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16. Abstract
Air Quality measurements along Texas freeways have been completed at six sites, representing "at grade", "elevated", and "cut" roadbed configurations, and representing "coastal plain", "inland plain", "hill country", and "mountain" climates in Texas. Measurements at each site consisted of carbon monoxide concentrations at ten downwind and two upwind locations, vehicle length, count, and speed by lane, and detailed wind speed, wind direction, temperature, relative humidity, and solar radiation between five and 100 feet. Nitrogen oxide concentrations at four downwind and one upwind station were also measured at selected sites. The instruments were interfaced to a Data General NOVA 1200 minicomputer, allowing effectively simultaneous recording of all instruments. The resulting data were logged on magnetic cassette and later transferred to standard nine track tape. Hydrocarbons were also measured at some sites, being recorded on chart recorders and later transferred to tables included in this report.

A number of cases selected from the data have been compared to several popular dispersion models. A method has been developed for evaluating the source strength of a roadway. The accuracy of various pollution monitoring instruments has been evaluated.

This report and the experimental data on magnetic tapes are available from the Texas State Department of Highways and Public Transportation and NTIS. They are also available at modest costs from Dr. Jerry A. Bullin, Chemical Engineering Department, Texas A&M University, College Station, Texas 77843, phone 713-845-3361.

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Interim Report

on

ANALYTICAL AND EXPERIMENTAL ASSESSMENT OF HIGHWAY IMPACT ON AIR QUALITY

by

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N. J. Green

Submitted to

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and
TEXAS TRANSPORTATION INSTITUTE
College Station, Texas 77843

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Dispersion data for several roadway pollutants have been collected at six different sites in Texas. A computationly fast model for carbon monoxide dispersion from at grade roadways has been developed and released in FORTRAN and hand held calculator forms. The experimental data have been reduced to three meaningful formats which will be used for further model development.

Disclaimer

Summary

The objective of this project was to correlate air quality along roadways with the traffic, meteorological and topographical conditions. In conducting the work, air quality measurements along Texas freeways were made at six sites, representing "at grade", "elevated", and "cut" roadbed configurations, and representing "coastal plain", "inland plain", "hill country", and "mountain" climates in Texas. Measurements at each site consisted of carbon monoxide concentrations at ten downwind and two upwind locations, vehicle length, count, and speed by lane, and detailed wind speed, wind direction, temperature, relative humidity, and solar radiation between five and 100 feet. Nitrogen oxide concentrations at four downwind and one upwind station were also measured at selected sites. The instruments were interfaced to a Data General NOVA 1200 minicomputer, allowing effectively simultaneous recording of all instruments. The resulting data were logged on magnetic cassette and later transferred to standard nine track tape. Hydrocarbons were also measured at some sites, being recorded on chart recorders and later transferred to tables included in this report.

A number of cases selected from the data have been compared to several popular dispersion models. A method has been developed for evaluating the source strength of a roadway. The accuracy of various pollution monitoring instruments has been evaluated. The final report on this project will be completed in late 1979 and will include a detailed analysis of the data and comparison to several of the currently popular dispersion models.

Chapter I

Introduction

Currently, the Federal Highway Administration requires the submission of environmental impact statements for proposed new roadways or major improvements to existing roadways before the project is begun. As a part of these statements, air quality reports must be prepared giving predicted estimates of carbon monoxide concentrations along the proposed roadway. These predictions include values for carbon monoxide levels from immediately after construction to as much as 20 years later. The air quality reports are reviewed by several agencies, including the Texas Air Control Board, the Federal Highway Administration, the Environmental Protection Agency, and others. Highways which would seriously degrade air quality would probably not receive federal financing. The National Ambient Air Quality Standards are used as a basis for judging the air quality.

There have been many mathematical models proposed for use in making predictions of carbon monoxide levels along roadways. These models are capable of making predictions for various meteorological, topographical and roadway conditions. One of the major problems with these models has been in their validation. Only a few experimental validation programs have been undertaken, and they have met with varying degrees of success.

Project 218, "Analytical and Experimental Assessment of Highway Impact on Air Quality," for which this is an interim report, addresses the validation problem. The measurements required for model validation are vehicle count, speed, and type mix (car or truck), wind speed and direction, and carbon monoxide concentrations at various distances from the roadway. In this project, all of the required data were collected at six sites in Texas, including two in Houston, two in Dallas, and one each in San Antonio and El Paso. Approximately 360 hours of data were collected during the project.

Chapter II

Site Descriptions

Introduction

Data collection was carried out at six sites in Texas. The experimental sites included one "at grade" site each in Houston, Dallas, San Antonio, and El Paso. In addition there was a "cut" site in Houston and an "elevated" site in Dallas. Each of these sites was chosen under considerations for equipment constraints and experimental procedure requirements, such as highway and wind orientations, right of way widths, and others. At least 150 feet of clear space on both sides of the roadway were required in order for the equipment to be located properly. At all sites, except the Dallas elevated site, the roadway ran east-west in order to take advantage of the prevailing south wind. This maximized the amount of crosswind situations for which data was collected. The Dallas elevated site ran north-south, and thus did not have the advantage of the prevailing south wind. However, this was the most suitable elevated site which could be found, in terms of the other site selection criteria.

The remainder of this chapter consists of the site descriptions and instrumentation layouts for the project. The following chapter will give a more detailed description of the instruments and their operation.

Houston At Grade Site

This site was located at Loop 610 and Link Road, approximately one mile west of the IH45 and Loop 610 interchange on the north side of Houston. An overhead view of the site may be seen in Figure 1. The symbols used in Figures 1 through 12 are defined in Table 1. Traffic on Loop 610 was moderate at all times of the day, heaviest just before 8:00 AM and just after 5:00 PM, but seldom heavy enough to impede free traffic flow. The freeway ran in a south-

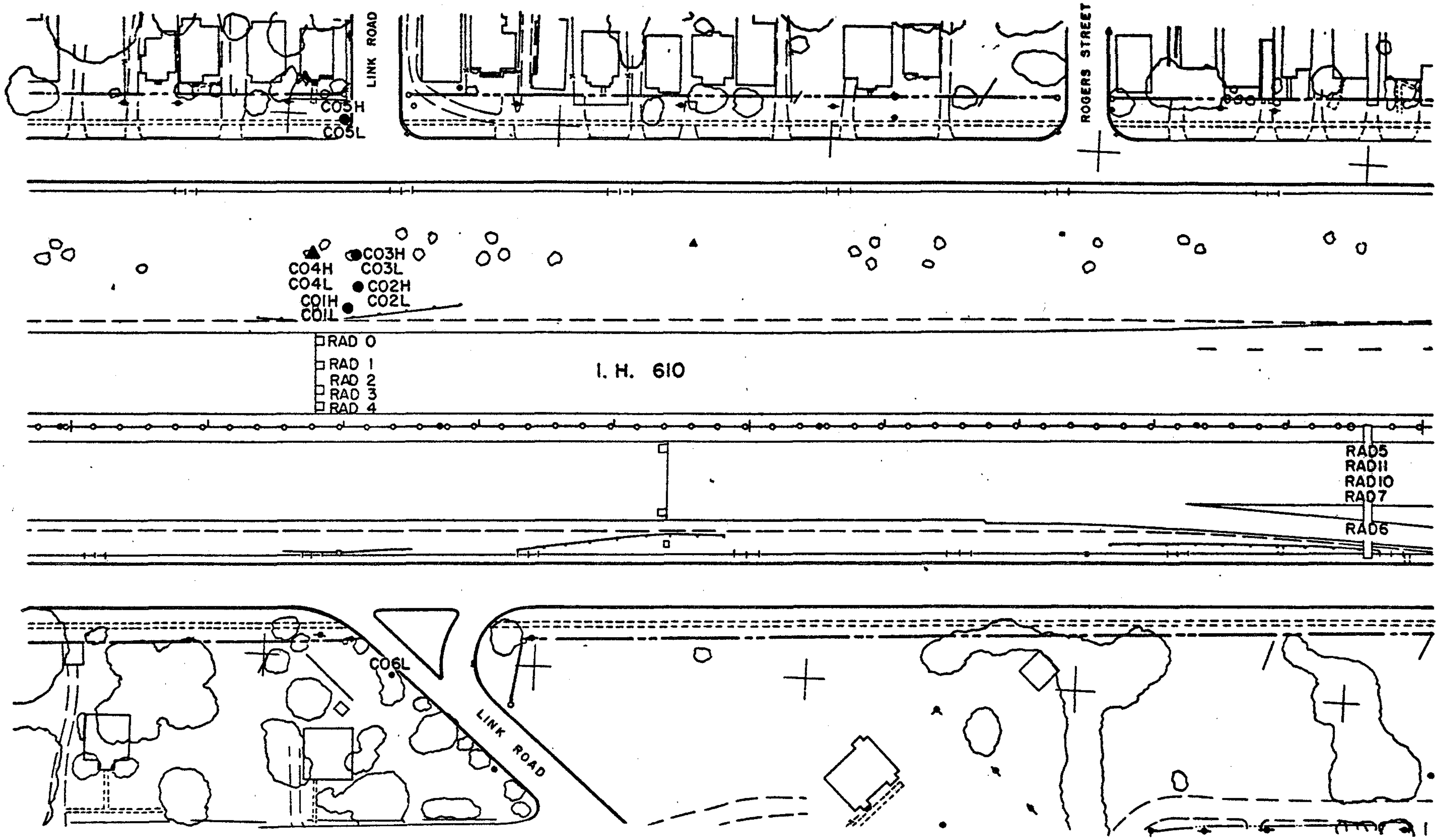

Figure 1

Overhead view - Houston, IH10 at Link Road

Table 1

Project 218 Instrument List

Name	Channel	Instrument	Sample Interval
RAD0	1	Radar	.01 sec
RAD1	2	"	"
RAD2	3	"	"
RAD3	4	"	"
RAD4	5	"	"
RAD5	6	"	"
RAD6	7	"	"
RAD7	8	"	"
RAD10	9	"	"
RAD11	10	"	"
VA1.5m	11	1.5 meter vertical anemometer	2 sec
VA10m	12	8 "	4 sec
VA20m	13	16 "	5 sec
VA40m	14	30 "	5 sec
HA1.5m	15	1.5 meter horizontal anemometer	15 sec
HA10m	16	8 "	"
HA20m	17	16 "	"
HA40m	18	30 "	"
WV1.5m	19	1.5 meter wind vane	5 sec
WV1.0m	20	8 "	"
WV20m	21	16 "	"
WV40m	22	30 "	"
TM1.5m	23	1.5 meter thermometer	60 sec
TMP10m	24	9 "	"
TMP20m	25	13 "	"
TMP30m	26	25 "	"
RH1.5m	27	1.5 meter psychrometer	"
RH30m	28	25 "	"
PYRAN	29	Heliopyranometer	"
CO1H	30	Ecolyzers	10 sec
CO1L	31	"	"
CO2H	32	"	"
CO2L	33	"	"
CO3H	34	"	"
CO3L	35	"	"
CO4H	36	"	"
CO4L	37	"	"
CO5H	38	"	"
CO5L	39	"	"
CO6H	40	"	"
CO6L	41	"	"
NOX1	43	NOX Monitor	"
NOX2	45	"	"
NOX3	47	"	"
NOX5	49	"	"
NOX6	51	"	"

west and northeast direction (compass heading 78°). The active roadway consisted of five 12-foot wide lanes in each direction, with a 20-foot wide median in the center and ten-foot wide shoulders at each roadedge. The center median had a five-foot chain link fence at its center. The two outside lanes were acceleration and deceleration lanes for a set of entrance and exit ramps located 400 feet west of and 1000 feet east of the project's location. A lightly travelled two-lane access road paralleled the freeway on each side. On the south side, the access road was separated from the shoulder by a 40-foot wide grass median. The project equipment was set up on the 100-foot wide grass boulevard between the freeway and the north side access road. Land use in this area consisted of single story dwellings and trees up to 30 feet tall on both sides of the roadway. The grass strips between the freeway and the access road were relatively smooth, with scattered six-foot pine trees. Figure 2 shows the equipment layout at this site. The symbols in Figure 2 are also defined in Table 1.

Houston Cut Site

This site was located at IH10 and Reinerman Road. Figure 3 shows an overhead view of the site. In this area, the freeway was depressed approximately 35 feet below the local ground level, lying at the bottom of a cut with walls sloping at roughly 30°. The freeway consisted of five 12-foot wide lanes in each direction separated by a 20-foot wide median with a chain link fence at its center. There was a ten-foot wide shoulder adjoining the two outside lanes. The freeway ran southwest and northeast (compass heading 82°), and was well travelled at most times of the day. At the top of the cut on each side, a 35-foot wide three lane access road paralleled the freeway. Single story dwellings surrounded by trees up to 40 feet tall characterized the landscape around the

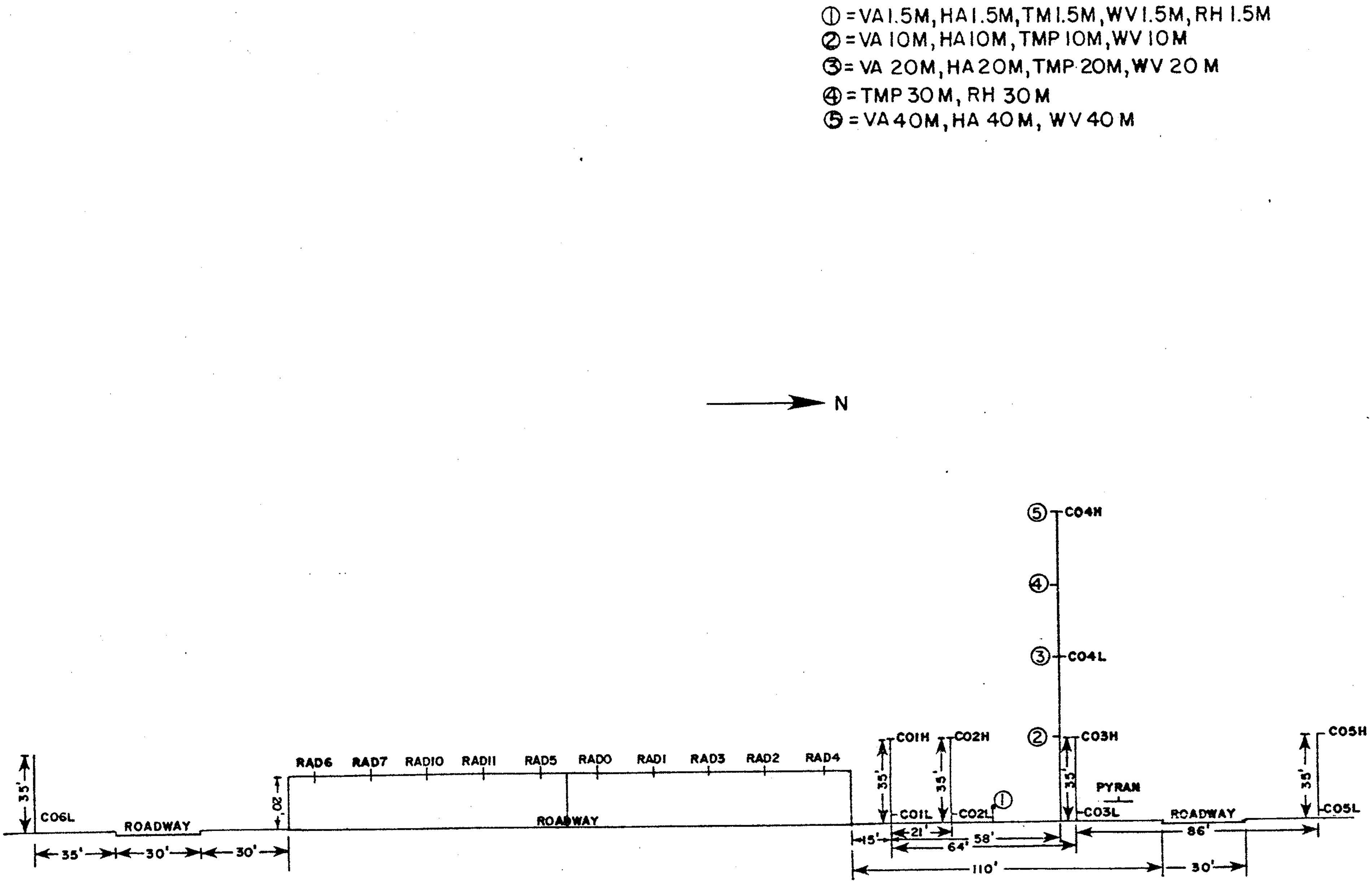

FIGURE 2

CROSS SECTION - HOUSTON, IH10 AT LINK ROAD

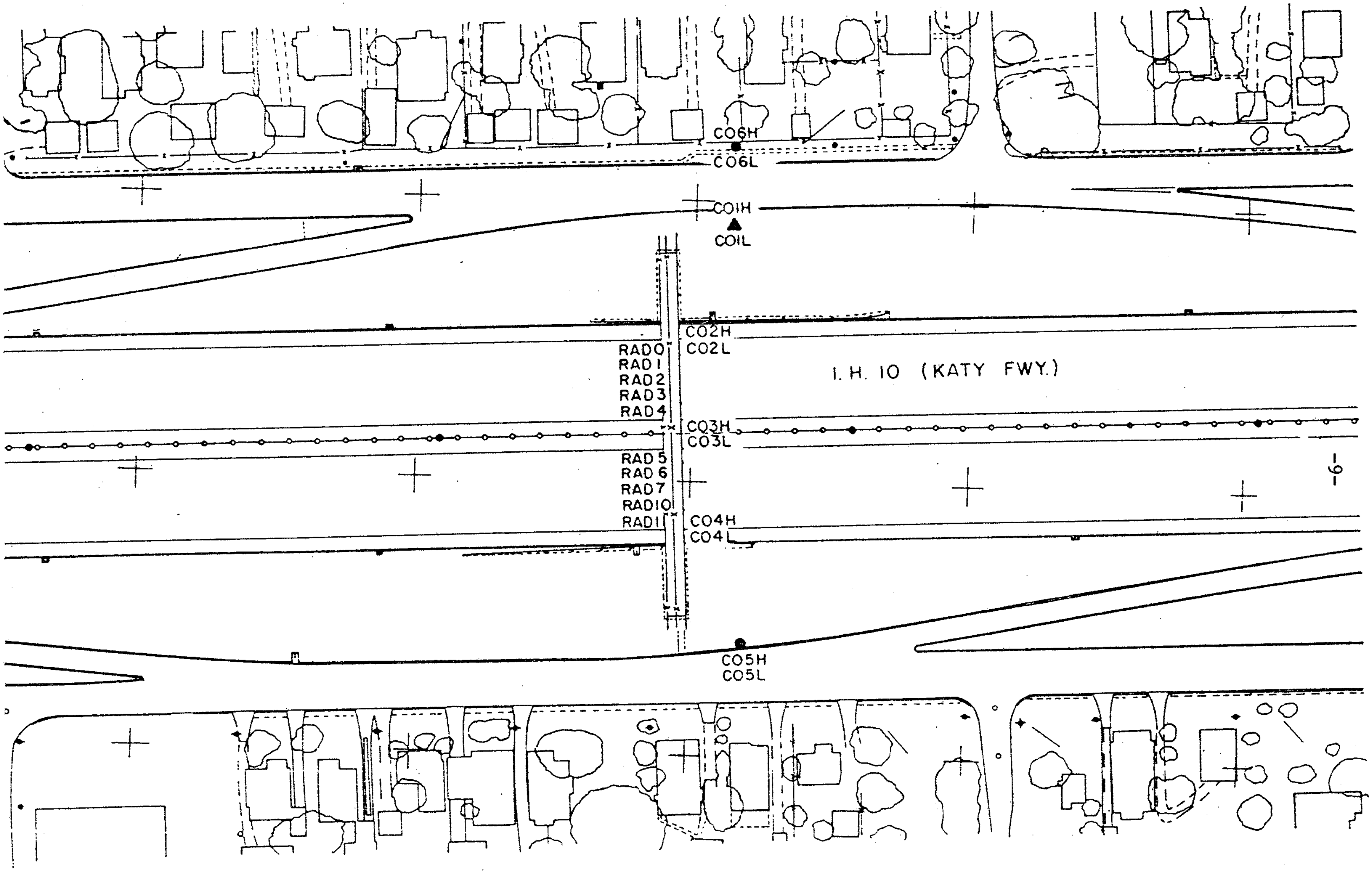

FIGURE 3

OVERHEAD VIEW - HOUSTON, KATY FREEWAY

freeway. Figure 4 shows the equipment layout at this site.

Dallas Elevated Site

This site was located just south of the downtown interchange on IH45, between Forest and Pennsylvania Avenues. Figure 5 gives an overhead view of this site. The freeway runs northwest and southeast (compass heading 151°). There were three 12-foot wide lanes in each direction, with an exit lane on the southbound side dividing from the freeway at the point where the monitoring instruments were located. There was a 20-foot wide center median with a chain link fence at its center, and a ten foot wide shoulder on each side. The entire freeway was elevated 20 feet above local ground level on an earth filled concrete wall which became a viaduct where Forest and Pennsylvania Avenues passed under the freeway. A two lane access road paralleled the freeway at ground level on each side, separated from the freeway wall by grassy boulevards with scattered 8-foot oaks and crepe myrtle bushes. On the west side, the boulevard was 110 feet wide at its widest point. On the east side, the boulevard was only 40 feet wide. Land use in the area consisted primarily of one and two story apartments and small businesses.

There were two major problems with this site. First, the heavily travelled Highway 75 was located less than half a mile east of the site, occasionally affecting the background monitors. More severe was the lack of radars over the three northbound lanes of the freeway. A permanent counting station was established at this site shortly before the project was moved away, and it is hoped that historical data will be able to make up for the lack of radars.

The project equipment was arranged as shown in Figure 6.

Dallas At Grade Site

This site was actually east of Dallas, in the suburb of Mesquite. An

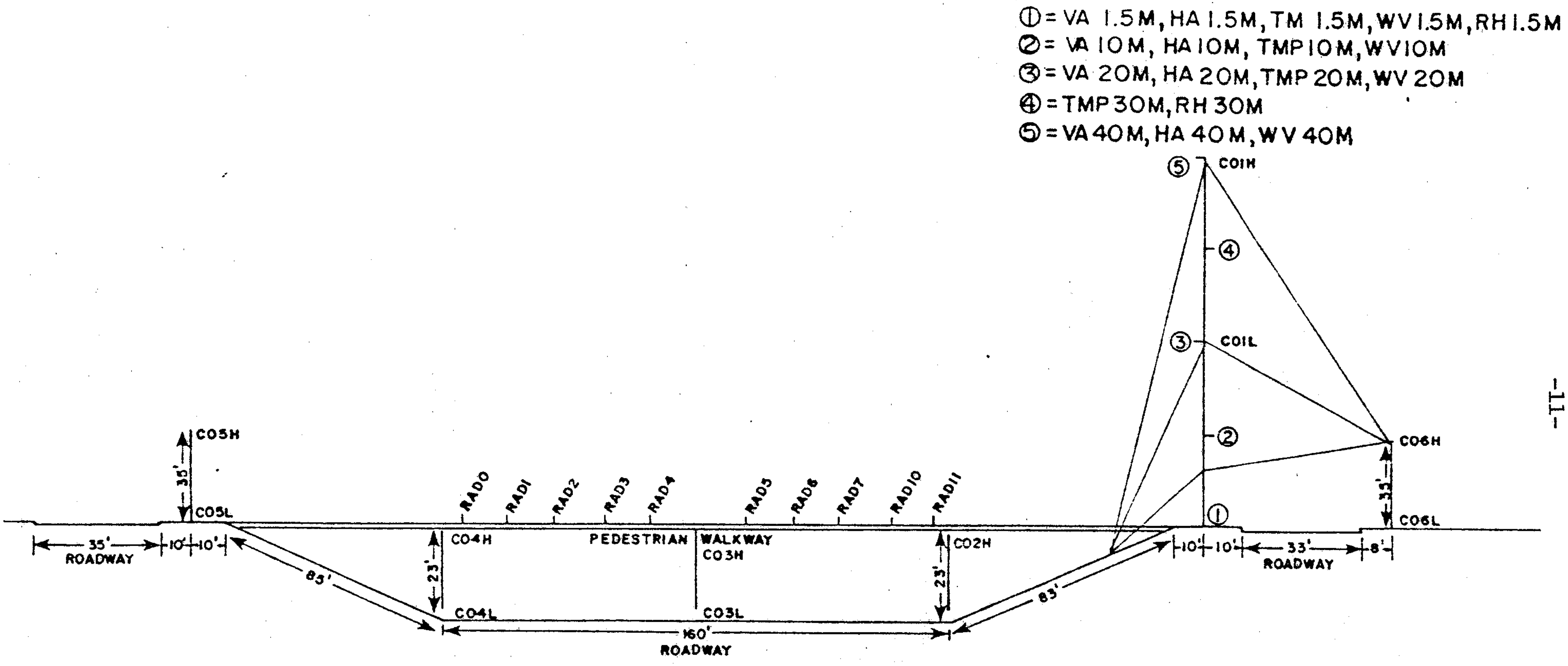

FIGURE 4

CROSS SECTION - HOUSTON, KATY FREEWAY

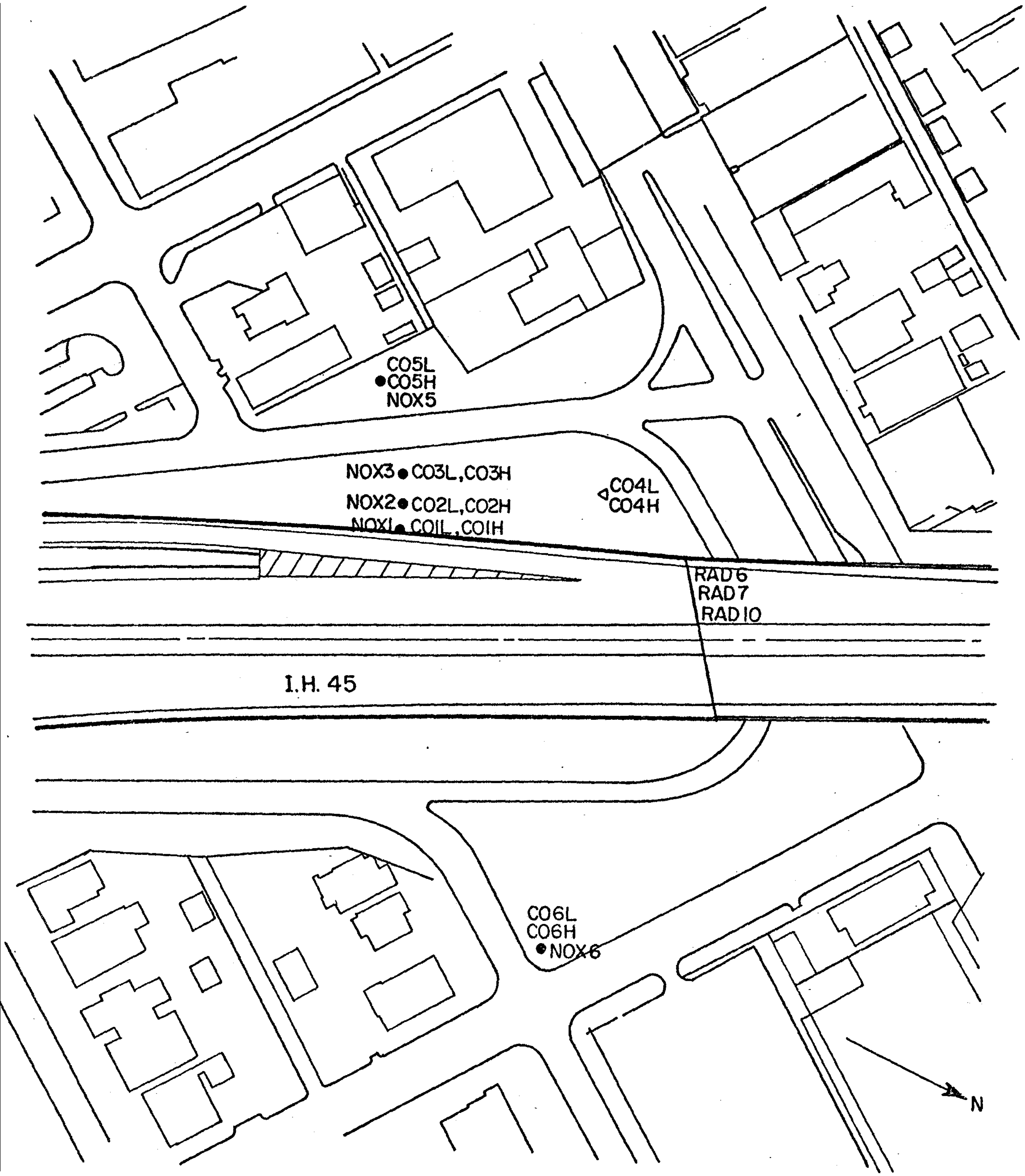

Figure 5

Overhead View

Dallas, IH45 at Forest Avenue

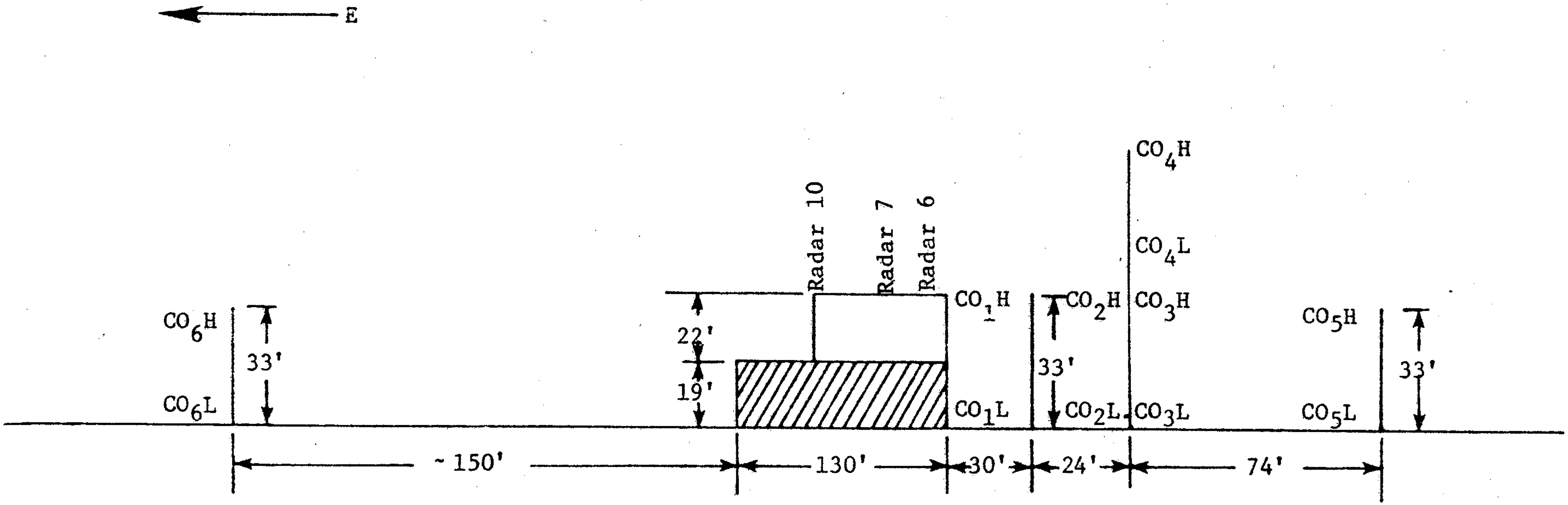

FIGURE 6

INSTRUMENT LOCATIONS: Project 218

Dallas: IH45 at Forest Avenue

overhead view of this site is shown in Figure 7. The freeway ran in a southwest and northeast direction (compass heading 56°), and consisted of two twelve-foot wide lanes in each direction with a 38-foot wide grassy median separating the directions. Each outside lane had a ten foot shoulder. A two-lane access road paralleled the freeway in each direction, separated from it by grassy medians. On the eastbound side, the median was 66 feet wide and on the westbound side, the median was 42 feet wide. Except for the Motley Drive overpass, two service stations, and a small creek, the surrounding terrain was flat grassland. The instrument layout for Project 218 is shown in Figure 8. This site presented some problems, among them being the fact that at times the access roads carried a significant fraction of the total traffic and the fact that the center median was wide enough to cause a separation of the mixing cells.

San Antonio Site

This site was located at the Military Highway overpass on IH410, one mile west of the San Pedro street overpass. Figure 9 shows an overhead view of this site. The freeway consisted of three lanes in each direction, running southwest and northeast (compass heading 68°) and a 20-foot wide median with a chain link fence down the center. There was also a ten-foot wide shoulder along the north edge of the freeway. Also on the north side of the freeway, separated from the shoulder by a ten-foot grassy median, was a two lane, 20-foot wide access road. The terrain surrounding the site was characterized by single story dwellings and trees up to 40 feet tall, although the triangular area on which the equipment was located was flat and grassy. Equipment locations are shown in Figure 10.

El Paso Site

An overhead view of this site is shown in Figure 11. The freeway consisted of six 12-foot wide lanes in each direction, and ran in a roughly east west (compass heading 79°) direction. There was a 20-foot median with a chain link fence along its center, and a ten-foot shoulder on each outside lane. On the north side of the road, an exit lane cut through the receptor area, with one receptor located between the freeway and the exit lane and another located on the edge of the exit lane. A fifty-foot wide sandy boulevard separated the freeway from a 30-foot wide access road on the north side of the freeway, and a 120-foot wide sandy boulevard separated the freeway from a similar access road on the south side of the freeway. Since there were only ten signal wires available for radar units, the two outside lanes on each side were monitored by a single unit. Counts in these lanes are accordingly less accurate. The equipment layout for Project 218 is shown in Figure 12. Land use in the area consisted of single story dwellings and businesses.

Data Collection Periods

Experimental data were collected at the previously discussed sites during the following periods:

Site	Period
Houston "at grade"	May & December, 1976; January & February, 1977
Houston "cut site"	September & October, 1976
Dallas "elevated site"	May & June, 1977
Dallas "at grade"	July & August, 1977
San Antonio "at grade"	October, 1977
El Paso "at grade"	November & December, 1977

The particular days and times that data were collected are noted in the data.

