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The Airborne Sampling Program for the 1992 ARB Southern California Transport Assessment Study

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Research Division

The Airborne Sampling Program for the 1992 ARB Southern California Transport Assessment Study

Final Report

Contract No. A132-162

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DISCLAIMER

The statements and conclusions in this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

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The work described in this report was funded by the California Air Resources Board (ARB). The Research Division of the ARB was responsible for administration of the contract, and Mr. Chuck Bennett was the ARB project officer until his retirement at the end of 1992. Dr. Bart Croes was the interim project officer who was followed by Mr. Leon Dolislager.

The extra efforts of the ARB meteorology staff in preparing daily weather and pollution forecasts for this program are noteworthy. In particular, the efforts of Mr. Dennis King and Mr. Steve Gouze are noted. During daily briefings for the field crews, their knowledge, cooperation, and dedication contributed to the success of the program.

During the summer period of the program, the aircraft was used on a non-interfering basis for both the ARB sampling program and Southern California Edison's (SCE) "Project Mohave". If the aircraft was not being used for the ARB program, it then was made available to SCE for their program. The cooperation of Mr. Chuck Bennett (ARB) and Dr. Rob Farber (SCE) in making this arrangement work contributed to both programs. Extra data (e.g., nephelometer measurements and tracer gas samples) were collected for ARB because of extra instrumentation installed aboard the aircraft for the SCE program. A performance audit performed for the SCE program also provided further assurance of the quality of the ARB data.

Mercado-Gardner, a Minority-owned Business Enterprise (MBE), contributed to the production of the Data Volume that was produced for this program. Art Scholl Aviation, a Woman-owned Business Enterprise (WBE), provided the base of operations and other aviation related services used by the aircraft.

This report was submitted in fulfillment of ARB Contract No. A132-162, "Three-Dimensional Air Quality Monitoring in Support of Transport Assessments" by Sonoma Technology, Inc. (STI) under the sponsorship of the California Air Resources Board. Work was completed as of March 1, 1994.

ABSTRACT

The California Air Resources Board (ARB) sponsored a meteorological and air quality data collection program in Southern California during the summer and fall of 1992. During the field measurement portion of the program, continuous upper-air wind and temperature data were collected using radar wind profilers. Additional air quality and meteorological measurements were made during 13 sampling flights performed by an instrumented aircraft.

The aircraft data were previously reported to the ARB in a separate data volume and are not included herein. This report documents the airborne sampling that was performed. The report details the sampling instrumentation used, the operation procedures followed, and the quality assurance steps used to produce the data that were reported.

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1. INTRODUCTION

The California Air Resources Board (ARB) sponsored a meteorological and air quality data collection program in Southern California during the summer and fall of 1992. During the field measurement portion of the program, Radar Wind Profilers (RWPs) were operated by the National Oceanic and Atmospheric Administration (NOAA) to collect continuous upper-air wind and temperature data, and an aircraft operated by Sonoma Technology, Inc. (STI) was flown on selected days to collect air quality data aloft. Data from these measurements will be used by the ARB to assess the transport of ozone and ozone precursors between air basins in the Southern California area.

At the beginning of the measurement program, NOAA sited their RWPs to document transport between the South Coast Air Basin (SoCAB) and the Southeast Desert Air Basin (SEDAB). During the second half of the program, several of the RWP sites were moved in order to study transport between the SoCAB and the San Diego Air Basin (SDAB). To coordinate the measurements made by the aircraft and the RWPs, the airborne sampling program was split into two parts (July 21 - August 13 and October 14 - November 3, 1992).

During the two study periods, a total of 13 flights were flown by the aircraft. The aircraft was instrumented to make real-time (continuous) measurements of various meteorological and air quality parameters. During sampling, the aircraft also collected grab samples that were analyzed for Reactive Organic Gases (ROGs). These data were processed and reported to Dr. John Holmes of ARB's Research Division in a separate data volume report entitled Data Collected by the STI Aircraft During the 1992 ARB Southern California Transport Assessment Study (Anderson et al., 1993). The real-time data and the results of the ROG analyses were reported in both hard copy and magnetic media formats.

During the ARB measurement program, Southern California Edison (SCE) was conducting a separate study entitled "Project Mohave". One element of the SCE program consisted of tracer gas releases within the ARB study domain. Under a cooperative sampling agreement between SCE and the ARB, SCE provided a tracer sampling system and collection media for use aboard the aircraft during ARB sampling flights. Although SCE will report the results of the tracer analyses directly to the ARB when they become available, this report will document the activities associated with the collection of the tracer samples.

This report documents the various operational aspects of the STI airborne sampling program. The data have previously been reported (Anderson et al., 1993) and will not be duplicated herein. Instead this report describes how measurements were made, how sampling days were selected, the objectives of the aircraft sampling program, and what QA/QC and data processing procedures were used to produce the data that were reported.

Section 2 of this report presents an overview of the aircraft sampling program. The section begins with an outline of the objectives of the aircraft sampling program. A general

overview of the aircraft program follows, and the section ends with a summary of the sampling performed by the aircraft.

Section 3 discusses the flight patterns that were used during the sampling flights and shows typical examples. The section also describes the rationale for each pattern that was flown.

Details of the sampling platform, the sampling instrumentation, and systems aboard the aircraft are described in Section 4.

Section 5 describes operational procedures that were used during the aircraft program. The section begins with a discussion of the selection of sampling days, general aircraft related procedures follow, and the section ends with a description of the sampling procedures associated with the collection of ROG and tracer gas samples.

Section 6 presents general quality assurance steps that were followed throughout the program. The section also describes the calibration equipment used during the program and the quality assurance procedures associated with calibration equipment. The section ends by presenting the results of the three performance audits that were performed during the program.

Section 7 discusses the data processing steps that were followed to convert the raw (as recorded aboard the aircraft) data into final engineering unit validated data.

General comments on the data are contained in Section 8. This section points out some measurements that were not required but that were made and reported. The validity levels for these extra data are stated in Section 8.

Section 9 lists the references used in this report.

2. PROGRAM OVERVIEW

2.1 OBJECTIVES

The general objective of the airborne air quality measurements was to provide upper-air air quality measurements to complement continuous upper-air wind and temperature measurements that were made by NOAA using Radar Wind Profilers (RWPs). Specific objectives of the aircraft measurements were to provide data that could be used by ARB for many types of analyses, including:

- documenting ozone and ozone precursor transport between air basins;
- estimating pollutant fluxes between air basins (using the winds from the radar profilers);
- providing aloft pollutant data to enhance meteorological analyses of transport processes;
- documenting the mixed-layer characteristics (mixed-layer depth, degree of mixing, existence of multiple layers, etc.) in source and receptor regions; and
- comparing these results with the results from the radar profilers.

2.2 GENERAL OVERVIEW

NOAA operated seven RWPs from June through October, 1992, to document pollutant transport between the South Coast Air Basin (SoCAB) and the Southeast Desert (SEDAB) and San Diego (SDAB) air basins. STI provided airborne air quality measurements to complement the profiler measurements.

The aircraft was available for sampling during two periods. The first period (called the summer period) was from July 21 through August 13, 1992. Sampling performed during this period focused on SoCAB-SEDAB transport couples. The second period (the fall period) was from October 14 through November 3, 1992 and sampling was designed to focus on the SoCAB-SDAB transport couple. During both periods, the aircraft and crew were based at the Rialto, CA Airport. Each flight began and ended at the Rialto Airport.

Sampling days for the aircraft were selected by the ARB staff on a forecast basis. Forecasts were prepared and discussed with the flight crew each afternoon. A final "go" decision was made the evening before sampling was performed.

Normally, two flights per day were flown on each day that had been selected for sampling. During the summer period, the first flight of the day normally began about 0500

and ended between 0830 and 0900 PDT. The second flight began about 1500 and ended between 1830 to 1900 PDT. For the summer period, the following days were selected for sampling:

- July 27, 1992 — two flights;
- July 30, 1992 — after discussion and agreement of the ARB staff, only one flight was performed due to an equipment failure and unexpected weather conditions;
- August 1, 1992 — two flights;
- August 4, 1992 — two flights;
- August 9, 1992 — two flights; and
- August 13, 1992 — two flights.

During the fall period, unfavorable sampling conditions existed throughout the scheduled study period (October 14 through October 28, 1992). Thus, the aircraft program was extended through November 3, 1992. Two flights were flown on November 2, 1992. Sampling on November 2, 1992 was performed from about 0700 to 1030 and 1400 to 1730 PST.

2.3 SUMMARY OF SAMPLING PERFORMED BY THE AIRCRAFT

During the two sampling periods, the aircraft:

- flew 13 flights during which about 45 hours of continuous (real-time) sampling data were collected;
- performed 94 spirals;
- flew 11 traverses;
- performed one orbit to collect a special ROG sample;
- collected 65 ROG grab samples; and
- collected 28 grab samples (summer program only) for tracer gas analyses.

3. FLIGHT PATTERNS

Prior to each sampling period discussed in the following sections, the sampling (flight) patterns to be used by the aircraft were reviewed with, and approved by, the ARB staff. In general, the sampling patterns were designed to characterize the spatial and temporal distribution of ozone, ozone precursors, and existing meteorological conditions at specific locations throughout the sampling domain.

