate SF_6, Freon, and oxygen successfully; consequently all Freon analyses were done on the AID GC.

The GCs were numbered 1 through 8 for simplicity of identification, although no instrument was designated number 4, due to the requirements of the electronic integrators, each of which processed the output from several instruments. The Baseline units were removed from service after the first five experiments; two more S^3 instruments replaced them after the twelfth experiment as GCs numbers 1 and 2 because of drift problems. The detection limit of the GCs was about 5 parts per trillon (ppt) for SF_6 and about 100 ppt for Freon.

A chromatograph showing a good separation of the tracer gases using a 5A molecular sieve column is illustrated in Figure 6 (Lavery et al., 1982). The SF_6 and Freon separate before the large oxygen peak, with a total analysis time of about 4 min per sample. The SF_6 areas were calculated by an electronic digital integrator (the area under the peaks is directly proportional to concentration). With six chromatographs and an average of 4 min per sample, a total of 90 samples per hour could be analyzed.

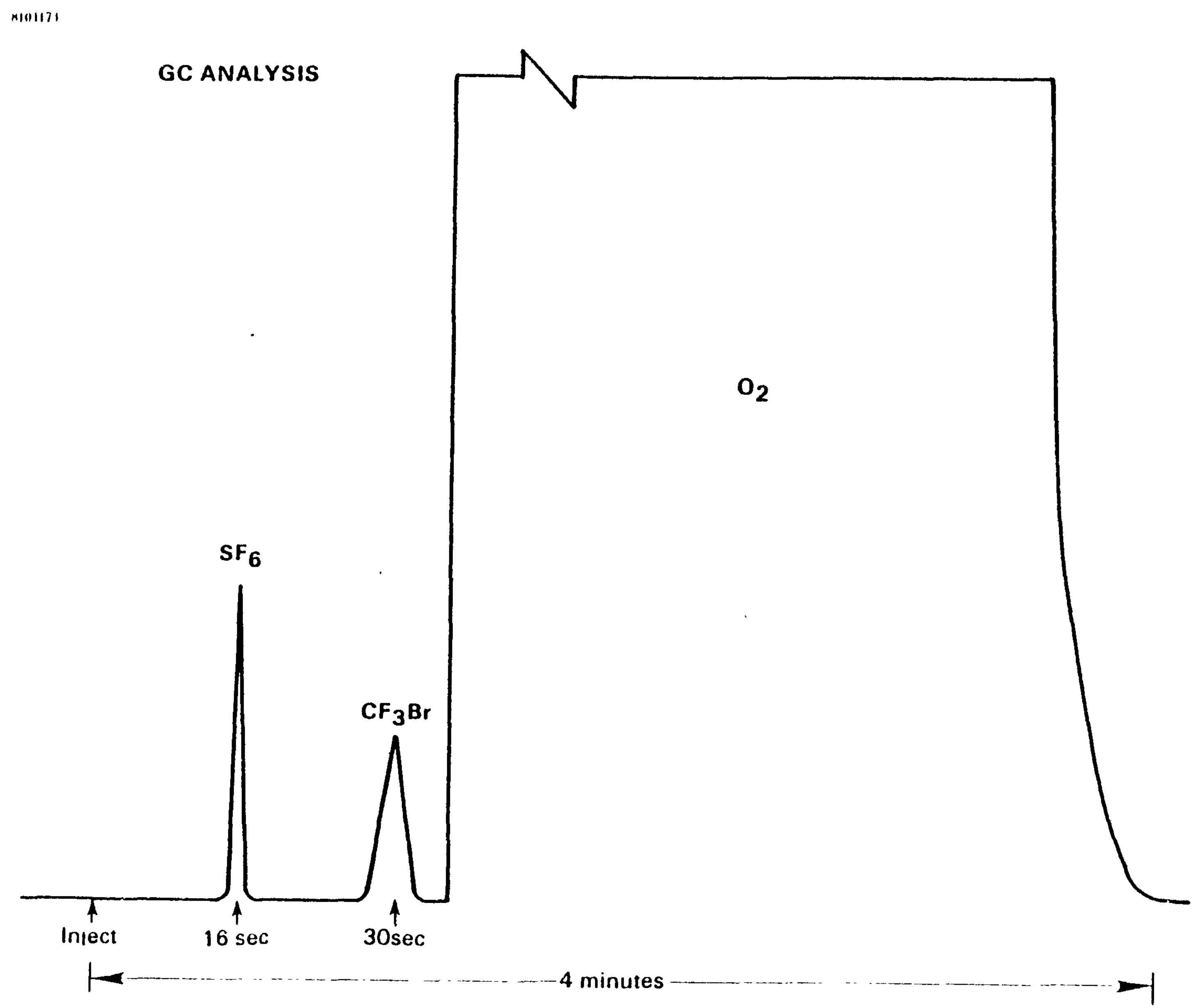

Figure 6. Tracer gas chromatogram.

For quality assurance, about 3% of the bag samples from each experiment were analyzed again, usually on a chromatograph different from that used in the first analysis; all Freon analysis, of course, had to be done on GC #8 (AID). These "recount" data have been used for estimates of the precision of the analytical procedures. Most analyzed bags were then flushed two times with nitrogen and returned to the field. The exceptions were bags that contained high tracer concentrations (greater than 1 part per billion SF_6 or greater than 10 part per billion Freon); these bags were discarded to prevent possible contamination caused by tracer desorption from the bag walls. Figure 7 (Lavery et al., 1982) illustrates the flow of procedures followed in the bag sampling and analysis.

Calibrations were performed on each GC at the start and finish of each analysis day. Nine calibration gases, ranging from about 10 ppt to 40 ppb SF_6 and from about 200 ppt to 800 ppb Freon, were used to calibrate each GC in the early experiments. The calibration points were reduced to seven (10 ppt to 10 ppb SF_6) in later experiments because no SF_6 tracer concentration greater than 10 ppb was ever detected in the field studies. A check with one calibration gas (usually 100 ppt SF_6) was performed every four hours on every GC; information (date, time, and integrator area) was then written on the same data sheet. Because of the large number (more than 14,000) of tracer analyses performed with these data, the actual calculation of concentrations, Figure 8 (Lavery et al., 1982), from GC responses was done by computer at ERT's office in Concord, MA. Experiment, bag, and sampler numbers, sampler location code, and sampling time were entered into the computer system from the sampler log sheets by means of a remote terminal in NAWC's laboratory in Boise. GC calibration data (GC number, time and date

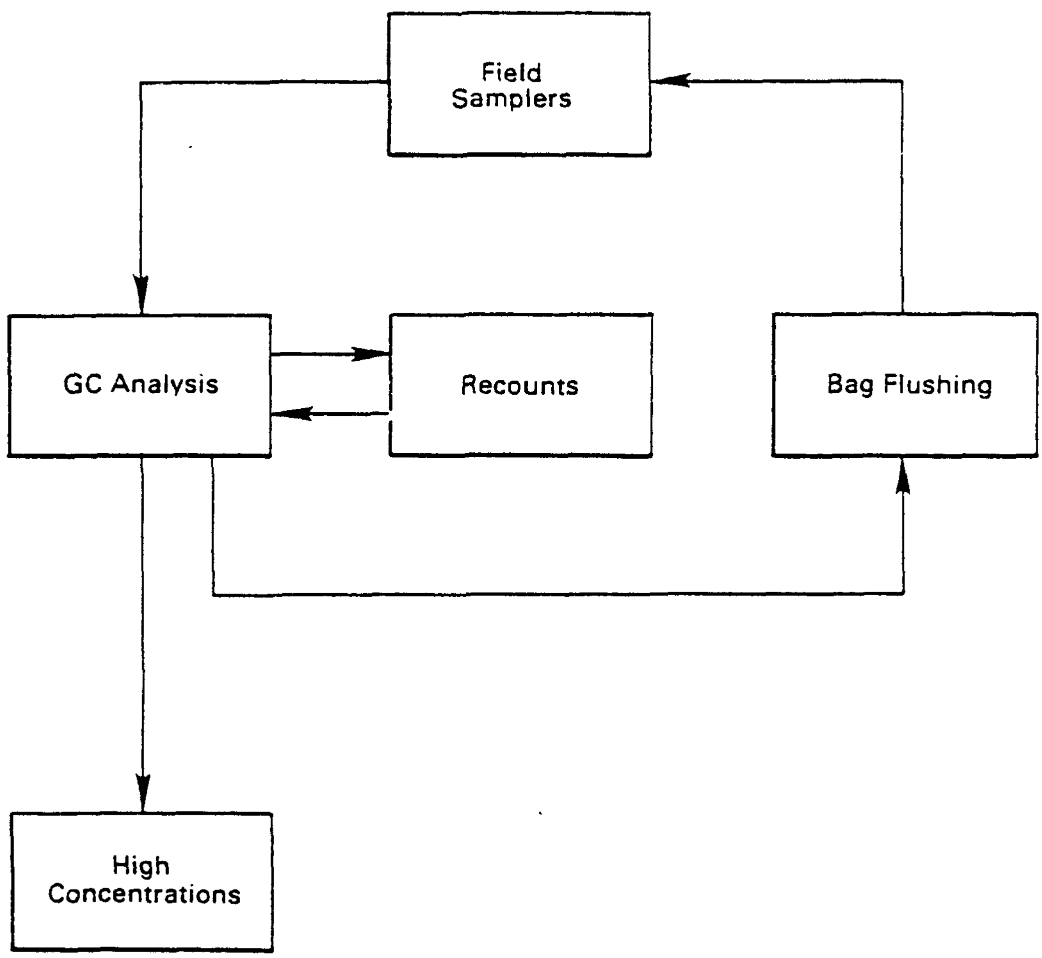

Figure 7. Bag sampling and analysis procedures.

