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# ACID-MODES 1988: SUMMARY DATA REPORT
# AIRCRAFT MEASUREMENTS OF SELECTED POLLUTION SPECIES

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## Aircraft Measurements of Selected Pollution Species

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ABSTRACT. Cloud water samples were taken and chemical, meteorological, and aerosol measurements were made with the NOAA King Air C-90 aircraft during August and September 1988 in northeastern Pennsylvania in support of the Acid Model Operational-Diagnostic Evaluation Study (Acid-MODES). Two other aircraft were involved: Battelle Laboratory's G-1 and the West German Hawker-Siddeley (HS) 125. This report lists the objectives of Acid-MODES, the instrumentation used and the data obtained with the NOAA King Air, and the King Air's data processing, data quality and data availability.

## 1. INTRODUCTION

National Acid Precipitation Assessment Program (NAPAP) funding has been used to develop a Regional Acid Deposition Model (RADM). This Eulerian model is designed to simulate both meteorological and chemical parameters: the meteorological portion is for depicting and predicting airflow across the United States at varying altitudes as a function of time; the chemical portion is for superimposing known chemical processes onto the airflow framework. Chang (1985) reported on the first operational model; Chang (1986) discussed preliminary model evaluation studies; and, Chang, et al. (1987) discussed the model's physical concepts and formulation.

The Acid Deposition and Oxidant Model (ADOM) was developed by the Ontario Ministry of the Environment and the Atmospheric Environment Service, Environment Canada, with support from the Electric Power Research Institute (EPRI) and the Federal Republic of Germany's Unweltbundesamt.

Both RADM and ADOM needed assessment and verification with real-time observations; therefore, the Acid Model Operational-Diagnostic Evaluation Study (Acid-MODES) project was initiated to obtain the needed observations; two intensives were planned. The aircraft scientific research for Acid-MODES was directed jointly by NOAA and Battelle Laboratories. Three aircraft were involved in the first intensive: the NOAA King Air, Battelle Northwest Laboratory's G-1, and the German FhG Hawker-Siddeley (HS) 125.

This report includes the overall objectives of the first Acid-MODES program, instrumentation used and data obtained with the NOAA King Air, and the King Air's data processing, quality, and availability. Analysis of all aircraft data will appear in later publications.

## 2. OBJECTIVES

The first Acid-MODES intensive was to concentrate on three major topics:

1. Vertical exchange of pollutants.

2. Nonlinearity of transformation processes.

3. Chemical history of polluted air masses.

The EPA Advisory Group for Aircraft Measurements suggested that the aircraft intensive portion focus on characterizing pollutant fields by

- obtaining measurements of the distribution of trace constituents on a regional scale,

- studying the influence of frontal passages on the spatial and temporal distribution of primary and secondary pollutants,

- studying the clear-air oxidant formation and chemical balances, and

- obtaining measurements of the influence of non-precipitating cloud processes.

The Advisory Group also suggested the aircraft intensive focus on measurements for aqueous phase enhancement under different oxidant conditions to determine propensities for nonlinearity.

For a more detailed description of the evaluation program's goals, see Dennis and Laulainen (1988).

## 3. DATA COLLECTION

### 3.1 Field Sites

The Battelle G-1 and the German HS maintained flight operations out of Port Columbus International, Columbus, OH, in conjunction with the Operations Center. The Operations Center was responsible for decision making and supervision of all flight activities. Harrisburg, PA was the base of flight operations for the King Air because of its shorter range capability and its flight objectives.

### 3.2 Flight Plans

Flight plans were developed and each aircraft had different flight objectives. The King Air had three objectives: flights over the Appalachian chain (Blue Ridge Mountains) for comparison with ground stations; cloud-water collection flights; and Acid-MODES objective flights. The G-1 and the HS had Acid-MODES objective flights only.

Blue Ridge: Two flights of approximately 3-hour duration each were flown along the Appalachian Mountains, with profiles over specific ground sites at Scotia, PA, Shenandoah National Park, VA, Whitetop Mountain, VA, on the first flight, then over Mt. Mitchell, NC, and Brasstown Bald, GA, on the second. Figure 1 shows the flight track of each flight.