3.1 SUMMER PERIOD SAMPLING

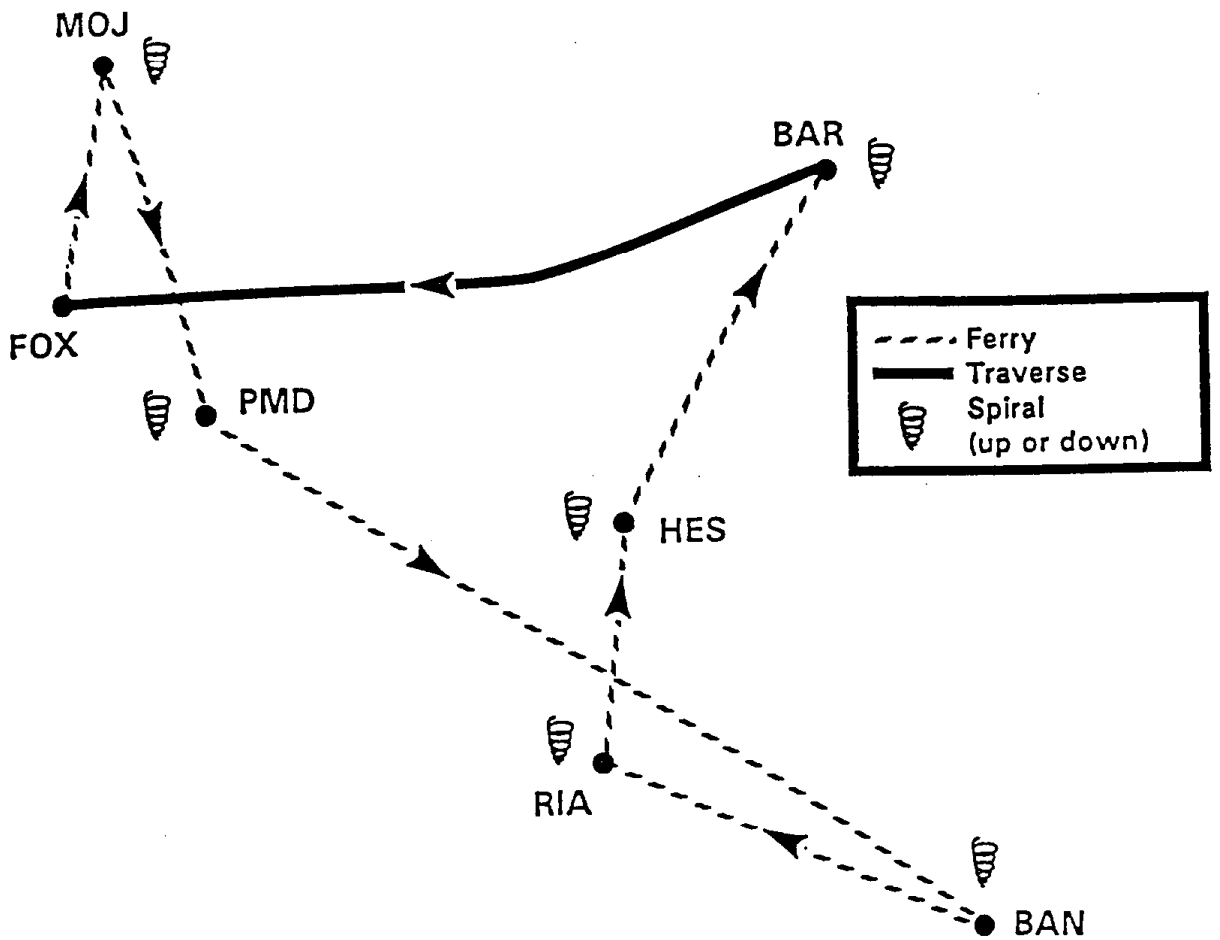
During the summer period, flight patterns were designed to document transport between the SoCAB and the SEDAB. Sampling patterns used by the aircraft included spirals at (or near) profiler sites located at Rialto, Palmdale, Mojave Airport, Hesperia, Barstow, and Banning Airport (near the Whitewater profiler site). A spiral is a vertical sounding flown over a fixed ground location during a climb or descent of the aircraft. Spirals generally were made from about 1525 meters (5000 feet) above ground level (agl) to as low as safety permitted. In some cases, clouds covered some of the sampling locations and in these cases the aircraft spiraled down to the top of the clouds. When conditions allowed, spirals at the airport locations were continued down to about 5 to 10 meters agl over the runway. Each flight also included a long traverse (sampling at a constant altitude between two different locations) between Barstow and General Fox Field.

A typical summer morning flight pattern is shown in Figure 3.1. The figure shows a flight route with spirals at Rialto, Hesperia, and Barstow, a traverse from Barstow to General Fox Field, and then spirals at Mojave, Palmdale, and Banning. Each flight also ended with a spiral at Rialto (see discussion in Sections 5.2.3 and 7.1).

Figure 3.2 illustrates a typical summer afternoon flight pattern. The major difference between the morning and afternoon flight patterns was the order in which the route was flown. The reversal of the flight route in the afternoon allowed the aircraft to sample in the Barstow area between 1700 to 1800 PDT as requested by the ARB.

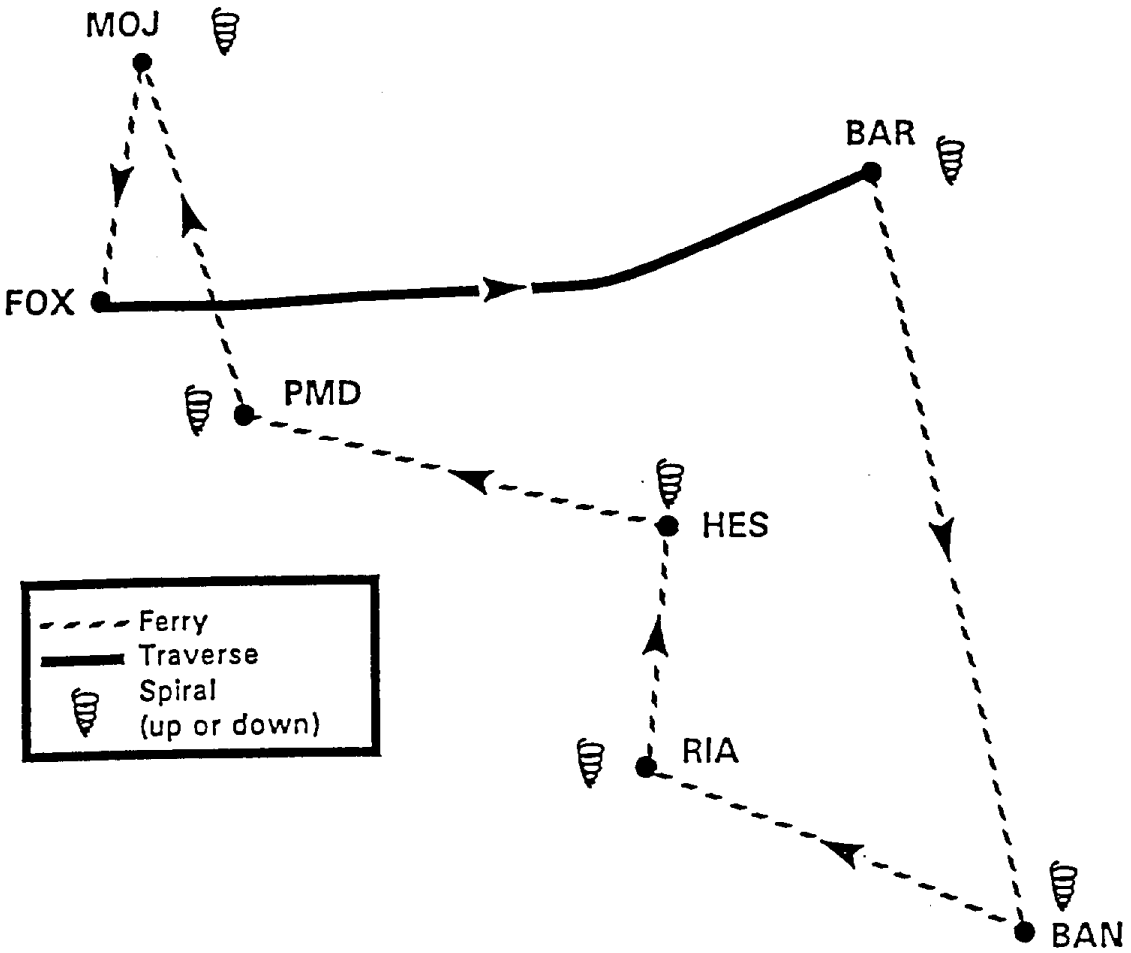
3.2 FALL PERIOD SAMPLING

The purpose of sampling during the fall period was to document transport between SoCAB and SDAB. Meteorological conditions favorable for transport did not occur throughout the last half of October and the ARB chose to extend the aircraft program through November 3, 1992. Because NOAA began removing their profiler units, the ARB staff authorized two flights on November 2 despite less than ideal meteorological conditions for transport.



ID.	LOCATION DESCRIPTION	LATITUDE	LONGITUDE
RIA	Rialto Airport	33°07.7	117°24.2
HES	Hesperia Profiler site	34°24.0	117°24.1
BAR	Profiler site near Barstow	34°50.9	117°07.7
FOX	General Fox Airport	34°44.5	118°13.1
MOJ	Mojave Airport	35°03.5	118°09.0
PMD	Profiler site near Palmdale	34°35.6	118°02.2
BAN	Banning Airport	33°55.4	116°51.0

Figure 3-1. A typical summer morning flight pattern flown by the STI aircraft.



ID.	LOCATION DESCRIPTION	LATITUDE	LONGITUDE
RIA	Rialto Airport	33°07.7	117°24.2
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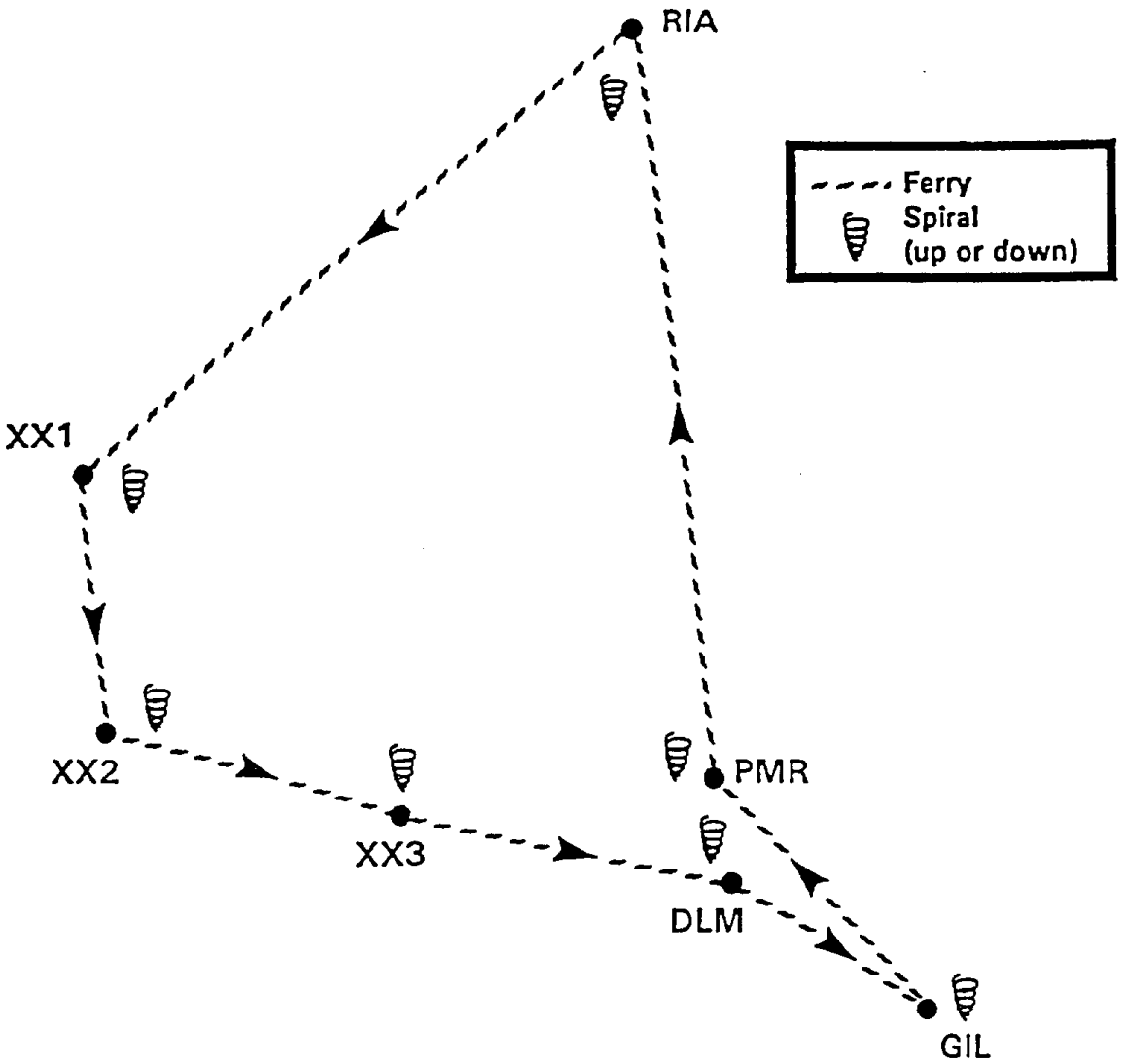
BAR	Profiler site near Barstow	34°50.9	117°07.7
FOX	General Fox Airport	34°44.5	118°13.1
MOJ	Mojave Airport	35°03.5	118°09.0
PMD	Profiler site near Palmdale	34°35.6	118°02.2
BAN	Banning Airport	33°55.4	116°51.0