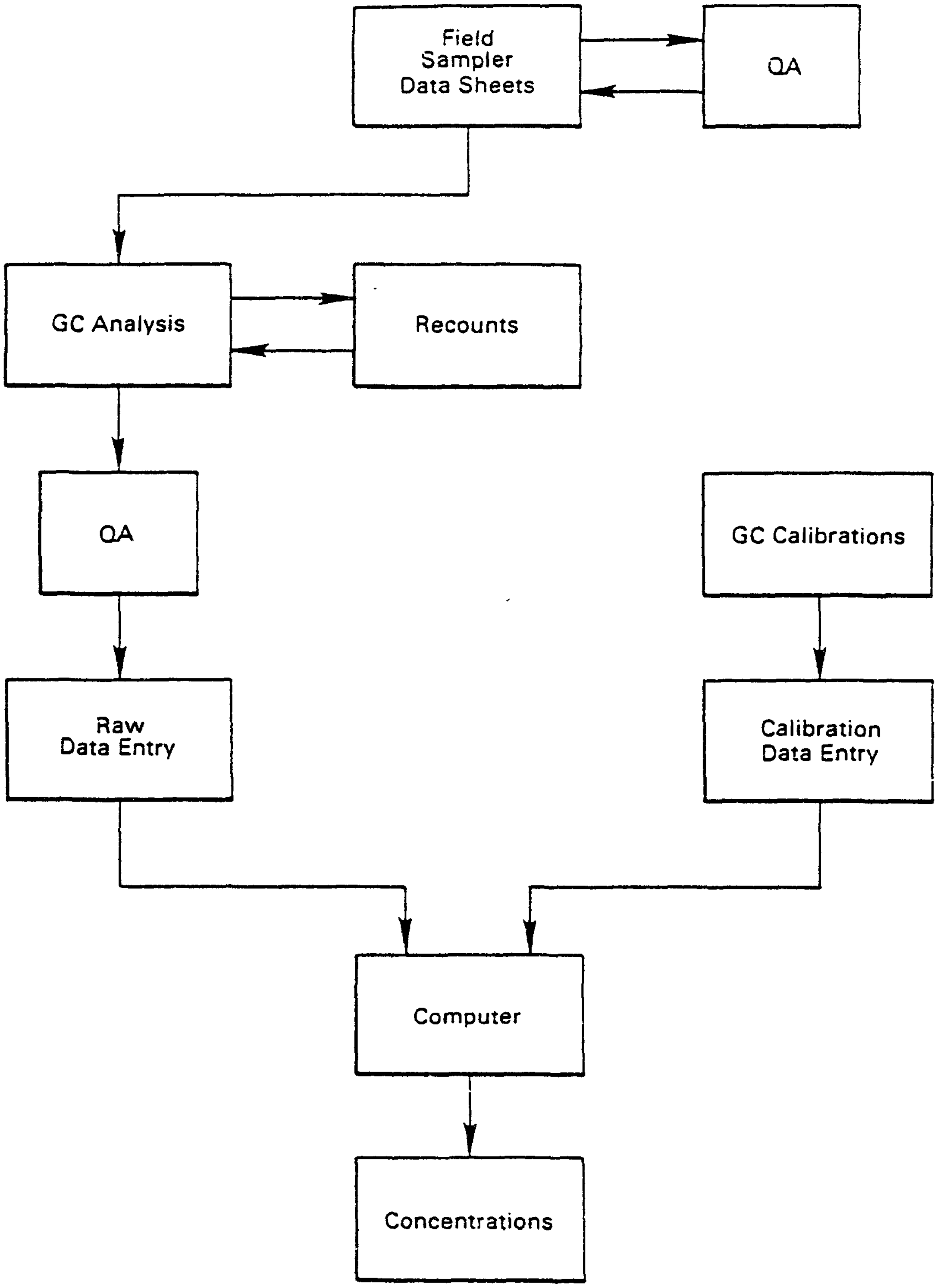

Figure 8. Procedures to obtain tracer gas concentrations.

of calibration, calibration gas concentrations, and GC responses) were similarly entered from calibration log sheets. After sample analysis, GC number, bag number, experiment number, analysis time and date, and GC responses were entered and merged with sampler data. The concentration in the bag was then calculated from the GC response (peak height or peak area) by means of curves fit to the calibration data.

In view of the huge number of tracer samples and the operation of the gas chromatographs for 16 h per day, the tracer analysis system worked quite well. All samples were analyzed within 48 h of sample collection. The main deficiency was that only one chromatograph could analyze both SF_6 and Freon. The only major instrument problem occurred during the early experiments when it was difficult to obtain reproducible results from three of the chromatographs. These chromatographs were subsequently replaced, and the analysis proceeded smoothly. The preliminary recount statistics show good reproducibility of the tracer analysis system.

4.4 TRACER GAS DATA TAPE FILES

Data are stored at the National Computer Center, Environmental Research Center, Research Triangle Park, North Carolina on Sperry UNIVAC 1100/83 systems magnetic tape, nine track, odd parity, ASCII-quarter word mode, density 6250 BPI, tape number 004700. Record length is 132 characters, and the block size is 1320 words, or 40 records per block.

UNIVAC users may assign the tape, @ASG,T CCB,U9S//////Q,004700 using UNIVAC ECL. Upon request, copies can be furnished and translated into formats acceptable to any computer using nine-track tape drives.

4.4.1 Tape File Index

There are 18 tape files, one for each experiment, numbered 613 to 630 following the corrected meteorological tower data on tape number 004700. Table 13 shows how tape files are related to experiments and dates of operation.

TABLE 13. TRACER GAS TAPE FILES

File no.	Exp. no.	Date 1980	Exp. hours (MST)	Stability class
613	201	10/16	1700 to 2300	E
614	202	10/17	1700 to 2300	E
615	203	10/20	0000 to 0800	E to F
616	204	10/21	0000 to 0800	E
617	205	10/23	0000 to 0800	E
618	206	10/24	0000 to 0800	E
619	207	10/25	0000 to 0800	E to F
620	208	10/27	1700 to 0100	E to F
621	209	10/28	1700 to 0100	F
622	210	10/30	1700 to 0100	E to F
623	211	10/31	0000 to 0800	E to F
624	212	11/02	1700 to 2400	E to F
625	213	11/04	0000 to 0800	E to F
626	214	11/05	0200 to 1000	E to F
627	215	11/06	0000 to 0700	E to F
628	216	11/09	0000 to 0700	E to F
629	217	11/10	0200 to 1000	E to F
630	218	11/12	0200 to 1000	E

4.4.2 Tape File Records

Table 14 shows the tracer data formats on each data record within the files. The first two records of the first block of each file contain alphabetic characters for the column headings for the data records that follow. Table 15 is a printout of the first block (40 records) of the first tracer data file (Experiment 201). Tracer concentrations of SF_6 are

TABLE 14. TRACER DATA FORMAT

Position	Contents	Heading	Comments
1 to 3	Experiment number	EXP	
5 to 12	Sample collection date	SAMPLING DATE	mm/dd/yy
14 to 16	Collection location	SITE	characters
20 to 22	Sampler ID	SID	characters
24 to 29	Bag Number	BAG	6 digits
32 to 35	Sampling start time	SAMPLING START	hhmm (MST)
38 to 41	Sampling end time	SAMPLING END	hhmm (MST)
44	Sample flag	QF	G = valid sample R = recount sample Q = questionable sample B = bad sample S = suspect sample
46 to 53	Analysis date	ANALYSIS DATE	mm/dd/yy
56 to 59	Analysis time	ANALYSIS TIME	hhmm (MST)
63	Gas chromatograph	GC #	
66 to 75	GC response to SF6	SF6 RESPONSE	F10.2 FORTRAN format
77 to 80	GC attenuation for SF6 analysis	GC AT	FORTRAN integer zero if GC is not AID
82 to 91	GC response to Freon	FREON RESPONSE	F10.2 FORTRAN format
93 to 96	GC attenuation for Freon analysis	GC AT	FORTRAN integer
102 to 110	SF6 concentrations	SF6 PPT	F9.1 FORTRAN format
113	Data reduction flag	QF	Always "E"
118 to 126	Freon concentration	FREON PPT	F9.1 FORTRAN format
129	Data reduction flag	QF	Blank if no Freon analysis; "E" otherwise

Notes:

1. Headings occupy first two records of the file.
2. Records are sorted by sampling location, sample collection date, sampler ID and sample flag, in that order.

