WILLIAMS AIR FORCE BASE AIR QUALITY MONITORING STUDY. APPENDICE--ETC(U)

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Williams Air Force Base
Air Quality Monitoring

Appendix LEVEL
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Protection of the environment requires effective regulatory actions based on sound technical and scientific data. The data must include the quantitative description and linking of pollutant sources, transport mechanisms, interactions, and resulting effects on man and his environment. Because of the complexities involved, assessment of exposure to specific pollutants in the environment requires a total systems approach that transcends the media of air, water, and land. The Environmental Monitoring Systems Laboratory at Las Vegas contributes to the formation and enhancement of a sound monitoring-data base for exposure assessment through programs designed to:

- develop and optimize systems and strategies for monitoring pollutants and their impact on the environment
- demonstrate new monitoring systems and technologies by applying them to fulfill special monitoring needs of the Agency's operating programs

This report presents an evaluation of the impact of aircraft operations on air quality at Williams Air Force Base near Phoenix, Arizona. The data reported here will serve as input for defining the accuracy limits of the Air Quality Assessment Model. This program was funded by the Department of the Air Force, Department of the Navy and the U.S. Environmental Protection Agency under an interagency agreement.

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CONTENTS OF VOLUME II

Figures .................................................. vi
Tables .................................................... viii

Appendices
A. Project Organization and Implementation ..................... A-1
B. Related Special Studies .................................. B-1
C. Measurement Principles and Performance Specifications for
   WAFB Analyzers ........................................ C-1
D. Calibration Procedures for Air Quality Monitoring
   Instrumentation .......................................... D-1
E. Daily Trailer Inspection, Zero and Span Checks, and Station
   Calibration Adjustments .................................. E-1
F. Coding for Data Switches (Thumbwheels) of the Data Links
   at Monitoring Stations ................................... F-1
G. Lists of Secondary Calibration Gases and Their Locations
   and Dates of Use at WAFB ............................... G-1
H. Hourly Averages and Time Series Plots of the Data .......... H-1
I. Data Processing ........................................... I-1
J. Procedure for Acoustic Sounder Data Reduction at
   Williams AFB .............................................. J-1
K. Cumulative Frequency Distributions of Air Quality
   Parameters ................................................ K-1

References for Appendices .................................. R-1
FIGURES

<table>
<thead>
<tr>
<th>Number</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>Horizontal dispersion coefficient as a function of downwind distance from the source, runs 2 and 4</td>
</tr>
<tr>
<td>B-2</td>
<td>Horizontal dispersion coefficient as a function of downwind distance from the source, runs 1 and 5</td>
</tr>
<tr>
<td>B-3</td>
<td>Horizontal dispersion coefficient as a function of downwind distance from the source, run 6</td>
</tr>
<tr>
<td>B-4</td>
<td>Horizontal dispersion coefficient as a function of downwind distance from the source, run 7</td>
</tr>
<tr>
<td>B-5</td>
<td>Horizontal dispersion coefficient as a function of downwind distance from the source, run 3</td>
</tr>
<tr>
<td>B-6</td>
<td>ROSE measurement sites at WAFB</td>
</tr>
<tr>
<td>C-1</td>
<td>Interior floor plan of air quality monitoring trailer</td>
</tr>
<tr>
<td>E-1</td>
<td>Trailer inspection checklist</td>
</tr>
<tr>
<td>E-2</td>
<td>Daily calibration checklist</td>
</tr>
<tr>
<td>G-1</td>
<td>Calibration system for air quality trailers</td>
</tr>
<tr>
<td>H-1 to H-91</td>
<td>Hourly averages of CO, NO, NOx, NMHC, nephelometer, wind speed, and wind direction data by month</td>
</tr>
<tr>
<td>H-92 to H-134</td>
<td>One-minute time series plots of CO, NO, NOx, and NMHC for selected days</td>
</tr>
<tr>
<td>I-1</td>
<td>Flowchart for WAFB data acquisition and processing</td>
</tr>
<tr>
<td>I-2</td>
<td>Flowchart for processing of one-hour average tapes (Tape III)</td>
</tr>
<tr>
<td>I-3</td>
<td>List of Tape III edits</td>
</tr>
<tr>
<td>I-4</td>
<td>The process for creating the Met Tape</td>
</tr>
<tr>
<td>Number</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>I-5</td>
<td>An example of tabular listings for WAFB</td>
</tr>
<tr>
<td>I-6</td>
<td>An example of frequency distribution for one year at WAFB</td>
</tr>
<tr>
<td>I-7</td>
<td>Example of yearly cumulative frequency distribution of CO</td>
</tr>
<tr>
<td>I-8</td>
<td>Summary of recoverable data at WAFB for June 1976 through June 1977</td>
</tr>
<tr>
<td>I-9</td>
<td>Sample listing of the Met Tape</td>
</tr>
<tr>
<td>J-1</td>
<td>Example of acoustic sounder chart analysis</td>
</tr>
<tr>
<td>K-1</td>
<td>Yearly cumulative frequency distribution for CO, station 1</td>
</tr>
<tr>
<td>K-2</td>
<td>Yearly cumulative frequency distribution for CO, station 2</td>
</tr>
<tr>
<td>K-3</td>
<td>Yearly cumulative frequency distribution for CO, station 3</td>
</tr>
<tr>
<td>K-4</td>
<td>Yearly cumulative frequency distribution for CO, station 4</td>
</tr>
<tr>
<td>K-5</td>
<td>Yearly cumulative frequency distribution for CO, station 5</td>
</tr>
<tr>
<td>K-6</td>
<td>Yearly cumulative frequency distribution for NMHC, station 1</td>
</tr>
<tr>
<td>K-7</td>
<td>Yearly cumulative frequency distribution for NMHC, station 2</td>
</tr>
<tr>
<td>K-8</td>
<td>Yearly cumulative frequency distribution for NMHC, station 3</td>
</tr>
<tr>
<td>K-9</td>
<td>Yearly cumulative frequency distribution for NMHC, station 4</td>
</tr>
<tr>
<td>K-10</td>
<td>Yearly cumulative frequency distribution for NMHC, station 5</td>
</tr>
<tr>
<td>K-11</td>
<td>Yearly cumulative frequency distribution for NOX, station 1</td>
</tr>
<tr>
<td>K-12</td>
<td>Yearly cumulative frequency distribution for NOX, station 2</td>
</tr>
<tr>
<td>K-13</td>
<td>Yearly cumulative frequency distribution for NOX, station 3</td>
</tr>
<tr>
<td>K-14</td>
<td>Yearly cumulative frequency distribution for NOX, station 4</td>
</tr>
<tr>
<td>K-15</td>
<td>Yearly cumulative frequency distribution for NOX, station 5</td>
</tr>
<tr>
<td>K-16</td>
<td>Yearly cumulative frequency distribution for nephelometer, station 1</td>
</tr>
<tr>
<td>K-17</td>
<td>Yearly cumulative frequency distribution for nephelometer, station 2</td>
</tr>
<tr>
<td>K-18</td>
<td>Yearly cumulative frequency distribution for nephelometer, station 3</td>
</tr>
<tr>
<td>K-19</td>
<td>Yearly cumulative frequency distribution for nephelometer, station 4</td>
</tr>
<tr>
<td>K-20</td>
<td>Yearly cumulative frequency distribution for nephelometer, station 5</td>
</tr>
<tr>
<td>Number</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>B-1</td>
<td>Wind Dispersion Study Results, WAFB, June 1976</td>
</tr>
<tr>
<td>B-2</td>
<td>WAFB Aerosol Sampler Identification and Data</td>
</tr>
<tr>
<td>B-3</td>
<td>Total Particle Size Distributions</td>
</tr>
<tr>
<td>B-4</td>
<td>Particle Size Distributions According to Particle Type</td>
</tr>
<tr>
<td>B-5</td>
<td>Longpath Measurement Location Summary</td>
</tr>
</tbody>
</table>
APPENDIX A

PROJECT ORGANIZATION AND IMPLEMENTATION

This appendix provides a chronology of WAFB project events that took place during the planning and implementation of the field monitoring program, including the related special studies. This information is provided for the benefit of the reader whose interest lies at the planning or managerial level as well as to document the events that took place during the implementation of field monitoring efforts.

The basic WAFB monitoring study was implemented by means of an interagency agreement (EPA-IAG-R5-0788) entered into by EMSL-LV and the USAF Civil Engineering Center (AFCEC), with participation from the U.S. Navy Aircraft Environmental Support Office. The Navy was expected to participate by providing funding and technical input through the Air Force.

The interagency agreement established a cooperative study to assess the impact of aircraft emissions on ambient air quality by monitoring two air bases, one Air Force base and one Navy base. EMSL-LV provided monitoring of air quality and meteorological parameters toward the overall goal of model evaluation for Williams AFB. This study was an extension of work being performed by the EPA on "Impact of Airport Emissions."

The original objective was to determine the impact of aircraft and air facility-related pollutant emissions on local air quality and to measure that impact over a statistically acceptable period of time. The data provided from the study were used to calculate air quality frequency distributions and to validate existing airport models. The study consisted of three major parts: qualitative definition of impact, assessment of impact, and investigation of model accuracy.

Additional project tasks were defined in Amendment 1 to the interagency agreement. The agreement reached among the Air Force, EPA, and Navy participants in Boston, Massachusetts, on August 12, 1975, specified equipment and instrumentation purchase modifications. This amendment also provided for related special studies ancillary to the overall program tasks.

A second amendment to the interagency agreement set forth administrative changes within the Air Force program organization and added the report requirements for the one-year measurement effort at Williams AFB.
WAFB PROGRAM ORGANIZATION

Major Peter A. Crowley, chief of the Air Quality Research Division of AFCEC, Kirkland AFB at New Mexico, coordinated the study with WAFB and AF Headquarters Training Command. The EPA Project Officer for this study was Mr. Roy B. Evans, from the Monitoring Operations Division, Air Quality Branch (MOA) at EMSL-LV. Technical direction for monitoring at WAFB was the responsibility of Mr. Karl F. Zeller, a meteorologist from the National Oceanic and Atmospheric Administration (NOAA) assigned to MOA as principal investigator for the study. Lockheed Electronics Company, Inc., under EPA Contract 68-03-2369, performed the assembly, installation, and operation of the monitoring network at WAFB beginning in January 1976 and ending in July 1977, with logistical support provided by AF technical personnel at WAFB. In August 1977, reporting on monitoring operations, data reduction, and data processing to hourly averages for the complete monitoring period was begun by NSI under EPA Contract 68-03-2591.

The Air Force contracted with Argonne National Laboratories (ANL) to compare pollutant frequency distributions as calculated by AQAM to the WAFB data base in order to evaluate the model. ANL is performing the model calculation under various conditions of meteorology and emissions activity. Data on emissions at WAFB from aircraft and other nearby activity were assembled separately from the air quality monitoring, the latter being the responsibility of EMSL-LV. Emissions data for the aircraft mix and activity schedules were provided to the USAF by Stanford Research Institute for use in AQAM model calculations. Any model revisions will be conducted by ANL.

Amendment 2 to the interagency agreement transferred responsibility for participation in the agreement to the U.S. Air Force Civil and Environmental Engineering Development Office (CEEDO) at Tyndall AFB, Florida. Technical project officer responsibility was transferred from Major P. A. Crowley to Captain Dennis F. Naugle.

IMPLEMENTATION OF MONITORING OPERATIONS

Contractor personnel, under EPA guidance, fabricated and installed the monitoring stations and performed system checkout. Monitoring operations and the quality control to maintain operations within acceptable limits were specified by EMSL-LV and MOA and monitored by Mr. Karl F. Zeller, principal investigator of the EPA portion of the WAFB project. Operations activities performed by EPA contract personnel included:

- Liaison between Williams AFB and EMSL-LV personnel
- Maintenance and repair of continuous air quality and meteorological instruments
- Procurement of operating supplies
- Quality control and calibration
• Training of USAF technicians to operate monitoring systems
• Special studies liaison between ANL and EPA principal investigator
• Generation of daily data printouts and instrument charts
• Modification and installation of additional meteorological instrumentation
• Public relations effort and occasional tours of the air quality monitoring network

Activity conducted by EMSL-LV personnel included:
• Project design and technical direction
• Data systems specification and acquisition
• Evaluation leading to modifications in air quality and meteorology hardware
• Preparation of data processing software and specification of data acceptability limits
• Liaison with special interest groups for information and tours

The contractor developed a periodic maintenance procedure and schedules that were followed during monitoring operations. Initially, the EPA trained USAF-enlisted personnel of the 6th Mobile Air Weather Squadron to operate, calibrate, and perform minor maintenance. Periodic rotation of USAF personnel required that additional EPA contractor personnel be assigned to assist in training and maintaining continuity of operations. Special studies and data-handling requests from the USAF were coordinated by the contractor with direction from EMSL-LV.

The WAFB monitoring operations were inspected by the EPA during the two months prior to June 1976 to demonstrate that the five mobile stations and the central data acquisition system conformed to the original EPA plan. The inspection consisted of two parts:

1. Reviewing all trailers and central data acquisition equipment to ensure proper procedures for:
   • Stabilization of trailers
   • Physical mounting of instruments and auxiliary equipment
   • Electronic and electrical connections
   • Installation of ambient air sampling manifold
   • Safety practices and procedures
2. Demonstrating valid operation for the Beckman Model 6800 Gas Chromatograph, ML NO/NO\textsubscript{x} analyzer, MRI nephelometer, Gill propeller vane, and ML data system through:

- Calibration

- Operation in the continuous mode for ambient air sampling

- Accurate transmission of data from the data acquisition system as voltage printouts for air quality sensor responses to the central data ML 9400 magnetic tape

Some meteorological instruments were added after monitoring operations were started. Contractor personnel performed operation of the acoustic sounder under EPA direction.
APPENDIX B

RELATED SPECIAL STUDIES

The experience gained in earlier airport air quality studies (discussed in Section 1 of this report) had indicated that data from five fixed-site monitoring stations could not be expected to answer all the questions raised by those previous studies. To augment the air quality measurements and to expand on the results to be gained from the five-station air quality network measurements, several short-term studies were carried out. Each study addressed a specific aspect of the overall goal of either monitoring or modeling aircraft pollution. The USAF program and the WAFB study were performed to provide information on the horizontal and vertical dispersion of aircraft emissions and total pollution flux from an operating airbase.

Vertical dispersion was investigated by the static jet study, a scanning laser Doppler velocimeter system (SLDVS) study, and a Barringer correlation spectrometer (COSPEC) study as discussed in Section 4. The acoustic sounder study (Appendix J) also provided information on vertical dispersion through characterization of mixing depth at WAFB. Horizontal dispersion was investigated through a wind dispersion study, the COSPEC study, and a gas-filtered correlation (GFC) spectrometer study.

Remote or long-path air quality measurements were used at WAFB to measure buoyant plume rise of aircraft emissions and to estimate total pollutant flux arising from other sources on the airbase. Remote sensing instrumentation is also useful in measuring the average pollutant concentration over a given path for comparison with model calculations. Most models can be expected to calculate and predict area concentration averages with greater success than specific point averages. Four different techniques of remote sensing were evaluated at WAFB: the SLDVS, the remote optical sensing of emissions (ROSE) system, the COSPEC system, and the GFC spectrometer system.

Each of the following studies was discussed briefly in Section 4, and this appendix contains the indicated additional information on:

- EPA recommendations on the evaluation of AQAM (includes copy of report by Karl F. Zeller)
- Preliminary air quality analysis (1975) (includes copy of report by Karl Zeller and Monty Price)
- Horizontal wind dispersion parameter investigation
- Particle morphology of aerosols collected at WAFB
The question basic to the WAFB study was how to actually evaluate or justify an air quality model. No single party to the interagency agreement conducting the study had made a formal recommendation. At the request of the USAF, Mr. Karl Zeller, principal investigator during this study, prepared a recommendation on the subject entitled, "Verification of AQAM: A Complex Air Quality Model Using the Gaussian Dispersion Approach to Estimate the Air Pollution Impact of Air Force Bases." This paper is included in the following pages.
VERIFICATION OF AQAM: A COMPLEX AIR QUALITY MODEL USING THE GAUSSIAN DISPERSION APPROACH TO ESTIMATE THE AIR POLLUTION IMPACT OF AIR FORCE BASES

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Mr. Karl Zeller

INTRODUCTION

There is a need to define an acceptable approach for the verification of Gaussian air quality simulation models for multiple source complexes. The demand for answers to air quality questions is so strong that some models have been formulated and applied extensively prior to proper evaluation. Hopefully, proposed models would be subjected to a verification procedure to enable the model developer either to defend a particular use of his model or to indicate possible situations in which his model produces invalid or questionable results.

Each complex Gaussian air quality model is comprised of submodels to describe source emissions, pollutant dispersion and transport, plume rise, source-receptor geometry, and meteorology. In the modeling of complex geometric situations, it is currently necessary to use empirical dispersion parameter values (standard deviations of plume spread as a function of downwind distance or time and atmospheric stability) derived from continuous point sources. Sometimes these values are applied with subjective modifications. For example, models used for airports or highways use the same dispersion parameters as models used for elevated area or point sources.

One logical approach would involve the separate verification of each of the submodels based on specific experiments; however, expense dictates that accuracy of the overall model be examined.

There are many opinions as to how a Gaussian model that uses subjective modifications to handle the various configurations encountered should be validated, verified, or calibrated. In this discussion a specific approach for complex Gaussian models of airport scale is suggested. The data requirements for model verification include meteorology and emission data (the necessary information for model concentration calculations) and measured air quality concentrations (including background information) with which to compare the calculations.
Previous verification programs comparing short-term (1-3 hours) calculations (Koch and Thayer 1971, Rote, et al. 1973) with observations have demonstrated the difficulty in coming to specific conclusions using any one comparison technique or statistic. The scatter-diagram approach prevalent in the literature has not been particularly useful for verification because of wide scatter and low correlation between measured and calculated concentrations. The reason direct comparison of calculations to observations does not provide good results is the statistical nature of the complex Gaussian model. For instance, the Gaussian approach assumes steady-state conditions over a specific period of time, usually one hour. When modeling intermittent or moving sources such as automobiles or aircraft, simplifying assumptions are necessarily made; for instance, taxiing aircraft are usually modeled as line sources considered to be continuous over periods relatively long compared to individual aircraft taxi time. In reality, there is not a continuous Gaussian plume stretched out downwind of such sources but intermittent ones that are locally distorted by variable wind speed and direction (turbulence). Data collection for such comparisons is presently accomplished by a network of monitors at fixed horizontal and vertical locations. The total number of monitors or stations is usually less than five because of monetary restraints. Considering these limitations, it is not surprising that short-term calculations and observations do not correlate well. The comparison of cumulative frequency distributions, on the other hand, has enabled some modelers to make general statements about the overall performance of their specific models.

RECOMMENDED VERIFICATION APPROACH

It is assumed that a large data base is taken over a period long enough to provide information under varying conditions of meteorology and emission modes. Assuming such a data base is available, the following procedures for model verification are proposed.

DISCUSSION OF THE DATA BASE

The data base discussion should include efforts made to provide background information and quality assurance during the actual collection of data. A discussion of the adequacy of the numbers and locations of actual air quality monitoring sites should be included, together with specific geometry relating sources and receptors to the general meteorological conditions during the data collection period.

COMPARISONS FOR ANALYSIS

A thorough verification requires that data and concentration calculations (model predictions) be compared under a number of different circumstances. Because of the conglomerate nature of the complex Gaussian model, certain meteorological conditions or receptor locations may give better or worse results compared to others in the same model application. Each monitoring
location should therefore be evaluated separately in addition to overall
evaluation of the model. Evaluating each monitoring location separately will
give the modeler an indication of the performance of the dispersion submodel
under different situations. This is important because at the present time the
dispersion submodels of most Gaussian complex models are subjective in nature
and not based on dispersion experiments. There is reason to believe that a
great deal of the wide scatter in observed and predicted values already
discussed is the result of the dispersion submodel. The airport pollution
data should be stratified in the following categories:

1. High and low emission density periods.
2. Periods of the day (can include more than one hour) dependent upon
   emission operations and meteorology.
3. Seasons (this category is optional and depends on the nature of the
data and problem).
4. Meteorological categories:
   - Wind direction - Increments will depend on situation.
   - Wind speed - Increments will depend on situation.
   - Stability category - Pasquill categories or in some cases stable,
     neutral, and unstable will be sufficient.
   - Mixing height - Two or three categories based on a chosen
     mixing height dependent upon the scale of the
     model application will be sufficient. For
     instance, in the case of airport models:
     mixing height below 100 m; mixing height above
     100 m; and unlimited mixing.

Note that the above categories are not meant to be mutually exclusive.
Only data that are above the noise level of the particular pollutant
monitoring instruments used should be evaluated. Although there is a specific
interest in pollutant levels approaching National Ambient Air Quality
Standards, all levels should be evaluated.

CUMULATIVE FREQUENCY DISTRIBUTIONS AND ERROR LIMITS

The data should first be sorted according to the above scheme; for
instance, all cases in a specific wind-direction category, all cases during
the morning hours, etc. (approximately 26 separate categories). The data
should then be displayed on cumulative frequency distribution diagrams,
similar to the one in Figure 1, if at least 30 observations within a given
category are available. If there are fewer than 30 observations, a scatter
diagram of observed versus calculated concentrations should be prepared.
Longer term averages -- for instance, monthly or yearly -- will inherently
have fewer data points for comparisons and therefore will require scatter
Figure 1. Cumulative frequency distribution for site #X during periods of Y wind direction.

B-6
diagrams. The use of the scatter diagram will give a qualitative feel for the performance of the model even though in some cases resultant coefficients for calibration purposes may be lacking in significance.

It is desirable to have a number measure of model performance for specific cases. A cumulative frequency distribution of the calculation error should be constructed to allow the modeler to report the percentage of trials for which his estimate was within a specific range of the observation. A similar approach was used by Koch and Thayer (1971): frequency distribution plots of absolute value of overpredictions and underpredictions similar to Figure 2 should be prepared. The approach suggested in this discussion is to subtract each observation from each corresponding model prediction. This will provide information on the distribution of overpredictions and underpredictions in addition to the overall tendency of the model to over- or underpredict in that specific category. Subtracting the cumulative percentage of overpredictions from the cumulative percentage of underprediction (see Figure 2) at a specific concentration difference will give the percent of comparisons that fall within that specific concentration error limit. The error limits and corresponding percentages can then be plotted on a frequency distribution diagram similar to Figure 3. The modeler will then be able to report that in the given situation his predictions were within \( x \) (\( \mu g/m^3 \)) \( y \) percent of the time for that particular data category using the verification data set. It must be recognized that the percentage of error is not displayed in the above technique; that is, the number difference between a predicted value of 2 and a measured value of 4 is the same as between that of 100 and 102 but the percent error is quite different.

PERCENT ERROR DISTRIBUTION

In order to evaluate the percentage error and make the verification results usable for all ranges of concentrations, the following procedure should be followed.

Using the same categories previously discussed, prepare frequency diagrams of the percent error, \( E_i \), as shown in Figure 4.

\[
E_i = \frac{x_c -(\bar{x}_o - R_b)}{(\bar{x}_o - R_b)} \times 100
\]

where: \( E_i \) = Percent error per case
\( x_c \) = Model calculation without background
\( \bar{x}_o \) = Observed air quality
\( R_b \) = Estimate of background air quality

The display of Figure 4 will also enable the model evaluator to discuss model bias, \( \bar{E} \), randomness, \( \sigma_E^2 \), and overall variance, \( \sigma_T^2 \), for each category.

B-7
Figure 2. Delta concentration: in this example, 77-31, or 46 percent of the time, the difference between observed and predicted was within $\pm 20 \mu g/m^3$. 
Example from Figure 2:
46% of the time the model predicts within + 20.

Question: How often does the model predict within + 6 \(\mu g/m^3\)?
Answer: 20 percent

Cumulative Percent

Figure 3. Error Limit Diagram.

where:

\[ \bar{E} = \frac{1}{n} \sum_{i=1}^{n} E_i \] (bias)

\[ \sigma_E^2 = \frac{1}{n} \sum_{i=1}^{n} (E_i - \bar{E})^2 \] (randomness)

\[ \sigma_T^2 = \frac{1}{n} \sum_{i=1}^{n} E_i^2 \] (overall variance)
EMISSION SUB-MODEL ADJUSTMENT

Because each of the inputs to the model has uncertainties expressed as a standard deviation (σ), the model output cannot be expected to match perfectly with the measured concentrations. However, if the actual variations of the input parameters are independent of each other and the input parameters are the true mean values of their distributions, then the percentage error assuming $x_b = 0$, $E = (x_c$ model $- x_o$ observation), should be normally distributed with mean zero and a total standard deviation, $σ_E$. If the mean $E$ is significantly different from zero, as determined by a statistical test, then the question "What is causing the error?" should be asked. Assuming that adequate quality assurance is maintained for the measured pollution concentration and meteorological data, the largest uncertainties will probably be either in the emission inventory or within the model itself.

Although in theory the measured product of the concentration, $x_o$, observation, and the wind velocity, $U$, is a flux (mass/area-time) and can be used with a model to compute the emissions $Q$ (g/sec), this inverse of the

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Figure 5. Percent error and cumulative frequency diagram.
standard modeling technique is not practical. A possible technique to test
the emission inventory would be to break the data sets into two significantly
different meteorological conditions such as stable and unstable. If the
emission inventory is in error and the model is consistent, $E$ should show
similar bias from zero for both periods.

If the $E$ values are significantly different for both conditions the
emission inventory and the model may both be in error.

Such an analysis can be used to justify modifying the emission inventory $Q$
to set $E$ to zero for both data sets as a whole. If this adjustment of $Q$ is
valid, then a third data set, independent of the two used as described above,
can be used to determine $E$. If $E$ is not significantly different from zero for
this new data set, then the adjusted $Q$ value would appear to be the valid one
to use for further study of the model.

MODEL VERIFICATION DISCUSSION

A subjective discussion should accompany each comparison, pointing out
various aspects specific to the model and data base being used. The
discussion will depend upon the interpretation of the investigator. Next, the
data should be multistratified using the above single categories; for
instance, one stratum may be all cases during winter morning periods with
windflow from a northerly direction, atmospheric conditions stable, and low
wind speeds. In this case the categories would be mutually exclusive. This
data comparison should also be presented in both frequency distribution and
scatter diagrams of observed versus predicted if there are more than 30
examples and scatter diagrams only if there are less than 30 examples. Each
distribution or scatter diagram should be evaluated and subjectively
discussed.

It is recognized that there is a great expense involved in extensive model
calculations to fulfill the above requirements. Perhaps in practice models
can be evaluated generally in the broad single category groups using a subset
of the total data set to evaluate cumulative frequency distributions. A few
of the multistratified categories should then be selected for specific model
performance, preferably those with the most data. When the model is then used
in a specific application and that application is in question and not
previously verified, the data base would be reevaluated for the specific
situation in question.

CONCLUSIONS

Upon completion of the above analysis, assuming a good air quality data
base, the modeler would have a good idea of how valid his model really is. In
addition, an independent model user or Environmental Impact Statement reviewer
would be able to scan the verification report and obtain a quick feel of how
the model performs compared to a real data set.
The recommended verification procedure discussed above does not require specific model correlation coefficients or any other number on which to determine a pass/fail grade for the model.

The final decision as to whether the model is valid or not, therefore, will not depend upon any specific performance limitation; however, it will depend upon the user's ability to support the use of the model in any instance based on the verification analysis.

ACKNOWLEDGEMENT

This discussion was prepared by Karl Zeller, NOAA meteorologist on assignment to EPA, Las Vegas, Nevada. Thanks are due Dr. David Mage, EPA, Las Vegas, Nevada, for helpful suggestions used in the preparation of this discussion.

REFERENCES


PRELIMINARY AIR QUALITY ANALYSIS (1975)

The ambient air analysis study (Section 2), conducted as a preliminary guide to the development of the WAFB monitoring operations, provided qualitative information on plume rise and initial exhaust plume pollutant concentration as a function of distance. The static jet portion of this study was conducted during idle and power engine modes while a helicopter made downwind passes at altitudes between 3.1 m and 42.7 m AGL.

Relative concentrations based on the averages from all traverses of the helicopter were used to determine effective plume rise, useful for vertical dispersion verification. From these averages, jet exhaust plumes were located at 7 m AGL, 50 m downwind; 20 m AGL, 100 m downwind; 20 m AGL, 150 m downwind; and 21 m AGL, 200 m downwind. The full report is included in its unpublished form.
INTRODUCTION

The EPA, the Air Force, and Argonne National Laboratory (ANL) have an interest in determining the influence of airport activities on the surrounding air quality. Computer models have been developed to assess this influence. In order to prove the usefulness of these models, they must be validated using real data. Efforts to gather airport air quality data in the past (previous efforts include studies of Los Angeles, O'Hare, National Airport, and Atlanta) have not provided data useful for this function. Therefore, the Air Force and the EPA have entered into an interagency agreement (EPA-IAG-R5-0788) that provides for a long-term study to collect data with which to make statistical validations of the models.