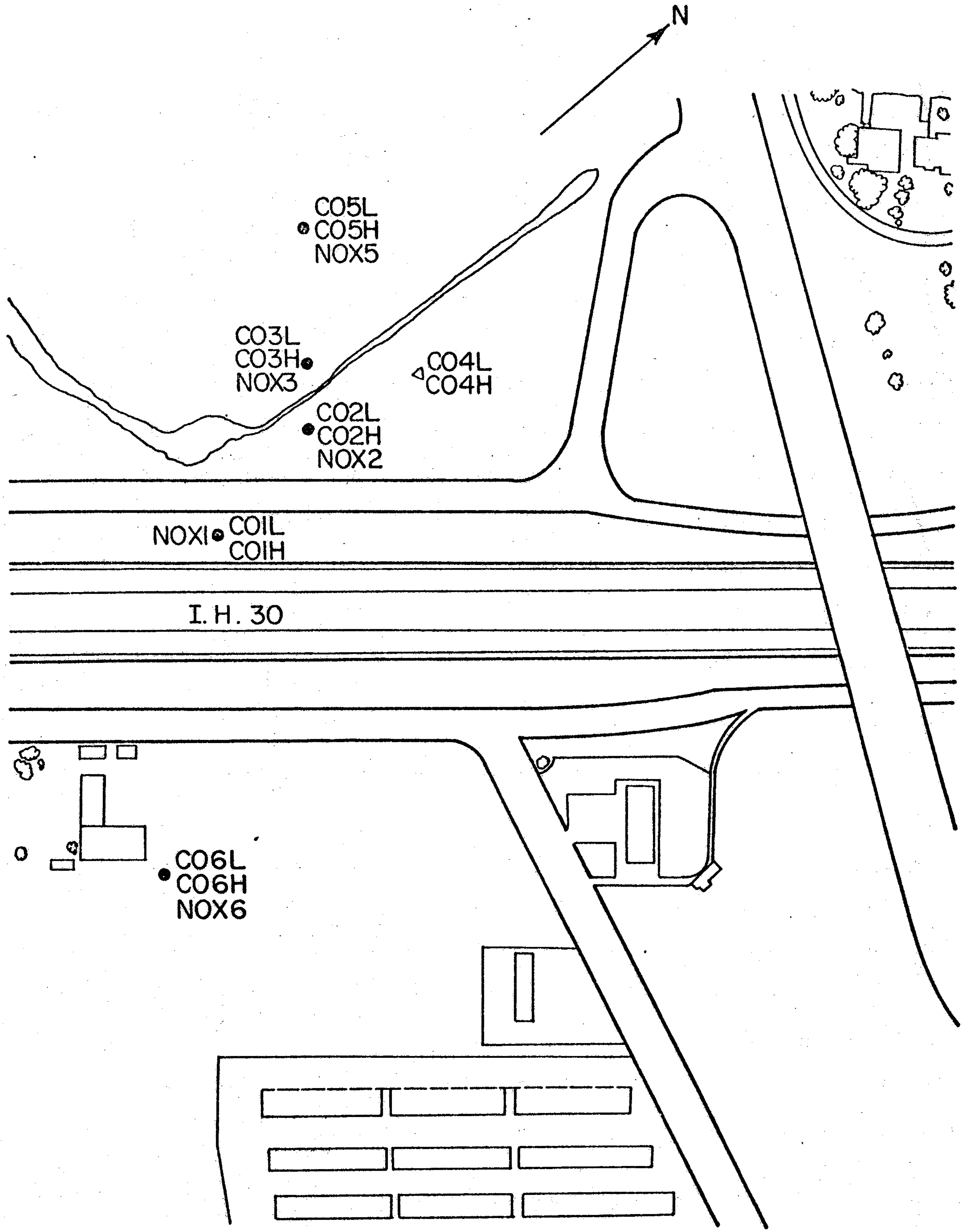

Figure 7

Overhead View

Dallas, IH30 at Motely Drive

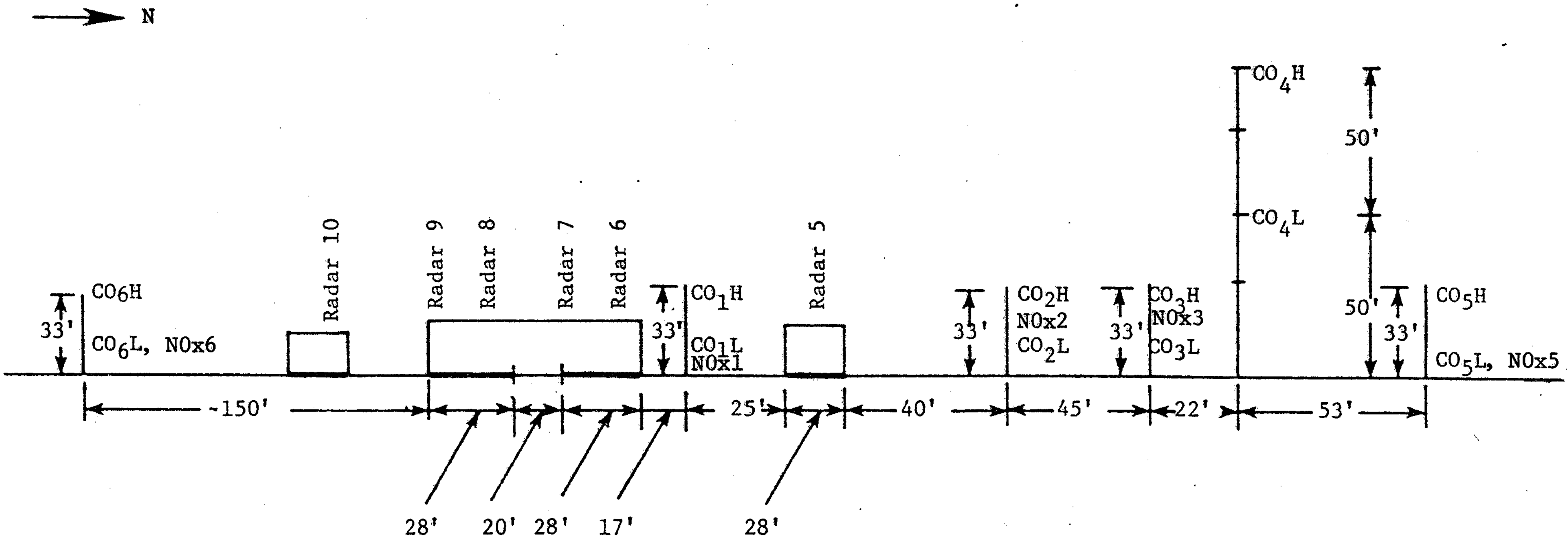

FIGURE 8

INSTRUMENT LOCATIONS: Project 218

Dallas: IH30 at Motley Drive

D. II

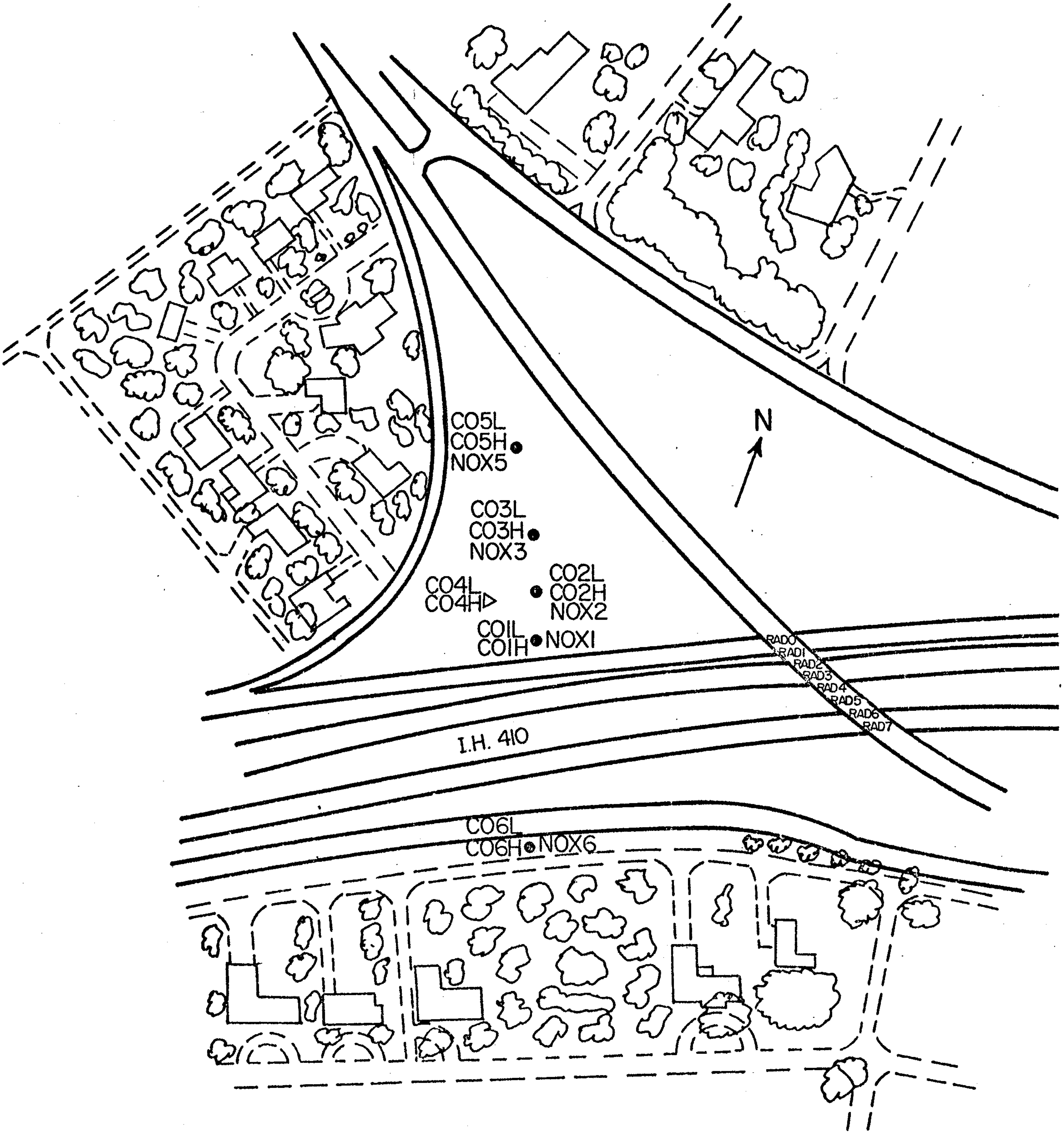

FIGURE 9

OVERHEAD VIEW
San Antonio, IH410 at Military Highway

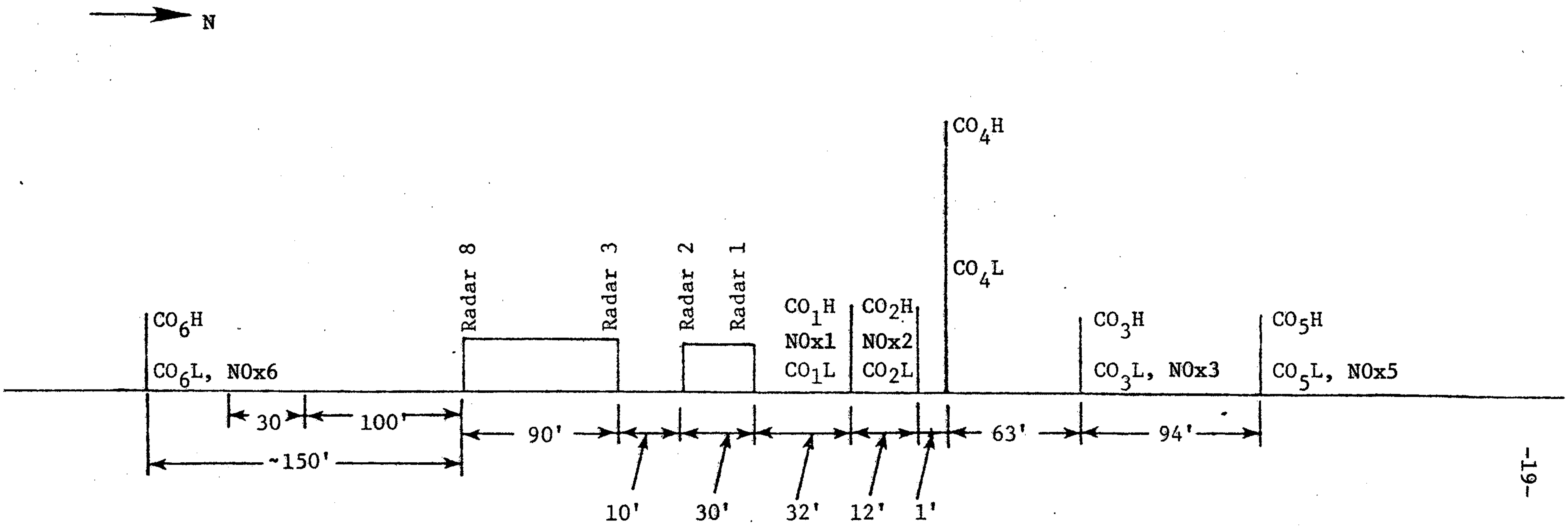

FIGURE 10

INSTRUMENT LOCATIONS: Project 218

San Antonio: IH410 at Military Highway

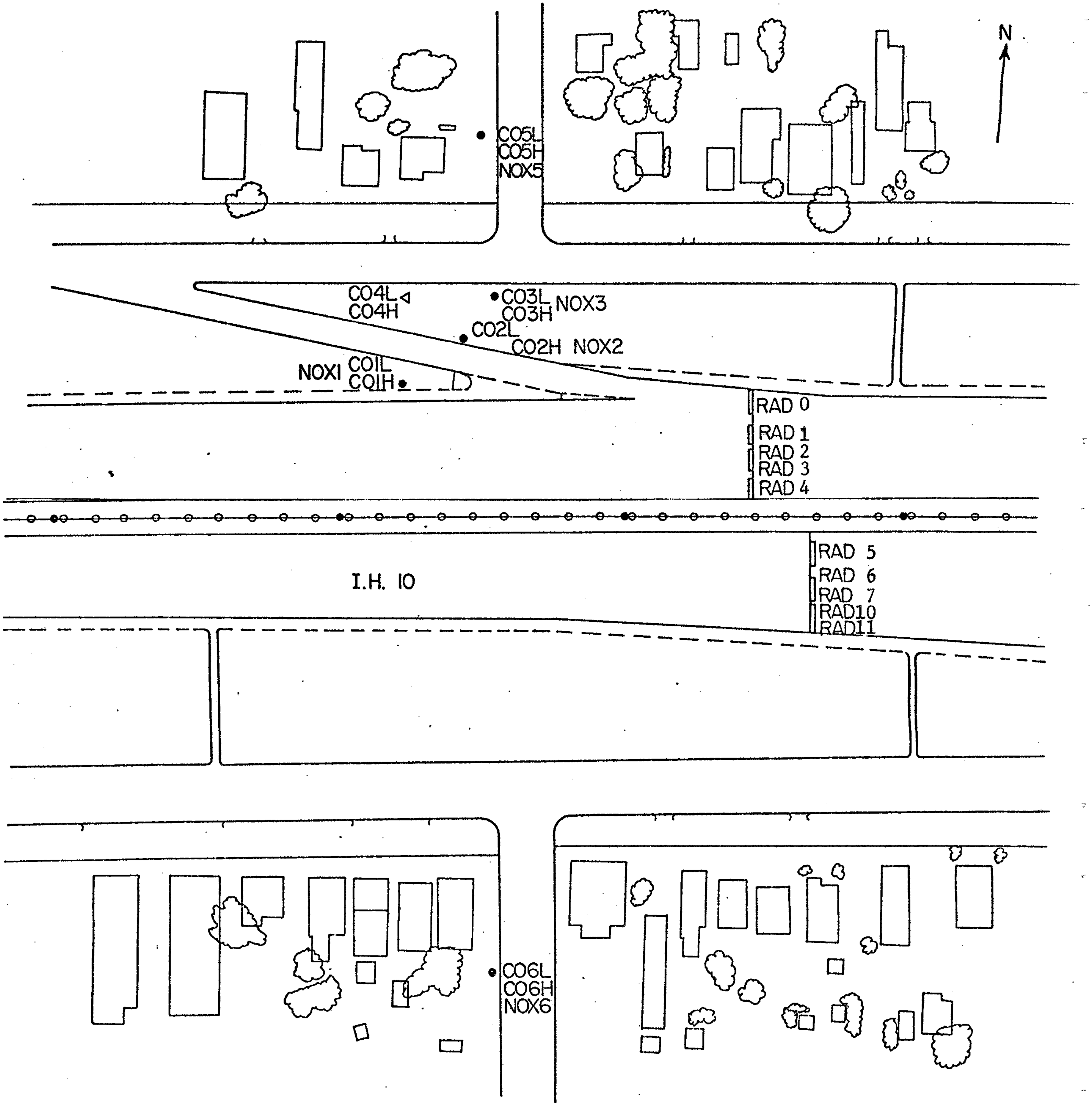

Figure 11

Overhead View

El Paso IH10 at Luna Street

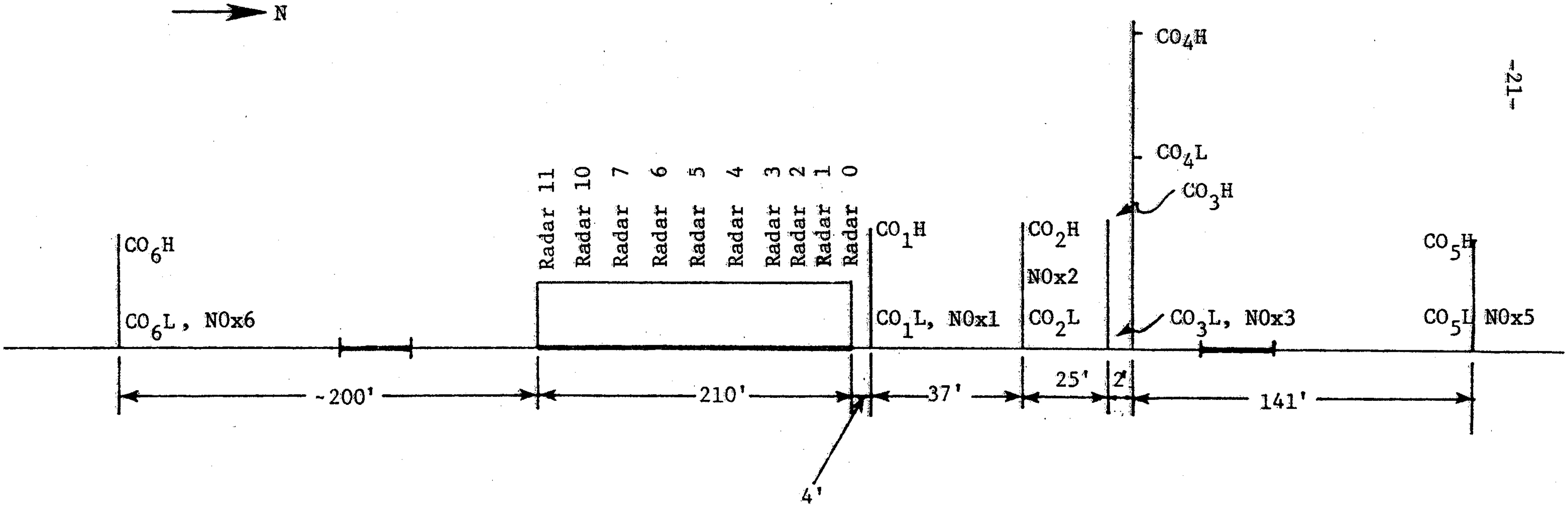

FIGURE 12

INSTRUMENT LOCATIONS: Project 218

El Paso: IH10 at Luna Steeet

Chapter III

Experimental Methods

Introduction

An extensive program of data collection was performed during Project 218, "Analytical and Experimental Assessment of Highway Impact on Air Quality." This data included concentrations of carbon monoxide, nitrogen oxides, and hydrocarbons beside the roadway, along with extensive meteorological and vehicular data. The systems used to collect the samples and the data will be discussed in this chapter. The data handling techniques will be discussed in the next chapter.

Data Collection System

Data recording from the meteorology instruments, radar units, and from the carbon monoxide, nitrogen oxides, and hydrocarbon sensors was performed by a Data General Nova 1200 minicomputer. Readings were taken via a Radian analog to digital converter and a 64 channel multiplexor. Data were stored on cassette magnetic tapes. With this method, readings from all instruments were taken essentially simultaneously rather than sequentially. The computer read each instrument at a rate commensurate with that instrument's response time and the rate of data fluctuation. Table 1 gives each instrument's sampling rate, as well as the six-letter code used by the computer to identify it. The required software program was written by File D-19 of the State Department of Highways and Public Transportation in Austin, Texas. This software was modified in minor ways by project personnel.

Traffic Measurement

In order to perform any highway air pollution model validation work it is necessary to know several parameters about the vehicles on the roadway. These include the vehicle count, the average vehicle speed, the heavy duty vehicle mix, and the vehicle age mix. The first three values were collected using Stevenson Mark 5 doppler-shift radar units obtained from the Texas Department of Public Safety. With these units and the minicomputer, the vehicle count, speed and size mix were obtained on a by-lane basis. The vehicle age mix may be approximated using figures available from local vehicle registration tables.

Since the radar units were originally designed for use inside of a vehicle, they had to be modified for use in this project. This was accomplished by mounting them on 10-inch "C" clamps and providing them with waterproof housings. A further modification involved replacing the 3/4 turn potentiometers used to adjust the range of the units with ten turn potentiometers. These provided much finer range control and worked very well.

To obtain traffic flow information, each radar unit was placed over a single traffic lane looking down at the roadway at an angle of 45°. The size of the field of view was then varied both in length and diameter by adjusting the range control on each unit. The radar units had both an indicator needle and a 0-10 v recorder output. The range control was turned down until the indicator needle barely indicated the detection of compact cars. The field of view was then restricted to an elliptical area approximately 15 ft long and 10 ft wide at the pavement. Since a car moving at 60 miles per hour spent only 1/2 of a second in the unit's field of view, the indicator needle did not have time to respond before the car was out of the field. However, due to its speed, the computer obtained full response from the unit via the recorder output.

The radar unit sent a voltage pulse to the computer for each vehicle passage. The height of the pulse was proportional to the vehicle's speed and the number of pulses was equal to the number of vehicles, resulting in an accurate vehicle count. The area under the pulse was also proportional to the length of the vehicle. This allowed the cars to be separated from trucks, giving an accurate breakdown of the heavy duty vehicle fraction. To obtain the area under the pulse the computer was required to do a numerical integration. Since most pulses coming from the radars were less than 1/2 second long, the radars were monitored at a very high rate of speed. A sampling rate of 100 samples per second was selected as the highest practical rate. At this rate, the NOVA computer was idle only 5% of the time while it spent 94% of the time processing the radar units. The remaining 1% of the time was sufficient to handle all other samples, compute averages, and to run the cassette units and the teletype. The numerical integration method used was the fastest in terms of computer time available. The readings were simply summed for the duration of the pulse and then divided by a calibration factor after the pulse was over. The result was then compared to five length categories selected by the programmer and the appropriate counter was incremented by one. The speed was also summed with the appropriate vehicle speed accumulator. At the end of each one minute interval the vehicle speed, count and length information was averaged and written to the cassette tape. The five vehicle categories were chosen as category 1-cars, category 2-cars and pick-ups, category 3-light trucks, category 4-heavy trucks, and category 5-calibration and tailgates.

For a discussion of traffic measurement in highway air pollution research see Bullin and Polasek (1978a).

Meteorological Measurements

Windspeed and Direction:

Horizontal windspeed and direction were measured with six-cup anemometers and windvanes manufactured by Texas Electronics. The starting threshold for the anemometers was 0.75 mph with an accuracy of ± 1% of full scale. The wind vanes had a starting threshold of 1.0 mph and an accuracy of ± 0.5%. The anemometers used the light chopper technique while the wind direction vanes used potentiometers in a one volt circuit.

Gill propeller anemometers (Model No. 27100) were used to determine the vertical wind speeds. This instrument had a starting threshold of less than 0.5 mph and an accuracy of ± 1.0% of full scale.

In order to obtain a good description of the wind profile, stations containing the horizontal windspeed and direction and vertical windspeed sensors were located at heights of 5, 26, 52, and 102 ft. This equipment was largely trouble free.

Atmospheric Temperature and Humidity:

To obtain information on atmospheric stability, temperature measurements were made with Texas Electronics Model No. 2015 thermistors at several heights. These units had an accuracy of ± 0.5% of full scale and were located at heights of 5, 29, 42, and 82 ft.

The relative humidity was measured at heights of 5 and 82 ft with Texas Electronics Model No. 2013 relative humidity systems. The psychrometers determined the relative humidity by utilizing the fact that a fiber, such as a hair, changes length in proportion to the amount of water vapor present in the air. An inductance change was induced in a coil by this change in length. The accuracy of this instrument was better than ± 3% relative humidity.

Solar Radiation

The incoming solar radiation was measured with an Eppley Model No. 8-48 pyranometer. Due to the low voltage output of this instrument, an amplifier was constructed that fed an amplified signal to the analog to digital interface. This instrument was very trouble free.

Carbon Monoxide Sensors

Carbon monoxide concentrations were measured with Energetics Science Model 2600 Ecolyzers. These analyzers used acid electrochemical sensors to determine the carbon monoxide concentration in parts per million, with an accuracy of ± 0.5 ppm. They were easily operated, but frequent instrument calibrations were required for span and zero drift. The accuracy of these instruments was also affected by the pH value of the acid in the cell. As the cell aged, the acidity of the cell decreased and the accuracy of the analyzer also decreased. With careful attention and frequent calibration these instruments had an error of no greater than 1 ppm of carbon monoxide.

Twelve Ecolyzers were used to measure the carbon monoxide concentrations in this project. Ten of these instruments were located on short towers that sampled at heights of 5 and 35 ft. Two more Ecolyzers were located on a tall tower and sampled from heights of 47 and 101.5 ft.

To sample air from the elevated stations, air was drawn down to the Ecolyzers by small vacuum pumps located downstream of the sample withdrawal point for the Ecolyzers. In the case of the tall tower, the air passed through black one-inch, thin-wall polyethylene tubing from the elevated intakes to the Ecolyzers. The same type of tubing was also used for the samples taken at 35-foot heights on the short towers at the Houston sites. In all cases, this tubing was allowed to weather in the sun for several days before actual use. The short towers were modified at the sites in Dallas, San Antonio, and El Paso. At these sites air was drawn down to the Ecolyzers through galvanized tubing.

Before September 16, 1976 all Ecolyzers were read by the computer at a rate of once every 30 seconds. An examination of the data taken prior to this time revealed the carbon monoxide concentrations to be changing faster than had been expected. Thereafter, the Ecolyzers were read at a rate of once every ten seconds.

A second sampling system, consisting of sequential bag samplers, was also used at both sites in Houston. Each bag sampler consisted of a container that held 24 bags made of PVC, aluminized polyester, or other material. The container also held a pump for each bag, six-volt dry cell batteries for power and the necessary control circuitry. During the period of operation, the control circuitry would sequentially energize each pump for 15 minutes and then switch to the next pump. The pumps were set to deliver 60 ml of air per minute into each bag for a total of about 900 ml per bag. This yielded a total of six hours of samples, with each sample representing a fifteen-minute average concentration.

The bag samplers proved to be quite difficult from an operational point of view, so their use was discontinued after the data collection in Houston was completed. In the bag samplers used, the timer would sometimes skip over several bags, or the check valve would remain open and the sample would be lost. In addition, the pumps were unstable and the flow rate did not necessarily remain constant. For a more complete discussion of bag samplers as they were used in this project and the difficulties faced in their use see Bullin and Polasek (1978d).

Nitrogen Oxides Sensors

Nitrogen oxides were measured at the last four sites using five MacMillan Instruments Model 2200 $NO/NO_2/NO_x$ meters. Each of these sensors sampled from a height of five feet on each of the five short towers. They used the photometric detection of the chemiluminescence resulting from the flameless reaction of nitric oxide (NO) with ozone. All NO_x compounds were first converted into nitric oxide for subsequent measurement via the chemiluminescent detection method. These instruments had a rated precision of ± 1.0% of full scale, with a minimum detectable sensitivity of 10 ppb. Periodically they were calibrated with a certified span gas. The span calibration tended to be quite stable. The instruments were rezeroed periodically throughout each run in order to minimize their large unpredictable zero drifts.

Hydrocarbon Sensors

Introduction:

Three different types of hydrocarbon sensors were used during the data collection phase of Project 218. One instrument was read by the minicomputer and the data stored directly onto magnetic tape. The other two instrument types produced graphical output which then had to be manually translated into usable data. The latter two systems also measured the carbon monoxide concentration in addition to measuring the hydrocarbon concentration.

Byron Instruments Chromatograph:

The Byron Instrument Model 233D gas chromatograph checked for methane, total hydrocarbons less methane, and carbon monoxide. The gas chromatograph separated these gases into three streams which were then passed through a hydrogen flame ionization detector. The carbon monoxide stream passed over a nickel catalyst which converted it into methane before it went through the detector. The minimum detectable concentration of these component gases was in the 10-20 ppb range with a rated accuracy of ± 1.0% of full scale.

Because of restrictions on where the analyzer could be located, only one Byron chromatograph was used in Project 218. It was located in the trailer which also housed the minicomputer in order to keep it in a relatively constant temperature environment. Copper tubes were run from the analyzer to a sample point outside the trailer. This sample point was located at a height of five feet. A small vacuum pump downstream of the analyzer maintained a constant flow rate through the tubing. The analyzer drew a sample from the stream once every five minutes.

Baseline Industries Monitor:

Two Baseline Industries Model FID 1020 BTR Flame Ionization Gas Chromatographs were used to detect methane, non-methane hydrocarbons, and carbon monoxide. The FID's used a graphical output system with a chart accuracy of ± 2.0%. Zero drift was rated to be less than 5% of full scale per day, with a noise drift of less than 5% of full scale. Each FID was located at a height of five feet near one of the Ecolyzer stations. This later allowed a direct comparison to be made between the two instruments.

Beckman Hydrocarbon Analyzers:

Two Beckman Model 400 Hydrocarbon Analyzers were borrowed from the Texas State Department of Highways and Public Transportation for use in Project 218. These instruments used a gas chromatograph with a flame ionization detector to detect hydrocarbons, as had the other sensors. They had a full scale sensitivity of 0-1 ppm methane with range multipliers of 1, 10, 100, and 1000. These instruments had a rated reproducibility of ± 1.0% of full scale. They could be read by the computer and the data stored on magnetic tape. However, they proved entirely unsuitable for use in this project.

Chapter IV

Data Handling

Introduction

A Data General NOVA 1200 minicomputer was used to collect the data and record it onto cassette magnetic tape. It was therefore possible to collect data from each instrument type essentially simultaneously rather than sequentially and, because of this, show a dynamic response to traffic and meteorological conditions. However, this also means that data collection occurred at a prodigious rate; over 25,000 numbers per hour were recorded onto tape. This chapter is concerned with the methods used to collect the data and to manipulate it into a useful format.

Data Collection

The NOVA 1200 minicomputer used to collect data for this project was equipped with three cassette tape drives, a teletype console, a Radian analog to digital converter and a 64 channel multiplexor. The computer read each instrument type at a rate commensurate with the response time of those instruments and the rate of data fluctuation. The sampling rate used with each instrument is given in Table 1, along with the six letter code used by the computer to identify it. Special notice should be given to the fact that the sampling rate for the Ecolyzers was changed after September 15, 1976. Prior to this time, a sampling rate of once every 30 seconds was used. However, after this data was analyzed, the carbon monoxide concentrations were found to be fluctuating at a higher rate than expected. In order to properly sample the analog data, the sampling rate was changed to once every ten seconds.

After each instrument was read, the value was checked against maximum and minimum expected values for that instrument type. These values could be set by the operator. If a value fell outside the expected range, the operator was so informed on the teletype and a special record was entered on the tape.

The data were storedon cassette tape in sixteen-bit word, variable-length record blocks. This means that each number (e.g., word) handled by the computer consisted by 16 binary bits and that the numbers were collected into groups, called records, before being stored on tape. These records were not all of the same length, and they themselves were grouped together and placed on the tape in a block format. In order to do so, the computer stored data in a temporary file, called a buffer, before placing it on tape. When the buffer was full, the contents of the buffer were placed on the tape in block form in one operation. A list of the records used to store data can be found in Table 2. The length of type 0, 5, 11, ..., 17 records was determined by the amount of computer memory available after the program was set up.

Type 2 and 3 records were special Ecolyzer calibration records. The Ecolyzers were calibrated at approximate two hour intervals since their zero and span readings tended to drift. The procedure followed was to issue a Begin Calibrate (Type 2) record, ground the A/D input for the channel, rezero the instrument, attach a bag of CO calibration gas, reattach the instrument to the A/D, wait 30 seconds, reground the A/D input, wait one minute, reattach the instrument to the A/D and issue an End Calibrate (Type 3) record for the channel.

The span drift is smooth and gradual as far as is known, so a linear correction factor could later be applied to the Ecolyzer data. These corrections were fairly small (<10%). On the other hand, however, it was found that the zero drift was occasional, sudden, and drastic and no correction factor could be applied to the data. Usually zero drift was small enough to be completely masked by minute-to-minute fluctuations in the CO level, although at very low CO concentrations, (e.g., 1 ppm or less) the zero drift could approach 30%

TABLE 2

Raw Data Formats

Type 0, 5	Type 1	Type 2,3,6,7	Type 4	Type 10	Type 11, ..., 17
Length	Length	Length	Length	Length	Length
Type	Type	Type	Type	Type	Type
Time high	Time high	Time high	Time high	Time high	Time high
Time low	Time low	Time low	Time low	Time low	Time low
ASCII code	Channel	Channel	Channel	Channel	Channel
	Sample Interval		bad time high	sample interval	Interval
•	data type		bad time low	min expected value	Lost data count
	max expected value		bad value	max expected value	min expected value
•	min expected value			begin time high	max expected value
	calibration factor			begin time low	sample value
•	zero adjustment factor			end time high	sample value
	ASCII code			end time low	
ASCII code	ASCII code			veh 1 count	•
	ASCII code			veh 1 spd high	•
				veh 1 spd low	•
				veh 2 count	
				veh 2 spd high	sample value
				veh 2 spd low	
				•	
				•	
				•	
				veh 5 count	
				veh 5 spd high	
				veh 5 spd low	

of the instrument reading.

In addition to writing the raw data to cassettes, the computer also calculated 5-, 15-, and 60-minute averages for all channels. These averages were written on the teletype for operator inspection. If any of the average values looked unusual, the operator could take corrective action and/or enter a Type 5 record onto tape detailing the problem.

Data Handling

The AMDAHL 470 V6 computer at Texas A&M University was used for data manipulation. All data for Project 218 originally resided on cassette magnetic tapes which the AMDAHL was not equipped to read. Before the AMDAHL could be used to manipulate the data, it was necessary to make three changes in the data format.

First, it was necessary to transfer the data to nine track tapes. This transfer was done by a direct copy method; no changes were made in and no checks performed on the data during the transfer process.

The second step involved data translation; although the data now resided on nine track tapes, the data form used by the NOVA is incompatible with IBM (and AMDAHL) conventions. Because of this difference, the standard software used by the AMDAHL to unpack data blocks and break records down to get to individual numbers could not be used. The data blocks and records first had to be broken down by programmer written software and then repacked using IBM conventions. The program to do this has been labeled Set A and a copy can be found in Appendix A.

The third stage of the data reformatting operation was performed in two steps. The NOVA uses ASCII (American Standard Coding For Information Interchange) to represent all data, but the AMDAHL uses EBCDIC (Extended Binary

Coded Decimal Interchange Coding) for the same purposes. Therefore, it was necessary to convert data from ASCII to EBCDIC coding with a user written program before any further data manipulation could be performed. This program has been labelled Set B and can be found in Appendix B. The Set B program also converted the integer formats of the raw data (i.e., 100 A/D counts) into more easily understood floating point numbers (i.e., 2.5 ppm). The restructured data was then stored on a temporary disk file and sorted using the standard IBM Sort/Merge Utility program. This packaged program sorted the data by date, channel (instrument), record type and time of day, in that order. The result from this last operation was then stored on standard nine track tape.

Final Format of Data

The data was later moved back into disk files and dumped from there onto paper for visual inspection by project personnel. Data known to be bad for any reason (i.e., the vertical windspeed is 0 mph because the vertical anemometers were tangled in cable) were marked for deletion, but questionable data were not marked for deletion. In addition, all calibration readings were converted into the form of Type 7 cards. The type 7 card contains the zero adjustment readings and calibration readings as shown in Table 3.

Data deletion and the addition of the calibration readings were accomplished while the data was stored on disk files using the WYLBUR text editing system available at Texas A&M University (Pearson, 1975).

After data manipulation was completed, the data was again placed on nine-track tapes. As the data presently exist on tape, there are six card formats used to store the data. The format types are

-1: used as a terminator to signal the end of data for a channel

1: the data parameters for a channel

5: alphanumeric message
7: calibration data
10: traffic data
11: general data

All six format types have similar fields in the first twelve columns. The first six columns are devoted to a time parameter. Column 7 is left blank on all format types. Columns 8 and 9 hold the format identifier. The channel number is contained in Columns 10-12 on all cards except Type 5 cards. The use and format of each group on all format types are given in Table 3.

TABLE 3

DATA CARD FORMAT TYPES

First Twelve Columns

Columns	Format	Content
1-2	I2	hours value in a 24 hr day
3-4	I2	minutes of the time parameter
5-6	I2	seconds
7	1X	blank
8-9	I2	format identifier
10-12	I3	channel identifier

Type -1 Format Cards

They are compatible with any of the formats used for reading any other card. A Type -1 card is distinguished by a negative hours reading, 99 minutes, 99 seconds, and a channel of -1. Two terminators in succession signal the end of the data set.

Type 1 Format Cards

Columns	Format	Content
13-15	I3	data type
16-20	I5	sampling rate
26-30	I5	minimum expected integer value of the channel
31-35	I5	maximum expected integer value of the channel
36-40	I5	integer value of the unity reading
41-45	I5	integer offset value
46-52	A6	instrument name

TABLE 3 (Cont'd)

Type 5 Format Cards

Columns	Format	Content
10-80	A	manually entered alphabetic messages

Type 7 Format Cards

Columns	Format	Content
8-9	I2	format identifier
10-12	I3	channel identifier
13-15	I3	channel's data type
17	I1	the value 4 signifying that 4 data items follow
18-24	F7.2	channel reading with the A/D grounded
25-31	F7.2	instrument zero before adjustment
32-38	F7.2	instrument zero after adjustment
39-45	F7.2	calibration reading; the values are the raw A/D values plus the offset value (Cols. 41-45 on a Type 1 card) divided by the unity value (Cols. 36-40 on a Type 1 card). (if this value is exactly 0.00 then the reading is missing)

TABLE 3 (Cont'd)

Type 10 Cards

Columns	Format	Content
13-15	2X	blanks
16-20	I5	number of cars
21-25	F5.1	average speed of the cars*
26-30	I5	number of cars and pickups
31-35	F5.1	average speed of cars and pickups*
36-40	I5	number of light trucks
41-45	F5.1	average speed of light trucks*
46-50	I5	heavy trucks
51-55	F5.1	average speed of heavy trucks*
56-60	I5	calibration and tailgates
61-65	F5.1	calibration and average speed of tailgates*

*averaging period is one minute

Type 11 Cards

Columns	Format	Content
13-15	I5	data type
16	1X	blank
17	I1	number of data items that follow (1-9)
18-73	(1-9) F7.2	1-9 data items

Chapter V

Results

Analysis of Data Accuracy

In any data collection endeavor, there are many sources of error. Every instrument used has errors associated with it and, in addition, the entire data collection system has its own associated errors. Table 4 lists the overall accuracy of the data taken during this project, as far as is known. This section of the report details how these error limits were established.

A/D Error:

The data collection system for this project employed a 12 bit analog to digital converter (A/D). There are two possible errors in this unit. First, the span or gain could drift, causing any input to be interpreted as some factor greater or less than its actual value. This error is expressed as a fixed fraction of any particular reading. It reaches its maximum magnitude at the maximum data value and vanishes completely at a data reading of zero. The second type of error, the zero or offset drift is one by which a zero input produces an apparent voltage. This error is constant over the entire range of input values and is usually expressed as a fraction of the full scale reading.

In this project, the gain was checked in ten channels every time the project was moved. If there was any significant span drift in those channels, the entire A/D was checked and calibrated. However, span drift never exceeded eight counts out of an input value of 1331, or 0.6%. It was felt this low error would not warrant the effort required to correct it. The zero drift was checked daily in twelve channels. It never exceeded ten counts or 0.25%. This was judged to be negligible in light of the errors found in the instruments themselves.

Table 4

Instrument Accuracy

	Instrument	error
I.	A/D	0.6% span drift, 0.25% zero drift
II.	Radar	
	a. overall count	2%
	b. heavy duty vehicle fraction	10%
	c. speed	3 mph + 10% of reading
III.	Vertical Anemometer	5% of span drift (max) *
IV.	Horizontal Anemometer	1% of zero drift (max) * **
V.	Wind Vanes	10° in Houston, 5° all other sites **
VI.	Thermometers	1.5°F
VII.	Psychrometer	3% relative humidity *
VIII.	Pyranometer	15 watts/square cm
IX.	Ecolyzers	0.5 ppm CO **

* Manufacturers Ratings, not checked by project personnel

** See text for more detailed error description

Traffic Parameter Errors:

The errors associated with the radar units were due primarily to the fact that this project required more than a simple global traffic count. The radar unit signals carried the traffic count, traffic speed, and heavy duty vehicle fraction on a lane by lane basis. It was decided that since this information was potentially quite valuable to a highway air pollution study, every effort should be made to record it.

There were three factors that influenced the quality of the radar data. First, the speed calibration remained quite stable and gave few problems. If the span reading was within 2 miles per hour (3%) of the desired 65-mile per hour reading, the unit was left alone. This parameter was checked weekly. The second, and slightly more troublesome source of error was the range control which regulated the size of the unit's field of view. If the field of view was too large, the radar detected vehicles in adjacent lanes as well as misfiling the vehicles as to length. If the field of view was too small, the radar would misfile vehicles as to length and could easily miss the smaller vehicles. A rigorous check of the range required the use of an analog integrator and about fifteen minutes per radar. This type of check was accordingly made only when the project was moved to a new site or when a radar had to be replaced. A partial check could be made by observing the behavior of the indicator needle on the radar unit itself. This check was sufficient to assure the overall accuracy of the count, but not precise enough to assure 100% accurate vehicle length classification. The indicator needle check was typically made once per week. The third source of error resulted from the misalignment of the radar heads. The heads were supposed to be aligned at an angle of 45° with respect to the horizontal. Since the radar can only detect that component of the velocity which is directly toward or away from the radar head and since a change in the angle causes a change in the size of the field of view, an error of 5° in the angle results in an 8% error in the apparent speed and a 14% error in the apparent vehicle length. The heads were aligned to within 2° of the desired 45° angle at each site. However, at those sites where sign bridges were employed to support the radar units, vibrations misaligned the heads by as much as 10°. This was not corrected for unless the error became great enough to cause the unit to pick up vehicles in adjacent lanes or miss vehicles passing through the unit's field of view. Replacement units were aligned correctly.

Two methods were used to assess the accuracy of the radar units. The sampling towers at the first site in Houston were placed in line with the already existing loop counters of a permanent counting station on IH610. A listing of the data from several typical one-hour counting periods during May 1976 is given in Table 5. Because the two counting systems did not agree, project personnel then used any available time to make manual counts lane by lane for five-minute periods to compare with the radar counts during the same time periods. The results of these counts were used to establish the overall accuracy of the radar units to within 2%. A typical comparison between manual and radar counts is shown in Table 6. The length categories were not as accurate since no true breakdown could be established between autos and pick-ups and vans (vehicle categories 1 and 2) or between short and long trucks (vehicle categories 3 and 4). However, the break between autos and trucks was fairly clear (within 10%). Manual counts were performed at all sites in order to maintain the high confidence levels in the radar counts.

Vertical Anemometers:

These instruments were not checked by project personnel. The values

Table 5. Comparison of Radar to Loop Counts

IH610 - Westbound

Date	Time	Radar Count	Loop Counters	Ratio
May 15, 1976	1100	2284*	3580	1.57
	1400	2077*	3390	1.63
May 19	1800	4448	5120	1.15
May 20	0800	3924	4940	1.26
	0900	3487	4300	1.23
	1000	3000*	3620	1.21
	1100	2971	3480	1.17
	1200	3032	3490	1.15
	1300	2816*	3630	1.29
May 25	1500	3441	3830	1.11
	1600	4230	4700	1.11
	1700	4772	5180	1.09
	1800	4868	5340	1.10
May 26	0800	3311	3550	1.07

Mean: 1.28

Std. dev.: 0.21

Mean: 1.15**

Std. dev.: .06**

* One radar inactive

** Excludes times when one radar was inactive

Table 6

Comparison of Manual and Radar Traffic Counts

Range of vehicles per 5 min. period	No. of 5 min. counts	Average % error	Std. dev. of % error
1-20	49	-5.4	16.9
21-40	33	-1.0	7.1
41-60	7	2.8	5.7
61-80	6	2.3	5.3
81-100	7	2.2	2.2
101-120	1	3.6	
121-up	4	2.2	1.9

quoted here are those in the operator's manual. The primary source of error in these instruments is due to the fact that the propellers employed did not quite follow the cosine law with respect to wind angle. When the wind was within 2° of the horizontal (the vertical windspeed component was less than 3% of the horizontal component) the propeller stalled and did not turn at all. When the wind angle was at 45° with respect to the horizontal (the vertical component was as large as the horizontal component) the instrument read 5% low. In view of the instability in the vertical windspeed, these errors were regarded as negligible. The starting threshold for these instruments was quite low, 0.5 mile per hour (0.26 meter/sec.).

Horizontal Anemometers:

There were three sources of error in these instruments, only one of which was considered in the operator's manual. The starting threshold for these instruments was quoted as 0.75 mile per hour. This meant that in low windspeed conditions, typically found on late summer and fall mornings, the recorded windspeed was less than the actual windspeed. A second source of error was due to the mass of the anemometer cups. When a wind gust struck an instrument, it would spin at greater than the actual windspeed for some time thereafter. This meant that in gusty conditions, the recorded windspeed was higher than the actual windspeed. A third source of error had to do with the sensing of the windspeed. The instruments used a photo chopper and frequency to voltage converter to generate the requisite signal to the A/D. At windspeeds below 2 miles per hour, the output of the frequency to voltage converter began to break up into a series of spikes instead of a smooth voltage output. Since the A/D logged point values only, the wind appeared to be much more turbulent than was actually the case. Considerable care should be taken in low windspeed cases for this reason.

Wind Vanes:

The primary error in the wind vanes is due not to any error in the instrument, but instead to the alignment procedures used by project personnel. In Houston the vanes were pointed toward north as closely as possible and correction factors noted from this. This procedure was accurate to within 10°. At all other sites, the vanes were pointed at prominent landmarks and the bearings of these landmarks were used to compute correction factors. This procedure was accurate to within 5°. As the standard deviation of the wind direction was seldom below 15°, this error was considered negligible.

Thermometers:

The operator's manual stated that these instruments were accurate to within 0.5°F (0.3°C). However, when a test was made in Dallas which placed 2 instruments on the east face of the 100 ft tower and 2 instruments on the west face, all at the 35-foot level, it was observed that those on the east face read 0.75°F (0.4°C) higher than those on the west face in the mornings and the thermometers on the west face read 1.1°F (0.6°C) higher than those on the east face in the afternoons. From this it was infered that sunlight was causing a temperature rise in the instruments. The total error in the instruments was taken as the square root of the sum of the squares or 1.5°F (0.83°C).

Psychrometers:

The project personnel did not check the accuracy of the psychrometers. The operator's manual stated that the instruments were accurate to within 3% relative humidity.

Pyranometer:

The error in this data comes not from the instrument, but rather from an an amplifier used to magnify the signal to a level acceptable to the A/D. The voltage must be boosted 41 times to be intelligible to the A/D. The amplifier used for this task had a maximum error of 1%. Since the maximum pyranometer reading expected in these latitudes is 1500 watts/sq cm, all pyranometer readings should be regarded as within 15 watts/sq cm of the correct value.

Ecolyzers:

Since the carbon monoxide concentrations were the primary purpose of this project, it was considered quite important to establish the limits of the instrument's accuracy. A preliminary test in College Station showed that both zero and span drift over a 24-hour period were severe enough to seriously degrade the quality of the data. Accordingly, a method was developed by which the Ecolyzers were recalibrated every 2 to 4 hours and the zero and span drifts noted. Later, a linear correction was assumed for the span drift and, if necessary, the zero drift. To check on the success of this procedure, two instruments were run side by side for several days at each Houston site. The instruments were treated no differently from any other Ecolyzer on the project. The standard program was used to apply the calibration factors. The results were most impressive. Figure 13 shows both instruments plotted against time. As can be seen the instruments tracked each other quite well. It is also interesting to note that the CO concentration varies quite rapidly in the near vicinity of roadways. This makes intermittent sampling instruments, such as gas chromatographs, poor for this purpose unless some method is used to make the sample representative of the sampling time.