TABLE 15. TRACER CONCENTRATION DATA - SAMPLE PRINTOUT

EXP	SAMPLING DATE	SITE	SID	BAG	SAMPLING START	SAMPLING END	Q F	ANALYSIS DATE	ANALYSIS TIME	GC #	SF6 RESPONSE	GC AT	FREON RESPONSE	GC AT	SF6 PPT	Q F	FREON PPT	Q F
201	10/16/80	26C	195	011415	2000	2100	G	10/17/80	700	2	53528.00	0			181.0	E	.0	
201	10/16/80	26C	195	011416	2100	2200	G	10/17/80	700	2	19881.00	0			67.7	E	.0	
201	10/16/80	26C	195	011409	2200	2300	G	10/17/80	700	1	1873.00	0			7.9	E	.0	
201	10/16/80	26C	195	011413	2300	2400	G	10/17/80	700	3	.00	0			.0	E	.0	
201	10/16/80	26C	195	011412	2400	2500	G	10/17/80	700	3	.00	0			.0	E	.0	
201	10/16/80	26E	227	011729	1840	1850	G	10/17/80	1400	2	17560.00	0			50.6	E	.0	
201	10/16/80	26E	227	011730	1850	1900	G	10/17/80	1400	3	11740.00	0			50.6	E	.0	
201	10/16/80	26E	227	011732	1900	1910	G	10/17/80	1400	3	3095.00	0			13.3	E	.0	
201	10/16/80	26E	227	011731	1910	1920	G	10/17/80	1400	2	1175.00	0			3.4	E	.0	
201	10/16/80	26E	227	011725	1920	1930	G	10/17/80	1400	1	.00	0			.0	E	.0	
201	10/16/80	26E	227	011725	1920	1930	R	10/17/80	1400	3	.00	0			.0	E	.0	
201	10/16/80	26E	227	011724	1930	1940	G	10/17/80	1400	1	.00	0			.0	E	.0	
201	10/16/80	26E	227	011726	1940	1950	G	10/17/80	1400	2	572.00	0			1.7	E	.0	
201	10/16/80	26E	227	011728	1950	2000	G	10/17/80	1400	1	58890.00	0			178.8	E	.0	
201	10/16/80	26E	227	011727	2000	2010	G	10/17/80	1400	3	1184.00	0			5.1	E	.0	
201	10/16/80	28K	165	011300	1710	1720	G	10/17/80	700	3	103041.00	0			512.5	E	.0	
201	10/16/80	28K	165	011298	1720	1730	G	10/17/80	700	2	45295.00	0			153.3	E	.0	
201	10/16/80	28K	165	011306	1810	1820	G	10/17/80	700	1	27626.00	0			105.1	E	.0	
201	10/16/80	28K	165	011303	1820	1830	G	10/17/80	700	1	3213.00	0			13.3	E	.0	
201	10/16/80	28K	165	011299	1840	1850	G	10/19/80	700	8	.27	64			18.6	E	.0	
201	10/16/80	28K	165	011070	1845	1855	G	10/19/80	700	8	.00	64			.0	E	.0	
201	10/16/80	28K	165	011297	1850	1900	G	10/19/80	700	8	.00	64			.0	E	.0	
201	10/16/80	28K	165	011064	1855	1905	G	10/19/80	700	8	.50	64			32.8	E	.0	
201	10/16/80	28K	165	011063	1905	1915	G	10/19/80	700	8	.39	64			26.1	E	.0	
201	10/16/80	28K	165	011069	1915	1925	G	10/19/80	700	8	.00	64			.0	E	.0	
201	10/16/80	28K	165	011067	1925	1935	G	10/19/80	700	8	.19	64			13.5	E	.0	
201	10/16/80	28K	165	011068	1935	1945	G	10/19/80	700	8	.00	64			.0	E	.0	
201	10/16/80	28K	165	011061	1945	1955	G	10/19/80	700	8	.19	64			13.5	E	.0	
201	10/16/80	28K	165	011060	1955	2005	G	10/19/80	700	8	.00	64			.0	E	.0	
201	10/16/80	28K	165	011059	2005	2015	G	10/19/80	700	8	1.66	64			98.6	E	.0	
201	10/16/80	31E	191	012590	1700	1710	G	10/17/80	700	1	.00	0			.0	E	.0	
201	10/16/80	31E	191	012598	1710	1720	G	10/17/80	700	3	515.00	0			2.6	E	.0	
201	10/16/80	31E	191	012588	1730	1740	G	10/17/80	700	3	.00	0			.0	E	.0	
201	10/16/80	31E	191	012591	1740	1750	G	10/17/80	700	1	.00	0			.0	E	.0	
201	10/16/80	31E	191	012592	1750	1800	G	10/17/80	700	2	1871.00	0			6.5	E	.0	
201	10/16/80	31E	191	012595	1800	1810	G	10/17/80	700	1	58884.00	0			217.6	E	.0	
201	10/16/80	31E	191	012596	1810	1820	G	10/17/80	700	3	113702.00	0			565.2	E	.0	
201	10/16/80	31E	191	012597	1820	1830	G	10/17/80	700	2	84090.00	0			283.5	E	.0	

contained in record positions 102 to 110 (F9.1 FORTRAN format), and Freon concentrations are located in positions 118 to 126 (F9.1 FORTRAN format). A quality flag accompanies each concentration that must be "E" to validate the value. Since no Freon tracer was released until Experiment 208, the "0" values listed in the records in Table 15 do not have an "E" flag indicating no measured value rather than a zero Freon concentration.

An overall evaluation of the sample quality is indicated in record position 44 where an appearance of "G", "Q", "B" or "S" indicates quality. An "R" in this flag position indicates the sample is one that has been analyzed twice or "recounted".

Four reflection mast sampler systems were used during Experiments 203 to 218. Air samples were drawn in from 3 m and 6 m (in addition to the normal 1-m height) and also from an uphill site equal in elevation to the 6-m height. Normally, the 3-m height was sampled on only one of the reflection masts; the other masts had two samplers, 1-m and 6-m, in addition to the uphill sampler. All reflection mast systems are recorded under one collection location identification in tape record position 14 to 16; each sampler in the mast system is recorded with a separate number in record position 20 to 22. The uphill sampler is denoted "900", 1-m height "901", 3-m height "903", and 6-m height "906".

4.5 GAS CHROMATOGRAPH CALIBRATION DATA TAPE FILES

Calibration data observed on GC's during all experiments are stored on eight files, 631 to 638, immediately following the tracer gas data tape files on the same tape reel and with the same tape block and record specifications.

4.5.1 Tape File Index

There are eight tape files, one for each GC employed in tracer gas analysis. Nine calibration gases were used to determine responses in each GC in early experiments, but this number was reduced to seven or less in later experiments when no SF_6 tracer concentration greater than 10 ppb was ever detected. GC number 8, the AID instrument, has calibration data on two files, 637 and 638; the first has calibrated responses for SF_6 and the second for Freon. No GC was assigned number 4. Table 16 shows how tape files 631 to 638 related to calibration data.

TABLE 16. GAS CHROMATOGRAPH CALIBRATION DATA TAPE FILES

File no.	GC no.
631	1
632	2
633	3
634	5
635	6
636	7
637	8 (SF_6)
638	8 (Freon)

4.5.2 Tape File Records

Table 17 shows the formats for each data record. The first record of each calibration procedure contains alphabetic characters to identify and supplement the calibration data that follows. Table 18 is a printout of the first block, 40 records, of the first file.

TABLE 17. GC CALIBRATION DATA FORMAT

Position	Contents	Comments
1 to 5	Attenuation	I5 FORTRAN format, always "1" except for GC #8 where measured value is presented
7 to 16	GC response	F10.2 FORTRAN format, area under tracer gas peaks on GC except GC #8 where peak height is measured
18 to 27	Calibration gas concentration	F10.2 FORTRAN format

Notes:

1. The header record that precedes each calibration is in the format:
   "GC" - GC number
   "COL" - molecular sieve column number
   "GAS" - 1=SF_6, 2= Freon
   "mm/dd/yy" - date of calibration
   "hhmm" - hour and minute of calibration (MST)
2. The last record for each calibration contains a value of -1 in each field.

TABLE 18. GAS CHROMATOGRAPH CALIBRATION DATA - SAMPLE PRINTOUT

```
GC: 2 COL. 2 GAS: 1  10/17/80   600
     1     2811.00     12.00
     1    30693.00    104.00
     1    89046.00    301.00
     1   270426.00    930.00
     1   528937.00   1850.00
     1   702174.00   3600.00
     1   928208.00  10300.00
     1  1066229.00  21100.00
     1  1210523.00  41900.00
    -1       -1.00     -1.00
GC: 2 COL. 2 GAS: 1  10/17/80  1310
     1     3437.00     12.00
     1    36070.00    104.00
     1   106374.00    301.00
     1   326965.00    930.00
     1   555160.00   1850.00
     1   707055.00   3600.00
     1   910548.00  10300.00
    -1       -1.00     -1.00
GC: 2 COL. 2 GAS: 1  10/17/80  2130
     1     3305.00     12.00
     1    32429.00    104.00
     1   102495.00    301.00
     1   293941.00    930.00
     1   443451.00   1850.00
     1   547779.00   3600.00
     1   852645.00  10300.00
     1  1076960.00  21100.00
     1  1224061.00  41900.00
    -1       -1.00     -1.00
GC: 2 COL. 2 GAS: 1  10/18/80   640
     1     3021.00     12.00
     1    30672.00    104.00
     1    91384.00    301.00
     1   284862.00    930.00
     1   544169.00   1850.00
     1   729299.00   3600.00
     1   962474.00  10400.00
     1  1127000.00  21100.00
```

SECTION 5

PILOT BALLOON WIND DATA

5.1 PILOT BALLOON WIND SYSTEM

North American Weather Consultants (NAWC) operated pilot balloon systems from the more upwind of two locations about 1.3 km NW and SE of the center of CCB (see Figure 2). Wind profiles are derived from double theodolite measurements of trajectories from pilot balloons (pibals) or minisonde balloons released approximately once an hour.

Two theodolites were positioned a known distance apart, and both theodolites were aligned to true north. The positions of the theodolites are determined by the azimuth and elevation angles of theodolite station 2 as observed by theodolite station 1. After the balloon is released, both theodolite stations take simultaneous measurements of the balloon's position, which is recorded as an azimuth and an elevation angle as observed from each station. Thus, at each data point, two rays are defined. The first ray is the ray R1 from Theodolite 1 to the balloon described by the angles AZ1 and EL1. The second ray R2 is described by the angles AZ2 and EL2 and is analogous to the ray R1. Theoretically, these two rays will intersect at the exact location of the balloon but experimental errors generally cause the two rays to be skew and not intersect at all. Based on two such nonintersecting rays, the position of the balloon is analyzed as follows.

It is necessary to find the line segment AB connecting a point A on R1 with a point B on R2 such that the segment AB is the shortest possible line segment with endpoints on the two rays. This constrains the segment AB to be perpendicular to both R1 and R2. Now let R1 no longer be a ray of infinite length, but be a vector originating at Theodolite 1 and ending at the Point A. Similarly, R2 becomes a vector originating at Theodolite 2 and ending at the Point B. Because the experimental error in determining the balloon's position is an error in the measurement of an angle, the resulting linear error in balloon position is directly proportional to the distance from the point of observation to the balloon. Therefore, the point chosen as the most probable location for the balloon is the Point C lying on the line segment AB such that the ratio of the distances AC/BC is equal to the ratio R1/R2. Thus, if the origin of the coordinate system is taken as Theodolite 1 and the vector AB is taken as the vector originating at the Point A (Point A is now synonymous with R1) and ending at the Point B, the balloon position C can be expressed by the following equation:

$$C = R1 + \left(\frac{R1}{R1+R2}\right) AB$$

The quantity reported in the column labeled "error" in the heading records of each tape file is actually the length of the line segment AB.