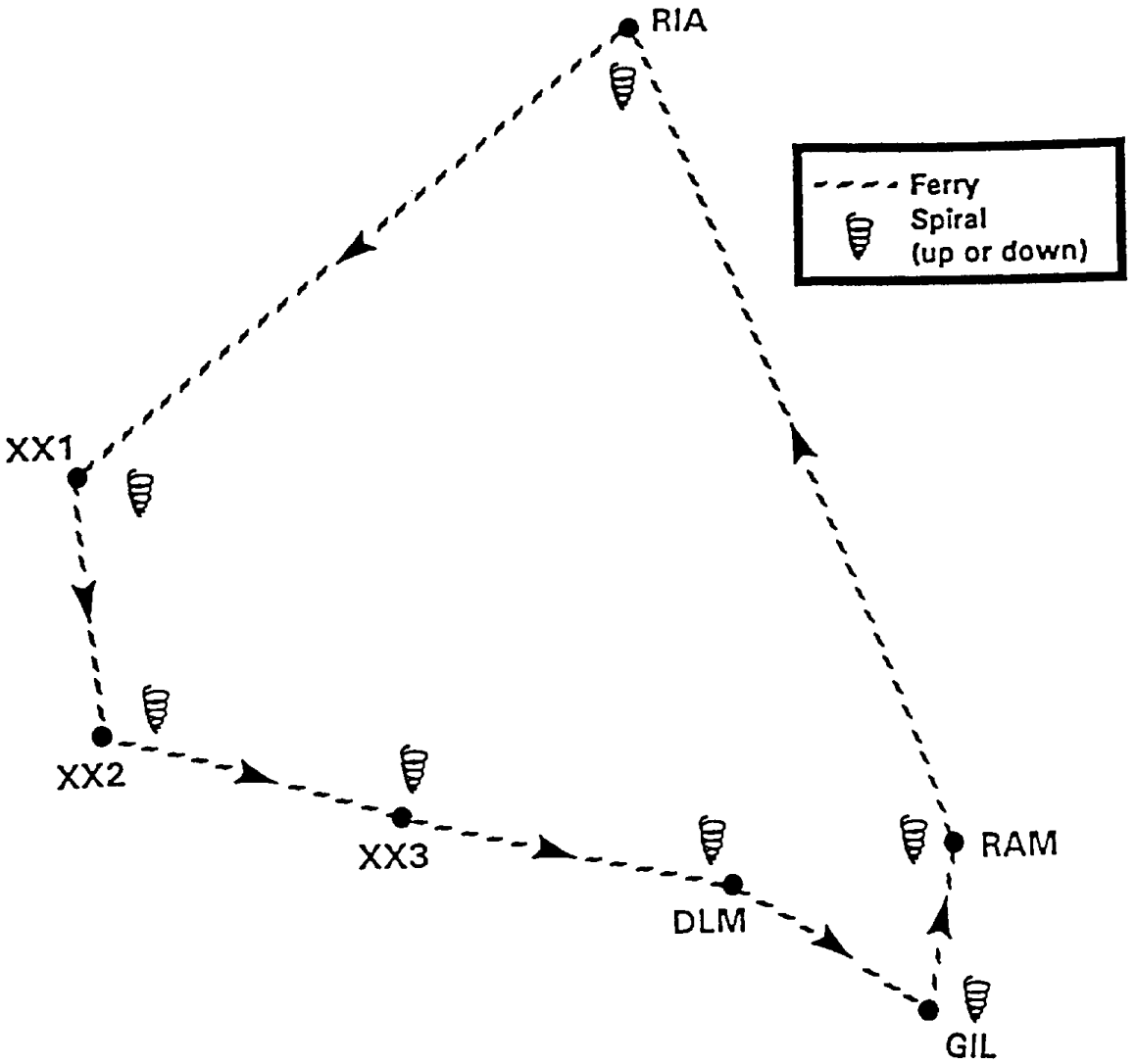
Figure 3-2. A typical summer afternoon flight pattern flown by the STI aircraft.

The morning and afternoon flight routes used November 2, 1993 are shown in Figures 3-3 and 3-4. Each flight consisted of eight spirals starting and ending at the Rialto Airport. Each flight pattern was similar through completion of sampling at the Gillespie Airport location. In order to further document coastal transport during the morning hours, the ARB requested sampling at the Palomar Airport before the aircraft returned to Rialto. For the afternoon flight, the ARB requested sampling at the Ramona Airport to document any inland transport that may have existed.



LOCATION		LATITUDE	LONGITUDE
RIA	Rialto Airport	33°07.7	117°24.2
XX1	Over-water location about halfway between Long Beach and Catalina	33°33.0	118°14.0
XX2	Over-water location about 10 miles southeast of Catalina	33°11.0	118°13.0
XX3	Over-water location about halfway between Catalina and Del Mar	33°05.0	117°45.5
DLM	Over-water location near Del Mar	32°57.5	117°17.5
GIL	Gillespie Airport	32°49.6	116°58.3
PMR	Palomar Airport	33°07.7	117°16.8

Figure 3-3. Sampling route flown by the STI aircraft during the 11/2/92 AM flight.



LOCATION		LATITUDE	LONGITUDE
RIA	Rialto Airport	33°07.7	117°24.2
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XX3	Over-water location about halfway between Catalina and Del Mar	33°05.0	117°45.5
DLM	Over-water location near Del Mar	32°57.5	117°17.5
GIL	Gillespie Airport	32°49.6	116°58.3
RAM	Ramona Airport	33°02.3	116°54.8

Figure 3-4. Sampling route flown by the STI aircraft during the 11/2/92 PM flight.

4. SAMPLING PLATFORM, INSTRUMENTATION, AND SYSTEMS

4.1 SAMPLING PLATFORM

4.1.1 Aircraft

The aircraft used during the ARB sampling program was a Piper Aztec, model PA23-250. The Aztec is a twin engine, low wing aircraft with retractable landing gear. The aircraft was chosen as a sampling platform because of its stable flight characteristics, its available electrical power, its load carrying capabilities, and its ability to fly for periods of up to five hours if needed.

A radar transponder aboard the aircraft allowed FAA flight controllers to determine the position of the aircraft and provided controllers with a direct readout of the aircraft's altitude (Mode C). This feature was required by the FAA to coordinate sampling patterns flown by the aircraft with other air traffic.

The aircraft's 140 amp, 28 volt DC electrical system provided power to two 1000 watt (115 volt AC, 60 Hz) invertors which were used to power the research instrumentation that required AC power. DC instrumentation was powered directly from the aircraft's 28 volt electrical system. All research instrumentation was protected by a separate circuit breaker installed in the aircraft's breaker panel as well as the standard built-in fuses and circuit breakers.

4.1.2 Crew

The flight crew consisted of a pilot and an instrument operator. The instrument operator monitored the sampling instrumentation, collected grab samples (ROG and tracer) as required, and documented the sampling events as each flight proceeded. During sampling days, both a backup pilot and a backup instrument operator were on call.

4.2 INSTRUMENTATION

4.2.1 Continuous Sampling Instrumentation

Table 4-1 lists the continuous sampling instruments that were operated aboard the aircraft. The table lists the equipment manufacturer and model used, the analysis technique, instrument ranges available for use, the approximate time response to 90%, and the approximate resolution of each instrument. **Please note that both the ozone and NO/NO_x monitors were operated using Teflon particle inlet filters.**

Table 4-1. Continuous sampling instruments for the STI aircraft.

Parameter	Sampler Manufacturer and Model	Analysis Technique	Normal Measurement Ranges (Full Scale)	Time Response (to 90%)	Approximate Lower Quantifiable Limit
NO/NO_x	Thermo Environmental Model 42	Chemiluminescence	50,100,200,500 ppb	< 20 sec.	0.5 ppb
O_3	Monitor Labs 8410E	Chemiluminescence	200, 500 ppb	12 sec.	2 ppb
b_{scat}[a]	MRI 1560 series (modified by Waggoner)	Integrating Nephelometer	100, 1000 x 10^{-6} m^{-1} Dual Range	1 sec.	1 x 10^{-6} m^{-1}
Dew Point[a]	Cambridge Systems 137-C	Cooled Mirror	-50 to 50°C	0.5 sec./°C	0.5°C
Altitude	II-Morrow Validyne P24	Altitude Encoder Pressure/Transducer	0 - 5000 m msl 0 - 5000 m msl	1 sec. < 1 sec.	1 m 5 m
Temperature	YSI/MRI	Bead Thermister/ Vortex Housing	-30 to 50°C	5 sec.	0.5°C
Temperature[a] (redundant)	Rosemont 102 AV/AF	Platinum Resistance	-50 to +50°C	1 sec.	0.5°C
Turbulence[a]	MRI 1120	Pressure Fluctuations	0 - 10 $cm^{2/3}$ s^{-1}	3 sec. (60%)	0.1 $cm^{2/3}$ s^{-1}
Broad Band[a] Radiation	Epply	Pyranometer	0 - 1026 W m^{-2} Cosine Response	1 sec.	2 W m^{-2}
Ultraviolet[a] Radiation	Epply	Barrier-Layer Photocell	295 - 385 nm 0 - 34.5 W m^{-2} Cosine Response	1 sec.	0.1 W m^{-2}
Position	II-Morrow 618	LORAN-C	Lat.-Long.	< 1 sec.	50 m
Data Logger (includes time)	STI 386 Acquisition System	Dual Floppy Disks and Hard Disk	± 9.99 VDC	Records data 1 s^{-1}	.005 VDC
Stripchart Recorder	Linear Instruments	Dual Channel	0.01, 0.1, 1, 10 VDC	< 1 sec.	
Printer	Seiko DPU-411-040			Prints out data every 10 secs. and at every event or data flag change.	
Aztec AC Power (2 units)	Avionic Instruments, Inc. Model #2A-1000-1A	Static Inverter	2000W 110V 60 Hz	-	-

a These measurements were optional. The instruments were installed on the aircraft, and operated, but since the data were not required by the ARB, the data were not subjected to rigorous QC or validation.

4.2.2 Grab Sample Equipment

During each flight, ROG samples were collected. During the summer sampling period only, a sequential sampler (supplied by SCE) was operated aboard the aircraft to collect samples that will be analyzed for tracer gas concentrations. Sections 4.3.1 and 4.3.2 discuss the ROG and tracer sampling equipment as systems.

4.2.3 Sample Inlets

Air for the sampling instrumentation mounted inside the aircraft was obtained through three sample inlet tubes installed one above the other in a "dummy" window on the left side of the aircraft. The inlets were 4.5 cm (1 3/4") diameter aluminum tubes that extended about 15 cm (6") out past the skin of the aircraft and faced forward into the airstream. Exhaust from the aircraft engines exited the engine nacelles under the wing and well away from the sample inlets.