Prior to the long-term study, it was necessary to attempt to delineate pollutant transport qualitatively to determine the necessary numbers and locations of long-term air quality monitoring stations.

To accomplish the preliminary study, (referred to by the Air Force as the "Ambient Air Analysis Survey at Selected Locations" study), the Air Force, the EPA, and ANL joined efforts during the period April 1-18, 1975. The preliminary study was divided into three experiments: a grab sampling effort at selected locations around the airport (primary responsibility of ANL); a single-jet impact study (primary responsibility of the EPA with ANL bag sampling support); an effort to determine the adequacy of certain ambient air quality instrumentation considered for possible use in the long-term study (responsibility of the EPA) (this effort was continued through June 1975).

The purpose of this report is to present data collected by the EPA during the short-term April 1975 study at Williams AFB. The data presented here were taken at an air monitoring station set up to accomplish the third objective above, and by the EPA H-34 air quality monitoring helicopter during the single-jet study. This report presents only the EPA data. No conclusions are
drawn. This report should be used in conjunction with ANL's report in order to obtain a complete record of the experiment.

AIR MONITORING STATION

An Air Stream trailer equipped with monitoring instruments was used by the EPA to monitor ambient air at Williams AFB. The trailer was located in the southeast portion of the base near the southeast end of Runway Number Three, 150 feet from Antenna Station Number 1101 and approximately 500 feet from the nearest runway (Figure 1). A REM model 612B chemiluminescence ozone analyzer was used to measure ozone. A Monitor Labs chemiluminescent nitrogen oxide analyzer Model 8440 was used to determine nitric oxide and nitrogen dioxide. The NO/NO2 instrument failed early in the experiment; therefore no NO/NO2 data are reported. A Beckman Model 6800 gas chromatograph was used to measure total hydrocarbons, methane, and carbon monoxide. All data were recorded on strip charts. Ambient air was drawn into the trailer through a covered sampling port in the ceiling of the trailer. A 1 1/2-inch-diameter sampling manifold made of Teflon tubes joined with stainless steel tubing was connected to the sampling port. A pump was used to draw air through the manifold at the rate of 10 cubic feet per minute. One-quarter-inch Teflon sampling lines connected the instruments to the stainless steel portion of the sampling manifold. A Staplex TFIA high-volume sampler was used to collect particulate matter. The sampler was enclosed in a wooden frame located 100 feet from the trailer. A second Beckman 6800 gas chromatograph was located in Room 8 of Building 320. This instrument sampled room air and was used to analyze bags collected during the special static-jet study. The data from this instrument were recorded on strip charts but not reduced.

Calibration standards used in the study were as follows: The carbon monoxide standard was prepared by the Matheson Gas Company. The concentration (approximately 2.8 ppm in air) was determined by comparison with an NBS-prepared carbon monoxide standard. The mixture of propane, methane, and carbon monoxide used as a standard was prepared by Matheson Gas Company. The propane and methane concentrations were determined by that company using gas chromatography. The carbon monoxide concentration was determined by comparison to standard. The ozone calibration concentration was determined by measuring the calibration stream with a Dasibi ozone analyzer that had been calibrated using the KI method defined in the Federal Register, Volume 36, number 84, April 30, 1971.

The Beckman 6800 calibration was done by passing calibration gas through the instrument at 20 ml min while in the calibration mode. The instrument was spanned so that 8.6 ppm methane represented 86 percent of scale, 8.6 ppm methane and 1.8 ppm propane (14.0 ppm carbon) represented 70 percent of total hydrocarbon scale, and 2.8 ppm carbon monoxide represented 78 percent of scale. The REM ozone analyzer was calibrated by zeroing it with filtered air giving a 0.000 ppm ozone reading on the Dasibi ozone analyzer, then supplying ozone produced by a Monitor Labs Model 8440 ozone generator at concentrations of 0.50 to 0.80 ppm. The REM was set at the 0.0 to 0.2 ppm range and the recorder scale was 0.0 to 0.1 ppm.

B-15
The ambient air was monitored at the EPA trailer location continuously from April 9 to June 18, except for minor interruption for maintenance and calibrations. The ozone instrument sampled intermittently from April 9 to April 17. The Beckman 6800 sampled instantaneously once every five minutes from a continuous sampling stream of 5 liters/min. In order to get a representative sample from the Beckman 6800, a 5 gallon (18.9 liters) averaging bottle was placed between the sample manifold and the instrument. The characteristics of the averaging bottle (volume/flow = 3.8 sec.) would cause a 6.1 percent error in the reading if a one-minute pollution step change of 10 times normal concentration were to pass through the sample inlet. The data for April 9-17 are given in Table I. The data for April 17 to June 18 are given in the appendix.

The high-volume filters were changed every day at approximately 4:00 p.m. The flow rates at the beginning and ending of the sampling period were measured. The filter paper was dried and weighed before and after sampling by the Clark County Air Pollution Lab. The results are listed in Table II.

There are many causes of error that plague the quality of collected air quality data. The most common are instrument drift, changes in environmental conditions, and errors resulting from sample handling. The problems caused by changes in environmental conditions, such as changes in temperature and pressure could be significant if instruments were not housed in an enclosed environment. The sampling temperature and pressures of the EPA trailer were not recorded, and the data herein are not corrected for the slight variations in these parameters. However, environmental chamber tests show these errors to be small. The ozone drift was sometimes as much as +.010 ppm in the negative direction. Values below minimum detectable concentrations are recorded as .000 in Table I. Taking into consideration all possible errors, the ozone values can be reasonably considered to be conservative with + .02 ppm. The total maximum hydrocarbon span drift was 4 percent of fullscale; the maximum methane span drift was 2 percent of fullscale; the maximum carbon monoxide drift was 4 percent of fullscale. The zero drift of the Beckman 6800 was not tested because the instrument has an auto-zero. The Beckman 6800 was calibrated weekly and checked daily during the period April 18 through June 24, 1975.

During the first two weeks in April, an additional check of instrument performance was performed. Bag samples of CO were intercompared using the ANL NDIR and the EPA Beckman 6800. The results are shown in Table III.

In order to use the data presented herein for evaluating the possible success of a longer study, it must be pointed out that the normal background levels of these pollutants must be subtracted from the presented measurements in order to assess the contribution of local sources. Approximate worldwide background levels are: methane, 1.4 ppm; total hydrocarbon (except methane) 0.02 ppm; carbon monoxide, 0.25 ppm; nitric oxide, 0.005 ppm; and nitrogen dioxide, 0.001 ppm.
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**TABLE I: AVERAGE VALUES OF NO, NO₂, O₃, TOTAL HYDROCARBON, METHANE, AND CO CONCENTRATIONS MEASURED BY THE EPA TRAILER AT WILLIAMS AFB — APRIL 10-17, 1975**
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<td></td>
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TABLE II. PARTICULATE MATTER COLLECTED WITH A HIGH VOLUME SAMPLER AT WILLIAMS AFB, APRIL 11-17, 1975.
( ) indicate approximations because flow rate was not recorded.

<table>
<thead>
<tr>
<th>Time/Date</th>
<th>Sample-flow rate (cfm)</th>
<th>Sample weight</th>
<th>Concentration (ug/m³)</th>
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<td>.0418 gm</td>
<td>(45)</td>
<td></td>
</tr>
<tr>
<td>4PM 4/19/75 - 4PM 4/19/75</td>
<td>.0607 gm</td>
<td>(60)</td>
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<tr>
<td>4PM 4/20/75 - 4PM 4/20/75</td>
<td>.0406 gm</td>
<td>(30)</td>
<td></td>
</tr>
<tr>
<td>4PM 4/21/75 - 4PM 4/21/75</td>
<td>.0948 gm</td>
<td>(66)</td>
<td></td>
</tr>
<tr>
<td>4PM 4/22/75 - 4PM 4/22/75</td>
<td>.0989 gm</td>
<td>(97)</td>
<td></td>
</tr>
<tr>
<td>4PM 4/23/75 - 4PM 4/23/75</td>
<td>.1270 gm</td>
<td>(133)</td>
<td></td>
</tr>
<tr>
<td>4PM 4/24/75 - 4PM 4/24/75</td>
<td>.1955 gm</td>
<td>(366)</td>
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</tr>
</tbody>
</table>
SINGLE-JET STUDY

The objective of the single-jet study was to document the air quality contribution of a single, static jet during idle and power modes.

TABLE III. COMPARISON OF CO CROSS-CALIBRATION STANDARDS BETWEEN THE ANL NDIR AND THE EPA BECKMAN 6800

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample</th>
<th>CO Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NDIR</td>
</tr>
<tr>
<td>4/05/75</td>
<td>#2 unknown</td>
<td></td>
</tr>
<tr>
<td>4/11/75</td>
<td>Argonne sample</td>
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</tr>
<tr>
<td>4/15/75</td>
<td>#5 1-2 p.m.</td>
<td>0.6</td>
</tr>
<tr>
<td>4/15/75</td>
<td>#7 1-2 p.m.</td>
<td>0.9</td>
</tr>
<tr>
<td>4/15/75</td>
<td>#7 2-3 p.m.</td>
<td>0.7</td>
</tr>
<tr>
<td>4/15/75</td>
<td>#7 3-4 p.m.</td>
<td>1.0</td>
</tr>
<tr>
<td>4/15/75</td>
<td>#13 3-4 p.m.</td>
<td>1.1</td>
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<tr>
<td>4/15/75</td>
<td>#5 2-3 p.m.</td>
<td>0.8</td>
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The experiment was carried out on Saturday, April 5, 1975. The sampling consisted of data from an array of ground stations at which bag samples and data from an air quality instrumented helicopter were collected. A visual concept of the experiment is presented in Figure 2.

Samples were taken at the 13 ground locations. They were first analyzed by ANL for carbon monoxide with a Beckman NDIR analyzer. The sample bags were then analyzed for total hydrocarbon, methane, and carbon monoxide with the EPA Beckman 6800 located in Room 8. The sampling procedure for the Beckman 6800 was to operate the instrument in the calibration mode, connect the bag to the calibration input port, squeeze the bag so that 100 ml of sample flushed the sampling system during the minute before sampling, and then flush the sample through the sampling system at 20 ml per minute until the sampling cycle was completed. The results are listed in Table IV. The error caused by squeezing the sample from the bag into the Beckman 6800 was tested by comparing the readings of the standard samples dispensed from a bag and a cylinder. The results showed that the bag-sample readings were: total hydrocarbon, no change; methane, 5 percent low; and carbon monoxide, 7 percent low.
Figure 2. Artist depiction of single-jet study at Williams AFB.

O = Sampling locations

B-22
### TABLE IV. THE TOTAL HYDROCARBON, METHANE, AND CARBON MONOXIDE ANALYSIS OF BAG SAMPLES COLLECTED DURING THE AIRCRAFT TEST AT WILLIAMS AFB, APRIL 5, 1975.
This analysis was done on a Beckman 6800 chromatograph.

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<th>Comments</th>
</tr>
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<td>THC</td>
<td>He</td>
</tr>
<tr>
<td>1</td>
<td>no sample</td>
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<td>3</td>
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<tr>
<td>13</td>
<td>no sample</td>
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<th>Comments</th>
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<th>Comments</th>
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**TABLE IV. (continued)**
The EMSL-LV H-34 helicopter (designated RAPS II) outfitted with various air monitoring instruments made three flights in support of the ground-based single-jet study. Its mission was to define the vertical distribution of pollutant and pollutant related parameters. The first of these flights was aborted because of power failures. The next two flights consisted of two missions each, delineated by the power settings of the T-38 used in the study.

Instrumentation on board RAPS II consisted of a REM ozone monitor, Monitor Labs NO/NOx monitor, Beckman CO analyzer, Meloy SO2 analyzer, MRI nephelometer, Cambridge temperature and dewpoint sensors, pressure altimeter, and air speed indicator.

The positional equipment, DME’s and VOR, normally used on RAPS II in conjunction with the air pollution instrumentation, were not used because of the confined area of the testing site. Location was identified by keying a systematic series of numbers based on ground locations into the data system by means of thumbwheel switches. Altitude was logged in from the radio altimeter; ground distance from the T-38 was entered according to the siting of ground markers. Also entered was the type of test and the approximate time spent in the plume (i.e., cross plume or down plume). All data was recorded on a Monitor Labs data system Model 7200 and on magnetic tape. Simultaneously, strip-chart recordings were made of CO, NOx, and temperature.

During the entire testing period, no evidence of SO2 was recorded -- that is, concentration values remained at the zero level during this time. Ozone was measured in the 35-55 ppb (v/v) range and did not appear to fluctuate significantly on passing in and out of the jet plume. Table V is a summary of the peak airborne pollutant data per pass. These are the raw data. No corrections have been made for temperature and pressure effects (on the pollutant and on the instruments) nor have corrections been implemented regarding lag and response times of the instruments or helicopter system as a whole.

Because of a known severe temperature effect on the Beckman CO analyzer, coupled with significant changes in cabin temperature, it is believed that most of the first AM CO data is invalid since the CO analyzer was drifting to adapt to cabin temperature. The later CO data was stable.

Examinations of the pollutant concentration measured by the helicopter show an impact of the jet plume well above the normal height for measuring air quality. For instance, the jet plume during the first afternoon test was detected at 70 feet AGL at 200 m downwind.

DISCUSSION OF GROUND DATA

It is interesting to note that the total hydrocarbon (THC) results were extremely high during the period of the short term study (April 9-17). The values of THC increased significantly the evening of April 11 and April 13 through April 17. The highest value observed was 9.0 ppm at 1:00 a.m. April 16, 1975. Throughout the rest of the sampling period, the THC levels were
TABLE V. HELICOPTER DATA COLLECTED DURING
THE SINGLE-JET STUDY OF 5 APRIL AT WILLIAMS AFB

<table>
<thead>
<tr>
<th>Downwind Distance from Exhaust (meters)</th>
<th>NO (ppm)</th>
<th>NOx (ppm)</th>
<th>Began CO (10^-6)</th>
<th>CO (ppm)</th>
<th>Temperature (C°)</th>
<th>Inside/Outside</th>
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| 2nd AM                                  |          |           |                  |         |                 |                |
| 50                                      | 0.001    | 0.010     | 0.3              | 26.1    | 26.0            |                |
| 10                                      | 0.003    | 0.008     | 0.2              | 26.4    | 26.2            |                |
| 90                                      | 0.000    | 0.000     | 0.3              | 26.1    | 26.0            |                |
| 70                                      | 0.000    | 0.005     | 0.3              | 26.5    | 26.8            |                |
| 10                                      | 0.003    | 0.011     | 0.3              | 26.5    | 26.0            |                |
| 10                                      | 0.001    | 0.006     | 0.4              | 27.0    | 26.2            |                |
| 100                                     | 0.000    | 0.005     | 0.4              | 26.5    | 26.1            |                |
| 70                                      | 0.000    | 0.006     | 0.3              | 26.9    | 26.5            |                |
| 10                                      | 0.000    | 0.006     | 0.5              | 26.6    | 26.4            |                |
| 50                                      | 0.005    | 0.013     | 0.3              | 26.8    | 26.4            |                |
| 50                                      | 0.000    | 0.005     | 0.3              | 26.9    | 26.5            |                |
| 20                                      | 0.001    | 0.006     | 0.3              | 22.9    | 22.2            |                |

* The jet engine of the T-38 was cut off prior to these four passes.
** Parallel to exhaust
*** Background
more in line with what would be expected. During the period of the short-term study, there was a considerable amount of local agricultural activity including the spraying of chemicals. This may be one possible explanation of the extremely high THC values.

Pollution roses from CO and THC were constructed with the April 17 - June 18 data using approximately the highest third of the concentration values for each given month. For example, the THC rose for June represents all values greater than or equal to 1.50 ppm, which was the one-third data breakoff point (i.e., in this particular case 32.8 percent all the THC measurements for that period). The pollution roses (Figures 3, 4, 6, 7, 9 and 10) therefore represent the percentage of the time for which the wind was coming from a given direction with simultaneous high values of THC or CO. The breakoff points and the percentage of each month's readings used for the CO and THC pollution roses are given in Table VI.

| TABLE VI. BREAKOFF VALUES AND PERCENTAGES FOR POLLUTION ROSES |
|--------------------|--------------------|--------------------|
| April  |
| THC   | 1.58    |
| CO    | 0.50    |
| May   |
| THC   | 1.52    |
| CO    | 0.52    |
| June  |
| THC   | 1.50    |
| CO    | 0.42    |

In order that an analysis may be performed, wind roses were constructed using all of the wind measurements for each of the three months (Figures 5, 8 and 11). These offered a basis for comparison with the pollution roses. Using the pollution roses, determinations can then be made as to possible pollution sources in the Williams AFB area.

Note that the same general trend can be observed from the comparison of the wind roses and both pollution roses for each of the three time periods. This trend shows a higher percentage of relatively higher pollution values coming from the east and east-southeast directions.

In addition, the highest pollution values recorded, by month, for each pollutant, the time each occurred, and the wind conditions at the time are given in Table VII.

HORIZONTAL WIND DISPERSION PARAMETER INVESTIGATION

The Pasquill stability class dispersion parameters are an important input to the approach used in AQAM. The purpose of the horizontal wind dispersion
Figure 5. WAPB transmitter site wind rose, April 1975.

Figure 6. WAPB transmitter site THC pollution rose, May 1975.
Figure 9. WAFB transmitter site THC pollution rose, June 1975.

Figure 10. WAFB transmitter site CO pollution rose, June 1975.
Figure 11. WAFB transmitter site wind rose, June 1975.
TABLE VII. SUMMARY OF HIGHEST MONTHLY VALUES

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study was to determine how the subjective observation of stability class at WAFB (i.e., the method of determining stability class from WABAN observations [21]) compared with the measured horizontal dispersion values from propeller vane wind measurements and how this comparison would affect the AQAM results. A wind study was conducted at WAFB during the first week of monitoring -- June 1976 -- using the R. M. Young Gill propeller vanes. These vanes are light and have a fast time response. The average AGL height for the vanes was 8 m. Lightweight propeller vanes are effective for the measurement of WS in the 1 m to 10 m wavelength, which is an intermediate scale important to atmospheric diffusion.*

From June 1 to 8, 1976, strip-chart recordings of WS and WD were collected in seven periods of several hours each from all monitoring stations of the network. From these records, a shorter period of homogeneous turbulence (June 4 through 7) was selected for detailed analysis, when winds were generally light -- below 5 m/s. Maximum temperatures were in the mid 30's (°C) and minimums were in the low 20's, typical of summer weather in the Phoenix valley.

## APPENDIX: AIR QUALITY DATA - APRIL 17 THROUGH JUNE 18, 1975

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* ( = Peak value during hour.)
The method of estimating the horizontal Gaussian dispersion parameters \( \sigma_y \) from wind records was taken from a September 28, 1970, EPA course discussion entitled, "Diffusion of Air Pollution - Theory and Application." The process of this analysis was to compute qualitative horizontal dispersion coefficients, \( \sigma_y \), as a function of downwind distance, \( x \), from a monitoring site so that the stability class could be determined and then compared with the Pasquill classes subjectively derived from surface weather observations. The formula used to calculate \( \sigma_y \) was:

\[
\sigma_y = \sigma \delta \quad \text{(Eq. 1)}
\]

where:

\[
\sigma = \sqrt{\frac{I(\theta_i - \theta)^2}{n - 1}}
\]

and:

\[
x = \text{Diss}
\]

and:

\[
\delta = \text{WS}
\]

\[
\sigma = \text{SD of wind direction R}
\]

\[
\theta = \text{Azimuth angle of the wind}
\]

\[
s = \text{Averaging time for each increment}
\]

\[
n = \text{Number of averaging time periods per measurement period}
\]

\[
\delta = \text{Ratio of the Lagrangian to Eulerian time scales (approx. 4)}
\]

\[
y = \text{Lateral direction normal to VMWD.}
\]

The total extreme WD difference, \( \Delta \theta \), within the \( \delta \) averaging time was also measured on the charts and averaged for the experiment period. This was intended as an additional indication of the spread of small-scale turbulence. Table B-1 summarizes all the wind dispersion calculations made. The values of average wind azimuth angle, \( \theta \), are approximate since more precise measurements were not conducted. Figures B-1 through B-5 are plots of the calculated \( \sigma_y \) versus \( x \) on graphs that also indicate the six Pasquill stability classes (A to C are unstable, D is neutral, E and F are stable).

Calculations were performed with the strip-chart data from Periods 2 to 5 using a 5-minute averaging time (Table B-1) to test whether or not turbulence at all the trailers was similar \( (\sigma_y \text{ and } x \text{ were determined at several trailers using the same averaging time to extract } \theta \text{ during the same period). In the nighttime case, period 2, the values of } \sigma_y \text{ were similar except for station 4 (Figure B-1). In the daytime case, period 5, all values of the dispersion coefficient were sufficiently close to assume that similar turbulence took place at all trailers (Figure B-2). Some of the charts showed}}
TABLE B-1. WIND DISPERSION STUDY RESULTS, WAFB, JUNE 1976

| Run | Date      | Start Time | Stop Time | Averaging Time (min) | # Time Increments for Period (degrees) | Instrument Magnitude (magnetic north = 0°) | Instrument Magnitude (degrees) | Instrument Magnitude (m/sec) | x=x̄ | y=0 | x=x̄+x̄ | y=0+y | x=x̄ | y=0 | x=x̄ | y=0 | x=x̄ | y=0 |
|-----|-----------|------------|-----------|----------------------|----------------------------------------|------------------------------------------|----------------------------------------|-------------------------------|------|-----|----------------|--------|------|-----|------|-----|------|-----|------|-----|------|-----|
| 1   | 4 Jun     | 0900       | 1545      | 5                    | 70                                     | 179                                      | 6                                      | 2.8                           | 3.4  | 3740| 120  | 57     |       |     |      |     |     |     |
| 2   | 4-5 Jun   | 0900       | 1545      | 5                    | 60                                     | 77                                       | 27                                     | 1.0                           | 2.2  | 1040| 25   | 17     |       |     |      |     |     |     |
| 3   | 4-5 Jun   | 0900       | 1545      | 5                    | 60                                     | 120                                      | 31                                     | 2.1                           | 2.5  | 1340|     |        |       |     |      |     |     |     |
| 4   | 4-5 Jun   | 0900       | 1545      | 5                    | 60                                     | 115                                      | 40                                     | 1.1                           | 1.4  | 950 |     |        |       |     |      |     |     |     |
| 5   | 5 Jun     | 0900       | 1545      | 5                    | 52                                     | 115                                      | 6                                      | 2.0                           | 2.4  | 260 | 28   | 12     |       |     |      |     |     |     |
| 6   | 5 Jun     | 0900       | 1545      | 5                    | 97                                     | 243                                      | 33                                     | 3.2                           | 3.8  | 2190| 82   | 25     |       |     |      |     |     |     |
| 7   | 5 Jun     | 0900       | 1545      | 5                    | 124                                    | 253                                      | 24                                     | 3.2                           | 1.0  | 409 | 54   | 17     |       |     |      |     |     |     |
| 8   | 5 Jun     | 0900       | 1545      | 5                    | 273                                    | 20                                       | 3.5                                     | 2.1                           | 725  | 81  | 27   |        |       |     |      |     |     |     |
| 9   | 6 Jun     | 1400       | 1720      | 5                    | 40                                     | 233                                      | 14                                     | 5.2                           | 6.2  | 1550| 77   | 35     |       |     |      |     |     |     |
| 10  | 6 Jun     | 1400       | 1720      | 5                    | 40                                     | 259                                      | 15                                     | 5.8                           | 7.0  | 1850| 57   | 27     |       |     |      |     |     |     |
| 11  | 6 Jun     | 1400       | 1720      | 5                    | 36                                     | 273                                      | 14                                     | 3.6                           | 4.3  | 1340| 83   | 31     |       |     |      |     |     |     |
| 12  | 6 Jun     | 1400       | 1720      | 5                    | 104                                    | 92                                       | 31                                     | 3.0                           | 1.8  | 973 | 25   | 13     |       |     |      |     |     |     |
| 13  | 6 Jun     | 1400       | 1720      | 5                    | 52                                     | 90                                       | 20                                     | 2.9                           | 3.5  | 1710| 25   | 15     |       |     |      |     |     |     |
| 14  | 6 Jun     | 1400       | 1720      | 5                    | 34                                     | 44                                       | 24                                     | 3.7                           | 6.6  | 2770| 33   | 15     |       |     |      |     |     |     |
| 15  | 7 Jun     | 1100       | 1400      | 2.5                  | 80                                     | 167                                      | 20                                     | 5.5                           | 3.3  | 1610| 63   | 17     |       |     |      |     |     |     |
| 16  | 7 Jun     | 1100       | 1400      | 5                    | 72                                     | 213                                      | 31                                     | 6.0                           | 7.2  | 4810| 70   | 15     |       |     |      |     |     |     |
| 17  | 7 Jun     | 1100       | 1400      | 7.5                  | 41                                     | 214                                      | 44                                     | 5.8                           | 10.5 | 8030| 87   | 33     |       |     |      |     |     |     |
| 18  | 8 Jun     | 0740       | 1040      | 5                    | 52                                     | 84                                       | 6                                      | 2.0                           | 2.4  | 260 | 28   | 12     |       |     |      |     |     |     |
| 19  | 8 Jun     | 0740       | 1040      | 5                    | 17                                     | 104                                      | 10                                     | 3.8                           | 13.7 | 2400| 29   | 8      |       |     |      |     |     |     |
| 20  | 8 Jun     | 0740       | 1040      | 5                    | 10                                     | 115                                      | 10                                     | 2.5                           | 6.1  | 1070| 64   | 19     |       |     |      |     |     |     |
| 21  | 8 Jun     | 0740       | 1040      | 5                    | 14                                     | 62                                       | 13                                     | 4.4                           | 8.5  | 1940| 24   | 11     |       |     |      |     |     |     |
Figure B-1. Horizontal dispersion coefficient as a function of downwind distance from the source, runs 2 and 4.
Figure B-2. Horizontal dispersion coefficient as a function of downwind distance from the source, runs 1 and 5.
Figure B-3. Horizontal dispersion coefficient as a function of downwind distance from the source, run 6.
Figure B-4. Horizontal dispersion coefficient as a function of downwind distance from the source, run 7.
Figure B-5. Horizontal dispersion coefficient as a function of downwind distance from the source, run 3.
larger small-scale change in direction at station 4, but since this was smaller than most averaging times, the stability calculations were not affected. For example, notice the \( \Delta \theta \) (total span of WD difference during period) values for runs 3, 5, and 7 at station 4 in Table B-1.

The remaining sets of calculations were performed to determine the effect of different downwind distances on stability class. Different averaging times were used to calculate \( \sigma_y \) and \( x \) in runs 3, 4, 6 and 7. Run 4 indicates that between 1-1/4 and 5-minute averaging times, the stability classes are about the same. If in fact the stability classes are the same for different averaging times, then the assumptions of the derivation and method are supported. The results are better for runs 6 and 7. Note in Figures B-3 and B-4 that the \( \sigma_y \) values almost exactly parallel the Pasquill lines. Although period 6 was in the early morning, it still shows that a Pasquill Class A would be insufficient to describe the magnitude of instability at WAFB. For the daytime case, period 7, the magnitude of instability that occurred over the hot WAFB runways exceeded Class A. Longer averaging times were used to calculate the diffusion coefficient in run 3. This early morning period (Class F by subjective classification) was the most stable of the four study days. Even so, this most stable period compared to a Class C.

A comparison of the average total variation of direction within the averaging time gives an indication of the turbulence intensity at small wavelengths. In the early morning hours, period 5 for example, \( \Delta \theta \) was 15° to 30°, whereas during the day the values were usually more than twice that. The nighttime fluctuations were usually more frequent because of mechanical turbulence, but the daytime small-scale fluctuations were larger as a result of thermal turbulence.

In conclusion, because of the intense insolation in the Phoenix valley, the lower atmosphere remains from slightly unstable to extremely unstable throughout the day and into the night during the summer. Pasquill stability classes seem to be low by an average of two classes. The most unstable case, Class A, is off by a factor of 2 or 3.

PARTICLE MORPHOLOGY OF AEROSOLS COLLECTED AT WAFB

In November 1975, the EPA (with the assistance of the Illinois Institute of Technology Research Institute [IITRI] as a contractor) conducted an experimental program in the Phoenix metropolitan area to measure the mass flux and to identify aerosols entering and leaving Phoenix. Data obtained were to be used by the EPA to develop control strategies for air quality control regions in the southwestern United States. In conjunction with the Phoenix study, the EPA requested that aerosol samples be collected at WAFB to determine the impact of the base on local air quality. Microscopic examination of the collected aerosols was conducted to determine what differences, if any, existed between particle types collected at WAFB and those collected in the Phoenix metropolitan area.