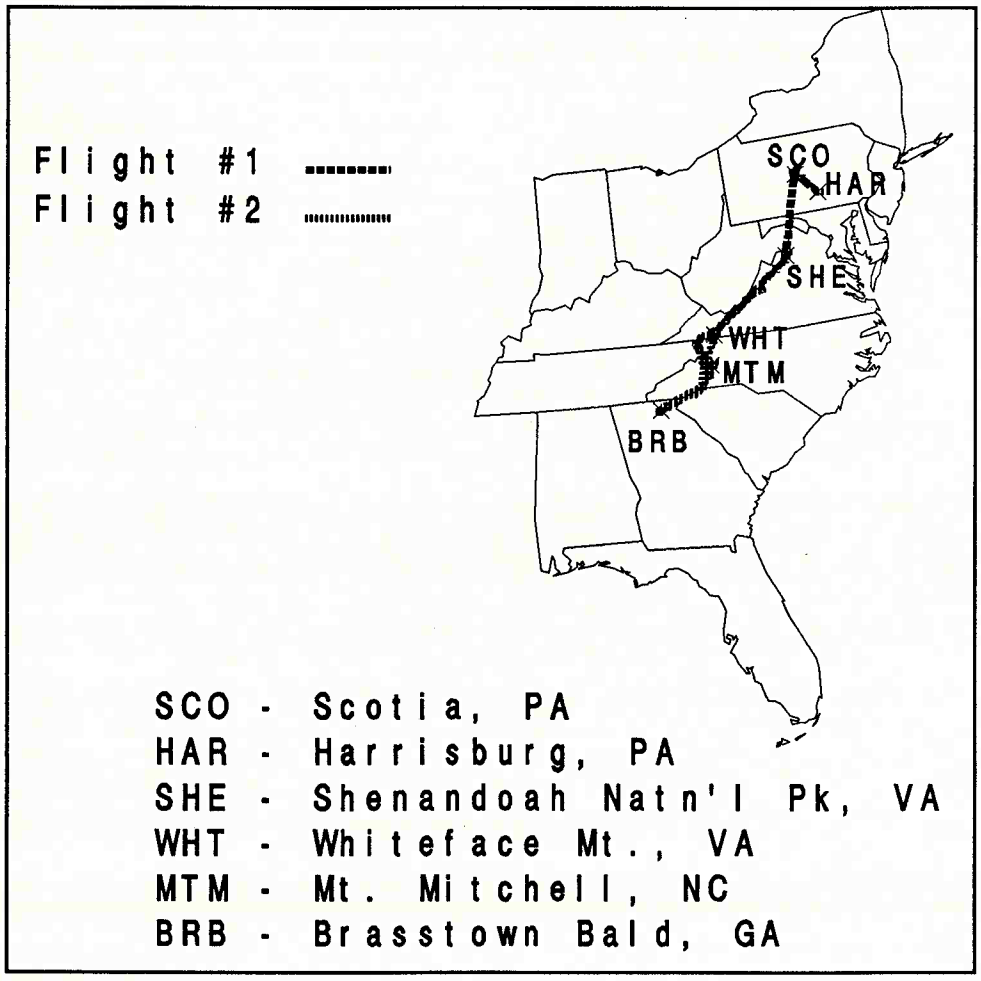


**Figure 1** Blue Ridge flight tracks of the NOAA King Air.

Cloud-water collection: Five flights of approximately 2-3 hour duration each were flown to collect cloud-water samples from nonprecipitating, uniform clouds. A modified Mohnen slotted-rod collector was used (Kim, 1991). Flight tracks were adjusted in flight to stay in stratiform cloud and to sample at different levels. Most sampling was done around the Harrisburg area.

Acid-MODES: Seven flights of approximately 4-hour duration each were flown with Acid-MODES objectives. The King Air plans (in conjunction with the G-1 and the HS) were the zipper-curtain and the high-resolution box patterns.

The zipper-curtain plan (Figure 2) was designed to provide spatial coverage over a broad region containing both source and receptor areas. In this plan, the King Air and the G-1 flew zig-zag patterns on a horizontal plane at the same altitude in RADM grid regions, while the HS flew zig-zag patterns in the vertical on the perimeter (dolphin pattern) of the regions. Each zipper-curtain called for approximately 8 hours of sampling. The King Air landed at the end of the "zipper", refueled, then continued the zipper pattern back to Harrisburg. One complete zipper-curtain flight (two flights) was accomplished during the project.