The values listed as "direction correction" in the heading records have been applied to both the observed angles and the computed wind directions.

The wind directions and speeds are midpoint averages. For example, the wind at min 3.5 is taken from the midpoint of the balloon position at min 3 and min 4. If min 4 was missing and it was necessary to use min 3 and min 4.5, then the resultant wind would really be representative of min 3.75 instead of min 3.5.

In situations where only one theodolite was operative or where one theodolite lost track of the balloon, an assumed balloon ascent rate was employed to determine vertical distance. If one theodolite lost track near the end of the run, then calculations were based on a continued constant vertical velocity. In all such cases, the assumed ascent rate is indicated in the heading records and the requirement of a continued vertical velocity noted by a special record at the end of wind profile data records.

5.2 PILOT BALLOON WIND DATA TAPE FILES

Data are stored at the National Computer Center, Environmental Research Center, Research Triangle Park, North Carolina on Sperry UNIVAC 1100/83 systems magnetic tape, nine track, odd parity, ASCII-quarter word mode, density 6250 BPI, tape number 004700. Record length is 132 characters, and the block size is 1320 words, or 40 records per block.

UNIVAC users may assign the tape, @ASG,T CCB,U9S//////Q,004700 using UNIVAC ECL. Upon request, copies can be furnished and translated into formats acceptable to any computer using nine track tape drives.

5.2.1 Tape File Index

There are 27 tape files, 9 containing wind profiles for 9 days preceeding the days with tracer gas release, and 18 with data from experiments 201 to 218. Files are numbered 639 to 665 following the gas chromatograph calibration data on tape number 004700. Table 19 shows how tape files are related to experiments and dates of operation.

TABLE 19. PILOT BALLOON WIND TAPE FILES

File no.	Exp. no.	Date 1980	Release location
639	102	9/17	NW
640	103	9/19	SE
641	104	9/20	SE
642	105	9/22	SE
643	106	9/23	SE
644	107	9/24	SE
645	108	9/25	SE
646	109	9/26	SE
647	110	9/27	SE
648	201	10/16	NW
649	202	10/17	NW
650	203	10/20	SE
651	204	10/21	SE
652	205	10/23	SE
653	206	10/24	SE
654	207	10/25	SE
655	208	10/27	NW
656	209	10/28	NW
657	210	10/30	SE
658	211	10/31	SE
659	212	11/02	NW
660	213	11/04	SE
661	214	11/05	SE
662	215	11/06	SE
663	216	11/09	NW
664	217	11/10	SE
665	218	11/12	SE

5.2.2 Tape File Records

The first seven records of each pilot balloon ascent are alphabetic characters that identify and describe the observation. The next two records are alphabetic characters of column headings for the data record that follow. A blank record separates each balloon ascent during an experiment. Table 20 illustrates the data formats on each data record within the files.

TABLE 20. PILOT BALLOON WIND DATA FORMAT

Position	Contents	Heading	Comments (FORTRAN Format)
1 to 5	Time from release	TIME (MIN)	F5.2, min.sec
10 to 15	Azimuth angle, theodolite 1	AZ.1 (DEG)	F6.2, degrees.tenths
19 to 24	Elevation angle, theodolite 1	EL.1 (DEG)	F6.2, degrees.tenths
29 to 34	Azimuth angle, theodolite 2	AZ.2 (DEG)	F6.2, degrees.tenths
38 to 43	Elevation angle, theodolite 2	EL.2 (DEG)	F6.2, degrees.tenths
46 to 51	Linear error of balloon position	ERROR (M)	F6.1, meters.tenths
56 to 60	E-W coordinate of balloon position	X (M)	I5, meters
65 to 69	N-S coordinate of balloon position	Y (M)	I5, meters
74 to 78	Ht. of balloon above datum, 944.9 m	Z (M)	I5, meters
82 to 86	E-W component of wind speed	U (MPS)	F5.1, meters per sec
90 to 94	N-S component of wind speed	V (MPS)	F5.1, meters per sec
98 to 102	Vertical speed	W (MPS)	F5.1, meters per sec
106 to 110	Wind speed	SPEED (MPS)	F5.1, meters per sec
115 to 117	Wind direction	DIRN (DEG)	I3, degrees

Table 21 is a printout of the first block, 40 records, of the first file. It illustrates a situation where only one theodolite was operative and an assumed ascent rate was used.

TABLE 21. PILOT BALLOON WIND DATA - SAMPLE PRINTOUT

EPA SMALL HILL IMPACT STUDY (CINDER CONE BUTTE)
CASE 102 - NORTH-WEST - STD.WT.
DATE: 9/17/80 TIME: 2302 MDT
DIRECTION CORRECTION = 20 DEGREES
BASE LINE 335 MTRS WITH THEODOLITE 2 2 MTRS ABOVE THEODOLITE 1
THEODOLITE 2 LIES ON THE 240.5 DEGREE AZIMUTH OF THEODOLITE 1
ASCENT RATE = 183 MTRS PER MINUTE

TIME (MIN)	AZ.1 (DEG)	EL.1 (DEG)	AZ.2 (DEG)	EL.2 (DEG)	ERROR (M)	X (M)	Y (M)	Z (M)	U (MPS)	V (MPS)	W (MPS)	SPEED (MPS)	DIRN (DEG)
1.50	345.80	51.20				-59	235	301	-.7	3.1	3.4	3.2	166
2.00	346.30	46.80				-89	367	402	-1.2	3.9	3.4	4.0	162
2.50	344.40	46.10				-130	466	503	-1.7	3.1	3.4	3.5	151
3.00	340.90	45.90				-191	553	603	-2.2	2.7	3.3	3.5	140
3.50	337.10	45.80				-264	627	699	-2.5	2.5	3.2	3.5	134
4.00	334.10	45.60				-340	701	796	-2.4	2.8	3.2	3.7	139
4.50	332.90	45.00				-406	794	892	-2.5	2.8	3.2	3.8	138
5.00	330.60	44.70				-490	869	988	-1.9	1.8	3.1	2.6	133
5.50	330.10	46.10				-517	900	1079	-.6	.2	3.0	.6	109
6.00	329.30	48.80				-523	881	1171					

EPA SMALL HILL IMPACT STUDY (CINDER CONE BUTTE)
CASE 102 - NORTH-WEST - STD.WT.
DATE: 9/18/80 TIME: 0000 MDT
DIRECTION CORRECTION = 20 DEGREES
BASE LINE 335 MTRS WITH THEODOLITE 2 2 MTRS ABOVE THEODOLITE 1
THEODOLITE 2 LIES ON THE 240.5 DEGREE AZIMUTH OF THEODOLITE 1
ASCENT RATE = 183 MTRS PER MINUTE

TIME (MIN)	AZ.1 (DEG)	EL.1 (DEG)	AZ.2 (DEG)	EL.2 (DEG)	ERROR (M)	X (M)	Y (M)	Z (M)	U (MPS)	V (MPS)	W (MPS)	SPEED (MPS)	DIRN (DEG)
2.00	1.60	43.20				11	428	402	-.0	3.8	3.4	3.8	179
2.50	359.90	41.50				-0	568	503	-.9	5.3	3.4	5.3	170
3.00	356.70	39.00				-42	744	603	-1.6	5.5	3.3	5.7	163
3.50	353.80	37.80				-97	897	699	-1.9	4.6	3.2	5.0	157
4.00	351.10	37.60				-159	1021	796	-2.2	4.1	3.2	4.7	152
4.50	348.70	37.40				-228	1144	892	-2.5	4.1	3.2	4.8	149
5.00	346.40	37.10				-307	1269	988	-2.6	4.4	3.1	5.1	149
5.50	344.70	36.50				-385	1407	1079	-2.3	4.1	3.0	4.7	150
6.00	343.60	36.50				-446	1518	1171	-1.9	3.8	3.0	4.3	153
6.67	342.80	36.40				-518	1676	1293	-1.2	3.4	3.0	3.6	161
7.00	343.30	37.00				-516	1721	1354	-.0	.9	3.0	.9	179

SECTION 6

TETHERSONDE AND MINISONDE DATA

6.1 TETHERSONDE AND MINISONDE DATA SYSTEMS

North American Weather Consultants (NAWC) operated tethersonde and minisonde systems from the same two locations NW and SE of CCB from which the pilot balloons were released. The tethersonde was operated in an ascent-descent sequence yielding profiles of temperature, pressure, wind speed and direction at intervals of once an hour (or more frequently) to heights of at least 200 m above the local terrain. Release times were scheduled 30 min after the pilot balloon soundings to obtain wind profiles every half hour.

The principal quality control check performed by NAWC, other than routine operational checks before each flight, was a comparison of the output from the sonde package with data taken concurrently from the 150 m tower. Three profiles taken when the sonde was flown from the NW sounding site, about 1.5 km SSW of Tower A, have been compared with tower data taken during experiment 201. Averaged data for the period of 15 min at a constant altitude near 80 m are also compared with tower data at that level. The temperature data from the sonde appear to be about 1° C high, although the profiles are still useful in defining gradients. The wind speed data compared favorably with the now corrected tower data.

Minisonde flights were conducted when wind speeds were too high to allow tethersonde operation, or when the tethersonde system was not working. The minisonde was operated as a free release balloon sounding to heights as high as 500 mb or 5.5 km. Sometimes the balloon was tracked to serve as a pilot balloon for wind profiles. Minisonde data consisted of profiles of temperature, wet bulb temperature and pressure.

6.2 TETHERSONDE AND MINISONDE DATA TAPE FILES

Data are stored at the National Computer Center, Environmental Research Center, Research Triangle Park, North Carolina on Sperry UNIVAC 1100/83 systems magnetic tape, nine track, odd parity, ASCII-quarter word mode, density 6250 BPI, tape number 004700. Record length is 132 characters, and the block size is 1320 words, or 40 records per block.