Aerosol samples were collected on November 17, 18, 21, 23-24 (overnight), and 25, 1975, with four samplers located at three different sites at WAFB:
near site 4 at Building 16; at a remote sensing unit near site 2; and at a
transmitter antenna near site 1 that had samplers situated at 1.55 m and 4.5 m
AGL. Sampling intervals were chosen to take advantage of windflow patterns in
the Phoenix valley area. Battelle five-stage fractionating samplers were
used. Stage collection plates were 2.54-cm-diameter glass discs, and a 0.4-µm
pore-size nucleopore filter was used as a backup filter. The first two glass
disc stages were coated with Apiezon grease to minimize bounce off of the
larger particles; the final three stages were uncoated. At a flow rate of
0.05 liter/m, assuming uniform density, cut sizes for the five stages were 4
µm, 1 µm, 0.5 µm, and 0.25 µm. Table B-2 lists sampler identifications and
actual count of particles on each stage.

Microscopic Analysis

All samples collected at WAFB were submitted to the Fine Particles
Research Section of IITRI for microscopic examination. All Glass-disc
collection substrates were examined by optical microscopy, and some were
further examined by scanning electron microscopy. Selected nucleopore filters
were also examined by scanning electron microscopy. The first two stages
were coated with Apiezon grease, which has a crystalline structure that
interferes with the identification of aerosols by polarized light microscopy.
Samples were prepared by warming them to melt the grease and to remove this
interference; some particles are lost in this process. General observations
made during the examination of each sample are given in an IITRI report.

The particle size distribution data indicate that, on a number basis, the
mean particle diameter at each sampling site was less than 2 millimeters (mm).
Any sulfate particles lost during particle removal from the substrates would
also have fallen into this size category [26, 27]. In addition to
categorization by size, the particles were also categorized into two basic
types — mineral and nonmineral. The mineral category contained various soil
minerals, fly ash spheres, and higher density particles such as metal
fragments. The nonmineral category included the fine carbonaceous particles,
carbonized flakes, biological particles, and tire rubber particulate. Size
distribution data obtained are presented in Tables B-3 and B-4.

Summary of Results

The primary components of atmospheric aerosols in terms of mass at WAFB
are minerals indigenous to the soil of the area. Motor vehicle traffic was
partially responsible for resuspension of the soil minerals. Analysis in the
size ranges shown indicates that the vehicles themselves contributed only
minor concentrations of particulates to the atmosphere.

The major differences between WAFB and Phoenix aerosols were
concentrations of clay aggregates and clay-coated minerals and higher
(ammonium) sulfate concentrations at WAFB. The mineral concentrations were
probably because there are fewer paved roadways and shoulders around WAFB
compared to the Phoenix metropolitan area (i.e., surrounding agricultural land
use). The greater sulfate concentrations were the result, at least in part,
of the closer proximity of WAFB to large smelter plants. This conclusion was
supported by the presence of copper—sulfur, lead—bismuth, and tin species on
<table>
<thead>
<tr>
<th>Date</th>
<th>Site</th>
<th>Time</th>
<th>Sampler No</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Backup</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 Nov 75</td>
<td>Transm. 5'</td>
<td>1220 - 1820</td>
<td>D</td>
<td>48</td>
<td>47</td>
<td>2046</td>
<td>2045</td>
<td>2044</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Transm. 15'</td>
<td>1220 - 1820</td>
<td>E</td>
<td>49</td>
<td>50</td>
<td>2053</td>
<td>2054</td>
<td>2055</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Bldg. 16</td>
<td>1140 - 1735</td>
<td>1003</td>
<td>16</td>
<td>15</td>
<td>2012</td>
<td>2011</td>
<td>2010</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Remote unit</td>
<td>1110 - 1710</td>
<td>1004</td>
<td>46</td>
<td>45</td>
<td>2043</td>
<td>2042</td>
<td>2041</td>
<td>2</td>
</tr>
<tr>
<td>18 Nov 75</td>
<td>Transm. 5'</td>
<td>1105 - ?</td>
<td>D</td>
<td>55</td>
<td>56</td>
<td>2058</td>
<td>2057</td>
<td>2056</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Transm. 15'</td>
<td>1105 - ?</td>
<td>E</td>
<td>57</td>
<td>58</td>
<td>2065</td>
<td>2066</td>
<td>2067</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Bldg. 16</td>
<td>1040 - 1710</td>
<td>1003</td>
<td>51</td>
<td>53</td>
<td>2059</td>
<td>2060</td>
<td>206</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>Remote unit</td>
<td>1055 - 1735</td>
<td>1004</td>
<td>54</td>
<td>59</td>
<td>2062</td>
<td>2063</td>
<td>2064</td>
<td>7</td>
</tr>
<tr>
<td>21 Nov 75</td>
<td>Transm. 5'</td>
<td>--</td>
<td>1001 (control)</td>
<td>70</td>
<td>69</td>
<td>2082</td>
<td>2081</td>
<td>2080</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Transm. 5'</td>
<td>0545 - 1545</td>
<td>D</td>
<td>112</td>
<td>113</td>
<td>2148</td>
<td>2149</td>
<td>2150</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Transm. 15'</td>
<td>0545 - 1545</td>
<td>E</td>
<td>114</td>
<td>115</td>
<td>2151</td>
<td>2152</td>
<td>2152</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Bldg. 16</td>
<td>--</td>
<td>1006 (control)</td>
<td>68</td>
<td>67</td>
<td>2079</td>
<td>2078</td>
<td>2077</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bldg. 16</td>
<td>0505 - 1505</td>
<td>1003</td>
<td>111</td>
<td>110</td>
<td>2147</td>
<td>2146</td>
<td>2110</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Remote unit</td>
<td>0530 - 1530</td>
<td>1004</td>
<td>108</td>
<td>109</td>
<td>2109</td>
<td>2108</td>
<td>2107</td>
<td>14</td>
</tr>
<tr>
<td>23-24 Nov</td>
<td>Transm. 5'</td>
<td>2110 - 0720</td>
<td>D</td>
<td>119</td>
<td>130</td>
<td>2141</td>
<td>2140</td>
<td>2139</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Transm. 15'</td>
<td>2110 - 0720</td>
<td>E</td>
<td>137</td>
<td>136</td>
<td>2144</td>
<td>2143</td>
<td>2142</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Bldg. 16</td>
<td>2125 - 0730</td>
<td>1003</td>
<td>132</td>
<td>131</td>
<td>2132</td>
<td>2131</td>
<td>2145</td>
<td>9</td>
</tr>
<tr>
<td></td>
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<td>2055 - 0710</td>
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<td>135</td>
<td>134</td>
<td>2138</td>
<td>2137</td>
<td>2136</td>
<td>11</td>
</tr>
<tr>
<td>25 Nov 75</td>
<td>Transm. 5'</td>
<td>0650 - 1540</td>
<td>E</td>
<td>151</td>
<td>156</td>
<td></td>
<td></td>
<td></td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Transm. 15'</td>
<td>0650 - 1540</td>
<td>D</td>
<td>159</td>
<td>157</td>
<td></td>
<td></td>
<td></td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Bldg. 16</td>
<td>0700 - 1555</td>
<td>1004</td>
<td>160</td>
<td>161</td>
<td></td>
<td></td>
<td></td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Remote unit</td>
<td>0640 - 1530</td>
<td>1003</td>
<td>162</td>
<td>158</td>
<td></td>
<td></td>
<td></td>
<td>21</td>
</tr>
</tbody>
</table>
## TABLE B-3. TOTAL PARTICLE SIZE DISTRIBUTIONS

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>&lt;2 μm</th>
<th>2-8 μm</th>
<th>8-20 μm</th>
<th>20-40 μm</th>
<th>&lt;40 μm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ft Transmitter</td>
<td>836</td>
<td>248</td>
<td>122</td>
<td>27</td>
<td>6</td>
<td>1239</td>
</tr>
<tr>
<td>Building 16</td>
<td>761</td>
<td>245</td>
<td>147</td>
<td>42</td>
<td>12</td>
<td>1207</td>
</tr>
<tr>
<td>Remote unit</td>
<td>552</td>
<td>255</td>
<td>133</td>
<td>34</td>
<td>14</td>
<td>988</td>
</tr>
</tbody>
</table>

### Number Percentage

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>&lt;2 μm</th>
<th>2-8 μm</th>
<th>8-20 μm</th>
<th>20-40 μm</th>
<th>&lt;40 μm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ft Transmitter</td>
<td>67.5</td>
<td>20.0</td>
<td>9.8</td>
<td>2.2</td>
<td>.5</td>
<td>100</td>
</tr>
<tr>
<td>Building 16</td>
<td>16.0</td>
<td>20.3</td>
<td>12.2</td>
<td>3.5</td>
<td>1.0</td>
<td>100</td>
</tr>
<tr>
<td>Remote unit</td>
<td>55.9</td>
<td>25.8</td>
<td>13.5</td>
<td>3.4</td>
<td>1.4</td>
<td>100</td>
</tr>
</tbody>
</table>

## TABLE B-4. PARTICLE SIZE DISTRIBUTIONS ACCORDING TO PARTICLE TYPE

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>&lt;2 μm</th>
<th>2-8 μm</th>
<th>8-20 μm</th>
<th>20-40 μm</th>
<th>&gt;40 μm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
<td>No. %</td>
</tr>
<tr>
<td><strong>Mineral</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 ft Transmitter</td>
<td>330</td>
<td>56.0</td>
<td>150</td>
<td>25.5</td>
<td>84</td>
<td>14.2</td>
</tr>
<tr>
<td>Building 16</td>
<td>305</td>
<td>50.5</td>
<td>161</td>
<td>26.6</td>
<td>100</td>
<td>16.5</td>
</tr>
<tr>
<td>Remote unit</td>
<td>201</td>
<td>39.2</td>
<td>175</td>
<td>34.0</td>
<td>101</td>
<td>19.7</td>
</tr>
</tbody>
</table>

|                 |       |        |         |          |        |       |
| **Nonmineral**  |       |        |         |          |        |       |
| 5 ft Transmitter| 506   | 77.8   | 98      | 15.2     | 38     | 5.8   |
| Building 16     | 456   | 75.7   | 84      | 14.0     | 47     | 7.8   |
| Remote unit     | 351   | 73.9   | 80      | 16.8     | 32     | 6.7   |

### Mineral

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>&lt;2 μm</th>
<th>2-8 μm</th>
<th>8-20 μm</th>
<th>20-40 μm</th>
<th>&gt;40 μm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ft Transmitter</td>
<td>330</td>
<td>56.0</td>
<td>150</td>
<td>25.5</td>
<td>84</td>
<td>14.2</td>
</tr>
<tr>
<td>Building 16</td>
<td>305</td>
<td>50.5</td>
<td>161</td>
<td>26.6</td>
<td>100</td>
<td>16.5</td>
</tr>
<tr>
<td>Remote unit</td>
<td>201</td>
<td>39.2</td>
<td>175</td>
<td>34.0</td>
<td>101</td>
<td>19.7</td>
</tr>
</tbody>
</table>

### Nonmineral

<table>
<thead>
<tr>
<th>Sample Site</th>
<th>&lt;2 μm</th>
<th>2-8 μm</th>
<th>8-20 μm</th>
<th>20-40 μm</th>
<th>&gt;40 μm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ft Transmitter</td>
<td>506</td>
<td>77.8</td>
<td>98</td>
<td>15.2</td>
<td>38</td>
<td>5.8</td>
</tr>
<tr>
<td>Building 16</td>
<td>456</td>
<td>75.7</td>
<td>84</td>
<td>14.0</td>
<td>47</td>
<td>7.8</td>
</tr>
<tr>
<td>Remote unit</td>
<td>351</td>
<td>73.9</td>
<td>80</td>
<td>16.8</td>
<td>32</td>
<td>6.7</td>
</tr>
</tbody>
</table>
the small particle size stages of the impactor collectors. Significant numbers of particles in the light-scattering size range were present at all sites on all dates. The majority of the particles in the light-scattering range were mineral particles and liquid containing sulfate droplets. A complete report on this Williams aerosol study is in the IITRI report [18] and in a subsequent EPA publication.

Assuming an average size distribution that remained constant over the monitoring period, it is possible to infer a particle mass loading (for an average WAFB atmosphere) from bscat measurements. Unfortunately, the greatest variability was shown in the less-than-2-μm-diameter size range in this study for a short period of time. Details of this correlation have been presented by Tombach and Charlson [19, 28] who state that particulate size distribution and specific gravity, remaining constant with time, can have the following approximate proportionality:

\[ m(g/m)^3 = 0.45 + 0.55 \cdot \beta(m^{-1}) \]  

(Eq. 2)

where \( \beta \) is the scattering at wavelengths visible to the human eye.

REMOTE OPTICAL SENSING OF EMISSIONS STUDY

Long-path infrared spectroscopic measurements of CO concentrations were made during the period February 10 through 19, 1976, at WAFB. These measurements provided integrated CO concentrations over the path length between two points for the measurement. They were included as a part of the program because of the inherent difficulty of comparing the average value predictions of dispersion models with the fixed-point values obtained from conventional sampling stations. This instrumentation provides path-averaged concentrations for more direct comparison to models. This section describes the experimental procedures used and presents the results of the measurements. Complete details of the experiment are available in an EPA letter report by Dr. William Herget [29].

The long-path measurements were carried out using the ROSE system, which is basically a mobile infrared grating spectrometer. The infrared light source and receiver units were equipped with telescopic optics to permit long-path (up to 3 km) measurements. The measured gas concentrations obtained in this manner are the same concentrations that would be obtained if the gas molecules were uniformly distributed over the optical path length.

The sites (optical paths) for the ROSE measurements were chosen to correspond with major WAFB operations. They were located to be near conventional point sampling stations (not in operation at the time of the ROSE measurements). In Figure B-6, the five sampling sites are indicated by "SS," and the paths used for the ROSE measurements are indicated by a line connecting a pair of letters (e.g., "A" indicates the ROSE van location and "A*" indicates the light-source location). Characteristics of the paths are summarized in Table B-5.
TABLE B-5. LONG-PATH MEASUREMENT LOCATION SUMMARY

<table>
<thead>
<tr>
<th>Date</th>
<th>Path</th>
<th>Time</th>
<th>Range (m)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-10</td>
<td>A</td>
<td>1200-1800</td>
<td>670</td>
<td>Vicinity of jet warmup, taxi, and shutdown (&quot;X's&quot; in Figure 1)</td>
</tr>
<tr>
<td>2-11</td>
<td>A</td>
<td>0630-1500</td>
<td>670</td>
<td></td>
</tr>
<tr>
<td>2-11</td>
<td>B</td>
<td>1700-1800</td>
<td>810</td>
<td></td>
</tr>
<tr>
<td>2-12</td>
<td>B</td>
<td>0615-1730</td>
<td>810</td>
<td></td>
</tr>
<tr>
<td>2-13</td>
<td>C_1</td>
<td>0830-1630</td>
<td>1880</td>
<td>Parallel to main taxiway</td>
</tr>
<tr>
<td>2-17</td>
<td>C_2</td>
<td>0630-1530</td>
<td>1940</td>
<td></td>
</tr>
<tr>
<td>2-18</td>
<td>D</td>
<td>0900-1650</td>
<td>1150</td>
<td>Across taxiway and runways</td>
</tr>
<tr>
<td>2-19</td>
<td>E</td>
<td>0630-1645</td>
<td>2140</td>
<td>Across north boundary of WAFB</td>
</tr>
</tbody>
</table>

The CO spectrum covers the spectral region from about 2,040 to 2,240 cm\(^{-1}\). Water vapor interferes towards the low wave number side and renders the region below about 2,150 cm\(^{-1}\) useless for CO analysis in the long-path measurements. Most of the spectra were recorded from 2,150 to 2,250 cm\(^{-1}\) with spectral resolution of about 1 cm\(^{-1}\).

A total of 236 individual CO concentration measurements were made during the seven days of long-path data collection. Highest average CO concentrations of about 4 ppm were measured along path A. For this path, those concentrations above about 1.2 ppm were obtained when the optical path was traversed by an individual jet plume for an appreciable period of time. Along other optical paths most concentrations remained under 1 ppm. An exception was at 1407 hours on path E; at this time there were five jets idling at the east end of taxiway 5 (about 20 m south of the optical path), and the path-averaged concentration was measured at 3 ppm.

Visual observation of the jet exhausts and the fact that the highest CO concentrations occurred along path A (as opposed to path C) suggested that the jet plumes were rising very quickly.

CORRELATION SPECTROMETER STUDY

Environmental Measurements, Inc. (EMI) performed six days of measurements from October 20 to 27, 1976, using the Barringer COSPEC. The goal was to document NO\(_2\) pollution flux entering and leaving the base. Additional data were gathered on regional pollution levels in the greater Phoenix and in the vicinity of Sky Harbor Airport. Total sulfur measurements were used as indicators of external emissions entering the WAFB area.

An EMI moving laboratory measured SO\(_2\) and NO\(_2\) overhead burdens with the COSPEC remote sensor and total sulfur (TS) and NO\(_X\) at ground level with
continuous analyzers. The remote sensing COSPEC was also mounted on a tripod near the taxiway, site 3, WAFB, and vertical and horizontal profiles of NO\textsubscript{2} were made over two different intervals. The main goal was achieved by circumnavigating the base on the perimeter road that circled the main aircraft operations area. The basic perimeter traverse was 13.5 km long and required 25 minutes to complete. These measurements around the base were carried out 25 times in six days. Typical readings and peak values for both total burden and ground-level measurements are tabulated below:

<table>
<thead>
<tr>
<th></th>
<th>Typical</th>
<th>Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO\textsubscript{2} total burden (ppmM)*</td>
<td>20-60</td>
<td>157</td>
</tr>
<tr>
<td>NO\textsubscript{2} total burden (ppmM)</td>
<td>20-40</td>
<td>152</td>
</tr>
<tr>
<td>TS ground-level (ppb)</td>
<td>0-5</td>
<td>12</td>
</tr>
<tr>
<td>NO\textsubscript{x} ground-level (ppb)</td>
<td>50-150</td>
<td>905</td>
</tr>
</tbody>
</table>

* ppmM = parts per million - meters

As tabulated above, the typical SO\textsubscript{2} values varied over 40 ppmM while the NO\textsubscript{2} varied over a 20 ppmM band. This difference documented expectation, though further analysis of the data would be required to provide a qualified observation. The moving laboratory measurements indicated:

- Ground-level TS at low concentration showing external emission of this type entering WAFB to be limited
- Ground-level NO\textsubscript{x} variation with automobile traffic in the area and perimeter of WAFB

Results of the greatest potential value were the ground-level NO\textsubscript{x} data showing varying levels at WAFB and at Sky Harbor Airport (near Phoenix), which can be used to document transport of Phoenix metropolitan emissions into the WAFB area. The stationary COSPEC results suggest a higher relative concentration "bubble" of NO\textsubscript{2} to the northwest of WAFB toward the Phoenix area. A peak concentration has not been computed. This bubble peak was ~30 ppmM at 2° elevation north-northwest of WAFB. A detailed report on the study is available in the EMI report, "Moving Laboratory Survey at Williams Air Force Base," [24].

GAS-FILTERED CORRELATION SPECTROMETER STUDY

Three nondispersive infrared instruments were used at WAFB for long- and short-path remote sensing measurements [11]. A gas-filtered correlation (GFC) spectrometer depends for its sensitivity on the correlation between the structure in the spectrum of the gas species to be measured and that of the same species in the correlation cell. Generally, the spectral bandpass of the instrument includes several absorption lines so that there will be large fluctuations in transmittance at different wavelengths when the beam traverses
the correlation cell. The most important advantage of the GFC technique over other nondispersive infrared techniques is its ability to discriminate against particulate matter and gas species other than the one being measured.

Peak height and duration of the CO signal from the nondispersion infrared instruments caused by jet plumes depended primarily on ambient WS and WD. The study did not directly yield sufficient information on the plume rise. The velocity of the rise during the short length of time the plume was observed was too small for observations perpendicular to the runway with a single GFC instrument. Response time of the instrument is too slow, and in situ wind velocity determinations are also limiting factors in this development since the higher CO concentration parcel is not present for a sufficient period of time.

SCANNING LASER DOPPLER VELOCIMETER SYSTEM INVESTIGATION

Data from a scanning laser Doppler velocimeter system (SLDVS) were prepared to determine the feasibility of using the system to map the concentration of particulate pollution in the atmosphere around airports in the context of the overall USAF program. The system was operated at Kennedy International Airport from September 1974 through May 1975 for the purpose of detecting and tracking aircraft wake vortices during landings on runway 31R. Since the system measures laser radiation backscattered by particles in the atmosphere, it was postulated that the data from the system could be used to determine the concentration of these particles. The data consisted of tape recordings of digitized spectra along with time and spatial coordinates. In this investigation, the total signal was plotted as a function of vertical and horizontal position during the time required for the system to make a single scan through a vertical plane perpendicular to the end of runway 31R. Approximately 450 such vertical signal profiles were prepared from data taken during 50 landings on five separate days in the spring of 1975.

A preliminary analysis of the data was performed to determine the relationship between signal and atmospheric backscatter coefficients and to evaluate the general quality of the resulting data. This data analysis indicated that the system was successful in measuring changes in returned signal strength, based on the repeatability of data from scan to scan.

In summary, the principle of using an SLDVS for airport pollution monitoring of atmospheric backscatter coefficient appears to be feasible. A reasonable amount of data was obtained and processed with the system at Kennedy International Airport. To obtain data of value to the WAFB project, however, further extensive development of an optimum system configuration specific to dispersion particle size at WAFB would have to occur. A complete report of this study, including vertical scans has been prepared by Raytheon Company [25].
APPENDIX C
MEASUREMENT PRINCIPLES AND PERFORMANCE SPECIFICATIONS FOR WAFB ANALYZERS

This appendix provides the principle of measurement and the performance specifications for CO, NMHC, and NOx specified for the two multicomponent analyzers used at Williams AFB. It also presents a brief narrative of the sampling procedure to obtain scattering coefficient measurements with the integrating nephelometer and to record wind speed and direction measurements.

Section 4 of this report presented the standard deviation of calibration of the air quality analyzers used at Williams AFB. Sections 2 and 3 described the preliminary study used in part to select the sampling and analytical procedures for CO, HC corrected for methane (as methane), and oxides of nitrogen (NOx); the study was also used to designate performance specifications. However, to assess the actual instrument performance, the current practice and experience of other investigators are presented. These are provided to allow the reader to compare the demonstrated performance at Williams to that normally expected as a result of experience developed since mid-1976, when the two methods were published in the Federal Register.

The following discussions first present the general characteristics of the analytical methods selected for use at WAFB. Where possible, the precision and accuracy obtained by other investigators are provided. The application of sampling and analytical procedures for monitoring operations in the field usually results in two levels of performance: 1) the anticipated performance specified during procurement and monitoring operations; and 2) the actual performance achieved using current technology to calibrate the method under actual field conditions.

The technology of air quality measurement systems has evolved since 1973. The measurement systems employed at WAFB were tested in 1975 and purchased early in 1976. The measurement of emissions at WAFB included emphasis on nonmethane hydrocarbons (NMHC) or, more precisely, total hydrocarbons corrected for methane and measured as methane. No assumptions are made regarding the instrumental response to hydrocarbons or substances other than methane. Carbon monoxide was also measured using the same instrumental configuration. After conversion to methane, it was measured as methane. The calibration required to permit the determination of NOx concentrations from an analyzer that measured NO and NOx was not specified until December 1976, after monitoring operations of air quality had begun in June 1976.

Current accepted procedures for measuring the performance of automated air quality measurement methods are well documented, and they provide a mechanism
for arriving at the relative precision and accuracy of the analyzers. Instrumental precision (over the full range of measurement) is normally determined by performing calibrations at multiple concentration levels throughout the range. Independent audits of performance are also used to develop accuracy statements, as in the case of State and local monitoring programs. Calibration at several different concentration levels and independent audits of the calibration process were not performed at WAFB. Calibration records were utilized in order to assign precision uncertainty to the data for the WAFB analyzers. Calibration traceability to acceptable standards was also utilized to provide further information about the measurement accuracy of the data collected at WAFB.

Performance specifications for the air quality and meteorology analyzers used at WAFB were determined by EMSL-LV and are representative of commercial instrumentation available in 1975. These specifications are presented so that study analysts can evaluate the data collection process in terms of expected instrumental precision and accuracy. An analysis of the measurement precision and accuracy limits obtained in the field is presented in Subsection 4.3.

**SAMPLING AND ANALYTICAL PROCEDURE FOR CO, CH₄, AND TOTAL HYDROCARBON - BECKMAN MODEL 6800 GAS CHROMATOGRAPH**

**Principle**

Measured volumes of ambient air are delivered 4 to 12 times per hour to a gas chromatographic column where HC, CO₂, and H₂O are separated from CH₄ and CO. Methane is transferred and measured in a hydrogen flame ionization detector. Carbon monoxide is eluted to a catalytic reduction tube and reduced to CH₄ before passing through the flame ionization detector. Hydrocarbons are transferred quantitatively to the detector, and NMHC is determined by subtracting the CH₄ from the total hydrocarbon (THC) value [31].

**Application**

The method is applicable in its most sensitive range to semicontinuous measurement of THC, CH₄, and CO in ambient atmospheres over the range 0.050-0.2 ppm for THC, 0.050-1 ppm for CO, and 0.050-2.0 ppm for CH₄ [32] (ASTM Book of Standards, 1978, Part 26, D3416-78). The range can be extended to higher concentrations.

**Calibration**

Calibration gases of 5 percent, 15 percent, 40 percent, and 80 percent of full-scale concentration range are used to determine linearity of the Flame ionization detector response to each component. The calibration gases consist of two component mixtures of CH₄ and CO and are used for all three components analyzed, since each constituent is determined as CH₄.
Precision

Precision of repeated measurements of calibration gases is \( \pm 0.5 \) percent of full-scale at higher concentrations (10 ppm). At lower concentrations, precision of repeated measurements is 2 percent of full-scale. However, NMHC measurements can vary 0.322 ppm on the average, and standard deviation between different instruments can range from 0.217 to 0.454 ppm [33].

Accuracy

Accuracy is conditional on the purity of zero air and calibration standards. Performance audits using standard materials supplied by EPA have demonstrated that CO measurements by the flame ionization detector over a range of 3.43 ppm to a nominal 40.6 ppm produced an average difference of 2.3 percent [34].

Performance Specifications

- Automatic analysis 12 times per hour
- Range selection from 1 to 10 ppm full scale
- Precision of the greater of \( \pm 0.5 \) percent of full scale or 0.05 ppm
- Linearity of \( \pm 1 \) percent of full scale
- Compensated zero drift that is automatically adjusted during each 5-minute analysis cycle
- Output of 0 to 5 Vdc

The Beckman instruments, after installation in the remote stations, were factory serviced and checked for proper operation by Beckman service engineers. An orientation course was held for USAF and contractor monitoring operation personnel.

SAMPLING AND ANALYTICAL PROCEDURE FOR MEASURING NO AND NO\(_x\) BY CHEMILUMINESCEENCE - MONITOR LABS MODEL 8440 ANALYZER

Principle

The chemiluminescence procedure for measuring NO\(_2\) employs gas phase reactions of NO and O\(_3\) to form NO\(_2\) and light. Detection of NO\(_x\) (NO + NO\(_2\)) requires conversion of NO\(_2\) to NO since it is directly proportional to NO in the presence of excess O\(_3\). In most cases, NO\(_2\)-to NO converters are capable of quantitative conversion for long periods before needing maintenance [35].
Application

This principle is an EPA Federal Reference Method and has application in ambient and automated monitoring networks ranging from 0.005 to 1 ppm giving a linear response over these concentrations.

Sampling

The chemiluminescence instruments sample continuously and have a rapid response (less than 2 seconds). NOx and NO measurements produce NO2 measurements by difference in data processing.

Calibration

Gas phase titration is recommended for concentrations ranging from 0 to 1 ppm. Calibration should be done on a monthly basis coinciding with converter (NO2 to NO) efficiency checks. Instrumentation may be calibrated with NO2 either from gas phase titration of NO with O3 or from an NO2 permeation device.

Precision

Zero and span checks are required weekly, at a minimum, to determine precision within current guidelines [36]. The weekly span check should provide NO2 concentrations between 0.08 and 0.1 ppm with a control limit of ± 0.025 ppm.

Accuracy

Accuracy is affected by small interferences from NH3 and other compounds that convert to NO or decompose to NO in the sample converter. The NH3 interference is eliminated by operating the converter at a temperature of less than 400°C. Accuracy data are acquired with quarterly performance audits using different standards and equipment to provide test atmospheres. Permeation tube and gas phase titration calibration should show agreement within ± 5 percent [37, 38].