A comparison of the time averaged values shows results which are just as impressive. Figure 14 shows the 15-minute averages of one Ecolyzer against the other for two sampling days. Almost every point falls within the 1 ppm

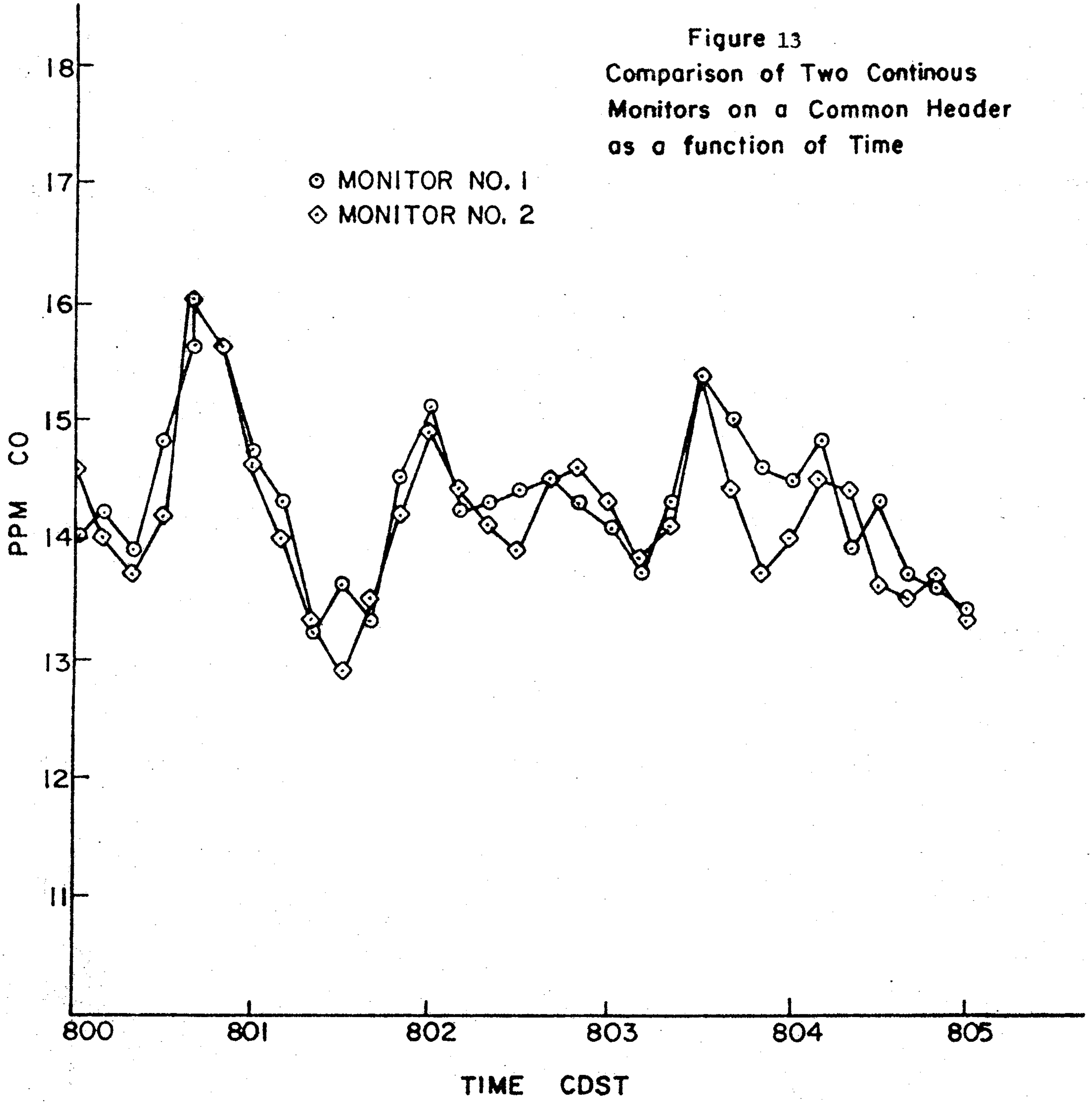

Figure 13
Comparison of Two Continous Monitors on a Common Header as a function of Time

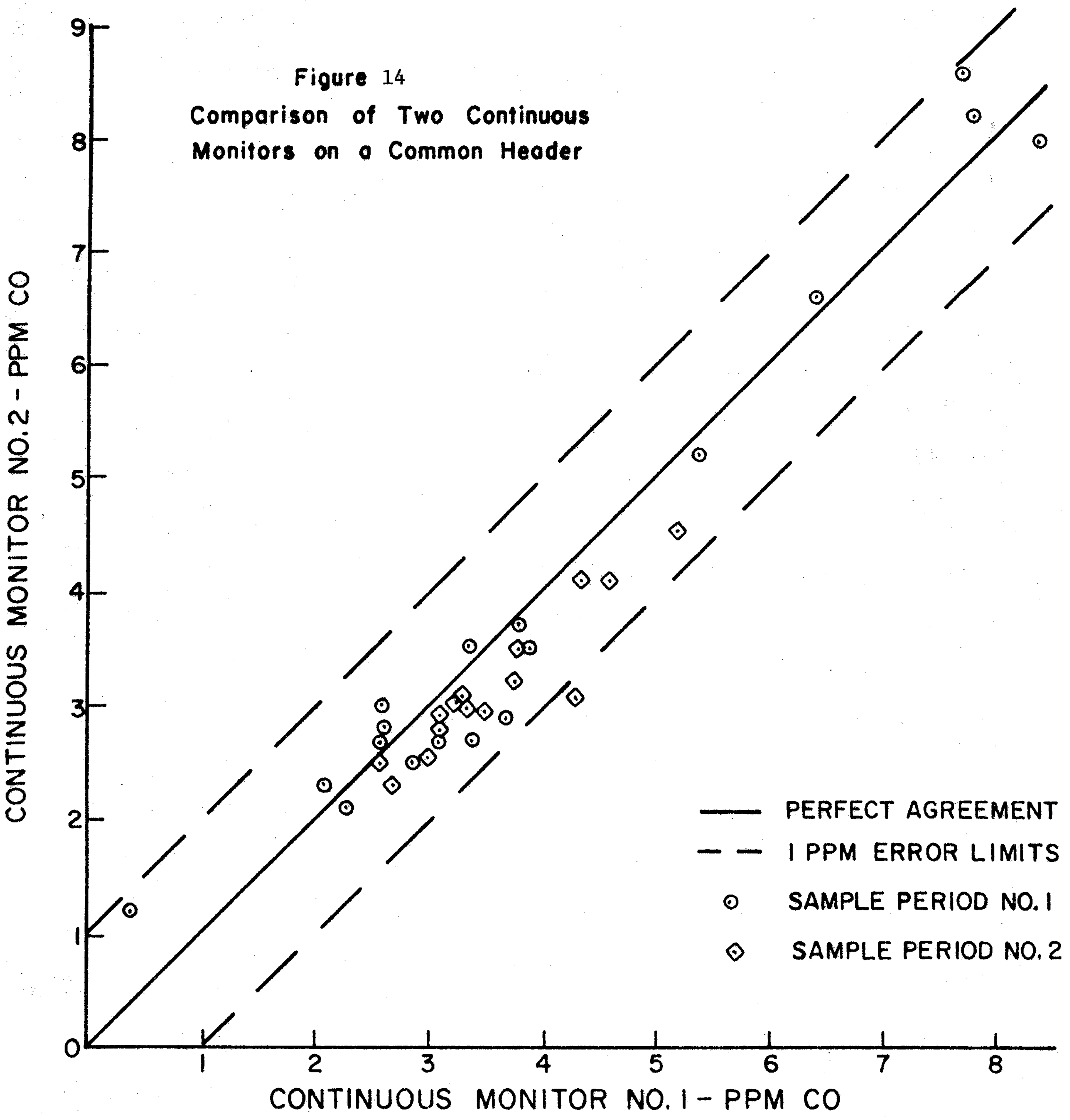

Figure 14
Comparison of Two Continuous Monitors on a Common Header

error limits. From a total of 101 fifteen minute averages, the average error was 0.3 ppm ± 0.25 ppm. This is less than the manufacturer's ratings. To be on the safe side, the manufacturer's ratings were used as the stated error bounds.

Nitrogen Oxide Monitors:

Compared to the carbon monoxide data, the results of the nitrogen oxide instruments were poor. The problems encountered emphasize the need to carefully evaluate instrument reliability and accuracy before attempting to employ the instruments in the field.

The instrument problems had three underlying causes. First, the instruments were too complex to be field repaired and had to be returned to the manufacturer if anything went wrong. Second, although the manufacturer's specifications indicated that the instruments were suitable for field use, it was later learned that they were not intended for such use. Third, since only five instruments were available, the loss of a single instrument represented a 20% loss in the nitrogen oxide data collection capability.

The first problem with the instruments was late delivery. Only three of the five instruments were delivered in September of 1976 as specified in the purchase order, and one of these was defective. This instrument was returned to the manufacturer, leaving two instruments available for monitoring. It was decided to run performance tests on the instruments at both Houston sites as the project was preparing to move from the IH10 to the IH610 site.

Initial tests at both sites showed that the instruments could not correctly assess both NO and NO_2 concentrations near roadways because the instrument's cycle time was too long to track the second by second concentration fluctuations. The same tests showed that the dessicators used in the instruments were good for about 20 to 30 hours operation, meaning that they had to be baked dry after each 2-3 days of data collection. Dry silica gel was kept on hand to alleviate this problem.

The project was being moved to the Dallas elevated (IH45) site before all five instruments were delivered. At this time it was found that design modifications had been made in the two new units and the repaired unit which changed the specifications of these instruments. It was decided to have the two other instruments updated as well by returning them to the manufacturer at this time. Shortly afterward, one of the modified instruments failed and also had to be returned. Nitric oxide monitoring was halted until the three instruments were returned.

All instruments were in working order before the project left the Dallas elevated site (IH45). It was found that the instruments required at least one hour's warmup time to stabilize. Furthermore, they could not be left on standby overnight without deactivating the dessicator. Also, span drift was quite severe. After several weeks of data collection, the drift had become so severe that three of the instruments could not be calibrated correctly. While the project was being moved to the Dallas at grade site, these three instruments were returned to the manufacturer, where the problem was diagnosed as due to the use of silica gel in the dessicators instead of the molecular sieves orginally supplied. The remaining two instruments were also returned to the manufacturer and all five were modified to use silica gel.

The project was ready to collect data at the Dallas at grade (IH30) site before the instruments were back. Two instruments failed on the first day of data collection. The manufacturer diagnosed the problem as thermal effects, in spite of the fact that the maximum ambient temperature was 10° below the maximum rated temperature.

While the manufacturer was repairing these instruments, the remaining three instruments were being shut down whenever the ambient temperature came within 15° of the rated maximum temperature. This practice was discontinued after it was noted that the instruments were giving good results only from 8:00 AM to 11:00 AM. When the repaired instruments were again available, it was decided to operate the instruments in the afternoons in spite of temperature problems. Another instrument failed and had to be returned to the manufacturer, and the four remaining instruments suffered zero and span drifts exceeding 20%. This error was judged to be too large for correction.

During this period, the calibrator used with these instruments ran out of span gas and had to be returned to the manufacturer. However, at the San Antonio (IH410) and El Paso (IH10) sites, sampling was continued using the electronic calibration feature internal to each instrument.

After sampling had been completed in El Paso, the instruments were sent to the Texas State Department of Highways and Public Transportation for final calibration. The results of this calibration work are shown in Appendix G. The factors from the January 1979 memo were used on a series of fifteen-minute averages to obtain NOX profiles from the road. The resulting profiles showed no correlation with the carbon monoxide profiles. The highest concentrations were usually not at the roadedge and the profiles showed discontinuities at all locations at one time or another. Accordingly the NOX values noted in the data should be examined carefully before use. For persons interested in analyzing the NOX data, the raw data and electronic span readings are available in units of PPB. In calculating the 5-, 15-, and 60-minute averages, which are reported in the data set available on nine track magnetic tapes, the electronic span readings were assumed to be the span drift. These values should be adjusted by the calibration factors determined by the State Department of Highways and Public Transportation. The factors are given in Appendix G.

Bag Sampler Work

Originally, it was planned to back up the Ecolyzers with bag sequential samplers. There were ten bag samplers, each of which had 24 polyvinyl chloride bags. The timing circuitry was programmed to fill the bags sequentially at the rate of fifteen minutes per bag, giving the samplers the capability of running for six hours. In initial runs, an Ecolyzer was used to analyze the bag contents, but in later phases, a gas chromatograph was used to make the samplers completely independent of the Ecolyzers. The results were published in Environmental Science and Technology (Bullin and Polasek, 1978d). A summary of this work is included here.

In the first experimental tests the bag samplers showed little, if any, correlation with the continuous monitors (Ecolyzers) when operated several feet from the Ecolyzer locations. An attempt was made to locate the source of the discrepancies. A header was constructed which drew a sample from a single point and supplied it to two bag samplers and two Ecolyzers simultaneously. One sampler utilized polyvinyl chloride (PVC) bags, and the other used Tedlar bags to test the possibility that the PVC bags were interacting with the sample. After several six hour runs, all the concentration data were compared. The Ecolyzers, as has been previously stated, matched each other better than expected. Much of the scatter vanished from the PVC equipped bag sampler data, indicating that a representative sample was not reaching the sampler if a header was not attached. The Tedlar equipped bag sampler had more scatter than the PVC equipped sampler. The Tedlar bags were accordingly replaced with PVC bags and several more runs made. The results showed that the bag samplers matched each other and the Ecolyzers quite well except in the region of 4 to 6 ppm, where one sampler tended to give low values.

A study was then made to categorize the effect of sample deterioration.

The test was conducted by filling a number of bags of a given material with a calibration gas and analyzing the contents of the bags at given intervals up to 100 hours later. The results showed that the Tedlar bags were totally unacceptable for ambient air analysis. The PVC bags were found to be acceptable if analyzed within 24 hours. Five-layer bags constructed of layers of polyester, polyvinyl chloride, aluminum foil, polymide, and polyethylene were acceptable for CO, but completely unacceptable for nonmethane hydrocarbons. Aluminized polyester three-layer bags were the only tested bag material judged suitable for long term storage of both CO and hydrocarbons. No sample deterioration was noted during the 100 hour test in these bags.

Discussion of Experimental Results

Carbon Monoxide Data:

The results of the study showed that at the sites examined, no threat to air quality existed from carbon monoxide. At the roadedge, values rarely exceeded 9 ppm, which is the National Ambient Air Quality Standard for eight hours exposure. Furthermore, the 9 ppm concentrations were never maintained longer than one hour at a time. Thus the eight hour average concentration never approached the eight hour standard. In fact, the eight hour averaged roadedge concentrations were typically 1 to 3 ppm. For averaging periods of five minutes or longer, no concentrations were observed to exceed the Air Quality Standard for 1 hour exposure of 35 ppm. Individual data readings would occasionally exceed 30 ppm, but these concentrations existed only as short duration (10 to 60 second) spikes, probably caused by individual, grossly mistuned vehicles.

Dispersion from all sites was typically quite good as well. The far downwind monitors, located 200 to 600 feet downwind of the roadway rarely differed by more than 0.5 ppm from the background concentration. Also, the monitor at the top of the 100 ft. tower, located 60 to 250 ft. from the roadway frequently showed values of more than 0.5 ppm above background concentration. These findings indicate that the air in the near vicinity of the roadways monitored is considerably less stable than most air pollution models assume. Table 14 shows this clearly when CO4H, CO5H, and CO5L predicted and actual values are examined.

The data also supports the conclusion that this turbulance is caused to a large degree by the traffic in the area. At the Houston at grade site, two cases were monitored in which the traffic was greatly slowed or stopped entirely for a five to ten minute period. In both cases, the concentrations rapidly rose to about five times their previous values, and the meteorology changed to show an episode of negative wind shear with unstable gravity waves progressing through the site. Breakup of the wave phenomena and negative wind shear coincided with a return to normal traffic flow in one case and increased heating of the roadway surface with increasing sun angle in the other. Moe et al. (1978) have examined these episodes in considerable detail and reported that under these special conditions, CO concentrations increased an order of magnitude above the models predictions.

Power spectra and delay correlation have been run on selected cases from the data base. This work will be briefly mentioned here and will be presented in detail in the final project report (Report No. 218-5). The data sets analyzed show high degrees of correlation between wind speed and wind direction, wind direction and CO concentrations, wind speed and CO concentrations, and between the CO concentrations, wind directions, and wind speeds measured at different locations. Power spectra indicate that all variables are random, with no clear dominant frequency or frequencies. Delay analyses show that wind directions change first, followed by wind speeds, followed at random intervals by the various CO monitors. In general, wind instruments at the higher altitudes change before those instruments at the lower altitudes, and all wind instruments change before the slower responding CO monitors can follow. Wind speed changes typically follow wind direction changes within 15 to 30 seconds, while CO monitor delays run from 20 to 120 seconds. The delays were highly consistent within themselves, but showed no orderly progression of CO through the system. It can thus be inferred that CO reached all parts of the system quite rapidly, and the delays observed were due to individual differences in the response times of the monitors. One factor of great interest was that the background monitors also showed good correlation with the wind direction in particular. This initially caused some concern, since it implied that the background monitors were not located far enough upwind of the roadway to avoid contamination from turbulent mixing.

However, further examination of the cases in question showed that even if the average wind direction was across the road from the south, there were a few brief periods when the direction was shifted by over 90 degrees to an oblique wind out of the north. Even 10 seconds of such behavior was sufficient to cause a detectable rise in the background monitor reading. It is conjectured that these brief periods do not introduce much error in the background readings, and in any case, moving the instruments further from the roadway would not have helped much, since they were already 100 to 200 ft. from the road.

Total Hydrocarbons Data:

Total hydrocarbons were monitored by five instruments using flame ionization detectors. Three of the instruments were dual column gas chromatographs which separate methane from the rest of the hydrocarbons. Under atmospheric conditions these instruments performed poorly due to the fact that they were not completely stable with respect to temperature. The instruments also required clean hydrogen and clean air for the operation of the detector, and small variations in supply pressure could greatly affect the instrument zero and calibration.

The unenhanced detectors were two Beckman 400 units. These instruments had nonthermostated heating elements to keep the detector temperature at a high value. Under ambient conditions, the detector tended to drift, causing shifts in the calibration points. Frequently, the shifts were so large that the panel adjustments could not either properly zero or span. The instrument also blew fuses and had the detector flame go out frequently. Data produced by these instruments was so sparse and poor that they were removed from the data set completely.

Two Baseline 2000 Gas Chromatographs were also used under ambient conditions. The primary faults of these instruments were that they would analyze only four samples per hour, and they were operating at the lower detection limits. The instruments had the ability to detect ambient levels of methane and nonmethane hydrocarbons. However, baseline drift and detector noise made it nearly impossible to accurately measure peak heights or areas. This data has therefore not been included in the data set.

A Byron 233D gas chromatograph was employed inside the lab trailer in San Antonio and at the Dallas at grade site. The sample intake in both cases was run outside of the lab trailer and attached to the chain link fence surrounding the trailer at a four foot height. In Dallas, the intake was located at approximately the same distance from the freeway as tower 3. In San Antonio, the intake was located about 40 feet further from the roadway than tower 3. The Byron collected a sample every five minutes and analyzed it for methane, nonmethane hydrocarbons, and carbon monoixde. The results were logged on a chart recorder. The data are shown in Appendix F in tabular form.

In general, the nonmethane hydrocarbons concentration was less than 2 ppm for the five minute average value and rarely exceeded 4 ppm.

Emission Factors by Mass Balance Techniques

Introduction:

In most experimental programs, carbon monoxide is usually the pollutant measured since vehicles emit significant quantities of this gas. It is also relatively inert and easily measured. The data collected usually include wind speeds and directions, temperature, atmospheric stability, traffic counts and speeds along with the pollutant concentrations. A major difficulty arises when one attempts to input this information into a model. This lies in the fact that traffic counts and speeds were measured while the models require the actual pollutant emission rates from the vehicles.

To the present, the only connection between the traffic counts and speeds and the pollutant emission rates has been through the use of the Environmental Protection Agency's Publications AP-42 (1973) and MOBILE 1 (1978). Thus, in all experimental model validation programs except those using a tracer gas, all of the parameters have been measured directly except for the pollutant emission rate. The emission rates or factors are calculated from AP-42 and MOBILE 1 given average vehicle speed, percentage of cold vehicle operation, percentage of travel by vehicle category (automobiles, light trucks, heavy trucks), vehicle age distribution, geographic location (high or low altitude or California) and ambient temperature. Obviously, some of this information, such as percentage of cold vehicle operation and vehicle age distribution, is very difficult or effectively impossible to obtain.

According to AP-42 and MOBILE 1, the emission data were obtained from test fleets of consumer-owned vehicles within various major cities. These vehicles were selected by model year, make, engine size, transmission, and carburetor in such proportion as to be representative of both normal production of each model year and the contribution of that model year to total miles traveled. There are, of course, many difficulties which arise in attempting such an enormous task. These include (1) are the vehicles selected truly representative of their population? (2) are dynamometer tests equivalent to actual vehicle usage?

In this section, a method to determine the actual emission rate from roadways based on material balance principles is discussed. These actual emission rates may be used as the source strength in modelling work. The method is the first "real world" check on the information in AP-42 and MOBILE 1. The method will also provide an excellent check on the validity and internal consistency of experimental pollutant dispersion data.

Mass Balance Concept:

The material or mass balance concept is based on the principle that the amount of a particular pollutant flowing past any vertical plane downwind of a roadway minus the amount flowing past a vertical plane upwind of a roadway must equal the amount generated by the traffic on the roadway. This assumes, of course, that there is no sink or disappearance of the material between the two planes. Since many roadways may be assumed to be line sources, the planes on either side of the roadway may be reduced to lines. Thus, the amount of carbon monoxide flowing past a tower downwind minus the carbon monoxide flowing past a tower upwind must be equal to the amount generated by the traffic on the roadway. For this to apply, it is, of course, necessary that the plume of the pollutant from the roadway be entirely defined within the height of the tower.

The experimental setup required to perform a material balance across the roadway should consist of one tower upwind and one downwind of the roadway. The towers should be instrumented with the pollutant measuring instruments at various heights. At least one of the towers and preferably both should be instrumented with wind speed and direction instruments at various heights. The vehicle counts, speeds and categories should also be measured.

The calculations are quite simple. The upwind concentrations can be subtracted from the downwind concentrations to obtain the concentrations due to the roadway. The product of the concentration times the component of the mean wind speed normal to the roadway are plotted as a function of height or position on the tower. This function is then graphically integrated to obtain pollutant mass per time per length of roadway. The traffic information can then be used to convert to pollutant mass per vehicle per distance traveled. In the strictest sense, the integration should be performed both upwind and downwind of the roadway. However, this would be necessary only if a significant gradient in the upwind concentration existed and the upwind tower was also instrumented for wind speed and direction.

Evaluation and Application of Mass Balance Technique:

The validity of the mass balance technique can best be established where tracer gases with well defined, known emission rates are used. Once the validity of the technique is established, it can be used on any pollutant within the guidelines mentioned in the previous section. The tracer gas data from Cadle, *et al*. (1975) at General Motors (GM Data) and from Dabberdt, *et al*. (1975) at Stanford Research Institute (SRI Data) were used for validation purposes. The mass balance technique was then applied to the carbon monoxide data from this report and from Dabberdt. The SRI tracer gas data and carbon monoxide data were taken at the same time. Only the cases where the plume was well defined within the height of the available towers were used from all data sets.

General Motors Data:

The GM dispersion experiment reported by Cadle *et al*., was performed on the North-South Straightway at the GM Proving Ground in Milford, Michigan. The test track was three lanes wide in each direction; however, only two lanes in each direction were used. The portion of the track where the dispersion monitoring equipment was placed was essentially flat. A fleet of 382 cars equipped with catalytic converters and air pumps was used to generate the roadway traffic. Seven or eight pickup trucks were used to release a known emission rate of sulfur hexafluoride (SF_6). The SF_6 was released into the exhaust system of the pickups. The gas samples for SF_6 analysis were collected using modified Development Science syringe samplers. The samplers collected a 30 cc sample over a one-half hour period. A dual column gas chromatograph with an electron capture detector was used to analyze for the SF_6. It can be accurately measured at concentrations as low as 10 parts per trillion. Several of the sampling stations were located on two towers on each side of the track. The towers were instrumented at heights of 1, 4, and 10 meters with meteorological and sample collection equipment at each station. Thus, the data were well suited to verify the mass balance technique.

Stanford Research Institute Data:

The SRI experiment, reported by Dabberdt and Sheller, was performed at three different sites. The first site was on a stretch of U.S. Highway 101, midway between the Lawrence and San Thomas Expressways in Santa Clara, California. The road is a major intrastate freeway with three lanes of traffic in each direction. The land surrounding the location consists mainly of level fields with a low growth of grasses. This land characteristic extends unbroken to a radius of 0.75 km around the sampling location, with only two obstructions inside a one kilometer radius.

Traffic was monitored with a system consisting of two shielded cable traffic sensors, data processor and recorder, and a programmer. Data recorded were vehicle speed and axle number.

Two vans were equipped to release two tracer gases: sulfur hexafluoride (SF_6) and fluorotribromo-methane ($F_{13}B_1$). The vans were driven continuously in the traffic stream, in the center lane, and at the general traffic speed. One of the tracer gases was released while traveling in one direction, and the other gas was released while traveling in the opposite direction. The vans were instrumented so that the amount of tracer released could be obtained by two methods.

The gas samples were taken with Environmental Measurements Incorporated sequential multiple-bag samplers. The samplers obtained an integrated air sample at a rate of 4-ℓ/hour, using a 150-ms on cycle every second. The gas samples were analyzed by means of dual gas chromatographs with electron capture detectors. There were two towers on each side of the roadway and one tower in the median strip, all equipped with meteorological and/or sample collection equipment at heights of 2.0, 3.8, 7,5. and 14.2 meters.

The second site was at a cut-section segment of Interstate 280 in San Jose, and was not used in the present study. The third site was located at a pair of viaducts, each about 24 m wide. A 15 m gap separates the two viaducts, which are just above the roof level of the surrounding two-story houses. Six lanes of traffic flow east, and 5 lanes flow west (including a two lane on ramp). The scope of the experiment was the same as at previous locations.

There were three towers at this site; one on either side of the pair of viaducts, and one in between the two viaducts. Air samplers were located at heights of approximately 10, 27, 33, 43, and 58 feet on all three towers. In addition, there were meteorological instruments on the center tower at the various heights.

Sensitivity of Mass Balance Calculations to Errors in Measured Parameters:

The accuracy of the results from the mass balance calculations depend, of course, on the accuracy of the individual measurements used in the calculations. The required parameters are wind direction, wind speed, traffic count and carbon monoxide concentrations. The sensitivity of the results from the Texas data to the errors in the various individual parameters is discussed in this section.

One factor which must be considered in a sensitivity analysis of the mass balance technique is that all of the parameters involved are random variables. Thus, the standard deviation or the variance must be considered in analyzing the effect of an error. In almost all cases, the errors are well within the standard deviation. In the Texas data, five-minute average data was used in the calculations.

Wind Direction:

The wind direction measurements were accurate to within five degrees. Most of this error was due to alignment during setup. In the mass balance calculations the sine of the angle with respect to the road is used to determine the component of the mean wind normal to the roadway. The wind angle error will have a maximum effect at the minimum angle, where the sine is smallest and has the greatest slope. Only those cases where the wind angle with respect to the roadway was 20-degrees or greater were used in the mass balance calculations. At a 20 degree angle, an error of 5 degrees results in a 20% change in the emissions calculated by the mass balance technique. On the other hand, at a 45-degree angle, an error of 5 degrees results in only an 8.3% change in the calculated emissions. The above sensitivity estimates assume that all four wind vanes were in error by the maximum amount in the same direction at the same time. The probability of this occuring is, of course, quite low. The standard deviation in the wind direction was typically 20° as compared to the error of 5°.

Wind Speed:

The horizontal anemometers were accurate to within 0.5 mile per hour as compared to the typical standard deviation of 1.5 miles per hour. Since no cases were used in the mass balance calculations with wind speeds of less than three miles per hour, the maximum effect on the mass balance results would be 17%. In most cases, the wind speed was 5 miles per hour or greater.

Carbon Monoxide:

As discussed previously, the Ecolyzers were accurate to within about 0.25 ppm as compared to typical standard deviations of about 1.0 ppm. As was the case for the wind speed and direction, the carbon monoxide was measured at four levels downwind of the roadway. However, it was also necessary to measure carbon monoxide upwind of the roadway since the net emissions due to the roadway were desired. The upwind instruments were typically at least 150 ft. from the roadway and positioned at heights of 5 and 33 feet. The upwind concentration was calculated by averaging the values from these two instruments. Thus, the maximum contribution to the error in the mass balance results would be due to the error in the upwind carbon monoxide concentration. However, no cases were selected for the mass balance calculations where the difference in the two upwind values was greater than 0.5 ppm or where only one upwind value existed.

An error of 0.25 ppm in the carbon monoxide measurements could cause an error in the mass balance results as high as 50% in some cases where the downwind values were near the upwind values. However, in most cases, the net concentration difference across the roadway was about 2.0 ppm or greater. Thus, the error in the mass balance results for most cases would be less than 25%.

Traffic Counts:

The error in the traffic counts was found to be within 2% based on manual counts. Since the total emissions from the roadway were divided by traffic to obtain the emissions in terms of grams per vehicle mile, the influence of the traffic error on the final result would also be within 2%.

General Discussion of Errors:

The possibility does exist, of course, that all parameters could have the maximum error in the same direction at the same time. However, the probility of this occurring is quite small. As previously discussed, the process of diffusion of pollutants from roadways is a random process. Thus, the application of the mass balance technique must be for some averaged time period. For the Texas data, the mass balance calculations were performed with five-minute averages. Therefore, from the consideration of maximum error accumulation and characterization of a random process, the average emission factor from several five minute periods would have much greater reliability than a single individual value.

Results of Material Balance Calculations:

The mass balance technique was applied to 19 cases from the GM data and 8 cases from Site 1 and 15 cases from Site 3 of the SRI data. In each of these cases, either SF_6 or $F_{13}B$ or both were used. Sample calculations applying the mass balance technique to the GM, SRI and Texas data are shown in Appendix E. The emission factors obtained from the GM data are shown in Table 7 along with the precisely measured emission rates. As can be seen from this table, the calculated and measured emission rates agree closely. The averaged

Table 7

Comparison of Calculated and Actual Emission Factors for General Motors Data

Date	D.M. I.D.	Wind Angle with Roadway, deg	Tower 1 Calculated Emission Rate gm SF_6/m-hr	Tower 2 Calculated Emission Rate gm SF_6/m-hr	Measured Emission Rate gm SF_6/m-hr
October 2, 1975	275080959	255	0.21	0.18	0.25
	275083959	262	0.26	0.19	0.25
	275090959	267	0.18	0.16	0.25
	275093958	268	0.19	0.22	0.25
October 3, 1975	276081459	143	0.21	0.22	0.28
	276094459	165	0.17	0.14	0.28
October 6, 1975	279080959	192	0.29	0.29	0.25
	279084000	187	0.30	0.26	0.25
	279090959	188	0.33	0.28	0.25
	279093059	183	0.33	0.26	0.25
October 10, 1975	383081959	190	0.24	0.25	0.26
	283085000	201	0.26	0.23	0.26
	283092000	175	0.27	0.22	0.26
October 20, 1975	293103458	202	0.28	0.28	0.30
	293110458	202	0.33	0.31	0.30
October 21, 1975	294080502	165	0.39	0.36	0.30
October 27, 1975	300080000	128	0.20	0.22	0.29
October 29, 1975	302080456	270	0.20	0.17	0.28
October 30, 1975	303080957	253	0.20	0.22	0.29
		Average	0.26	0.23	0.27
		Standard Deviation	0.06	0.06	0.02

rates agree remarkably well. The mass balance calculations were performed for both downwind towers. As shown in Table 7, the calculated emission rates for the two towers agree within 10% for most cases. The good agreement between the calculated emission rates and the measured emission rates and especially the excellent agreement between the calculated values for the two towers show that the mass balance technique is valid.

The emission factors calculated from the SRI data are shown in Tables 8 and 9 along with the measured emission rates. In this work, SF_6 was emitted on one side of the roadway and $F_{13}B_1$ on the other. As can be seen in Table 6 for Site 1, the average calculated emission rate is about twice the measured emission rate for both SF_6 and $F_{13}B_1$. In addition, there is considerable scatter in the agreement between individual values. The mass balance technique could not be used for the SF_6 tracer at Site 3 since the SF_6 plume was not completely contained in the downwind tower. The results for the $F_{13}B_1$ tracer at Site 3, shown in Table 9, are less scattered than for Site 1. The average calculated $F_{13}B_1$ emission rate was almost exactly twice the average measured rate, as was the case for Site 1. Since the average calculated emission rates for two tracers at Site 1 and one tracer at Site 3 were almost exactly twice the measured rates, it is reasonable to conclude that there is a systematic error in the data or in the calculations used here.

The mass balance technique was used to determine the carbon monoxide emissions for Sites 1 and 3 from the SRI data and for the Houston, Dallas, San Antonio and El Paso sites from the Texas A&M data. The calculated carbon monoxide emissions by the mass balance technique and the carbon monoxide rate calculated by SRI based on AP-42 are compared in Tables 8 and 9 for Sites 1 and 3 of the SRI data.

The carbon monoxide emission rates calculated by the mass balance technique

Table 8

Comparison of Calculated and Actual Emission Factors for SRI Data (Site 1)

Date	Time	Traffic Veh/hr	Wind Angle with Respect to Roadway	SF_6 Calculated mg/m-sec	SF_6 Emitted mg/m-sec	$F_{13}B_1$ Calculated mg/m-sec	$F_{13}B_1$ Emitted mg/m-sec	CO Calculated mg/m-sec	CO Estimated by SRI mg/m-sec	Calculated Emission Factor gm CO/veh-mi
1-30-75	16:00	6646	39.4	0.1648	0.090	———	0.378	65.2	30.81	56.83
	17:00	6593	71.4	———	———	1.08	0.408	69.2	32.95	60.79
	18:00	4611	50.2	0.2608	0.086	———	0.300	23.2	14.44	29.14
2-5-75	12:00	4169	37.9	0.0320	0.092	0.624	0.319	17.2	13.06	23.90
	13:00	4411	48.9	0.240	0.123	0.784	0.336	23.2	13.81	30.47
	14:00	4862	50.9	0.3408	0.125	0.952	0.318	28.4	15.23	33.83
	15:00	6551	62.2	0.3808	0.114	1.00	0.401	48.8	20.70	43.15
	16:00	6517	69.7	0.2720	0.103	0.720	0.424	64.0	33.88	56.88
			Average:	0.24	0.10	0.86	0.37	42.4	21.8	41.87

Table 9

Comparison of Calculated and Actual Emission Factors for SRI Data (Site 3)

Date	Time	Traffic Veh/hr	Wind Angle with Respect to Roadway	$F_{13}B_1$ Calculated mg/m-sec	$F_{13}B_1$ Emitted mg/m-sec	CO Calculated mg/m-sec	CO Estimated by SRI mg/m-sec	Calculated Emission Factor gm CO/veh-mi
8-12-75	14:00	5542	273	.696	.370	29.6	17.36	30.93
	15:00	6725	276	.720	.365	40.0	31.00	34.45
	16:00	8496	280	.808	.425	30.0	26.60	20.45
	17:00	8368	273	.760	.270	——	26.20	——
8-14-75	14:00	5710	275	.840	.362	33.6	17.88	34.08
	16:00	8577	280	.800	.376	48.8	26.90	32.96
8-19-75	15:00	6719	286	.800	.462	36.8	21.10	31.73
	16:00	8658	288	.432	.313	49.6	27.10	33.18
8-21-75	5:00	977	34.3	1.48	.559	8.8	3.07	52.17
	9:00	3933	78.7	1.208	.496	24.0	12.41	35.35
	10:00	4317	85.5	.640	.441	36.8	13.64	49.38
	11:00	5304	105.5	1.080	.553	28.0	16.69	30.58
8-26-75	6:00	4880	85.7	1.296	.492	12.8	15.26	——
	7:00	8397	100.5	1.176	.566	31.2	26.30	21.52
	8:00	6891	92.3	——	.548	——	21.59	——
			Average:	0.92	0.43	31.52	19.64	32.49

for the Texas A&M data are shown in Tables 10, 11, 12, 13 and 14. These tables also compare the mass balance results with the emission rates predicted by AP-42 and MOBILE 1. The values used in inputs to AP-42 and MOBILE 1 are:

1) By-lane speeds and counts from project radars.
2) For AP-42, the 1976 Harris County vehicle age distribution by vehicle type, as presented in Table 15, was used for all sites.
3) For MOBILE 1, the vehicle type mix and percent cold start and hot start as presented in Tables 15 and 16, were used.
4) For any parameter not specified, the national average was used.

In the present work, countywide averages for traffic information such as heavy duty vehicle mix and percent hot and cold starts were used to represent the specific section of expressway where experimental data were collected under this project. As more accurate and appropriate traffic information becomes available, the emission factor estimates will be revised. The citywide average figures were supplied by the Texas State Department of Highways and Public Transportation.

A summary comparison of the average emission factors from the mass balance technique, AP-42 and MOBILE 1 for all of the "at grade" sites from the Texas data is shown in Table 17. The Houston (Winter) and San Antonio averages agree within about 25% with the MOBILE 1 predictions. The Dallas average is approximately double the MOBILE 1 predictions while the Houston (Spring) and El Paso averages are roughly three to four times the MOBILE 1 predictions. It is also interesting to note that the MOBILE 1 emission factor estimates are from 35 to 85% higher than the AP-42 estimates.

The Houston (Spring) data were the first data collected under this project. However, there is no indication in the data or calibration procedures of any unusual error.

Table 10

Comparison of Calculated and MOBILE 1 Emission Factors for Houston "at grade" Site (Spring)

Time	Traffic veh/ 5 min	Acute angle of wind with roadway, deg	Calculated Emission Factor, gm CO/veh-mi	Emission Factor from AP-42 gm CO/veh-mi	Emission Factor from MOBILE 1 gm CO/veh-mi
May 25, 1976					
14:30	500	73	222.4	22.21	30.21
14:35	470	76	217.4	22.21	30.71
14:40	553	67	197.1	22.21	30.49
14:45	543	73	218.9	22.22	30.52
14:50	541	69	173.1	22.22	31.04
14:55	527	73	173.1	22.22	30.98
15:45	608	80	122.0	23.16	27.08
15:50	695	87	111.9	23.0	34.64
16:00	706	88	91.9	22.22	31.87
16:10	946	67	64.3	22.22	31.28
16:15	561	77	110.0	22.21	30.55
16:25	702	89	90.2	22.22	30.69
16:35	672	64	74.1	22.22	30.28
		Average	143.6	22.35	31.56
		Standard Deviation	58.6	0.09	2.02

Table 11

Comparison of Calculated and MOBILE 1 Emission Factors for Houston "at grade" Site (Winter)

Time	Traffic veh/ 5 min	Acute Angle of wind with roadway, deg	Calculated Emission Factor, gm CO/veh-mi	Emission Factor from AP-42 gm CO/veh-mi	Emission Factor from MOBILE 1 gm CO/veh-mi
January 12, 1977					
18:05	641	14.0	23.0	31.65	42.09
18:20	632	14.0	24.8	31.64	40.95
18:25	597	14.0	75.1	30.35	40.24
18:55	520	12.0	15.5	31.63	40.76
January 13, 1977					
11:30	414	13.0	80.8	28.49	38.76
		Average:	43.8	30.75	40.56
		Standard Deviation	31.4	0.65	1.21

Table 12

Comparison of Calculated and MOBILE 1 Emission Factors for Dallas "at grade" Site

Time	Traffic veh/ 5 min	Acute Angle of wind with roadway, deg	Calculated Emission Factor, gm CO/veh-mi	Emission Factor from AP-42 gm CO/veh-mi	Emission Factor from MOBILE 1 gm CO/veh-mi
August 3, 1977					
14:30	224	61	80.8	20.04	31.36
14:45	239	44	47.7	19.64	30.54
14:50	238	47	35.7	19.69	30.63
August 11, 1977					
07:25	398	83	35.0	21.47	34.69
07:30	339	88	36.8	21.21	35.64
07:35	356	85	45.6	21.30	34.48
09:35	218	69	127.3	19.53	31.12
09:40	214	49	75.3	19.72	31.48
09:45	199	62	138.2	19.72	31.48
14:00	239	61	25.2	19.87	31.06
14:35	260	66	66.5	19.55	30.03
15:00	225	40	70.8	19.61	29.98
		Average:	65.4	20.11	31.87
		Standard Deviation:	36.2	.23	1.93

Table 13

Comparison of Calculated and MOBILE 1 Emission Factors for San Antonio Site

Time	Traffic veh/ 5 min	Acute Angle of wind with roadway, deg	Calculated Emission Factor, gm CO/veh-mi	Emission Factor from AP-42 gm CO/veh-mi	Emission Factor from MOBILE 1 gm CO/veh-mi
October 6, 1977					
11:30	477	31	21.5	20.73	35.33
11:35	524	38	44.8	20.74	31.57
11:40	533	23	30.6	20.74	33.64
11:50	510	26	19.5	19.22	32.79
11:55	491	27	14.5	19.22	32.78
12:00	505	43	27.4	19.23	31.53
12:10	547	43	54.6	19.23	32.85
12:25	459	34	53.5	19.22	32.88
12:35	473	34	30.6	19.22	32.63
12:40	492	46	40.9	19.22	32.56
12:45	534	41	49.0	19.22	32.55
12:50	536	48	68.3	19.24	32.72
12:55	535	43	96.5	19.22	32.68
		Average:	42.4	19.57	32.81
		Standard Deviation	22.7	0.19	0.93

Table 14

Comparison of Calculated and MOBILE 1 Emission Factors for El Paso Data

Time	Traffic veh/ 5 min	Acute Angle of wind with roadway, deg	Calculated Emission Factor, gm/veh-mi	Emission Factor from AP-42 gm/veh-mi	Emission Factor from MOBILE 1 gm/veh-mi
November 29, 1977					
15:05	430	53	79.8	26.16	35.04
15:15	486	83.5	96.0	26.15	35.25
15:20	487	89.4	88.7	26.04	34.79
15:25	486	72.8	107.5	26.14	35.23
15:30	516	85.3	101.3	26.10	35.52
15:40	600	84.3	59.7	26.09	35.08
15:55	588	83.7	95.3	26.13	36.17
16:00	508	52.2	79.7	27.66	36.56
16:05	519	65.1	146.7	26.14	35.18
17:40	521	29.5	60.7	27.74	36.14
December 1, 1977					
12:00	404	14.1	27.3	26.00	36.07
December 3, 1977					
9:55	406	44.9	118.2	28.30	37.45
10:00	374	47.3	136.2	27.67	36.54
10:05	445	47.1	166.3	28.35	37.27
10:10	422	49.9	181.7	28.34	37.86
10:20	396	43.6	166.6	28.03	36.71
10:25	429	46.2	172.5	28.13	36.95
10:30	457	49.1	149.0	28.20	37.14
10:35	428	47.6	156.6	25.96	35.04
10:40	435	43.1	122.1	26.58	36.10
10:45	459	44.6	181.1	26.63	36.17
10:50	452	45.4	122.2	26.02	35.30
10:55	428	36.0	129.1	26.66	36.36
11:15	484	34.0	110.8	26.02	25.12
		Average	119.0	26.84	36.04
		Standard Deviation	41.5	0.94	0.89

Table 15

1976 Harris County Vehicle Age Distribution
by Vehicle Type - (Source DMV)

Year	Automobile,%	Pickup,%	Heavy Duty Gas,%	Heavy Duty Deisel,%
1976	8.7	10.4	6.1	6.1
1975	10.5	11.4	12.8	13.6
1974	12.3	12.7	13.7	16.7
1973	12.7	12.1	13.7	17.1
1972	10.5	9.2	10.9	9.7
1971	8.3	6.8	7.6	8.2
1970	7.7	6.2	7.0	8.0
1969	7.0	6.4	6.8	6.8
1968	5.9	5.1	5.0	4.3
1967	4.4	4.1	3.9	2.8
1966	3.7	3.9	3.2	2.3
1965	2.9	3.2	2.4	1.6
pre-1965	5.5	8.5	7.0	2.9

Table 16

Vehicle Operating Mode for MOBILE-1

City	County	PCCO[a]	PCHS[b]	PCCC[c]
Houston	Harris	15.1	27.1	24.4
Dallas	Dallas	19.2	34.5	27.8
San Antonio	Bexar	23.3	31.8	31.2
El Paso	El Paso	17.9	30.1	25.4

a - % of non-catalyst-equipped light duty vehicles
vehicle miles traveled accumulated in cold start mode
b - % of catalyst-equipped light duty vehicles
vehicle miles traveled accumulated in hot transient mode
c - % of catalyst-equipped light duty vehicle
vehicle miles traveled in cold start mode

Vehicle Type Mix for MOBILE-1

City	County	LOV[a]	LDT1[b]	LDT2[c]	HDG[d]	HDD[e]	MC[f]
Houston	Harris	0.725	0.171	0.042	0.023	0.006	0.033
Dallas	Dallas	0.720	0.176	0.043	0.023	0.006	0.031
San Antonio	Bexar	0.720	0.176	0.043	0.023	0.006	0.031
El Paso	El Paso	o.720	0.176	0.043	0.023	0.006	0.031

a - Light Duty Vehicles (automobiles)
b - Light Duty Trucks (lower weight class)
c - Light Duty Trucks (upper weight class)
d - Heavy Duty Gas Vehicles
e - Heavy Duty Deisel Vehicles
f - Motor Cycles

Table 17

Summary Comparison of Calculated, AP-42 and MOBILE 1 Emission Factors for all "at Grade" Sites from Texas Data

Site	Cal'd Emission Factor gm CO/veh-mi	Emission Factor from AP-42 gm CO/veh-mi	Emission Factor from MOBILE 1 gm CO/veh-mi
Houston (Spring)	143.6	22.35	31.56
Houston (Winter)	43.8	30.75	40.56
Dallas	65.4	20.11	31.87
San Antonio	42.4	19.57	32.81
El Paso	119.0	26.84	36.04

Using the 1975 Federal Test Procedure, Liljedahl and Terry (1977) of Automotive Testing Laboratories, Inc. found that 1973 through 1976 model year passenger cars in Houston had a composite carbon monoxide emission factor of 43.1 gm/veh-mi. Their carbon monoxide results for Houston are shown in Table 18. They also obtained a composite carbon monoxide emission factor for passenger cars in Phoenix of 45.6 gm/veh-mi as shown in Table 19. The climate in El Paso is fairly comparable to the climate in Phoenix. As can be seen from Tables 18 and 19 the standard deviations for the emission factors are almost as large as the emission factors themselves. The type vehicles to be used in the tests were specified and specific owners were solicited to volunteer their vehicles using a strong incentive program.