UNIVAC users may assign the tape, @ASG,T CCB,U9S//////Q,004700 using UNIVAC ECL. Upon request, copies can be furnished and translated into formats acceptable to any computer using nine track tape drives.

6.2.1 Tape File Index

There are 17 tape files, 10 containing tethersonde data, and 7 with minisonde data. Files are numbered 666 to 675 for tethersonde data, 676 to 682 for minisonde data. Tables 22A and 22B show how tape files are related to experiments and dates of operation.

TABLE 22A. TETHERSONDE DATA TAPE FILES

File no.	Exp. no.	Date 1980	Release location
666	201	10/16	NW
667	202	10/17	NW
668	203	10/20	SE
669	204	10/21	SE
670	205	10/23	SE
671	206	10/24	SE
672	207	10/25	SE
673	208	10/27	NW
674	209	10/28	NW
675	212	11/02	NW

TABLE 22B. MINISONDE DATA TAPE FILES

File no.	Exp. no.	Date 1980	Release location
676	211	10/31	SE
677	213	11/04	SE
678	214	11/05	SE
679	215	11/06	SE
680	216	11/09	SE
681	217	11/10	SE
682	218	11/12	SE

Note: No valid tethersonde or minisonde data from Experiment 210, 10/30.

6.2.2 Tape File Records

The first six records of each tethersonde ascent-descent are alphabetic characters that identify and describe the observation. The next two records are alphabetic characters of column headings for the data records that follow. A blank record separates each tethersonde ascent-descent during an experiment. Table 23 contains the data formats on each data record within the files.

TABLE 23. TETHERSONDE DATA FORMAT

Position	Contents	Heading	Comments (FORTRAN Format)
1 to 7	Time of observation	TIME (MIN)	F7.4, HH.MMSS
11 to 15	Barometric pressure	PRES. (MBS)	F5.1, millibars.tenths
19 to 23	Height of obs. AGL	HT. (M)	F5.1, meters.tenths
26 to 30	Temperature	TEMP (C)	F5.1, degrees celsius.tenths
33 to 37	Rel. humidity	RH (%)	F5.1, percent.tenths
40 to 43	Mixing ratio	M.R.	F4.1, ratio.tenths
47 to 51	Wind direction	DIRN. (DEG)	F5.1, degrees.tenths
54 to 58	Wind speed	SPD. (MPS)	F5.1, meters per second.tenths
62 to 66	Potential temperature	P.T. (K)	F5.1, degrees kelvin.tenths
70 to 73	Voltage	VOLTS	F4.1, volts.tenths

Table 24 is a printout of the first block, 40 records of the first file. It illustrates a tethersonde ascent from the surface to 309 m, with the first block of records containing the identification and heading records and data records up to 151.2 m.

The first four records of each minisonde ascent are alphabetic characters that identify and describe the observation. The next two records are alphabetic characters of column headings for the data records that follow. A blank record separates each minisonde ascent during an experiment. This instrument was used when high winds prevented use of the tethersonde, and in all experiments after 212, when the tetersonde system did not operate. Data recorded were not subject to quality assurance procedures as were the pilot balloon data or the tethersonde data. Table 25 contains the data formats on each data record within the files.

TABLE 24. TETHERSONDE METEOROLOGICAL DATA - SAMPLE PRINTOUT

EPA SMALL HILL IMPACT STUDY - TETHERSONDE DATA (CINDER CONE BUTTE)
CASE: 201 LOCATION: NORTH WEST SITE
DATE: 10/16/80 SOUNDING BEGIN: 1726 MST ALTITUDE BEGIN: SFC
SOUNDING END: 1803 MST ALTITUDE END: 309 M
TEMP. CAL. PSYCHROMETER: 51.0F , SONDE: 10.0 C
PRESSURE CAL. BAROMETER: 893 MBS, SONDE: ----

TIME (MIN)	PRES. (MBS)	HT. (M)	TEMP. (C)	RH. (%)	M.R.	DIRN. (DEG)	SPD. (MPS)	P.T. (K)	VOLTS
17.2615	892.6	4.2	9.8	49.9	4.3	322.2	3.9	292.3	12.4
17.2649	891.5	14.4	9.8	48.4	4.2	319.8	5.9	292.4	12.4
17.2724	891.0	18.7	10.1	48.5	4.3	330.5	7.7	292.7	12.5
17.2758	890.6	22.5	10.3	45.1	4.0	319.3	8.8	293.0	12.4
17.2832	889.9	28.9	10.0	45.3	4.0	324.4	8.8	292.8	12.4
17.2907	889.1	36.3	10.2	45.5	4.1	330.8	8.9	293.1	12.5
17.2941	888.7	40.6	10.3	45.4	4.1	326.2	8.8	293.1	12.4
17.3016	887.6	50.4	10.6	45.4	4.1	324.9	8.9	293.5	12.5
17.3050	887.4	51.9	10.0	44.5	3.9	324.6	8.8	293.0	12.4
17.3125	887.0	55.8	10.0	45.6	4.0	317.1	7.8	293.0	12.4
17.3159	886.1	64.5	9.9	46.9	4.1	319.5	7.9	293.0	12.4
17.3234	885.5	70.3	9.9	46.2	4.0	315.0	9.0	293.1	12.4
17.3308	885.1	73.7	9.8	46.4	4.0	321.8	8.9	293.0	12.4
17.3342	884.8	77.0	9.4	46.2	3.9	320.7	8.8	292.6	12.4
17.3417	884.3	81.2	9.8	46.7	4.1	324.1	9.3	293.1	12.4
17.3451	883.7	87.1	9.4	47.0	4.0	322.2	8.8	292.7	12.4
17.3525	882.5	98.2	9.4	47.3	4.0	322.5	8.2	292.9	12.4
17.3600	882.4	99.5	9.5	47.5	4.0	326.6	8.4	292.9	12.4
17.3634	881.9	104.3	9.4	46.3	3.9	317.5	8.9	292.9	12.4
17.3708	881.3	109.4	9.3	46.8	3.9	333.2	8.7	292.8	12.4
17.3743	880.8	113.9	9.3	47.5	4.0	317.3	8.9	292.9	12.3
17.3817	880.3	118.9	9.2	46.3	3.9	328.7	8.6	292.8	12.4
17.3852	880.3	119.0	9.2	46.7	3.9	325.0	9.0	292.8	12.4
17.3926	879.5	126.2	9.3	46.0	3.9	312.3	9.3	293.0	12.3
17.4001	879.1	130.5	9.3	45.6	3.8	320.9	8.7	293.0	12.4
17.4035	878.2	138.5	9.2	46.7	3.9	320.2	8.5	293.0	12.3
17.4109	878.3	137.7	8.9	46.8	3.8	317.5	9.1	292.7	12.4
17.4144	877.9	142.0	8.9	46.6	3.8	323.1	9.2	292.8	12.4
17.4218	877.5	145.4	9.1	45.0	3.8	318.0	9.3	293.0	12.4
17.4252	877.2	148.5	9.2	46.6	3.9	325.5	9.2	293.1	12.3
17.4327	877.0	150.5	9.0	47.4	3.9	319.8	9.6	292.9	12.3
17.4401	876.9	151.2	8.8	47.4	3.9	316.6	9.5	292.8	12.3

TABLE 25. MINISONDE DATA FORMAT

Position	Contents	Heading	Comments (FORTRAN Format)
1 to 6	Time from release	Time (SEC)	F6.1, MM.SEC(tenths); 8.9=8:54; 9.0=9:00; 9.2=9:12
9 to 13	Temperature	TEMP. (C)	F5.1, degrees celsius.tenths
18 to 22	Wet bulb temperature	WET BULB (C)	F5.1, all data unusable
29 to 33	Barometeric pressure	PRESSURE (MBS)	F5.1, millibars.tenths

Note: Altitude of observation must be developed from pilot balloon profile that tracked minisonde ascent. Balloon ascent rate and time from release will yield altitude.

Table 26 is a printout of the first block, 40 records, of the first file. It illustrates the beginning of a minisonde ascent with observations of temperature and pressure at 6- or 12- second intervals. The presence of erroneous wet bulb data is also evident.

TABLE 26. MINISONDE METEOROLOGICAL DATA - SAMPLE PRINTOUT

EPA SMALL HILL IMPACT STUDY - MINISONDE DATA (CINDER CONE BUTTE)
CASE: 211 LOCATION: SOUTHEAST SITE
DATE: 10/31/80 RELEASE TIME: 0401 MST

TIME (SEC)	TEMP. (C)	WET BULB (C)	PRESSURE (MB)
8.9	0.5	-69.9	917.0
9.0	0.5	-69.9	915.5
9.2	0.4	-69.9	912.8
9.4	4.0	-69.9	910.3
9.6	5.0	-69.9	907.4
9.8	5.3	-69.9	905.0
9.9	5.4	-69.9	902.6
10.1	5.5	-69.9	900.4
10.3	5.8	-69.9	898.4
10.5	6.1	-69.9	896.5
10.7	6.5	-69.9	894.8
10.8	7.6	-69.9	893.3
11.0	8.6	-69.9	892.0
11.2	9.7	-69.9	890.6
11.4	10.7	-69.9	888.8
11.6	11.0	-69.9	887.1
11.7	11.2	-69.9	885.1
11.9	11.3	-69.9	883.3
12.1	11.4	-69.9	881.4
12.3	11.5	-69.9	879.3
12.5	11.5	-69.9	877.1
12.6	11.5	-69.9	875.4
12.8	11.5	-69.9	873.8
13.0	11.6	-69.9	872.0
13.2	11.6	-69.9	870.0
13.4	11.6	-69.9	868.1
13.5	11.6	-69.9	866.1
13.7	11.7	-69.9	864.2
13.9	11.9	-69.9	862.0
14.1	11.9	-69.9	859.8
14.3	11.8	-69.9	857.8
14.4	11.7	-69.9	855.8
14.6	11.7	-69.9	853.5
14.8	12.3	-69.9	851.5
15.0	12.6	-69.9	848.7

SECTION 7

EPA COMPLEX TERRAIN MODEL DEVELOPMENT

SHIS #1 MODELER'S DATA ARCHIVE - 1982

by
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7.1 MODELERS' DATA ARCHIVE

The present modelers' data archive for the first Small Hill Impaction Study (SHIS #1) of the CTMD program contains observed 1-h average tracer concentration data, tracer release information, and meteorological variables and derived parameters estimated at release height for each of the hours during SHIS #1 in which either SF_6 or Freon tracer gas was released. The method of estimating meteorological data appropriate to the release heights of the tracer gases relies on a few central assumptions, and is objectively applied to all the data with few exceptions. Those assumptions and a description of the procedures are presented in the following sections.