Performance Specifications

- Detection limit of 2 ppb for NO, NOx, and NO2
- Span stability of less than ± 1 percent per day from all sources, with instrument ± 5°C from calibration temperature and less than ± 2 percent span drift per 14 days with instrument ± 5°C from calibration temperature
- A maximum temperature span coefficient of 0.2 percent per degree Celsius over the range 25°C ± 20°C
- Zero instability of less than 0.1 percent full scale per month, ± 3°C from set temperature 0.025 percent per degree Celsius
- Lag time less than 3 seconds from a step change at the input
- Repeatability of ± 1 percent for NO and NOx output
- Operating temperature of 0°C to 50°C
- Measuring ranges of 0.05 ppm, 0.1 ppm, 0.5 ppm, 1 ppm, and 5 ppm full scale (0.5 ppm range used at WAFB)
- Response time of 1.0 second, 5 seconds, 20 seconds, and 1 minute nominal, switch selectable. (These are the time lags for the instrument to reach 63.5 percent of a constant input concentration.)

SAMPLING AND ANALYSIS PROCEDURE FOR MEASUREMENT OF SCATTERING COEFFICIENT
WITH THE INTEGRATING NEPHELOMETER—METEOROLOGY RESEARCH, INC., MODEL 1550B

Principle

An air sample drawn continuously through the instrument at a rate of about 1.4 x 10⁻³ m³/min is periodically illuminated by a xenon flashlamp, and the amount of light scattered by the aerosol is measured by a photomultiplier detector. The geometric configuration of the integrating nephelometer is such that the instrument integrates the scattering over a range of angles from 90° to 170°, measuring the approximate extinction coefficient as a result of scattering, \( b_{scat} \).

Application

The integrating nephelometer will measure the scattering coefficient, \( b_{scat} \), for most normal ambient atmospheric aerosols. Exceptions are those aerosols composed primarily of large particles—for example, very wet fogs and large particles and dark-colored particles. Research has shown that there is a good correlation between the scattering coefficient and the mass concentration of particulates in the ambient atmosphere, when the instrument is calibrated for this application [39]. The MRI integrating nephelometer can be used to measure scattering coefficients over the range of 0.1 x 10⁻⁴ m⁻¹ to 100 x 10⁻⁴ m⁻¹. The scattering coefficient for particle-free air is 0.23 x 10⁻⁴ m⁻¹ at sea level (at the effective wavelength of the instrument), and it decreases with altitude. Efficiency of sampling systems is typically 90 percent and the range of the instrument is approximately the scattering produced by ambient aerosol concentration of 0 to 3800 µg/m³.

Interferences in mass measurement are those of gases and, if dry aerosol mass is of interest, of moisture on the particles and size distribution. If the scattering solely from the atmospheric aerosol is desired, then the contribution from gases must be removed. Scattering coefficient of clean air at sea level is 0.23 x 10⁻⁴ m⁻¹, which may be subtracted from the overall scattering coefficient to arrive at the aerosol contribution. The effect of other gases in the ambient atmosphere is negligible. The maximum zero drift to be expected over a period of several days corresponds to a change in scattering coefficient of about 0.1 x 10⁻⁴ m⁻¹, i.e., less than 1 to 2
percent of a typical urban aerosol reading and less than 10 to 20 percent of the readings encountered in clean desert air. The gain drift over the same period of time is less than 3 percent of a reading.

Calibration

Calibration of the integrating nephelometer is normally accomplished using filtered cylinder air for zero input and a known flow of Freon 12 for span input. The instrument response is then set to correspond to these inputs, both of whose scattering coefficients are known and predetermined. In addition, the linearity of the instrument response may be checked using internal electronic circuitry.

Precision

The root mean square precision of the integrating nephelometer in actual use is between 3 and 4 percent of the reading of scattering coefficient for the normal ambient atmospheric conditions. A slight decrease in precision may occur for readings in extremely clear air, with the exact degree depending on the care exercised in calibration of the instrument. The precision in visibility and mass concentration is the same as that for the scattering coefficient [40].

Accuracy

The accuracy of the integrating nephelometer is better than ± 10 percent of reading of scattering coefficient for the normal ambient atmospheric aerosol, based on theoretical computation of the scattering and actual experience with the linearity of the instrument. The accuracy is expected to be somewhat poorer for aerosols composed primarily of large particles or droplets (e.g., dust storms, fogs) with a maximum expected error of 35 percent.

Performance Specifications

- Scattering coefficient \( (b_{scat}) \) of 0 to \( 10 \times 10^{-4} \text{m}^{-1} \) or a local visual distance of infinity to 1.6 km or a mass concentration (approximately) of 0 to 380.0 \( \mu \text{g/m}^3 \)
- System accuracy of ± 10 percent of full scale for \( b_{scat} \) and local visual distance
- Output of 0 to 5 volts (V) full scale, which was later changed to 0 to 4 V full scale

WIND SPEED AND DIRECTION SENSORS - R.M. YOUNG GILL PROPELLER VANES

Principle

An integrated sensor unit is mounted on a vertical support above any surrounding obstructions (vegetation, buildings, terrain). A rotating
propeller responds to wind movement, and a directional vane rotates to respond to the prevailing wind direction. Wind speed is recorded by measuring the revolutions per minute (rpm) of the propeller assembly and wind direction is measured as an angular deflection of the vane assembly away from a preset reference point (corresponding to true north at the site location).

**Calibration**

The wind-speed cup assembly is calibrated by connecting a known-rpm electric motor assembly to the propeller shaft and adjusting the rpm output to correspond to the standard motor. The wind direction vane assembly is calibrated by setting the true north (zero deflection) reference line either visually with a theodolite or by comparison to a magnetic compass reading (as corrected for geographical declination).

**Precision**

The R.M. Young assembly is capable of measuring wind speeds to within $\pm 0.05$ m/s above the threshold of $0.25$ m/s.

**Performance Specifications**

- Threshold of $0.25$ m/s
- Range of $0$ to $40$ m/s
- Output of $0$ to $4$ Vdc for WS
- Distance constant of one revolution for propeller vane per $30$ cm of air flow (The distance that air flows past the propeller while the propeller responds to 63.2 percent of a step increase or decrease in wind speed.)
- Range in WD of $0$ to $352$ degrees (8 degree deadband from $352$ degrees to $360$ degrees) in the deadband, voltages greater than full scale are rejected by the computer editing programs.
- Potentiometer linearity of $0.25$ percent for WS output reading
- Output of $0$ to $3.52$ Vdc for WD

**ACCESSORY EQUIPMENT FOR EACH STATION**

- Elhygen Mark IV hydrogen generator used to supply hydrogen ($H_2$) gas to the Beckman Model 6800 gas chromatograph. (Considerable problems were encountered in the use of this instrument; subsequently bottled $H_2$ was used.)
- Sola Electric constant voltage transformer of the harmonic neutralized type to protect the equipment against power fluctuations and transients
Heat/cool airconditioner capable of maintaining the internal temperature of the monitoring stations to \( \pm 2^\circ\text{C} \) of a present value.

Standard air-sampling glass manifolds of nominal 2.5-cm diameter with moisture and particulate traps, including glass ballast volume for Beckman 6800 gas chromatograph to provide a sample air residence time (ratio of volume to flow rate) of approximately seven times the interrogation rate of the data acquisition system.

STATION ENCLOSURE SPECIFICATIONS

Air quality trailer station enclosures (Westinghouse model 66204-70 or equivalent), were used as shown in Figure C-1.

Figure C-1. Interior floor plan of air quality monitoring trailer.

- Length 4-4.5 m, 5-5.9 m with tongue
- Width 2.4 m, height 2.4 m from ground to roof
- Steel underframe
- Wood or metal body
- Sheet aluminum exterior; prepainted outside aluminum at least 0.48 mm thick, minimum 6 mm plywood backing or equivalent
- Running gear: 2 axles, for 1362 kg payload
- Hitch weight: not greater than 363 kg or less than 181 kg
- Forward frame extension crank handle adjustment for leveling independent braking system; electric brakes on one axle; and breakaway safety system
- Body watertight, entry door sealed against weather
- Insulation: fiberglass and vapor barrier, floor and wall 7.6 cm, ceiling 15 cm
- Subfloor: exterior grade plywood 1.9 cm thick with protective covering of erosion-resistant sheet steel on underside
- Interior floor: vinyl asbestos tile or sheet 2.3 mm thick, residential grade
- Interior wall: finished plywood paneling
- Ceiling: 1.27 cm acoustical tile, white, textured, residential grade
- Leveling pad and jack at each corner of frame
- Entry door with panic bar, width 91 cm, height 7 m
- Roof cover: nonreflective, nonskid coating
- Roof structure: capable of supporting 726 kg, toe plate, ladder: 2.5 cm steel, 35.6 cm wide, 40.6 cm between rung, offset 19 cm from the back of trailer; roof railing: height 1 m
- Inside heating and cooling thermostat - residential type
- Two wall cabinets, height 76 cm, width 68 cm, depth 32 cm
- Counter top, length 1.85 m, depth 61 cm, composition: Formica on 1.8 cm plywood
- Two base cabinets mounted on floor, height, 86.4 cm, width 83.8 cm, depth 61.1 cm
- Gas bottle compartments capable of holding four gas T-size cylinders, double doors or single swing-up door to outside to replace cylinders
- **Power:** 150 amperes (A), 115/230 V, single phase, 60 hertz (Hz)
- **Heating and lighting:** all electric equipment to operate at 115/230 Vac
- **Circuit-breaker panel design for underground hookup and provisions for 11 circuits**
- **Main switch provided to disconnect power to everything**
- **Three conductor wires throughout**
- **Six interior duplex outlets**
- **Three exterior all-weather 120-V duplex outlets -- 2 on roof and 1 on road side wall**
- **Interior lights:** 1.22-m double flush-mounted fluorescent lights
- **Air-conditioner/heater:** 23,000 Britich thermal unit (Btu) cooling, 13.5 kilowatt (KW) heating
APPENDIX D

CALIBRATION PROCEDURES FOR AIR QUALITY MONITORING INSTRUMENTATION

The instrument performance results presented in Section 4 were derived from calibration and daily calibration check data recorded continuously during the field monitoring period. This appendix presents the procedures utilized at WAFB for station calibration. These procedures are a vital link between the measured data set and the analyses presented in Section 5 with respect to impact assessment and rational air quality standards.

BECKMAN 6800 AIR QUALITY GAS CHROMATOGRAPH

The Beckman gas chromatograph utilizes the principle of flame ionization detection for continuous measurement of volatile organic materials in the atmosphere. The principle of operation is the differentiated production of a relative number of ions in both a pure hydrogen flame and a flame containing hydrocarbon molecules. The sensing device unit contains a gas-mixing chamber and burner, an igniter and polarizing electrode, and an ion collector and vent. Positively charged carbon atoms (ions) produced in the flame are drawn to the negatively charged collector where the charge is neutralized by electrons produced in a high-impedance amplifier.

Through calibration using known hydrocarbon type, physical alignment of the detector, the maintenance of carefully controlled combustion conditions, the number of electrons produced in the process will generate a voltage proportional to the number of carbon atoms present. Relative response for various organic compounds has been correlated by numerous investigators [17]:

<table>
<thead>
<tr>
<th>Organic Class</th>
<th>Effective Carbon Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aliphatic carbon atom</td>
<td>1.0</td>
</tr>
<tr>
<td>Aromatic carbon atom</td>
<td>1.1</td>
</tr>
<tr>
<td>Olefinic carbon atom</td>
<td>1.2</td>
</tr>
<tr>
<td>Acetylenic carbon atom</td>
<td>1.4</td>
</tr>
<tr>
<td>Carbonyl carbon atom</td>
<td>0.0</td>
</tr>
</tbody>
</table>

This principle of measurement was selected because of the ease of operation over wide concentration ranges, the automatic zeroing feature, the relative insensitivity of the system to air and water vapor, and the ability
for subtraction to compute NMHC concentrations for use in data processing. There are several possible disadvantages to this type of pollutant sensor: the background electronic noise must be below the minimum carbon atom signal level at the lower end of amplitude range of approximately $10^5$ to 1; the analyzer requires a skilled operator; the analyzer lacks total specificity in the absence of a means to separate individual constituents; and calibration to obtain uncertainty limits for hydrocarbon compounds (THC) is very difficult.

The air quality chromatograph provides voltage signals for CO, CH$_4$, and THC using two separate output signals. One is a 0-10 millivolt (mV) recorder output from the flame ionization detector used for programming and troubleshooting the instrument. The second output signal is from each component monitored and goes to three separate 0-5 V memory outputs, which store and hold peak voltage until it is updated after each component analysis is completed. The three memory outputs (CO, CH$_4$, and THC) were used for data acquisition in normal operation at WAFB.

The calibration procedure was the same for the recorder and memory output voltage, each being adjusted with a separate attenuator located on the individual component cards, as recommended in the Beckman Instruction Manual, 614-082181-B.

Calibration was begun when the chromatograph had been started according to the recommended startup procedure. Calibration ranges of operation were selected according to the following:

- THC (as methane) was calibrated on range 2 between 2 and 20 ppm. Range 3 increased full-scale range by a factor of 10.
- CH$_4$ and CO were calibrated on full-scale range, variable between 1.2 and 12 ppm. Ranges 2 and 3 multiplied range factors by 10.

To start the calibration, the following switches (see Instruction Manual) were checked for function:

- Manual/Auto, in Auto position
- Calibrate/Operate, in Operate position
- Manual Att/Auto Att, in Auto Att position
- Single/Continuous, in Continuous position
- Start, off
- Reset, off
- Flame Out Override, off
- Auto Zero, off
- Calibration Standard, off

D-2
Flow rate at the sample vent was measured with a flowmeter capable of measuring flows in the range of 150 cm$^3$/min. This value was recorded for future reference. At any point that tests were not acceptable, the procedure was discontinued and corrective action was implemented. Calibration then proceeded through the following steps.

The electronic zero for each component was checked with the Single/Continuous switch in the Single position and watched for the reset light to come on, indicating the end of a complete cycle. The Manual/Auto switch was then placed in Manual position. The Start switch was activated momentarily, and Auto Zero switch was then turned on. The next sequence of the test involved component cards for CO, CH$_4$, and THC located in the lower drawer of the gas chromatograph. A digital voltmeter was connected to the memory test point of the component card to be checked, and the Manual/Auto switch was placed in Manual position. The output signal was adjusted to zero with the zero attenuator, if indicated. The Manual/Auto switch for that card was then placed in Auto position. This procedure was repeated for the remaining two component cards. After all three cards were tested or adjusted, the Auto Zero switch was placed in the Off position, and the gas chromatograph returned to the reset condition.

Ultrapure air was next introduced into the calibration inlet, and the following switches were set:

- Manual/Auto to the Auto position
- Single/Continuous to the Continuous position
- Standard Calibration to On

Flow was measured at the sample vent, compared to the value recorded prior to step 1 above, and adjusted with the regulator on an ultrapure air bottle.

The gas chromatograph was operated in automatic mode for two or more complete cycles, followed by tests on the memory outputs of all three component cards. Ultrapure air was then removed from the calibration inlet. The ultrapure air response was required to be within 1 percent of the electronic zero or calibration was discontinued.

The calibration gas was connected and flow at the sample vent was measured and adjusted as in step 2 above. The gas chromatograph was operated on calibration gas for two or more complete cycles (10 minutes). Memory outputs were monitored for the next three cycles. If tests were repeatable to within 1 percent of full scale, the instrument was then calibrated with span gas.
By placing the Single/Continuous switch in the Single position and waiting for the reset light to come on, indicating the end of a cycle, automatic cycling was stopped. Signal outputs for the three components were measured and recorded for the cycle just completed. The gas chromatograph was then placed in the span calibration mode by setting the front panel switches as follows:

- Manual/Auto, to Manual position
- Calibrate/Operate, to Calibrate position
- Manual Att/Auto Att, to Auto Att position
- Manual Range, to 10 position

Signal outputs were turned on by momentarily actuating the Start switch. For the component to be calibrated, the Manual/Auto switch at the top of that component card was placed in the Manual position. The calibration control on the front panel was then adjusted to compare with the signal voltage for that component.

Using known concentrations of the calibration gas, measured signal output, and full-scale signal output, the new full-scale range was calculated with the following formula:

$$\text{new full-scale range (ppm)} = \left( \frac{\text{full-scale signal (V)}}{\text{signal measured for cal gas (V)}} \right) \times \text{cal gas (ppm)}$$

Voltage of the signal output required to produce the full-scale range was calculated by:

$$\text{signal out (V)} = \left( \frac{\text{cal gas (ppm)}}{\text{desired full scale (ppm)}} \right) \times \text{(full scale voltage signal)}$$

Signal output voltage was then obtained by adjusting the respective recorder or memory attenuator, located on the component card. The component card Manual/Auto switch was then switched to the Auto position.

This procedure was repeated for the remaining two components and the gas chromatograph was placed in automatic mode, setting the front panel switches in the following positions:

- Calibrate/Operate switch to Operate
- Manual/Auto switch to Auto

ML MODEL 8440 NO−NOx ANALYZER

Procedures utilizing dilution atmospheres and cylinders of known concentration were used for the span calibration of NO/NOx. Dilution of a
gas cylinder containing 50 to 100 ppm nitric oxide with a dynamic dilution system to the calibration level of about 0.4 ppm required precise regulation of gas flow and a source of ultrapure air for the dilution gas. Flow control was maintained by a Bendix Model 8852 Dynamic Calibration System. Ultrapure air was supplied by an AADCO pure air generator with a Gast Teflon-ringed compressor. Calibration gas was also introduced directly into the instrument from low concentration cylinders of NO in nitrogen and NO₂ in air.

The ML 8440 measured NO and NOₓ, and each output had to be calibrated separately for zero and span. The difference may be calibrated to read as NO₂; however, NO₂ is not measured directly by the instrument.

Several hours of operation were allowed to stabilize the electronics and reduce the reaction chamber's background illumination to manufacturers' specifications. The background illumination must be less than an equivalent output of 20 ppb of NO, determined by taking the difference of the instrument output with the ozone generator turned on and off, while the instrument is sampling ultrapure air. After this test was completed, the ozone generator was returned to the On position.

The operator then selected the appropriate full-scale calibration range with the five-position, front-panel range switches for NO and NOₓ. Although the outputs were independent, the same range had to be used for each. A range was normally selected so that the span gas concentration would be close to 75 percent of full scale for routine calibrations. The standard range selected was 0.5 ppm.

The operator then selected the desired level of signal averaging with the resistance-capacitance time-constant front-panel switches. Time constants were selectable for 1, 5, 20, and 60 seconds. These were the times required for the signal output voltage to reach 63.5 percent of full-scale concentration. Normally the 60-second time constant was selected since it provided the most stable response for calibration.

After range and time-constant selection had been completed, ultrapure air was introduced into the sample inlet connection. A T in the sample inlet line was provided, with one branch connected to a flowmeter and the input flow adjusted until there was an excess flow of ultrapure air. The inlet gas flow could not be so great that a significant positive pressure developed in the analyzer.

The instrument was allowed to stabilize for 5 to 10 minutes while sampling ultrapure air. The zero attenuators for NO and NOₓ were adjusted until the output signal read zero volts. Five minutes were allowed after each adjustment for the instrument to stabilize at the new settings. The final zero voltages and attenuator settings were recorded.

The sample inlet was then removed from ultrapure air and connected to a calibration gas with a certified value. The excess flow was reestablished with the flowmeter and adjusted to approximately the same level as was used for ultrapure air. A period of 5 to 10 minutes was required for the instrument to stabilize on the span gas concentration. The span attenuators
for NO and NO\textsubscript{x} were adjusted to produce the proper calibration voltage. This voltage was determined using the following formula:

\[
\text{adjusted calibration voltage} = \frac{\text{span gas concentration (ppm)}}{\text{full-scale range (ppm)}} \times \text{full-scale volts}
\]

After each attenuator adjustment, 5 minutes were allowed for the instrument to stabilize at the new value. After the final adjustments had been made, the adjusted calibration voltages and the span attenuator settings were recorded.

The sample inlet was disconnected from span gas and the ambient air was then connected to the manifold. Five minutes were allowed for the instrument to start reading ambient air concentrations.

**MRI MODEL 1550B INTEGRATING NEPHELOMETER CALIBRATION**

Calibration of the MRI Model 1550B integrating nephelometer consisted of introducing two gases (pure air and Freon 12) with known scattering coefficients, \(b_{\text{scat}}\), into the optical measuring assembly. The instrument response for each gas was adjusted to read the value of \(b_{\text{scat}}\) for that gas. With two points of the nephelometer scale set, the instrument was fully calibrated, assuming that the output is linear in units of scattering coefficient.

To verify the full-scale response of the instrument at a later date without having to inject the Freon 12 calibration gas, a check of the electronic response to a constant light source directed toward the nephelometer phototube receptor was made at the time of the full calibration. The specific instrument response to this test was noted and was used as a check point for instrument span during subsequent checks of calibration.

Before calibration, the instrument was properly set up as stated in the instruction manual. The instrument was placed on line for at least one hour for stabilization before calibration, during which time it was operated in the following mode to establish the pure air set point:

- **Data system switch** for channel 8 in position 9 (inoperative)
- **Range switch** on front panel of electronic unit in position A/C
- **Function switch** in the pure air position
- **Air intake and exhaust hoses** on the optical assembly disconnected and the intake tube plugged with Kimwipes, soft cloth, or other flexible and porous material, and outlet pipe plugged with a rubber stopper
- **Clean, filtered air from blower unit flowing into assembly**
If the instrument was previously operating in the sampling mode continuously for more than one hour, only 20 minutes were required for the clean air to purge the optical assembly so that the pure air set point could be established.

After the stabilization period, the background potentiometer was adjusted until the scattering coefficient read $0.23 \times 10^{-4} \text{m}^{-1}$, thereby setting the first point on the nephelometer readout scale.

The clean air line was then removed from the blower unit and connected to a can of Freon 12 equipped with a valve, a slow restrictor, and a filter assembly. The valve was opened and Freon 12 introduced into the optical assembly until the output was stable for 5 minutes. If the nephelometer readout value was the desired theoretical value of $3.6 \times 10^{-4} \text{m}^{-1}$, the data switch for Channel 8 was moved to Position 3 and left for 5 minutes while the data system polled 5 times. If the readout was not $3.6 \times 10^{-4} \text{m}^{-1}$, but was within $0.2 \times 10^{-4} \text{m}^{-1}$ of that value, an adjustment was performed using the gain potentiometer on the front panel prior to switching for data system polling. If an adjustment of more than $0.2 \times 10^{-4} \text{m}^{-1}$ was required, the adjustment was made with the gain potentiometer as before; however, the output was not polled by the data system since this misalignment indicated a possible improper setting of the pure air data point. In this case, the pure air data point was rechecked prior to establishing the Freon 12 data point.

After the Freon 12 point was set and recorded by the data system, Channel 8 was switched to Position 9. Pure air was then again used to purge the optical chamber, and the instrument reading, $0.23 \times 10^{-4} \text{m}^{-1}$ was polled five times by the data system by setting the Channel 8 switch to Position 2 (adjusted pure air) for 5 minutes. Channel 8 was then switched to Position 9 (inoperative). The two calibration points were thereby established.

The final requirement of calibration was to establish a value of cal check response. To do this the optical assembly was prepared for pure air as was described previously, and a 20-minute purge time was allowed. The function switch was then rotated to the cal check position. Five additional minutes were allowed for the cal check value to be reached. Channel 8 was then switched to Position 4 (adjusted cal check) and 5 minutes were allowed for data system polling. The Channel 8 switch was then returned to Position 9 (inoperative) and the instrument calibration was complete.

The instrument was then prepared for routine monitoring by first removing the material from the intake tube and the rubber plug from the exhaust tube. The intake and exhaust hoses were then reconnected. The function switch was moved to the run position and the desired scale was selected with the scale-selector switch. A period of five minutes was allowed for the instrument to stabilize on ambient air. The channel 8 switch was then set in position 0 (range 1) or position 1 (range 2). The corresponding scale settings on the nephelometer are A/C for range 1 and B/D for range 2.
DAILY TRAILER INSPECTION, ZERO AND SPAN CHECKS, AND STATION CALIBRATION ADJUSTMENTS

Daily trailer inspection, zero and span calibrations, and station calibration adjustments, performed in that order, were control procedures continuously performed during the entire monitoring period at WAFB. The performance of these procedures was a check and cross-check of system operations in order to detect unexpected changes in the physical layout of the system or the monitoring routine that could cause loss of data acquisition time, system degradation, or poor quality data.

TRAILER INSPECTION

The first daily procedure utilized the trailer inspection checklist (Figure E-1) to review the monitor station sensors and intake manifold. This daily inspection provided input for decisions on the daily calibration activity that followed.

ZERO AND SPAN CHECKS

The second daily procedure, zero and span checks on the air monitoring instruments at all of the five stations, was performed to provide unadjusted calibration data entered on the data calibration checklist (Figure E-2) and also used to make daily adjusted calibrations to predetermined values at one station per day. These data could later be used for a conversion of voltages to concentration (engineering) units, for correcting data to account for zero and span fluctuations, and to construct control charts that were analyzed to evaluate instrument performance on a continuing basis. The order in which the five stations were checked was altered daily to avoid any bias to the collection of the data. The zero and span calibration was normally carried out by AF personnel through the following procedures: First, all the data switches except wind velocity were changed to position 9 (inoperative code). The instruments were then ready to be checked individually. The wind azimuth was placed in the zero calibrate position and the data switch for channel 7 was changed to position 4 (unadjusted zero check). The monitoring screen on the remote data logger was observed while the central data system polled five times. During each poll, the value for channel 7 was recorded on a calibration checksheet while the central system recorded the same value on magnetic tape. The wind azimuth was then switched to the span calibrate position. The wind azimuth calibrations were electronic or instrumental. The data switch for channel 7 was set to position 5 (unadjusted calibrate check).
Before entering the trailer, the following should be checked:

1. Air sampling cane. OK ____ Other ____ (explain reverse side)
2. Nephelometer air intake. OK ____ Other ____ (explain reverse side)
3. Is propellor and vane responding? YES ____ NO ____
4. Any noted physical damage to outside of trailer or exposed equipment? (If yes, explain reverse side) YES ____ NO ____
5. Check clean air system for the GC. OK ____ HOT ____ NOISY ____
6. Is trailer blocking and tie down all right? YES ____ NO ____

The rest of the checks are inside the trailer.

1. Is air conditioner running? YES ____ NO ____
2. Does the roof leak in inclement weather? YES ____ NO ____
3. Check air sampling manifold for connections. OK ____ OTHER ____ (explain reverse side)
4. Check air sample pump. OK ____ OTHER ____ (explain reverse side)
5. Check Nephelometer pump. OK ____ OTHER ____ (explain reverse side)
   a. Pressure Gauges - Hydrogen fuel
      Burner air
      Air carrier
      Service air
      Hydrogen carrier
   b. Check service air water trap (back of instrument) for moisture.
   c. Memory outputs - 1. ____
      2. ____
      3. ____
   d. Auto zero background reading. ____
   e. Oven light flashing? YES ____ NO ____
   f. Catalytic converter light on? YES ____ NO ____
   a. Is power light on? YES ____ NO ____
   b. Is generate light going on and off? YES ____ NO ____
   c. Is low water light on? YES ____ NO ____
   d. Output pressure. ____
   e. Reservoir water level. ____
   a. Is power on? YES ____ NO ____
   b. Mode switch position. ____
   c. Scale range. ____
   d. Is blue flasher light working? YES ____ NO ____
   e. Meter reading. ____

Figure E-1. Trailer inspection checklist.
9. Monitor Labs 8440
   a. Inches of drierite left (approximately)? __________
   b. Is power on? YES _____ NO _____
   c. Meter reading for NO. __________
   d. Meter reading for NO. __________
   e. NO flow meter reading. __________
   f. NO flow meter reading. __________
   g. Ozone flow meter reading. __________
   h. Vacuum reading. __________
   i. Range NO. __________
   j. Range NO. __________
   k. Time constant NO. __________
   l. Time constant NO. __________
   m. Function switch setting. __________

10. Wind Speed and Direction
    a. Is power on? YES _____ NO _____
    b. Are meters reading on scale? YES _____ NO _____
    c. Are meters responding to changes? YES _____ NO _____

11. Data System
    a. Is power on? YES _____ NO _____
    b. The station is polled every minute. Observe one cycle. Did
       channels (00 to 16) and data appear in the readout?
       YES _____ NO _____
    c. Does the trailer have a flashlight? YES _____ NO _____
    d. Is there a spare set of batteries? YES _____ NO _____
    e. Is there a pen available? YES _____ NO _____

12. Number of feet of paper left on strip chart recorder 0815 run only.

13. Remove used strip chart recorder paper on 1600 run only.

14. Special checks to be made:

Completed time _______ Date _______ Initials _______

Figure E-1 (continued).