A number of conclusions can thus be reached. It is apparent that AP-42 cannot adequately represent current emission factors. MOBILE 1 agrees with some checks of actual vehicle emissions and with some mass balance cases. Much more data is needed to adequately describe vehicular emission factors. The mass balance technique is a theoretically sound method to determine emissions from roadways. The method has been validated by applying it to experiments where tracer gases with a precisely measured emission rate were used. The technique can be used to determine the emission rate of any material from a roadway provided there is no chemical reactions or settling. This is the first real world method to check the emission rates predicted by AP-42 and MOBILE 1 or any other emission factor publication. More precise experimental measurements would increase the accuracy of the method. In addition, an instrument array on a tall tower upwind as well as downwind would improve the accuracy of the results.

Table 18

CO Emissions vs. model year for Houston (1976) From Liljedahl and Terry (1977)

Year	Number Vehicles	Average Milage	CO emissions gm/veh-mi Mean	CO emissions gm/veh-mi Standard Deviation
1965-1972	0	——	——	——
1973	27	51574	60.4	40.6
1974	27	35550	64.3	41.2
1975	28	28549	32.9	32.5
1976	34	11468	20.8	19.5
Composite	116	30531	43.1	38.2

Table 19

CO Emissions vs. model year for Phoenix (1976) From Liljedahl and Terry (1977)

Year	Number Vehicles	Average Milage	CO emissions gm/veh-mi Mean	CO emissions gm/veh-mi Standard Deviation
1965	3	96613	174.6	85.2
1966	7	90811	95.9	53.6
1967	12	94790	99.9	43.9
1968	28	1876	80.9	38.6
1969	30	84733	80.2	50.8
1970	35	75517	77.5	59.0
1971	40	68814	51.6	24.6
1972	45	56076	47.5	21.5
1973	50	43961	50.1	32.9
1974	50	34849	58.8	38.3
1975	49	25814	25.1	22.5
1976	151	12793	15.1	14.9
Composite	500	44467	45.6	42.3

Available Data Formats

The experimental data collected during this project will be available in three formats. Each format has certain helpful characteristics, and the user should decide which format or formats would be most applicable to the study being undertaken. All data will be delivered on 9 track magnetic tape at 1600 bytes per inch with IBM standard labels unless other tape densities and labels are requested.

Formats 1 and 2 consist of exactly the same numbers. Both give the time averaged traffic, meteorology, and pollutant data, along with the standard deviations in the meteorology and pollutant data. Pollutant data have been corrected for zero and span drift by assuming a linear drift between calibrations. No corrections were applied to the meteorology or traffic data. As such, the data in these two formats are most useful to those users who are constructing, calibrating, or verifying dispersion models based on 15-minute or 1 hour average values.

Format 1 data are simply a taped copy of the Set C averages (see Appendix C). A simple tape to print utility such as IBM's IEBGENR can be used to list the data or to move it to a text editing system file for easy user reference. In this form, the data base occupies approximately 1,000 feet of 9 track tape.

Format 2 data was generated from the Format 1 data in order to make it more easily assimilatable by the computer. Each average was reformatted to a single line of data 820 bytes long, consisting of a 40 byte identifier and 78 ten byte floating point numbers. In this way, SAS 76, a statistical analysis package available at Texas A&M could reach the data easily and perform analyses on it. In this form, it is also easily manipulatable by Fortran. The data in this format still occupy 1,000 feet of 9 track tape.

The Format 1 data should always be requested along with the Format 2 data, since the Format 1 data contains a copy of the daily log in addition to the instrument averages. The log is a guide to indicate questionable data or unusual conditions in the data base. More importantly, the Format 1 data contain the lane by lane breakdown of the traffic data. When a radar failed, that lane showed no traffic until the radar could be repaired and replaced. The overall traffic count was not modified to correct for this. Accordingly, the user must make whatever corrections he sees appropriate. Without the Format 1 data, it is impossible to correct for this error in any way.

Format 3 data are of greatest value to those who are interested in the minute-by-minute micrometeorology and pollutant dispersion. This format contains what is essentially the raw sample values logged from the instruments, with notations of the calibration errors. The data are arranged in fixed length, 80 byte records, making it look like cards to the computer. A detailed description of each type record and a sample data set extracted from the data base are listed in Appendix D. Please note that although this sample contains only 5 minutes of data from only 1 of each type instrument, it occupies 2 pages. Data in this format are extremely bulky, occupying over 3,000 feet of 9 track tape at 1,600 bytes per inch. Accordingly, this format should not be requested unless the user intends to expend large amounts of programming time in data reduction.

Comparison of Results With Model Predictions

Introduction:

The various numerical dispersion models presently available were developed using one or more of the several roadway carbon monoxide dispersion data sets, none of which were taken in Texas. In this section, the relationship among the model predictions and a portion of the Texas data is examined. The data subset used here is biased, however, since it consists of only the 5-minute average cases used in the mass balance work discussed earlier in this report. Thus, only the cases in which the carbon monoxide concentrations were well-defined within the height of the tall tower were used. These cases represent considerably less than 10% of the data at most sites. The four models used are discussed below.

Discussion of Models:

CALINE-2

This model is a revision of CALAIR, the originial California line source dispersion model. It is based on the work of Turner (1970) and Ranzieri, _et al_. (1975). CALINE-2 employs a fixed box model together with a Gaussian dispersion model. The box model is used to simulate the initial dispersion of pollutants caused by the mechanical turbulence resulting from the moving vehicles. The box model assumes the emissions are uniformly distributed over the roadway and up to a fixed height, termed a "mixing lid." In an experimental program known as "Project Smoke" performed by the California Division of Highways (1972), this lid was determined to be equal to the width of all the traffic lanes plus the median plus a distance of about ten feet on both sides of the roadway. Three equations are used to predict the carbon monoxide concentrations for parallel, oblique and cross winds. The equations for the parallel and cross wind cases are based on the use of the continuous line source equation. The oblique case is treated as a trigonometric relationship of the other two. A calibration factor is not required for each site; however, the model was validated with experimental data from California only.

HIWAY

The HIWAY model was developed for the Environmental Protection Agency by Zimmerman and Thompson (1974), based on Turner's (1970) work. The calculational procedure is centered around numerical integration of the Gaussian plume point source equation for a finite length. For certain unstable and neutral conditions, an equation of the form suggested by Bierly and Hewson (1962) is used. From a computational viewpoint, this model involves a fairly time-consuming numerical integration procedure. No site calibration is required.

AIRPOL-4

This model, developed by Carpenter and Clemena (1975), also uses the Gaussian type of formulation. However, AIRPOL-4 is unique in that it uses two Euclidean coordinate systems, mapping the roadway coordinate system onto the receptor coordinate system. This transformation allows the Gaussian equation to be integrated over all roadway points contributing to the pollution at a particular location. The values of the dispersion coefficients are obtained from the Pasquill-Gifford curves, but they are modified to account for sampling time as a function of stability. Carpenter and Clemena (1975) give two equations that greatly reduce the required computation time for cases of nearly perpendicular or nearly parallel winds. No site calibration is necessary; however, the model was validated from Virginia data only.

The TRAPS Models

The original TRAPS model was developed by Maldonado and Bullin (1977). This model uses a combination of empirical fits and gradient type diffusion formulas. It was verified using experimental data from Virginia, North Carolina, Tennessee and California. Data collected in Texas under Project 218 were not used in verifying either the original model or the TRAPS II and 52 models. The TRAPS II model (Bullin and Polasek, 1978b,c) was developed from the original TRAPS model by making two simplifications that greatly increased the computational speed. The resulting model is approximately 50% faster than the original model, and ten times faster than any other highway pollution dispersion model. The original model was improved by substituting a polynomial equation for an iterative step in the program. In addition, the virtual origin, which will be discussed below, is now calculated by direct iteration rather than the secant method used in the original TRAPS model.

The total source of a highway is not concentrated in a single, thin line, but rather is diffused from a large area, with the original dispersion taking place due to the mechanical turbulance of the vehicles. The virtual origin is the location of a hypothetical line source that will produce a plume having the dispersion of the actual area source. In the TRAPS models, an empirical equation derived from dimensional and statistical analyses is used to calculate the roadedge concentration at a five-foot height. The result is then matched to the Gaussian plume by direct iteration. Maldonado (1976) originally used the secant method to determine the virtual origin distance.

The equation describing the downwind, off the road concentrations employs the power law wind profile. However, the log-law profile more accurately describes the velocity profile near the earth, since it accounts for the site dependent friction velocity and surface roughness factors. Therefore, the log-law profile was determined for the site under the given conditions, and the power law profile fitted to the results through the use of a fourth degree polynomial equation. In the original model, the power law profile was fitted to the log-law profile through the use of an iterative procedure.

Application of Models:

All of the above models were applied to the data cases used in the mass balance work. The meteorological, geometrical, and traffic data for each case were used as input variables for each of the models, and the resulting carbon monoxide concentrations were compared to the data values.

Emission Factors: The emission factors used in the models were obtained with the use of a modified AP-42 computer program (BIGAP) obtained from the Texas State Department of Highways and Public Transportation. The AP-42 emission factors used corresponded to the prediction for the nearest 5 degrees in the temperature and the nearest 5 miles per hour in speed. The national average heavy duty mix and the 1976 Harris County vehicle age distribution given in Table 15, were used in the program. A 20% cold start, 10% hot start mix was also used. In some of the cases the traffic data for a given lane were missing or were obviously in error. In these instances the data were estimated according to similar time periods on another day.

The results of the model predictions for each case were then multiplied by the ratio of the mass balance emission factor to the AP-42 emission factor to obtain the model predictions for the mass balance emission factors.

Site Geometries: The roadway and receptor geometries used in the models were consistent with the site descriptions given previously. The model restrictions were also taken into account. Therefore, for a given model-site combination, the model was run for various sections of the roadway and the results for the respective receptors were added to obtain the predicted concentration due to the entire roadway. The model-site combinations were handled as follows:

CALINE-2 - Houston at-grade - The model was run one time for the entire main roadway for each case.

CALINE-2 - Dallas at-grade - The model was run once for each of the access roads and for each direction of travel on the main roadway for each case.

CALINE-2 - San Antonio - The model was run once each for the westbound access road and the main roadway for each case.

TRAPS - Houston at-grade - This combination was handled the same as for CALINE-2.

TRAPS - Dallas at-grade - This combination was handled the same as for CALINE-2, except that TRAPS has a lower limit of 29 feet for roadway width, and since the roadway width at this site was less than 29 feet, extra width was added on the upwind side to satisfy the requirement.

TRAPS - San Antonio - This was handled the same as for CALINE-2, except that the width fixup, as above, was used for the access road.

AIRPOL-4A - Houston at-grade - Each direction of travel on the main roadway was handled as a distinct lane group for each case.

AIRPOL-4A - Dallas at-grade - Each access road and each direction of travel on the main roadway was handled as a distinct lane group for each case.

AIRPOL-4A - San Antonio - The westbound access road and each direction of travel on the main roadway was handled as a distinct lane group for each case.

HIWAY - Houston at-grade - The model was run once for the entire main roadway for each case. One mile was used for roadway length both in the upwind and downwind directions.

HIWAY - Dallas at-grade - The model was run once for each access road and once for the main roadway for each case. One mile was used for the roadway length both in the upwind and downwind directions.

HIWAY - San Antonio - The model was run once for the westbound access road and once for the main roadway for each case. One quarter mile was used for roadway length both in the upwind and downwind directions.

Meteorological Data: All of the models require as input variables the windspeed, stability category, and wind angle. For those models requiring the 10-meter windspeed, the 26-foot measurement for each case was used. The 5-foot measurement for each case was used for input windspeed for HIWAY. The average of the wind direction at the four station levels was used as wind angle input for each case. For determination of the stability class, the 26-foot windspeed was used.

Results and Comparison: Model prediction results are presented in Table 20. The model predictions using MOBILE 1 emission factors are given in the upper section of each page for a given case. Model predictions using the emission factor calculated by the mass balance technique for each case are given in the lower section of each page in the table. The identification number corresponding to the date and time of the case is given in column one. Column two contains the 26 foot windspeed, the acute angle of the wind with respect to the roadway, and the stability class, from top to bottom in that order. The traffic rate for the entire roadway in vehicles per hour is given in column three. Columns four through nine give the standard receptor location, measured carbon monoxide concentration (less background), and model prediction concentrations. This format is presented at the beginning of the table.

As can be seen in the tables, the difference between model predictions and data values is generally less for the cases in which the mass balance emission factor was used than for the corresponding cases using the AP-42 emission factor. It may be noted that predicted horizontal concentration profiles generally deviate less from the data for mass balance cases than for the corresponding MOBILE 1 cases. This provides an additional check on the mass balance technique, since the horizontal profile was not used in the technique.

Additional analyses and conclusions will be included in the final report (218-5) on this project. The additional work will include linear regressions of observed versus predicted concentrations. This will probably be done for all receptors in a case, the 5 feet receptors, the 33 feet receptors, and the receptors used in the mass balance calculations. This analysis should be performed for both AP-42 and mass balance emission factor cases, allowing comparison of the two.

GUIDE TO TABLE 20

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
Date Time at end of averaging period.	Wind speed at 26 ft. Wind angle wrt roadway. Stability class.	Vehicles per hour.	Location					
			description corresponding to site schematics in Chapter II.					
	Model predictions in top section are for MOBILE 1 emission factors.							
	Model predictions in bottom section are for mass balance emission factors.							

Table 20. Comparison of Model Predictions with the Data Format

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576 1430	11.9 73° 2	6000	CO1H	1.3	0.3	0.1	0.001	0.35
			CO1L	2.9	1.2	0.8	1.714	0.92
			CO2H	1.3	0.3	0.3	0.016	0.33
			CO2L	3.6	1.1	0.5	1.424	0.80
			CO3H	2.0	0.3	0.3	0.112	0.31
			CO3L	2.2	0.8	0.4	1.026	0.63
			CO4H	0.2	0.0	0.0	0.0	0.14
			CO4L	1.7	0.1	0.1	0.011	0.26
			CO5H	1.6	0.3	0.3	0.277	0.30
			CO5L	2.1	0.5	0.3	0.650	0.42
			CO1H	1.3	2.0	1.0	−.010	2.60
			CO1L	2.9	9.0	6.0	12.617	6.81
			CO2H	1.3	2.0	2.0	−0.120	2.40
			CO2L	3.6	8.0	4.0	10.484	5.91
			CO3H	2.0	2.0	2.0	0.821	2.30
			CO3L	2.2	6.0	3.0	7.550	4.61
			CO4H	0.2	0.0	0.0	0.000	1.000
			CO4L	1.7	1.0	1.0	0.080	1.90
			CO5H	1.6	2.0	2.0	2.043	2.20
			CO5L	2.1	4.0	2.0	4.787	3.10

Table 20. Comparison of Model Predictions with the Data

Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	8.9	5640	C01H	2.2	0.4	0.1	0.001	0.41
1435	76°		C01L	4.5	1.5	1.1	2.136	1.08
	2		C02H	1.8	0.4	0.3	0.018	0.39
			C02L	4.8	1.2	0.7	1.781	0.94
			C03H	2.4	0.4	0.3	0.134	0.36
			C03L	2.9	1.0	0.6	1.287	0.73
			C04H	0.3	0.0	0.0	0.0	0.15
			C04L	1.8	0.1	0.5	0.012	0.15
			C05H	1.8	0.4	0.1	0.343	0.30
			C05L	2.2	0.7	0.3	0.817	0.35
			C01H	2.2	2.9	1.0	-0.010	2.94
			C01L	4.5	10.8	7.8	15.123	7.63
			C02H	1.8	2.9	1.9	-0.127	2.74
			C02L	4.8	8.8	4.9	12.607	6.66
			C03H	2.4	2.9	1.9	-0.949	2.54
			C03L	2.9	6.9	3.9	9.113	5.19
			C04H	0.3	0.0	0.0	0.0	1.08
			C04L	1.8	1.0	1.0	-0.088	2.15
			C05H	1.8	2.9	1.9	2.428	2.45
			C05L	2.2	4.9	2.9	5.785	3.52

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	13.3	6636	CO1H	2.1	0.7	0.3	0.000	0.40
1440	67°		CO1L	4.4	2.3	1.6	1.868	1.10
	3		CO2H	1.6	0.7	0.5	0.002	0.37
			CO2L	4.5	1.9	1.9	1.645	0.99
			CO3H	2.0	0.7	0.5	0.040	0.34
			CO3L	2.2	1.5	1.0	1.277	0.82
			CO4H	0.2	0.0	0.1	0.0	0.10
			CO4L	1.6	0.3	0.4	0.001	0.29
			CO5H	1.7	0.5	0.5	0.195	0.33
			CO5L	2.1	1.0	0.7	0.868	0.59
			CO1H	2.1	4.4	1.8	0.000	2.57
			CO1L	4.4	15.1	10.6	12.078	7.10
			CO2H	1.6	4.4	3.5	0.018	2.40
			CO2L	4.5	12.4	7.1	10.632	6.39
			CO3H	2.0	4.4	3.5	0.257	2.22
			CO3L	2.2	9.8	6.2	8.253	5.32
			CO4H	0.2	0.0	.9	0.0	0.62
			CO4L	1.6	1.8	2.7	0.009	1.86
			CO5H	1.7	3.5	3.5	1.260	2.13
			CO5L	2.1	6.2	4.4	5.609	3.82

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	13.0	6516	CO1H	0.5	0.3	0.1	0.000	0.38
1445	73°		CO1L	2.9	1.2	1.0	1.821	1.07
	3		CO2H	0.9	0.3	0.3	0.003	0.37
			CO2L	3.7	1.1	0.5	1.611	0.96
			CO3H	1.9	0.0	0.3	0.033	0.34
			CO3L	2.3	0.3	0.4	1.261	0.80
			CO4H	0.3	0.8	0.0	0.0	0.08
			CO4L	1.4	0.1	0.1	0.001	0.29
			CO5H	2.2	0.3	0.3	0.179	0.33
			CO5L	2.3	0.5	0.4	0.863	0.59
			CO1H	0.5	2.0	1.0	0.000	2.76
			CO1L	2.9	8.9	6.9	13.063	7.68
			CO2H	0.9	2.0	2.0	0.020	2.66
			CO2L	3.7	7.9	3.9	11.556	6.90
			CO3H	1.9	0.0	2.0	0.236	2.46
			CO3L	2.3	1.9	2.9	9.044	5.71
			CO4H	0.3	5.9	0.0	0.000	0.59
			CO4L	1.4	1.0	1.0	0.010	2.07
			CO5H	2.2	2.0	2.0	1.281	2.36
			CO5L	2.3	3.9	2.9	6.187	4.24

Table 20. (Con't) Houston at- grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576 1450	1.14 69° 3	6492	CO1H	1.1	0.4	0.1	0.000	0.46
			CO1L	2.5	1.5	1.1	2.006	1.20
			CO2H	1.1	0.4	0.3	0.003	0.45
			CO2L	3.6	1.3	0.7	1.769	1.09
			CO3H	1.8	0.4	0.4	0.042	0.40
			CO3L	2.3	1.0	0.6	1.377	0.92
			CO4H	0.3	0.0	0.0	0.0	0.11
			CO4L	1.4	0.1	0.3	0.001	0.34
			CO5H	1.6	0.4	0.3	0.207	0.39
			CO5L	1.9	0.6	0.4	0.940	0.66
			CO1H	1.1	2.3	0.8	0.000	2.57
			CO1L	2.5	8.6	6.2	11.187	6.70
			CO2H	1.1	2.3	1.6	0.016	2.49
			CO2L	3.6	7.0	3.9	9.863	6.08
			CO3H	1.8	2.3	2.3	0.234	2.26
			CO3L	2.3	5.5	3.1	7.681	5.06
			CO4H	0.3	0.0	0.0	0.0	0.62
			CO4L	1.4	0.8	1.6	0.008	1.87
			CO5H	1.6	2.3	1.6	1.153	2.18
			CO5L	1.9	3.1	2.3	5.243	3.66

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576 1455	10.1 73° 2	6324	C01H	1.7	0.4	0.1	0.001	0.42
			C01L	3.8	1.5	1.1	1.942	1.13
			C02H	1.4	0.4	0.3	0.018	0.39
			C02L	4.2	1.3	0.7	1.615	0.99
			C03H	2.2	0.4	0.3	0.125	0.36
			C03L	2.3	1.0	0.6	1.163	0.77
			C04H	0.2	0.0	0.0	0.0	0.15
			C04L	1.6	0.1	0.3	0.013	0.31
			C05H	1.7	0.4	0.3	0.314	0.35
			C05L	2.3	0.7	0.4	0.736	0.52
			C01H	1.7	2.3	0.8	0.008	2.34
			C01L	3.8	8.6	6.2	10.852	6.31
			C02H	1.4	2.3	1.6	0.101	2.18
			C02L	4.2	7.0	3.9	9.021	5.53
			C03H	2.2	2.3	1.6	0.701	2.03
			C03L	2.3	5.5	3.1	6.497	4.28
			C04H	0.2	0.0	0.0	0.0	0.86
			C04L	1.6	0.8	1.6	0.070	1.71
			C05H	1.7	2.3	1.6	1.753	1.95
			C05L	2.3	3.9	2.3	4.113	2.88

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576 1545	8.4 80° 2	7296	CO1H	1.7	0.8	0.2	0.003	0.64
			CO1L	5.9	2.7	1.9	3.950	1.75
			CO2H	1.1	0.8	0.5	0.027	0.61
			CO2L	5.1	2.2	1.1	3.300	1.52
			CO3H	3.2	0.8	0.5	0.224	0.56
			CO3L	3.8	1.8	0.8	2.384	1.18
			CO4H	0.0	0.0	0.0	0.0	0.24
			CO4L	0.3	0.3	0.3	0.018	0.46
			CO5H	2.0	0.6	0.5	0.615	0.54
			CO5L	2.5	1.1	0.6	1.513	0.82
			CO1H	1.7	2.6	0.5	0.011	2.11
			CO1L	5.9	8.9	6.3	12.995	5.74
			CO2H	1.1	2.6	1.6	0.089	2.00
			CO2L	5.1	7.4	3.7	10.857	5.00
			CO3H	3.2	2.6	1.6	.737	1.84
			CO3L	3.8	5.8	2.6	7.844	0.80
			CO4H	0.0	0.0	0.0	0.0	1.53
			CO4L	0.3	1.1	1.1	.058	1.53
			CO5H	2.0	2.1	1.6	2.033	1.79
			CO5L	2.5	3.7	2.1	4.978	2.69

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052567	7.8	8340	C01H	3.1	0.8	0.2	0.000	0.81
1550	87°		C01L	6.8	3.0	2.1	4.728	1.87
	2		C02H	1.5	0.8	0.6	0.006	0.75
			C02L	6.2	2.4	1.2	4.062	1.63
			C03H	3.0	0.8	0.6	0.197	0.69
			C03L	4.8	1.8	0.9	2.723	1.28
			C04H	0.0	0.0	0.0	0.0	0.29
			C04L	0.6	0.3	0.3	0.011	0.59
			C05H	2.1	0.8	0.6	0.712	0.63
			C05L	2.7	1.2	0.8	1.482	0.89
			C01H	3.1	2.4	0.5	0.000	2.63
			C01L	6.8	9.7	6.8	15.272	6.03
			C02H	1.5	2.4	1.9	0.019	2.43
			C02L	6.2	7.8	3.9	13.121	5.25
			C03H	3.0	2.4	1.9	0.637	2.24
			C03L	4.8	5.8	2.9	8.796	4.14
			C04H	0.0	0.0	0.0	0.000	0.92
			C04L	0.6	0.9	0.9	0.034	1.89
			C05H	2.1	2.4	1.9	2.301	2.04
			C05L	2.7	3.9	2.4	4.787	2.87

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	7.9	8472	CO1H	2.5	0.7	0.1	0.000	0.59
1600	88°		CO1L	4.5	2.7	1.9	4.233	1.68
	1		CO2H	1.2	0.7	0.6	0.004	0.53
			CO2L	4.5	2.3	1.0	3.656	1.42
			CO3H	2.4	0.7	0.6	0.168	0.52
			CO3L	3.8	1.7	0.7	2.450	1.06
			CO4H	0.2	0.0	0.0	0.0	0.26
			CO4L	0.6	0.3	0.4	0.009	0.42
			CO5H	2.5	0.7	0.4	0.633	0.50
			CO5L	3.5	1.1	0.6	1.330	0.67
			CO1H	2.5	2.1	0.4	0.000	1.70
			CO1L	4.5	7.9	5.4	12.208	4.84
			CO2H	1.2	2.1	1.7	0.012	1.53
			CO2L	4.5	6.6	2.9	10.545	4.09
			CO3H	2.4	2.1	1.7	0.484	1.49
			CO3L	3.8	4.9	2.1	7.066	3.06
			CO4H	0.2	0.0	0.0	0.000	0.74
			CO4L	0.6	0.8	1.2	0.025	1.20
			CO5H	2.5	2.1	1.2	1.824	1.45
			CO5L	3.5	3.3	1.7	3.835	1.94

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576 1610	10.8 67° 2	11352	CO1H	1.1	0.7	0.3	0.006	0.76
			CO1L	3.9	2.7	1.8	3.266	2.00
			CO2H	0.4	0.7	0.6	0.041	0.70
			CO2L	3.5	2.1	1.1	2.699	1.73
			CO3H	2.1	0.7	0.6	0.241	0.66
			CO3L	2.8	1.5	0.8	1.931	1.34
			CO4H	0.2	0.0	0.0	0.0	0.30
			CO4L	0.6	0.3	0.4	0.028	0.55
			CO5H	1.9	0.6	0.6	0.548	0.63
			CO5L	2.2	1.1	0.7	1.218	0.90
			CO1H	1.1	1.4	0.6	0.012	1.56
			CO1L	3.9	5.5	3.8	6.720	4.11
			CO2H	0.4	1.4	1.2	0.084	1.45
			CO2L	3.5	4.3	2.3	5.549	3.56
			CO3H	2.1	1.4	1.2	0.495	1.36
			CO3L	2.8	3.2	1.7	3.972	2.75
			CO4H	0.2	0.0	0.0	0.000	0.61
			CO4L	0.6	0.6	0.9	0.058	1.23
			CO5H	1.9	1.2	1.2	1.126	1.30
			CO5L	2.2	2.3	1.4	2.504	1.85

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	10.2	6732	CO1H	1.3	0.4	0.1	0.001	0.43
1615	77°		CO1L	4.0	1.7	1.2	1.994	1.17
	2		CO2H	0.9	0.4	0.3	0.015	0.40
			CO2L	4.0	1.4	0.7	1.667	1.09
			CO3H	2.3	0.4	0.3	0.116	0.37
			CO3L	2.7	1.0	0.6	1.208	0.80
			CO4H	0.0	0.0	0.0	0.0	0.15
			CO4L	0.3	0.1	0.3	0.010	0.32
			CO5H	1.5	0.4	0.3	0.312	0.36
			CO5L	1.9	0.7	0.4	0.768	0.54
			CO1H	1.3	1.5	0.5	0.005	1.54
			CO1L	4.0	5.9	4.5	7.181	4.21
			CO2H	0.9	1.5	1.0	0.054	1.45
			CO2L	4.0	5.0	2.5	6.002	3.91
			CO3H	2.3	1.5	1.0	0.416	1.34
			CO3L	2.7	3.5	2.0	4.348	2.87
			CO4H	0.0	0.0	0.0	0.000	0.54
			CO4L	0.3	0.5	1.0	0.035	1.34
			CO5H	1.5	1.5	1.0	1.124	1.29
			CO5L	1.9	2.5	1.5	2.764	1.93

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	8.2	8424	CO1H	2.0	0.7	0.1	0.001	0.65
1625	89°		CO1L	5.0	2.6	1.8	3.458	1.66
	2		CO2H	1.2	0.7	0.6	0.023	0.61
			CO2L	4.7	2.2	1.1	2.898	1.45
			CO3H	2.4	0.7	0.6	0.198	0.55
			CO3L	3.5	1.7	0.8	2.106	1.13
			CO4H	0.1	0.0	0.0	0.0	0.23
			CO4L	0.4	0.3	0.3	0.015	0.47
			CO5H	2.0	0.7	0.6	0.540	0.52
			CO5L	2.2		0.7	1.343	0.77
			CO1H	2.0	2.0	0.4	0.004	1.91
			CO1L	5.0	7.7	5.3	10.165	4.87
			CO2H	1.2	2.0	1.6	0.069	1.79
			CO2L	4.7	6.5	3.2	8.517	4.26
			CO3H	2.4	2.0	1.6	0.580	1.62
			CO3L	3.5	4.9	2.4	6.191	3.33
			CO4H	0.1	0.6	0.0	0.000	0.69
			CO4L	0.4	0.8	0.8	0.045	1.38
			CO5H	2.0	2.0	1.6	1.587	1.54
			CO5L	2.2	3.2	2.0	3.950	2.27

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
052576	10.7	8064	C01H	0.9	0.4	0.3	0.000	0.64
1635	64°		C01L	3.5	1.8	1.4	2.419	1.55
	3		C02H	0.4	0.5	0.4	0.005	0.61
			C02L	3.5	1.5	1.0	2.122	1.40
			C03H	2.0	0.5	0.4	0.060	0.56
			C03L	2.9	1.1	0.7	1.642	1.16
			C04H	0.1	0.0	0.1	0.0	0.16
			C04L	0.5	0.3	0.3	0.003	0.46
			C05H	1.1	0.4	0.4	0.267	0.52
			C05L	1.7	0.7	0.5	1.113	0.84
			C01H	0.9	1.0	0.7	0.000	1.57
			C01L	3.5	4.3	3.3	5.919	3.80
			C02H	0.4	1.3	1.0	0.013	1.50
			C02L	3.5	3.7	2.3	5.192	3.43
			C03H	2.0	1.3	1.0	0.147	1.37
			C03L	2.9	2.7	1.7	4.018	2.83
			C04H	0.1	0.0	0.3	0.00	0.400
			C04L	0.5	0.7	0.7	0.007	1.13
			C05H	1.1	1.0	1.0	0.654	1.27
			C05L	1.7	1.7	1.3	2.725	2.07

Table 20 (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
011277 1805	12.3 14° 4	7692	CO1H	0.8	0.5	2.4	0.528	1.93
			CO1L	3.0	2.3	3.1	11.098	5.65
			CO2H	2.0	0.7	2.3	0.995	1.89
			CO2L	2.6	1.9	2.9	8.829	4.67
			CO3H	2.3	0.7	2.0	1.850	1.94
			CO3L	0.1	1.3	2.5	6.011	3.44
			CO4H	0.2	0.0	0.5	0.033	0.93
			CO4L	0.4	0.3	1.7	0.739	1.50
			CO5H	0.3	0.5	1.3	2.294	1.77
			CO5L	0.6	0.9	1.6	3.730	2.27
			CO1H	0.8	0.3	1.3	0.288	1.05
			CO1L	3.0	1.2	1.7	6.064	3.09
			CO2H	2.0	0.4	1.2	0.544	1.03
			CO2L	2.6	1.0	1.6	4.825	2.55
			CO3H	2.3	0.4	1.1	1.011	1.06
			CO3L	0.1	0.7	1.4	3.28	1.88
			CO4H	0.2	0.0	0.3	0.018	0.51
			CO4L	0.4	0.1	0.9	0.404	0.82
			CO5H	0.3	0.3	0.7	1.254	0.97
			CO5L	0.6	0.5	0.9	2.038	1.24

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
011277 1820	14.1 14° 4	7584	CO1H	0.7	0.5	1.9	0.415	1.70
			CO1L	2.3	1.9	2.5	8.635	4.81
			CO2H	1.3	0.5	1.9	0.855	1.66
			CO2L	2.0	1.6	2.3	6.870	3.99
			CO3H	2.0	0.5	1.7	1.446	1.68
			CO3L	-0.1	1.2	2.1	4.681	2.94
			CO4H	-0.3	0.0	0.4	0.027	0.83
			CO4L	0.5	0.3	1.4	0.580	1.31
			CO5H	0.3	0.4	1.2	1.790	1.53
			CO5L	0.6	0.8	1.3	2.907	1.95
			CO1H	0.7	0.3	1.2	0.252	1.03
			CO1L	2.3	1.1	1.5	5.230	2.92
			CO2H	1.3	0.3	1.2	0.473	1.00
			CO2L	2.0	0.9	1.4	4.160	2.41
			CO3H	2.0	0.3	1.0	0.876	1.02
			CO3L	-0.1	0.7	1.3	2.835	1.78
			CO4H	-0.3	0.0	0.2	0.016	0.50
			CO4L	0.5	0.2	0.9	0.351	0.79
			CO5H	0.3	0.2	0.7	1.084	0.92
			CO5L	0.6	0.5	0.8	1.760	1.18

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
011277	15.1	7164	CO1H	0.5	0.4	1.7	0.386	1.37
1825	14°		CO1L	3.0	1.6	2.1	8.353	4.36
	4		CO2H	2.0	0.4	1.6	0.733	1.35
			CO2L	2.8	1.3	2.1	6.645	3.59
			CO3H	2.7	0.4	1.5	1.376	1.43
			CO3L	0.5	0.9	1.9	4.515	2.64
			CO4H	0.1	0.0	0.4	0.025	0.66
			CO4L	0.5	0.1	1.2	0.548	1.07
			CO5H	0.5	0.4	0.9	1.716	1.33
			CO5L	0.9	0.7	1.2	2.796	1.74
			CO1H	0.5	0.7	3.2	0.720	2.55
			CO1L	3.0	3.0	4.0	15.589	8.14
			CO2H	2.0	0.7	3.0	1.368	2.52
			CO2L	2.8	2.5	4.0	12.402	6.71
			CO3H	2.7	0.7	2.7	2.569	2.67
			CO3L	0.5	1.7	3.5	8.426	4.92
			CO4H	0.1	0.0	0.7	0.047	1.24
			CO4L	0.5	0.2	2.2	1.022	2.00
			CO5H	0.5	0.7	1.7	3.202	2.47
			CO5L	0.9	1.2	2.2	5.219	3.24

Table 20. (Con't) Houaton at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
011277	7.4	6240	CO1H	1.5	0.8	5.5	0.39	2.35
1855	12°		CO1L	3.0	3.1	7.6	17.402	8.24
	5		CO2H	2.8	0.8	5.3	0.888	2.31
			CO2L	2.8	2.4	7.1	14.386	7.00
			CO3H	2.7	0.8	4.4	2.112	2.45
			CO3L	0.4	1.8	5.9	10.179	5.30
			CO4H	0.1	0.0	0.6	0.009	1.02
			CO4L	0.4	0.4	3.5	0.613	1.80
			CO5H	0.3	0.8	2.6	3.289	2.47
			CO5L	0.2	1.2	3.2	6.558	3.61
			CO1H	1.5	0.3	2.1	0.149	0.90
			CO1L	3.0	1.2	2.9	6.617	3.14
			CO2H	2.8	0.3	2.0	0.338	0.88
			CO2L	2.8	0.9	2.7	5.470	2.67
			CO3H	2.7	0.3	1.7	0.803	0.93
			CO3L	0.4	0.69	2.2	3.871	2.01
			CO4H	0.1	0.0	0.2	0.003	0.39
			CO4L	0.4	0.1	1.3	0.233	0.69
			CO5H	0.3	0.3	1.0	1.250	0.94
			CO5L	0.2	0.4	1.2	2.494	1.37

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
011377 1130	14.3 13° 4	4968	CO1H	-	0.3	1.2	0.354	0.88
			CO1L	1.7	1.1	1.5	6.394	3.33
			CO2H	-1.0	0.3	1.2	0.637	0.91
			CO2L	1.8	1.0	1.5	5.024	2.71
			CO3H	1.1	0.3	1.1	1.120	1.02
			CO3L	0.8	0.7	1.2	3.362	1.95
			CO4H	0.3	0.0	0.3	0.030	0.44
			CO4L	1.5	0.1	0.8	0.449	0.72
			CO5H	1.1	0.3	0.7	1.320	0.95
			CO5L	0.5	0.4	0.8	2.061	1.25
			CO1H	-	0.6	2.6	0.737	1.84
			CO1L	1.7	2.3	3.1	13.330	6.95
			CO2H	-1.0	0.6	2.6	1.327	1.90
			CO2L	1.8	2.0	3.1	10.474	5.64
			CO3H	1.1	0.6	2.3	2.334	2.13
			CO3L	0.8	1.4	2.6	7.008	4.06
			CO4H	0.3	0.0	0.6	0.062	0.91
			CO4L	1.5	0.3	1.7	0.936	1.50
			CO5H	1.1	0.6	1.4	2.751	1.99
			CO5L	0.5	0.9	1.7	4.297	2.61

Table 20. (Con't) Houston at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
080377 1430	5.1 61° 1	2688	CO1H	2.2	0.0	0.3	0.072	0.47
			CO1L	0.8	2.2	0.3	1.363	0.55
			CO2H	1.5	0.0	0.3	0.271	0.30
			CO2L	1.1	1.9	0.3	0.845	0.39
			CO3H	1.1	0.0	0.3	0.310	0.25
			CO3L	1.1	1.7	0.3	0.610	0.30
			CO4H	0.1	0.0	0.0	0.020	0.19
			CO4L	0.2	0.0	0.0	0.203	0.22
			CO5H	0.8	0.2	0.0	0.305	0.20
			CO5L	-0.3	0.9	0.0	0.421	0.22
			CO1H	2.2	0.0	0.8	0.185	1.21
			CO1L	0.8	5.6	0.8	3.512	1.41
			CO2H	1.5	0.0	0.8	0.698	0.77
			CO2L	1.1	4.8	0.8	2.177	1.01
			CO3H	1.1	0.0	0.8	0.798	0.65
			CO3L	1.1	4.4	0.8	1.573	0.77
			CO4H	0.1	0.0	0.0	0.052	0.48
			CO4L	0.2	0.0	0.0	0.524	0.56
			CO5H	0.8	0.4	0.0	0.786	0.52
			CO5L	-0.3	2.4	0.0	1.085	0.56