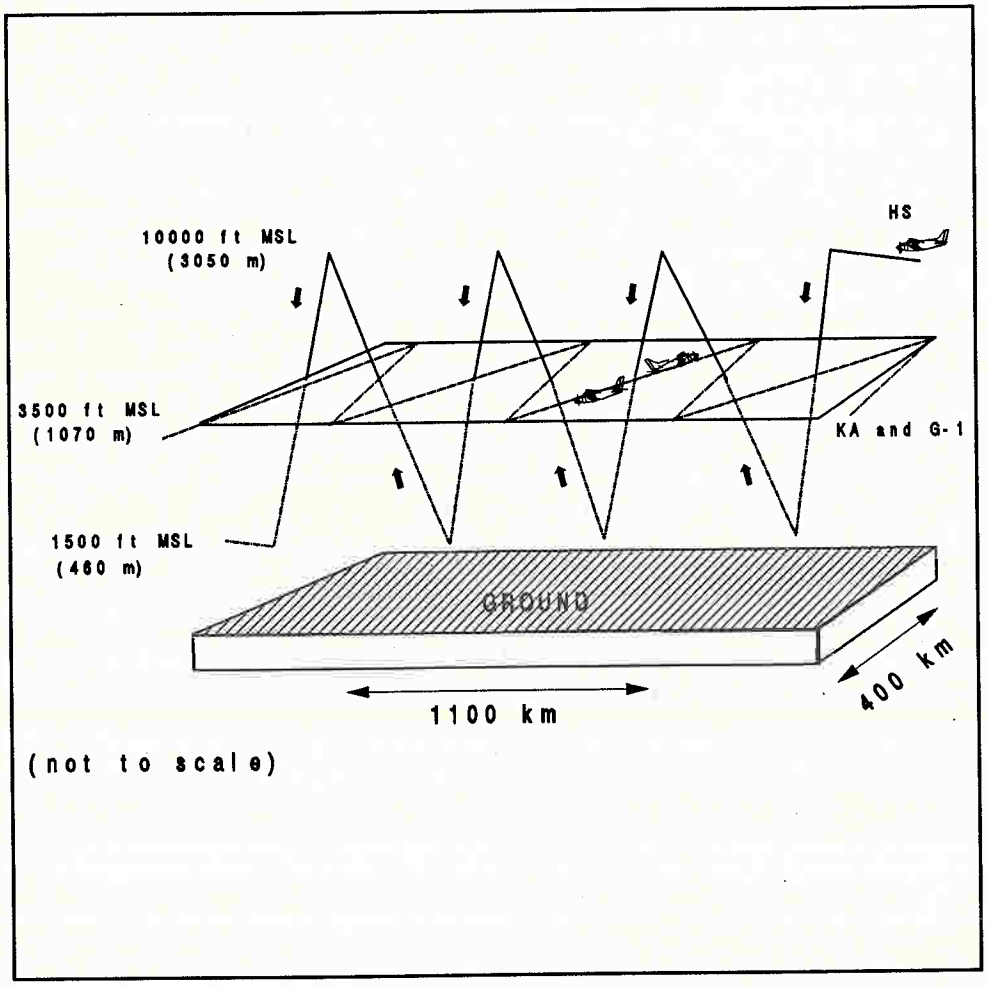


**Figure 2** Aircraft sampling pattern for zipper-curtain.

The high-resolution box plan (Figure 3) was designed to collect data encompassing four RADM grids located downwind of a major emissions source. In this plan, the King Air flew two zig-zag patterns through the grid area at approximately 7000 feet (2135 m): circuits 1 and 2, where circuit 2 was with a 90° offset (see Figure 3). After refueling, the King Air flew circuit 3, which was a repeat of the pattern in circuit 1, but at 10000 feet (3050 m). The G-1's circuit 1 and 2 was a zig-zag pattern through the same grid areas at 10000 feet (3050 m), then reverse (see Figure 3); circuit 3 for the G-1 was the same as circuit 1, but at 4000 ft (1220 m). The HS flew dolphin patterns on the perimeter for all circuits. Two high-resolution box patterns (four flights) were flown.