Three 9.5 mm (3/8") and one 6.5 mm (1/4") diameter Teflon sample inlet lines were inserted through the bottom sample inlet tube to provide sample air for the continuous gas analyzers, the ROG sampling system, and the tracer gas sampling system. The Teflon tubes were exposed directly to the ambient air.

Two of the 9.5 mm (3/8") inlet lines were used for the NO/NO_x and ozone analyzers. Inside the aircraft, each of these inlet lines terminated in a separate glass manifold. Each manifold consisted of a 9.5 mm (3/8") inlet into an expansion chamber measuring 15 cm (6") in length by 2.5 cm (1") in diameter. Two 6.5 mm (1/4") static sample ports were attached to the side of the expansion chamber. Volume expansion inside the chamber slowed the incoming sample air flow. Teflon sampling lines from the NO/NO_x and ozone monitors were attached to static ports on their respective glass manifold. Excess air from the manifolds was dumped into the aircraft cabin.

The third 9.5 mm (3/8") Teflon sample inlet provided air for the tracer gas sampling system described in Section 4.3.1. The 6.5 mm (1/4") line provided sample air for the ROG system described in Section 4.3.2.

The nephelometer was connected to the top inlet tube in the dummy window via a length of flex hose. The nephelometer exhaust was routed via a flex hose to the data acquisition system for cooling. Air flow from the middle inlet tube was routed to various instruments inside the aircraft for cooling purposes.

4.2.4 External Sensor Mounting Locations

The inlet for the dew point sensor was mounted on the outside of the dummy window and the sensor head itself was mounted on the inside of the window. The temperature probe was mounted on the outside of the dummy window. The turbulence sensor was installed in a pitot-static tube mounted under the left wing.

An Apollo model 618 Loran unit was installed in the aircraft's instrument panel. Digital output from the unit was routed to the on-board data acquisition system.

4.3 SYSTEMS FOR GRAB SAMPLES

4.3.1 Sampling System for the Collection of Tracer Gas Samples

The sequential sampler and the collection media described in this section were supplied to the ARB program by SCE. The system was used only during the summer sampling flights, and the analysis and reporting of the analytical results are the responsibility of SCE. This section documents the system as it was used during the ARB program.

The tracer samples were collected by flowing sample air through an activated charcoal element built on a stainless steel mesh mounted in a small (2- to 3-inch) pyrex tube. Each tube was called an "element" and usually had a four- or five-digit number inscribed on the tube. Twenty such elements were mounted in sequential "positions" (numbered 1-20) in a "cartridge" type belt. Each belt was identified as ANATEX followed by a five-digit number (e.g., ANATEX 21005). Prior to sampling, a belt containing 20 elements was loaded into the sequential sampler. The sampler was operated manually during a flight.

The sample inlet system consisted of a 1.2 m (4 ft) length of 9.5 mm (3/8") Teflon tubing that entered the aircraft through the bottom inlet tube in the dummy window. Sample air was delivered by ram air pressure. The sample inlet tubing terminated in a reduction assembly consisting of the 9.5 mm (3/8") inlet tubing and a smaller 6.4 mm (1/4") Teflon tube telescoped together. The other end of the 6.4 mm tube slipped tightly over an inlet fitting on the sequential sampler. Internally, the sampler operated a flow control device and pump to control the sample air flow through each manually selected sampling element.

4.3.2 Sampling System for the Collection of ROG Samples

ROG sampling was performed aboard the aircraft during all flights. The ROG sampling system was provided by Biospherics Research Corporation (BRC) and consisted of a 2.4 m (8') length of 6.5 mm (1/4") diameter Teflon sample inlet tubing, a special sample pump, a 1.8 m (6') length of 6.5 mm (1/4") diameter Teflon sample delivery tubing, a two way toggle valve and pressure gauge assembly (called a "purge tee"), and 0.8 L (liter) stainless steel canisters for sample collection. Each canister was evacuated, baked, and sealed by BRC before the program. A Nupro valve assembly on the inlet of each canister was used to seal the canister. A brass Swagelok cap protected the threaded portion of the canister inlet that was used to connect the canister to the purge tee assembly.

To avoid system contamination, the ROG sample inlet tubing was capped at the inlet during all non-flight periods. The sample inlet and delivery tubing were connected to the inlet and exhaust ports of the sample pump using stainless steel Swagelok fittings. The

sample delivery tubing from the pump was connected to the purge tee assembly with a stainless steel Swagelok fitting.

5. OPERATIONAL PROCEDURES

5.1 SELECTION OF SAMPLING DAYS

As mentioned briefly in Section 2.2, all sampling days were selected by the ARB staff on a forecast basis. Each forecast began about mid-afternoon when ARB staff meteorologists prepared weather and pollution forecasts for the next day. Inputs for their forecasts included information gathered from the National Weather Service (NWS), local soundings, current pollution values in the sampling area, discussions with local area forecasters, and models used to predict transport between different air basins. The forecast was then reviewed with the ARB program manager.

About 1600 each day, a conference call was initiated by the ARB to discuss the forecast and reach a final decision concerning sampling activities for the next day. A member of the ARB meteorology group, the ARB program manager, the aircraft field manager, and an SCE staff member (during the summer period only) were participants in the conference call. SCE was involved since the aircraft was also being used (on a non-interfering basis) for SCE's Project Mohave. Thus, if ARB did not select a day for sampling, the aircraft then became available to SCE for their sampling needs.

5.2 AIRCRAFT-RELATED PROCEDURES

5.2.1 Pre-program Procedures

The calibration systems used during field operations were a CSI 1700 gas phase calibrator and a Dasibi 1003 PC ozone transfer standard. Each was checked and certified by AeroVironment, Inc. (AV) prior to the field program. Details of the calibration systems used are included in Section 6.2.1.

The ozone monitor that was used aboard the aircraft was run and calibrated periodically (in the STI laboratory) for about 10 days before being installed in the aircraft. The NO/NO_x monitor was also checked and calibrated several times during a three week period before being installed aboard the aircraft.

The nephelometer was cleaned, calibrated, and tested before installation in the aircraft. The temperature and dew point sensors, which are permanently mounted on the aircraft, were checked using wet and dry bulb measurements from a sling psychrometer.

Prior to the study period, the aircraft was instrumented and test flights were flown. Data recorded during these flights were processed and reviewed to ensure that all instruments were operational.

The ozone monitor aboard the aircraft was subjected to two performance audits before the start of the summer period by teams of auditors from the Quality Assurance Section of the ARB. The ARB did not audit the NO/NO_x monitor for reasons described in Section 6.2.2. Another audit of the aircraft (for the SCE sampling program) was performed by AV early in the summer period. AV audited the performance of the NO/NO_x and ozone monitors. The results of these three audits are discussed in Section 6.2.2.

Flight plans were finalized and copies of a tentative operating schedule and flight plans were delivered to the FAA for review and comments. Prior to the first actual sampling flight, the aircraft performed a "survey" flight. The purpose of this flight was to locate each sampling location, enter coordinates of each sampling location into the memory of the Loran navigation unit used aboard the aircraft, familiarize pilots with the sampling locations and flight patterns, and to evaluate any potential sampling problems (e.g., FAA coordination, unmarked towers, noise sensitive areas, etc.) that would cause a revision of the sampling patterns. It was determined that the aircraft would have a great deal of difficulty sampling above the Whitewater profiler site because of terrain features (mountains). This was discussed with the ARB and Banning Airport was selected as the alternative sampling location. No other problems were encountered.

5.2.2 Ground Operating Procedures

At the start of each study period, power was applied to various monitors aboard the aircraft. Instruments which required a warmup period were then operated continuously throughout each period. This was accomplished by transferring power from an external ground source to internal aircraft power just before the aircraft was ready to taxi for take-off. The transfer was instantaneous and was performed in the reverse order after the aircraft landed.

The sample inlet line used for ROG sampling was plugged as soon as the aircraft landed and the plug was not removed until the aircraft was ready to taxi for the next flight. In a similar manner, the two exhaust ports on the ROG "purge tee" assembly (inside the aircraft) were capped during non-flight periods. Thus, the entire ROG sampling system was sealed from organic vapors and other contaminants that might be encountered while on the ground at the Rialto Airport.

During non-sampling periods, the NO/NO_x and ozone monitors aboard the aircraft were calibrated periodically. The monitors were normally calibrated before and after each sampling day.

Prior to every flight (and on every non-flight day), each sampling instrument aboard the aircraft was checked and verified operational or non-operational through the use of check lists and pre-sampling forms.

A second complete data acquisition system, a spare ozone monitor, a spare NO/NO_x monitor, and numerous other spare parts were maintained (for additional backup) at the aircraft base of operations.

5.2.3 In-flight Procedures

During vertical spirals, the aircraft would normally climb or descend at a rate of about 2.5 m/sec (500 ft/min). In a few instances, different rates were used to comply with FAA requests to schedule the aircraft into or out of an airport's traffic pattern. The rates used were fast enough to avoid inadvertent sampling of the aircraft exhaust but at the same time did not exceed the response time of the various monitors. Varying airspeeds of 55 m/sec (120 mph) to 67 m/sec (150 mph) were used while the aircraft was enroute or traversing from one sampling location to the next.

The data acquisition system computer aboard the aircraft included dual floppy disk drives and a hard drive. During data acquisition, data were continuously recorded to one of the floppy disk drives and simultaneously to the hard drive. Thus, the second floppy drive was available as a backup unit for data storage as well as a source for the complete data acquisition system operating instructions. The hard drive contained a backup copy of the information recorded on the primary floppy.

During each flight, the instrumentation and the data acquisition system were run continuously. The real-time instrument data were recorded once per second and stored on a floppy diskette and the computer's hard drive. A printer recorded instantaneous values every ten seconds and also served as a recording backup. A dual channel strip chart recorder was also operated during each flight. Normally, ozone and temperature were plotted in real-time, and these data were reviewed continuously during a flight by the instrument operator.

A "zero spiral" was usually flown as a part of each sampling flight. The purpose was to document the "zero response" of the NO/NO_x and ozone monitors. Each monitor was placed into its "zero" mode of operation, and the instrument's response was recorded during changes in altitude. Even though this sampling was called a zero spiral, the data were usually recorded during a descent from the last sampling location to the Rialto Airport for landing.

The instrument operator recorded the start- and end-time, altitude, and location of each sampling event (spiral, grab sample, zero, etc.) in flight record sheets. In addition, the instrument operator activated an event switch to mark each sampling event. The event switch (flag) was recorded by the data acquisition system and was used during data processing.

5.3 SAMPLING PROCEDURES

5.3.1 ROG Sample Procedures

ROG grab samples were collected in stainless steel canisters that were provided by Biospherics Research Corporation (BRC). The canisters were prepared for sampling in the BRC laboratory. During preparation, each canister was cleaned, baked under vacuum, and also sealed under vacuum. Boxes of prepared canisters were shipped by BRC to STI where the canisters were stored until needed.

When a sampling flight was anticipated, the required number of canisters were transferred to and stored aboard the aircraft. At least one extra canister was always loaded aboard the aircraft and was available as a backup.

The inlet plug on the ROG sample line was removed just prior to take-off. After take-off, the caps on the "purge tee" assembly (inside the aircraft) were removed and the ROG sample pump was turned on and run continuously throughout the remainder of the flight. Thus, the sample delivery system was thoroughly purged prior to the collection of the first sample.