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
080377 1445	6.5 44° 1	2868	CO1H	1.8	0.0	0.3	0.103	0.53
			CO1L	0.8	2.0	0.3	1.348	0.61
			CO2H	0.5	0.0	0.2	0.294	0.31
			CO2L	-0.1	1.7	0.3	0.692	0.36
			CO3H	0.5	0.0	0.2	0.309	0.25
			CO3L	0.2	1.2	0.2	0.504	0.28
			CO4H	0.1	0.0	0.0	0.037	0.20
			CO4L	0.2	0.0	0.0	-.219	0.23
			CO5H	0.5	0.2	0.0	0.278	0.20
			CO5L	-0.6	--	0.0	0.353	0.20
			CO1H	1.8	0.0	0.5	0.160	0.83
			CO1L	0.8	3.2	0.5	2.106	0.95
			CO2H	0.5	0.0	0.2	0.459	0.49
			CO2L	-0.1	2.7	0.5	0.081	0.56
			CO3H	0.5	0.0	0.2	0.483	0.39
			CO3L	0.2	1.9	0.2	0.787	0.44
			CO4H	0.1	0.0	0.0	0.058	0.32
			CO4L	0.2	0.0	0.0	0.342	0.36
			CO5H	0.5	0.2	0.0	0.435	0.32
			CO5L	-0.6	1.7	0.0	0.551	0.32

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
080377	4.4	2856	CO1H	1.5	0.0	0.3	0.121	0.61
1450	47°		CO1L	0.9	3.0	0.5	1.867	0.70
	1		CO2H	0.6	0.0	0.3	0.392	0.36
			CO2L	0.0	2.6	0.3	1.061	0.45
			CO3H	0.5	0.2	0.3	0.429	0.31
			CO3L	0.1	2.2	0.3	0.764	0.34
			CO4H	-0.1	0.0	0.0	0.042	0.23
			CO4L	0.4	0.0	0.3	0.297	0.26
			CO5H	0.4	0.3	0.3	0.403	0.23
			CO5L	-0.6	1.7	0.3	0.529	0.25
			CO1H	1.5	0.0	0.4	0.141	0.71
			CO1L	0.9	3.4	0.5	2.176	0.82
			CO2H	0.6	0.0	0.4	0.467	0.42
			CO2L	0.0	3.1	0.4	1.237	0.53
			CO3H	0.5	0.2	0.4	0.500	0.36
			CO3L	0.1	2.5	0.4	0.890	0.40
			CO4H	-0.1	0.0	0.0	0.049	0.27
			CO4L	0.4	0.0	0.4	0.346	0.31
			CO5H	0.4	0.4	0.4	0.470	0.27
			CO5L	-0.6	2.0	0.4	0.616	0.29

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177 0725	2.3 83° 4	4780	CO1H	1.7	0.0	1.3	0.034	1.79
			CO1L	2.5	11.0	2.6	6.508	1.94
			CO2H	2.3	0.5	1.5	0.157	1.49
			CO2L	2.4	9.2	2.3	5.738	1.79
			CO3H	1.4	0.8	1.5	0.296	1.36
			CO3L	1.8	7.9	2.1	5.051	1.60
			CO4H	-0.2	0.0	0.0	0.0	0.90
			CO4L	0.7	0.2	0.8	0.044	1.21
			CO5H	-	1.0	1.3	0.551	1.18
			CO5L	0.8	5.8	1.8	4.272	1.37
			CO1H	1.7	0.0	1.3	0.034	1.81
			CO1L	2.5	11.1	2.6	6.559	1.95
			CO2H	2.3	0.5	1.5	0.158	1.50
			CO2L	2.4	9.3	2.3	5.782	1.81
			CO3H	1.4	0.8	1.5	0.298	1.37
			CO3L	1.8	8.0	2.1	5.090	1.61
			CO4H	-0.2	0.0	0.0	0.0	0.91
			CO4L	0.7	0.2	0.8	0.044	1.22
			CO5H		1.0	1.3	0.555	1.19
			CO5L	0.8	5.9	1.8	4.305	1.38

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177	2.9	4065	CO1H	1.5	0.0	0.7	0.024	1.56
0730	88°		CO1L	2.3	6.9	1.5	5.987	1.65
	4		CO2H	2.0	0.2	0.7	0.131	1.28
			CO2L	2.1	5.2	1.5	4.932	1.43
			CO3H	1.0	0.3	0.7	0.257	1.16
			CO3L	1.5	4.4	1.2	4.352	1.28
			CO4H	-0.1	0.0	0.0	0.0	0.79
			CO4L	0.6	0.2	0.5	0.034	1.04
			CO5H	-	0.5	0.7	0.482	1.01
			CO5L	0.4	3.5	1.2	3.698	1.09
			CO1H	1.5	0.0	0.7	0.024	1.61
			CO1L	2.3	7.1	1.6	6.180	1.70
			CO2H	2.0	0.2	0.7	0.135	1.32
			CO2L	2.1	5.4	1.6	5.091	1.47
			CO3H	1.0	0.3	0.7	0.265	1.20
			CO3L	1.5	4.5	1.2	4.493	1.32
			CO4H	-0.1	0.0	0.0	0.0	0.82
			CO4L	0.6	0.2	0.5	0.035	1.08
			CO5H		0.5	0.7	0.498	1.04
			CO5L	0.4	3.6	1.2	3.818	1.13

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177 0735	3.6 85° 4	4276	CO1H	1.2	0.0	0.5	0.018	1.44
			CO1L	2.0	5.2	1.1	4.136	1.55
			CO2H	2.4	0.2	0.5	0.089	1.20
			CO2L	2.6	4.2	1.1	3.416	1.34
			CO3H	1.0	0.2	0.5	0.176	1.08
			CO3L	1.8	3.2	1.0	3.009	1.21
			CO4H	-0.1	0.0	0.0	0.0	0.73
			CO4L	0.4	0.0	0.5	0.023	0.97
			CO5H	–	0.5	0.5	0.333	0.94
			CO5L	0.6	2.6	0.6	2.554	1.04
			CO1H	1.2	0.0	0.6	0.024	1.91
			CO1L	2.0	6.9	1.5	5.470	2.06
			CO2H	2.4	0.2	0.6	0.118	1.58
			CO2L	2.6	5.6	1.5	4.517	1.78
			CO3H	1.0	0.2	0.6	0.233	1.43
			CO3L	1.8	4.3	1.3	3.980	1.61
			CO4H	-0.1	0.0	0.0	0.000	0.96
			CO4L	0.4	0.0	0.6	0.030	1.28
			CO5H		0.6	0.6	0.441	1.24
			CO5L	0.6	3.4	0.9	3.378	1.37

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177 0935	5.3 69° 2	2617	CO1H	0.8	0.0	0.3	0.081	0.51
			CO1L	0.1	2.4	0.3	1.616	0.59
			CO2H	–	0.0	0.3	0.311	0.35
			CO2L	1.1	1.9	0.3	1.053	0.41
			CO3H	1.1	1.4	0.3	0.378	0.30
			CO3L	0.4	0.0	0.3	0.848	0.33
			CO4H	0.0	0.0	0.0	0.005	0.22
			CO4L	0.9	0.0	0.2	0.206	0.27
			CO5H	–	0.2	0.3	0.440	0.24
			CO5L	0.3	1.1	0.3	0.660	0.25
			CO1H	0.8	0.0	1.3	0.332	2.09
			CO1L	0.1	9.8	1.3	6.609	2.41
			CO2H		0.0	1.3	1.271	1.43
			CO2L	1.1	7.8	1.3	4.309	1.69
			CO3H	1.1	5.9	1.3	1.545	1.24
			CO3L	0.4	0.0	1.3	3.468	1.37
			CO4H	0.0	0.0	0.0	0.020	0.91
			CO4L	0.9	0.0	0.7	0.841	1.11
			CO5H		0.7	1.3	1.799	0.98
			CO5L	0.3	4.6	1.3	0.270	1.04

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177 0940	5.3 49° 2	2565	C01H	0.6	0.0	0.3	0.216	0.56
			C01L	-	2.2	0.3	2.117	0.64
			C02H	-	0.0	0.3	0.533	0.37
			C02L	0.9	1.9	0.3	1.317	0.43
			C03H	0.8	0.0	0.3	0.584	0.32
			C03L	0.1	1.6	0.3	1.046	0.35
			C04H	0.2	0.0	0.0	0.030	0.24
			C04L	0.9	0.0	0.3	0.377	0.29
			C05H	-	0.2	0.3	0.573	0.26
			C05L	0.3	1.3	0.3	0.808	0.27
			C01H	0.6	0.0	0.8	0.515	1.34
			C01L	-	5.3	0.8	5.063	1.53
			C02H	-	0.0	0.8	1.275	0.88
			C02L	0.9	4.6	0.8	3.150	1.03
			C03H	0.8	0.0	0.8	1.398	0.76
			C03L	0.1	3.8	0.8	2.501	0.84
			C04H	0.2	0.0	0.0	0.069	0.57
			C04L	0.9	0.0	0.8	0.901	0.69
			C05H	-	0.4	0.8	1.371	0.61
			C05L	0.3	3.1	0.8	1.932	0.65

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177	5.6	2384	CO1H	0.7	0.0	0.2	0.128	0.46
0945	62°		CO1L	-0.1	1.8	0.3	1.786	0.51
	2		CO2H	-	0.0	0.2	0.390	0.32
			CO2L	1.0	1.1	0.3	1.204	0.38
			CO3H	1.0	0.0	0.2	0.455	0.27
			CO3L	0.2	1.1	0.3	0.963	0.30
			CO4H	0.4	0.0	0.0	0.010	0.21
			CO4L	1.0	0.0	0.0	0.263	0.24
			CO5H	-	0.2	0.0	0.79	0.22
			CO5L	0.3	1.0	0.3	0.745	0.24
			CO1H	0.7	0.0	0.1	0.561	2.03
			CO1L	-0.1	7.7	1.4	7.842	2.24
			CO2H	-	0.0	0.7	1.710	1.40
			CO2L	1.0	4.9	1.4	5.284	1.68
			CO3H	1.0	0.0	0.7	1.997	1.19
			CO3L	0.2	4.9	1.4	4.226	1.33
			CO4H	0.4	0.0	0.0	0.042	0.91
			CO4L	1.0	0.0	0.0	1.156	1.05
			CO5H	-	0.7	0.0	2.102	0.98
			CO5L	0.3	4.2	1.4	3.273	1.05

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177 1400	3.7 61° 1	2868	C01H	1.3	0.0	0.3	0.141	0.56
			C01L	0.4	2.8	0.3	2.496	0.64
			C02H		0.0	0.3	0.500	0.36
			C02L	-0.1	2.7	0.3	1.593	0.47
			C03H	0.1	0.2	0.3	0.577	0.31
			C03L	0.0	2.2	0.3	1.149	0.38
			C04H	0.3	0.0	0.0	0.041	0.23
			C04L	0.5	0.0	0.3	0.381	0.26
			C05H		0.3	0.3	0.572	0.25
			C05L	-0.5	1.7	0.3	0.789	0.26
			C01H	1.3	0.0	0.3	0.114	0.46
			C01L	0.4	2.3	0.3	2.025	0.52
			C02H		0.0	0.3	0.406	0.29
			C02L	-0.1	2.2	0.3	1.292	0.38
			C03H	0.1	0.1	0.3	0.468	0.25
			C03L	0.0	1.8	0.3	0.932	0.30
			C04H	0.3	0.0	0.0	0.033	0.19
			C04L	0.5	0.0	0.3	0.309	0.22
			C05H		0.3	0.3	0.464	0.20
			C05L	-0.5	1.4	0.3	0.640	0.22

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
08117 1435	9.9 66° 2	3126	CO1H	1.2	0.0	0.2	0.048	0.38
			CO1L	0.6	1.1	0.3	0.846	0.45
			CO2H	-	0.0	0.0	0.178	0.26
			CO2L	0.6	1.1	0.3	0.642	0.34
			CO3H	0.3	0.0	0.0	0.220	0.23
			CO3L	0.4	0.8	0.2	0.510	0.28
			CO4H	0.1	0.0	0.0	0.003	0.17
			CO4L	0.3	0.0	0.0	0.121	0.20
			CO5H	-	0.0	0.0	0.240	0.18
			CO5L	-0.3	0.8	0.0	0.390	0.22
			CO1H	1.2	0.0	0.3	0.105	0.85
			CO1L	0.6	2.4	0.7	1.874	0.99
			CO2H		0.0	0.0	0.395	0.58
			CO2L	0.6	2.4	0.7	1.422	0.75
			CO3H	0.3	0.0	0.0	0.486	0.51
			CO3L	0.4	1.7	0.3	1.129	0.61
			CO4H	0.1	0.0	0.0	0.007	0.37
			CO4L	0.3	0.0	0.0	0.269	0.44
			CO5H		0.0	0.0	0.531	0.41
			CO5L	-0.3	1.7	0.0	0.864	0.48

Table 20. (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
081177	5.9	2699	CO1H	1.5	0.0	0.3	0.216	0.61
1500	40°		CO1L	0.8	2.0	0.3	1.679	0.70
	2		CO2H	-	0.0	0.3	0.459	0.38
			CO2L	0.3	1.5	0.3	0.966	0.43
			CO3H	0.5	0.0	0.3	0.475	0.32
			CO3L	0.1	1.2	0.3	0.760	0.35
			CO4H	0.3	0.0	0.0	0.043	0.24
			CO4L	0.5	0.0	0.3	0.332	0.29
			CO5H	-	0.0	0.3	0.445	0.26
			CO5L	-0.3	0.9	0.3	0.582	0.26
			CO1H	1.5	0.0	0.7	0.509	1.44
			CO1L	0.8	4.7	0.7	3.964	1.67
			CO2H		0.0	0.7	1.083	0.90
			CO2L	0.3	3.6	0.7	2.282	1.01
			CO3H	0.5	0.0	0.7	1.123	0.76
			CO3L	0.1	2.9	0.7	1.794	0.83
			CO4H	0.3	0.0	0.0	0.101	0.58
			CO4L	0.5	0.0	0.7	0.783	0.69
			CO5H		0.0	0.7	1.051	0.61
			CO5L	-0.3	2.2	0.7	1.376	0.61

Table 20 (Con't) Dallas at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677 1130	6.9 31° 2	5724	CO1H	1.5	0.5	0.9	0.966	1.14
			CO1L	2.4	2.0	1.0	3.337	1.52
			CO2H	0.6	0.5	0.9	1.055	1.07
			CO2L	0.4	2.0	0.9	2.931	1.36
			CO3H	0.5	0.7	0.7	1.172	0.77
			CO3L	1.2	1.4	0.9	1.856	0.92
			CO4H	0.1	0.0	0.2	0.044	0.78
			CO4L	0.4	0.2	0.7	0.559	0.99
			CO5H	-	0.7	0.3	0.992	0.60
			CO5L	-0.8	0.8	0.7	1.208	0.63
			CO1H	1.5	0.3	0.5	0.558	0.69
			CO1L	2.4	1.2	0.6	2.031	0.92
			CO2H	0.6	0.3	0.5	0.642	0.65
			CO2L	0.4	1.2	0.5	1.784	0.83
			CO3H	0.5	0.4	0.4	0.714	0.51
			CO3L	1.2	0.8	0.5	1.129	0.56
			CO4H	0.1	0.0	0.1	0.027	0.48
			CO4L	0.4	0.1	0.4	0.340	0.60
			CO5H	-	0.4	0.2	0.604	0.36
			CO5L	-0.8	0.5	0.4	0.735	0.38

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	7.0	6288	C01H	1.3	0.6	0.8	0.607	1.07
1135	38°		C01L	2.6	2.3	0.9	2.720	1.39
	2		C02H	1.4	0.5	0.8	0.693	1.26
			C02L	1.2	2.0	0.9	2.419	0.99
			C03H	0.6	0.6	0.6	0.884	0.78
			C03L	1.7	1.4	0.8	16.797	0.87
			C04H	0.2	0.0	0.2	0.008	0.68
			C04L	0.4	0.2	0.5	0.300	0.91
			C05H	-	0.5	0.5	0.810	0.56
			C05L	-0.5	0.9	0.6	1.046	0.59
			C01H	1.3	0.9	1.1	0.862	1.51
			C01L	2.6	3.2	1.3	3.860	1.97
			C02H	1.4	0.6	1.1	0.983	1.79
			C02L	1.2	2.8	1.3	3.422	1.40
			C03H	0.6	0.9	0.9	1.255	1.10
			C03L	1.7	1.9	1.1	2.236	1.23
			C04H	0.2	0.0	0.2	0.011	0.97
			C04L	0.4	0.2	0.6	0.426	1.30
			C05H	-	0.6	0.6	1.149	0.80
			C05L	-0.5	1.3	0.9	1.484	0.84

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	8.0	6396	CO1H	1.7	0.5	0.8	1.165	1.25
1140	2.3°		CO1L	2.2	2.1	1.0	2.874	1.59
	2		CO2H	0.7	0.5	0.8	1.199	1.17
			CO2L	0.4	1.9	0.8	2.495	1.41
			CO3H	0.5	0.5	0.6	1.111	0.88
			CO3L	1.1	1.1	0.8	1.525	0.92
			CO4H	0.4	0.0	0.3	0.131	0.89
			CO4L	0.7	0.2	0.5	0.768	1.09
			CO5H	-	0.5	0.3	0.893	0.60
			CO5L	-0.7	0.8	0.5	0.939	0.62
			CO1H	1.7	0.4	0.7	1.061	1.14
			CO1L	2.2	1.9	0.9	2.619	1.45
			CO2H	0.7	0.4	0.7	1.092	1.06
			CO2L	0.4	1.8	0.7	2.273	1.29
			CO3H	0.5	0.4	0.6	1.012	0.80
			CO3L	1.1	1.0	0.7	1.389	0.84
			CO4H	0.4	0.0	0.3	0.120	0.81
			CO4L	0.7	0.1	0.4	0.699	0.99
			CO5H	-	0.4	0.3	0.745	0.55
			CO5L	-0.7	0.7	0.4	0.856	0.56

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677 1150	6.6 26° 1	6120	CO1H	0.9	0.5	0.3	1.071	1.02
			CO1L	1.4	2.2	0.5	3.095	1.35
			CO2H	0.7	0.5	0.3	1.099	0.96
			CO2L	0.5	1.9	0.5	2.590	1.18
			CO3H	0.3	0.7	0.3	0.979	0.68
			CO3L	1.0	1.4	0.3	1.348	0.73
			CO4H	0.2	0.0	0.2	0.201	0.72
			CO4L	0.4	0.2	0.3	0.740	0.87
			CO5H	–	0.5	0.2	0.650	0.46
			CO5L	-0.7	0.7	0.2	0.725	0.46
			CO1H	0.9	0.3	0.2	0.636	0.61
			CO1L	1.4	1.3	0.3	1.837	0.80
			CO2H	0.7	0.3	0.2	0.652	0.57
			CO2L	0.5	1.1	0.3	1.537	0.70
			CO3H	0.3	0.4	0.2	0.581	0.41
			CO3L	1.0	0.8	0.2	0.800	0.44
			CO4H	0.2	0.0	0.1	0.119	0.43
			CO4L	0.4	0.1	0.2	0.439	0.52
			CO5H	–	0.3	0.1	0.386	0.27
			CO5L	-0.7	0.4	0.1	0.430	0.27

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677 1155	7.4 27° 1	5892	CO1H	0.9	0.5	0.3	0.883	0.90
			CO1L	1.1	2.2	0.5	2.603	1.19
			CO2H	0.5	0.5	0.3	0.911	0.85
			CO2L	0.1	1.9	0.3	2.185	1.04
			CO3H	0.2	0.7	0.3	0.827	0.61
			CO3L	0.7	1.2	0.3	1.148	0.65
			CO4H	0.2	0.0	0.2	0.157	0.65
			CO4L	0.3	0.2	0.3	0.607	0.78
			CO5H	-	0.3	0.2	0.558	0.41
			CO5L	-0.6	0.9	0.2	0.623	0.41
			CO1H	0.9	0.3	0.2	0.390	0.40
			CO1L	1.1	1.0	0.3	1.149	0.53
			CO2H	0.5	0.2	0.2	0.402	0.38
			CO2L	0.1	0.8	0.2	0.964	0.46
			CO3H	0.2	0.3	0.2	0.365	0.27
			CO3L	0.7	0.5	0.2	0.507	0.29
			CO4H	0.2	0.0	0.1	0.069	0.29
			CO4L	0.3	0.1	0.2	0.268	0.35
			CO5H	-	0.2	0.1	0.246	0.18
			CO5L	-0.6	0.4	0.1	0.274	0.18

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	5.8	6060	CO1H	0.9	0.7	0.3	0.613	0.90
1200	43°		CO1L	1.5	2.5	0.7	3.365	1.25
	1		CO2H	1.1	0.7	0.3	0.713	0.84
			CO2L	0.8	2.1	0.7	2.920	1.11
			CO3H	0.5	0.7	0.3	0.931	0.64
			CO3L	1.1	1.5	0.5	1.648	0.74
			CO4H	0.0	0.0	0.2	0.025	0.59
			CO4L	0.3	0.2	0.3	0.339	0.77
			CO5H	–	0.7	0.3	0.777	0.46
			CO5L	-0.6	–	0.3	0.943	0.48
			CO1H	0.9	0.6	0.3	0.532	0.78
			CO1L	1.5	2.1	0.6	2.919	1.08
			CO2H	1.1	0.6	0.3	0.619	0.73
			CO2L	0.8	1.8	0.6	2.533	0.97
			CO3H	0.5	0.6	0.3	0.808	0.55
			CO3L	1.1	1.3	0.4	1.429	0.64
			CO4H	0.0	0.0	0.1	0.021	0.51
			CO4L	0.3	0.1	0.3	0.294	0.67
			CO5H	–	0.6	0.3	0.674	0.40
			CO5L	-0.6	0.7	0.3	0.818	0.41

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	6.7	6564	CO1H	1.1	0.5	0.7	0.624	1.09
1210	43°		CO1L	1.9	2.4	0.9	3.575	1.50
	2		CO2H	1.7	0.5	0.7	0.738	1.04
			CO2L	1.2	2.0	0.9	3.191	1.37
			CO3H	0.5	0.7	0.7	1.052	0.82
			CO3L	1.0	1.4	0.9	2.089	0.96
			CO4H	0.2	0.0	0.2	0.003	0.68
			CO4L	0.5	0.2	0.5	0.273	0.96
			CO5H	-	0.7	0.3	1.028	0.61
			CO5L	-0.5	0.9	0.7	1.392	0.67
			CO1H	1.1	0.9	1.1	1.037	1.82
			CO1L	1.9	4.0	1.4	5.944	2.50
			CO2H	1.7	0.9	1.1	1.227	1.73
			CO2L	1.2	3.4	1.4	5.305	2.27
			CO3H	0.5	1.1	1.1	1.749	1.36
			CO3L	1.0	2.3	1.4	3.473	1.59
			CO4H	0.2	0.0	0.3	0.006	1.14
			CO4L	0.5	0.3	0.9	0.454	1.59
			CO5H	-	1.1	0.6	1.710	1.02
			CO5L	-0.5	1.4	1.1	2.314	1.11

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	5.0	5508	CO1H	0.3	0.0	0.5	0.946	0.99
1225	34°		CO1L	1.0	2.9	0.7	3.558	1.33
	1		CO2H	1.2	0.7	0.5	0.956	0.92
			CO2L	0.7	2.4	0.7	3.037	1.18
			CO3H	1.0	0.9	0.3	1.083	0.68
			CO3L	1.0	1.5	0.7	1.654	0.75
			CO4H	0.8	0.0	0.2	0.103	0.68
			CO4L	1.1	0.3	0.3	0.604	0.86
			CO5H	-	0.7	0.3	0.802	0.48
			CO5L	-0.3	1.0	0.3	0.927	0.50
			CO1H	0.3	0.0	0.8	1.539	1.61
			CO1L	1.0	4.7	1.1	5.790	2.17
			CO2H	1.2	1.1	0.8	1.556	1.50
			CO2L	0.7	3.9	1.1	4.941	1.92
			CO3H	1.0	1.4	0.6	1.762	1.11
			CO3L	1.0	2.5	1.1	2.692	1.22
			CO4H	0.8	0.0	0.3	0.167	1.11
			CO4L	1.1	0.6	0.6	0.983	1.39
			CO5H	-	1.1	0.6	1.306	0.78
			CO5L	-0.3	1.7	0.6	1.509	0.81

Table 20.(Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677 1235	6.6 34° 1	5676	CO1H	0.6	0.5	0.3	0.723	0.90
			CO1L	0.8	2.0	0.3	2.672	1.17
			CO2H	1.1	0.5	0.3	0.784	0.83
			CO2L	0.6	1.9	0.3	2.283	1.04
			CO3H	0.1	0.5	0.3	0.823	0.61
			CO3L	0.4	1.0	0.3	1.251	0.66
			CO4H	0.1	0.0	0.2	0.078	0.61
			CO4L	0.3	0.2	0.3	0.460	0.76
			CO5H	-	0.3	0.2	0.609	0.42
			CO5L	-0.6	0.8	0.2	0.701	0.44
			CO1H	0.6	0.5	0.3	0.679	0.84
			CO1L	0.8	1.9	0.3	2.508	1.10
			CO2H	1.1	0.5	0.3	0.736	0.78
			CO2L	0.6	1.8	0.3	2.143	0.97
			CO3H	0.1	0.5	0.3	0.773	0.57
			CO3L	0.4	1.0	0.3	1.174	0.62
			CO4H	0.1	0.0	0.2	0.073	0.57
			CO4L	0.3	0.2	0.3	0.432	0.72
			CO5H	-	0.3	0.2	0.572	0.40
			CO5L	-0.6	0.8	0.2	0.658	0.41

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677 1240	5.3 46° 2	5904	CO1H	0.6	0.8	0.8	0.525	1.14
			CO1L	0.9	2.9	1.2	3.163	1.46
			CO2H	1.2	0.8	0.8	0.630	1.07
			CO2L	0.8	2.5	1.2	2.839	1.34
			CO3H	0.3	0.8	0.8	0.925	0.83
			CO3L	0.5	1.7	1.0	1.892	0.95
			CO4H	0.2	0.0	0.2	0.002	0.71
			CO4L	0.5	0.3	0.5	0.213	0.98
			CO5H		0.8	0.5	0.922	0.63
			CO5L	-0.4	1.2	0.8	1.272	0.66
			CO1H	0.6	1.1	1.1	0.659	1.43
			CO1L	0.9	3.6	1.5	3.971	1.83
			CO2H	1.2	1.1	1.1	0.791	1.34
			CO2L	0.8	2.1	1.5	3.565	1.68
			CO3H	0.3	1.1	1.1	1.161	1.04
			CO3L	0.5	2.1	1.3	2.376	1.19
			CO4H	0.2	0.0	0.2	0.002	0.89
			CO4L	0.5	0.4	0.6	0.268	1.23
			CO5H		1.1	0.6	1.157	0.79
			CO5L	-0.4	1.5	1.1	1.597	0.83

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	6.7	6408	CO1H	0.6	0.7	0.3	0.691	0.93
1245	41°		CO1L	1.1	2.2	0.7	3.145	1.20
	1		CO2H	1.3	0.7	0.3	0.784	0.88
			CO2L	1.0	2.0	0.5	2.731	1.08
			CO3H	0.3	0.5	0.3	0.940	0.66
			CO3L	0.7	1.2	0.3	1.557	0.71
			CO4H	0.3	0.0	0.2	0.036	0.64
			CO4L	0.5	0.2	0.3	0.398	0.81
			CO5H	-	0.5	0.3	0.754	0.46
			CO5L	-0.3	0.8	0.3	0.896	0.47
			CO1H	0.6	1.0	0.5	1.040	1.40
			CO1L	1.1	3.3	1.0	4.734	1.81
			CO2H	1.3	1.0	0.5	1.180	1.33
			CO2L	1.0	3.1	0.8	4.110	1.63
			CO3H	0.3	0.8	0.5	1.415	0.99
			CO3L	0.7	1.8	0.5	2.343	1.07
			CO4H	0.3	0.0	0.3	0.054	0.97
			CO4L	0.5	0.3	0.5	0.599	1.22
			CO5H	-	0.8	0.5	1.134	0.69
			CO5L	-0.3	1.3	0.5	1.349	0.71

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	6.1	6432	CO1H	0.5	0.7	0.5	0.524	0.94
1250	48°		CO1L	1.5	2.3	0.7	3.490	1.29
	1		CO2H	1.9	0.7	0.5	0.636	0.88
			CO2L	1.6	2.4	0.7	3.054	1.16
			CO3H	0.6	0.9	0.3	0.925	0.68
			CO3L	0.9	1.5	0.7	1.760	0.77
			CO4H	0.3	0.0	0.2	0.010	0.61
			CO4L	0.6	0.3	0.3	0.262	0.82
			CO5H		0.7	0.3	0.816	0.49
			CO5L	-0.2	1.0	0.3	1.017	0.51
			CO1H	0.5	1.4	1.06	1.093	1.95
			CO1L	1.5	5.7	1.4	7.284	2.70
			CO2H	1.9	1.4	1.06	1.328	1.85
			CO2L	1.6	5.0	1.4	6.376	2.41
			CO3H	0.6	1.8	0.7	1.931	1.42
			CO3L	0.9	3.2	1.4	3.674	1.60
			CO4H	0.3	0.0	0.4	0.021	1.28
			CO4L	0.6	0.7	0.7	0.547	1.70
			CO5H		1.4	0.7	1.704	1.03
			CO5L	-0.2	2.1	0.7	2.123	1.06

Table 20. (Con't) San Antonio at-grade

DATA SET	METEOROLOGY	TRAFFIC	PROBE	MEAS. CONC. (ppm)	TRAPS CONC. (ppm)	CALINE CONC. (ppm)	HIWAY CONC. (ppm)	AIRPOL CONC. (ppm)
100677	8.7	6420	CO1H	0.6	0.5	0.5	0.500	0.94
1255	43°		CO1L	1.3	1.9	0.7	2.782	1.24
	1		CO2H	1.8	0.5	0.5	0.590	0.87
			CO2L	1.4	1.5	0.7	2.486	1.12
			CO3H	0.7	0.3	0.3	0.833	0.68
			CO3L	1.0	1.0	0.7	1.637	0.78
			CO4H	0.4	0.0	0.2	0.002	0.58
			CO4L	0.8	0.2	0.3	0.218	0.82
			CO5H	–	0.3	0.3	0.809	0.51
			CO5L	0.0	0.7	0.3	1.093	0.54
			CO1H	0.6	1.5	1.5	1.476	2.76
			CO1L	1.3	5.5	2.0	8.214	3.67
			CO2H	1.8	1.5	1.5	1.742	2.56
			CO2L	1.4	4.5	2.0	7.340	3.31
			CO3H	0.7	1.0	1.0	2.460	2.01
			CO3L	1.0	3.0	2.0	4.835	2.31
			CO4H	0.4	0.0	0.5	0.005	1.71
			CO4L	0.8	0.5	1.0	0.643	2.41
			CO5H		1.0	1.0	2.390	1.51
			CO5L	0.0	2.0	1.0	3.228	1.61

Table 20. (Con't) San Antonio at-grade

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APPENDIX A

SETA

JCL

This program reads the raw data from a nine track tape written on a NOVA minicomputer, converts the data to IBM standard format, and writes it on another 9 track tape using IBM conventions. The program performs a preliminary error check on each block of data in order to trap gross errors which could cause subsequent data reduction programs to fail, and warns the user of each bad block of data in order to facilitate recovery.

```
//SETA JOB (W127,001D,002,005,JP),' POLASEK FOR TTI'
/*LEVEL        0
/*SETUP
/*JOBPARM R=256,9=2
//STEP1 EXEC ASMFC,REGION=128K
//ASM.SYSIN DD UNIT=SYSDA,DSN=WYL.JP.WDT.DATASM,DISP=SHR
//STEP2 EXEC FORTGCLG,REGION=128K
//FORT.SYSIN DD UNIT=SYSDA,DSN=WYL.JP.WDT.DATAFRT,DISP=SHR
//GO.DUMMY DD DUMMY
//FT02F001 DD DUMMY
//FT01F001 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(01,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F002 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(02,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F003 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(03,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F004 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(04,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F005 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(05,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F006 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(06,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F007 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(07,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F008 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(08,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F009 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(09,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F010 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(10,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F011 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(11,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F012 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(12,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F013 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(13,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F014 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//       LABEL=(14,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
```

```
//FT01F015 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(15,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F016 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(16,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F017 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(17,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F018 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(18,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F019 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(19,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F020 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(20,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F021 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(21,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F022 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(22,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F023 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(23,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F024 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(24,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F025 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(25,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F026 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(26,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//FT01F027 DD UNIT=TAPE9,VOL=SER=ZZ3893,DISP=(OLD,PASS),
//         LABEL=(27,NL,,IN),DCB=(LRECL=3200,BLKSIZE=3200,DEN=2,RECFM=U)
//GO.SYSIN DD UNIT=SYSDA,DSN=WYL.JP.WDT.DATAIN,DISP=SHR
```

DATA SET

WYL.JP.WDT.DATAFRT

```
      DOUBLE PRECISION DDNM(50)
      INTEGER*2 DATA(2000),DM(10)
      DM(1)=10
      DO 105 J=2,10
      DM(J)=0
  105 CONTINUE
      I=1
      IBD=0
      IBLK=0
      READ(5,500) NFILE
      READ(5,501) (DDNM(J),J=1,NFILE)
    1 CONTINUE
      IBLK=IBLK+1
      CALL GETR(DDNM(I),ITST,DATA,ILNG)
      IF (ITST) 2,4,3
    2 IF (ITST .EQ.-1) GO TO 6
      WRITE (6,600) ITST,DDNM(I)
      STOP
    3 IF (IBD .GT.2) GO TO 1
      IBD=IBD+1
      IBLK=IBLK-1
      BACKSPACE 1
      WRITE (6,601) IBD, DDNM(I)
      GO TO 1
    4 IL=ILNG/2
      IBD=0
      JS=2
    5 JL=DATA(JS)
      JDM=DATA(JS+1)
      JE=JS+JL-1
      IF (JE .GT.IL) GO TO 1
      IF (DATA(JS+2) .LT.32 .OR. DATA(JS+2) .GT. 110) GO TO 7
      IF ( JL .GT. 135 .OR. JL .LT. 5) GO TO 7
      IF (DATA(JS+1) .LT.0 .OR. DATA(JS+1) .GT.20) GO TO 7
      IF (JDM .EQ.0 .OR.JDM .EQ.5) CALL LIST(DATA,JS+4,JE)
      WRITE (2,200) (DATA(N),N=JS,JE)
      IF (JE .EQ.IL) GO TO 1
      JS=JE+1
      GO TO 5
    6 CALL ENDQ(DDNM(I),ITST,'LEAVE')
      WRITE (6,603) DDNM(I)
      IBLK=0
      I=I+1
      IF (I .GT. NFILE) STOP
      GO TO 1
    7 WRITE (6,602) IBLK,DDNM(I)
      GO TO 1
  200 FORMAT (20(100I6))
  500 FORMAT (I5)
  501 FORMAT (8(A8,2X))
  600 FORMAT (' RETRY:',I2,'  FILE:',A8)
  601 FORMAT (' READ ERROR:',I5,'    FILE:',A8)
  602 FORMAT (' ********BAD BLOCK',I3,' FILE:',2X,A8,'  ********')
  603 FORMAT ('   END OF ',A8,///)
      END
```

```
    SUBROUTINE LIST(I,JU,KU)
    INTEGER*2L(128)/0,1,2,3,55,45,46,47,22,5,37,11,12,13,14,15,16,17,
   >18,18,60,61,50,38,24,25,63,39,34,34,53,53,64,90,127,123,91,108,
   >80,125,77,93,92,78,107,96,75,97,240,241,242,243,244,245,246,247,
   >248,249,122,94,76,126,110,111,124,193,194,195,196,197,198,199,
   >200,201,209,210,211,212,213,214,215,216,217,226,227,228,229,230,
   >231,232,233,192,0,208,0,0,121,27*0,250,0,204,7/
    INTEGER*2 I(2000),C(2),IB(55)
    CALL CNVRT(ITM,I(JU-2),I(JU-1))
    IB(2)=I(JU-3)
    J=4
    IA=KU-JU+5
    IH=ITM/360000
    IM=ITM/6000-IH*60
    DO 18 I1=JU,KU
    J=J+1
    CALL DEPAK(I(I1),C)
    IF ( C(1) .GE. 128 .OR.C(2).GE. 128) GO TO 4
    IB(J)=256*L(C(1)+1)+L(C(2)+1)
    IF (C(1).NE.13) GO TO 16
    IB(J)=0
    GO TO 19
 16 IF(C(2).NE.13) GO TO 17
    IB(J)=L(C(1)+1)*256
    GO TO 19
 17 CONTINUE
 18 CONTINUE
 19 IF (J.GT.IA) J=IA
    IF (J .GT.50) J=50
    JD=J-4
    IF (ITM .EQ. 0) RETURN
    WRITE (6,600) IB(2),IH,IM,(IB(K),K=5,J)
600 FORMAT (10X,'TYPE: ',I2,' AT ',I2,':',I2,' HOURS.',50A2)
  4 RETURN
    END
```

```
SUBROUTINE CNVRT (I,IH,IL)
INTEGER*2 IH,IL
I=IL
IF (I .LT.0) I=I+65536
I=I+65536*IH
RETURN
END
SUBROUTINE DEPAK(I,J)
INTEGER*2 I, J(2), K(2)
LOGICAL*1 A(4)
EQUIVALENCE (K,A)
K(1)=I
K(2)=0
A(4)=A(1)
A(1)=A(3)
J(1)=K(1)
J(2)=K(2)
RETURN
END
```