Because the meteorological data contained in the archive are spatial estimates of the meteorological conditions affecting the transport and dispersion of the tracer gases, they should be viewed as approximate. At

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Section 7.1 to 7.5 and Section 7.7.

best, the data could adequately represent conditions at the release point. At worst, the data could be misleading. This is particularly evident in the estimated wind direction. For example, the wind set at the 40-m level on Tower A was partially operational during all of Experiments 205, 206, 210, and 211. Some data from this instrument are recoverable, but winds are estimated at this level only by making an assumption about the variability in wind directions between 40 m and 80 m. At times, the assumption may not represent the real situation. With the scale of CCB, a resulting wind direction error of 10° could at times cause the modeled plume to miss the hill entirely during a period when the actual plume produced significant concentrations on the hill. Potential users of this archive should be aware that subjective estimates of the most appropriate wind directions as derived from evidence of actual plume transport directions are in preparation, and will be included in a second version of this archive when available.

7.2 TRACER CONCENTRATION DATA

Methods of collection and analysis of SF_6 and Freon tracer gas data are described by Lavery et al. (1982), and revised calibration procedures are described by Strimaitis et al. (1983). Procedures and results of quality assurance analyses of the tracer data are described by Greene and Heisler (1982).

Tracer gas concentration data from the SHIS #1 data base available through EPA include data from 1-h samplers, colocated 1-h samplers, 10-min samplers, and reflection mast samplers (a subset of the 10-min samplers), and "recount" concentration data resulting from re-analyzing a subset of all bag samples as part of the quality assurance program. The data base also provides additional information on the sampler location and the quality of each individual sample.

Tracer gas data contained in the modeler's data archive have been assembled from these data. All values are reported as 1-h averages. These averages include concentrations from all 1-h sampling bags labeled as good, the average of good concentrations obtained from the two samples collected at co-located sampler sites, the average of the two concentrations obtained from samples included in the recount analyses, the average of good 10-min concentrations at standard 10-min sampler sites, and the average of good 10-min concentrations obtained at the foot of the sampling mast locations. In the case of the 10-min samples, hourly concentration averages are included only if no more than one 10-min period was missing from the hour.

The position of each sampler is included in the archive along with the 1-h average tracer gas concentration. The coordinate system is a Cartesian system with origin at the center of Cinder Cone Butte, x-axis oriented toward the E, and y-axis oriented toward the N. The sampler position identification code for each concentration is also included. A map of CCB identifying each sampler position is presented in Figure 4.

7.3 TRACER RELEASE INFORMATION

The modeler's data archive contains the average emission rate of the tracer gas source, the polar coordinates of the source position is the elevation of the base of the source crane, the height of the source above the ground, and the times at which the tracer gas was turned on and turned off.

As discussed in Greene and Heisler (1982), the emission rate is an average mass release rate (g/s) from the time at which the release valve was opened to the time at which it was shut off. In some cases, this period of time was less than 1 h, but in most cases it was several hours. The start and stop times for the release are referenced to the beginning and ending time of each experiment hour, respectively. A start time of -10 (min) indicates that the tracer was released 10 min before the start of the sampling hour, and a time of -5 (min) indicates a release ended 5 min before the end of the hour.

Coordinates of the source position are expressed in the hill coordinate system, a polar grid centered on CCB. The zero height contour in this system corresponds to the 3100-ft elevation MSL (944.9 m). Release elevations are presented in meters above the ground, and the elevation of the ground at the release position is given as the difference in meters from 944.9 m MSL. A topographical map of CCB is shown in Figure 1.

7.4 METEOROLOGICAL DATA

Meteorological data contained in the modelers' data archive differ from those contained in the SHIS #1 data base in that all quantities apply to the release height of the tracer gas rather than to the height of fixed instrument levels, derived parameters computed from the meteorological data base are included, and 1-h averages are constructed. Background information on the design of the SHIS #1 meteorological data system can be found in Lavery et al. (1982), and information on the adjustments applied to the data in preparing the refined data base can be found in Strimaitis et al. (1983) and Greene and Heisler (1982).

A "spline under tension" method is used to interpolate meteorological variables between instrument levels on Tower A (Cline, 1974). This method produces a linear interpolation when a tension factor of 50 is specified, and a cubic spline curve through the data when a tension factor of zero is specified. The suggested nominal tension factor of 1.0 produces a smooth curve through all data points in a profile without the cusps and regions of high curvature between data points common with the cubic spline. After inspecting a number of profiles produced with tension factors between 0.5 and 3.0, the factor 1.2 was selected. This factor produces slightly greater curvature near instrument levels than does a factor of 1.0, but it also reduces the magnitude of local maxima/minima between data points in regions where the vertical gradient of the profile quantity must change sign.

Meteorology representative of release height is assumed to be equivalent to data taken from the Tower A vertical profile at the same height above the surface as the height of release even though the surface elevation at the release point generally differs from the surface elevation at Tower A. This approximation is consistent with the spatial resolution of the meteorological instrumentation because the release locations lie between 1 and 2.5 km from Tower A, because differences in surface elevations between the base of Tower A and release locations vary between -6.1 m and 1.5 m with a mean difference of -3.7 m, and because the vertical resolution of wind measurements on Tower A is 30 m or greater above 10 m (wind sets are located at 2, 10, 40, 80, and 150 m).

The 5-min sequence of data in the modeler's data archive is constructed as follows:

- Tower A wind speeds, wind directions, and temperatures contained in the refined data base are scanned for missing data. If missing 5-min values are found, they are replaced with values estimated using linear interpolation in time. Only UVW prop wind data are used to develop wind information because the F460 cup-and-vane instruments were placed at the 2-, 10-, and 150-m levels while most release heights are between 20 m and 60 m.

- The temperature, the vertical component of the wind speed, and the horizontal wind speed and direction are estimated at release height by "spline under tension" interpolation with a tension factor of 1.2. Horizontal speeds and directions are first broken into wind components, and the components are interpolated to obtain the wind direction at release height. The speeds are interpolated directly. The 40-m level wind data are incomplete in four of the experiments (205, 206, 210, 211) leaving the undesirable prospect of having to interpolate the profile between 10 m and 80 m. However, the u-component (E) of the wind data from 40 m is available, and the mean winds were approximately SE during each of these experiments rather than nearly N or S. Assuming that the directional wind shear was small (between 40 m and 80 m) at Tower A during these four experiments, estimates of the wind speed at 40 m are made with the 40-m u-component and the 80-m wind direction. The resulting wind speed profiles indicate that the speeds estimated at 40 m are generally reasonable, and so these speed and direction estimates of 40-m level winds are used in the interpolation procedure for nearly all 5-min periods when the 40 m v-component was unavailable. Because the wind directions near 40 m appear to differ substantially from those at 80 m during the first hour and twenty minutes and the last hour of Experiment 211, the spline interpolation is used for these periods of time.

- Turbulence data are estimated at release height by employing a linear interpolation rather than the spline interpolation. The turbulence velocity scales σ_u, σ_v, and σ_w are obtained from the turbulence intensity values contained in the refined data base by multiplying by the wind speed. Unlike wind and temperature data, missing turbulence data are not filled in by interpolating in time. However, estimates of σ_w are prepared for those experiments in which one of the horizontal wind speed props malfunctioned at the 40-m level. In these instances (205, 206, 210, 211) reported values of I_z in the refined data base are flagged as bad because the reported wind speed is incorrect, but because the w-prop was working, the σ_w values are not necessarily deficient. σ_w is recovered by multiplying the original value of I_z by the original value of the wind speed. A prop response correction derived from the work of Horst (1973) is applied. More information on its application to CCB data can be found in Strimaitis et al. (1983). No prop response corrections are applied to σ_u or σ_v.

- The Brunt-Vaisala frequency, N, is estimated at source height by interpolating the temperature profile in the immediate vicinity of the release height to obtain the local temperature gradient.

- The critical streamline height, H_c, is obtained from the splined profiles of temperature and wind speed by means of the integral formula presented in Lavery et al. (1982). A bulk Hill Froude number is calculated for the layer between H_c and the top of the tower, 150 m, and also for the layer between 2 m and 150 m. The hill height in both calculations is the difference between 95 m and the height of the bottom of the layer.

- The Turner dispersion stability class is calculated from net radiation and wind speed data by means of the method of Williamson and Krenmayer (1980). Wind speeds measured by the cups at the 10-m level on Tower A (reported as scalar averages) and the net radiation data are interpolated in time whenever missing values are encountered. The stability class is calculated as a number between 1 and 6, where 1 denotes stability class A. Both the stability class and the 10-m wind speed are included in the data archive.

Most 1-h average data in the modelers' data archive are obtained from this sequence of 5-min average data interpolated to release height. Only stability class data are not obtained in this way. The 1-h stability class is found from the 1-h average net radiation and 10-m wind speed. In a second method for computing the hourly stability class, the 10-m 1-h average wind speed is combined with cloud information according to the Turner objective method. Because cloud observations were not recorded as part of the SHIS #1 data base, we are providing the 1-h average 10-m wind speeds as part of the modelers' archive so that other users of the archive may obtain the cloud cover data from Mountain Home AFB or Boise, Idaho and determine the stability class.

The remaining 1-h average data in the modeler's data archive are constructed as follows:

- The wind speed and direction are calculated as both vector and scalar averages. Two versions of the scalar wind direction are calculated. One is a scalar average of the 5 min vector resultant wind directions. The second is a vector average of unit vectors along each 5-min vector resultant wind direction so that all directions have equal weighting, as in the scalar average, but the averaging is performed with vector arithmetic.