To connect a canister to the purge tee assembly, the toggle valve on the purge tee assembly was set to exhaust through both exhaust ports. The protective Swagelok cap was removed from a sample canister and air flow from the purge tee assembly was used to flush the dead air space inside the inlet of the canister. After about 15 seconds of flushing, the Swagelok fittings between the purge tee assembly and the canister were secured. Air from the pump then exhausted through the other port of the assembly into the aircraft cabin.

To sample, the toggle valve was switched to the "Sample" position (air to the canister only), and the Nupro valve on the canister was opened. At the same time, the start time and altitude were recorded on the instrument operator's flight sheet record. The canister was filled for the duration of the desired altitude change, normally about the lowest 300 m (two minutes) of a spiral. To end sampling, the Nupro valve was closed, the "purge tee" assembly removed, and the Swagelok cap reinstalled on the canister. The toggle valve was not repositioned until this procedure was completed. This ensured that the contents of the canister would not be lost after it had been collected.

Immediately after each ROG sample was collected an identification tag was attached to the canister. The tag data included canister identification number, date, altitudes, start- and end-times of the sampling, location of the sample, and comments. This information was also duplicated in the operator's flight notes.

After a flight, the samples were inventoried, labels checked against flight notes, and chain of custody forms prepared. When a series of flights had been completed, all exposed canisters were shipped to BRC by United Parcel Service.

5.3.2 Tracer Sample Procedures

Several "belts" of sampling tubes were received with the sampler unit supplied by SCE. Each belt consisted of 20 "elements" (small glass tubes) mounted in the belt. Each end of a glass sampling tube (an element) was protected with a stopper. Before a flight, the stoppers were removed and the belt with its elements was installed in the sequential sampler. The sampler was manually advanced to the first element to be exposed and then shut-off.

The inlet line (described in Section 4.3.1) was not connected to the sampler unit until just before the first sampling event was anticipated. This allowed ram air to purge the inlet system before sampling was initiated.

Sampling began when an "ON-OFF" switch on the sampler was activated. This caused a sample pump and valve system internal to the sampler to draw air through the first sampling element. To end sampling, the "ON-OFF" switch was deactivated. A second switch on the sampler was then used to advance the sampler to the next element to be exposed. A LED readout on the unit displayed the element position that was currently ready to sample or that was being sampled. Normally only two or three samples were collected during each flight. Samples were collected only during spirals, and a sample element was exposed throughout the entire spiral.

Sampling forms were prepared prior to a flight that listed the identification of each sampling element and its position in a sampling belt. The instrument operator used this form during the flight to document the details of sampling for each element.

When both flights for a day were completed, the sampler was opened, the sampler belt removed, and the stoppers reinstalled on the ends of the elements. The numbers on the elements were checked against the instrument operator's flight notes, and the sampler belt was stored until further sampling or until it was shipped to the laboratory that will perform the tracer analysis. Elements were never removed from their respective belt and were returned to the laboratory as they were received.

6. QUALITY ASSURANCE AND CALIBRATION

6.1 GENERAL QUALITY ASSURANCE PROCEDURES

General steps used throughout the program to assure the quality of the aircraft data are outlined below:

- Checklists and log sheets, specific to the instruments and sampling system operated aboard the aircraft, were designed during the preparation phase. These were used throughout the program to standardize operational procedures and to document all activities relating to the measurements.

- Prior to the sampling program, each piece of sampling equipment to be used aboard the aircraft was checked. The aircraft was instrumented, and test flights were flown. Data recorded during these flights were processed and reviewed to ensure that the complete instrumentation package (as a system) was operational.

- System checks of the aircraft and the sampling systems were performed daily during the program.

- Using checklists, extensive operational checks were performed on each instrument prior to each sampling flight.

- The on-board printouts were reviewed after each flight to detect instrument problems.

- Simultaneous use of the computer's floppy drive and hard drive as well as a printer aboard the aircraft provided redundant (backup) recording of the data recorded by the aircraft data acquisition system.

- The aircraft project manager debriefed flight crews after each flight to determine operational problems.

- Data diskettes and flight notes were copied after each flight. Data processing was initiated within a couple of hours after a flight was completed, and the data were carefully reviewed by the project manager to identify any problems. Problems that were noted were discussed with the flight crew.

- After a flight was completed, ROG and tracer samples were inventoried, sampling summaries were prepared and checked, and chain of custody forms were prepared.

- Chain of custody forms accompanied all samples being delivered to the various analytical laboratories.

- Prior to the program, the calibration system and ozone transfer standard were delivered to AeroVironment, Inc. (AV). AV certified the flow rates of the calibration system and performed a 6 x 6 certification of the ozone transfer standard.

- Multi-point calibrations of the gas monitors were performed throughout the study period.

- Several times during the program, ozone output from the calibration system was checked against the STI ozone transfer standard. This provided a cross check of the calibration unit that was used to routinely calibrate the ozone monitor aboard the aircraft.

- Calibrations of the gas monitors aboard the aircraft were performed by two different personnel from STI and an AV consultant to ensure that systematic calibration procedure problems did not exist.

- Performance audits of the gas monitors (while mounted in the aircraft) were performed by various audit teams from the ARB and AV. The audit results are described in Section 6.2.2.

6.2 AIRCRAFT SYSTEM QUALITY CONTROL AND CALIBRATION

6.2.1 Calibration Procedures

During the program (both preparation and sampling phases), the ozone and NO/NO_x monitors used aboard the aircraft were calibrated using a Columbia Scientific Instruments (CSI) Model 1700 gas phase calibrator.

The flows of the CSI calibration systems were certified by AV. The output of the CSI ozone generator was calibrated using the STI transfer standard which was an absolute photometer (Dasibi Model 1003-PC). No significant differences were noted between the determined flows and ozone values for the calibration system and previously determined values.

Before being installed in the aircraft, the NO/NO_x and ozone monitors were calibrated in the laboratory. Cross calibrations of the NO/NO_x and ozone monitors were done for three weeks prior to the project start. The NO/NO_x calibrations included comparisons to two other new Thermo Environmental Instruments, Inc., Model 42 Chemiluminescence NO/NO_x Analyzers.

After the laboratory checks and calibrations were completed, the gas instruments were installed in the aircraft. Aboard the aircraft, the temperature and dew point sensors were checked using wet and dry bulb measurements from an aspirated psychrometer. Test flights

were then flown. Data recorded during these flights were processed and reviewed to ensure that the instruments were functional.

During the program, daily checks were performed on all sensors to ensure that the sensors were operational. Extensive operational checks of each instrument were performed prior to each flight using checklists.

Throughout the study period, multi-point calibrations of the gas monitors were performed routinely, and the nephelometer was calibrated several times. During a sampling episode, the gas monitors were usually calibrated after the last flight of the day. After calibration results had been calculated and reviewed, correction factors were selected and applied to the data during data processing.

The CSI gas phase calibrator system used consisted of a dilution system and an ozone generator. NO concentrations were generated in the CSI calibrator by diluting a stable concentration of NO gas (source) with zero air (dilution gas). Ozone concentrations were produced by using a UV source (cold cathode mercury arc lamp) to irradiate an incoming stream of zero air (ozone free). Mass flow controllers in the CSI unit were used to maintain desired flow rates.

The NO/NO_x monitor was calibrated using NO concentrations generated by the CSI calibrator. Concentrations of NO that were generated for multi-point calibrations ranged from 0 (zero air only) to 93.5 parts per billion (ppb). Ozone concentrations generated by the CSI and used to perform multi-point calibrations of the ozone monitor ranged from 0 (zero air only) to 473 ppb. The nephelometer was calibrated using filtered air for a clean air value and Freon 12 for an upscale point.

Gas from a single cylinder of NO calibration gas (10.8 ppm) was used throughout the program as the NO calibration source. The NO source cylinder was supplied and its concentration certified by Scott Marrin, Inc. of Riverside, California. "Ultra Pure" zero air from three different gas cylinders was used for dilution gas. Scott Marrin also provided and certified the contents of the Ultra Pure gas cylinders that were used.

6.2.2 Performance Audits

On July 2, 1992 an audit team from the ARB Quality Assurance Section challenged the performance of the ozone monitor aboard the aircraft. During the audit, a leak was detected in the monitor, and the audit was terminated. Examination of calibration records for a 6/30/92 STI calibration of this monitor indicated the monitor had been working properly at the time of the calibration. Thus, the leak had developed between the last calibration and the audit.

After the instrument had been repaired, a re-audit was performed by the ARB QA Section on July 20, 1992. The ARB QA Section report indicated:

- the Average % Difference for the ozone monitor was -6.3%,
- a Standard % Deviation of 0.6%, and
- a Correlation of .99997.

The report concluded "...that the instrument was operating within ARB's control limits." A copy of the ARB Audit report is included in the Appendix.

The NO/NO_x monitor had been setup to measure on the 100 ppb full scale range. Since the ARB could not produce audit concentrations within the operating range of the instrument, they did not audit this instrument.

The ARB contract indicated the aircraft equipment would be subjected to a post-sampling program audit. Since the program extension used most of the remaining contract funding, the ARB (through Mr. Chuck Bennett) agreed to waive this requirement.

For work that was being performed for SCE (Project Mohave), the instruments (same as used for this ARB contract) aboard the aircraft were subjected to another performance audit by AV. The audit was performed July 24, 1992, and AV reported (AeroVironment, 1992) the following results:

- Ozone — Average % Difference -3.0%
  Correlation 1.0000,
- NO — Average % Difference -5.8%
  Correlation 0.9999, and
- NO_x — Average % Difference -8.1%
  Correlation 0.9999.

The AV audit report concluded that "All instruments audited were found to be operating within the Environmental Protection Agency recommended criteria..." A copy of this audit report is also included in the Appendix.

7. DATA PROCESSING

7.1 AIRCRAFT AND FIELD PROCEDURES

Many sampling and data collection procedures affect processing of the data. These procedures are discussed in this section.

Prior to each flight, a pre-flight record (form) was completed following detailed checklists that had been developed. The checklists led the operator through various checks and tests to ensure each instrument was operating properly prior to sampling. The checklists also required written documentation (on a pre-flight form) of various settings and readings for each instrument.

During each flight, the instrumentation and the data acquisition system were run continuously. During portions of each flight, the data being recorded were invalid because instruments were being zeroed (at times other than a zero spiral) or the aircraft was being positioned to start another sampling event. The only data that were plotted were those recorded during valid sampling events (spirals, orbits, traverses, or zero spirals). These sampling events were called "passes" and were numbered sequentially from the beginning of each flight, starting at one. All data were processed and are contained on the magnetic media.

Aboard the aircraft, the on-board scientist (instrument operator) controlled an event switch that was used to flag sampling events (passes). The data flag was recorded by the data acquisition system and used during data processing steps to identify sections of data to be processed.

The operator also filled out standardized sampling forms (flight records) that summarized each sampling event. Information written on the form included the start- and end-time of each pass, sampling altitudes used, instrument ranges, and any special sampling that was performed (e.g., ROG, and/or tracer gas samples collected) including sample identification, flow measurements, and vacuum readings (when required). These forms also contained space for comments concerning the sampling. During data processing, the information contained in the flight notes was checked against the flags and other data that were recorded by the data acquisition system.