DATA SET

WYL.JP.WDT.DATASM

```
QSIO     TITLE '   QSAM VARIABLE LENGTH INPUT/OUTPUT ROUTINE'           QSI00010
*********************************************************************** QSI00020
*                                                                     * QSI00030
*        QSAM VARIABLE LENGTH INPUT/OUTPUT ROUTINE   -  FORTRAN       * QSI00040
*        ROCKETDYNE DIVISION   N. A. R.                 2/12/68       * QSI00050
*                                                                     * QSI00060
*********************************************************************** QSI00070
*                                                                     * QSI00080
*        ENTRY POINTS                                                 * QSI00090
*                                                                     * QSI00100
*                       GETR    INPUT   (OPEN DCB IF NECESSARY)       * QSI00110
*                                                                     * QSI00120
*                       PUTR    OUTPUT  (OPEN DCB IF NECESSARY)       * QSI00130
*                                                                     * QSI00140
*                       ENDQ    CLOSE DATA CONTROL BLOCK              * QSI00150
*                                                                     * QSI00160
*********************************************************************** QSI00170
*                                                                     * QSI00180
*        THIS ROUTINE MAY BE USED TO READ/WRITE SEQUENTIAL DATA       * QSI00190
*        SETS.  THE DATA MANAGEMENT USED IS QSAM.  ONLY ONE DATA      * QSI00200
*        SET EACH CAN BE INPUT AND OUTPUT AT A TIME.  THAT IS,        * QSI00210
*        ONE DATA SET FOR INPUT AND ONE DATA SET FOR OUTPUT CAN       * QSI00220
*        BE OPEN AT THE SAME TIME.  IN ORDER TO INPUT/OUTPUT MORE     * QSI00230
*        THAN ONE DATA SET, THE 'OLD' DATA SET MUST BE CLOSED         * QSI00240
*        PRIOR TO INPUT/OUTPUT OF THE 'NEW' DATA SET.                 * QSI00250
*                                                                     * QSI00260
*        DATA SETS ARE AUTOMATICALLY OPENED WHEN GETR OR PUTR IS      * QSI00270
*        CALLED AND THE DCB FOR GETR OR PUTR IS CLOSED.  DATA SETS    * QSI00280
*        ARE CLOSED VIA CALLING ENDQ.  TWO OPTIONS ARE PROVIDED FOR   * QSI00290
*        CLOSING DATA SETS, NAMELY                                    * QSI00300
*                                                                     * QSI00310
*        CLOSE AND POSITION AT BEGINNING OF THE DATA SET              * QSI00320
*        CLOSE AND POSITION AT THE END OF THE DATA SET                * QSI00330
*                                                                     * QSI00340
*        FOR CALLING SEQUENCES, SEE SPECIFIC ENTRY POINT              * QSI00350
*                                                                     * QSI00360
*********************************************************************** QSI00370
```

```
QSIO     START 0                                                        QSI00385
*                                                                       QSI00390
*        GENERAL REGISTER DEFINITIONS AND USAGE                         QSI00400
*                                                                       QSI00410
R0       EQU   0              SCRATCH                                   QSI00420
R1       EQU   1              PARM 1 POINTER  AND  SCRATCH              QSI00430
R2       EQU   2              PARM 2 POINTER                            QSI00440
R3       EQU   3              PARM 3 POINTER                            QSI00450
R4       EQU   4              PARM 4 POINTER                            QSI00460
R5       EQU   5              DCB BASE REGISTER                         QSI00470
R6       EQU   6              SCRATCH                                   QSI00480
R7       EQU   7                                                        QSI00490
R8       EQU   8                                                        QSI00500
R9       EQU   9                                                        QSI00510
R10      EQU   10                                                       QSI00520
R11      EQU   11             POINTER TO CALLER'S SAVE AREA             QSI00530
R12      EQU   12             PROGRAM BASE REGISTER                     QSI00540
R13      EQU   13             SAVE AREA POINTER                         QSI00550
R14      EQU   14             EXTERNAL RETURN                           QSI00560
R15      EQU   15             EXTERNAL LINKAGE                          QSI00570
*                                                                       QSI00590
*        ENTRY POINTS                                                   QSI00600
*                                                                       QSI00610
         ENTRY GETR                                                     QSI00620
*                                                                       QSI00630
         ENTRY PUTR                                                     QSI00640
*                                                                       QSI00650
         ENTRY ENDQ                                                     QSI00660
```

```
*        G E T R   C A L L I N G   S E Q U E N C E                     * QSI00680
*                                                                      * QSI00690
*********************************************************************** QSI00700
*                                                                      * QSI00710
*        CALL GETR(DDNAME,IND,ARRAY,NCHAR)                             * QSI00720
*                                                                      * QSI00730
*        DDNAME   8 CHARACTER LITERAL OR VARIABLE WHICH IS THE         * QSI00740
*                 DDNAME FROM THE DD CARD OF THE DATA SET              * QSI00750
*                                                                      * QSI00760
*         ARRAY   ARRAY INTO WHICH THE RECORD IS MOVED.  ARRAY         * QSI00770
*                 MUST BE DIMENSIONED SUCH THAT IT CAN RECEIVE         * QSI00780
*                 THE LARGEST RECORD EXPECTED.  SIZE OF ARRAY          * QSI00790
*                 SHOULD CORRESPOND TO BLKSIZE FROM DCB PARM.          * QSI00800
*                                                                      * QSI00810
*         NCHAR   INTEGER*4 VARIABLE.  THE VALUE PASSED BACK TO        * QSI00820
*                 THE CALLER IS THE NUMBER OF CHARACTERS MOVED         * QSI00830
*                 INTO ARRAY.  IF AN ERROR OR END FILE CONDITION       * QSI00840
*                 IS DETECTED, NCHAR IS UNDEFINED                      * QSI00850
*                                                                      * QSI00860
*           IND   INTEGER*4 VARIABLE.  THE VALUE PASSED BACK TO        * QSI00870
*                 THE CALLER INDICATES THE FOLLOWING                   * QSI00880
*                                                                      Q QSI00890
*            -3   NOT MORE THAN ONE DATA SET CAN BE OPENED AT          * QSI00900
*                 THE SAME TIME BY GETR                                * QSI00910
*                                                                      * QSI00920
*            -2   DATA SET COULD NOT BE OPENED SUCCESSFULLY.           * QSI00930
*                 PROBABLY MEANS THAT DDNAME DID NOT CORRESPOND        * QSI00940
*                 TO DDNAME FROM DD CARD                               * QSI00950
*                                                                      * QSI00960
*            -1   END FILE DETECTED                                    * QSI00970
*                                                                      * QSI00980
*             0   NO ERRORS WERE DETECTED                              * QSI00990
*                                                                      * QSI01000
*            >0   AN ERROR HAS OCCURRED.  THE VALUE PASSED BACK        * QSI01010
*                 TO THE CALLER IS STATUS BYTES 0 AND 1 AND            * QSI01020
*                 SENSE BYTES 0 AND 1, LEFT TO RIGHT IN IND            * QSI01030
*                                                                      * QSI01040
*********************************************************************** QSI01050
```

```
         USING GETR,R15                                                 QSIO1070
GETR     B     G#1                                                      QSIO1080
         DC    X'4',CL5'GETR'                                           QSIO1090
G#1      STM   R14,R12,12(R13)                                          QSIO1100
         L     R12,LDPNT                                                QSIO1110
         DROP  R15                                                      QSIO1120
         USING QSIO,R12                                                 QSIO1130
         BAL   R6,INIT              INITIALIZE - SAVE AREA CHAIN ETC.   QSIO1140
         LA    R5,GETDCB            POINT TO DCB                        QSIO1150
         USING IHADCB,R5                                                QSIO1160
         TM    DCBOFLGS,X'10'       IS DCB OPEN?                        QSIO1170
         BC    1,G#2                YES. BRANCH                         QSIO1180
         MVC   DCBDDNAM,0(R1)       NO.. MOVE DDNAME TO DCB             QSIO1190
         MVC   GDDNAME,0(R1)        SAVE DDNAME                         QSIO1200
         XC    DCBLRECL,DCBLRECL    0 TO LRECL.  OPEN GETS IT FROM DD   QSIO1210
         OPEN  (GETDCB,(INPUT))     OPEN DCB FOR INPUT                  QSIO1220
         TM    DCBOFLGS,X'10'       WAS OPEN SUCCESSFUL?                QSIO1230
         BC    1,G#4                YES. BRANCH                         QSIO1240
         B     ER#2                 NO.. TAKE ERROR EXIT                QSIO1250
G#2      CLC   GDDNAME,0(R1)        DID CALLER CHANGE DDNAME?           QSIO1260
         BNE   ER#3                 YES. TAKE ERROR EXIT                QSIO1270
G#4      GET   GETDCB,(R3)          GET A RECORD                        QSIO1280
         LH    R0,DCBLRECL          PICK UP RECORD LENGTH               QSIO1290
         ST    R0,0(R4)             AND PASS IT TO CALLER               QSIO1300
         B     EXIT                 GO EXIT TO CALLER                   QSIO1310
```

```
*        P U T R   C A L L I N G   S E Q U E N C E                    * QSI01330
*                                                                     * QSI01340
*********************************************************************** QSI01350
*                                                                     * QSI01360
*        CALL PUTR(DDNAME,IND,ARRAY,NCHAR)                            * QSI01370
*                                                                     * QSI01380
*        DDNAME   8 CHARACTER LITERAL OR VARIABLE WHICH IS THE        * QSI01390
*                 DDNAME FROM THE DD CARD OF THE DATA SET             * QSI01400
*                                                                     * QSI01410
*         ARRAY   ARRAY FROM WHICH THE RECORD IS WRITTEN              * QSI01420
*                                                                     * QSI01430
*         NCHAR   INTEGER*4 VARIABLE OR CONSTANT WHICH IS THE         * QSI01440
*                 NUMBER OF CHARACTERS TO BE WRITTEN                  * QSI01450
*                                                                     * QSI01460
*           IND   INTEGER*4 VARIABLE.  THE VALUE PASSED BACK TO       * QSI01470
*                 THE CALLER INDICATES THE FOLLOWING                  * QSI01480
*                                                                     * QSI01490
*            -3   NOT MORE THAN ONE DATA SET CAN BE OPENED AT         * QSI01500
*                 THE SAME TIME BY PUTR                               * QSI01510
*                                                                     * QSI01520
*            -2   DATA SET COULD NOT BE OPENED SUCCESSFULLY.          * QSI01530
*                 PROBABLY MEANS THAT DDNAME DID NOT CORRESPOND       * QSI01540
*                 TO DDNAME FROM DD CARD                              * QSI01550
*                                                                     * QSI01560
*            -1   NOT USED                                            * QSI01570
*                                                                     * QSI01580
*             0   NO ERRORS WERE DETECTED                             * QSI01590
*                                                                     * QSI01600
*            >0   AN ERROR HAS OCCURRED.  THE VALUE PASSED BACK       * QSI01610
*                 TO THE CALLER IS STATUS BYTES 0 AND 1 AND           * QSI01620
*                 SENSE BYTES 0 AND 1, LEFT TO RIGHT IN IND           * QSI01630
*                                                                     * QSI01640
```

```
         USING PUTR,R15
PUTR     B     P#1                                                    QSI01660
         DC    X'4',CL5'PUTR'                                         QSI01670
P#1      STM   R14,R12,12(R13)                                        QSI01680
         L     R12,LDPNT                                              QSI01690
         DROP  R15                                                    QSI01700
         USING QSIO,R12                                               QSI01710
         BAL   R6,INIT            INITIALIZE - SAVE AREA CHAIN ETC.   QSI01720
         LA    R5,PUTDCB          POINT TO DCB                        QSI01730
         USING IHADCB,R5                                              QSI01740
         TM    DCBOFLGS,X'10'                                         QSI01750
         BC    1,P#2              IS DCB OPEN?                        QSI01760
         MVC   DCBDDNAM,0(R1)     YES. BRANCH                         QSI01770
         MVC   PDDNAME,0(R1)      NO.. MOVE DDNAME TO DCB             QSI01780
         OPEN  (PUTDCB,(OUTPUT))  SAVE DDNAME                         QSI01790
         TM    DCBOFLGS,X'10'     OPEN DCB FOR OUTPUT                 QSI01800
         BC    1,P#4              WAS OPEN SUCCESSFUL?                QSI01810
         B     ER#2               YES. BRANCH                         QSI01820
P#2      CLC   PDDNAME,0(R1)      NO.. TAKE ERROR EXIT                QSI01830
         BNE   ER#3               DID CALLER CHANGE DDNAME?           QSI01840
P#4      L     R0,0(R4)           YES. TAKE ERROR EXIT                QSI01850
         STH   R0,DCBLRECL        PICK UP RECORD LENGTH               QSI01860
         PUT   PUTDCB,(R3)        AND STORE IT IN DCB                 QSI01870
         B     EXIT               PUT A RECORD                        QSI01880
                                  GO EXIT TO CALLER                   QSI01890
```

```
*        E N D Q   C A L L I N G   S E Q U E N C E                    * QSI01892
*                                                                     * QSI01893
*********************************************************************** QSI01894
*                                                                     * QSI01895
*        CALL ENDQ(DDNAME,IND,OPTION)                                 * QSI01896
*                                                                     * QSI01897
*        DDNAME   8 CHARACTER LITERAL OR VARIABLE WHICH IS THE        * QSI01898
*                 DDNAME FROM THE DD CARD OF THE DATA SET             * QSI01899
*                                                                     * QSI01900
*           IND   INTEGER*4 VARIABLE.  THE VALUE PASSED BACK TO       * QSI01901
*                 THE CALLER INDICATES THE FOLLOWING                  * QSI01902
*                                                                     * QSI01903
*            -2   DDNAME DOES NOT CORRESPOND TO A DATA SET THAT       * QSI01904
*                 WAS PREVIOUSLY OPENED                               * QSI01905
*                                                                     * QSI01906
*             0   DATA SET HAS BEEN CLOSED                            * QSI01907
*                                                                     * QSI01908
*        OPTION   THE LITERAL 'REWIND' OR 'LEAVE' OR A VARIABLE       * QSI01909
*                 CONTAINING THE CHARACTERS REWIND OR LEAVE           * QSI01910
*                                                                     * QSI01911
*                 REWIND - POSITION DATA SET AT BEGINNING             * QSI01912
*                  LEAVE - POSITION DATA SET AT END                   * QSI01913
*                                                                     * QSI01914
* NOTE ***        IF THE DATA SET IS ALREADY CLOSED THEN OPTION       * QSI01915
*                 HAS NO EFFECT.  E.G. IF A DATA SET IS CLOSED        * QSI01916
*                 WITH LEAVE AND LATER A CALL TO ENDQ IS MADE         * QSI01917
*                 WITH REWIND - THE DATA SET WILL NOT BE POSITIONED   * QSI01918
*                 AT THE BEGINNING                                    * QSI01919
*                                                                     * QSI01920
*********************************************************************** QSI01921
```

```
         USING ENDQ,R15                                                 QSI01923
ENDQ     B     E#1                                                      QSI01924
         DC    X'4',CL5'ENDQ'                                           QSI01930
E#1      STM   R14,R12,12(R13)                                          QSI01940
         L     R12,LDPNT                                                QSI01950
         DROP  R15                                                      QSI01960
         USING QSIO,R12                                                 QSI01970
         BAL   R6,INIT                INITIALIZE - SAVE AREA CHAIN ETC. QSI01980
         USING IHADCB,R5                                                QSI01990
         LA    R5,PUTDCB              POINT TO DCB                      QSI02000
         CLC   PDDNAME,0(R1)          CLOSE THIS ONE?                   QSI02010
         BE    E#2                    YES. BRANCH                       QSI02020
         LA    R5,GETDCB              NO.. POINT TO OTHER DCB           QSI02030
         CLC   GDDNAME,0(R1)          CLOSE THIS ONE?                   QSI02040
         BNE   ER#2                   NO.. TAKE ERROR EXIT              QSI02050
E#2      TM    DCBOFLGS,X'10'         IS DCB OPEN?                      QSI02060
         BC    8,EXIT                 NO.. BRANCH                       QSI02070
         CLC   0(6,R3),=C'REWIND'     YES. DOES HE WANT TO REWIND?      QSI02080
         BE    E#4                    YES. BRANCH                       QSI02090
         CLOSE ((R5),LEAVE)           NO.. CLOSE WITH LEAVE OPTION      QSI02100
         B     EXIT                   GO EXIT TO CALLER                 QSI02110
E#4      CLOSE ((R5),REREAD)          CLOSE WITH REREAD                 QSI02120
         B     EXIT                   GO EXIT TO CALLER                 QSI02130
```

```
         USING QSIO,R12                                                   QSI02150
INIT     LR    R11,R13               SAVE CALLER'S SA POINTER             QSI02160
         LA    R13,SA                INITIALIZE NEW SA POINTER            QSI02170
         ST    R13,8(R11)            CHAIN                                QSI02180
         ST    R11,4(R13)            SAVEAREAS                            QSI02190
         LM    R1,R4,0(R1)           LOAD PARAMETER POINTERS              QSI02200
         SR    R0,R0                 ZERO                                 QSI02210
         ST    R0,0(R2)              TO CALLER'S ERROR INDICATOR          QSI02220
         BR    R6                    LOCAL RETURN                         QSI02230
*                                                                         QSI02240
*        ERROR EXIT #2               DCB FAILED TO OPEN SUCCESSFULLY      QSI02250
*                                                                         QSI02260
ER#2     LA    R0,2                  SET ERROR INDICATOR = 2              QSI02270
         B     ER#4                  GO MAKE IT NEGATIVE                  QSI02280
*                                                                         QSI02290
*        ERROR EXIT #3               DDNAME CHANGE WHILE DCB WAS OPEN     QSI02300
*                                                                         QSI02310
ER#3     LA    R0,3                  SET ERROR INDICATOR = 3              QSI02320
ER#4     LNR   R0,R0                 MAKE ERROR INDICATOR NEGATIVE        QSI02330
         ST    R0,0(R2)              AND PASS TO CALLER                   QSI02340
*                                                                         QSI02350
*        EXIT TO CALLER                                                   QSI02360
*                                                                         QSI02370
EXIT     LR    R13,R11               RESTORE CALLER'S SA POINTER          QSI02380
~~         LM    R14,R12,12(R13)       RESTORE REGISTERS                    QSI02390~~
         MVI   12(R13),X'FF'         INDICATE RETURN                      QSI02400
         BR    R14                   EXIT TO CALLER                       QSI02410
```

```
*                                                                       QSI02430
*        EODAD ROUTINE                                                  QSI02440
*                                                                       QSI02450
EOFX     LA    R0,1                    SET ERROR INDICATOR = 1          QSI02460
         B     ER#4                    GO MAKE IT NEGATIVE AND EXIT     QSI02470
*                                                                       QSI02480
*        SYNAD ROUTINE                                                  QSI02490
*                                                                       QSI02500
ERRX     LR    R1,R0                   POINT TO STATUS INDICATOR AREA   QSI02510
         MVC   0(2,R2),12(R1)          MOVE STATUS 0 & 1 TO CALLERS IND QSI02520
         MVC   2(2,R2),2(R1)           MOVE SENSE  0 & 1 TO CALLERS IND QSI02530
         BR    R14                     EXIT TO IOS                      QSI02540
*                                                                       QSI02550
         EJECT                                                          QSI02560
LDPNT    DC    A(QSIO)                 ADDRESS OF LOAD POINT            QSI02570
SA       DC    18F'0'                                                   QSI02580
GDDNAME  DC    CL8' '                                                   QSI02590
PDDNAME  DC    CL8' '                                                   QSI02600
GETDCB   DCB   DSORG=PS,DEVD=DA,SYNAD=ERRX,MACRF=(GM),EODAD=EOFX,      XQSI02610
               EROPT=ACC                                                QSI02620
PUTDCB   DCB   DSORG=PS,DEVD=DA,SYNAD=ERRX,MACRF=(PM)                   QSI02630
         EJECT                                                          QSI02640
         DCBD  DSORG=(QS),DEVD=(DA)                                     QSI02650
```

DATA SET

WYL.JP.WDT.DATAIN

```
    38
FT01F001  FT01F002  FT01F003  FT01F004  FT01F005  FT01F006  FT01F007  FT01F008
FT01F009  FT01F010  FT01F011  FT01F012  FT01F013  FT01F014  FT01F015  FT01F016
FT01F017  FT01F018  FT01F019  FT01F020  FT01F021  FT01F022  FT01F023  FT01F024
FT01F025  FT01F026  FT01F027  FT01F028  FT01F029  FT01F030  FT01F031  FT01F032
FT01F033  FT01F034  FT01F035  FT01F036  FT01F037  FT01F038  FT01F039  FT01F040
FT01F041  FT01F042  FT01F043  FT01F044  FT01F045  FT01F046  FT01F047  FT01F048
```

APPENDIX B

SETB

JCL

This program converts all ASCII characters in the raw data to EBCDIC characters used by the AMDAHL, and converts all integer numbers recorded by the A/D to their floating point equivalents. The data, which on the input file is entered strictly by time, is resorted into a by channel order and the resulting data set stored on another 9 track tape.

```
//SETB JOB (W127,001D,005,005,JP),' POLASEK FOR DATA'
/*SETUP
/*LEVEL        0
/*JOBPARM      9=2,R=320
//STEPB1 EXEC WATFIV,REGION=320K
//FT01F001 DD UNIT=TAPE9,VOL=SER=ZZ3894,DSN=RAWDATA.F110177.L112477.LR,
//          DISP=(OLD,PASS),LABEL=(4,SL,,IN)
//FT02F001 DD UNIT=SYSDA,DSNAME=&&SMISRT,SPACE=(CYL,(30,10)),
//        DISP=(NEW,PASS),DCB=(RECFM=VB,LRECL=3700,BLKSIZE=13000)
//SYSIN DD UNIT=SYSDA,DSN=WYL.JP.WDT.SETB.SOURCE,DISP=(SHR,PASS)
/*
//STEPB2 EXEC SORTWK,REGION=128K
//SORTIN DD UNIT=SYSDA,DSN=&&SMISRT,DISP=(SHR,DELETE)
//SORTOUT DD UNIT=TAPE9,VOL=SER=000123,DISP=(NEW,PASS),
//       LABEL=(9,SL),DSN=CHDATA.F110177.L112477.LC,
//      DCB=(LRECL=3700,BLKSIZE=22000,RECFM=VB)
//SYSIN DD *
 SORT FIELDS=(5,5,CH,A,15,5,CH,A,10,5,CH,A,20,15,CH,A),FILSZ=E35000
 RECORD TYPE=V,LENGTH=(3700,3700,3700,,110)
 END
```

DATA SET

WYL.JP.WDT.SETB.SOURCE

```
//$OPTIONS     T=(5)
      INTEGER*2 IX(20)/1,2,3,4,5,6,7,8,9,10,18,12,13,14,15,16,17,
     >11,19,20/
      INTEGER*2L(128)/0,1,2,3,55,45,46,47,22,5,37,11,12,13,14,15,16,17,
     >18,18,60,61,50,38,24,25,63,39,34,34,53,53,64,90,127,123,91,108,
     >80,125,77,93,92,78,107,96,75,97,240,241,242,243,244,245,246,247,
     >248,249,122,94,76,126,110,111,124,193,194,195,196,197,198,199,
     >200,201,209,210,211,212,213,214,215,216,217,226,227,228,229,230,
     >231,232,233,192,0,208,0,0,121,27*0,250,0,204,7/
      INTEGER   IN(64),IT(64),MN(64),MX(64),UN(64),OF(64),
     > IE(11,64,28)/19712*0/,IC(5),IB(150),NM(3,64)
      INTEGER*2 SP0,SP1,SP2/0/,C(2)
      INTEGER*2 NTO(50)
      REAL O(150)
      IREAD=1
      IPO=1
      READ (5,502) (NTO(I),I=1,50)
      IF=1
      SP0=0
      SP1=1
      READ (5,500) N
    1 READ (5,501,END=3) I,IN(I),IT(I),MN(I),MX(I),UN(I),OF(I),
     >(NM(J,I),J=1,3)
      DO 2 J=1,3
      CALL DEPAK(NM(J,I),C)
    2 NM(J,I)=(256*L(C(1)+1)+L(C(2)+1))*65536
      GO TO 1
    3 DO 21 I=1,N
    4 READ (IREAD,100,END=20) IA,(IB(J),J=2,IA)
      CALL CNVRT(ITM,IB(3),IB(4))
      IF (IB(2)-1)  15,12,5
    5 IF (IB(2)-10) 10,8,6
    6 IF (IA .LT.10) GO TO 4
      IB(5)=IB(5)+1
      IN(IB(5))=IB(6)
      UN(29) =1
      DO 7 J=10,IA
      K=J-9
      IF (UN(IB(5)).EQ.0) UN(IB(5))=32000
    7 O(K)=FLOAT(IB(J)+OF(IB(5)))/FLOAT(UN(IB(5)))
      IE(11,IB(5),IF)=IE(11,IB(5),IF)+1
      WRITE (2,200) SP1,IX(IB(2)),IB(5),ITM,K,(O(J),J=1,K)
      GO TO 4
    8 CALL CNVRT(ITM,IB(10),IB(11))
      IB(5)=IB(5)+1
      DO 9 J=1,5
      ID=11+3*J
      IC(J)=IB(ID)
      CALL CNVRT(IPD,IB(ID+1),IB(ID+2))
      O(J)=0.
      IF (IC(J).GT.0) O(J)=FLOAT(IPD)/FLOAT(IC(J)*UN(IB(5)))
    9 CONTINUE
```

```
      WRITE (2,201) SP1,IB(2),IB(5),ITM,(IC(J),O(J),J=1,5)
      IE(10,IB(5),IF)=IE(10,IB(5),IF)+1
      GO TO 4
   10 IF (IB(2)-5)11,15,11
   11 IB(5)=IB(5)+1
      IF ( IB(5) .GT.64 .OR. IB(5) .LT. 1) GO TO 4
      WRITE (2,200) SP1,IB(2),IB(5),ITM
      IE(IX(IB(2)),IB(5),IF)=IE(IX(IB(2)),IB(5),IF)+1
      GO TO 4
   12 ID=5
   13 IF (ID.GE.IA) GO TO 4
      IB(ID)=IB(ID)+1
      IN(IB(ID))=IB(ID+1)
      IT(IB(ID))=IB(ID+2)
      MN(IB(ID))=IB(ID+3)
      MX(IB(ID))=IB(ID+4)
      UN(IB(ID))=IB(ID+5)
      OF(IB(ID))=IB(ID+6)
      DO 14 J=1,3
      CALL DEPAK(IB(ID+J+6),C)
   14 NM(J,IB(ID))=(256*L(C(1)+1)+L(C(2)+1))*65536
      J=IB(ID)
      ID=ID+10
      GO TO 13
   15 DO 18 J=5,IA
      CALL DEPAK(IB(J),C)
      IF ( C(1) .GE. 128 .OR.C(2).GE. 128) GO TO 4
      IB(J)=(256*L(C(1)+1)+L(C(2)+1))*65536
      IF (C(1).NE.13) GO TO 16
      IB(J)=0
      GO TO 19
   16 IF(C(2).NE.13) GO TO 17
      IB(J)=(L(C(1)+1)*256)*65536
      GO TO 19
   17 CONTINUE
   18 CONTINUE
   19 IF (J.GT.IA) J=IA
      IF (J .GT.50) J=50
      JD=J-4
      IF (ITM .EQ. 0) GO TO 4
      IF (IB(2).EQ.0) CALL DMRTN(IB(2),NTO,IPO)
      IF (IB(2).NE.0) GO TO 197
      DO 195 M=1,64
      IE(1,M,IF)=IE(1,M,IF)+1
      WRITE (2,204) SP1,SP2,M,SP1,IN(M),IT(M),MN(M),MX(M),UN(M),OF(M),
     >(NM(K,M),K=1,3)
  195 CONTINUE
  197 CONTINUE
```

```
      ~~IF (IB(2).EQ.0) SP0=SP0+2~~
      SP1=SP0+1
      IF (IB(2).EQ.0) IF=IF+1
      IF (IB(2) .EQ. 0) WRITE (6,601)
      WRITE (6,600) IB(2),ITM,(IB(K),K=5,J)
      WRITE (2,202) SP0,IB(2),SP2,ITM,JD,(IB(K),K=5,J)
      IE(5,1,IF)=IE(5,1,IF)+1
      GO TO 4
   20 CONTINUE
   21 CONTINUE
      I1=SP0+1
      M=SP0/2+1
      DO 22 J=1,64
      IE(1,J,M)=IE(1,J,M)+1
      WRITE (2,204)I1,SP2,J,SP1,IN(J),IT(J),MN(J),MX(J),UN(J),OF(J),
     >(NM(K,J),K=1,3)
   22 CONTINUE
      WRITE (2,203) SP2,SP2,SP2,SP2,((IE(J,K,1),J=1,11),K=1,64)
      WRITE (6,602) (( IE(J,K,1),J=1,11),K=1,64)
      DO 23 I=2,SP0,2
      I1=I+1
      M=I/2+1
      WRITE (2,203) I,SP2,SP2,SP2,((IE(J,K,M),J=1,11),K=1,64)
      WRITE (6,602)((IE(J,K,M),J=1,11),K=1,64)
   23 CONTINUE
  100 FORMAT (200(10I6))
  200 FORMAT (3I5,I15,I5,2(250F10.2))
  201 FORMAT (3I5,I15,7(I5,F5.1))
  202 FORMAT (3I5,I15,I5,100A2)
  203 FORMAT (3I5,I15, 65(11I5))
  204 FORMAT (3I5,I15,6I10,3A2)
  500 FORMAT (I5)
  501 FORMAT (10I8)
  502 FORMAT (50I1)
  600 FORMAT ('   TYPE:  ',I1,'  AT ',I10,5X,200A2)
  601 FORMAT (///)
  602 FORMAT (///,64(20X,11I5,/))
      STOP
      END
```

```
      SUBROUTINE CNVRT (I,IH,IL)
      INTEGER IH,IL
      I=IL
      IF (I .LT.0) I=I+65536
      I=I+65536*IH
      RETURN
      END
      SUBROUTINE DMRTN(I,J,K)
      INTEGER*2 J(50)
      I=J(K)
      K=K+1
      RETURN
      END
      SUBROUTINE DEPAK(I,J)
      INTEGER*2  J(2), K(2)
      LOGICAL*1 A(4)
      EQUIVALENCE (K,A)
      K(1)=I
      K(2)=0
      A(4)=A(1)
      A(1)=A(3)
      J(1)=K(1)
      J(2)=K(2)
      RETURN
      END
//$DATA
0505555555055555550555555550555555550555
```

1	1	10	-100	2047	20	0	16722	21060	12336
2	1	10	-100	2047	20	0	16722	21060	12592
3	1	10	-100	2047	20	0	16722	21060	12848
4	1	10	-100	2047	20	0	16722	21060	13104
5	1	10	-100	2047	20	0	16722	21060	13360
6	1	10	-100	2047	20	0	16722	21060	13616
7	1	10	-100	2047	20	0	16722	21060	13872
8	1	10	-100	2047	20	0	16722	21060	14128
9	1	10	-100	2047	20	0	16722	21060	12337
10	1	10	-100	2047	20	0	16722	21060	12593
11	200	11	-854	854	5	0	16726	11825	19765
12	400	11	-854	854	5	0	16726	12576	19760
13	600	11	-854	854	5	0	16726	12832	19760
14	600	11	-854	854	5	0	16726	13344	19760
15	1500	12	0	614	20	0	16712	11825	19765
16	1500	12	0	819	20	0	16712	12576	19760
17	1500	12	0	1228	20	0	16712	12832	19760
18	1500	12	0	1638	20	0	16712	13344	19760
19	500	13	0	2047	6	0	22103	11825	19765
20	500	13	0	2047	6	0	22103	11825	19765
21	500	13	0	2047	6	854	22103	12832	19760
22	500	13	0	2047	6	58	22103	13344	19760
23	6000	14	921	1791	13	-512	19796	11825	19765
24	6000	14	921	1791	13	-512	19796	12624	19760
25	6000	14	921	1791	13	-512	19796	12880	19760
26	6000	14	921	1791	13	-512	19796	13136	19760
27	6000	15	0	2047	20	0	18514	11825	19765
28	6000	15	0	2047	20	0	18514	13088	19760
29	6000	16	0	1500	1	0	22864	16722	8270
30	3000	17	0	2047	41	0	8224	20291	18481
31	3000	17	0	2047	41	0	8224	20291	19505
32	3000	17	0	2047	41	0	8224	20291	18482
33	3000	17	0	2047	41	0	8224	20291	19506
34	3000	17	0	2047	41	0	8224	20291	18483
35	3000	17	0	2047	41	0	8224	20291	19507
36	3000	17	0	2047	41	0	8224	20291	18484
37	3000	17	0	2047	41	0	8224	20291	19508
38	3000	17	0	2047	41	0	8224	20291	18485
39	3000	17	0	2047	41	0	8224	20291	19509
40	3000	17	0	2047	41	0	8224	20291	18486
41	3000	17	0	2047	41	0	8224	20291	19510
42	0	0	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0

APPENDIX C

APPENDIX C

This program accepts as input the results for program SETB and calculates a set of averages for whatever time period is specified. If calibration values are specified for the instrument, the calibrations are carried out by assuming linear drift between calibrations. Average wind direction is determined by a vector sum of individual wind directions in lieu of an arithmetic summation. If less than 75% of the data is present for any instrument during a time period, that instrument's average is not calculated and the location of the instrument is replaced by stars in the output.

```
C VARIABLE DEFINITIONS.  THESE OCCUPY A LARGE AREA OF CORE.  320K
C ARE NEEDED TO RUN WATFIVE.
      INTEGER *4  IBC(20),ITD(10),IAC(20),IN(20)
      REAL*4 SCT(11,6,150),CA(20),CZB(20),CZA(20),CC(20)
      REAL*4 SPD(6),D(200),COD(200),AV(64,150),SG(64,150)
     >,FCTR(20),TSP(10,150)
      INTEGER*2 ITC(11,6,150)/9900*0/,ITF(20),ITTL(10,
     >150)
      INTEGER*4 DATE(8)
      CF=29.
C
C
C
C
C THIS TELLS HOW MANY DAYS OF DATA NEED BE TAKEN.  I5.
      READ (5,5010) MA
      DO 580 MB=1,MA
C
C
C
C
C
C THERE ARE TWO CARDS FOR EACH DAY OF DATA.  THE FIRST IS THIS:8A4.
C A 20 CHARACTER HEADER PRINTED ON EACH AVERAGE.
      READ (5,5020) DATE
C
C
C THE SECOND IS A CARD CARRYING THE TIME PARAMETERS.  BEGIN,INTERVAL,EN
C 3I10.  TIMES MUST BE SUPPLIED IN MINUTES.
      READ(5,5000) IBT, IAT, IET ,CF
```

```
C
C
C
      IBT=IBT*6000
      IAT=IAT*6000
      IET=IET*6000
    2 CONTINUE
C
C
C
C INITIALIZATION SECTION.  SETS TIME FOR HEADER AND FIXES VARIABLES
      CALL ITIM(IH,IX,IS,IAT)
      IF (IX .EQ. 0) IX=60
      DO 7 I=1,64
      DO 7 J=1,150
      SG(I,J)=10.**30.
      AV(I,J)=10.**30.
      DO 7 K=1,6
      IF (I .LT. 12) SCT(I,K,J)=0.0
      IF (I .LT. 12) ITC(I,K,J)=0
    7 CONTINUE
      WRITE (2,6010)
C
C
C
C NOW THE LOG IS READ IN AND IMMEDIATLY PRINTED OUT.
   9  CONTINUE
      READ (1,1010,END=9) IH,IM,IS,IT,(IN(J),J=1,15)
      IF (IH .LT. 0) GOTO 10
      WRITE(2, 6000) IH, IM, (IN(J), J=1, 15)
      GO TO 9
 10   CONTINUE
C
C
C
C THE FIRST TEN CHANNELS ARE RADAR CHANNELS AND AS A RESULT MUST BE
C HANDLED SEPERATLY.  THIS SECTION HANDLES THEM.
   20 CONTINUE
      READ (1,1020,END=580) IH,IM,IS,IT,I,ITT,INC,ITY
      IF (ITY .GT. 10) GO TO 140
      IBTT=IBT
      IETT=IBT+IAT
      K=1
      DO 30 J=1,5
      ITC(I,J,K)=0
      SCT(I,J,K)=0.
 30   CONTINUE
      ICTT=0
   40 CONTINUE
      READ (1,1040,END=580) IH,IM,IS,IT,I,ITT,(ITF(L),SPD(L),L=1,5)
      IF (IH .LT. 0) GO TO 20
```

```
      IC=IH*360000+IM*6000+IS*100
      IF (ICTT .EQ.IC) GO TO 40
      IF (IC .GT. IET) GO TO 40
      ICTT=IC
      IF (IC-IBTT) 40, 60, 60
 60   IF (IC-IETT) 70, 100, 100
 70    DO 80 L=1, 5
      ITC(I, L, K) = ITC(I, L, K)+ITF(L)
      SCT(I, L, K)=SCT(I, L, K)+ITF(L)*SPD(L)
 80   CONTINUE
      GO TO 40
 100  IF (IETT .GE. IET) GO TO 40
      IBTT=IETT
      IETT=IETT+IAT
      K=K+1
      DO 105 M=1, 5
      ITC(I,M,K)=0
      SCT(I,M,K)=0.
 105  CONTINUE
      GO TO 70
 130   CONTINUE
C
C
C
C THIS SECTION HANDLES ALL METEROLOGICAL INSTRUMENTS.  THE WIND VANES
C HAVE THEIR OWN SPECIAL CHARACTERISTICS AND ARE ROUTED DIFFERENTLY.
      READ (1,1020,END=540) IH,IM,IS,IT,I,ITT,INC,ITY
  140 CONTINUE
       K=1
      IZ=0
      SUM1=0.
      SUMSQ1=0.
      SUM=0.
      SUMSQ=0.
      IBTT=IBT
      IETT=IBT+IAT
      IF (IH .LT. 0) GO TO 540
      IF (ITY .EQ. 17) GO TO 310
      NMBR=IAT/INC
  150 CONTINUE
      READ (1,1050,END=540)IH,IM,IS,ID,I,ID,  IL, (D(L), L=1, IL)
      IF (IH .LT. 0) GO TO 130
      ITD(1)=IH*360000+IM*6000+IS*100
      IF (ITD(1) .LT. IBT-10*INC) GO TO 150
      L=2
 210  CONTINUE
      ITD(L)=ITD(L-1)+INC
      L=L+1
      IF (L .LE. IL) GO TO 210
      L=1
  220 CONTINUE
```

```
      IF (ITD(L) .LT. IBTT) GO TO 230
      IF (ITD(L) .GE. IETT) GO TO 250
      IZ=IZ+1
      IF (IO .EQ. 13) GO TO 240
      SUM=SUM+D(L)
      SUMSQ=SUMSQ+D(L)**2
 230  CONTINUE
      L=L+1
      IF (L .GT. IL) GO TO 150
      GO TO 220
C
C
C
C HERE IS THE WIND VANE HANDLING SECTION.
 240  CONTINUE
      DD1=D(L)*3.1415926/180.
      DD=SIN(DD1)
      DD1=COS(DD1)
      SUM=SUM+DD
      SUM1=SUM1+DD1
      SUMSQ=SUMSQ+DD**2
      SUMSQ1=SUMSQ1+DD1*DD1
      GO TO 230
 250  CONTINUE
      IF (IZ .LT. 2) GO TO 260
      AV(I,K)=SUM/IZ
      SG(I,K)=SQRT (ABS(SUMSQ-(SUM*SUM/IZ))/(IZ-1))
      IF (SUM*SUM/IZ .GT. SUMSQ) SG(I,K)=-SG(I,K)
      IF (ID .NE. 13) GO TO 260
      AV(I,K)=(180/3.1415926)*ATAN2(AV(I,K), SUM1/IZ)
      IF (AV(I,K) .LT. 0.) AV(I,K)=AV(I,K)+360.
      SG(I,K)=SQRT(ABS(SG(I,K)**2)+((SUMSQ1-(SUM1**2/IZ))/(IZ-1)))*57.14
      IF ( SUM*SUM/IZ .GT. SUMSQ .OR.SUM1**2/IZ .GT.SUMSQ1) SG(I,K)=-SG(
     >I,K)
 260  CONTINUE
      IF (IZ .GT. 3*NMBR/4) GO TO 270
      AV(I,K)=10.**30.
      SG(I,K)=10.**30.
 270  CONTINUE
      K=K+1
      IBTT=IETT
      IETT=IETT+IAT
      IF (IETT .GT. IET) GO TO 290
      SUM=0.
      SUM1=0.
      SUMSQ=0.
      SUMSQ1=0.
      IZ=0
      GO TO 220
 290  CONTINUE
      CALL DMRD
```

```
      GO TO 130
C
C
C
C THE ECOLYZERS ALSO REQUIRE A DIFFERENT APPROACH.  THEY ARE HANDLED IN
C SECTION.  THEY ARE THE ONLY INSTRUMENTS WHICH HAVE A CALIBRATION FACT
C INTRODUCED.  THE METEROLOGICAL INSTRUMENTS DO NOT REQUIRE SUCH TREATM
  300 CONTINUE
      READ (1,1020,END=540) IH,IM,IS,IT,I,ITT,INC,ITY
      IF (IH .LT. 0) GO TO 540
  310 CONTINUE
      K=1
      IZ=0
      SUM1=0.
      SUMSQ1=0.
      SUM=0.
      SUMSQ=0.
      IBTT=IBT
      IETT=IBT+IAT
      CA(1)=0.
      CZB(1)=0.
      CZA(1)=0.
      CC(1)=1.
      IBC(1)=0
      M=1
      NK=2
      CA(NK)=0.
      CZB(NK)=0.
      CZA(NK)=0.
      CC(NK)=1.
      IBC(2)=10000000
  320 CONTINUE
      READ (1,1050,END=540) IH,IM,IS,IT,I,ITT,IL,(D(J),J=1,IL)
      IF (IT .GT. 10) GO TO 324
      IBC(NK)=IH*360000+IM*6000+IS*100
      CA(NK)=D(1)
      IF (D(2) .EQ. 0.) D(2)=D(1)
      CZB(NK)=D(2)-D(1)
      IF (D(3) .EQ. 0.) D(3)=D(1)
      CZA(NK)=D(3)-D(1)
      CC(NK)=(D(4)-CZA(NK))/CF
      IF (D(4) .EQ. 0.) CC(NK)=CC(NK-1)
      NK=NK+1
      CA(NK)=CA(NK-1)
      CZB(NK)=CZA(NK-1)
      CZA(NK)=CZA(NK-1)
      CC(NK)=CC(NK-1)
      IBC(NK)=10000000
      GO TO 320
  322 CONTINUE
      READ (1,1050,END=540)IH,IM,IS,ID,I,ID,  IL, (D(L), L=1, IL)
```

```
      IF (IH .LT. 0) GO TO 300
  324 CONTINUE
      ITD(1)=IH*360000+IM*6000+IS*100
      L=2
  330 CONTINUE
      ITD(L)=ITD(L-1)+INC
      L=L+1
      IF (L .LE. IL) GO TO 330
      L=1
  335 CONTINUE
      IF (ITD(L) .LT. IBTT) GO TO 322
      IF (ITD(L) .GE. IETT) GO TO 350
      IZ=IZ+1
      DD=CA(M)+(CA(M+1)-CA(M))*(ITD(L)-IBC(M))/(IBC(M+1)-IBC(M))
      DD1=CZB(M)+(CZA(M+1)-CZB(M))*(ITD(L)-IBC(M))/(IBC(M+1)-IBC(M))
      DD2=CC (M)+(CC (M+1)-CC (M))*(ITD(L)-IBC(M))/(IBC(M+1)-IBC(M))
      D(L)=(D(L)-DD-DD1)/DD2
      IF (ITD(L) .GE. IBC(M+1)) M=M+1
      SUM=SUM+D(L)
      SUMSQ=SUMSQ+D(L)**2
  340 CONTINUE
      L=L+1
      IF (L .GT. IL) GO TO 322
      GO TO 335
C
  350 CONTINUE
      IF (IZ .LT. 2) GO TO 360
      AV(I,K)=SUM/IZ
      SG(I,K)=SQRT (ABS(SUMSQ-(SUM*SUM/IZ))/(IZ-1))
      IF (SUM*SUM/IZ .GT. SUMSQ) SG(I,K)=-SG(I,K)
  360 CONTINUE
      IF (IZ .GT. 3*NMBR/4) GO TO 370
      AV(I,K)=10.**30.
      SG(I,K)=10.**30.
  370 CONTINUE
      K=K+1
      IBTT=IETT
      IETT=IETT+IAT
      IF (IETT .GT. IET) GO TO 390
      SUM=0.
      SUM1=0.
      SUMSQ=0.
      SUMSQ1=0.
      IZ=0
      GO TO 335
  390 CONTINUE
      CALL DMRD
      GO TO 300
  540 CONTINUE
      IBTT=IBT-IAT
      NAVG=(IET-IBT)/IAT
```

```
      IPAG=1
C
C
C
C
C
C
C
C
C THIS IS THE REPORT WRITING SECTION
      DO 570 J=1, NAVG
      ITTL(3,J)=0
      ITTL(2,J)=0
      ITTL(1,J)=0
      TSP(1,J)=0.
      TSP(2,J)=0.
      DO 545 I=1, 6
      SCT(11,I,J)=0.
      ITC(11, I, J)=0
 545  CONTINUE
      DO 560 I=1, 11
      IF (I .EQ. 11) GO TO 546
      ITC(I, 6, J)=ITC(I, 1, J)+ITC(I, 2, J)+ITC(I, 3, J)+ITC(I, 4, J)
      SCT(I, 6, J)=SCT(I, 1, J)+SCT(I, 2, J)+SCT(I, 3, J)+SCT(I, 4, J)
 546  CONTINUE
      DO 550 K=1,6
      IF (I .EQ. 11) GO TO 548
      ITC(11, K, J)=ITC(11, K, J)+ITC(I, K, J)
      SCT(11, K, J)=SCT(11, K, J)+SCT(I, K, J)
 548  CONTINUE
      IF (ITC(I,K,J) .NE. 0)SCT(I,K,J)=(SCT(I,K,J)/ITC(I,K,J))*1.4
 550  CONTINUE
 560  CONTINUE
      ITTL(3, J)=ITC(11,6,J)
      TSP(3,J)=SCT(11,6,J)
      DO 565 I=1, 5
      IZ=I+5
      ITTL(1,J)=ITTL(1,J)+ITC(I,6,J)
      ITTL(2,J)=ITTL(2,J)+ITC(IZ,6,J)
      TSP(1,J)=TSP(1,J)+SCT(I,6,J)     *ITC(I,6,J)
      TSP(2,J)=TSP(2,J)+SCT(IZ,6,J) *ITC(IZ,6,J)
 565  CONTINUE
      IF (ITTL(1,J).NE.0) TSP(1,J)=TSP(1,J)/ITTL(1,J)
      IF (ITTL(2,J) .NE. 0) TSP(2,J)=TSP(2,J)/ITTL(2,J)
      IF (IPAG .EQ. 1) WRITE(2,6010)
      IF (IPAG .EQ. 2) IPAG=0
      IPAG=IPAG+1
      CALL ITIM(IH,IM,IS,(IBT+IAT*J))
      WRITE (2,6040)IX,IH,IM,DATE
      WRITE (2,6020) AV(43,J),(ITC(I,1,J),I=1,11),(AV(I,J),I=14,26,4),
     >AV(29,J),SG(43,J),(SCT(I,1,J),I=1,11),(SG(I,J),I=14,26,4),SG(29,J)
```

```
      WRITE (2,6050) AV(45,J),(ITC(I,2,J),I=1,11),(AV(I,J),I=13,25,4),
     >SG(45,J),(SCT(I,2,J),I=1,11),(SG(I,J),I=13,25,4)
      WRITE (2,6060) AV(47,J),(ITC(I,3,J),I=1,11),(AV(I,J),I=12,28,4),
     >SG(47,J),(SCT(I,3,J),I=1,11),(SG(I,J),I=12,28,4)
      WRITE (2,6060) AV(49,J),(ITC(I,4,J),I=1,11),(AV(I,J),I=11,27,4),
     >SG(49,J),(SCT(I,4,J),I=1,11),(SG(I,J),I=11,27,4)
      WRITE (2,6070) AV(51,J),(ITC(I,5,J),I=1,11),AV(36,J),
     >SG(51,J),(SCT(I,5,J),I=1,11),SG(36,J)
      WRITE (2,6080) (ITC(I,6,J),I=1,10),AV(37,J),(SCT(I,6,J),I=1,10),
     >SG(37,J)
      WRITE (2,6090) AV(40,J),ITTL(1,J),ITTL(2,J),(AV(I,J),I=30,34,2),
     >AV(38,J),SG(40,J),TSP(1,J),TSP(2,J),(SG(I,J),I=30,34,2),SG(38,J)
      WRITE (2,6100) AV(41,J),ITTL(3,J),(AV(I,J),I=31,35,2),AV(39,J),
     >SG(41,J),TSP(3,J),(SG(I,J),I=31,35,2),SG(39,J)
 570  CONTINUE
  580 CONTINUE
      WRITE (2,6010)
C
C
C
C
C
C
C THESE ARE THE FORMATS RESPONSIBLE FOR THE READS A D WRITES,
 1010 FORMAT (3I2,I3,18A4)
 1020 FORMAT (3I2,3I3,5I5)
 1040 FORMAT (3I2,3I3,5(I5,F5.1))
 1050 FORMAT (3I2,3I3,I2,9F7.0)
 5000 FORMAT (3I10,F5.0)
 5010 FORMAT (I5)
 5020 FORMAT (8A4)
 6000 FORMAT (´ ´,I2,´:´,I2,´ NOTE:´, 18A4)
 6010 FORMAT (´1´)
 6020 FORMAT (8X,F7.1, 6X,11I6, 5X,4F7.1,F8.0/8X,F7.2, 6X,11F6.1, 5X,
     >4F7.2,F8.1,/)
 6050 FORMAT (8X,F7.1, 6X,11I6, 5X,4F7.1/8X,F7.2, 6X,11F6.1, 5X,4F7.2/)
 6060 FORMAT (8X,F7.1, 6X,11I6, 5X,5F7.1/8X,F7.2, 6X,11F6.1, 5X,5F7.2/)
 6070 FORMAT (8X,F7.1, 6X,11I6,19X, F7.1/8X,F7.2, 6X,11F6.1,19X, F7.2/)
 6080 FORMAT (21X,10I6,25X,F7.1/21X,10F6.1,25X,F7.2/)
 6100 FORMAT (8X,F7.1,36X, I6,39X,4F7.1/8X,F7.2,36X, F6.1,39X,4F7.2/)
 6090 FORMAT (8X,F7.1,21X,I7,23X,I7,23X,4F7.1/8X,F7.2,21X,F7.1,23X,F7.1,
     >23X,4F7.2/)
 6040 FORMAT (////,40X,I3,´ MINUTE AVERAGE AT ´,I2,´:´,I2,10X,´FILE: ´,
     >8A4)
      STOP
      END
      SUBROUTINE DMRD
    1 CONTINUE
      READ (1,100) K
      IF (K .LT. 1) RETURN
      GO TO 1
```

```
100 FORMAT (I5)
    END
    SUBROUTINE ITIM(I,J,K,L)
    I=L/360000
    J=L/6000-I*60
    K=L/100-J*60-I*3600
    RETURN
    END
```

APPENDIX D

APPENDIX D

DATA FORMAT FOR DETAILED EXPERIMENTAL DATA

In this format, each record is arranged as a card image. Thus the records will be discussed as if they were actually cards. Table D-1 in this Appendix shows a listing of an example data set extracted from one day's data to illustrate the following discussion.