- Temperatures and parameters calculated from the splined profiles of the 5-min temperature and wind data (N, H_c, Fr) are simply averaged to provide 1-h average values.

- Horizontal turbulence data, σ_u and σ_v, are computed for 1-h periods by adding the contribution due to the 5-min turbulence values to the contribution due to the variability of the 5-min average winds. Let $(\sigma)_{60,0}$ denote the total 1-h value of the standard deviation, let $(\sigma)_{5,0}$ denote the total 5-min standard deviation, and let $(\sigma)_{60,5}$ denote the standard deviation of the 5-min average winds over a 1-h period. Then:

  $$(\sigma)^2_{60,0} \simeq (\sigma)^2_{60,5} + \overline{(\sigma)^2_{5,0}}$$

  Note that although prop response corrections are not applied to the $(\sigma)_{5,0}$ values, they are implicity contained in $(\sigma)_{60,5}$ because the 5-min wind data in the refined data base include corrections for prop response and wake effects. Also, because no time interpolation is performed on the 5-min turbulence data, less than a full set of 12 values may be available during some hours. In these cases the average of the $(\sigma)^2_{5,0}$ values will be incomplete. The number of $(\sigma)_{5,0}$ values contained in each hour are denoted by N(su), N(sv), and N(sw) in the archive.

- The vertical turbulence σ_w is computed for 1-h averaging periods in the same way as σ_u and σ_v, but the prop response correction suggested by Horst (1973) is also applied. Neither the $(\sigma_w)_{5,0}$ or the $(\sigma_w)_{60,5}$ data used in the formula for $(\sigma_w)_{60,0}$ have the correction already applied. Rather, the correction is applied directly to $(\sigma_w)_{60,0}$. Also, the construction of $(\sigma_w)_{60,0}$ by the above formula is exact in the case of σ_w, but only approximate in the case of σ_u and σ_v.

7.5 ARCHIVE STRUCTURE

The modelers' data archive contains two type of files: meteorological data and tracer release data files; and tracer concentration files. The experiment number, the experiment hour (the number of the hour within the experiment, not the hour of the day) and the tracer gas identify each file.

Most of the items in the file have already been discussed. In the block of 5-min meteorological data, the time designation includes the Julian day, the hour of the day, and the ending time (in seconds past the hour) of each of the 5-min periods. The sharp signs denote the number of levels of data from Tower A that are included in the spline interpolation. Because missing temperature and wind data are interpolated in time prior to interpolating in height, most files contain splines fit to the maximum possible number of temperature (8) and wind (5) levels. However, the turbulence data were not interpolated in time, and have correspondingly fewer levels of data for interpolating in height.

In the 1-h average concentration data, the first three characters denote the sampler location, and the day and time follow as in the meteorology file. Concentrations are given in ppt, followed by a data quality flag (they should all be G) and a column indicating whether the concentration is from a 1-h sample (0), or made up of five or six individual 10-min samples. The Cartesian coordinates of the sampler position follow (x, y, z), expressed in meters.

7.6 MODELERS' DATA TAPE FILES

Data are stored at the National Computer Center, Environmental Research Center, Research Triangle Park, North Carolina on Sperry UNIVAC 1100/83 systems magentic tape, nine track, odd parity, ASCII-quarter word mode, density 6250 BPI, tape number 002689. Record length is 132 characters, and the block size is 1320 words, or 40 records per block.

UNIVAC users may assign the tape, @ASG,T CCBTR,U9S//////Q,002689 using UNIVAC ECL. Upon request, copies can be furnished and translated into formats acceptable to any computer using nine track tape drives.

7.6.1 Tape File Index

There are four tape files; for each tracer gas, there is one file of combined meteorological data and tracer release data and one file of tracer gas concentrations. Table 27 shows how the tape files are arranged on the tape.

TABLE 27. MODELERS' DATA TAPE FILES

File no.	Experiment no.	Comments
1	201 to 218	SF_6 meteorological and tracer release data
2	201 to 218	SF_6 tracer concentration data
3	208 to 218	Freon meteorological and tracer release data
4	208 to 218	Freon tracer concentration data

7.6.2 Tape File Records - Meteorological and Tracer Release Data

The first record of the file is composed of alphabetic characters that identify the experiment, hour and tracer. The second record has alphabetic characters that reveal the tracer release data with regard to emission rate, position of the mobile crane, height of emission release, and start and stop time of the release. The third record is a blank, and the fourth has alphabetic characters that are column headings for 12 records of meteorological data that follow. A blank record follows the meteorological records, and eight alphabetic records follow, containing hourly averages of meteorological data. Table 28 illustrates the data formats of the meteorological records.

Table 29 is a printout of the first block, 40 records, of file no. 1, the first file of combined meteorological and tracer release data related to SF_6 gas. The first block contains data from the first hour of the first experiment, 201, as well as data from part of the second hour. File no. 3

TABLE 28. MODELERS' METEOROLOGICAL RECORD DATA FORMAT - TOWER A

Position	Contents	Heading	Comments (FORTRAN Format)
1 to 3	Day (Julian)	DAY	I3
5 to 6	Hour	HR	I2
8 to 11	Seconds	SEC	I4
15	Stability class	SC	I1
20 to 23	10-m wind speed, C&V	MS(10)	F4.1, meters per second
27 to 30	Average temp. (splined)	TEMP	F4.1, degrees celsius
33	Number of data points in Tower A profile	#	I1
37 to 40	Average wind speed (splined)	WS	F4.1, meters per second
44 to 48	Average wind direction (splined)	WD	F5.1, degrees
50	Number of data points in Tower A profile	#	I1
53 to 57	Average vertical wind (splined)	W	F5.3, meters per second
59	Number of data points in vertical wind Tower A profile	#	I1
63 to 70	Turbulence velocity u-component (along-wind)	Sigma-U	F8.3, meters per second
72	Number of data points interpolated in Tower A profile	#	I1
76 to 83	Turbulence velocity v-component (cross-wind)	Sigma-V	F8.3, meters per second
85	Number of data points interpolated in Tower A profile	#	I1
89 to 96	Turbulence velocity w-component (vertical)	Sigma-W	F8.3, meters per second

(continued)

TABLE 28. (Continued)

Position	Contents	Heading	Comments (FORTRAN Format)
98	Number of data points interpolated in Tower A profile	#	I1
102 to 105	Height of critical streamline	HC	F4.1, meters
110 to 114	Hill Froude number	FR(HC)	F5.1, calculated for the layer HC to 150 m
118 to 122	Froude number	FR	F5.1, calculated for the layer 2 m to 150 m
126 to 130	Brunt-Viasala frequency	N	F5.4

is similar to file no.1 except the tracer release data are associated with another gas, Freon, and meteorological parameters are estimated for different release heights.

7.6.3 Tape File Records - Tracer Concentration Data

The first record of the file is composed of alphabetic characters that identify the experiment, hour, and tracer concentrations. Data records follow the first record and continue until another alphabetic identification record is encountered to indicate another hour begins. Table 30 shows the data formats for the tracer concentration records.

TABLE 29. MODELER'S METEOROLOGICAL AND TRACER RELEASE DATA - SAMPLE PRINTOUT

EXP 201 EXP-HR 1 SF6
RATE(G/S) = .090 POSITION(M,DEG,M) = 991.4, 316.5, -7.0 HEIGHT(M) = 30.0 START(MIN) = -14 STOP(MIN) = 60

DAY	HR	SEC	SC	MS(10)	TEMP	#	WS	WD	#	W	#	SIGMA-U	#	SIGMA-V	#	SIGMA-W	#	HC	FR(HC)	FR	N
290	17	300	4	6.1	10.3	8	7.1	311.3	5	.195	5	-999.999	0	-999.999	0	-999.999	0	.0	999.0	999.0	.0000
290	17	600	4	6.3	10.2	8	7.1	311.4	5	.169	5	.762	5	.660	5	.434	5	.0	999.0	999.0	.0059
290	17	900	4	5.5	10.3	8	7.0	309.9	5	.312	5	.712	5	.729	5	.506	5	.0	22.8	26.1	.0051
290	17	1200	4	5.5	10.2	8	6.5	309.0	5	.220	5	.775	5	.524	5	.438	5	.0	9.8	11.0	.0000
290	17	1500	4	5.7	10.1	8	7.0	313.9	5	.196	5	.592	5	.765	5	.490	5	.0	7.0	7.7	.0053
290	17	1800	4	5.6	10.0	8	6.9	314.8	5	.221	5	.653	5	.541	5	.407	5	.0	5.6	6.1	.0096
290	17	2100	4	6.0	9.8	8	7.4	317.4	5	.235	5	.539	5	.505	5	.428	5	.0	5.3	5.7	.0134
290	17	2400	4	6.2	9.7	8	7.4	316.8	5	.225	5	.519	5	.457	5	.382	5	.0	4.9	5.4	.0139
290	17	2700	4	5.7	9.5	8	7.2	315.9	5	.187	5	.614	5	.404	5	.353	5	.0	4.1	4.5	.0132
290	17	3000	5	5.1	9.4	8	6.4	313.6	5	.196	5	.398	5	.294	5	.321	5	.0	3.5	3.8	.0209
290	17	3300	5	4.5	9.3	8	6.2	313.1	5	.149	5	.336	5	.265	5	.233	5	2.0	3.1	3.1	.0204
290	18	0	5	4.2	9.2	8	6.0	311.5	5	.144	5	.251	4	.232	5	.222	4	2.0	2.9	2.9	.0254

HOURLY AVERAGES:
STABILITY CLASS = 4 10-M WIND SPEED = 5.6
TEMPERATURE = 9.8
SCALAR WIND SPEED = 6.8 VECTOR WIND SPEED = 6.8
VECTOR DIRECTION = 313.3 UNIT VECTOR DIRECTION = 313.2 SCALAR DIRECTION = 313.2
SIGMA-U = .735 SIGMA-V = .607 SIGMA-W = .239 SIGMA-W (HORST CORRECTION) = .401
N (SU) = 11 N (SV) = 11 N (SW) = 11
HC = 0 FR(HC) = 172.2 FR = 172.9 BRUNT-VAISALA FREQUENCY = .0111