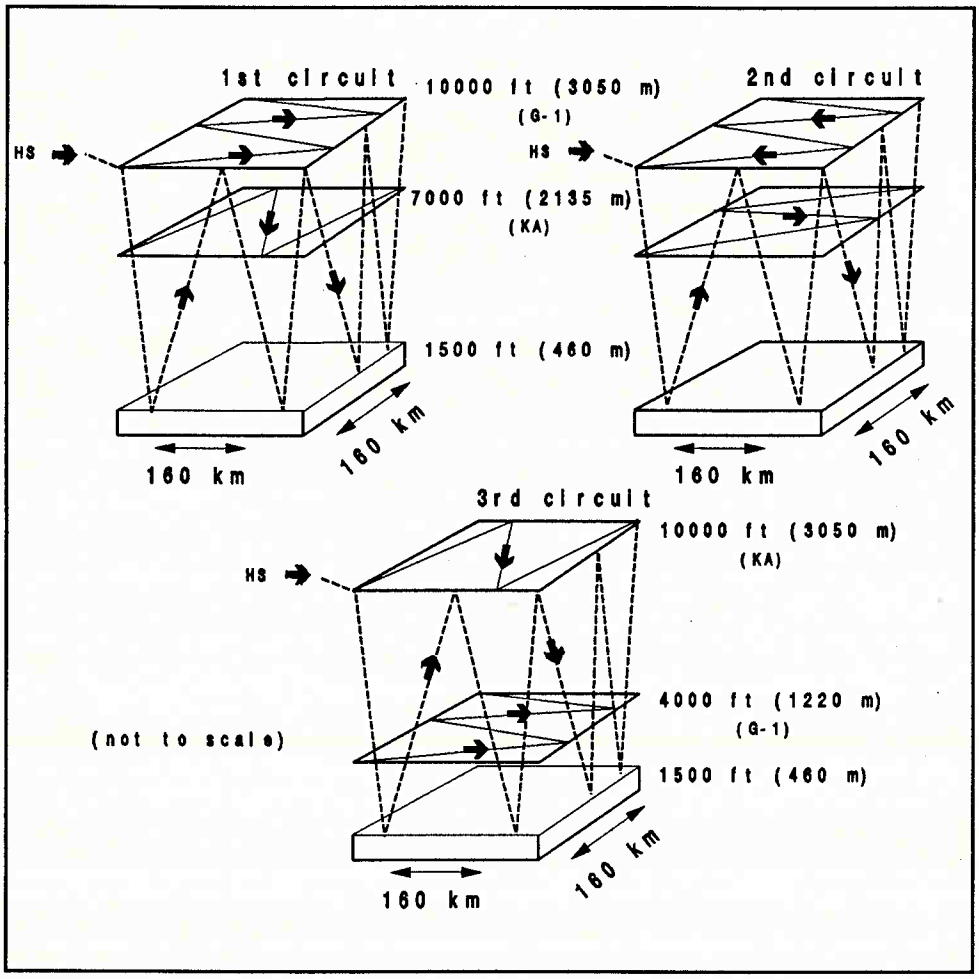


**Figure 3** High-resolution box flight pattern.

The G-1 and the HS had additional Acid-MODES objective flights that did not include the King Air; these flight plans are not included in this report. Before beginning the zipper-curtain or the high-resolution box flights, the King Air flew a profile over the Scotia site. Also, before beginning either pattern, all three aircraft did close-range, in-flight intercomparisons for approximately 15 minutes. These will be used to assess bias among the aircraft systems.

### 3.3 Daily Operations

Preparation time for the flights was approximately 3 hours. This included instrument warm-up time and calibrations on all instruments.

After the flight, the Principal Investigators and flight crew met for an informal de-briefing of flight and scientific conditions. These post-flight debriefings included in-flight changes, flight weather conditions, and instrument status and/or problems. Pre-flight, in-flight, and post-flight log notes are presented in the Appendix.

## 4. INSTRUMENTATION

The NOAA King Air (Beechcraft C-90) used for the measurements described here is owned and operated by NOAA's Aircraft Operations Center in Miami, FL. It is equipped to measure aerosols, trace gases, and meteorological parameters (Wellman et al., 1989). It is also equipped with a LORAN navigational system (Advanced Navigation Inc.). The data-acquisition system aboard the aircraft during Acid-MODES was a Particle Measuring Systems, Model DAS-64, and had the capability of recording 24 instrument outputs (14 fast analog and 10 slow analog channels), as well as data from the Forward-Scattering Spectrometer Probe (FSSP) and the Active-Scattering Aerosol Spectrometer Probe (ASASP). Details of the data system are described by Wilkison and Boatman (1988).