Each card type has a rigidly defined format specified by columns 8 and 9. All formats carry similar fields in columns 1 through 9.

Columns 1 through 6 hold a time parameter for the card in HHMMSS format where HH refers to hours after midnight, MM refers to minutes after the hour, and SS refers to seconds after the minute. The value and meaning of the time parameter varies depending on the card format and will be covered under each card type description.

At present, six different card formats are being used:

-1 = terminator
1 = channel parameters
5 = log entry
7 = instrument calibration data
10 = traffic data
11 = nontraffic data

A -1 or terminator card is used after the last log entry and after the last data card for each channel. The end of an entire data set is signaled by two terminators in succession. All terminator cards are identical and can be read in under any format without an illegal conversion error. However, any one of five fields can be used as a flag to alter program flow. These cards contain an hours parameter of -9, a minutes parameter of 99, a seconds parameter of 99, and a format parameter of -1. In order for the card to be read properly by other formats, it was necessary to include a "-1" in columns 11 and 12, and a "1" in column 17. The rest of the card is blank.

Type 1 cards contain zeros in columns 1 through 6, a "1" in column 9 and in column 15. Columns 11 and 12 contain the channel number. Columns 16 through 20 contain the sampling interval in hundredths of a second. Columns 21 through 25 contain the instrument type. The following types were used:

Type 10 = Radar

Type 11 = Vertical Anemometer until NO_x monitors were used, Thereafter NO_x monitor.

Type 12 = Horizontal Anemometer

Type 13 = Wind Vane

Type 14 = Thermometer

Type 15 = Psychrometer

Type 16 = Pyranometer

Type 17 = Ecolyzer

Type 18 = Vertical Anemometer after NO_x monitors were employed.

Columns 26 through 30 contain the minimum expected A/D value for the channel in I5 format. Columns 31 through 35 contain the maximum expected A/D value for the channel in I5 format. Columns 36 through 40 contain the A/D value corresponding to 1 unit (mile per hour, degree Farenheit, part per million, etc.). Columns 41 through 45 contain the A/D value equal to zero units. Columns 46 through 52 contain a six character instrument name.

Type 5 or log entry cards contain the time the message was entered in Columns 1 through 6 and a 5 in column 9. Columns 10 through 80 contain the log entry.

A type 7 card contains calibration information for a particular channel. The first six columns contain the time the calibration was made to the nearest five minutes. Column 9 contains a "7", indicating the card type. Columns 11 and 12 contain the number of the channel that was calibrated. Columns 14 and 15 contain the instrument type as detailed under type 1 cards. Column 17 contains a "4" to indicate that 4 values follow. Columns 18 through 45 contain 4 F7.2 numbers. Columns 18 through 24 contain the units read with the A/D inputs shorted. Columns 25 through 31 contain the units read with the instrument set to zero before any adjustments were made. Columns 32 through 38 contain the instrument's zero reading after any adjustments were made. Columns 39 through 45 contain the instrument reading while being spanned. For Ecolyzers, this number should ideally be 29.00 before July 21, 1977 and 22.50 after that time, as span gases were changed on that day. A 0.00 in any field indicates that the value was unknown, not that it was zero. The user must take whatever corrective action he feels is appropriate in such cases.

Type 10 cards contain traffic data on a minute by minute basis. Each card gives traffic information for 1 minute and 1 lane. Columns 1 through 6 give the ending time of the one minute period to which the card applies. Columns 8 and 9 contain a "10", indicating the card type. Columns 11 and 12 contain the channel number of the radar supplying the information. Columns 13 through 15 are blank. Columns 16 through 65 contain the actual traffic data, consisting of 5 pairs of numbers. The first number of each pair is an I5 integer giving vehicle count. The second number of each pair gives the average speed in a F5.1 format. Each pair of numbers represents a particular vehicle type. The first type, contained in columns 16 through 25 represents light duty gasoline vehicles (motorcycles, cars, pickups, etc.). The second type, contained in columns

26 through 35, represents heavy duty gasoline vehicles (short trucks). The third type (columns 36 through 45) represents short diesel trucks. The fourth type (columns 46 through 55) represents long trucks. The fifth type was to be reserved for calibration purposes, but, in practice, it sometimes caught tailgaters, registering two closely spaced vehicles as one very long vehicle. There is considerable overlap in these categories, and caution should be used in assigning accuracies to the classes.

The largest number of cards in any data set are the type 11 cards. These contain the data for all instruments except the radars. The first 6 columns contain the time of the first data reading on the card. Columns 8 and 9 contain an "11", detailing the card type. Columns 11 and 12 contain the channel number the card refers to. Columns 14 and 15 contain the instrument type as detailed under card type 1. Column 17 contains an integer telling how many data readings are contained on the card. One to nine successive data points follow in F7.2 format. With the initial time on the card and the sampling interval from the channel's type 1 card, the time of any data point can be ascertained.

The overall arrangement of the data consists of the log, followed by a terminator, followed by all the radar channels, each consisting of a type 1, all type 10's in chronological order, and a terminator for each channel. The other channels then follow in numerical order, each consisting of a type 1, any type 7's in chronological order, all the type 11's in chronological order, and a terminator. An extra terminator follows the last channel to designate the end of the data set.

TABLE D-1

SAMPLE DATA SET

```
1613 0 05 5-18-77. TEST OF CO MONITORS.  NOX BOXES NOT OUT.
-99999 05 END OF MESSAGE SECTION
000000 01  6  1    1   10 -200 2047   20    0 RADRO5
1714 0 10  6      15 35.6    2 35.7    0  0.0    0  0.0    0  0.0
1715 0 10  6       8 35.9    0  0.0    0  0.0    0  0.0    0  0.0
1716 0 10  6       6 31.3    0  0.0    0  0.0    0  0.0    0  0.0
1717 0 10  6       0  0.0    0  0.0    0  0.0    0  0.0    0  0.0
1718 0 10  6       8 37.7    0  0.0    0  0.0    0  0.0    0  0.0
1719 0 10  6       5 35.7    0  0.0    0  0.0    0  0.0    0  0.0
1720 0 10  6       6 36.6    0  0.0    0  0.0    0  0.0    0  0.0
1721 0 10  6       2 39.4    0  0.0    0  0.0    0  0.0    0  0.0
1722 0 10  6       3 37.6    0  0.0    0  0.0    0  0.0    0  0.0
1723 0 10  6       1 35.8    0  0.0    0  0.0    0  0.0    0  0.0
1724 0 10  6       2 39.6    0  0.0    0  0.0    0  0.0    0  0.0
1725 0 10  6       2 34.5    1 39.1    0  0.0    0  0.0    0  0.0
-99999 -1 -1    1
000000 01 11  1  200   18 -854  854    5    0 VA1.5M
171414 11 11 18 9  -1.20   1.20  11.20  -1.60  -5.00   8.00   7.80   2.20   4.20
171432 11 11 18 9   0.00   1.20  -3.00   2.00  -0.20  -1.00   2.60   1.20  -1.00
171450 11 11 18 9  11.80   7.60   7.60   2.40   7.20   8.20   3.80   2.60   2.00
1715 8 11 11 18 9   2.20   1.40  -1.20  -0.20   0.20  -1.60   6.40  -1.00   0.20
171526 11 11 18 9   2.20  -1.00  -5.00  -3.60  -0.80   0.00   4.40   1.60   0.80
171544 11 11 18 9   5.60  11.40  -4.00   2.60   5.60   5.40  -2.00 -11.80  -6.00
1716 2 11 11 18 9   5.80   2.40   3.60   2.00  -1.80  -8.00  -4.20 -10.00  -2.80
171620 11 11 18 9  -1.20   5.20   0.80  -2.00   2.20   1.20  -2.60  -2.40  -1.60
171638 11 11 18 9   3.40   2.40   2.40   0.00   0.40   3.20  -1.20  -0.40   0.00
171656 11 11 18 9  -0.40   2.00  -2.60   6.40   6.80   5.20   1.20   0.80   1.60
171714 11 11 18 9   2.80   1.60   1.60   6.80   6.00  -0.40  -4.00 -21.20   8.40
171732 11 11 18 9   5.40  10.00   7.60   4.80  23.00  -1.40  -2.80  -7.40  -0.40
171750 11 11 18 9  -0.60  -1.60   0.80   0.00  -1.00  -6.40  -0.40  -2.60   1.80
1718 8 11 11 18 9  -1.40   2.80   6.20   1.60  -2.80  -3.60  -3.20   0.40  -4.80
171826 11 11 18 9  -0.20  -9.60   0.00   2.00   1.20  -4.00  -2.20  -4.20  -9.00
171844 11 11 18 9  -4.60   3.80  -1.20  -8.00  -7.60  -1.80  -9.40  -3.00  -3.60
1719 2 11 11 18 9   0.60  -1.60   8.80   6.00  -0.20   2.60  -1.00  -0.20   1.60
171920 11 11 18 9   1.60   0.60   2.00   0.00  -0.80   0.80   3.40   2.20  -0.40
171938 11 11 18 9   1.00   1.00   3.60   8.00   8.00   2.80  -2.40  -3.00   0.80
171956 11 11 18 9   0.80   1.60  -3.60 -17.80  -4.20  -5.40  -1.00  -0.40  -6.00
172014 11 11 18 9   0.40  10.20  20.80   2.20  -3.20  -5.40   0.40  -4.40   2.80
172032 11 11 18 9 -12.40   8.00   0.40  -2.60  -1.80  -4.20  -0.20   3.20   2.20
172050 11 11 18 9  -7.60  -5.20  -2.40  -8.40 -10.00   0.40  -1.80  -5.00   2.40
1721 8 11 11 18 9   2.40   1.20   1.60   4.80   4.80   4.80   1.60   1.20   0.80
172126 11 11 18 9   6.40  -1.00  -1.00  -0.40  -1.00   0.40   0.00   0.80   1.20
172144 11 11 18 9   0.00   1.80  -0.20  -3.40  -0.40   2.00  -3.40   0.00  -5.20
1722 2 11 11 18 9   4.00  -5.20   0.00  -4.40   1.40   0.60  -3.80   0.40   0.40
172220 11 11 18 9  -1.40  -1.00   1.60   1.60   0.80   0.60  -0.20   0.00  -3.40
172238 11 11 18 9   0.40  -4.20   1.60   3.20   0.00   1.00   2.80   2.00  -2.40
172256 11 11 18 9  -5.60  -7.80   0.00   1.00   4.60  -1.00  -0.20  -2.00  -2.00
172314 11 11 18 9  -3.20  -0.80  -0.60   0.00   0.00   1.40   3.40   1.60   1.60
172332 11 11 18 9   7.60   3.60   0.80   0.40  -2.40  -4.20 -20.00  -4.60   1.20
172350 11 11 18 9   2.80   4.80   3.20  -6.60 -19.60 -15.60 -15.60 -11.00   0.80
```

```
1724 8 11 11 18 9  -3.40   -7.80 -25.00 -13.20   -4.40    0.80    3.20    2.60    5.20
172426 11 11 18 9  -5.40    2.20  -4.40    3.00    2.00    0.00   -2.20  -10.20   0.00
172444 11 11 18 9   0.60   -1.00   1.20    2.80   -2.80   -2.40    1.80    3.20    1.80
1725 2 11 11 18 9  -1.20   10.20  -3.40  -16.40   -1.40    1.40   -4.20   -7.40   -1.60
172520 11 11 18 9  -4.60   -1.20   0.40    0.80    0.60    2.00    4.40    5.60    1.60
172538 11 11 18 9  -0.20   -3.40  -8.00    0.40    1.80   -4.80    1.80   -4.80   -9.20
172556 11 11 18 9  -2.80  -21.60 -16.40    0.00    9.20    1.20    0.80   -2.80   -5.80
-99999 -1 -1     1
000000 01 15  1 1500    12      0  614    20      0 HA1.5M
171530 11 15 12 9    3.80    4.50   5.55    3.90    3.90    4.15    3.95    3.20    6.10
171745 11 15 12 9    5.05    4.75   8.70    4.20    5.10    4.00    6.30    4.00    5.35
1720 0 11 15 12 9    3.60    2.65   4.95    4.20    6.45    6.00    6.25    5.60    4.05
172215 11 15 12 9    3.30    2.95   3.20    3.85    4.10    5.00    5.10    6.35    4.90
172430 11 15 12 9    4.95    4.65   5.20    5.80    5.35    6.00    7.50    8.30    6.30
-99999 -1 -1     1
000000 01 19  1  500    13      0 2047     6      0 WV1.5M
171435 11 19 13 9 177.50 153.17 157.50 179.50 167.83 179.83 167.17 149.00 170.50
171520 11 19 13 9 185.33 179.00 168.67 168.50 153.67 163.33 198.67 157.83 160.33
1716 5 11 19 13 9 175.00 163.33 161.33 194.00 181.67 203.67 182.83 174.67 161.67
171650 11 19 13 9 165.17 189.50 156.50 185.83 180.00 142.33 146.67 170.00 149.67
171735 11 19 13 9  93.67 142.67 153.33 158.50 162.00 144.67 183.17 192.33 175.00
171820 11 19 13 9 169.67 183.67 173.00 155.00 165.17 174.67 156.33 165.33 172.17
1719 5 11 19 13 9 181.00 156.50 163.50 177.17 171.17 166.33 158.67 154.83 157.33
171950 11 19 13 9 161.67 151.67 159.00 146.00 198.33 230.67 165.50 128.00 171.33
172035 11 19 13 9 187.33 210.17 190.67 151.83 157.67 189.33 172.33 185.33 166.50
172120 11 19 13 9 167.83 172.33 181.00 184.17 170.67 177.00 167.00 156.17 157.67
1722 5 11 19 13 9 144.17 161.33 177.33 186.83 186.00 181.17 171.00 178.00 179.00
172250 11 19 13 9 170.67 177.33 230.67 200.00 181.00 186.17 175.33 189.17 173.17
172335 11 19 13 9 162.17 150.00 126.00 179.83 166.33 173.33 145.17 161.17 128.67
172420 11 19 13 9 175.00 159.33 164.17 173.17 165.83 153.67 172.50 165.17 179.67
1725 5 11 19 13 9 169.67 165.67 154.00 158.17 172.33 158.33 154.50 155.67 171.17
172550 11 19 13 9 175.67 158.33 172.33 152.17 185.00 164.50 183.50 173.50 170.67
-99999 -1 -1     1
000000 01 23  1 6000    14    921 1791    13   -512 TP1.5M
1717 0 11 23 14 9   81.54   81.92  81.23   81.08   80.85   80.15   80.23   80.31   79.85
-99999 -1 -1     1
000000 01 27  1 6000    15      0 2047    20      0 RH1.5M
1717 0 11 27 15 9   51.20   51.10  51.15   51.20   51.10   51.60   51.75   51.90   51.90
-99999 -1 -1     1
000000 01 29  1 6000    16      0 1500     1      0 PYRANM
1717 0 11 29 16 9 611.00 323.00 306.00 376.00 258.00 241.00 250.00 254.00 274.00
-99999 -1 -1     1
000000 01 31  1 1000    17    -41 2047    41      0   COIL
172000  7 31 17 4    0.05    0.39   0.39   28.12
171310 11 31 17 9    3.20    3.20   3.00    2.68    2.34    2.27    2.20    2.17    2.02
171440 11 31 17 9    2.05    2.02   2.05    2.20    2.24    2.24    2.34    2.44    2.46
171610 11 31 17 7    2.46    2.39   2.34    2.32    2.22    2.22    2.27
172450 11 31 17 9    1.83    1.83   1.73    1.68    1.59    1.56    1.61    1.54    1.49
-99999 -1 -1     1
-99999 -1 -1     1
```

APPENDIX E

Sample Calculation of Mass Balance Technique Using Texas A&M Data

As previously stated, to arrive at average vehicular emission factors from time averaged dispersion and traffic data, it is necessary to know the wind speed component across the roadway and the mass per volume of pollutant as functions of height. When these functions are multiplied together and integrated over the height of the plume, the result is the total mass of pollutant leaving a unit length of roadway per unit time. Dividing this figure by the number of vehicles passing the site per unit time yields an emission factor in units of mass per vehicle-length traveled. EPA publications which estimate emissions specifically quote CO concentrations in gm/vehicle mile. Most popular dispersion models accept emission factors in these units.

An example case is solved here to show the procedure followed in converting the Texas data into vehicular emission factors. The chosen period was the 5 minute period ending at 7:35 AM on August 11, 1977. At this time, the project was monitoring at IH30 and Motley Drive in Dallas. The following data were obtained (see data sheet shown in Table E-1):

Z = Height (ft)	u = horizontal wind speed (m/hr)	θ = wind angle (° from north)	CO = concentration (PPM)
102	3.9	151	1.2
47	3.7	147	1.7
33	3.6	137	2.3
5	3.1	130	3.1

Only one background instrument was operating, and it read (CO_{BG}=) 1.3 ppm.

Observed total traffic was 338 vehicles per 5 minutes. However, one radar unit was out of service at that time. Data from other days indicated that the missing lane count was typically 5.4% of the total traffic count. Therefore, to extrapolate a more accurate total traffic, the observed total was multiplied by 1 + 5.4/100 = 1.054, yielding 356 vehicles per 5 minutes.

At this site, the report shows that the roadway ran at an angle of 56° from the north. By trigonometry, the component of the wind across the road is equal to the total wind speed multiplied by the sine of the angle measured with respect to the roadway. Since the sign of the number is of no importance in the present application, the absolute value of the number is taken, yielding

$$u_x = u*ABS(SIN[\theta - 56°]) \qquad (E\text{-}1)$$

Since the only carbon monoxide of interest is that contributed by the roadway, the background CO must be subtracted. Since background is assumed independent of height, all cases in which the background instruments showed a difference of greater than 0.5 ppm were discarded, and in the remaining cases, the values were averaged and taken as the true background. If only a single instrument was operating, the need for averaging was eliminated. In cases where background instrument read more than 0.5 ppm over a downwind instrument, the case was discarded. In all other cases, the background reading was subtracted from the downwind readings to obtain a net value for CO concentration due to the road. If this concentration was negative, it was set to zero.

$$CO_n = (CO - CO_{BG}) \geq 0 \qquad (E\text{-}2)$$

Application of Equations E-1 and E-2 to the data yield

Z(ft)	u_x(mph)	CO_n(PPM)
102	3.8	0
47	3.6	0.4
33	3.5	1.0
5	2.9	1.8

CO_n is shown as volumetric parts per million. To be used in the emission factor calculations, the values must be converted to grams of CO per cubic meter of air. An equation of state is necessary for this conversion. Since pressures are low, the perfect gas law may be used. According to this law $V = \frac{RT}{P}$ where

P is the absolute pressure

V is the volume of one mole of gas

T is the absolute temperature

R is a conversion factor to match the units.

For this use, it is accurate enough to approximate P = 1 atmosphere and T = 25°C = 298.25°K = 77°F. The calculations are simplified if V is given in cubic meters. R can be found in the CRC Handbook of Chemistry and Physics to be $8.21 \times 10^{-5} \frac{m^3 \text{ atm}}{\text{gmol } {}^\circ K}$. The volume of 1 gm mole of CO is therefore

$$V = \frac{8.21 \times 10^{-5} \text{ m}^3}{\text{gmol } {}^\circ K} \left| \frac{298.25 \ {}^\circ K}{} \right| \frac{}{1 \text{ atm}} = 0.0245 \frac{m^3}{\text{gmol}}$$

Taking the inverse of this shows that there are $40.8 \frac{\text{gmol CO}}{m^3}$. Since there are 28 gm/gmole of CO

$$\text{Density of CO} = \frac{40.8 \text{ gmol}}{m^3} \left| \frac{28 \text{ gm}}{\text{gmol}} \right. = 1140 \text{ gm/m}^3$$

Therefore, 1140 gm CO are dispersed in 10^6 m^3 of air for each ppm. Stated in mathematical terms.

$$\frac{1140 \text{ gm CO}}{10^6 \text{ m}^3 \text{ air}} = 1.14 \times 10^{-3} \frac{\text{gm CO}}{m^3 \text{ air}} = 1 \text{ ppm CO in air}$$

or

$$1.14 * 10^{-3} \frac{\text{gm CO}}{m^3 \text{ ppm}} .$$

u_x must also be converted from miles per hour to meters per hour if the units are to cancel properly. The CRC shows a conversion factor of 1609 $\frac{m}{mi}$. Thus, the mass of CO being carried away from the roadway at each height can be calculated as

$$CO_m = CO_n(ppm) * u_x(mi/hr) * (1.14 \times 10^{-3} \frac{gm\ CO}{m^3\ ppm}) * (1609 \frac{m}{mi}) \qquad (E-3)$$

CO_n = CO downwind - CO upwind.

Application of this equation yields:

Z(ft)	Z(m)	u_x(mi/hr)	CO_n(PPM)	$CO_m \left(\frac{gm\ CO}{m^2\ hr}\right)$
102	13.1	3.8	0	0
47	14.3	3.6	0.4	2.7
33	10.0	3.5	1.0	6.5
5	1.5	2.9	1.8	9.8

If Z in m is plotted against CO_m, the area bounded by the curve and the lines Z = 0 and CO_m = 0 is equal to the mass of CO emitted from a unit length of roadway for a unit time. A graphical method of integration was used. It consisted of plotting the points on graph paper and using a planimeter to determine the bounded area. The scales chosen were 5 m/inch in the Z azis and 2 gm/m^2 hr/in the CO_m axis. Each square inch was therefore 5m* 2 gm/m^2 hr = 10 $\frac{gm\ CO}{m\ hr}$. The completed graph for this case is shown in Figure E-1.

The planimeter showed 12.1 in^2 under the curve, indicating 121 gms CO per hour emitted from each meter of roadway. To convert this into the desired units of gm CO/vehicle mile, it is necessary to convert the meters of roadway to miles and to divide by the total traffic. That is

$$\text{Emission Factor} = \frac{121 \text{ gm CO}}{\text{m hr}} \Bigg| \frac{1609 \text{ m}}{\text{mi}} \Bigg| \frac{5 \text{ min}}{356 \text{ vehicles}} \Bigg| \frac{\text{hr}}{60 \text{ min}}$$

$$= 45.6 \frac{\text{gm CO}}{\text{vehicle mi}}$$

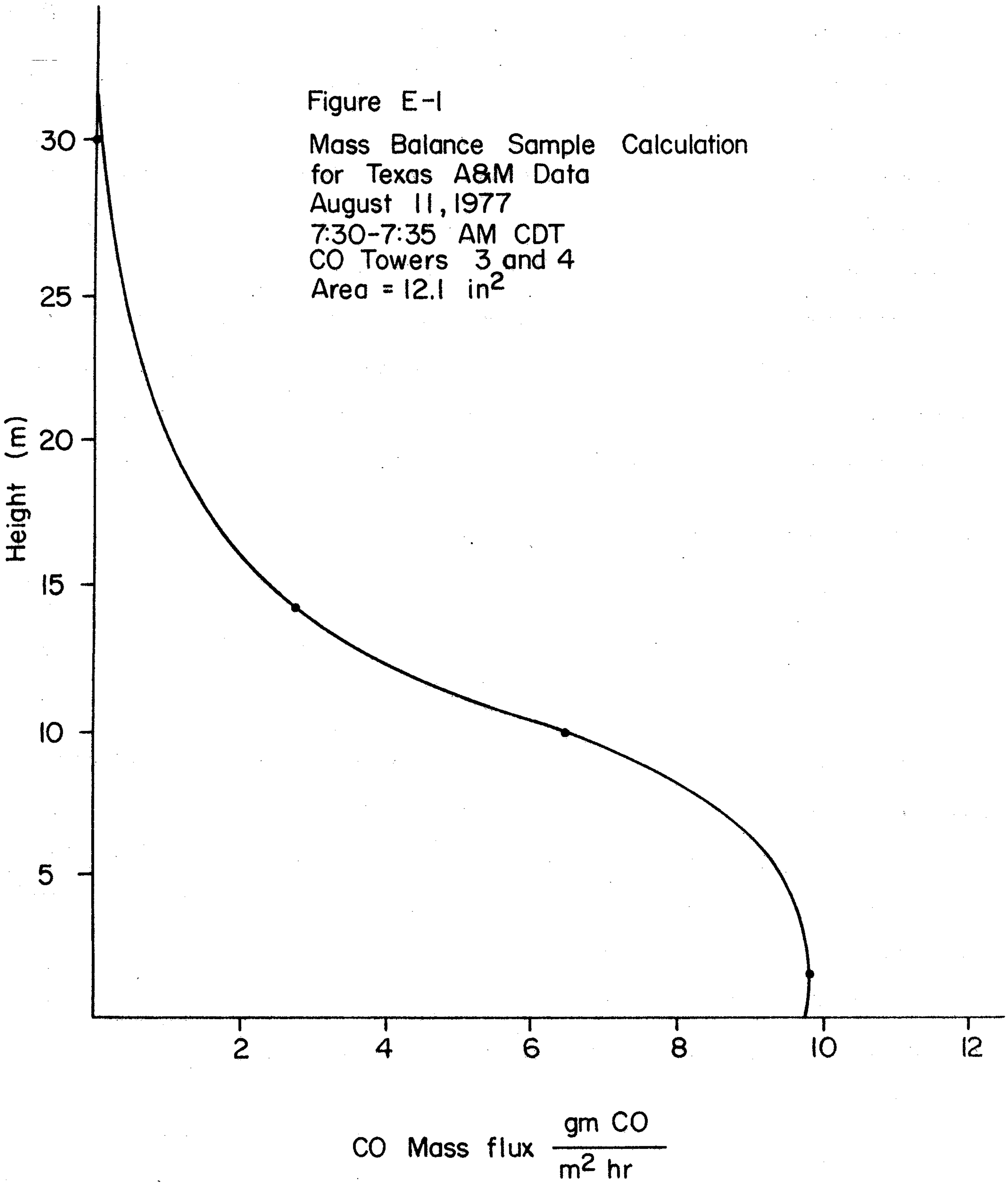


Figure E-1

Mass Balance Sample Calculation
for Texas A&M Data
August 11, 1977
7:30-7:35 AM CDT
CO Towers 3 and 4
Area = 12.1 in^2

Sample Calculation of Mass Balance Technique for GM Data

The GM data reduction is somewhat different from that of the Texas data due to the fact that GM traced SF_6, a heavy gas having no natural background, instead of CO. Also, GM listed wind speeds in meters per second instead of miles per hour. The roadway ran exactly north-south, meaning that the 56° in Equation (E-1) could be replaced by zero. The data set selected as an example ended at 8:10 AM on October 2, 1975. The results of this sampling period may be found on page 86 of the GM Report. Due to the wind direction, the eastern towers were downwind of the roadway, and the tower 15 meters from the roadway has been chosen for illustration purposes. This tower is represented by channels 13, 14, and 15. The following data were reported:

Z=height(m)	u=windspeed(m/sec)	θ=wind angle(°)	SF_6(PPB)
10.5	1.95	325	.282
4.5	1.68	328	1.093
1.5	1.64	334	1.417

In order to use these data, u_x must be obtained by the use of Equation (E-1), modified as mentioned above. In addition, the calculations required to convert ppb SF_6 to grams per meter^3 of SF_6 must be modified to account for the heavier weight of SF_6 per mole. SF_6 weighs 146.1 gm/mole as opposed to the 28 gm/mole of CO. Using the ideal gas law as before, with the average temperature in the GM cases studied being approximately 280°K, it can be shown that 1 gmole of SF_6 occupies 0.0230 m^3, implying that there are 43.48 $\frac{\text{gmol } SF_6}{m^3}$.

Since there are 146.1 gm/gmole SF_6,

$$1\ m^3\ SF_6 = \frac{43.48\ gmol}{m^3}\left|\frac{146.1\ gm}{gmol}\right. = 6352\ gm\ SF_6/m^3$$

Therefore, 6352 gm SF_6 are dispersed in $10^9\ m^3$ of air for each ppb. Mathematically

$$\frac{6352\ gm\ SF_6}{10^9 m^3\ air} = 6.35 \times 10^{-6}\ \frac{gm\ SF_6}{m^3\ air} = 1\ ppb\ SF_6$$

The conversion factor is thus $6.35 \times 10^{-6}\ \frac{gm\ SF_6}{m^3\ ppb}$.

In order to keep the units consistant with the Texas data, u_x must be converted from meters per second to meters per hour by multiplying by 3600 sec/hr.

Equation (E-3) then becomes

$$SF_{6m} = SF_6(ppb)*u_x(m/sec)*6.35 \times 10^{-6}\left(\frac{gm\ SF_6}{m^3\ ppb}\right) * 3600\left(\frac{sec}{hr}\right)$$

or

$$SF_{6m} = SF_6 * u_x * 2.29 \times 10^{-2}$$

Carrying out the calculations

Z(m)	u_x(m/sec)	$SF_{6m}\left(\frac{gm\ SF_6}{m^2\ hr}\right)$
10.5	1.12	.00723
4.5	0.890	.0223
1.5	0.719	.0233

Plotting Z against SF_{6m} yields the emission factor as before. Because of the relative smallness of SF_{6m}, the chart scales have to be different in order to obtain enough area for the planimeter to work accurately. The scales of choice are 2 meters per inch for Z and 0.005 $\frac{\text{gm SF}_6}{\text{m}^2\text{ hr}}$ for SF_{6m}. In this way each square inch represents 0.01 $\frac{\text{gm SF}_6}{\text{m hr}}$. The resulting graph shown in Figure E-2 encloses 21.1 in^2, making the emission factor .211 $\frac{\text{gm SF}_6}{\text{m hr}}$.

For this run, the vehicles were releasing SF_6 at a measured rate of 3.39 liters per minute. As the vehicles passed the sampling locations they were moving at 80 kph (49.8 mph). According to the GM Report, vehicles passed the monitoring location 15.5 times per hour.

At 80 kph, a vehicle covers

$$\frac{80\text{ kilometers}}{\text{hr}}\Bigg|\frac{1000\text{ m}}{\text{kilometers}}\Bigg|\frac{\text{hr}}{60\text{ min}} = 1333.3\text{ meters/minute.}$$

Therefore 3.39 liters of SF_6 are emitted over 1333.3 meters on each pass, or at the rate of 0.002542 liters per meter per pass. Since 15.5 passes were made per hour, the actual emission factor is 0.002542 $\frac{\ell}{\text{m pass}}$ * 15.5 $\frac{\text{passes}}{\text{hr}}$ = 0.0394 $\frac{\ell\text{ SF}_6}{\text{m hr}}$. Using the ideal gas formula and remembering that 1 m^3 = 1000 liters,

$$V = \frac{8.21*10^{-5}\text{m}^3\text{ atm}}{\text{gmol}^\circ\text{K}}\Bigg|\frac{280^\circ\text{K}}{}\Bigg|\frac{}{1\text{ atm}}\Bigg|\frac{1000}{\text{m}^3}\Bigg|\frac{1\text{ gmol SF}_6}{146.1\text{ gm SF}_6}$$

$$= 0.157\ \frac{\ell\text{ SF}_6}{\text{gm SF}_6}$$

or

$$\text{Specific weight of SF}_6 = \frac{1}{0.157\ \frac{\ell\text{ SF}_6}{\text{gm SF}_6}} = 6.36\ \frac{\text{gm SF}_6}{\ell\text{ SF}_6}$$

$$\text{Emission Rate} = \frac{0.0394\ \ell\text{ SF}_6}{\text{m hr}}\Bigg|\frac{6.36\text{ gm SF}_6}{\ell\text{ SF}_6} = 0.250\ \frac{\text{gm SF}_6}{\text{m SF}_6}$$

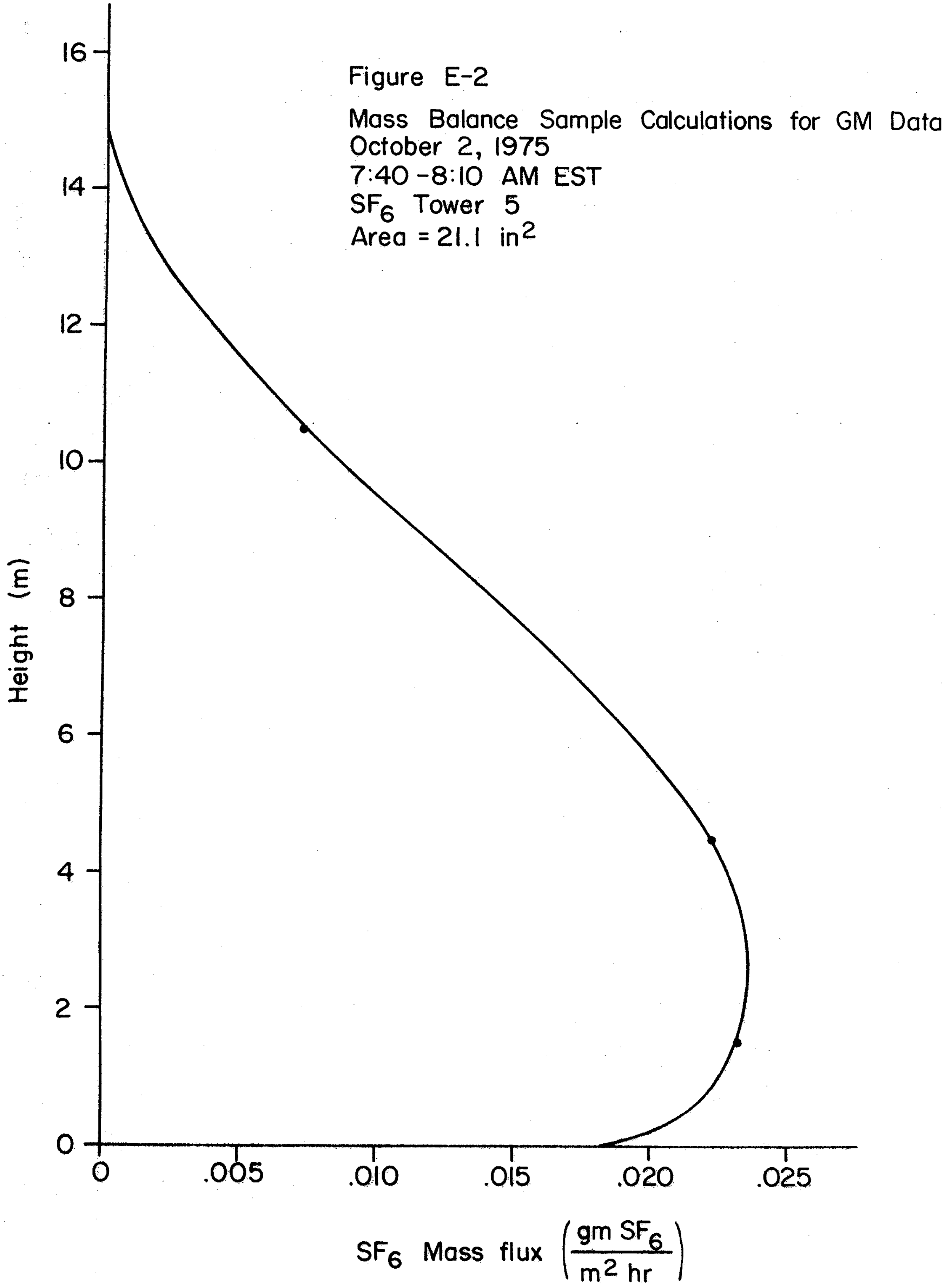


Figure E-2

Mass Balance Sample Calculations for GM Data
October 2, 1975
7:40-8:10 AM EST
SF_6 Tower 5
Area = 21.1 in^2

Sample Calculations of Mass Balance Technique Using SRI Data

The SRI data base is interesting because this group not only used two tracer gases, but also analyzed for carbon monoxide as well. In this way, a check on the technique can be performed with the tracer gases and a check on the emission factor estimating methods can be performed with carbon monoxide. A sample calculation will be performed with SF_6 only. The data set selected as typical was at Site 1 (at grade) on January 30, 1975, from 16:00 to 17:00. At this site, the roadway angle with respect to north was 111°. At the time the data were taken, the wind was generally out of the north, making the south side of the roadway the downwind side. Tower #2 was located 10.7 m south of the road edge and was thus best suited for application of the mass balance technique. The following data were quoted in the SRI report.

Z=height(m)	u=windspeed(m/sec)	θ=wind direction(°)	$SF_6 = \left(\frac{mg}{m^3}\right)$*
14.2	2.41	357	.0011
7.5	2.20	33	.00625
3.8	1.72	15	.011
2.0	1.68	341	.0108

*Progress Report 8 merely reports tracer concentrations and a single time. This can only be reconciled with the intervals over which the windspeed is quoted if it is assumed that the times quoted are the starting times for the intervals. Thus the time of the report used is 16:00. These data also shows that the far upwind instruments all showed SF_6 levels of zero. This was expected, since there were no sources of SF_6 in the area except the release vehicles used in the study.

The units in this report are quite easy to reconcile with the method used in the mass balance calculations. Equation (E-1) from the Texas data set can be used to calculate u_x if the 56° road angle is replaced by 111°. Multiplying $SF_6 \left(\frac{mg}{m^3}\right)$ by $u_x \left(\frac{m}{sec}\right)$ yields the mass of SF_6 being transported from the roadway (SF_{6m}) in units of $\frac{mg\ SF_6}{m^2\ sec}$. Carrying out the calculations:

Z(m)	u_x(m/sec)	$SF_{6_m} \left(\frac{mg\ SF_6}{m^2\ sec}\right)$
14.2	2.21	0.24
7.5	2.15	1.34
3.8	1.71	1.88
2.0	1.29	1.39

If Z is plotted against SF_{6m} on a scale of Z = 2m/in and $SF_{6m} = .02\ \frac{mg/m^2 sec}{in}$, each square inch represents $\frac{2\ m}{} \Big| \frac{.02\ mg}{m^2\ sec} = .04\ \frac{mg}{m\ \ sec}$. The resulting graph, shown in Figure E-3, encloses 4.1 in^2. Thus the emission rate is

$$\text{emission rate} = \frac{4.1\ in^2}{} \Big| \frac{.04\ mg/m\ sec}{in^2} = 0.164\ \frac{mg}{m\ sec}$$

The actual emission rate of SF_6 as stated by SRI was .0912 mg/m sec, calculated from the SF_6 flow rate and the cylinder weight loss.