E-3
DATA SWITCHES ON ENTRY

<table>
<thead>
<tr>
<th>Time</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

**I. WIND AZIMUTH**
- Unadjusted zero (4)
  1. 
  2. 
  3. 
  4. 
  5. 
- Unadjusted calibrate (5)
  1. 
  2. 
  3. 
  4. 
  5.

**II. NO-NOx**
- Unadjusted pure air (5)
  NOx
  1. 
  2. 
  3. 
  4. 
  5. 
- Unadjusted span (6)
  NOx
  1. 
  2. 
  3. 
  4. 
  5.

**III. NEPHELOMETER**
- Unadjusted pure air (5)
  1. 
  2. 
  3. 
  4. 
  5. 
- Unadjusted calibrate (6)
  1. 
  2. 
  3. 
  4. 
  5.

**IV. G.C.**
- Unadjusted span (4)
  Memory #1
  1. 
  2. 
  3. 
  4. 
  5.
  #2
  1. 
  2. 
  3. 
  4. 
  5.
  #3
  1. 
  2. 
  3. 
  4. 
  5.

DATA SWITCHES ON DEPARTURE

<table>
<thead>
<tr>
<th>Time</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
</table>

Initials
Five values were recorded during five polls. The wind azimuth sensor was returned to normal operation and channel 7 was returned to position 0 (normal operation).

The ML 8440 NO-NO$_x$ analyzer was connected to ultrapure air and allowed to stabilize for 5 to 10 minutes. The data switches for channels 1 and 2 were switched to position 5 (unadjusted pure air). Five readings were recorded on the calibration checksheet while the data system polled five times. Channels 1 and 2 were also returned to position 9 (inoperative). Span gas was introduced into the sample inlet of the instrument. Another 5- to 10-minute stabilization was allowed. The data switches for both channels were either set to position 6 (unadjusted span from the calibration system) or position 7 (unadjusted span from the low concentration cylinders), depending on the particular test atmosphere, while the central data system made five scans of the channels. The channels were returned to position 9, and the sample inlet was reconnected to the sampling manifold. After a 5-minute waiting period, the data switches for channels 1 and 2 were returned to position 1 (i.e., instrument range 3, ambient air).

The MRI nephelometer was switched to pure air and allowed to purge with filtered air for 20 minutes. The data switch for channel 8 was placed in position 5 (unadjusted pure air). The data system was observed to poll five times, and five voltage values were recorded on the calibration checksheets. The data switch for channel 8 was returned to position 9. The nephelometer mode switch was switched to the calibration check position and allowed to stabilize on this value for a simulated span output. The channel 8 data switch was rotated to position 7 (unadjusted calibration check) and five values were recorded for five data system polls. The channel was then set to position 9 while the technician returned the instrument to monitoring ambient air. After the instrument had stabilized, the channel was returned to position 0 (i.e., instrument range 1, ambient air).

The Beckman 6800 gas chromatograph was connected to a test calibration gas and allowed to stabilize for at least two five-minute cycles. Then the data switches for channels 3, 4, and 5 were placed in position 4 (unadjusted span). The data system was allowed to poll the instrument for 25 scans or the time needed by the gas chromatograph for five complete cycles. Since the gas chromatograph values changed only once every 5 minutes, it was required to record one value for every five data system scans for each of the three channels on the calibration checksheet. To verify performance of the gas chromatograph memory circuits, all five values were recorded for the first five polls of the central data system. Data switches for the three channels were then placed in position 9. The instrument was switched to monitoring ambient air and allowed to cycle for 10 to 15 minutes. The data switches were then set for position 1 (i.e., normal operation with averaging bottle residence volume included).

Air Force and contractor personnel recorded all the data from the calibration sheet onto permanent logbooks that remained at the remote station. The positions on all the data switches on the calibration checksheet were also recorded.
WILLIAMS AIR FORCE BASE AIR QUALITY MONITORING STUDY. APPENDICE--ETC(U)
JUL 80 D C SHEESLEY, S J GORDON, M L EHLEST EPA-68-03-2591
EPA/600/4-80-037-APP UNCLASSIFIED
STATION CALIBRATION ADJUSTMENTS

The daily station calibration of one station per day that followed the procedures given in Appendix D was performed by a calibration team of AF and contractor personnel. A station was not calibrated on the same day of each week, and each station was calibrated at least once in every 10 days.

Upon entering a trailer, the calibration team set the data switches on all channels of the remote data system to 9 indicating the trailer had been removed from normal ambient air sampling. The zero and span checks were first performed according to the procedures outlined above. Then adjusted calibrations were completed as follows.

Span gas was first applied to the Beckman 6800, and the instrument was allowed to stabilize. After stabilization, the ML 9400 remote data switches for CH₄, THC, and CO were placed in position 4. Five instantaneous values at 5-minute intervals were recorded automatically by the data system and manually on the calibration sheet. Data switches were then returned to 9 and the Beckman 6800 was adjusted to obtain the required calibration voltage for the desired full-scale operation range. The data switches for CH₄, THC, and CO were then placed in position 3, and five cycles of operation were again recorded to document adjustment on the magnetic tape. The data switches were then returned to 9 and the instrument returned to normal status for sampling ambient air. After stabilization to ambient air was achieved, the data switches were returned to position 1 indicating normal ambient air sampling.

Simultaneous with calibration of the Beckman 6800, calibration was applied to the sample input of the ML 8440 NO/NOₓ instrument allowing it to condition and stabilize. The data switches were then placed in position 5 and five one-minute values were recorded. The data switches were then turned to 9 and a span gas was applied to the ML 8440 sample input. Again the instrument was allowed to stabilize and the data switches were placed in position 7. Five values were recorded after which the data switches were again returned to 9. The above procedure was then repeated with zero and span adjusted to predetermined values and data switches 2 and 4 used rather than 5 and 7, indicating an adjusted zero and span. The sample inlet was then connected to the manifold system, and after stabilization the data switches for NO/NOₓ were instrumentally switched from 9 to 1, indicating an operational system collecting ambient air samples.

Pure air was introduced into the nephelometer and the instrument was allowed to stabilize utilizing the above switch settings. The data switch for the nephelometer was placed in position 5 and five one-minute values were recorded. The instrument was then placed in the calibrate mode and allowed to stabilize. The data switch for the nephelometer was placed in position 7 and five one-minute values were recorded. Pure air was again introduced into the nephelometer, and after stabilization the pure air point was adjusted to the scattering coefficient of pure air. The data switch for the nephelometer was then placed in position 2, and five one-minute values were recorded. Freon was then introduced into the nephelometer, and after stabilization the span was adjusted to the scattering coefficient of Freon. The data switch was placed in position 3, the five values were recorded, and the data switch was
returned to position 9. Again the nephelometer was placed in the calibrate mode and allowed to stabilize. The data switch was placed in position 4, and five one-minute values were recorded to document adjustment, after which the data switch was returned to position 9. The nephelometer was then returned to sampling ambient air and allowed to stabilize. The data switch was finally placed in 0 indicating an operational system.

The calibration values were recorded in logbooks provided for each individual instrument.
The monitoring stations were linked to the central data acquisition system through telephone lines to the ML Model MDM-300L, 700 baud modem, the Model 15C-2 internal system controller, the Model 7000R main frame, and the Model KVS 10-channel input.

The results of normal monitoring operations were relayed to the central data acquisition system by use of the data switches in the remote ML 9400 data link, read in order on the frame from left to right. Data switch (thumbwheel) coding was as follows:

Data Switch 1: NO
0 - Range 2
1 - Range 3
2 - Adjusted pure air
3 - Adjusted span from calibration system
4 - Adjusted span from low-concentration cylinder
5 - Unadjusted pure air
6 - Unadjusted span from calibration system
7 - Unadjusted span from low-concentration cylinders
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative

Data Switch 2: NO
0 - Range 2
1 - Range 3
2 - Adjusted pure air
3 - Adjusted span from calibration system
4 - Adjusted span from low-concentration cylinder
5 - Unadjusted pure air
6 - Unadjusted span from calibration system
7 - Unadjusted span from low-concentration cylinders
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative

Data Switch 3: CH₄
0 - Normal operation without averaging bottle
1 - Normal operation with averaging bottle
2 - Zero air check
3 - Adjusted span
4 - Unadjusted span
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative

Data Switch 4: THC
0 - Normal operation without averaging bottle
1 - Normal operation with averaging bottle
2 - Zero air check
3 - Adjusted span
4 - Unadjusted span
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative
Data Switch 5: CO
0 - Normal operation without averaging bottle
1 - Normal operation with averaging bottle
2 - Zero air check
3 - Adjusted span
4 - Unadjusted span
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative

Data Switch 6: Wind Speed
0 - Normal operation
1 - Adjusted zero
2 - Adjusted span
3 - Unadjusted zero
4 - Unadjusted span
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative

Data Switch 7: Wind Azimuth
0 - Normal operation
1 - Adjusted zero check
2 - Adjusted calibration check
3 - Adjusted 180° calibration check
4 - Unadjusted zero check
5 - Unadjusted calibration check
6 - Unadjusted 180° calibration check
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative
Data Switch 8: Nephelometer

0 - Range 1
1 - Range 2
2 - Adjusted pure air
3 - Adjusted Freon check
4 - Adjusted calibration check
5 - Unadjusted pure air
6 - Unadjusted Freon check
7 - Unadjusted calibration check
8 - Change in operating parameters or conditions to be recorded in the logbook
9 - Inoperative

Data Switch 0: Station number of special functions
APPENDIX G

LISTS OF SECONDARY CALIBRATION GASES AND THEIR LOCATIONS AND DATES OF USE AT WAFB

Air monitoring calibration gases that are relatively nonreactive (CO, CH₄) are available from manufacturers at high levels of concentration. Agreement on concentration among vendors' cylinders has been achieved only recently, partially because these gases were only recently available from the NBS. Availability at lower concentrations is very limited.

Cylinders of gases used to produce test atmospheres for calibration activity were obtained with certified analyses of concentration. Upon receipt of the gases, the vendor analysis was verified by cross-comparison to local gas standards, and the gases were subsequently cross-compared and analyzed at specified intervals to check for changes in concentration. The list of calibration gases, their use at each location, and dates of use are included in this appendix.

A van with a wheeled cart containing the dilution calibration system was used to deliver test and calibration atmospheres at different concentrations for the NO/NOₓ analyzer at each station. The van transported the Bendix Model 8851X Dynamic Calibration System (BDCS), the AADCO Model 737 zero air generator, calibration gas cylinders (NO/NOₓ and CO/CH₄), and compressors with silencer housing from site to site (Figure G-1).

NITRIC OXIDE SECONDARY CALIBRATION GAS STANDARDS USED IN TRAILERS FOR EACH MONITORING STATION CALIBRATION PERIOD

<table>
<thead>
<tr>
<th>ML 8440 Span Concentrations for NO†</th>
<th>Cylinder No.</th>
<th>NO (ppm)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trailer 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 1, 1976, through September 9, 1976</td>
<td>BDCS*</td>
<td></td>
</tr>
<tr>
<td>September 10, 1976, through December 4, 1976</td>
<td>CC1048</td>
<td>0.34</td>
</tr>
<tr>
<td>December 5, 1976, through December 12, 1976</td>
<td>CC1067</td>
<td>0.10</td>
</tr>
<tr>
<td>December 13, 1976, through June 1, 1977</td>
<td>CC1315</td>
<td>0.34</td>
</tr>
<tr>
<td>June 2, 1977, through June 30, 1977</td>
<td>CC1301</td>
<td>0.15</td>
</tr>
</tbody>
</table>

* BDCS on ML 8440 used between 6/1/76 and 9/9/76 to calibrate various gas concentrations based on flow rate. Values for this period using BDCS are presented in the section following this data.

** All stated values are ± 2 percent except as otherwise noted.

† Manufacturer's stated value
Figure G-1. Calibration system for air quality trailers.
### ML 8440 Span Concentrations Using BDCS for June 1, 1976, through September 9, 1976

#### Trailer 2

<table>
<thead>
<tr>
<th>Date Range</th>
<th>BDCS*</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1, 1976, through September 9, 1976</td>
<td>CC1266</td>
<td>0.40</td>
</tr>
<tr>
<td>September 10, 1976, through December 12, 1976</td>
<td>CC1302</td>
<td>0.28</td>
</tr>
<tr>
<td>December 13, 1976, through June 1, 1977</td>
<td>CC1314</td>
<td>0.49</td>
</tr>
<tr>
<td>June 2, 1977, through June 30, 1977</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Trailer 3

<table>
<thead>
<tr>
<th>Date Range</th>
<th>BDCS*</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1, 1976, through September 9, 1976</td>
<td>CC1071</td>
<td>0.33</td>
</tr>
<tr>
<td>September 10, 1976, through December 14, 1976</td>
<td>CC1299</td>
<td>0.29</td>
</tr>
<tr>
<td>December 15, 1976, through April 13, 1977</td>
<td>CC1316</td>
<td>0.24</td>
</tr>
<tr>
<td>April 14, 1977, through June 30, 1977</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Trailer 4

<table>
<thead>
<tr>
<th>Date Range</th>
<th>BDCS*</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1, 1976, through September 9, 1976</td>
<td>CC1262</td>
<td>0.42</td>
</tr>
<tr>
<td>September 10, 1976, through December 15, 1976</td>
<td>CC699</td>
<td>0.26</td>
</tr>
<tr>
<td>December 16, 1976, through March 17, 1977</td>
<td>CC1309</td>
<td>0.40</td>
</tr>
<tr>
<td>March 18, 1977, through June 1, 1977</td>
<td>CC1309</td>
<td>0.37</td>
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<tr>
<td>June 2, 1977, through June 30, 1977</td>
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<td></td>
</tr>
</tbody>
</table>

#### Trailer 5

<table>
<thead>
<tr>
<th>Date Range</th>
<th>BDCS*</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>June 1, 1976, through September 9, 1976</td>
<td>CC1264</td>
<td>0.40</td>
</tr>
<tr>
<td>September 10, 1976, through December 12, 1976</td>
<td>CC1317</td>
<td>0.30</td>
</tr>
<tr>
<td>December 13, 1976, through June 1, 1977</td>
<td>CC1317</td>
<td>0.26</td>
</tr>
<tr>
<td>June 2, 1977, through June 15, 1977</td>
<td>CC1317</td>
<td>0.26</td>
</tr>
<tr>
<td>June 16, 1977, through June 27, 1977</td>
<td>CC1315</td>
<td>0.34</td>
</tr>
<tr>
<td>June 28, 1977, through June 30, 1977</td>
<td>CC1302</td>
<td>0.19</td>
</tr>
</tbody>
</table>

### June 1, 1976, through June 17, 1976

**Used BDCS Ser. No. 300883-2 with B/C gauge settings of 80/30**

- Matheson cylinder RR47059 with concentration of 63 ppm NO in N₂
- Corrected flows: 
  - "B" = 10.72 cm³/min
  - "C" = 1518 cm³/min

**Span concentration**

\[
\frac{63 \times 10.72}{1518 + 10.72} = 0.44 \text{ ppm}
\]

### June 18, 1976, through June 21, 1976

**Used BDCS Ser. No. 300883-2 with B/C gauge settings of 70/30**

- Matheson cylinder RR25289 with concentration of 76 ppm NO in N₂
- Corrected flows: 
  - "B" = 8.98 cm³/min
  - "C" = 1518 cm³/min

**Span concentration**

\[
\frac{76 \times 8.98}{1518 + 8.98} = 0.45 \text{ ppm}
\]
June 22, 1976, through August 27, 1976

Used BDCS Ser. No. 300883-1 with B/C gauge settings of 70/40
Matheson cylinder RR25289 with concentration of 76 ppm NO in N₂
Corrected flows: "B" = 7.69 cm³/min "C" = 1400 cm³/min
Span concentration = \(\frac{76 \times 7.69}{1400 + 7.69}\) = 0.42 ppm

August 28, 1976, through September 1, 1976

Used BDCS Ser. No. 300883-1 with B/C gauge settings of 80/40
Airco cylinder LL1352 with concentration of 58.5 ppm NO in N₂
Corrected flows: "B" = 9.55 cm³/min "C" = 1400 cm³/min
Span concentration = \(\frac{58.5 \times 9.55}{1400 + 9.55}\) = 0.40 ppm

September 2, 1976, through September 9, 1976

Used BDCS Ser. No. 300883-1 with B/C gauge settings of 85/30
Airco cylinder LL1352 with concentration of 58.5 ppm NO in N₂
Corrected flows: "B" = 7.42 cm³/min "C" = 1010 cm³/min
Span concentration = \(\frac{58.5 \times 7.42}{1010 + 7.42}\) = 0.43 ppm

CROSS-COMPARISONS OF AIRCO LOW-CONCENTRATION CYLINDERS

1st Cross-Comparison - September 10, 1976

<table>
<thead>
<tr>
<th>Cylinder No.</th>
<th>Location</th>
<th>NO(ppm)</th>
<th>Volts</th>
<th>NOₓ(ppm)</th>
<th>Volts</th>
<th>Original Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1262*</td>
<td>Trailer 4</td>
<td>0.42</td>
<td>0.84</td>
<td>0.42</td>
<td>0.84</td>
<td>0.45</td>
</tr>
<tr>
<td>CC1048</td>
<td>Trailer 1</td>
<td>0.34</td>
<td>0.68</td>
<td>0.34</td>
<td>0.68</td>
<td>0.41</td>
</tr>
<tr>
<td>CC1266</td>
<td>Trailer 2</td>
<td>0.40</td>
<td>0.80</td>
<td>0.40</td>
<td>0.80</td>
<td>0.43</td>
</tr>
<tr>
<td>CC1071</td>
<td>Trailer 3</td>
<td>0.33</td>
<td>0.66</td>
<td>0.33</td>
<td>0.66</td>
<td>0.41</td>
</tr>
<tr>
<td>CC1264</td>
<td>Trailer 5</td>
<td>0.405</td>
<td>0.81</td>
<td>0.405</td>
<td>0.81</td>
<td>0.44</td>
</tr>
<tr>
<td>CC1067</td>
<td>Building 16</td>
<td>0.12</td>
<td>0.24</td>
<td>0.12</td>
<td>0.24</td>
<td>0.125</td>
</tr>
</tbody>
</table>

* Secondary standard evaluation:

Analysis performed at trailer 2 on ML 8440 for cross-comparison:
Cylinder No. CC1262 analyzed by Conoco at 0.41 ppm, September 7, 1976
Cylinder No. CC1262 analyzed by Phelps Dodge at 0.40 ppm, September 9, 1976

Concentration value =

\[
\text{Phelps Dodge conc.} + \text{Airco conc.} + \text{Conoco conc.} = \frac{0.42 \text{ ppm}}{3}
\]

G-4
### 2nd Cross-Comparison - November 5, 1976

<table>
<thead>
<tr>
<th>Cylinder No.</th>
<th>Location</th>
<th>NO (ppm)</th>
<th>Volts</th>
<th>NO(_x) (ppm)</th>
<th>Volts</th>
<th>Sept. 10 Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1262*</td>
<td>Trailer 4</td>
<td>0.42</td>
<td>2.54</td>
<td>0.42</td>
<td>2.54</td>
<td>0.42</td>
</tr>
<tr>
<td>CC1048</td>
<td>Trailer 1</td>
<td>0.33</td>
<td>1.95</td>
<td>0.33</td>
<td>1.95</td>
<td>0.34</td>
</tr>
<tr>
<td>CC1266</td>
<td>Trailer 2</td>
<td>0.41</td>
<td>2.45</td>
<td>0.41</td>
<td>2.45</td>
<td>0.40</td>
</tr>
<tr>
<td>CC1071</td>
<td>Trailer 3</td>
<td>0.30</td>
<td>1.78</td>
<td>0.30</td>
<td>1.78</td>
<td>0.33</td>
</tr>
<tr>
<td>CC1264</td>
<td>Trailer 5</td>
<td>0.40</td>
<td>2.40</td>
<td>0.40</td>
<td>2.41</td>
<td>0.41</td>
</tr>
<tr>
<td>CC1067</td>
<td>Building 16</td>
<td>0.11</td>
<td>0.65</td>
<td>0.11</td>
<td>0.65</td>
<td>0.12</td>
</tr>
</tbody>
</table>

* Secondary standard (see cross-comparison 1)

Tests performed at trailer #3 on ML 8440 Ser. No. 214 for cross-comparison

### 3rd Cross-Comparison - December 15, 1976

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>Location</th>
<th>NO (ppm)</th>
<th>Volts</th>
<th>NO(_x) (ppm)</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1071</td>
<td>Trailer 3</td>
<td>0.28</td>
<td>2.67</td>
<td>2.69</td>
<td>2.69</td>
</tr>
<tr>
<td>CC1316</td>
<td>Building 16</td>
<td>0.31</td>
<td>2.99</td>
<td>0.31</td>
<td>3.01</td>
</tr>
<tr>
<td>CC1299</td>
<td>Trailer 3a</td>
<td>0.29</td>
<td>2.79</td>
<td>0.29</td>
<td>2.79</td>
</tr>
<tr>
<td>CC1302</td>
<td>Trailer 2a</td>
<td>0.28</td>
<td>2.72</td>
<td>0.28</td>
<td>2.73</td>
</tr>
<tr>
<td>CC1317</td>
<td>Trailer 5a</td>
<td>0.30</td>
<td>2.91</td>
<td>0.30</td>
<td>2.90</td>
</tr>
<tr>
<td>CC1315</td>
<td>Trailer 1a</td>
<td>0.34</td>
<td>3.30</td>
<td>0.34</td>
<td>3.30</td>
</tr>
<tr>
<td>CC699</td>
<td>Trailer 4a</td>
<td>0.26</td>
<td>2.47</td>
<td>0.26</td>
<td>2.47</td>
</tr>
<tr>
<td>CC1301</td>
<td>Building 16</td>
<td>0.21</td>
<td>2.02</td>
<td>0.21</td>
<td>2.02</td>
</tr>
<tr>
<td>CC1067</td>
<td>Building 16</td>
<td>0.10</td>
<td>0.98</td>
<td>0.10</td>
<td>0.98</td>
</tr>
<tr>
<td>CC1262*</td>
<td>Trailer 4</td>
<td>0.42</td>
<td>4.05</td>
<td>0.42</td>
<td>4.05</td>
</tr>
<tr>
<td>CC1309</td>
<td>Building 16</td>
<td>0.40</td>
<td>3.88</td>
<td>0.40</td>
<td>3.88</td>
</tr>
<tr>
<td>CC1264</td>
<td>Trailer 5</td>
<td>0.40</td>
<td>3.82</td>
<td>0.40</td>
<td>3.82</td>
</tr>
<tr>
<td>CC1048</td>
<td>Trailer 1</td>
<td>0.32</td>
<td>3.08</td>
<td>0.32</td>
<td>3.08</td>
</tr>
<tr>
<td>CC1266</td>
<td>Trailer 2</td>
<td>0.41</td>
<td>4.00</td>
<td>0.41</td>
<td>4.00</td>
</tr>
<tr>
<td>CC1071</td>
<td>Trailer 3</td>
<td>0.27</td>
<td>2.66</td>
<td>0.27</td>
<td>2.68</td>
</tr>
</tbody>
</table>

* Secondary standard (see cross-comparison 1)

Analysis performed at trailer 3 on ML 8440 Ser. No. 214 for cross-comparison
### METHANE AND CARBON MONOXIDE SECONDARY CALIBRATION GAS STANDARDS USED IN TRAILERS FOR EACH MONITORING STATION CALIBRATION PERIOD

**Beckman 6800 Span Gas Cylinders Used for CH₄ and CO**

<table>
<thead>
<tr>
<th>Cylinder No.</th>
<th>CH₄ (ppm)</th>
<th>CO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2306</td>
<td>5.07*</td>
<td>4.95*</td>
</tr>
<tr>
<td>L2276</td>
<td>5.15</td>
<td>5.02</td>
</tr>
<tr>
<td>CC279</td>
<td>3.03</td>
<td>3.03</td>
</tr>
</tbody>
</table>

* Analyzed in Las Vegas against NBS SRM FF2546 in February 1977. These cylinders certified as secondary standards (results as indicated):

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>NO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1067</td>
<td>0.08</td>
</tr>
<tr>
<td>CC1316</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Also analyzed by NSI-RTP in August 1977 (results as indicated):

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>NO (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1067</td>
<td>0.075</td>
</tr>
<tr>
<td>CC1316</td>
<td>0.22</td>
</tr>
</tbody>
</table>
CROSS-COMPARISONS OF SCOTT-MARRIN CONCENTRATION CYLINDERS

The following procedure was utilized for cross-comparison of CH₄/CO standards.

- September 23, 1976.

Eight nominal 5 ppm CO/CH₄ gas cylinders were moved to trailer 5 to be cross-checked on the Beckman 6800. The cylinder numbers were L2306, L2274, L2271, L2276, L2334, MM9940, and L2277.

Before cross-comparing the cylinders, the trailer 5 gas chromatograph was calibration-checked using the span cylinder (12278) that was routinely used for calibration checks in this trailer. The previous week's calibration values were reviewed to determine if the instruments were performing satisfactorily. Since the calibration was very close to the desired span of 2 ppm/V, no adjustments were made to the gas chromatograph.

All of the eight cylinders were then analyzed on the gas chromatograph and the voltage outputs recorded. Since no absolute standard was available at this time, the concentrations listed on page 194 are Scott Marrin's analysis, except for cylinder MM9940. MM9940 (which had a +5% analysis and did not agree with the seven other cylinders having a +2% analysis) was assigned a new concentration value by averaging all the
other cylinder values and their voltages to determine the average ppm/V and using that value to determine the concentration for MM9940, based on its voltage response.

- December 23, 1976.

This cross-comparison was performed on the gas chromatograph in trailer 1. As before, all the cylinders were moved to this trailer and analyzed the same day. The gas chromatograph was not adjusted but was calibration-checked before performing the cross-comparison. This gas chromatograph (as well as those in all the trailers) was being calibrated weekly and calibration-checked daily, so there was no real need to perform an additional calibration if the instrument was operating properly.

The concentrations listed on page 195 were used; all are results of Scott-Marrin's analyses, since there was no higher order standard available at that time.


The third cross-comparison was performed on October 23, 1977. The monitoring network had been shut down since June 30, 1977. It was therefore necessary to restart the gas chromatograph from trailer 4 to perform this cross-comparison. This was done using CC278, and all the cylinders were analyzed during the same day as before. CC278 was repeated at the end of the comparison to show there had been no significant span change during the tests.

The results listed are the manufacturer's concentration values along with the voltage responses from the gas chromatograph. All the cylinders had been certified by the manufacturer to ±2% except MM9941 which was a ±5% analysis.