Data were sampled every 0.5 seconds on the fast analog channels and every 5 seconds on the slow analog channels, then recorded to tape every 5 seconds. Data were recorded on magnetic cartridge tapes using Algo Inc. recorder devices. There were two Algo systems: one for the instrumentation being recorded through the data acquisition system and one for the LORAN data. Additionally, grab-sample data were recorded every 30 seconds on floppy diskettes (excluding LORAN data) as a backup in case of tape or tape recorder failure.

Instrumentation aboard the aircraft is a fairly standard package and instruments may be added or removed to meet specific research objectives. For Acid-MODES, 11 of the 14 fast analog and 7 of the 10 slow analog channels were used for standard instrumentation. A flask-sampling system was installed; however, the flask information was recorded only in the in-flight logbook, and not on the DAS-64. Additionally, the cloud-water collection information is also recorded only in the in-flight log. Table 1 is a summary of the data recorded.

Table 1. Summary of data recorded during Acid-MODES

| Fast Analog | | Slow Analog | | Aerosol Data |
|---|---|---|---|---|
| 1 | Spare | 1 | Internal (no access) | FSSP |
| 2 | Spare | 2 | Internal (no access) | ASASP |
| 3 | $H_2O_2$ background | 3 | Photometer | |
| 4 | $H_2O_2$ signal | 4 | 1-in filter pack flow | |
| 5 | Spare | 5 | 90-mm filter pack flow | |
| 6 | Dynamic pressure | 6 | $H_2O_2$ flow A | LORAN Data |
| 7 | Temperature | 7 | $H_2O_2$ flow B | |
| 8 | Dew point | 8 | 90-mm filter pack flow | Latitude |
| 9 | $NO_y$ status | 9 | $NO_y$ range | Longitude |
| 10 | Dew point (duplicate) | 10 | Spare | Heading |
| 11 | $SO_2$ | | | |
| 12 | Pressure | | | |
| 13 | $NO_y$ signal | | | |
| 14 | Ozone | | | |

The following subsections describe the instrumentation used for Acid-MODES. Each description includes the principle of operation, the algorithm used to convert to engineering units, the specifications (range and accuracy), and calibration information.

### 4.1 K & K Inc.: $H_2O_2$ Analyzer

Principle of Operation: The $H_2O_2$ analyzer is a dual fluorimeter system with a wet chemical flow. In one channel, peroxidase enzyme catalyzes the reaction in which hydroperoxides form the fluorescent dimer of p-hydroxyphenylacetic acid (POPHA). Both $H_2O_2$ and organic hydroperoxide are measured; the peroxide concentration is directly proportional to the fluorescence intensity. In the second channel, $H_2O_2$ is selectively decomposed so that only organic hydroperoxides produce the fluorescence signal. This second channel acts as a background measurement. Output is in volts, and volts are converted to $H_2O_2$ parts per billion by volume (ppbv) by

$H_2O_2$ (ppbv) = h2fact * {[siga * bkth(2/flowa)] - [bkgda(2/flowb)]},

where h2fact = calibration factor (standard $H_2O_2$ mixing ratio/voltage deflection for the standard)
siga = signal value minus the signal offset
bkth = breakthrough value (catalase efficiency)
bkgda = background value minus the background offset
flowa = flow for signal channel
flowb = flow for background channel.

Specifications: Range: 0–10 ppbv
Accuracy: 0.1 ppbv

Calibration: There was a daily pre-flight calibration using a 1.6 ppbv ($2.93 \times 10^{-7}$ M) and 3.1 ppbv ($5.86 \times 10^{-7}$ M) standard solution. A daily in-flight calibration was done using the 1.6 ppbv standard solution.

## 4.2 Tavis: Dynamic Pressure Transducer

Principle of Operation: The transducer is a pressure-sensing capsule with electronic signal conditioning. It measures the difference between the static pressure port and the pitot tube. Output is in voltage, and is converted to millibars by

Dyn Press (mb) = 51.81147 * volts + 9.83586.