EXP 201 EXP-HR 2 SF6
RATE(G/S) = .090 POSITION(M,DEG,M) = 991.4, 316.5, -7.0 HEIGHT(M) = 30.0 START(MIN) = -74 STOP(MIN) = 0

DAY	HR	SEC	SC	MS(10)	TEMP	#	WS	WD	#	W	#	SIGMA-U	#	SIGMA-V	#	SIGMA-W	#	HC	FR(HC)	FR	N
290	18	300	5	4.0	9.1	8	5.9	311.0	5	.150	5	.239	5	.190	5	.222	5	4.0	3.1	2.7	.0215
290	18	600	5	3.8	9.1	8	5.9	311.6	5	.141	5	.212	5	.156	5	.181	4	5.0	3.0	2.5	.0270
290	18	900	5	3.5	9.0	8	5.5	308.6	5	.146	5	.233	4	.223	5	.188	5	7.0	3.0	2.2	.0287
290	18	1200	5	3.5	8.6	8	5.7	305.6	5	.146	5	.217	5	.192	5	.147	5	8.0	2.5	1.7	.0000
290	18	1500	5	3.6	8.8	8	5.7	306.6	5	.143	5	.145	5	.125	5	.143	5	7.0	2.6	1.8	.0314
290	18	1800	5	3.6	8.6	8	5.7	307.8	5	.142	5	.135	5	.145	5	.089	5	8.0	2.7	1.8	.0262
290	18	2100	6	3.3	8.5	8	5.6	309.0	5	.145	5	.143	5	.076	4	.076	5	9.0	2.7	1.7	.0311
290	18	2400	6	3.1	8.4	8	5.0	307.9	5	.153	5	.125	5	.142	5	.037	4	10.0	2.7	1.6	.0384
290	18	2700	6	3.0	8.2	8	5.1	311.2	5	.152	5	.098	5	.172	5	.127	5	11.0	2.7	1.6	.0409
290	18	3000	6	3.3	7.9	8	4.9	313.7	5	.130	5	.130	4	.115	5	.075	5	9.0	2.6	1.6	.0416
290	18	3300	5	3.5	7.7	8	5.1	313.9	5	.141	5	.124	5	.246	5	.072	5	8.0	2.5	1.6	.0374

TABLE 30. MODELERS' TRACER CONCENTRATION RECORD DATA FORMAT

Position	Contents	Comments (FORTRAN Format)
1 to 3	Sampler ID	A3
4 to 6	Tracer ID	A3
7 to 10	Year 1980	A4
12 to 14	Day (Julian)	I3
16 to 17	Hour	I2
20 to 23	Second-ending	I4
27 to 34	Concentration, PPT	F8.3
37	Quality flag (G)	A1
43	Number of samples in 1-h aver.	I1
46 to 53	X-coordinate (E-W) of sampler relative to center of CCB	F8.3, meters
56 to 63	Y-coordinate (N-S) of sampler relative to center of CCB	F8.3, meters
67 to 73	Z-Height of sampler above datum, 944.9 m	F7.3, meters

Table 31 is a printout of the first block, 40 records, of file no. 2, the first file of tracer concentration data. The first block contains tracer concentrations, SF_6, as 1-h averages collected as 1-h samples (0), or averaged from 5 or 6 individual 10-min samples. File no. 4 is similar to file no. 2 except the tracer gas concentrations are of Freon and the tracer release was started at Experiment 208.

TABLE 31. MODELER'S TRACER CONCENTRATION DATA - SAMPLE PRINTOUT

EXP 201	EXP-HR 1	SF6							
31ESF61980	290	18	0	1.820	G	5	195.146	149.741	27.411
37CSF61980	290	18	0	14.800	G	0	51.037	387.663	11.784
37GSF61980	290	18	0	48.580	G	5	29.594	224.788	51.507
37JSF61980	290	18	0	245.020	G	5	20.071	152.453	81.059
37ZSF61980	290	18	0	347.400	G	0	2.148	18.883	80.000
45JSF61980	290	18	0	170.900	G	0	-125.243	-96.103	78.809
45XSF61980	290	18	0	210.600	G	0	-84.852	-65.117	90.000
48ESF61980	290	18	0	40.090	G	5	-248.958	-66.708	32.902
48GSF61980	290	18	0	112.500	G	5	-204.157	-54.704	52.262
50GSF61980	290	18	0	140.808	G	6	-238.000	.000	50.000
60XSF61980	290	18	0	258.500	G	0	108.148	-61.117	50.000
64JSF61980	290	18	0	221.200	G	0	-157.378	20.719	83.353
67BSF61980	290	18	0	209.900	G	0	-359.959	207.823	8.935
67FSF61980	290	18	0	305.240	G	5	-246.197	142.142	47.955
67WSF61980	290	18	0	310.700	G	0	-213.908	123.500	60.000
67XSF61980	290	18	0	175.900	G	0	-153.852	89.883	70.000
69ZSF61980	290	18	0	457.500	G	0	-229.810	229.810	30.000
70HSF61980	290	18	0	407.100	G	0	-91.989	119.882	64.944
73JSF61980	290	18	0	126.500	G	0	-32.852	122.883	80.000
74DSF61980	290	18	0	149.400	G	0	-25.714	195.515	65.000
EXP 201	EXP-HR 2	SF6							
31ESF61980	290	19	0	339.840	G	5	195.146	149.741	27.411
31ZSF61980	290	19	0	168.680	G	5	85.148	64.883	80.000
37DSF61980	290	19	0	362.583	G	6	40.173	305.142	22.104
37JSF61980	290	19	0	174.333	G	6	20.071	152.453	81.059
37TSF61980	290	19	0	215.800	G	0	25.148	190.883	65.000
37ZSF61980	290	19	0	78.100	G	0	2.148	18.883	80.000
45GSF61980	290	19	0	7.600	G	6	-177.408	-136.130	49.210
48DSF61980	290	19	0	.233	G	6	-393.676	-106.289	3.439
60XSF61980	290	19	0	220.200	G	0	108.148	-61.117	50.000
64JSF61980	290	19	0	2.200	G	0	-157.378	20.719	83.353
65CSF61980	290	19	0	3.240	G	5	-243.413	65.222	50.000
67BSF61980	290	19	0	.000	G	0	-359.959	207.823	8.935
67DSF61980	290	19	0	9.600	G	0	-297.114	171.539	28.074
67XSF61980	290	19	0	188.400	G	0	-153.852	89.883	70.000
67YSF61980	290	19	0	11.000	G	0	-111.852	65.883	80.000
69ZSF61980	290	19	0	31.800	G	0	-229.810	229.810	30.000
70HSF61980	290	19	0	118.400	G	0	-91.989	119.882	64.944
72WSF61980	290	19	0	40.860	G	5	-109.065	263.306	30.000

7.7 CONCLUSION

The present contents of the modelers' data archive for SHIS #1 cover all experiment hours in which either SF_6 or Freon tracer concentrations are quantifiable at locations on Cinder Cone Butte, and in which these gases are released for a significant part of an hour. Meteorological data are estimated at tracer gas release height by means of data measured at Tower A, the 150-m tower erected approximately 2 km north of the hill. The method of estimation is applied objectively, and relies on few assumptions. Tracer gas concentrations for all available samplers are reported as 1-h averages.

Users of this archive should pay particular attention to the starting and stopping times included with the tracer gas release information. Observed tracer gas concentrations are not equivalent to modeled 1-h tracer gas concentrations if the release began well after the start of the hour, or if the release terminated well before the end of the hour. However, in some cases adjustments to the modeled 1-h tracer gas concentrations could be designed to take account of the actual release period, and the travel time from the source to the sampler array. In any case, it is the user's responsibility to screen out those periods which are inappropriate for driving his model.

The user should also consult the modeling work presented in the first and second CTMD milestone reports. These will give the user some idea of the representativeness of the interpolated wind directions contained in the archive for 45 of the experiment hours. Note, however, that the other meteorological data presented in those reports were not derived explicitly from the data contained in this archive. Present and future CTMD modeling will make use of the archive data.

Finally, two hours of the original 45 hours contained in the CTMD first milestone report have since been considered inappropriate for Gaussian model development. Experiment-hour 205-5 displays an SF_6 concentration pattern which appears to be inconsistent with the release height when compared to the pattern during the previous hour. Experiment-hour 209-7 contains a slowly propagating abrupt wind shift which clearly passes Tower A well before it passes the tracer gas release location, so Tower A data are not representative of the meteorological conditions at the release location.

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16. ABSTRACT

As part of the U.S. Environmental Protection Agency's effort to develop and demonstrate a reliable model of atmospheric dispersion for pollutant emissions in irregular mountainous terrain, the Complex Terrain Model Development Program was initiated. The first phase, a comprehensive tracer field study, was carried out on Cinder Cone Butte, Idaho, during the autumn of 1980. Eighteen quantitative tracer experiments were conducted, each lasting 8 hr at night or early morning. The main tracer gas was sulfur hexafluoride; a second tracer, Freon 13B1 was used in ten of the eighteen experiments. Averaged meteorological data were recorded from six towers near and on the slopes of the hill. Data consisted of direct and derived measures of temperature, wind, turbulence, solar and net radiation, and nephelometer coefficient of scattering. Hourly wind profiles were obtained from pilot balloon observations; tethersonde observations recorded profiles of wind and temperature.

Tracer gas concentrations were detected by a network of approximately 100 samplers located on the slopes of the hill. The system used to collect the data, the operation procedures used to run the system, and its performance record are described. Tables of tracer gas release data have been included to assist in any modeling effort. All meteorological and tracer concentration data have been edited and recorded on magnetic tape and are now available, upon request, at the National Computer Center, R.T.P., NC, either as copies or by interactive computer access.

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