Usually a zero spiral was flown once a flight. During these spirals, the gas analyzers were operated in their "zero" mode while the altitude of the aircraft varied. Thus, instrument response as a function of altitude was documented, and these data were used during data processing steps to account for these effects.

After each flight, data diskettes were copied, printer tapes reviewed and archived, documentation concerning grab samples was compared to flight notes and verified, and the flight notes (records) reviewed and duplicated. The duplicate diskettes and copies of the

flight notes were returned to STI headquarters in Santa Rosa. Initial processing of the diskettes was performed in the field, and the data were reviewed by project manager. Any problems or questions that were noted were discussed with the aircraft personnel.

After a flight, ROG and tracer samples were inventoried. Questions concerning samples were discussed and resolved after the samples had been unloaded from the aircraft.

7.2 DATA PROCESSING STEPS

The following data processing steps were performed to prepare and validate the data:

- The sampling date, the sampling period (start- and end-times), and the diskette identification number were determined from flight notes and compared with the information recorded on the disk. Differences were reconciled and corrected before other processing steps were initiated.

- As recorded during sampling, the real-time sensor data were written to the floppy in a space-saving binary file format which had to be "extracted" (dumped) into an ASCII test file format. This was the first step in processing the data. During the extraction program, the data were converted into a "raw" (as recorded) voltage file and also a separate "raw" engineering unit data file. Setup files containing nominal instrument range information were used to convert voltage values to engineering unit values.

- The extraction program also produced a summary of times during which the event switch (recorded by the data acquisition system) was activated or changed. This output was called an event summary.

- The original diskette was archived after the data had been extracted.

- The status of the event switch (from the event summary) was compared to the instrument operator's written flight notes and discrepancies were noted and appropriate corrective action taken.

- Using the event summary and flight notes, a tabular sampling summary was produced for inclusion with the data from each flight.

- Using the flight notes, a map was produced for each flight. Each sampling location was identified, and the appropriate three-letter identifier (to be used on the maps and included in the data files) was determined.

- The raw voltage data file that had been produced was archived.

- The raw engineering unit data that had been generated were then plotted in a strip chart format. At this stage of the processing, the entire flight was plotted regardless

of sampling status. The plots were reviewed, and data outliers were identified and flagged for later editing steps.

- Instrument calibration data were reviewed and calibration factors were selected. As required, instrument zero values were also determined.

- After calibration factors had been selected, they were applied to the raw engineering unit data. The processing program (an editing program) applied zero values, calibration factors, offsets, and altitude correction factors (when appropriate) to the raw engineering unit data. Adjustments to range inputs (used in prior processing steps) were applied when required.

- Inputs corresponding to the start and end of each sampling event (derived from the event summary and the flight notes) were added by the editing program to segment the data into individual passes.

- The type of sampling (spiral, traverse, orbit, etc.) performed during a pass and the location of the sampling (three letter identifier) were also added to the engineering unit file through the editing program.

- The editing program was also used to correct any other problems (e.g., removing "glitches" etc.) that had previously been identified.

- The data at this point were called preliminary engineering unit data.

- These preliminary data were again plotted (passes only) in a strip chart format and reviewed. Most of the discrepancies detected at this stage were corrected by the editing program, although a few required the flight data to be completely reprocessed.

- After all editing had been completed, preliminary engineering unit data plots were produced.

- Using the preliminary data plots, flight maps, sampling summaries, and processing notes as well as original flight notes, a data processing system review was performed. The review was performed by the aircraft program manager.

- Dates, times, locations, and type of sampling for each pass were checked and cross-checked among the various outputs. The plotted data for each measurement were reviewed, and relationships between parameters (e.g., NO-NO_x ratios, etc.) were examined. Problems that existed were corrected. The majority of problems detected at this stage were clerical in nature (wrong end point number on the sampling summary, etc.) and were easily corrected.

- When editing and review steps had been completed, the data were called final engineering unit data.

- After completion of all processing and editing, the data were plotted in "final" form, and magnetic media copies (floppy diskettes) of the final engineering unit data were produced.

- The data plots produced by the above steps present "snap shot" views of selected portions of a flight. The periods during which data were plotted were called passes (or sampling events). The data collected between these sampling events were not plotted but are contained in the magnetic media that were delivered to the ARB.

8. COMMENTS ON THE DATA

Hard copy sampling summaries, maps, and plots of the continuous data collected aboard the Aztec were prepared and delivered to the ARB (Anderson et al., 1993). Sets of diskettes containing the "final engineering unit data" from the real-time instruments operated aboard the aircraft were also delivered. No averaging was performed on any of the data reported on the magnetic media. The results of the ROG analyses were also presented to the ARB in hard copy and magnetic media.

The diskettes contained final processed, edited, and validated engineering unit data for all real-time instruments except the total and ultraviolet radiation sensors, the dew point sensor, and the turbulence probe. These sensors were not required by the contract. Since they were already installed aboard the aircraft, they were operated and their data were recorded and reported. During data processing, nominal calibration factors were applied, but their data were not reviewed or edited before inclusion on the diskettes.

The ultraviolet and total radiation sensors are extremely sensitive to variations from vertical alignment. During spirals and orbits, changes in aircraft heading caused a sinusoidal oscillation in their data. In addition, excursions in these data occurred as antenna wire shadows crossed the sensors. The sensors were also sensitive to aircraft radio transmissions. These transmissions resulted in spikes in the data. Although the data were included on the diskettes, users of these data are cautioned concerning the status of these measurements and are encouraged to contact the authors to discuss any proposed use of these data.

The nephelometer data were also not required by the contract, but the instrument was aboard the aircraft and operated and calibrated for the SCE program referenced within this report. Thus, these data were edited and included in the ARB data set.

During data processing, the data were carefully reviewed by the personnel who ran the sampling instrumentation aboard the aircraft. Every effort was made to remove bad data or to identify questionable data. No known errors exist. However, the test of a data set is in its use. Users of the data are encouraged to ask questions, make comments or suggestions, or to point out errors of discrepancies that may surface through their use of the data.

9. REFERENCES

AeroVironment, Inc. (1992) Quality assurance audit report SCE - Mohave project performed at Rialto, California for Southern California Edison. Report prepared for Southern California Edison, AV-R-92/6075, July.

Anderson J.A., Hansen P.W., Prouty J.D., and Gardner J.M. (1993) Data collected by the STI aircraft during the 1992 ARB Southern California Transport Assessment Study. Data volume prepared for the California Air Resources Board by Sonoma Technology, Inc., Santa Rosa, CA, STI-92120-1238-DV, January.

APPENDIX

AUDIT REPORTS

- Results of ARB's third quarter 1992 audit of STI's airborne air monitoring system.
- Quality Assurance Audit Report SCE-Mohave Project performed at Rialto, California for SCE, July 24, 1992.

ARB AUDIT REPORT

STATE OF CALIFORNIA
AIR RESOURCES BOARD
2020 L STREET
P.O. BOX 2815
SACRAMENTO, CA 95812

PETE WILSON, Governor

May 20, 1993

Jerry Anderson
Sonoma Technology, Inc.
5510 Skylane Blvd., Suite 101
Santa Rosa, CA 95403-1030

Dear Mr. Anderson:

During third quarter 1992, the Quality Assurance Section of the Air Resources Board (ARB) conducted a special studies performance audit of the airborne air monitoring system operated by your agency. The audit results indicated that the ozone analyzer had a leak in the system. A reaudit conducted several days later, indicated that the instrument was operating within ARB's control limits.

The audits were conducted in accordance with the Environmental Protection Agency's (EPA's) 40 CFR Part 58, Appendix A. The ozone analyzer was audited thru-the-probe, with National Institute of Standards Technology (NIST) traceable gases or a NIST traceable ozone transfer standard, thereby testing the integrity of the entire sampling system and analyzer efficiency.

Audit results are presented in the attached tables and reports. If you have any questions regarding the audits or desire additional audit procedure details, please contact Warren Crecy at (916) 324-2023.

Sincerely,

Alice Westerinen

Alice Westerinen, Manager
Quality Assurance Section
Monitoring and Laboratory Division

Attachments

cc: Warren Crecy

Final Report
07/01/92 To 09/30/92

AUDIT DATE	SITE NUMBER	AGENCY NUMBER	AGENCY DESCRIPTION	POLLUTANT	INSTRUMENT	PROPERTY NUMBER	STATION TYPE	AVERAGE % DIFFERENCE
** SITE #: 49999			SITE NAME: SANTA ROSA AIRPORT					
07/02/92	49999	75	SONOMA TECHNOLOGY INC	03	NL 8410E	654	SPM	-11.3
07/20/92	49999	75	SONOMA TECHNOLOGY INC	03	NL 8410	654	SPM	-6.3

ALL STATIONS
07/01/92 To 09/30/92
AIR QUALITY DATA ACCURACY ESTIMATES-BY SITE

AUDIT DATE	SITE #	AGENCY	POLLUTANT	AVE % DIFF	STANDARD DEVIATION	95% PROBABILITY LIMITS UPPER	LOWER	BEST FIT LINEAR REGRESSION SLOPE	INTERCEPT
** SITE #: 49999	SITE NAME: SANTA ROSA AIRPORT						AGENCY: SONOMA TECHNOLOGY INC		
07/02/92	49999	75	03	-11.3	1.6	-8.2	-14.4	0.9069	-0.0027
07/20/92	49999	75	03	-6.3	0.6	-5.1	-7.5	0.9417	-0.0009

05/18/93

ALL STATIONS
07/01/92 To 09/30/92
AIR QUALITY DATA ACCURACY ESTIMATES-BY POLLUTANT

POLLUTANT	NUMBER OF ANALYZERS AUDITED	AVERAGE OF THE AVERAGE PERCENT DIFFERENCE	STANDARD DEVIATION	95% PROBABILITY LIMITS UPPER %	LOWER %
O3	2	-8.8018	1.2024	-6.4452	-11.1584

CALIFORNIA AIR RESOURCES BOARD

FINAL PERFORMANCE AUDIT

BY

QUALITY ASSURANCE SECTION
MONITORING AND LABORATORY DIVISION
Manager: Alice Westerinen Ph: (916) 324-6191

Printout Date: 05/18/93

****

Site: SANTA ROSA AIRPORT ARB Site #: 49999 Audit Date: 07/02/92

****

Final Audit Results For O3
Instrument #: 654 EPA #: 017
Make & Model: ML 8410E

	Station Response	Station Net Resp.	True Value	Percent Difference
Zero:	0.000			
	0.371	0.371	0.412	-10.0
	0.164	0.164	0.184	-10.9
	0.060	0.060	0.069	-13.0

Average % Diff.	Standard % Dev.	Correlation	95% Probability Limits
-11.3	1.6	.99999	Upper= -8 Lower= -14

Remarks: CAL 06/30/92. REPAIRED SMALL LEAK. AS FURTHER TESTS WERE DONE, RESULTS GOT WORSE.