Specifications: Range: 0.236 to 4 pounds per square inch differential (psid)
Accuracy: 0.73%

Calibration: Calibration in the field is not necessary. An initial calibration was performed by the manufacturer on 19 November 1981; a laboratory calibration was performed on 30 May 1985. Calibration was verified during a Boulder Atmospheric Observatory (BAO) tower flyby on 13 October, 1988.

## 4.3 Rosemount: Total Temperature Sensor

Principle of Operation: A sealed platinum resistance sensing element measures total air temperature. For stability and protection, the sealed element is surrounded by a gold-platinum alloy radiation shield, which in turn is surrounded by a stainless steel shield. The resistance is measured in volts, which are proportional to total temperature by the following algorithm:

T (°C) = recorded volts * (range/5 volts) + offset,

where the range is +40°C to −60°C, and the offset is −60°C.

Specifications: Range: +40° to −60°C
Accuracy: ≥0.995 (measured temperature to total temperature) (±0.25°C plus 0.5% of the magnitude of the temperature in degrees Celsius).

Calibration: Intercomparison calibrations are performed using the BAO 300-m tower and an additional temperature probe. These calibrations are performed annually if possible; however, the last calibration that was performed before the Acid-MODES flights was 24 April 1986. A tower flyby on 13 October 1988 showed that the calibration was in good standing.

## 4.4 General Eastern: Dewpoint Hygrometer

Principle of Operation: An incoming parcel of air is directed into the dewpoint hygrometer chamber and is cooled at constant pressure by contact with the mirrored surface of a thermoelectric cooling module. Condensation appears on the surface at a temperature slightly below that of the thermodynamic dewpoint of the air. The observed dewpoint will differ from the thermodynamic dewpoint depending on the nature of the condensing surface, the condensation nuclei, and the sensitivity of the condensate-detecting apparatus. When the dew on the mirrored surface is of a constant thickness, it is in equilibrium with the partial pressure of the water vapor in the air sample. At this point, the temperature of the mirror equals the dewpoint temperature. The dewpoint is proportional to the voltage according to the following algorithm:

$T_d$ (°C) = recorded volts * (range/5.316 volts) + offset,

where the range is −75°C to +50°C, and the offset is −75°C.

Specifications: Range: −75° to +50°C
Accuracy: ±0.25°C at +50°C; ±1.0°C at −75°C

Calibration: The manufacturer calibrated the instrument on 25 November 1987 before it was installed on the aircraft. Annual calibrations are performed using a portable calibration unit. Balance checks were performed daily in-flight during the project, and the instrument was re-balanced if needed.

## 4.5 Thermo Environmental Instruments (TEI): $NO_y$ Analyzer

Principle of Operation: The $NO_y$ analyzer is a modified TEI $NO_x$ instrument (see Delaney et al., 1982). Ambient air is sampled directly (NO mode) or through the $NO_y$-to-NO converter ($NO_y$ mode). The chemiluminescence of NO and $O_3$ produce an intensity linearly proportional to the concentration of NO. The values (in ppbv) are derived by the following algorithm:

NO or $NO_y$ (ppbv) = [volts(either NO or $NO_y$ mode) − offset] * scaling factor,

where the scaling factor is a value of ppbv per volt.

Specifications: Range: 0–100 ppbv (range-selectable up to 10 parts per million (ppm)
Accuracy: 0.1 ppbv

Calibration: A four-point calibration was completed before the field intensive. Daily pre-flight and in-flight zero and span calibrations were performed in the field.

### 4.6. Thermo Electron Corporation (TECO): $SO_2$ Analyzer

Principle of Operation: Pulsating ultraviolet (UV) light (230–190 nm) is focused through a narrow-band filter into a fluorescent compartment through which sample air passes. The UV light excites the $SO_2$ molecules, and emits decay radiation that passes through another filter onto a photomultiplier tube (PMT). The amount of light energy impinging on the PMT is directly proportional in voltage to the amount of $SO_2$ in the sample:

$SO_2$ (ppbv) = so2max * (volts - vos)/(regs - vos),

where so2max = maximum $SO_2$ (ppbv) during span with given calibration gas
vos = zero voltage offset
regs = pressure regression value (changes daily).