1st Cross-Comparison - September 23, 1976

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>Location</th>
<th>THC(ppm)</th>
<th>Volts</th>
<th>CH4(ppm)</th>
<th>Volts</th>
<th>CO(ppm)</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>L2306</td>
<td>Trailer 1</td>
<td>5.07</td>
<td>2.59</td>
<td>5.07</td>
<td>2.55</td>
<td>4.95</td>
<td>2.50</td>
</tr>
<tr>
<td>L2274</td>
<td>Trailer 2</td>
<td>5.14</td>
<td>2.60</td>
<td>5.14</td>
<td>2.58</td>
<td>5.02</td>
<td>2.53</td>
</tr>
<tr>
<td>L2271</td>
<td>Trailer 3</td>
<td>5.11</td>
<td>2.58</td>
<td>5.11</td>
<td>2.56</td>
<td>4.98</td>
<td>2.53</td>
</tr>
<tr>
<td>L2276</td>
<td>Trailer 4</td>
<td>5.14</td>
<td>2.59</td>
<td>5.14</td>
<td>2.57</td>
<td>5.02</td>
<td>2.53</td>
</tr>
<tr>
<td>L2278*</td>
<td>Trailer 5</td>
<td>5.07</td>
<td>2.55</td>
<td>5.07</td>
<td>2.56</td>
<td>4.97</td>
<td>2.49</td>
</tr>
<tr>
<td>L2334</td>
<td>Trailer 5a</td>
<td>4.93</td>
<td>2.52</td>
<td>4.93</td>
<td>2.49</td>
<td>5.00</td>
<td>2.53</td>
</tr>
<tr>
<td>MM9940</td>
<td>Trailer 2a</td>
<td>4.98</td>
<td>2.51</td>
<td>4.98</td>
<td>2.51</td>
<td>5.02</td>
<td>2.54</td>
</tr>
<tr>
<td>L2277</td>
<td>Trailer 4a</td>
<td>5.13</td>
<td>2.58</td>
<td>5.13</td>
<td>2.60</td>
<td>5.04</td>
<td>2.57</td>
</tr>
</tbody>
</table>

* L2278, CH₄ 5.06 ppm and CO 4.65 ppm (+ 9%), Las Vegas analysis, April 22, 1977, (cylinder pressure 500 lb/in²)

Secondary standard evaluation (traceability)
Analysis performed at trailer 5 with Beckman 6800 gas chromatograph for cross-comparison

G-8
## 2nd Cross-Comparison - December 23, 1976

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>Location</th>
<th>THC (ppm)</th>
<th>Volts</th>
<th>CH₄ (ppm)</th>
<th>Volts</th>
<th>CO (ppm)</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC279</td>
<td>Trailer 1a</td>
<td>3.03</td>
<td>1.51</td>
<td>3.03</td>
<td>1.49</td>
<td>3.03</td>
<td>1.44</td>
</tr>
<tr>
<td>CC367</td>
<td>Building 16</td>
<td>3.02</td>
<td>1.50</td>
<td>3.02</td>
<td>1.51</td>
<td>3.04</td>
<td>1.45</td>
</tr>
<tr>
<td>CC370</td>
<td>Trailer 3a</td>
<td>3.02</td>
<td>1.51</td>
<td>3.02</td>
<td>1.50</td>
<td>3.04</td>
<td>1.45</td>
</tr>
<tr>
<td>CC369*</td>
<td>Trailer 2b</td>
<td>3.02</td>
<td>1.53</td>
<td>3.02</td>
<td>1.50</td>
<td>3.04</td>
<td>1.45</td>
</tr>
<tr>
<td>CC364</td>
<td>Trailer 5b</td>
<td>3.02</td>
<td>1.52</td>
<td>3.02</td>
<td>1.51</td>
<td>3.03</td>
<td>1.43</td>
</tr>
<tr>
<td>CC278</td>
<td>Trailer 4b</td>
<td>3.02</td>
<td>1.52</td>
<td>3.02</td>
<td>1.51</td>
<td>3.03</td>
<td>1.42</td>
</tr>
<tr>
<td>CC371</td>
<td>Building 16</td>
<td>4.17</td>
<td>2.06</td>
<td>4.17</td>
<td>2.04</td>
<td>4.15</td>
<td>2.03</td>
</tr>
<tr>
<td>CC355</td>
<td>Building 16</td>
<td>5.14</td>
<td>2.55</td>
<td>5.14</td>
<td>2.54</td>
<td>5.14</td>
<td>2.57</td>
</tr>
<tr>
<td>L2276</td>
<td>Trailer 4</td>
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<td>2.56</td>
<td>5.14</td>
<td>2.54</td>
<td>5.02</td>
<td>2.56</td>
</tr>
</tbody>
</table>

  Analysis performed at trailer 1 on Beckman 6800 gas chromatograph

## 3rd Cross-Comparison - October 25, 1977

<table>
<thead>
<tr>
<th>Cylinder</th>
<th>Location</th>
<th>THC (ppm)</th>
<th>Volts</th>
<th>CH₄ (ppm)</th>
<th>Volts</th>
<th>CO (ppm)</th>
<th>Volts</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC278</td>
<td>Trailer 4b</td>
<td>3.02</td>
<td>1.51</td>
<td>3.02</td>
<td>1.50</td>
<td>3.03</td>
<td>1.52</td>
</tr>
<tr>
<td>MM9941</td>
<td>Building 16</td>
<td>4.9 *</td>
<td>2.48</td>
<td>4.9 *</td>
<td>2.46</td>
<td>4.9 *</td>
<td>2.48</td>
</tr>
<tr>
<td>CC367</td>
<td>Trailer 3b</td>
<td>3.02</td>
<td>1.50</td>
<td>3.02</td>
<td>1.50</td>
<td>3.04</td>
<td>1.51</td>
</tr>
<tr>
<td>CC279</td>
<td>Trailer 1a</td>
<td>3.03</td>
<td>1.51</td>
<td>3.03</td>
<td>1.50</td>
<td>3.03</td>
<td>1.51</td>
</tr>
<tr>
<td>CC364</td>
<td>Trailer 5b</td>
<td>3.02</td>
<td>1.50</td>
<td>3.02</td>
<td>1.48</td>
<td>3.03</td>
<td>1.49</td>
</tr>
<tr>
<td>CC278</td>
<td>Trailer 4b</td>
<td>3.02</td>
<td>1.51</td>
<td>3.02</td>
<td>1.49</td>
<td>3.03</td>
<td>1.50</td>
</tr>
</tbody>
</table>

* MM9941, CH₄ 4.9 ppm and CO 4.9 ppm, March 24, 1976, manufacturer's original analysis ± 5%

MM9941, CH₄ 4.96 ppm and CO 4.81 ppm, April 22, 1977, Las Vegas analysis
MM9941, CH₄ 4.99 ppm and CO 5.02 ppm, March 14, 1978, NSI, Las Vegas analysis performed at trailer 4 on Beckman 6800 gas chromatograph
APPENDIX H

HOURLY AVERAGES AND TIME SERIES PLOTS
OF WILLIAMS AIR FORCE BASE DATA

This appendix consists of hourly averages and corrected 1-minute data plotted versus time. Hourly averages of CO, NO, NOx, and NMHC concentrations in parts per million by volume are shown in this appendix beginning with Figure H-1. Nephelometer data in units of $10^{-4} \text{m}^{-1}$ follow NMHC data. WS in meters per second and WD in degrees (0-352°) follow nephelometer data. The same order for all five monitoring stations is presented in Figures H-1 through H-91. Where there is insufficient data to calculate hourly averages, no tracing appears for that time period.

ATYPICAL EPISODES

One-minute graphical displays selected to demonstrate air quality concentrations in a 24-hour period are shown for four days of the monitoring period in Figures H-92 through H-134. The concentration scale in appropriate units is shown on the ordinate in the range needing description. Time is shown on the abscissa.

Observations were made from these data which support an indication of sources of NOx, NMCH, and CO upwind of Williams AFB under specific meteorological conditions. Concentrations plotted for one day under atypical meteorological conditions show how sources in areas surrounding the airbase could influence air quality at the base.

Assuming the diurnal wind pattern is representative for the Phoenix valley area, background air quality at WAFB is influenced by average air motion, dispersion, and sources of pollution in the area surrounding the airbase. Mixing depth in the lower regions in the atmosphere of the valley is also a major factor, which correlates to time of day and influences pollution dispersion with respect to average air motion.

The specific data shown here have been used to demonstrate that data evaluation must be done for particular meteorological conditions. These data also show that highest concentrations recorded at WAFB are due to infrequent calm or low WS conditions.

For an example, starting on September 26, 1976, WS was less than 3 m/s and the typical diurnal pattern of WD did not occur for three days. Air motion was slight to stagnant, and a gradual buildup of CO and NOx from sources...
outside the airbase could have occurred (Figures H-92 through H-101). NMHC concentrations are shown in Figures H-100 and H-101. Preliminary analysis of these data indicates that NMHC at station 3 is probably related to aircraft events, and elevated concentrations over normal levels are probably due to minimum dispersion conditions at the time.

On December 29, 1976, high concentrations of NO, NO\textsubscript{x}, NMHC, and CO were observed at all stations in the late afternoon. Again, wind speed had been low for two or more days, probably allowing buildup around Phoenix (Figures H-102 to H-114). WD was from the northwest, starting about 1200 hours. All air quality levels increased abruptly about 4 hours later, suggesting that an air parcel containing elevated levels of pollution moved into the WAFB area and out by about midnight. Nephelometer bscat, not shown in this example, was also recorded at high levels.

January 27, 1977, showed an excursion due to a meteorological condition reversed from the December 29 afternoon situation. The WD had been from the northwest for about 12 hours at low wind speeds the preceding day (Figures H-115 through H-118). Note that CO and NMHC levels are always higher at station 4 than at station 5 since other airbase activity is recorded at higher levels at station 4, and concentrations return to near normal background levels much more quickly at the outlying stations 1, 2, 3, and 5.

On May 11, 1977 (day 131), WS had been low for about 24-26 hours. Wind direction veered from south to north over the 24-hour period on this day. NO was low while NO\textsubscript{x}, CO, and NMHC began an abrupt rise in concentration about 2100 hours, which continued until midnight and then began decreasing (Figures H-119 through H-134). CO at station 3 was expanded (hours 1200 through 1400) to show short-term excursions where taxiing aircraft are most likely to be detected while in transit to takeoff.

The concentrations shown here have been used to demonstrate that data evaluation for WAFB must be correlated to a particular meteorological condition. These data also show that highest concentrations recorded at WAFB result from infrequent calm or low WS conditions.
Figure H-6.
Figure H-8.
Figure H-11.
Figure H-28.
Figure H-31.
Figure H-32.
Figure H-33.
Figure H-34.
Figure H-36.
Figure H-38.
Figure H-43.
Figure H-48.
Figure H-52.
Figure H-56.
Figure H-59.
Figure H-61.
Figure H-66.
Figure H-68.
Figure H-70.
Figure H-73.
Figure H-75.
NORTHROP SERVICES INC. LAS VEGAS NV
WILLIAMS AIR FORCE BASE AIR QUALITY MONITORING STUDY. APPENDIX--ETC(U)
JUL 80  D C SHEESLEY, S J GORDON, M L EHLERT  EPA-68-03-2591
UNCLASSIFIED  EPA/600/4-80-037-APP  NL

3.4

UNCLASSIFIED

Figure H-82.
Figure H-83.
Figure H-84.
Figure H-90.
Figure H-93.
Figure H-99.
NMHC (PPM)

STATION 2
DAY 364

Figure H-103.
Figure H-110.
Figure H-113.
Figure H-114.
Figure H-116.
Figure H-117.
Figure H-118.
Figure H-120.
Figure H-125.
Figure H-128.
Figure H-133.
APPENDIX I

DATA PROCESSING

Data processing for the WAFB project consisted of the following:

- Handling one-minute data tapes acquired from the air monitoring network (Section 2) and verifying the contents of these tapes (Tape I's)
- Calibrating the one-minute voltage tapes and converting the voltages to engineering units (Tape II's)
- Averaging the one-minute data to produce hourly averages and calculating the root mean square (RMS) average, the standard deviation, and the maximum and minimum for each hour (Tape III's)
- Coding WABAN meteorological data onto computer forms and tape cartridges and merging these data into a data file of consistent format for each month that air quality data were collected (Meteorology Tape)
- Presenting data in the form of tabular listings of hourly data and cumulative frequencies for NO, CO, NMHC, and nephelometer; cumulative frequency distribution of these four parameters; time plots of the hourly averages; time plots of minute values for four Julian days; and microfiche of the tabular listings
- Compressing 395 Level II tapes concatenated onto a 20-reel set for future analyses

AIR MONITORING NETWORK RAW VOLTAGE TAPES

These tapes contain the raw air quality data voltages and certain meteorological data recorded by the monitoring network and data acquisition system. Because these tapes are the original source of data for all the subsequent processing, they are called Level I tapes or Tape I's. The data on these tapes are unedited and uncorrected and so include the results of instrument calibration, instrument drift, instrument malfunction, and recording errors.

A Tape I was generated for each day of monitoring, resulting in 395 reels of tape for the project. Tape I's were removed from the central data acquisition system at approximately 1100 hours each day. After removal, the tape was mounted on a Cipher 7-track tape unit and printed on a Versatec line printer to provide a permanent record of the data. The line-printer output
was also scanned by the air quality engineer for errors in the following categories:

- Instrument operation
- Time of events
- Data coding switch number
- Data transmission

Because the data collection system had no automatic provision for determining instrument failure, the line-printer output was also used as a source of information on system operation.

The characteristics, format, and content of the Level I tapes are given below.

**Level I Tapes**

**Characteristics:**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reels:</td>
<td>7-in (600 ft)</td>
</tr>
<tr>
<td>Tracks:</td>
<td>7</td>
</tr>
<tr>
<td>Parity:</td>
<td>Odd</td>
</tr>
<tr>
<td>Density:</td>
<td>556 bits per inch (BPI)</td>
</tr>
<tr>
<td>Record Size:</td>
<td>Variable (85-132 characters nominal) 116</td>
</tr>
<tr>
<td>Code:</td>
<td>ASCII</td>
</tr>
</tbody>
</table>

**Format and Content:** (I3, 312, 1111, 16F6.4)

<table>
<thead>
<tr>
<th>Character No.:</th>
<th>Information:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Day</td>
</tr>
<tr>
<td>4-9</td>
<td>Time (HHMMSS)</td>
</tr>
<tr>
<td>10</td>
<td>Station</td>
</tr>
<tr>
<td>11</td>
<td>Thumbwheels as follow:</td>
</tr>
<tr>
<td>12</td>
<td>Empty</td>
</tr>
<tr>
<td>13</td>
<td>NO</td>
</tr>
<tr>
<td>14</td>
<td>NO₂</td>
</tr>
<tr>
<td>15</td>
<td>CH₄</td>
</tr>
<tr>
<td>16</td>
<td>THC</td>
</tr>
<tr>
<td>17</td>
<td>CO</td>
</tr>
<tr>
<td>18</td>
<td>WS</td>
</tr>
<tr>
<td>19</td>
<td>WD</td>
</tr>
<tr>
<td>20</td>
<td>NEPH</td>
</tr>
<tr>
<td>21-26</td>
<td>Channel 0 Empty</td>
</tr>
<tr>
<td>27-32</td>
<td>Channel 1 NO</td>
</tr>
</tbody>
</table>

I-2
TAPE I-TO-TAPE II PROCESSING

The calibrated engineering unit (one-minute) tapes are called Level II tapes or Tape II's. Processing of Tape I data started with the production of a corrected one-minute tape using zero and span check and calibration adjustment information that was recorded by the central data acquisition unit at WAFB. This initial editing of the raw data tapes was accomplished using an HP-9825 calculator, two Cipher Data 7-track tape recorders, two Cipher Data 9-track tape recorders, and HP-9826A digital plotter, and a Versatec LP-DI150 line printer. The Tape I-to-Tape II process is summarized in a flowchart in Figure I-1. A detailed description of the process follows. The 7-track tapes of series I were printed and checked, and calibration data with thumbwheel information were removed. An errata sheet listing necessary corrections and listings to be made was used during this process. The line-printer output of Tape I's was analyzed to determine the condition of the data on each tape.

A program for thumbwheel and calibration data was run on the HP-9825 to retrieve calibration zero and span voltages and thumbwheel codes from the Tape I's. The calibration voltages were printed and inspected for errors which included the following:

- Spurious noise spikes occurring during calibration
- Missing values from the data so that final readings were not obtained. The missing values were generally located on the Tape I printout and added to the list.
- Obviously wrong values caused by improper setting of the data switches
- A series of decreasing values for a "zero" or a series of increasing values for a "span," indicating insufficient time was allowed for stabilization during calibration

Errors in calibration were not corrected when they were caused by the following:

- Improper adjustment of flow rates or overflow rates
- Not allowing sufficient time for an instrument to span or zero
- Instrument malfunction
- Improper setting of range switches or time constants. Occasionally an attempt was made to correct a bad value if instrument operating history allowed the evaluation of zero and span values before and after any questionable value. If a reliable calibration value could not be obtained, corrections were made to the next valid value, and the questionable calibration value was discarded.

The calibration values were put into a correction array (see Correction Program) and stored on HP-9825 tape cartridges. Calibration was begun by writing a calibration card, which was checked and typed into the correction array, for an edit program specific for each day of monitoring from June 1, 1976, through June 30, 1977. Major steps in this process are listed below.

- The raw data tape series was read on the HP-9825 record.
- Calibration values for adjustment and zero and span were averaged and printed.
- Voltage data were converted to air quality concentrations and engineering units (see equations 1-3 below).
- Uncorrectable data were replaced with 9's on the Tape II's.

Tape II series were recorded on 9-track magnetic tape.

The conversion of voltage units to concentration and engineering units was made using the following equations:

For $\text{NO-NO}_x$:

\[
\text{ppm} = \left[ \frac{V_i - V_{01}}{T_i} + \frac{V_{01} - V_{02}}{T_2 - T_1} \right] \left( \frac{C}{V_1 - V_{01}} \right) \left[ 1 + T_i \frac{(V_1 - V_{01}) - (V_2 - V_{02})}{(T_2 - T_1) (V_2 - V_{02})} \right]
\]

(Eq. 1)

For $\text{CH}_4$, THC, and CO:

\[
\text{ppm} = V_i \left( \frac{C}{V_1} \right) \left[ 1 + T_i \frac{V_1 - V_2}{(T_2 - T_1) (V_2)} \right]
\]

(Eq. 2)
For the nephelometer:

\[
b_{\text{scat}} = \left[ V_i - (V_{\text{PA1}} - .09) - T_i \frac{V_{\text{PA1}} - V_{\text{PA2}}}{T_2 - T_1} \right] \left( \frac{\text{Freon b}}{V_{\text{FR}}} \right) \left( \frac{V_1 - V_{\text{PA1}} + .09}{V_2 - V_{\text{PA2}} + .09} \right) \left( 1 + T_i \right)
\]

\[
\left( \frac{(V_1 - V_{\text{PA1}} + .09) - (V_2 - V_{\text{PA2}} + .09)}{(T_2 - T_1)(V_2 - V_{\text{PA2}} + .09)} \right) \left( 10^{-4} \text{ m}^{-1} \right)
\]

where

- \( V_i \) is the instantaneous voltage at time \( T_i \), which is the time in minutes from the beginning of the previous calibration
- \( V_1 \) is the initial span voltage in volts
- \( V_2 \) is the final span voltage in volts
- \( V_{01} \) is the initial zero voltage in volts
- \( V_{02} \) is the final zero voltage in volts
- \( C \) is the span gas concentration in parts per million
- \( T_1 \) is the time for the initial zero and span in minutes from the time of last calibration
- \( T_2 \) is the time for the final zero and span in minutes from the beginning of the year
- \( V_{\text{PA1}} \) is the calibration pure air span in volts
- \( V_{\text{PA2}} \) is the corrected pure air span in volts
- Freon b is the span standard of Freon 12, \( \text{CCL}_2\text{F}_2 \)
- \( V_{\text{FR}} \) is the Freon calibration voltage in volts

The result of these four steps was a calibrated engineering-units tape of minute values for each raw voltage tape (Level I) produced at WAFB. These Level II tapes have the following characteristics and format.

[* Note: Pure air has a \( b_{\text{scat}} = 0.09 \text{ V} \) or \( 0.23 \times 10^{-4} \text{ m}^{-1} \).]

I-6
Characteristics:

Reels: 14-in (2400 ft)
Tracks: 9
Density: 1600 BPI
Parity: Odd
Record Size: 100 characters
Code: ASCII
Blocking Factor: 50

Format:

The tapes are unlabeled. Each record is followed by an interrecord gap (IRG) with a minimum length of 19 mm of blank tape.

<table>
<thead>
<tr>
<th>Character No.</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Julian day</td>
</tr>
<tr>
<td>4-5</td>
<td>Hour</td>
</tr>
<tr>
<td>6-7</td>
<td>Minute</td>
</tr>
<tr>
<td>8-9</td>
<td>Second</td>
</tr>
<tr>
<td>10</td>
<td>Trailer number</td>
</tr>
<tr>
<td>11</td>
<td>Spare</td>
</tr>
<tr>
<td>12</td>
<td>NO</td>
</tr>
<tr>
<td>13</td>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
</tr>
<tr>
<td>14</td>
<td>CH&lt;sub&gt;4&lt;/sub&gt;</td>
</tr>
<tr>
<td>15</td>
<td>THC</td>
</tr>
<tr>
<td>16</td>
<td>CO</td>
</tr>
<tr>
<td>17</td>
<td>WS</td>
</tr>
<tr>
<td>18</td>
<td>WD</td>
</tr>
<tr>
<td>19</td>
<td>NEPH</td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
<tr>
<td>21-28</td>
<td>NO</td>
</tr>
<tr>
<td>29</td>
<td></td>
</tr>
<tr>
<td>30-36</td>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
</tr>
<tr>
<td>37-44</td>
<td>CH&lt;sub&gt;4&lt;/sub&gt;</td>
</tr>
<tr>
<td>46-52</td>
<td>THC</td>
</tr>
<tr>
<td>54-60</td>
<td>CO</td>
</tr>
<tr>
<td>62-68</td>
<td>WS&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>70-76</td>
<td>WD&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>78-84</td>
<td>NEPH</td>
</tr>
<tr>
<td>86-92</td>
<td>PSP Pyranometer (station 4 only)</td>
</tr>
<tr>
<td>93-100</td>
<td>Temperature station 4</td>
</tr>
</tbody>
</table>

<sup>a</sup>value x 10 = m/s
<sup>b</sup>value x 100 = degrees
TAPE II-TO-III PROCESSING

Hourly average tapes are called Level III tapes of Tape III's. Each tape II was read through the HP-9825A calculator to total the number of air quality concentrations for each interval of 30 minutes before and 30 minutes after the hour during the monitoring period. Concentrations were read as valid data points only if they fell between the acceptable high and low limits of concentration for each air quality parameter. These limits (for NO, NOX, CH₄, THC, CO, and NEPH) were set after a series of adjustments and additions to the monitoring operations instrumentation at the beginning of the study had established the limits that the instrumentation was capable of measuring.

Hourly averages were calculated if the number of valid one-minute data points for a component in an hour was 30 or more. If the number of valid data points was less than 30 for a given hour, the hourly average was replaced by 9's.

The hourly average value, minimum and maximum concentration, root mean square, and standard deviation were calculated on the half hour for each air quality parameter. A simplified flowchart of the process that produced the one-hour averages (designated Tape III series) is in Figure 1-2).

The following steps were taken in the production of Tape III's:

- Read the Level II tapes, calculate an hourly average, root mean square, standard deviation, maximum, and minimum. Store this information on a 9-track tape, one tape for each month of data.
- Plot the hourly averages generated in step 1 and evaluate the plots for spurious values.
- Read the 9-track tapes into the DOE CDC-6400 computer and edit out spurious values.
- Make a list of averages that were edited out.
- Write the final Tape III on 9-track tape.

Thirteen Tape III's were generated. Each tape contains one-month of hourly data. Copies have been sent to ANL, and a copy has been retained in Las Vegas. The following parameters were utilized during production of the Tape III's.
Figure I-2. Flowchart for processing of one-hour average tapes (Tape III).
Average: \[ \bar{x} = \frac{1}{n} \sum_{i}^{n} x_i \] (Eq. 4)

Root Mean Square: \[ \bar{x}_{\text{RMS}} = \sqrt{\frac{1}{n} \sum_{i}^{n} x_i^2} \] (Eq. 5)

Standard deviation: \[ \sigma_x = \sqrt{\frac{1}{n-1} \sum_{i}^{n} (x_i - \bar{x})^2} \] (Eq. 6)

where

- \( x_i \) = Instantaneous one-minute reading for a component
- \( n \) = Number of valid data points over the hour

The root mean square average concentration was calculated to provide a measure of the average difference from the mean and to show air quality variability from hour to hour, and standard deviation was derived to give the difference from average value (or total deviation of concentration from average, throughout the hour).

The 9-track Tape III series data were then read through an HP-9825 calculator and data were plotted. This step produced a visual display that indicated unreasonable data in terms of trend, time of data change, abrupt change, etc. Suspect data on the plots were visually edited (deleted) from the Tape III series. A list of edits made through this visual inspection is shown in Figure I-3. The final Tape III series was sent to ANL for AQAM evaluation and was used to generate tabular summaries of hourly data, frequency distributions, and wind roses. Final plots of hourly averages for NO, NO\(_x\), CH\(_4\), THC, NMHC, CO, WS, and WD were made and are shown in Appendix H, Figures H-1 to H-91.

The tape characteristics and format are as follows:

**Tape III's**

**Characteristics:**
- Reels: 7-in (600 ft)
- Tracks: 9
- Parity: Odd
- Density: 800 BPI
- Record Size: 510 characters
- Code: ASCII
- Blocking Factor: 1
### INDEX of EDITS to WAFB HOURLY DATA

#### Figure 1-3. List of Tape III edits.
Format:

Each record on the tape is separated by an IRG. Each record contains data for one hour and one trailer. The tapes are unlabeled and contain approximately 3,500 records, varying with the number of days in the month being presented. Data for all parameters, for every hour of every day, are accounted for on the tape. Missing or invalid data are indicated by a value of -999.0000. In the event that an average value was missed because of an insufficient number of values (<30) for one-minute data, the third and fourth digits to the right of the decimal point in the above missing data code indicate the number of valid data points that exist for that hour.

Below is information specifying the values contained within each record of the tape and the location of each value within the record. (All character numbers are inclusive and refer to absolute position within the 510-character record.)

### 8-Character ID Field Information

<table>
<thead>
<tr>
<th>1-3</th>
<th>Julian day (left-justified)</th>
<th>Format A3</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>Hour (0-23)</td>
<td>I2</td>
</tr>
<tr>
<td>6-8</td>
<td>Trailer number (001-005)</td>
<td>I3</td>
</tr>
</tbody>
</table>

### Six 54-Character Air Quality Data Fields:

- **9-62** NO Format 6F9.4
- **93-116** NOx Format 6F9.4
- **117-170** CH4 Format 6F9.4
- **171-224** THC Format 6F9.4
- **225-278** CO Format 6F9.4
- **279-333** NEPH Format 6F9.4

Each of these fields contains the following values for the respective parameters:

- **First 9 characters** Hour average F9.4
- **Second 9 characters** Root mean square F9.4
- **Third 9 characters** Standard deviation F9.4
- **Fourth 9 characters** Minimum value for hour F9.4
- **Fifth 9 characters** Maximum value for hour F9.4
- **Last 9 characters** Last value (current hour) minus last value (preceding hour) F9.4

### 81-Character Met-Data Field:

- **333-341** Vector mean wind direction F9.4
- **342-350** Average WD F9.4
351-359 Standard deviation of direction F9.4
360-368 Vector mean wind speed F9.4
369-377 Average WS F9.4
378-386 Standard deviation of speed F9.4
387-395 $u'^2$ F9.4
396-404 $v'^2$ F9.4
405-413 $u'v'$ F9.4

18-Character Pyranometer Data
Field (trailer 4 only):

414-422 Total for hour F9.4
423-431 Running sum for day F9.4

The remainder of the record is blank and filled with -0.0000.

METEOROLOGICAL DATA FROM WABAN SHEETS

In addition to the wind speed and direction data collected by the air monitoring network, meteorology information was transcribed from WABAN reports of weather observations at WAFB. Acoustic sounder data were appended to the WABAN information.

The meteorological data were coded on computer forms and typed on tape cartridges. Both were used in constructing a formatted 9-track tape (Met Tape). The process for creating this tape is described in Figure 1-4. Copies of the final Met Tape are in the possession of ANL in Chicago, WAFB in Arizona, and EMSL-LV in Las Vegas. The characteristics and format of the Met Tape are described below:

Met Tape

Characteristics:

Parity: Odd
Density: 800 BPI
Code: ASCII
Record Size: 132 characters
Blocking: 38 records/block
File Structure: Each tape contains one file, terminated by three tape marks (23 octal character). Each record is followed by an IRG (19 mm of blank tape).
Figure I-4. The process for creating the Met Tape.

I-14
Below is information specifying the values contained within each record of the tape and the location of each value within the record. (Also included is a U.S. Department of Commerce NOAA "Key to Aviation Weather Reports" for information.)

<table>
<thead>
<tr>
<th>8-Character ID Field</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Julian day (left-justified) Format A3</td>
</tr>
<tr>
<td>4-7</td>
<td>Hour</td>
</tr>
<tr>
<td>8</td>
<td>&quot;O&quot; (blank)</td>
</tr>
</tbody>
</table>

**Five 8-Character Cloud-Cover Fields**

Each field corresponds to one cloud layer. If layer is not present, blanks were reported as:

1. Blank or
   - "E" estimated height
   - "M" measured
   - "W" indefinite
   - "V" variable

2-4. Blank or (left-justified) A3
    - ceiling height in hundreds of feet above station

5. Blank or
   - "-" thin
   - "x" obscuration

6-8. Sky A3
     - "CLR" (clear)
     - "SCT" (scattered)
     - "BKN" (broken)
     - "OVC" (overcast)

**11-Character Visibility and Weather Field:**

1-2. Visibility, reported in statute miles A2

3-11. Weather and observations if any; otherwise blank A9

**3-Character Pressure Field:**

Only reported every 3 hours; otherwise blank. Sea level pressure in millibars, i.e., 132 reported = 1013.2

I-15
4-Character Temperature Field:
1
2-4
Delimiter "/" Degrees F A4

3-Character Dewpoint Field:
1
2-3
Delimiter "/" Degrees F A4

8-Character Wind Field:
1
2-3
Delimiter "/" WD in tens of degrees from true north A8
4-5
WS in knots
6-8
Blank or gusts in knots

5-Character Altimeter Setting Field:
1
2-4
Delimiter "/" Altimeter setting (first figure of report missing) A5
5
Delimiter "/" or blank

43-Character Comments Field:
1-43
Free-format comments A43

7-Character Acoustic Sounder Field:
1-7
Acoustic sounder data (left-justified) A7

DATA PRESENTATION

The data contained on the Tape II's and Tape III's were further processed for presentation in the following forms:

- Tabular listings of hourly averages along with the minimum, maximum, and averages for daily and hourly time periods
- Frequency and cumulative frequency data for NOX, CO, NMHC, and nephelometer
- Log-probability plots of the cumulative frequencies in item 2
Parameter-versus-time plots of minute data for each trailer for Julian days 027, 131, 272, and 364

Parameter-versus-time plots of hourly data for each month and trailer for the entire project

Data completeness summary

Microfiche of the tabular listings

Tabular listing of the meteorological data

A yearly wind rose for each of the five trailers

Tabular Listings

An example of the tabular listings is shown in Figure I-5. The tabular listings were produced on the DOE CDC-6400 computer using a program called Tabular Summaries Software. Standard processing procedure was to create a disk file from a Level III tape and then read the file for processing. A copy of the program is available on request.