Printout Date: 05/18/93

****

Site: SANTA ROSA AIRPORT ARB Site #: 49999 Audit Date: 07/02/92

****

Van Ozone Response

Barometric Display (Volts) = 0.8665
Barometric Pressure (mmHg) = 757.760
Altitude Correction Factor = 1.0029

Response	Chart	True
Pre Zero	= 0.000	
High	= 40.200	0.412
Medium	= 17.900	0.184
Low	= 6.600	0.069
Post Zero	= -0.100	

No Van Audit Level Concentrations

Printout Date: 05/18/93

****

Site: SANTA ROSA AIRPORT ARB Site #: 49999 Audit Date: 07/02/92

****

Standards Van No.: A Year: 92 Quarter: 3 Version: 0

Superblend Cylinder Number: CC133
CO = 14363.00 THC = 6712.00
CH4= 6712.00 NO = 337.60
NOX= 337.60 SO2 = 151.20

H2S Superblend Cylinder Number: CC28237
CO = 13994.00 H2S = 294.60

Cylinder		Conc.	ID Number
Ultra Pure Air	=	0.000	CC12003
Low CO Cyl	=	6.910	CC12844
High CO Cyl	=	44.200	CC56465
O3 Corr Factor	=	1.0309	07412
PM10 Corr Factor	=	36.7500	0511

Barometric Pressure System Property Number = 18636
Barometric Pressure Slope = 406.484 Intercept = 405.542
Presentation Line Loss = 1.10%

SITE INFORMATION

Site Name: SANTA ROSA AIRPORT

Site Number: 49999

Audit Date: 07/02/92 Year: 92 Quarter: 3

Agency Number: 75 Agency: SONOMA TECHNOLOGY INC

Site Altitude: 120 Feet

Station Tech: JERRY ANDERSON

ARB Auditors: MIKE MIGUEL
WARREN CRECY

Van Number: A SOUTHWIND I

Standards Version: 0

Last Audit Date: / /

Remarks: SPECIAL STUDIES AUDIT - AIRPLANE

CALIFORNIA AIR RESOURCES BOARD

FINAL PERFORMANCE AUDIT

BY

QUALITY ASSURANCE SECTION
MONITORING AND LABORATORY DIVISION

Manager: Alice Westerinen Ph: (916) 324-6191

Printout Date: 05/18/93

****

Site: SANTA ROSA AIRPORT ARB Site #: 49999 Audit Date: 07/20/92

****

Final Audit Results For O3
Instrument #: 654 EPA #: 017
Make & Model: ML 8410

	Station Response	Station Net Resp.	True Value	Percent Difference
Zero:	0.000			
	0.363	0.363	0.386	-6.0
	0.159	0.159	0.171	-7.0
	0.063	0.063	0.067	-6.0

Average % Diff.	Standard % Dev.	Correlation	95% Probability Limits
-6.3	0.6	.99997	Upper= -5 Lower= -8

Remarks: LAST CALIBRATED ON 07/18/92.

Printout Date: 05/18/93

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Site: SANTA ROSA AIRPORT ARB Site #: 49999 Audit Date: 07/20/92

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Van Ozone Response

Barometric Display (Volts) = 0.8691
Barometric Pressure (mmHg) = 758.817
Altitude Correction Factor = 1.0015

Response		Chart	True
Pre Zero	=	0.000	
High	=	37.800	0.386
Medium	=	16.700	0.171
Low	=	6.600	0.067
Post Zero	=	0.000	

No Van Audit Level Concentrations

Printout Date: 05/18/93

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Site: SANTA ROSA AIRPORT ARB Site #: 49999 Audit Date: 07/20/92

****

Standards Van No.: A Year: 92 Quarter: 3 Version: 0

Superblend Cylinder Number: CC133
CO = 14363.00 THC = 6712.00
CH4= 6712.00 NO = 337.60
NOX= 337.60 SO2 = 151.20

H2S Superblend Cylinder Number: CC28237
CO = 13994.00 H2S = 294.60

Cylinder		Conc.	ID Number
Ultra Pure Air	=	0.000	CC12003
Low CO Cyl	=	6.910	CC12844
High CO Cyl	=	44.200	CC56465
O3 Corr Factor	=	1.0309	07412
PM10 Corr Factor	=	36.7500	0511

Barometric Pressure System Property Number = 18636
Barometric Pressure Slope = 406.484 Intercept = 405.542
Presentation Line Loss = 1.10%

SITE INFORMATION

Site Name: SANTA ROSA AIRPORT

Site Number: 49999

Audit Date: 07/20/92 Year: 92 Quarter: 3

Agency Number: 75 Agency: SONOMA TECHNOLOGY INC

Site Altitude: 120 Feet

Station Tech: JERRY ANDERSON

ARB Auditors: BURRIELL
RYNEARSON

Van Number: A SOUTHWIND I

Standards Version: 0

Last Audit Date: / /

Remarks:

AV AUDIT REPORT

AV-R-92/6075
Project: 210005

QUALITY ASSURANCE AUDIT REPORT

SCE - MOJAVE PROJECT

Performed at Rialto, California
for Southern California Edison

July 24, 1992

Submitted to: Dr. Rob Farber of Southern California Edison

By

AeroVironment Inc.
222 E. Huntington Drive
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(818) 357-9983

July 1992

EXECUTIVE SUMMARY

On July 24, 1992, the quality assurance department of AeroVironment Inc. conducted performance audits of the Sonoma Technology, Incorporated (STI) air quality monitoring aircraft at the Rialto Municipal airport located in Rialto, California. The STI aircraft is to be used to measure elevated pollutant concentrations as part of the Southern California Edison Mojave Generating Station Air Quality Monitoring Program.

All instruments audited were found to be operating within the Environmental Protection Agency recommended criteria, with the following exceptions.

No problems were noted.

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Section 1

INTRODUCTION

On July 24, 1992, the quality assurance department of AeroVironment Inc. (AV) conducted performance audits of the Sonoma Technology, Incorporated (STI) air quality monitoring aircraft at the Rialto Municipal Airport located in Rialto, California. The STI aircraft is to be used to measure elevated pollutant concentrations as part of the Southern California Edison (SCE) Mojave Generating Station Air Quality Monitoring Program.

The audit was performed in accordance with U.S. Environmental Protection Agency (EPA) guidelines (EPA, 1984, 1987). Table 1-1 lists the parameters audited at each site. All aspects of the audit, including methodology, results and recommendations are discussed in this report.

TABLE 1-1. Air quality parameters audited.

Parameter
SO_2*
Ozone
$NO/NO_x/NO_2$

* Not audited.

Section 2

DESCRIPTION OF AUDIT EQUIPMENT

o Sulfur Dioxide, Nitrogen Oxides and Ozone

Each AV multipoint audit, with the exception of ozone, was performed using a Dasibi Model 1009-MC dilution system, Serial Number 032, which AV's quality assurance department maintains. The zero air source was an AV built unit that uses Purafil and activated charcoal columns to remove sulfur, oxides of nitrogen and ozone species.

The span gases were obtained from National Institute of Standards and Technology (NIST)-traceable compressed gas cylinders (Scott-Marrin Cylinder JJ8486) of nitric oxide (NO) in nitrogen (N_2), and (Scott-Marrin Cylinder JJ14732) of sulfur dioxide (SO_2) in N_2. Scott-Marrin analyzed the gas concentration of each cylinder. The SO_2 analysis was performed in accordance with Environmental Protection Agency (EPA) Protocol #2 using gas chromatography with electrochemical detection and is directly traceable to NIST by intercomparison with GMIS, Cylinder CC68683 at 49.4 ppm sulfur dioxide in nitrogen. The NO analysis was performed in accordance with EPA Protocol #2 using chemiluminescence and is traceable to NIST by direct intercomparison with GMIS, Cylinder CC78179 at 50 ppm nitric oxide in oxygen-free nitrogen. Volumes were determined using an analytical balance traceable to the NIST MMAP 232.09/202491.

O_3 concentrations were generated by a stable ozone generator and verified by a certified transfer standard (a Dasibi Model 1003-PC photometer, S/N 5311) in accordance with the EPA technical assistance document for ozone transfer standards (EPA, 1979). The transfer standard is routinely certified against AV's primary laboratory standard (a Dasibi Model 1003 RS ozone standard, S/N 4239). The zero air source was an AV built unit that uses Purafil and activated charcoal columns to remove sulfur, oxides of nitrogen and ozone species.

Section 3

PERFORMANCE AUDIT PROCEDURES

Performance audits are conducted in accordance with procedures described in the EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I and II (U.S. EPA, 1984, 1987). Procedures are discussed below.

o SO_2, NO/NO_x and O_3

The audits of the air quality samplers began with the station technician identifying the appropriate data channel and taking it off line so that ambient data were no longer being collected. Next, the station technician disconnected the sample line of the corresponding analyzer from the sample manifold. After plugging the open port of the sampler manifold, the sample line or inlet filter was connected to the Dasibi dilution system via a vented glass manifold through which the audit span gas was introduced to allow the audit test atmosphere to travel through as much of the normal sampling train (i.e., filters, scrubbers, etc.) as possible. Each analyzer was challenged with specific concentrations of span gas as follows:

Audit Point	Concentration Range
	NO_x,NO,SO_2 & O_3
1	.0
2	.03 to .08
3	.15 to .20
4	.35 to .45

Ozone concentrations were generated by ultraviolet photometric methods and are referenced to AV's primary standard. SO_2 and NO/NO_x concentrations were generated by NIST-traceable cylinders and gas dilution.

o Nitrogen Dioxide

Nitrogen dioxide concentrations were introduced into the $NO/NO_x/NO_2$ analyzer by gas-phase titration (GPT) of NO with O_3. Nitric oxide reacts completely with ozone to produce nitrogen dioxide and oxygen.

The NO_2 input concentration was determined by the following equations:

$$[NO_2 \text{ input}] = \frac{[\text{NO input}] - [\text{NO reading}]}{\text{NO slope}}$$

where: [NO input] = analyzer's NO channel response to the NO span prior to the addition of O_3

[NO reading] = analyzer's NO response after the addition of O_3

NO slope = slope of the curve generated by linear regression of the NO concentrations versus the analyzer's response during the audit of the NO channel, where the NO input is the abscissa and the NO response is the ordinate

The final stage of the $NO/NO_x/NO_2$ analyzer audit was to determine the converter efficiency from the following relationships:

$$[NO_2 \text{ converted}] = [NO_2 \text{ input}] \frac{[NO_x \text{ initial}] - [NO_x \text{ final}]}{NO_x \text{ slope}}$$

where: $[NO_x \text{ initial}]$ = analyzer's NO_x channel response before the addition of O_3

$[NO_x \text{ final}]$ = analyzer's NO_x response after the input sample of NO is titrated with O_3

NO_x slope = slope obtained from the audit of the NO_x channel

The converter efficiency for each audit point was calculated using the following equation:

$$\frac{[NO_2 \text{ converted}]}{[NO_2 \text{ input}]} \times 100$$

The converter efficiency is defined as the slope of the linear regression using the NO_2 source versus the NO_2 converted x 100. The converter efficiency must be greater than or equal to 96 percent to pass the audit.

Section 4

PERFORMANCE AUDIT CRITERIA

AeroVironment's guidelines for evaluating the accuracy of the continuous air quality analyzers are shown in Table 4-1. Evaluation of the analyzers in this manner incorporates the relative error of the instrument response as a function of the slope, intercept, and correlation coefficient determined by a best fit line of the audit points. This method is in accordance with the principles of the U.S. EPA.

TABLE 4-1. Linear regression criteria.