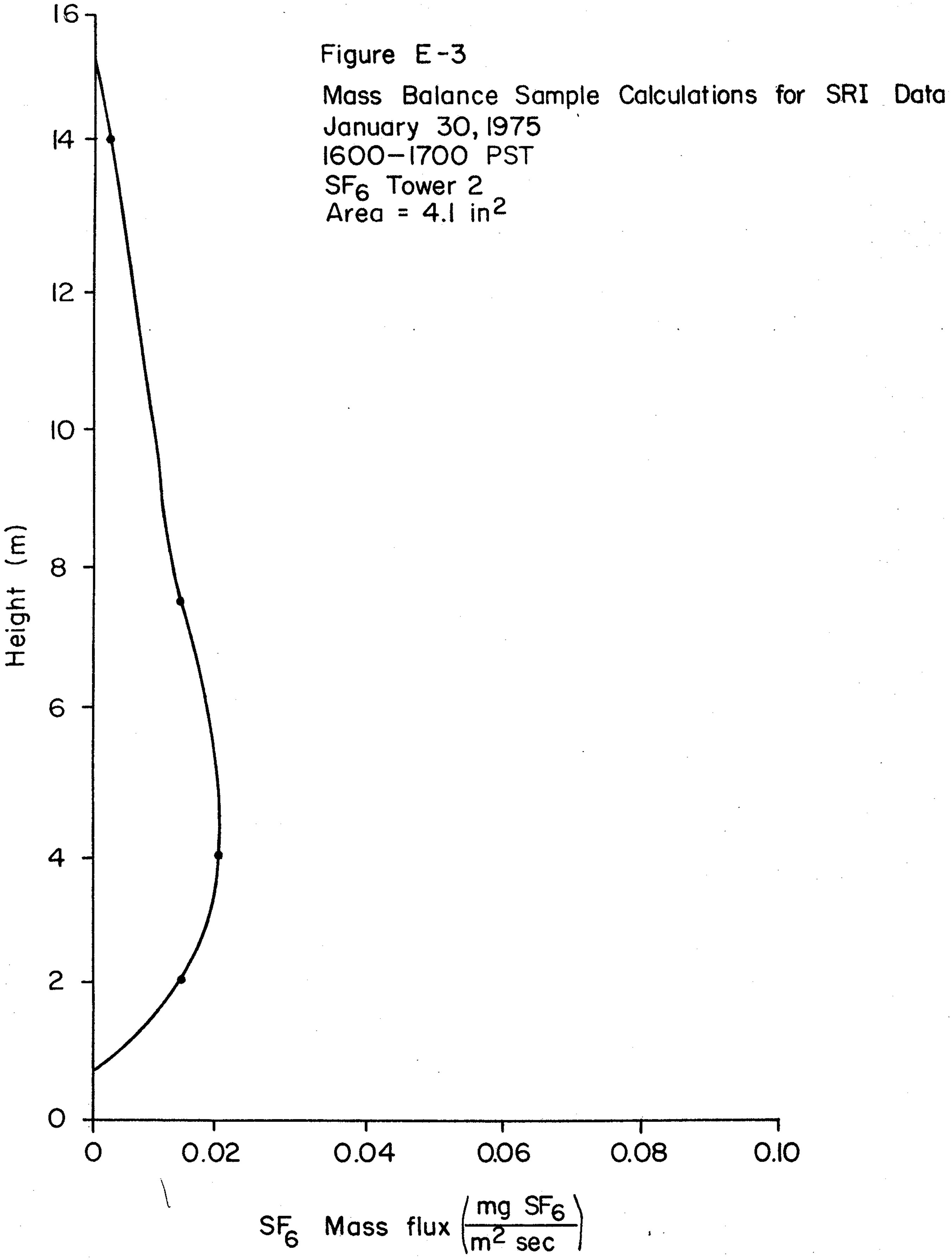


Figure E-3

Mass Balance Sample Calculations for SRI Data
January 30, 1975
1600-1700 PST
SF_6 Tower 2
Area = 4.1 in^2

APPENDIX F

Table F-1

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/10/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
08:00	2.88	1.41	--
08:05	2.35	1.36	2.33
08:10	2.35	1.39	1.2
08:15	2.1	1.96	1.65
08:20	2.01	1.4	1.2
08:25	2.02	1.59	0.69
08:30	2.03	1.48	2.13
08:35	1.79	1.49	0.41
08:40	2.0	1.48	1.38
08:45	1.79	1.45	0.51
08:50	1.83	1.46	0.99
08:55	1.82	1.46	1.06
09:00	0.81	1.46	0.59
09:05	2.0	1.46	2.03
09:10	1.80	1.46	1.09
09:15	1.80	1.44	0.81
09:20	1.72	1.43	0.44
09:25	1.76	1.42	0.98
09:30	1.66	1.38	0.86
09:35	1.74	1.43	2.8
09:40	1.64	1.43	0.36
09:45	1.74	1.39	1.48
09:50	1.67	1.43	0.23
09:55	1.64	1.42	0.83
10:00	1.63	1.45	1.07
10:05	1.68	1.37	2.37
10:10	1.61	1.38	1.16
10:15	1.73	1.38	0.86
10:20	1.56	1.37	0.18
10:25	1.63	1.38	0.49
10:30	1.63	1.38	0.98
10:35	1.66	1.41	0.92
10:40	1.64	1.37	1.06
10:45	1.59	1.44	0.30

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/10/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
10:50	1.63	1.4	0.21
10:55	1.65	1.39	0.39
11:00	1.65	1.4	1.65
11:05	1.62	1.45	1.31
11:10	1.7	1.42	1.14
11:15	2.74	1.42	1.09
11:20	1.59	1.39	0.4
11:25	1.62	1.37	0.85
11:30	1.58	1.38	0.35
11:35	1.54	1.33	0.5
11:40	1.54	1.38	0.24
11:45	1.58	1.37	1.13
11:50	1.57	1.38	0.7
11:55	1.63	1.38	1.04
12:00	1.78	1.45	1.78
12:05	1.65	1.43	0.49
12:10	1.62	1.41	0.36
12:15	1.68	1.43	0.48
12:20	1.63	1.41	0.69
12:25	1.68	1.39	0.46
12:30	1.67	1.39	0.25
12:35	1.71	1.39	0.25
12:40	1.86	1.36	0.48
12:45	1.68	1.36	0.13
12:50	1.68	1.37	0.69
12:55	1.64	1.41	0.3
13:00	1.68	1.41	0.3
13:05	1.68	1.4	0.51
13:10	1.7	1.45	0.85
13:15	1.86	1.48	1.43
13:20	1.75	1.45	0.95
13:25	1.86	1.39	1.48
13:30	1.68	1.43	0.38
13:35	1.74	1.41	2.38

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and

Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/10/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
13:40	1.74	1.43	1.78
13:45	1.65	1.41	0.64
13:50	1.65	1.4	0.09
13:55	1.67	1.41	0.33
14:00	1.66	1.4	0.33
14:05	1.68	1.4	0.62
14:10	1.7	1.38	0.99
14:15	1.8	1.4	0.5
14:20	1.67	1.91	0.55
14:25	1.95	1.41	0.85
14:30	1.74	1.41	1.37
14:35	1.77	1.42	0.56
14:40	1.66	1.4	0.48
14:45	1.7	1.4	0.34
14:50	1.67	1.38	0.45
14:55	1.65	1.42	1.08
15:00	1.75	1.4	0.19
15:05	1.66	1.4	0.36
15:10	2.27	1.44	2.22
15:15	1.73	1.46	1.76
15:20	1.72	1.43	0.75
15:25	1.62	1.41	0.25
15:30	1.69	1.41	0.87
15:35	1.62	1.41	0.18
15:40	2.29	1.41	2.6
15:45	1.95	1.41	0.35
15:50	1.74	1.39	0.74
15:55	1.85	1.38	1.91
16:00	1.65	1.36	0.44
16:05	1.79	1.37	0.66
16:10	1.69	1.38	0.46
16:15	1.65	1.41	0.74
16:20	1.75	1.38	0.7
16:25	1.70	1.41	0.96

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/10/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
16:30	1.73	1.41	0.94
16:35	1.80	1.42	1.71
16:40	1.70	1.4	1.0
16:45	1.75	1.4	1.12
16:50	1.76	1.43	1.47
16:55	1.78	1.48	1.82
17:00	1.78	1.47	1.38
17:05	1.89	1.46	1.75
17:10	2.00	1.43	2.74
17:15	1.72	1.42	0.8
17:20	1.74	1.42	1.33
17:25	1.69	1.39	1.2
17:30	1.78	1.43	0.66
17:35	1.73	1.42	2.5
17:40	1.84	1.39	2.91
17:45	2.25	1.43	1.51
17:50	1.75	1.43	0.89
17:55	1.70	1.42	0.88
18:00	1.89	1.38	0.61
18:05	1.85	1.44	0.72
18:10	1.53	1.38	0.75
18:15	1.70	1.38	2.36
18:20	1.68	1.38	0.85
18:25	1.65	1.41	0.48
18:30	1.68	1.42	1.61
18:35	2.46	1.42	0.89
18:40	1.63	1.38	0.75
18:45	1.81	1.38	1.66
18:50	4.83	3.68	24.1
18:55	1.18	1.44	1.44
19:00	1.97	1.38	1.71
19:05	3.54	1.42	0.5
19:10	4.21	1.39	0.65
19:15	1.78	1.42	0.53

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/10/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
19:20	1.91	1.42	1.42
19:25	1.87	1.62	--
Date: 8/11/77			
07:05	7.50	1.38	4.18
07:10	2.87	1.63	1.79
07:15	2.56	1.7	3.85
07:20	2.50	1.64	2.96
07:25	2.34	1.67	2.6
07:30	2.46	1.71	2.9
07:35	2.41	1.93	4.38
07:40	2.18	1.69	2.34
07:45	2.20	1.61	2.34
07:50	2.07	1.58	3.78
07:55	2.19	1.61	3.02
08:00	2.04	1.53	3.01
08:05	1.94	1.5	1.82
08:10	1.91	1.5	1.35
08:15	1.85	1.52	1.35
08:20	1.88	1.49	2.37
08:25	1.82	1.47	1.24
08:30	1.85	1.49	1.45
08:35	1.8	1.47	0.98
08:40	1.8	1.56	1.83
08:45	1.82	1.55	1.63
08:50	1.87	1.59	2.11
08:55	1.77	1.56	0.93
09:00	1.77	1.57	11.6
09:05	1.81	1.54	0.91
09:10	1.73	1.55	0.92
09:15	1.72	1.59	0.87
09:20	1.72	1.52	2.4

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and

Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/11/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
09:25	1.65	1.52	0.6
09:30	1.78	1.53	0.79
09:35	1.78	1.53	1.02
09:40	1.71	1.53	0.81
09:45	1.69	1.56	0.5
09:50	1.71	1.53	0.54
09:55	1.72	1.56	0.59
10:00	1.79	1.56	0.55
10:05	1.68	1.55	0.58
10:10	1.64	1.56	0.42
10:15	1.73	1.54	1.31
10:20	1.67	1.53	0.42
10:25	1.70	1.52	1.36
10:30	1.67	1.55	0.42
10:35	1.53	1.47	0.35
10:40	1.62	1.48	1.14
10:45	1.64	1.53	0.7
10:50	1.59	1.48	0.45
10:55	1.63	1.48	0.48
11:00	1.69	1.5	1.47
11:05	2.04	1.5	1.45
11:10	1.55	1.46	0.27
11:15	1.60	1.46	0.27
11:20	1.60	1.49	0.40
11:25	1.58	1.46	0.77
11:30	1.58	1.44	0.35
11:35	2.04	1.50	2.39
11:40	1.51	1.42	0.24
11:45	1.56	1.44	0.50
11:50	1.55	1.42	0.56
11:55	1.51	1.46	0.81
12:00	1.56	1.43	0.31
12:05	1.53	1.39	0.19
12:10	1.54	1.42	0.35

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/11/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
12:15	1.97	1.44	0.40
12:20	1.64	1.41	0.46
12:25	1.51	1.39	0.16
12:30	1.51	1.37	0.20
12:35	1.62	1.40	1.68
12:40	1.50	1.40	0.64
12:45	1.56	1.45	0.83
12:50	1.60	1.44	0.30
12:55	1.57	1.45	0.48
13:00	1.53	1.46	0.25
13:05	1.54	1.45	1.09
13:10	2.10	1.45	0.69
13:15	1.80	1.43	0.42
13:20	1.53	1.43	0.31
13:25	1.52	1.42	0.41
13:30	1.54	1.41	1.20
13:35	1.53	1.40	0.50
13:40	1.52	1.40	0.22
13:45	1.51	1.40	0.40
13:50	1.50	1.40	0.17
13:55	1.51	1.40	0.11
14:00	1.50	1.42	0.16
14:05	1.60	1.42	0.58
14:10	1.65	1.40	1.04
14:15	1.51	1.43	0.45
14:20	1.57	1.46	0.39
14:25	1.60	1.47	0.31
14:30	1.61	1.47	1.13
14:35	1.60	1.42	0.77
14:40	1.55	1.48	0.44
14:45	1.56	1.44	0.36
14:50	1.61	1.45	0.86
14:55	1.75	1.40	0.79
15:00	1.74	1.44	1.27

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/11/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
15:05	1.61	1.42	0.77
15:10	1.55	1.43	1.30
15:15	1.56	1.40	1.76
15:20	1.67	1.43	0.92
15:25	2.07	1.40	1.38
15:30	1.90	1.40	1.30
15:35	2.01	1.45	2.82
15:40	1.53	1.40	0.36
15:45	1.54	1.39	0.17
15:50	1.56	1.42	0.23
15:55	1.60	1.40	0.50
16:00	1.54	1.41	0.45
16:05	1.55	1.40	0.70
16:10	1.55	1.42	0.30
16:15	1.60	1.45	0.80
16:20	1.56	1.45	1.50
16:25	1.66	1.41	1.72
16:30	1.66	1.41	1.24
16:35	1.55	1.40	1.11
16:40	1.64	1.35	0.93
16:45	1.75	1.41	1.50
16:50	1.87	1.41	1.80
16:55	1.70	1.44	1.76
17:00	1.86	1.42	1.26
17:05	1.70	1.41	1.04
17:10	1.76	1.46	1.98
17:15	1.67	1.40	1.30
17:20	1.70	1.40	1.70
17:25	1.67	1.38	1.60
17:30	1.60	1.40	1.41
17:35	1.70	1.31	1.10
17:40	1.75	1.42	2.18
17:45	1.74	1.41	1.75
17:50	1.67	1.42	2.00

Table F-1 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

Dallas At Grade Site

Sampling Location: 5 ft high and 95 ft from North access road.
Date: 8/11/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
17:55	1.75	1.45	2.25
18:00	1.55	1.45	1.90

Table F-2

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

San Antonio Site

Sampling Location: 5 ft high and 125 ft from North access road.
Date: 10/6/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
1:40	2.21	1.63	0.50
1:45	2.20	1.65	0.48
1:50	2.15	1.65	0.50
1:55	2.25	1.60	0.55
2:00	2.20	1.65	0.65
2:05	2.20	1.65	0.67
2:10	2.15	1.63	0.70
2:15	2.22	1.68	0.90
2:20	2.20	1.75	1.10
2:25	2.10	1.70	1.03
2:30	2.10	1.70	0.70
2:35	2.17	1.67	0.60
2:40	2.35	1.92	0.56
2:45	2.30	1.87	0.62
2:50	2.20	1.82	0.60
2:55	2.21	1.78	0.62
3:00	2.16	1.73	0.65
3:05	2.10	1.71	0.77
3:10	2.10	1.66	0.07
3:15	1.96	1.50	0.30
3:20	1.92	1.36	0.42
3:25	1.95	1.42	0.37
3:30	1.98	1.45	0.40
3:35	2.00	1.39	0.45
3:40	2.00	1.40	0.42
3:45	2.03	1.45	3.70
3:50	2.00	1.40	4.18
3:55	2.10	1.62	0.91
4:00	2.13	1.63	1.16
4:05	2.10	1.62	0.71
4:10	2.05	1.65	0.57
4:15	2.07	1.64	0.67
5:20	2.20	1.70	1.60

Table F-2 (cont'd)

Total Nonmethane Hydrocarbons, Methane and Carbon Monoxide Data from Byron Gas Chromatograph

San Antonio Site

Sampling Location: 5 ft high and 125 ft from North access road.
Date: 10/6/77

Time	Total Nonmethane Hydrocarbon (PPM)	CH_4 (PPM)	CO (PPM)
5:25	2.13	1.68	1.81
5:30	2.06	1.65	1.27
5:35	2.12	1.70	1.80
5:40	2.10	1.72	1.85
5:45	2.08	1.68	1.51
5:50	2.11	1.72	1.97
5:55	2.13	1.73	1.86
6:00	2.10	1.73	1.78
6:05	2.15	1.71	2.00
6:10	2.13	1.72	1.94
6:15	2.12	1.72	1.95
6:20	2.10	1.71	2.05
6:25	1.95	1.73	1.74
6:30	1.92	1.71	1.58
6:35	1.90	1.71	1.43
6:40	2.00	1.73	1.67
6:45	2.00	1.73	1.74
6:50	2.00	1.73	1.88
6:55	2.01	1.75	1.77

APPENDIX G

Determination of McMillan Model 2200 Correction Factor

by

Roger Wayson

Texas State Department of Highways and Public Transportation,

D-8P February 17, 1978

BACKGROUND

During the period January 3, 1978 to January 9, 1978, inclusive, five nitric oxide instruments were evaluated to determine if a correction factor did indeed exist between the electrical spanning and the actual spanning of the instruments.

This was accomplished by applying the vented-output of a dynamic calibrator to the sample inlet of the NO_x instrument, recording the results, and determining a ratio between the reading and the actual value. (See Figure G-1) Two points were tested on each instrument to check for linearity.

The dynamic calibrator (TECO 101; S/N 2491-55) was calibrated in the Texas Air Control Board's calibration lab, as was the standard gas. The span gas values were: Nitric Oxide, 183.6 ppm; Nitric Dioxide, nil; total Nitric Oxides (NO_x), 183.6 ppm. This assured that our results were correlated with that of the Air Control Board. In effect, the Air Control Board was our standard, traceable to the National Bureau of Standards.

PROCEDURE

First the instruments were turned on and allowed to warmup for one hour. Next they were connected as described above and in Figure G-1. Then the instruments were zeroed and dilution ratios were selected appropriate to the 2 and 5 part-per-million range. Each instrument was checked using both concentrations, 1.34 and 4.61 p.p.m. Ample stabilization time was allowed for each test event. At this time electronic zeros and spans were also checked on each instrument. The NO_x instruments outputs were monitored using a 4 1/2 digit digital volt meter. This data was recorded and is displayed in Table G-1.

CONCLUSIONS

Readily apparent from the data listed in Table G-1 is the fact that no single correction factor can be calculated. For example, NO_x 1 and NO_x 6 have electric and dynamic spans very close on the 5 ppm range but the span values on the 2 ppm range are not close. This means that each instrument correction factor must be computed separately.

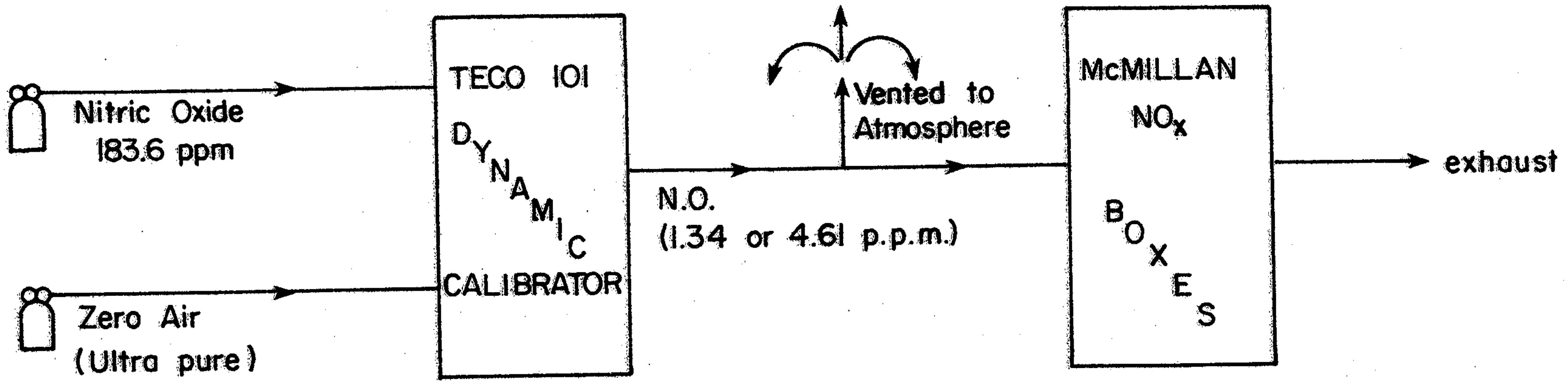


FIGURE G-1. NO Calibration Flow Scheme February 1978

For this evaluation I assumed the instrument outputs to be linear. If they are not, and Figure G-2 seems to support this, then more equipment must be made available so that each instrument could be checked using several levels of span gas. Another factor supporting non-linearity is the ratios of the readings obtained for the two dilution ratios not being consistent. If the instrument output were linear, then:

$$\frac{\text{ACTUAL VALUE}_1}{\text{INSTRUMENT OUTPUT}_1} = \frac{\text{ACTUAL VALUE}_2}{\text{INSTRUMENT OUTPUT}_2}$$

where 1 and 2 designate different dilution ratios outputs and readings.

For example, using the .0251 dilution ratio the output is NO_x=4.61 ppm; and the .0073 dilution ratio gives us an output of NO_x=1.34 ppm. The readings obtained for NO_x 1 are 7.80 ppm and 2.24 ppm, for the .0251 and .0073 dilution ratios, respectively. This sets up the following relation:

$$\frac{4.61 \text{ ppm}}{7.80 \text{ ppm}} = \frac{1.34 \text{ ppm}}{2.24 \text{ ppm}}$$

solving we have 0.591 = 0.598 a close relationship. However, as evidenced by Figure G-2, this is the most linear instrument. Calculating for all the instrument ratios we see that this relationship does not hold for them. Listed is the ratio results:

NOx 1 $0.591_{A1} = 0.598_{B2}$
NOx 2 $0.677_{A1} = 0.788_{B2}$
NOx 3 $0.738_{A1} = 0.654_{B2}$
NOx 5 $0.518_{A1} = 0.487_{B2}$
NOx 6 $0.591_{A1} = 0.478_{B2}$

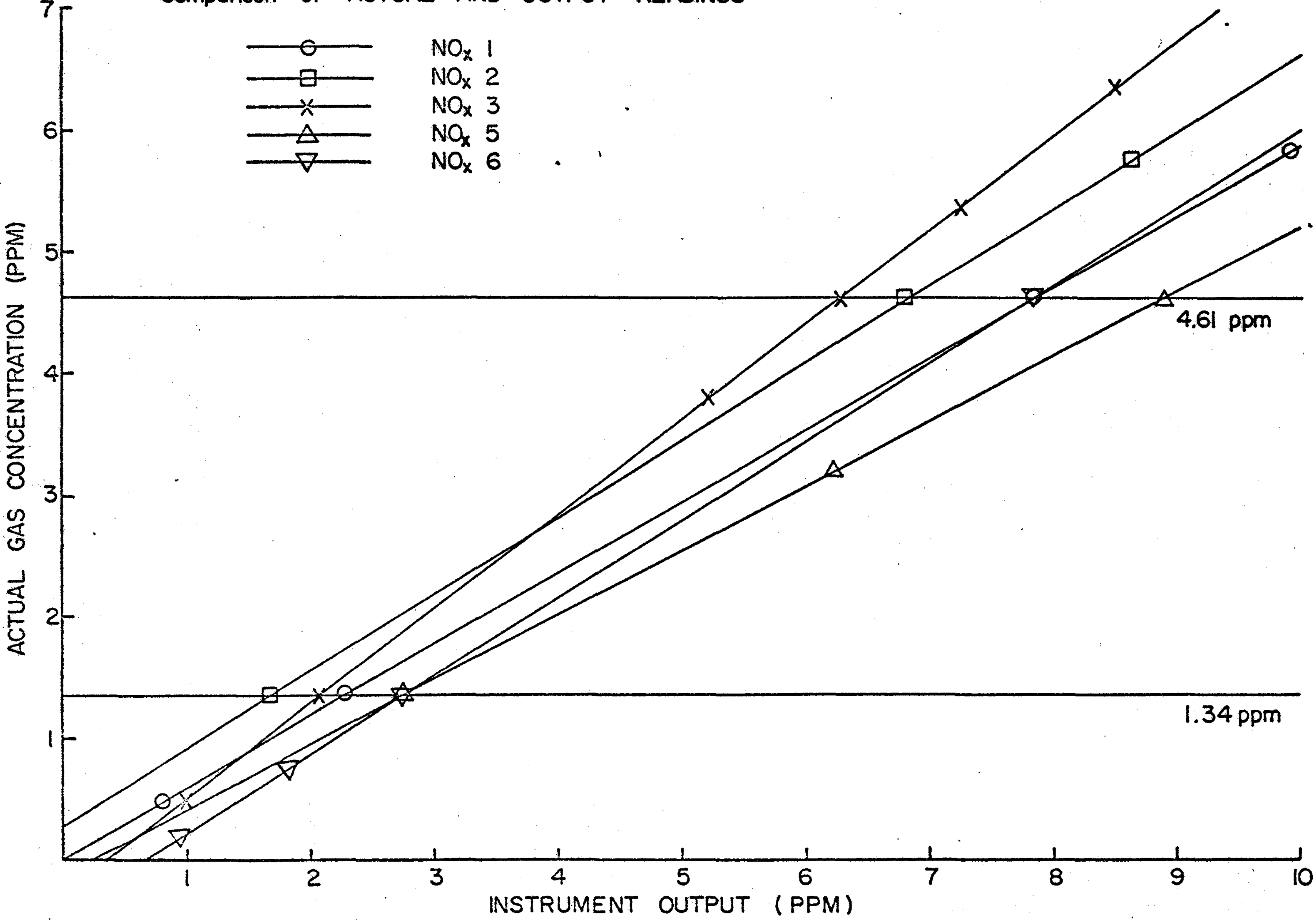
From this analysis we can see that NOx 1 and NOx 5 seem to be the most linear. This is shown graphically in Figure G-2.

For the time however, I will assume that the instruments are linear enough to give us "ballpark" correction factors. Assuming this, then the correction factors can be defined as follows:

$$\underset{\text{(C.F.)}}{\text{correction factor}} = \frac{\text{ACTUAL VALUE}_1}{\text{INSTRUMENT OUTPUT}_1} + \frac{\text{ACTUAL VALUE}_2}{\text{INSTRUMENT OUTPUT}_2}$$

FIGURE G-2

Comparison of ACTUAL AND OUTPUT READINGS



Therefore:

$$\text{C.F. (NOx 1)} = \frac{(0.591 + 0.598)}{2} = 0.594$$

$$\text{C.F. (NOx 2)} = \frac{(0.677 + 0.788)}{2} = 0.733$$

$$\text{C.F. (NOx 3)} = \frac{(0.738 + 0.654)}{2} = 0.696$$

$$\text{C.F. (NOx 5)} = \frac{(0.518 + 0.487)}{2} = 0.503$$

$$\text{C.F. (NOx 6)} = \frac{(0.591 + 0.478)}{2} = 0.535$$

A_1 dilution ratio .0251

B_2 dilution ratio .0073

I think these correction factors will give "ball park" figures when multiplied by the instrument readout but I do not think they will give absolute values.

Table G-1

RECORDED NOx SPAN VALUES

(Electrical and Dynamic)

Instrument and S/N	Elec. Zero	Dyn. Zero	Elec. Span	Dyn. Span	Inst. Range	Dilution Ratio[2]
McMillan Model 2200	-0.01	-0.01	2.83	7.80	5	.0251
S/N 2516[1] (NOx 1)				2.20	5	.0073
		-0.01		2.24	2	.0073
S/N 2515[3] (NOx 2)	0.04	0.05	2.15	6.80	5	.0251
				1.70	5	.0073
		0.06		1.68	2	.0073
S/N 2524 (NOx 3)	0.02	0.05	3.20	6.25	5	.0257
				2.05	5	.0073
		0.01		2.04	2	.0073
S/N 2523 (NOx 5)	0.00	0.00	2.85	8.90	5	.0251
				2.80	5	.0073
		0.01		2.75	2	.0073
S/N 2525[4] (NOx 6)	0.01	0.03	2.85	7.80	5	.0251
				2.85	5	.0073
		0.02		2.80	2	.0073

[1] Output meter sticks

[2] Span gas value, 183.6 ppm NO

[3] Panel meter inop; ozone generator light stays on

[4] Output leads reversed

Second Determination of McMillan Model 2200 Correction Factor

by

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Texas State Department of Highways and Public Transportation,

D-8P January 15, 1979

I. BACKGROUND

Once before (Report dated February 17, 1978) an attempt was made at a correction factor for the model 2200's McMillan nitric oxide analyzers, that were used as part of a research study. The conclusions drawn then were:

INSTRUMENT	5 PPM SCALE	2 PPM SCALE	OVERALL
NOx 1 (SN2516)	0.591	0.598	0.594
NOx 2 (SN2515)	0.677	0.788	0.733
NOx 3 (SN2524)	0.738	0.654	0.696
NOx 5 (SN2523)	0.518	0.487	0.503
NOx 6 (SN2525)	0.591	0.478	0.535

These ratios were developed by using electronic zero and electronic span similar to settings actually used in the field.

Since that time, two important developments have come about. First, more accurate methods and equipment are now available. Second, with the new equipment the calibrator used in the initial tests was found to be in error.

Because of these developments, a new series of tests were initiated. Mass flow meters[1] were used to insure accurate flows of nitric oxide and zero air. The nitric oxide span gas had a concentration of 100 ppm N 0 and was verified by the Texas Air Control Board.

The test set-up is shown in Figure G-3.

All tests were conducted in the Air Quality Lab of the Texas State Dept. of Highways and Public Transportation.

II. PROCEDURE

After ample warm-up time (overnight) the samplers were connected one-at-a-time as illustrated in Figure G-3. The dilution ratio was calculated using factory calibrated Hastings mass flow meters. Instrument outputs were monitored using a precision DVM.

Several types of tests were run. Tests were made to evaluate electronic drift, dynamic drift, and individual correction factors for the 2 and 5 ppm ranges. All tests deal with total Nitrogen Oxides. NO_2 & NO could not be checked individually at this time because of reactivity between the span gas and dilution air.

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[1] Factory Calibrated Hastings-Raydist Mass Flow Meters

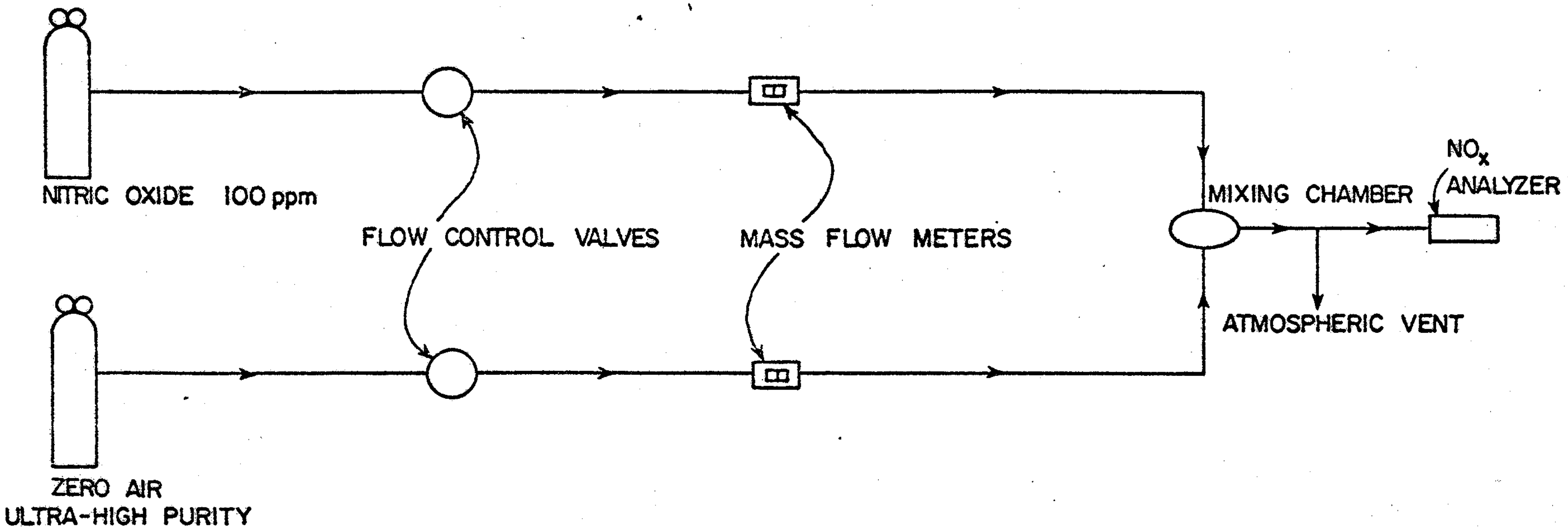

FIGURE G-3. NO Calibration Flow Scheme January 1979

The data is presented below.

III. DATA & CALCULATIONS

A. Drift

Dynamic Zero

Instrument	Date & Initial Setting (ppm)	Date & Final Reading (ppm)	Elapsed Time	Drift (ppm)/24 hours
NOx1	1 Dec 0.00	6 Dec 0.00	5 days	0.00
NOx2	1 Dec 0.00	6 Dec 0.02	5 days	0.00
NOx3	1 Dec 0.00	6 Dec 0.01	5 days	0.00
NOx5	1 Dec 0.00	6 Dec 0.00	5 days	0.00
NOx6	1 Dec 0.00	6 Dec -0.02	5 days	0.00

$\bar{x} = 0.00$
$\sigma = 0.00$

Electronic Zero

NOx1	6 Dec 0.00	13 Dec 0.00	7 days	0.00
		18 Dec 0.03	5 days	0.01
NOx2	6 Dec 0.00	13 Dec 0.01	7 days	0.00
		18 Dec 0.01	5 days	0.00
NOx3	6 Dec 0.00	13 Dec 0.00	7 days	0.00
		18 Dec 0.00	5 days	0.00
NOx5	6 Dec 0.00	13 Dec 0.02	7 days	0.00
		18 Dec 0.02	5 days	0.00
NOx6	6 Dec 0.00	13 Dec 0.04	7 days	0.01
		18 Dec -0.01	5 days	-0.01

$\bar{x} = 0.001$
$\sigma = 0.006$

Electronic Span

NOx1	6 Dec 3.00	13 Dec 3.00	7 days	0.00
		18 Dec 3.10	5 days	0.02
NOx2	6 Dec 3.00	13 Dec 2.96	7 days	-0.01
		18 Dec 3.05	5 days	0.02

Instrument	Date & Initial Setting (ppm)	Date & Final Reading (ppm)	Elapsed Time	Drift (ppm)/24 hours
NOx3	6 Dec 3.20**	13 Dec 3.15	7 days	-0.01
		18 Dec 3.10	5 days	-0.01
NOx5	6 Dec 3.00	13 Dec 2.95	7 days	-0.01
		18 Dec 3.00	5 days	0.01
NOx6	6 Dec 3.0	13 Dec 3.00	7 days	0.00
		18 Dec 2.98	5 days	0.00
				$\bar{x}$ = 0.001
				σ = 0.012

** UNABLE TO CALIBRATE LOWER

Dynamic Span

Instrument	Date & Initial Setting (ppm)	Date & Final Reading (ppm)	Drift Per Day	
NOx1	27 Nov - 3.4 ppm	30 Nov - 3.4	0.0	0%
NOx2	27 Nov - 3.4 ppm	30 Nov - 3.6	0.1	3%
NOx3	27 Nov - 3.4 ppm	30 Nov - 3.3	-0.05	-1%
NOx5	27 Nov - 3.4 ppm	30 Nov - 3.5	0.05	1%
NOx6	27 Nov - 3.4 ppm	30 Nov - 3.4	0.1	3%
			$\bar{x}$ = 1.2%	
			σ = 1.79%	

5 ppm range correlation (using electronic zero and electronic span of 60% full scale)

Instrument	Date	Input (ppm)	Reading (ppm)	Calculated Correction Factor
NOx1	1 Dec	1.87	2.6	0.72
	6 Dec	3.83	5.3	0.72
	13 Dec	1.60	2.1	0.76
	18 Dec	1.60	2.1	0.76
	19 Dec	1.05	1.4	0.75
				$\bar{x}$ = 0.74
				σ = 0.02
NOx2	1 Dec	1.75	2.0	0.88
	6 Dec	3.80	4.8	0.79
	13 Dec	1.60	1.9	0.84
	18 Dec	1.60	2.0	0.80
	19 Dec	1.05	1.2	0.88
				$\bar{x}$ = 0.84
				σ = 0.04

Instrument	Date	Input (ppm)	Reading (ppm)	Calculated Correction Factor
NOx3	1 Dec	1.71	1.9	0.90
	6 Dec	3.80	4.5	0.84
	13 Dec	1.60	1.8	0.90
	18 Dec	1.60	1.8	0.90
	19 Dec	1.10	1.2	0.92
				$\bar{x}$ = 0.89
				σ = 0.03
NOx5	1 Dec	1.65	2.3	0.72
	6 Dec	3.73	4.8	0.78
	13 Dec	1.55	2.3	0.67
	18 Dec	1.55	2.2	0.70
	19 Dec	1.10	1.6	0.69
				$\bar{x}$ = 0.71
				σ = 0.04
NOx6	1 Dec	1.56	2.3	0.68
	6 Dec	3.70	5.1	0.73
	13 Dec	1.55	2.1	0.74
	18 Dec	1.55	2.2	0.70
	19 Dec	1.10	1.5	0.73
				$\bar{x}$ = 0.72
				σ = 0.03

2 ppm range correlation (again using electronic zero and span)

NOx1	13 Dec	1.60	2.1	0.76
	19 Dec	1.05	1.4	0.75
				$\bar{x}$ = 0.76
NOx2	13 Dec	1.60	1.6	1.00
	19 Dec	1.05	1.1	0.95
				$\bar{x}$ = 0.98

Instrument	Date	Input (ppm)	Reading (ppm)	Calculated Correction Factor
NOx3	13 Dec	1.60	2.0	0.80
	19 Dec	1.10	1.3	0.85
				$\bar{x}$ = 0.83
NOx5	13 Dec	1.55	2.3	0.67
	19 Dec	1.10	1.7	0.65
				$\bar{x}$ = 0.66
NOx6	13 Dec	1.55	2.7	0.57
	19 Dec	1.10	1.9	0.58
				$\bar{x}$ = 0.58

IV. CONCLUSIONS

From the data it can readily be seen that the zero drift, both electronic and dynamic, are well within the manufacture's specifications. (See Table G-2) Electronic span also falls within specified tolerances. Dynamic span drift however falls out of specifications with two instruments. Overall however it appears that drift is not a problem.

Correction factors, using 60% electronic span on the 5 ppm range, were developed that show a high degree of repeatability. These factors could be used to correct data that had been taken in the field using the electronic span.

These correction factors are:

Instrument	5 ppm Range Correction Factor
NOx1	0.75
NOx2	0.85
NOx3	0.91
NOx5	0.70
NOx6	0.71

AND:

Instrument	2 ppm Range Correction Factor
NOx1	0.76
NOx2	0.98
NOx3	0.83
NOx5	0.66
NOx6	0.58

Limitations should be noted. As seen from the above listing, correction factors are different for 5 ppm range and 2 ppm range. Factors were not developed for the lower ranges because of test equipment limitations prohibiting repeatable results.

Correction factors were limited to two decimal places because of instability of the test instruments. This is evident from the standard deviation values listed for each correction factor.

In my opinion the correction factors developed could be used to correct data taken previously on the 5 and 2 ppm ranges.

Table G-2

MANUFACTURER'S CLAIMED PERFORMANCE SPECIFICATIONS***

Ranges: 0 - 5 ppm, 0 - 10 ppm, 0 - 20 ppm, 0 - 50 ppm for the 2100 $NO/NO_2/NO_x$ Meter.

0 - 0.5 ppm, 0 - 1.0 ppm, 0 - 2.0 ppm, 0 - 5.0 ppm for the 2200 $NO/NO_2/NO_x$ Meter.

Minimum Detectable Sensitivity: 10 ppb

Rise Time: 30 seconds

Fall Time: 30 seconds

Zero Drift: Less than 0.2 ppm/24 hours, 2100 $NO/NO_2/NO_x$ Meter.
Less than 0.01 ppm/24 hours, 2200 $NO/NO_2/NO_x$ Meter.

Span Drift: 1%/day maximum.

Precision: ± 1% (Full Scale)

Noise: ± 0.5% (Full Scale)

Linearity: 1% (Full Scale)

Operating Temperature Range: _10° C to 40° C

Operating Humidity Limits: 10% to 95% R. H.

Sample Flow: 1 liter/minute

Recorder Output: 0 - 1 volt and 0 - 100 millivolts full scale for each NO, NO_2 and NO_x outputs. Outputs can be millivolts with a 20 turn trim pot.

Built-in Calibration: Zero and Span Calibration controls provided.

Automatic Fault Diagnostic System: Detects errors in air flow, electronic module, ozone generation, thermal converter, cooling system. Also warns of need to recharge battery.

Optional Battery Pack: Typical 10 hours of continuous battery powered operation.

Dimensions: H - 7.5" (19.1 cm), W - 7.0" (17.8 cm), D - 16.0" (40.6 cm).

Weight: 12 lbs (5.44 kg), 21 lbs. (9.53 kg) with optional battery pack.

***taken from Instruction Manual For M E C series 2100 and 2200 $NO/NO_2/NO_x$ Meters. Sept. 1974