Frequencies and Cumulative Frequencies

Frequency data were calculated for one year extending from July 1976 through June 1977 for NOx, CO, NMHC, and bscat. The data for these parameters were accumulated into a yearly file, and the frequency distribution was calculated for the whole year. Computation was done on the DOE CDC-6400. An example of the frequency data is shown in Figure I-6.

Log-Probability Plots

The cumulative frequency data calculated for the yearly period of July 1976 through June 1977 were plotted on log-probability paper. The probability scale on the x-axis is based on the normal law of error. Percent cumulative frequency was plotted on the probability scale and concentration was plotted on the logarithmic axis. An example of the log-probability plots is shown in Figure I-7.

Parameter-versus-Time Plots

Parameter versus time was plotted for both minute data and hourly data. In the case of minute data, the x-axis spanned 24 hours of time and the y-axis gave the concentration of a particular parameter for a particular trailer. For hourly data, the x-axis spanned a month of time and the y-axis showed the parameter concentrations for five trailers. Axes in all cases were linear. The time plots were produced on an HP-9825 system using a 9-track Cipher tape drive and an HP-9862 plotter. The parameters plotted were CO, NO2, NO, NMHC, bscat, WS, and WD.
### Data Completeness Summary

A summary of recoverable data was computed for June 1976 through June 1977 showing the percent of recoverable data for all parameters collected by the air monitoring network (Figure 1-8).

### Microfiche

A print tape of the tabular listings was produced, and this was used to generate a microfiche of the tabular listings. Four microfiche sheets (42x reduction) contain the 520 pages of tabular listings. The microfiche and print tape are available through the EMSL-LV.
Figure I-7. Example of yearly cumulative frequency distribution of CO.
<table>
<thead>
<tr>
<th>Month</th>
<th>Nitric Oxide</th>
<th>n/a</th>
<th>Methane</th>
<th>Total Hydrocarbons</th>
<th>Carbon Monoxide</th>
<th>Vehemometer</th>
<th>Vector Mean Wind Direction</th>
<th>Vector Mean Wind Speed</th>
<th>Total Hydrocarbon (methane)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
<tr>
<td>July</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
<tr>
<td>August</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
<tr>
<td>September</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
<tr>
<td>October</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
<tr>
<td>November</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
<tr>
<td>December</td>
<td>95.3</td>
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<tr>
<td>January</td>
<td>95.3</td>
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<td>95.3</td>
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<td>3.2</td>
</tr>
<tr>
<td>February</td>
<td>95.3</td>
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<td>3.2</td>
</tr>
<tr>
<td>March</td>
<td>95.3</td>
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<td>95.3</td>
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<td>3.2</td>
</tr>
<tr>
<td>April</td>
<td>95.3</td>
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<td>3.2</td>
</tr>
<tr>
<td>May</td>
<td>95.3</td>
<td>95.3</td>
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</tr>
<tr>
<td>June</td>
<td>95.3</td>
<td>95.3</td>
<td>95.3</td>
<td>94.3</td>
<td>94.7</td>
<td>95.7</td>
<td>95.7</td>
<td>95.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Figure I-8. Summary of recoverable data at WAFB for June 1976 through June 1977.
Meteorological Data

A tabular listing of the Met Tape was produced on the DOE CDC-6400. A sample of the listing is shown in Figure I-9.

Wind Roses

A yearly wind rose for each trailer at WAFB was plotted. The wind roses show the percent occurrence of a particular WD and the WS in each direction (see Section 4 for examples).

CONCATENATION (PACKING) OF LEVEL II TAPES

Level II tapes (395 reels) containing all the aeromatic minute data were concatenated on 20 731-m magnetic tape reels at 1600 BPI. Each concatenated tape contains approximately 20 files of minute data in engineering units. Each file contains a day of data. One set of concatenated Level II tapes has been transmitted to EMSL-LV and an ATLAS library tape copy has been kept on the DOE CDC-6400 computer. No other copies of this data have been made. Copies may be obtained by request to the EPA.

COMPUTER PROGRAMS OF DATA PROCESSING

The following computer programs are presented:

- Correction Program (HP-9825)
- Thumbwheel and Calibration Program (HP-9825)
- Engineering Units Program (HP-9)
- Hourly Averages Program
- Tabular Summaries Software

Following each program is a description of the steps in the program. Additional software is available on request.

Description of the Correction Program

L. 0 Comments
L. 1 Dimension statements
L. 2 Manual entry of last file constructed, which will be modified to construct next file
L. 3 Automatically loads above file into calculator from cassette tape

I-22
Correction Program

01 "WILLIAMS AIR FORCE BASE PROGRAM FOR CALCULATING CORRECTION ARRAY."
21 ".raw: "FILE TO LOAD"
41 ent "TRAILER NUMBER"
51 ent "first day" 100-9
61 ent "second day" 10-9
71 ent "time T1" T1
81 ent "time T2" T2
91 for I=1 to 6
101 Vr[I]=cross[i-1,4]+Ec[i-1,4]+Ec[i-1,4]+Ec[i-1,4]
111 if I=1 goto 12
121 if I=2 goto 13
131 if I=3 goto 14
141 if I=4 goto 20
151 if I=5 goto 21
161 if I=6 goto 22
171 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=30
181 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=31
191 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=32
201 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=33
211 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=34
221 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=35
231 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=36
241 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=37
251 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=38
261 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=39
271 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=40
281 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=41
291 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=42
301 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=43
311 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=44
321 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=45
331 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=46
341 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=47
351 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=48
361 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=49
371 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=50
381 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=51
391 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=52
401 dsp "JULIAN DAY FOR T1+NO",r1[1:0]=53
411 ent "INITIAL ZERO FOR NO",B0[1:1]=40
421 ent "INITIAL ZERO FOR NO",B0[1:1]=41
431 ent "INITIAL ZERO FOR NO",B0[1:1]=42
441 ent "INITIAL ZERO FOR NO",B0[1:1]=43
451 ent "INITIAL ZERO FOR NO",B0[1:1]=44
461 ent "INITIAL ZERO FOR NO",B0[1:1]=45
471 ent "INITIAL ZERO FOR NO",B0[1:1]=46
481 ent "INITIAL ZERO FOR NO",B0[1:1]=47
491 ent "INITIAL ZERO FOR NO",B0[1:1]=48
501 ent "INITIAL ZERO FOR NO",B0[1:1]=49
511 ent "INITIAL ZERO FOR NO",B0[1:1]=50
521 ent "INITIAL ZERO FOR NO",B0[1:1]=51
531 ent "INITIAL ZERO FOR NO",B0[1:1]=52
541 ent "INITIAL ZERO FOR NO",B0[1:1]=53
551 ent "INITIAL ZERO FOR NO",B0[1:1]=54
561 ent "INITIAL ZERO FOR NO",B0[1:1]=55
571 ent "INITIAL ZERO FOR NO",B0[1:1]=56
581 ent "INITIAL ZERO FOR NO",B0[1:1]=57
591 ent "INITIAL ZERO FOR NO",B0[1:1]=58
601 ent "INITIAL ZERO FOR NO",B0[1:1]=59
611 ent "INITIAL ZERO FOR NO",B0[1:1]=60
621 ent "INITIAL ZERO FOR NO",B0[1:1]=61
631 ent "INITIAL ZERO FOR NO",B0[1:1]=62
641 ent "INITIAL ZERO FOR NO",B0[1:1]=63
651 ent "INITIAL ZERO FOR NO",B0[1:1]=64
661 ent "INITIAL ZERO FOR NO",B0[1:1]=65
671 ent "INITIAL ZERO FOR NO",B0[1:1]=66
681 ent "INITIAL ZERO FOR NO",B0[1:1]=67
691 ent "INITIAL ZERO FOR NO",B0[1:1]=68
Manual entry of trailer number for which calibration or calibration check data is to be entered.

These routines allow manual entry of the values corresponding to the question in the display. These are stored until they are ready to be used in the construction of a correction array.

Calculates the initial and final times in minutes from the beginning of the year.

Selects the various components and sends the program to the appropriate place to calculate the correction arrays:

1 → NO
2 → NOx
3 → CH₄
4 → THC
5 → CO
6 → Neph

NO, NOx:

\[ T_2 - T_1 = r_8; \quad V_{01} - V_{02} = r_9; \quad r_9/r_8 = \text{minute} \Delta V_0 \]

\[ V_1 - V_{01} = r_5 \]

\( r_5 \) = conversion volts to ppm

\[ r_8 \times r_5 + r_8; \quad V_2 + r_6; \quad r_5 - r_6 + r_6 \]

\[ r_6/r_8 = \text{minute} \Delta V/V_i - V_{01} \]

NOTE:

Array descriptions:

\[
\begin{align*}
\text{NO, NOx:} & \quad B[B,I] = V_{01} \\
\text{CH₄, THC, CO:} & \quad B[B,I] = V_{01} = 0.0 \\
\text{Neph:} & \quad B[B,I] = V_{PA1} - 0.09 \\
C[B,I] & = \frac{V_{01} - V_{02}}{T_2 - T_1} \\
C[B,I] & = 0.0 \\
C[B,I] & = \frac{V_{PA1} - V_{PA2}}{T_2 - T_1} \\
D[B,I] & = \frac{C}{V_{01}} \\
D[B,I] & = \frac{G}{V_1} \\
D[B,I] & = \frac{\text{Freon} B}{V_{FR}} \left( \frac{1}{V_2 - V_{PA2}} + 0.09 \right) \\
E[B,I] & = \frac{(V_1 - V_{01}) - (V_2 - V_{02})}{(T_2 - T_1)(V_1 - V_{01})} \\
E[B,I] & = \frac{V_1 - V_2}{(T_2 - T_1)(V_1)} \\
E[B,I] & = \frac{(V_1 - V_{PA1}) - (V_2 - V_{PA2})}{(T_2 - T_1)(V_1 - V_{PA1} + 0.09)} \\
F[B,I] & = T_1 \\
F[B,I] & = T_1 \\
F[B,I] & = T_1
\end{align*}
\]
L. 76  \[ \text{CH}_4, \text{THC, CO:} \]
\[ \frac{C}{V_1} = \text{conversion volts to ppm} \]
\[ \Delta T \times V_1 = r_2 \]
\[ V_1 - V_2 = r_6 \]
\[ \frac{r_6}{r_2} = \frac{V_1 - V_2}{(T_2 - T_1) V_1} \]

L. 77-80  \[ \text{Neph:} \]
\[ V_{PA1} + V_{PA2} = r_8; \]
\[ T_2 - T_1 = \Delta T \]
\[ \frac{r_8}{r_2} = \frac{V_{PA1} - V_{PA2}}{\Delta T} \]
\[ 3.6/V_{FR} = r_7; \]
\[ V_{PA1} + .09; \]
\[ V_{PA1} + .09 + r_10 \]
\[ r_9/r_10 = r_10; \]
\[ r_9 \times r_7 = \text{Freeon 8} \]
\[ \frac{V_{PA1} + .09}{(V_{PA1} + .09)} \]
\[ V_{PA1} - V_{PA2} = r_10; \]
\[ \Delta T \times r_9 = r_9; \]
\[ r_10/r_9 = \frac{(V_{PA1}) - (V_{PA2})}{(T_2 - T_1)(V_{PA1} + .09)} \]
\[ V_{PA1} - .09 = V_{PA1} \]

L. 81-85  Outputs comments to printer

L. 86  Records file just created to cassette tape

L. 87-121  Outputs to printer; the file just created

L. 122-123  Zeroes all values for construction of new file

Description of the Thumbwheel and Calibration Program

L. 0  Comments

L. 1-3  Dimension statements

L. 4  Manual entry of tape number

L. 5  Automatic entry of year

L. 6-7  Manual entry of dismount time and clearing of flag 1 for halt at midnight

L. 8-13  Output to printer for identification purposes

L. 14-31  Initialization

L. 32-47  Read routine with check for proper number of characters
Thumbwheel and Calibration Program

31: 'WILLIAMS AIR FORCE BASE PROGRAM FOR THUMBWHEEL: HWB: AL DATA':
32: dim X(150),Y(150),Z(150),W(150),V(150),U(150),A(150),B(150),C(150)
33: dim X(5,150),Y(5,150),Z(5,150),W(5,150),V(5,150),U(5,150),A(5,150),B(5,150),C(5,150)
34: dim D(150),E(150),F(150),G(150),H(150),I(150),J(150),K(150),L(150)
35: dim A(150),B(150),C(150),D(150),E(150),F(150),G(150),H(150),I(150),J(150),K(150),L(150)
36: dim M(150),N(150),O(150),P(150),Q(150),R(150),S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
37: dim R(150),S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
38: dim T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
39: dim N(150),O(150),P(150),Q(150),R(150),S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
40: dim P(150),Q(150),R(150),S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
41: dim Q(150),R(150),S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
42: dim R(150),S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
43: dim S(150),T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
44: dim T(150),U(150),V(150),W(150),X(150),Y(150),Z(150)
45: dim U(150),V(150),W(150),X(150),Y(150),Z(150)
46: dim V(150),W(150),X(150),Y(150),Z(150)
47: dim W(150),X(150),Y(150),Z(150)
48: dim X(150),Y(150),Z(150)
49: dim Y(150),Z(150)
50: dim Z(150)
51: dim 'MONDAY', 'TUESDAY', 'WEDNESDAY', 'THURSDAY', 'FRIDAY', 'SATURDAY', 'SUNDAY'
52: dim 'THUMBWHEEL'
124: sec 21ort "WIND DIRECTION";ort "AND NEPHELOMETER";ort "CALIBRATION DATA"
125: sec 2
126: for B=1 to 5
127: for D=1 to 7
128: if K(B,D)=0;goto 4
129: end ort "TRAILER";ort "";WD ";O;print 1
130: for I=1 to K(B,D);end ort I(B,K);I(K,I);I(I,D)+=1;endl
131: sec 15;K(B,D)=ort V10;V25;sec 2
132: if L(B,D)=0;goto 4
133: end ort "TRAILER";ort "";NEPH ";O;print 1
134: for L=1 to L(B,D);end ort I(B,K);I(K,L);I(L,I)+=2;endl
135: sec 1C (B,D)=ort Z10;Z25;sec 2
136: next D
137: next B
138: sec 21ort "CH4", THO; END "CALIBRATION DATA";sec 2
139: for B=1 to 5
140: for D=1 to 3
141: if G(B,D)=0;goto 4
142: end ort "TRAILER";ort "";CH4 ";O;print 1
143: for G=1 to G(B,D);end ort I(B,G);I(G,B);G=0;endl
144: sec 1F (B,D)=ort U10;U25;sec 2
145: if H(B,D)=0;goto 4
146: end ort "TRAILER";ort "";THO ";O;print 1
147: for H=1 to H(B,D);end ort I(B,H);I(H,B);H=0;endl
148: sec 1V (B,D)=ort V10;V25;sec 2
149: if I(B,D)=0;goto 4
150: end ort "TRAILER";ort "";CO ";O;print 1
151: for I=1 to I(B,D);end ort I(B,I);I(I,B);I=0;endl
152: sec 1W (B,D)=ort W10;W25;sec 2
153: next D
154: next B
155: use "save at midnight";beep;beep;beep
156: "PRT":
157: end ort "TRAILER";ort A[4,9];ort A[11,20];sec 1
158: ret
L. 48 Assignment of trailer number to B

L. 49-54 For trailer 1, E is the counter and if equal to 1, then the thumbwheels are stored for comparison and printed out. If E does not equal 1, then current value is compared with stored value. If they are the same, program continues; if not, then the thumbwheel values and time are printed out.

L. 55-60 Same as above for trailer 2 except F is the counter

L. 61-66 Same as above for trailer 3 except G is the counter

L. 67-72 Same as above for trailer 4, except H is the counter

L. 73-78 Same as above for trailer 5, except I is the counter

L. 79-80 Check to see if tape has passed midnight and is at the end; if so, thumbwheels are printed out.

L. 81-107 The following routines check each thumbwheel individually for a calibration or calibration check value. If the thumbwheel is not one of these values, the program continues. If it is a calibration value, then the value is stored in an array made up of the trailer number and thumbwheel value. Each has a counter so that only the proper number of values is stored.

L. 108 Check to see if tape is at midnight. If so, flag 1 is set and calibration values are output.

L. 111-117 The following routines output the calibration or calibration check data to the printer under the appropriate heading. First the counters are checked and, if zero, no output occurs. If other than zero, the trailer number and appropriate component and thumbwheel value are output. These are followed by the individual calibration and calibration check values. These are averaged and the average is output. As an example, NOx will be used.

L. 118 Counter check

L. 119 Output trailer number and component, and skip a space.

L. 120 Print out and add up the individual values.

L. 121-123 Skip a space, calculate the average. Output the average, skip two spaces, and go on to the next trailer.

L. 155 Alert operator to change tapes.

L. 156-158 End of program
Description of the Engineering Units Program

L. 0  Dimension statements and assignment of record length

L. 1-2  Manual loading of correction file

L. 3  Buffer size and type

L. 4-17  Initialization and setting up of table

L. 18-38  Tape read with check for record size and proper characters

L. 39  Value assignments:
   B = Trailer number
   E = Time in hours, minutes, seconds
   r3 = Day in minutes
   r4 = Hour in minutes

L. 40  Value assignments:
   73 = J = day
   073 + J$[1,3]$  
   r11 = Hour
   r12 = Minutes
   r13 = Seconds

L. 41  Statement to allow for thumbwheel changes in a given trailer

L. 42-47  Statements to allow the skipping of a trailer for calibration, calibration check, or any other reason desired

L. 48  x = Time in minutes

L. 49  Check to make sure the day is correct.

L. 50  C = NO voltage value; if thumbwheel = 9, then C is set equal to -9.9999. D is thumbwheel number.

L. 51  NOx voltage value; if thumbwheel = 9, then F is set equal to -9.9999. G is thumbwheel number.

L. 52  Same as above except for CH₄

L. 53  Same as above except for THC

L. 54  Same as above except for CO

L. 55  Same as above except for wind speed

L. 56-58  Same as above except for wind direction. A test is made to correct for an overshoot when direction passes the 8° null band.

L. 60  Same as above except for nephelometer
If the trailer number is 4, then a value (pyranometer) is given to \( V \); otherwise it is zero.

For NO, thumbwheel is checked for proper value. If OK, then, at this point, changes may be made to the data. In this case, NO value for trailer 3 was changed to correct for a problem, then the following calculation was made for all trailers:

\[
ppm = \left( \frac{V_{11} - V_{01}}{T_2 - T_1} \right) \left( \frac{V_{11} - V_{01}}{V_{11} - V_{01}} \right) \left( \frac{V_{11} - V_{01}}{V_{11} - V_{01}} \right)
\]

Same as above except for NO\(_X\). NOTE: Refer also to Correction Array Program for explanation of variables.

Same as above except for CH\(_4\) and equation:

\[
ppm = \left( \frac{V_{11} - V_{2}}{V_{11} - V_{2}} \right) \left( \frac{1 + T_i}{(T_2 - T_1)} \right)
\]

Same as above except for THC

Same as above except for CO

For nephelometer and calculate following:

\[
\beta = \left( \frac{V_{P11} - V_{PA2}}{T_2 - T_1} \right) \left( \frac{V_{P11} - V_{PA2} + 0.09}{V_{FR1}} \right) \left( \frac{V_{P11} - V_{PA2} + 0.09}{V_{P11} - V_{PA2} + 0.09} \right)
\]

Assigns first 20 characters on 7-track to first 20 characters on 9-track.

This checks each component for obviously wrong values.

Assigns values to array for writing to 9-track

Writes on 9-track

These statements read in correction arrays at specified times. Manually input.

Indicates tape is at end and must be replaced to continue.
<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. 116</td>
<td>Indicates that tape is at midnight</td>
</tr>
<tr>
<td>L. 117-118</td>
<td>Sets up buffer and clears interrupt</td>
</tr>
<tr>
<td>L. 119-122</td>
<td>Various programs for correcting recurring errors in records and changes from tape to tape</td>
</tr>
<tr>
<td>L. 123</td>
<td>Counter for number of records written on 9-track. This is outputted to the printer.</td>
</tr>
</tbody>
</table>

Description of Hourly Averages Program

<table>
<thead>
<tr>
<th>Line</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L. 0-7</td>
<td>Title header and comments</td>
</tr>
<tr>
<td>L. 8-9</td>
<td>Dimension statements</td>
</tr>
</tbody>
</table>
| L. 11-17 | Variable initialization  
Minimum value array filled with 999 |
| L. 18 | Manual entry of Julian day of tape |
| L. 28-29 | Automatic entry of stop and start times |
| L. 30-31 | Start time in hour, minute, second, reduced to hours plus 1/2 hour |
| L. 32-37 | Auto entry of stop and start times |
| L. 38-39 | Buffer size and type  
Decimal mode |
| L. 40-42 | Interrupt read routine |
| L. 43 | Start tape drive, transfer 93 characters  
Start of mainline |
| L. 45 | End of interrupt read routine |
| L. 46-48 | Interrupt service routine |
| L. 49 | Read Buffer into a $ |
| L. 50-51 | Test string for proper length |
| L. 55 | If improper, increment counter and reject record |
| L. 56 | Extract record time, convert to seconds |
| L. 57 | Station ID number = B |
| L. 58 | Test for valid station ID |
Hourly Averages Program
FiFE MINUTE TI:O HIIUP H.EPR'AE
'WILLIRM
" TRAF:1. ASOC:: T: ?TR:ACR
R1: mI 1
"SY
NICK PEE--E
Ch07,
POPDS":
R'E'
"F10
-:HRCTER

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OF SHIFTED TRFE I RE:ORD:I
"AUTO LOADING OF :'TART STOP TIIES':
'I
'NO MET READS OF ROUTINE'"
2[4-]-EE
)$[2,$E2rlO.ESC-OJc0-E!ICI:-:1O],
A$[v O],DSIC 10,B
A3:
I,:[
<
, 3, . 5, --,I HE "61
l: 3OJ30

': ".EADINIG

1 :

-k 0
1 14;=t . 4; " '-D IE1- i0
',,r-1=15 ,,o !65 L., 30
' r J=1 To 5

14:

?'' c I+J ]

I6

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I'?:

it-it JULIAN DAY OF TAPE"'E
e.nt "IF COLD START ENT.
1 OTHERWISE
12-r46;it r-45=1.1-r46; ,, 2

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11:

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0", r4

- 'MAKE SiJRE TAPE E-I, "1S M0UNTED" -Trit
READ DATA CART. " O=',E'S I =NO", r

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CPFTCH CRT I':- LOADED": :TF
rk o ;1,Jt-'1 ICE'45;t,
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4t -':, r 1=1 to 40 '0-DEI ) ;r,:xt I
I'-t St.rt tie
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'MAKE

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r :.

WIF[10

]


6-1 or B:51+42+1-r42iato 78
591 if val:R[5,101] 20000011-r42+r42iato 30
601 ir not r451.ir W=313ory R[5,101] 78
611 to not r451.ir W=313ory R[5,101] 78
621 ir r451.ir W=313ory R[5,101] 78
641 ir not r451.ir W=313ory R[7,101] 300011-r46
651 to r451.ir W=313ory R[7,101] 15-r46
561 to 2
671 ir r451.ir W=313ory R[5,101] 7
681 ir r451.ir W=313ory R[5,101] 7
691 ir not r451.ir W=313ory R[5,101] "T"
701 ir r451.ir W=313ory R[5,101] "END"
711 ir not r451.ir W=313ory R[5,101] "T"
721 ir not r451.ir W=313ory R[5,101] "T"
731 ir not r451.ir W=313ory R[5,101] "T"
741 ir not r451.ir W=313ory R[5,101] "T"
751 ir r451.ir not I1-5mab "T"
761 ir r451.ir not I1-5mab "WRITE"
771 ir r451.ir not I1-5mab "C"
781 bur "A"
791 ir not r19ion err "ERROR" 1=9
301 ire
311 "C"
321 val:R[3,10] =364000+W-
331 =val:R[2,20] =C1+val:R[10,12]-D
341 val:R[20,32] =F1+val:R[14,14]+r
351 val:R[38,44] =H1+val:R[15,15]+r
361 val:R[46,12] =L1+val:R[15,16]+r
371 val:R[44,38] =L1+val:R[17,17]+r
381 val:R[52,68] =r1+val:R[19,18]+r
391 val:R[72,72] =r1+val:R[19,18]+r
401 val:R[74,44] =T1+val:R[20,20]+r
411 ir B=441+val:R[38,32]+r41+r36+L=0675+r36
421 ir r1+r1.011+r1.010+r1.04+r1.4
431 ir #=tjune 8
441 ir B=4ur .B.D.O.C
451 ir B=4ur .B.D.O.P
461 ir B=4ur .B.O.K.H
471 ir B=4ur .B.O.L
481 ir B=4ur .B.O.H
491 ir B=4ur .B.O.T
501 ir B=4ur .B.O.2.r+1
511 ir B=4ur .B.O.4+r3
521 ir "NON"
531 "NON---1"
541 ir D==0 or D=#=tjune 2
551 ir D=to 114
561 ir C=.05 or C=.431+853+1-HCB1+6-HCB1+114
571 ir D=1-8CEB3
581 ir C=CEB3-8CEB3
591 ir C=C(5+8)+C(5+8)
601 ir C=8CEB3
611 ir C=C(b+8)+C(5+8)
621 ir C=C(8+8)+C(5+8)
631 ir C=C(5+8)+C(5+8)
641 ir C=8CEB3
651 "NON"
661 "NON---1"
671 ir G=0 or G=#=tjune 2
681 ir D=to 114
691 ir F=.05 or F=.431+853+1-HCEB+5+1-HCEB1+114
I-39:

123:  FF[i(25 + E) + 1] = FF[i(25 + E) + 1] + 1
125:  if F [150 + B] [1] = F [150 + B] [1] + 1
126:  if F [150 + B] [1] = F [150 + B] [1] + 1
127:  "CH4":
128:  "CH4---":
129:  if H[0] = 1 or H[1] = 1
130:  if M[0] or M[1] = 1
131:  goto 142
132:  if H = 1.1 or H = 1.1 + H[E+10] = 1 + H[E+10] + 1
133:  "THC":
134:  "THC---":
135:  if M[0] or M[1] = 1
136:  goto 155
138:  "CO":
139:  "CO---":
140:  if S[0] or S[1] = 1
141:  goto 160
142:  if N[0] = 0 or N[1] = 1
143:  goto 160
144:  if N[0] = 0 or N[1] = 1
145:  goto 160
146:  if N[0] = 0 or N[1] = 1
148:  "NEPH":
149:  "NEPH---":
150:  if U[0] or U[1] = 1
151:  goto 179
152:  if T = 0 or T[9.9] = T[9.9] + 1
153:  goto 179
155:  goto 179
157:  goto 179
159:  goto 179
170:  goto 179
172:  goto 179
I-41
310:  /* REJECT VALUES */
311:  fixd 0
312:  if [H[1]@01{rt "NO"+H[1]}
319:  fixd 4
320:  spec 2
321:  next 1
322:  /* end filters */
323:  "END CK":
324:  if (R<30) ->374 137H #7
325:  37/H*60+371+38+38
326:  if R=11-999+r38
327:  if R1+219+202+CE1+145]}
328:  if R1+257-F[1]+25]"t[1+175]}
329:  next 1
330:  fnt 1+zrc259
331:  fnt 2+zrc235
332:  fnt 3+zrc8
333:  fnt 4+zrc98
334:  fnt 5+zrc94
335:  fnt 6+zrc94
336:  fnt 7+zrc72
337:  wti 0:3
338:  for I=1 to 5
339:  str(I)+D$59,10)D$9,9)+I .ESPeJ 3.3D$E1,8)
340:  for J=0 to 225 by 5;wrt 3.6,CE1+J3;next J
341:  if J=4 ert 3.5r371r38
342:  if J=4 ert 3.4+EF1+90]
343:  if J=4 ert 3.7+EF1+72]
344:  wait 10
345:  wti 6.177800w5 16.177400
346:  for I=1 to 5
347:  str(I)+D$9,101D$9,9)+I .18)wrt 3.3D$E1,8)
348:  for J=0 to 225 by 5;wrt 3.6,CE1+J3;next J
349:  if (I@4) ert 3.5r371r38
350:  if (I@4) ert 3.4+EF1+90]
351:  if (I@4) ert 3.7+EF1+72]
352:  wait 10
353:  wti 6.177800w5 16.177400
354:  next 1
355:  "TO PRINT EACH RECORD, STORE J=0 TO 2 AFTER THE COLON":
356:  "PRINT BYPASS" 1 to 364
357:  for I=1 to 5
358:  str(I)+D$9,101D$9,9)+D$9,8)
359:  err D$[1+8]1 fixd 4
360:  for J=0 to 225 by 5
361:  err [1+J]
362:  next J
363:  next I
364:  for I=1 to 23010+CII)next I
365:  for I=1 to 3518+CII)next I
366:  for I=15 to 185 by 30
367:  for I=1 to 5
368:  999+CII]}
369:  next J
370:  next I
371:  for I=1 to 3010+CII)next I
372:  0=37+r42+R
373:  wti 0:2
374:  ret
375:  "ERROR":cfe 9lu1 0:31w1 6:177400
376: if ron=69; if ern=51; if erl=39; buf "A" goto 39
377: if ron=69; if ern=51; if erl=43; buf "A" goto 78
378: if ron=0; if ern>40 and ern<66; dsmp "CARTRIDGE DECK DOWN"; goto
379: if ron=0; if ern=15; dsmp "PRINTER OUT OF PAPER, OR DOWN"; goto
380: mnt a$[4:9]; ron; ern; arl; goto 9
381: goto
382: goto
383: buf "A" goto 39
384: dsmp "HELP! call a human! HELP!"; beep; wait 1000; goto
385: END:
386: fxz 0; dsmp "TAPE"; "COMPLETE"
387: goto
388: goto
389: for J=25 to 175 by 30
390: for I=1 to 5
391: goto
392: goto
393: next J
394: next I
395: goto 338
396: goto
397: if S=1; goto (A$[5; 10])+r4712+17+r5010+r49
398: r50=1+r50
399: if r50<31167400+2
400: if r50>31173400+2
401: goto
402: if r50=61; goto 78
403: if r50>21; goto (A$[5; 10])+r49+r49
404: if r50=31+r49/3+r49/3+r49/3+r49/3 or r49<r4712+r49
405: if r50=1; if r49<110+5=501apc 21; port "BAD RECORD AT"; r471173400+21; goto 76
406: if r50=0; goto (51173400+21; ret
407: goto 78
408: goto 78
L. 59-60 Test if record time is less than start time 1
L. 62-68 Tests for end of hour
L. 70 If end of tape go to "END" or end of stop time 2
L. 73-74 If end of stop time 1, rewind tape, display message Stop
L. 76 If end of hour, go to subroutine "WRITE"
L. 77 Go to subroutine "C"
L. 78 Clear buffer
L. 79 Error recovery, go to subroutine ERROR
End of mainline
L. 80 End of interrupt service routine
L. 81 Start of subroutine "C"
L. 82 Extract total time into seconds = X
L. 83 C = NO value
D = NO thumbwheel
L. 84 F = NO$_x$ value
G = NO$_x$ thumbwheel
L. 85 H = CH$_4$ value
K = CH$_4$ thumbwheel
L. 86 L = THC value
M = THC thumbwheel
L. 87 N = CO value
O = CO thumbwheel
L. 88 R$_1$ = Wind speed value
R$_2$ = Wind speed thumbwheel
L. 89 R$_3$ = Wind direction value
R$_4$ = Wind direction thumbwheel
L. 90 T = NEPH value
U = NEPH thumbwheel
L. 91 Pyranometer value into units = R$_{36}$
L. 92-101 Utility routine to print single value  
\[ P = \text{Station No.} \]
If \( Q = 1 \) - NO  
2 - NO\(_X\)  
3 - CH\(_4\)  
4 - THC  
5 - CO  
6 - NEPH  
7 - WS  
8 - WD

NO Routine  
L. 102-105 Valid thumbwheel check  
L. 106-107 Filter to reject absurd values  
L. 108-110 Increment counter  
\[ \Sigma \text{NO} \]
\[ \Sigma \text{NO}\_2 \]

L. 111 Last value of hour  
Minimum and maximum value determination

NO\(_X\) Routine  
L. 114-118 Valid thumbwheel check  
L. 119 Filter to reject absurd values  
L. 121 Counter  
L. 122 \[ \Sigma \text{NO}\_X \]
L. 123 \[ \Sigma \text{NO}\_X\^2 \]
L. 124 Last value for hour  
L. 125-126 Minimum and maximum value determination

CH\(_4\) Routine  
L. 130 Valid thumbwheel check  
L. 132 Filter to reject absurd values  
L. 134 Increment counter  
L. 135 \[ \Sigma \text{CH}_4 \]
L. 136 \[ \Sigma \text{CH}_4\^2 \]
L. 137 Last value of hour
L. 138-139 Minimum and maximum value determination

THC Routine
L. 143 Valid thumbwheel check
L. 145 Filter to reject absurd values
L. 147 Increment counter
L. 148 THC
L. 149 THC²
L. 150 Last value of hour
L. 151-152 Minimum and maximum value determination

CO Routine
L. 156 Valid thumbwheel check
L. 158 Filter to reject absurd values
L. 160 Increment counter
L. 161 CO
L. 162 CO²
L. 163 Last value of hour
L. 164-165 Minimum and maximum value determination

NEPH Routine
L. 169 Valid thumbwheel check
L. 171 Filter to reject absurd values
L. 173 Increment counter
L. 174 NEPH
L. 175 NEPH²
L. 176 Last value of hour
L. 177-178 Minimum and maximum value determination

Wind Speed & Wind Azimuth Routine
L. 181 Valid thumbwheel check
L. 185-186 Filter to reject absurd values
Volts correction into degrees and meters per second

Increment

Store wind azimuth values into array C[*]

\[
\begin{align*}
\Sigma v_i \sin \theta_i &= \Sigma v_i \\
\Sigma v_i \cos \theta_i &= \Sigma v_i \\
\Sigma \sin \theta_i &= \Sigma \sin \theta_i \\
\Sigma \cos \theta_i &= \Sigma \cos \theta_i
\end{align*}
\]

\[
\begin{align*}
r_{10} &= \sin \theta_i \\
r_{11} &= \cos \theta_i \\
\Sigma v_i \sin \theta_i &= \Sigma v_i \\
\Sigma v_i \cos \theta_i &= \Sigma v_i
\end{align*}
\]

\[
\begin{align*}
r_{15} &= v_i^2 = v_{xi}^2 + v_{yi}^2; \quad \tilde{v}_i^2 = \tilde{v}_i = r_{16}
\end{align*}
\]

\[
\begin{align*}
ru'v' &= \Sigma v_i \\
ru'^2 &= \Sigma v_i^2
\end{align*}
\]

\[
\begin{align*}
\Sigma v_i^2 &= \Sigma v_i^2 \quad \text{stored in } C[216-220] \\
\Sigma v_i' &= \Sigma v_i' \quad \text{stored in } C[201-205] \\
\Sigma v_i'^2 &= \Sigma v_i'^2 \quad \text{stored in } C[206-210]
\end{align*}
\]

\[
\begin{align*}
\Sigma \text{Pyranometer}
\end{align*}
\]

Return from subroutine "C"

Header

Clear write subroutine fl

I-47
Manipulations for ID header to be written on tape

DAY HOUR MIN
NNN NN 00

Begin write and averaging routine

Statistical test for NO

If number of readings is less than 30, then -.00XX is entered for mean, RMS and where XX is the number of reading for the hour.

\[ \bar{X}_{NO} = \frac{1}{n} \sum_{i=1}^{n} x_i \]

\[ \sigma_{NO} = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - (\bar{x})^2}{n-1}} \]

\[ \text{RMS}_{NO} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} x_i^2} \]

Statistical test for NO\(_x\)

\[ \bar{X}_{NO_x} \]

\[ \sigma_{NO_x} \]

\[ \text{RMS}_{NO_x} \]

Statistical test for CH\(_4\)

\[ \bar{X}_{CH_4} \]

\[ \sigma_{CH_4} \]

\[ \text{RMS}_{CH_4} \]

Statistical test for THC

\[ \bar{X}_{THC} \]

\[ \sigma_{THC} \]
RMS\textsubscript{THC}

Statistical test for CO

\( \bar{x} \) CO

\( \sigma \) CO

RMS\textsubscript{CO}

Statistical test for NEPH

\( \bar{x} \) NEPH

\( \sigma \) NEPH

RMS\textsubscript{NEPH}

\( r^8 \) = number of WS, WD readings

WS, WD calculations

Statistical tests

\( \bar{V}_x = 1/n\Sigma V_x \)

\( \bar{V}_y = 1/n\Sigma V_y \)

\( \sin\theta = 1/n\Sigma \sin\theta \)

\( \cos\theta = 1/n\Sigma \cos\theta_i \)

\( \bar{v}_i = ws = 1/n\Sigma v_i \)

\[ \sigma_{ws} = \sqrt{\frac{\Sigma_{i=1}^n v_i^2 - n(\bar{v}_i)^2}{n-1}} \]

\( \bar{u}' = 1/n\Sigma u'^2 \)

\( \bar{v}'^2 = 1/n\Sigma v'^2 \)

Routine using the ATN function for correct quadrant

\( r_{22} = \bar{v}_x \)

\( r_{23} = \bar{v}_y \)

\( V_{mws} = \sqrt{\bar{v}_x^2 + \bar{v}_y^2} \)

\( r_{22} = \sin\theta \)

\( r_{23} = \cos\theta \)
L. 254-257  \( r_{25} = \) Quadrant correction

L. 258-259  \( WD = \arctan(\sin \theta / \cos \theta) \)

L. 264  \( r_{20} = \) Constant looping factor

L. 265-268  \( D_i = \left| WD_i - WD \right| : D_i \text{ always} < 180^\circ \)

L. 269  \( \omega WD \text{ calculation} \)

\[
\omega WD = \sqrt{\frac{n}{\sum_{i=1}^{n} D_i^2}}
\]

L. 270  End averaging loop

L. 271-323  Filters operator notes

L. 310  Print number of rejected values in mainline read

L. 323  End of filters

L. 325-327  \( r_{37} = \) Hour Pyro  24 hours

L. 328  End air quality averaging

L. 329  Test for first hour of processing for last record of hour difference

L. 330-337  Last observed concentration minus last observed concentration from previous hour calculations

\[
X_n - X_0 \text{ Calculations}
\]

\[
E[*] = \text{Last observed} \quad F[*] = \text{Previous hour last observed}
\]

L. 338-344  Format statements

L. 345  Prepare to use interface number 3

L. 347  Write data routine

Add station No. to header and write same

I-50
L. 348 Write data for respective station number
L. 350-351 Write blanks to make record = 511 characters
L. 352 IRG command to tape deck
L. 354 End write
L. 355 Print data utility
     End utility
L. 364 Zero data summation array, C[*]
L. 365 Zero number of records counter array, D[*]
L. 366-370 Fill minimum value locations of data array with 999
L. 371 Zero number of bad records counter array, H[*]
L. 372 Zero pyranometer for hour
L. 373 Prepare to use interface #2
L. 374 Return
     End of write routine
L. 375 Error recovery utility
L. 385 End of tape routine
L. 386 End of tape audio-visual message
L. 388 \( X_n - X_o \) first hour routine
L. 391 \(-999 + X_n - X_o\) locations on C[*]
L. 394 \( X_n - X_o \)
     Cosmetic "END"
Tabular Summaries Software

*FILE
*OLIST
*NOENOSG
*NOSCAN
*REM.
PROCEDURE : TABLE
*REM.
AUTHOR : M. J. LIPHOLN 7/7/77
*REM.
SECTION : SSD/LV
*REM.
FUNCTION : THIS PROCEDURE IS DESIGNED TO PROVIDE THE USER WITH THE CAPABILITY OF PRINTING HOUR AVERAGES TABLE DATA.
*REM.
*REM.
THIS PROCEDURE IS TOTALLY INTERACTIVE.
*REM.
+EXAMPLES:
*REM.
+IF PROCFILE IS A LOCAL FILE, THEN USE
*REM.
CALL (TABLE)
*REM.
+IF PROCFILE IS NOT A LOCAL FILE, USE
*REM.
CALLA (CALL+,LECMUL,P=TABLE)
*REM.
+SCAN
+SCAPE (SCONNECT(INPUT*,OUTPUT*))
+SET (INPUT*,OR=OSHT;EGF=OSHT)
+WAFA HOUR AVERAGES TABLE GENERATOR
+x
+ROUTE CARD PRIOMTY (= DIGITS) \\
+READ (RPI)
+ENTER THE PF NAME OF THE DATA FILE \\
+READ (NAME)
+ENTER THE MONTH (1 TO 12) \\
+READ (MONTH)
+ENTER THE YEAR (76 TH 77) \\
+READ (YEAR)
+TEXT (TAG)
+TAB+1000+PU+GPAWAR+FWAFS
+APlyOFF
+FIN (OUTPUT)
+TTACH (TAPE6,*NAME*10=K51=AF)
+E#NO (TAPE6)
+FIN+LMO+OPT=2
+NO SCAN
+IF
+TAIL (U)
+FTRRN (TAPE1,TAPE2,TAPE3,TAPE4,TAPE5,TAPE6,TAPE10,TAPE11)
+DISPO*OUTPUT
+UP (2+3)
+FIND (TAPF)
+COPYBF (TAPF*,OUTPUT*)
+FIN(TAPE)
+LOEST (PRINT*AF)
+COPY (TAPE9,PHI,1)
+SCAN
+CATALOG (PRINT+,NAME*PRINTFILE10=K51=AF,RP=999)
+NO SCAN
+TEXT (TAG)
+PROGRAM +IT2 (INPUT*,OUTPUT*,TAPE1,TAPE2,TAPE3,TAPE4,TAPE5
+TAPE6,IN=OUT,TAPE7=OUTPUT*,TAPE8=510,TAPE9)
+FIN=FINISH A LINE(3)+ANALOG3)+RUN (3)+FIN(9)

I-52
**THIS ROUTINE IS DESIGNED TO PRODUCE TABLES OF MEAN AVERAGES DATA**

* FOR THE WILLIAMS AIR FORCE BASE PROJECT, THE DESIGN IS SET UP TO HANDLE FIVE STATIONS (EACH HAVING SEVEN PARAMETERS).

(77/05/01) M. J. LIPPOLD -LOCKHEED ELECTRONICS CO., INC.

**MODIFICATION 1: REQUEST ADDITIONAL TABLE TO SHOW IMC-CME * (77/04/13) M. J. LIPPOLD -LOCKHEED ELECTRONICS CO., INC.

**MODIFICATION 2: REQUEST AVG AND MAX SHOWN FOR EACH DAY (77/05/30) M. J. LIPPOLD -LOCKHEED ELECTRONICS CO., INC.

**MODIFICATION 3: REQUEST FILTERING OF DATA VALUES (77/05/20) M. J. LIPPOLD -LOCKHEED ELECTRONICS CO., INC.

**CONTINUE**

* SET UP CONTROL PARAMETERS AND THE TITLE ARRAYS

**SCAN**

IF YEAR = 1974 THEN

IF YFLG = 2 THEN

IMONTH = CAU('MONTH'+1)'YFLG) - CAU('MONT'91YFLG)

IDS = CAU('MONTH'+1)'YFLG)

**ENDSCAN**

IFMT (1) =10M (10M+12)

IFMT (2) =10M

IPN (1) =10M

IPN (1) =10M

IPN (1) =10M

IPN (2) =10M

IPN (3) =10M

IPN (4) =10M

IPN (5) =10M

IPN (6) =10M

IPN (7) =10M

IPN (8) =10M

IPN (9) =10M

IPN (10) =10M
INPUT IS ASSUMED TO BE ON TAPE 8. TAPE 1-5 ARE USED AS
SCRATCH FILES. TAPE 4 IS THE OUTPUT FILE.

READ(?,3) (DAY+1)*36,10N,ITR,1(XLINE(1)*1=1)
3 FORMAT(13,2) XIV=6+9.4+9.4*36+8.18+8.18
IF(EOF(3)) Y=5

CONVERT NC AND NOA TO PPM.
5 XLINE(1)=XLINE(1)*1000.00
XLINE(2)=XLINE(2)*1000.00
IF(XLINE(3)*LT.0.0) XLINE(3)=XLINE(3)-1.0
DO 6 I=1,1+1
IF(XLINE(1)*LE.9.0) XLINE(1)=9.9
IF(XLINE(1)*GT.999.9) XLINE(1)=9.9
6 CONTINUE
IF(XLINE(7)*LT.0) XLINE(7)=9.9
IF(XLINE(8)*GT.50.0) XLINE(8)=9.9

CHECK THE DAY RANGES.

IF(IDAY.LE.105) IDAY=105
IF(IDAY.GT.365) IDAY=365
TOLD=IDAY

COMPUTE THC = CH4

XLINE(4)=9.9
ATLXLINE(4)=XLINE(3)
IF((XLINE(4)*NE.9.9) AND (XLINE(3)*NE.9.9)) XLINE(9)=ATLX

WRITE ON THE APPROPRIATE SCRATCH FILE.

WRITE(?,7) (XAY+1)*10NH,12*1,14+(XLINE(1)*1=1+1)
7 FORMAT(13,2) XIV=6+12.2+11.2+9.4*(1+1)
GOTO 4

RE-IND SCRATCH FILES
9 NO I=1+1
10 CONTINUE

I-54
110 CONTINUE
120 CONTINUE

COMPUTE MAX- AVG AND MAX...

0: DO 120 J=1,4+1
1: GO TO 130
2: EN
3: T=0.0
4: X=0.0
5: DO 140 J=1,4
6: IF TAB(J).LE.-5.0 GO TO 140
7: IF (TAB(J).GE.XL) XI=TAB(J)
8: IF XI=1
9: LT=AT=TAB(J)
10: CONTINUE
11: LT=40.0
12: CONTINUE
13: GO TO 140
14: CONTINUE
15: CONTINUE
16: CONTINUE
17: CONTINUE
18: CONTINUE
19: CONTINUE
20: CONTINUE
21: CONTINUE
22: CONTINUE
23: CONTINUE
24: CONTINUE
25: CONTINUE
26: CONTINUE
27: CONTINUE
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104: CONTINUE
105: CONTINUE
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111: CONTINUE
112: CONTINUE
113: CONTINUE
114: CONTINUE
115: CONTINUE
116: CONTINUE
117: CONTINUE
118: CONTINUE
119: CONTINUE
120: CONTINUE

NO- OUTPUT THE APPROXIMATE TABLE...

WRITE (4,300)
300 FORMAT (IT*)

IF (X(J,L)=X(J,K)) GOTO 75

11 FORMAT (1L19,4T4,1L7,4T4,1L7,4T4,1L7,4T4,1L7)

CONTINUE

75 CONTINUE

91 CONTINUE

IF (J<6) GO TO 170

140 FORMAT (2*AVG=F4.1,2*F5.1)

GOTO 170

161 CONTINUE

58 CONTINUE

COMPUTE AND OUTPUT PERCENTAGE OF README DATA...

170 PCT = (IPCNT / (NAYS * 24.0)) * 100.00

WRITE (4,71) PCT

71 FORMAT (//,4X,10.4,11*,IPERCENT OF DATA IN ABOVE TABLE IS,*,...
ALAS MY FRIEND, OUR AFFAIR HAS REACHED AN END.

SCAN

TEXT(TAB)

NOTE=IT(TAB)

* DO YOU WANT TO SEND IT OFF NOW ?

PREAD(ANS)

IF (TYP=$YES)

OUTE(TAB+OL=IN+11D+1C+PR=PR[1])

ENDIF

ENDPROC

ENTRY(OMN!)

ENDPROC
APPENDIX J

PROCEDURE FOR ACOUSTIC SOUNDER DATA REDUCTION
AT WILLIAMS AIR FORCE BASE

Meteorological data required for input to the AQAM Gaussian formulation are WS, WD, mixing depth, and stability class. The AQAM model computes these parameters using WABAN data files. WABAN data recorded on the Form 10 report the hourly meteorological observations from which parameters are developed for the model. A critical portion of this process is the interpolation of data points from the WABAN form since the codes used are not direct meteorological measurements and therefore may not be representative.

For these reasons, redundant meteorological data to provide more direct observation of mixing depth (and somewhat less direct information on stability) were provided with the use of the Aerovironment Acoustic Sounder. This device can be used to get continuous information about the mixing depth to provide data on the dispersion of pollutants in the lowest kilometer of the atmosphere.

The Aerovironment Model 300 used at WAFB was a monostatic acoustic radar (transmitter and receiver use the same antenna) that emits a sound pulse upward and listens for the echo return of the pulse as it is reflected from turbulence regions in the first 500 m aloft. It plots the echo return (in proportion to height) on a recording chart every few seconds, creating on the chart a continuous picture of the atmospheric conditions above the device.

INTERPRETING ECHO RETURN SIGNAL

An understanding of the turbulence type and meteorological conditions responsible for the echo returns is necessary to correlate these data to the computer calculations of mixing depth made from WABAN observations. A monostatic acoustic radar listens to the acoustic energy scattered at a 180° angle. Temperature inhomogeneities in the atmosphere are responsible for 180° backscatter of the transmitted 1600-HZ pulse of energy.

A short study was conducted by EMSL-LV personnel on October 23, 24, and 25, 1976, to obtain side-by-side measurements with a tethered balloon and acoustic sounder. The study consisted of: 1) low-level atmospheric temperature profiles, and 2) winds-aloft measurements using pilot balloons (pibals). These data aided in interpreting acoustic sounder charts and refining the coding technique that appeared on the WABAN meteorology tape transmitted to ANL.
Pibals were standard single-theodolite, North-Star-aligned, 30-g balloon observations of 10-minute duration. Radiosonde data height computations were produced by integrating the hydrostatic equation using a Hewlett-Packard calculator system.

The temperature data were acquired utilizing an Airco tethered balloon and winch system in conjunction with a Buekers Model 4700 telemetry receiving and recording system and a VIZ radiosonde. In the radiosonde, pressure was determined by a baroswitch that was activated by an aneroid capsule. This arrangement was calibrated to ambient pressure through reference to a portable aneroid barometer, which in turn had been calibrated to the mercurial barometer at the Williams weather office, approximately 900 m from the site of the soundings. When properly calibrated, the baroswitch yields information accurate to 1 millibar. Temperature was measured by a thermistor, which is accurate to 0.1°C. The element used during the Williams soundings was referred to as an Accu-lok sensor; it is precalibrated so that a known temperature value is associated with a specific resistance, which eliminates the necessity of a baseline calibration procedure. The life span of an element is effectively unlimited, providing its protective coating is not cracked or soiled.

By comparing analyzed temperature data taken from tethered balloon soundings to acoustic echo return on the recorder chart, the coding technique used for the acoustic sounder data was tested. Agreement between a stable radiation inversion (at indicated height) and changes in the in situ vertical temperature field from tethered balloon measurements was favorable. In this way, EMSL-LV combined two atmospheric profile measuring devices to help extract additional information (over a limited time) on stability and mixing heights. The meteorological data essential to the AQAM model can be compared to a continuous record from the acoustic sounder.

ACOUSTIC SOUNDER CHART ANALYSIS

An example analysis is provided to explain the coding technique adopted specifically for WAFB. The vertical range on the conducting chart paper represents 20–500 m AGL. Nominal chart speed was 30.5 mm/h; however, each chart had manually recorded one-hour time marks because chart speed was not always uniform.

Figure J-1 shows the acoustic data returns for two consecutive days in October 1976. The first 24-hour period was cloudy with occasional drizzle. The second night had clear nighttime skies. The acoustic data returns were significantly different on these two occasions. More typical of WAFB was the second night with clear skies.

The code is a 6-digit number for each hour in the format ABm DEn. The extreme right-hand number, n, is the specific phenomenon designation. The following is a list of the phenomena specific to the WAFB study and their code numbers:

1 = Radiation inversion (typical to nighttime desert)

J-2
Figure J-1. Example of acoustic sounder chart analysis.
2 = Drainage winds (dense air that flows downhill in mountain-valley terrain)

3 = Layered returns (used when sounding echoes are stratified indicating multiple layers)

4 = Inversion base lifting above ground from morning solar heating (usually limited to 1 or 2 hours at WAFB)

5 = Subsidence inversion (usually caused by synoptic-scale high pressure over the region)

6 = Frontal inversion

9 = Normal daytime return (alternating light and dark spikes that are defined as hot plumes or thermal spikes; sometimes the top of these plumes were in evidence)

In addition to specific phenomena delineated above with a code number, the third digit, m, was used to further explain effects that might be of use for interpretation. They are:

1 = Superimposed return apparently from noise, possible turbulence, or precipitation

2 = Daytime noise (this is an undetermined graying of the return associated with base activity causing background acoustical noise)

3 = Indicates a transition period (usually used in uncertain sounding return records where the daytime returns were changing to nighttime)

4 = Apparent mechanical turbulence superimposed

The AB and DE designations are always the heights in tens of meters, indicating either the top or bottom of the various layers defined in the n code. The specific use of AB and DE varies with the n phenomenon. An 00 code is used when AB or DE are not determinable. In the case of inoperative equipment, the code 999999 was used.

To better explain the coding technique, Figure J-1 has been annotated with time separations and analyzed average height values. The code for each hour appears in a 6-digit form above each averaged hour with the local time indicated at the bottom. To help the reader understand the approach used, four hours — 1800L, 2100L, 000L, and 0900L — are explained in greater detail:

1800L: At this time the sun had set and the atmosphere was changing from daytime unstable to nighttime stable. It is not clear whether the returns were diminishing thermals or stable air; therefore code 3 was used in the third digit to indicate the top of the returns are at 60 m. A 9 was used in the sixth digit (n location) to indicate the air was relatively unstable.
2100L: The evening inversion from radiation cooling has started. The 08 in the AB location indicated that the average top of the return was at 80 m. The code 1 in the n location indicated radiation inversion.

0000L: The echo returns are stratified during this hour, typical for this time of night at WAFB; hence the code number 3 is in the n position indicating layered return. The top of the layer averaged 180 m; hence the code 18 in the CD block.

0900L: The sun has risen and the inversion has started to lift. The code number 4 is placed in the n position. There was an apparent line of demarcation between the stable and unstable air. The air average base of the inversion for this time block was 180 m; hence 18 is coded in the AB location. The echoes extend off the chart, so 00 is used in DE to indicate unknown height.
APPENDIX K
CUMULATIVE FREQUENCY DISTRIBUTIONS

WAFB Hourly Averages For Parameters Measured Between July 1976 and June 1977

Figure K-1. Yearly cumulative frequency distribution for CO, station 1.

K-1
Figure K-2. Yearly cumulative frequency distribution for CO, station 2.
Figure K-3. Yearly cumulative frequency distribution for CO, station 3.
Figure K-4. Yearly cumulative frequency distribution for CO, station 4.
Figure K-5. Yearly cumulative frequency distribution for CO, station 5.
Figure K-6. Yearly cumulative frequency distribution for NMHC, station 1.
Figure K-7. Yearly cumulative frequency distribution for NMHC, station 2.
Figure K-8. Yearly cumulative frequency distribution for NMHC, station 3.
Figure K-9. Yearly cumulative frequency distribution for NMHC, station 4.
Figure K-10. Yearly cumulative frequency distribution for NMHC, station 5.
Figure K-11. Yearly cumulative frequency distribution for NO\textsubscript{x}, station 1.
Figure K-12. Yearly cumulative frequency distribution for NO\textsubscript{x}, station 2.
Figure K-13. Yearly cumulative frequency distribution for NO\textsubscript{x}, station 3.
Figure K-14. Yearly cumulative frequency distribution for NO\textsubscript{x}, station 4.
Figure K-15. Yearly cumulative frequency distribution for NOX, station 5.
Figure K-16. Yearly cumulative frequency distribution for nephelometer, station 1.
Figure K-17. Yearly cumulative frequency distribution for nephelometer, station 2.
Figure K-18. Yearly cumulative frequency distribution for nephelometer, station 3.
Figure K-19. Yearly cumulative frequency distribution for nephelometer, station 4.
Figure K-20. Yearly cumulative frequency distribution for nephelometer, station 5.
REFERENCES FROM APPENDICES


35. Federal Register 41(232);52687, December 1976.