Slope		
Excellent	< ± 0.05	between analyzer response and audit concentration
Satisfactory	0.06 to 0.15	between analyzer response and audit concentration
Unsatisfactory	> ± 0.15	between analyzer response and audit concentration
Intercept		
Satisfactory	< ± 3%	of the analyzer range
Unsatisfactory	> ± 3%	of the analyzer range
Correlation Coefficient		
Satisfactory	0.9950 to 1.0000	linear analyzer response to audit concentrations
Unsatisfactory	<0.9950	nonlinear analyzer response to audit concentrations

* Reproduced from EPA Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Section 2.0.12, Page 39.

Section 5

AUDIT RESULTS AND ACTION

The station monitoring equipment information is provided in Appendix A. Audit results are presented in Appendices B and C. All instruments audited, with the following exceptions, were found to be operating within the EPA-recommended guidelines for air quality monitoring. Problems noted during the audit are presented below.

No problems were noted.

Section 6

RECOMMENDATIONS AND COMMENTS

The following presents recommendations and comments regarding items noted during the audit. Their implementation will result in improved operation of the site and potentially better data quality and data recoverability.

- The SO_2 analyzer was not in operation at the time of the audit and was not audited.

Section 7

REFERENCES

United States Environmental Protection Agency (1984): Quality assurance handbook for air pollution measurement systems, Volume I, Principles. Document EPA 600/9-76-005, Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina.

United States Environmental Protection Agency (1987): Quality assurance handbook for air pollution measurement systems, Volume II, Meteorological methods. Document EPA 600/4-77/027a, Environmental Monitoring Systems Laboratory, Research Triangle Park, North Carolina.

United States Environmental Protection Agency (1979): Technical assistance document for the calibration of ambient ozone monitors. Document EPA 600/4-79-057, Environmental Monitoring and Support Laboratory, Research Triangle Park, North Carolina.

Appendix A

STATION MONITORING EQUIPMENT INFORMATION

Site Name: STI Aircraft Date:7/24/92

Air Quality

Parameter/(abbreviation)	Manufacturer	Model No.	Serial No.	Instrument Range	Last Calibration	Date Installed	Instrument Log book	Manual (yes/no)	DAS Channel	DAS Range	Chart Ch. Id.	Chart range	Comments:
Ozone (O3)	Monitor Labs	8410	654	0 - 0.5 PPM	7/23/92	NA	Yes	Yes	NA	0 - 0.5 ppm	Ozone	0 to .5 ppm	
Oxides of Nitrogen (NOx)	Teco	42	291840-234	0 - 100 ppb	7/23/92	NA	Yes	Yes	NA	0 - 100 ppb	NOx	0 - 100 ppb	
Nitrogen Oxide (NO)	Teco	42	291840-234	0 - 100 ppb	7/23/92	NA	Yes	Yes	NA	0 - 100 ppb	NO	0 - 100 ppb	
Nitrogen Dioxide (NO2)	Teco	42	291840-234	0 - 100 ppb	7/23/92	NA	Yes	Yes	NA	0 - 100 ppb	NA	NA	
Sulfur Dioxide (SO2)	Meloy	SA285E	8K080	0 - 0.5 ppm	7/23/92	NA	Yes	Yes	NA	0 - 0.5 ppm	SO2	0 - 100 ppb	

Miscellaneous

Type (das/chart/etc.)	Manufacturer	Model No.	Serial No.	Measurement Range	Last Calibration	Date Installed	Instrument Log book	Manual (yes/no)	Comments:
Data logger	PC Clone	NA	NA	NA	7/23/92	NA	Yes	Yes	
Printer	Dot Matrix	NA	NA	NA	NA	NA	Yes	Yes	
Chart recorder	Linear	464	NA	0 to .5 ppm	7/23/92	NA	Yes	Yes	

Appendix B

SUMMARY OF RESULTS

SUMMARY OF AUDIT RESULTS

Site: STI Aircraft Project: SCE-Mojave Project Applicant: STI

AMBIENT AIR QUALITY MONITORS

Audit Date	Parameter	Chart Slope	Chart Intercept	Chart Correlation	DAS Slope	DAS Intercept	DAS Correlation
7/24/92	Ozone	NA	NA	NA	0.975	-0.000	1.0000
7/24/92	Oxides of Nitrogen	NA	NA	NA	0.949	-0.001	0.9999
7/24/92	Nitrogen Oxide	NA	NA	NA	0.965	-0.000	0.9999
7/24/92	Nitrogen Dioxide	NA	NA	NA	0.996	0.000	0.9995
7/24/92	Sulfur Dioxide	Not audited					

Audit Criteria: Slope 1.000 +/- 0.15; Intercept 0 +/- 3% fs; Correlation > 0.9950

Appendix C

AUDIT REPORTS

AEROVIRONMENT AUDIT RECORD
OXIDES OF NITROGEN

Date: 7/24/92
Start: 10:00 hr. PDT
Finish: 12:30 hr. PDT
Witnessed: Jerry Anderson

Site name: STI Aircraft
Project: SCE-Mojave Project
Applicant: STI
Operator: STI

Anz. make: Teco
Serial No.: 42-29184-234
Samp. flow: NA
Z setting: NA
Range: 0 - 100 ppb

Model: 42
Filter: NA
S. setting: NA
vacuum: NA

Operator provided correction factors: Corrected data = (IND. * A) + B

Last calibration date:7/23/92

	Chart	DAS
Factors= A:	1.000	1.000
B:	0.000	0.000

Audited by: Alex Barnett

NOX Audit Point	PPM Input (X)	PPM Chart (Y)	% diff. Chart	PPM DAS (Y)	% diff. DAS
1	0.000	NA	NA	0.000	NA
2	0.020	NA	NA	0.018	-12.6
3	0.050	NA	NA	0.047	-6.0
4	0.090	NA	NA	0.085	-5.6

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	NA	0.9494
Intercept:	NA	-0.0006
Correlation:	NA	0.9999
Avg. %Diff.:	NA	-8.1

Comments: None.

AUDIT EQUIPMENT

Dilution System: Dasibi model:1009mc s/n:032
Certification date: 7/23/92

Cylinder: JJ8486 Analysis date: 5/13/91
Analysis:(PPM) NO:19.72 ppm, Balance N2

ZERO AIR SOURCE

Make:AeroV Model:1 SN.1 Certification date: 7/23/92

AEROVIRONMENT AUDIT RECORD
NITRIC OXIDE

Date: 7/24/92
Start: 10:00 hr. PDT
Finish: 12:30 hr. PDT
Witnessed: Jerry Anderson

Site name: STI Aircraft
Project: SCE-Mojave Project
Applicant: STI
Operator: STI

Anz. make: Teco
Serial No.: 42-29184-234
Samp. flow: NA
Z setting: NA
Range: 0 - 100 ppb

Model: 42
Filter: NA
S. setting: NA
Pressure: NA

Operator provided correction factors: Corrected data = (IND. * A) + B

Last calibration date:7/23/92

	Chart	DAS
Factors= A:	1.000	1.000
B:	0.000	0.000

Audited by: Alex Barnett

NO Audit Point	PPM Input (X)	PPM Chart (Y)	% diff. Chart	PPM DAS (Y)	% diff. DAS
1	0.000	NA	NA	0.000	NA
2	0.020	NA	NA	0.018	-9.6
3	0.050	NA	NA	0.048	-3.8
4	0.090	NA	NA	0.086	-4.0

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	NA	0.9655
Intercept:	NA	-0.0005
Correlation:	NA	0.9999
Avg. %Diff.:	NA	-5.8

Comments: None.

AUDIT EQUIPMENT

Dilution System: Dasibi model:1009mc s/n:032
Certification date: 7/23/92

Cylinder:JJ8486 Analysis date: 5/13/91
Analysis:(PPM) NO:19.72 ppm, Balance N2

ZERO AIR SOURCE

Make:AeroV Model:1 SN.1 Certification date: 7/23/92

AEROVIRONMENT AUDIT RECORD
NITROGEN DIOXIDE

Date: 7/24/92
Start: 12:30 hr. PDT
Finish: 14:00 hr. PDT
Witnessed: Jerry Anderson

Site name: STI Aircraft
Project: SCE-Mojave Project
Applicant: STI
Operator: STI

Anz. make: Teco
Serial No.: 42-29184-234
Samp. flow: N/A
Z setting: N/A
Range: 0 - 100 ppb

Model: 42
Filter: NA
Vacuum: NA

Operator provided correction factors: Corrected data = (IND. * A) + B

Last calibration date:7/23/92

	Chart	DAS
Factors= A:	1.000	1.000
B:	0.000	0.000

Audited by: Alex Barnett

NO2 Audit Point	PPM Input (X)	PPM Chart (Y)	% diff. Chart	PPM DAS (Y)	% diff. DAS
1	0.000	NA	NA	-0.001	NA
2	0.015	NA	NA	0.016	9.6
3	0.052	NA	NA	0.052	0.6
4	0.073	NA	NA	0.072	-1.0

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	NA	0.9957
Intercept:	NA	0.0002
Correlation:	NA	0.9995
Avg. %Diff.:	NA	3.1

Converter efficiency
100.0%

Comments: NO2 not measured directly at site.

AUDIT EQUIPMENT

Dilution System: Dasibi model:1009mc s/n:032
Certification date: 7/23/92

Cylinder: JJ8486 Analysis date: 5/13/91
Analysis:(PPM) NO:19.72 ppm, Balance N2

ZERO AIR SOURCE

Make:AeroV Model:1 SN.1 Certification date: 7/23/92

AEROVIRONMENT AUDIT RECORD
OZONE

Date: 7/24/92
Start: 08:30 hr. PDT
Finish: 09:25 hr. PDT
Witnessed: Jerry Anderson

Site name: STI Aircraft
Project: SCE-Mojave Project
Applicant: STI
Operator: STI

Anz. make: Monitor Labs
Serial No.: 654
Samp. flow: 310 ccm
Auto span: NA
Range: 0 - 0.5 PPM

Model: 8410
Filter: NA
Span: 414
Zero: NA
Elevation: 1455 feet Ft.

Operator provided correction factors: Corrected data = (IND. * A) + B

Last calibration date:7/23/92

	Chart	DAS
Factors= A:	1.000	1.000
B:	0.000	0.000

Audited by: Alex Barnett

O3 Audit Point	PPM Input (X)	PPM Chart (Y)	% diff. Chart	PPM DAS (Y)	% diff. DAS
1	0.000	NA	NA	0.000	NA
2	0.057	NA	NA	0.055	-3.5
3	0.209	NA	NA	0.203	-2.9
4	0.429	NA	NA	0.418	-2.6

Linear Regression: (Y=PPM Corrected, X=PPM Input)

	Chart	DAS
Slope:	NA	0.9747
Intercept:	NA	-0.0004
Correlation:	NA	1.0000
Ave. %Diff.:	NA	-3.0

Comments: None.

AUDIT EQUIPMENT

Ozone source: Dasibi model: 1003pc s/n: 5311
Certification date: 7/23/92

Transfer standard: Dasibi model: 1003pc s/n: 5311
Certification date: 7/23/92

ZERO AIR SOURCE

Make:AeroV Model:1 SN.1 Certification date: 7/23/92

Comments: Standard is Dasibi sn 2409, sample freq = 42700, control freq = 21,025, cell temp = 37 deg. C, auto span 5334