Specifications: Range: 0–200 ppbv (range selectable)
Accuracy: 0.1 ppbv

Calibration: Zero and span calibrations, on the low range (0–10 ppbv), were performed daily. An in-flight span calculation was performed from takeoff up to the highest altitude.

### 4.7 Rosemount: Static Pressure Transducer

Principle of Operation: The transducer is a precision capacitance pressure-sensing capsule with electronic signal conditioning. It measures the pressure from a static pressure port. Conversion from pounds per square inch absolute (psia) to millibars is through the following algorithm:

Pressure (mb) = volts * 68.95.

Specifications: Range: 0–15 psia
Accuracy: >±0.1% Full Scale Pressure (FSP)

Calibration: No calibration is required in the field. The instrument performance was audited during the BAO tower flyby on 13 October 1988; no adjustment was necessary.

### 4.8 Thermo Electron Corporation (TECO): Ozone Analyzer

Principle of Operation: Ozone concentration is directly related to the magnitude of the attenuation of light, at 254 nm, in the absorption cell of the analyzer. Dual detectors monitor the changes in light intensity (both zero and sample), and an averaged intensity is calculated by the instrument using the Beer-Lambert Law: $I/I_o = \exp(-K\ell C)$,

where $I$ = light intensity of the ambient sample in the absorption cell
$I_o$ = light intensity measured with reference in the absorption cell

K = absorption coefficient, a function of the gas and wavelength; for ozone at 254 nm it is 308 $atm^{-1}$ $cm^{-1}$ at standard conditions (0°C and 760 mm pressure)
$\ell$ = length of the absorption cell (in cm)
C = concentration (in ppm).

Each cell measures either I or $I_o$; when one cell is measuring I the other is measuring $I_o$, and vice versa. Concentration (in ppbv) is proportional to voltage using the following algorithm:

C (ppbv) = (vd * 1.02890) + 1.17713,

where vd = (volts * 100) * [(1013.6/pressure) * (300/273.16)], which is for density correction.

Specifications: Range: 0–1.0 ppm
Accuracy: ±1.0 ppb

Calibration: An annual audit is performed using a National Institute of Standards and Technology (NIST) standard. The latest calibration was performed 11 February 1988.

## 4.9 LI-COR: Solar Radiation Photometer

Principle of Operation: A silicon photodiode measures solar radiation received from the whole sky (180° field of view). Through use of an amplifier, the volts are directly proportional to watts per square meter (W $m^{-2}$).

Solar radiation (W $m^{-2}$) = volts * 1000.

Specifications: Range: 0.4–1.2 $\mu$m (peak at 0.95 $\mu$m)
Accuracy: ±5%

Calibration: No calibration is performed in the field. The calibration was performed by the manufacturer against an Eppley Precision Pyranometer under full-sun conditions at midday on 25 April 1983. Uncertainty of the calibration was ±5%.

## 4.10 Filter Pack Systems: Aerosol Composition

### 4.10.1 One 1-in-Diameter System

A one-inch (25 mm) Nuclepore filter pack system was used for all flights. The sample diameter of the filter was reduced to 0.50 cm by means of a Teflon mask. Filter handling and X-ray fluorescence (XRF) analysis were provided by the University of Colorado. A mass flow meter (Kurz Inc.) monitored flow which is in liters per minute. The flow meter was calibrated 1 December 1986, and audited in September 1988.

### 4.10.2 Two 90-mm-Diameter Systems

Two 90-mm filter pack systems were used during the flights, one for total flow sampling and one for separated flow samples. Filters were provided by Pennsylvania State University; analysis was performed by Battelle Pacific Northwest Laboratories. Mass flow meters (Kurz Inc.) monitored flow which was in liters per minute. Both Kurz meters were calibrated in April 1988, before the flights, and one was audited in September 1988 and the other in November 1988.

## 4.11 Flask-sampling systems: Nonmethane Hydrocarbons

### 4.11.1 Pressurized Flask System

Washington State University, Pullman, supplied us with stainless steel internally electro-polished flasks for collecting nonmethane hydrocarbons during the Acid-MODES objective flights. The location (latitude/longitude), time, temperature, dewpoint, and altitude were recorded on the flasks and in the in-flight log book.

### 4.11.2 Evacuated Flask System

The University of California, Irvine, also supplied us with stainless steel internally electro-polished flasks for collecting of nonmethane hydrocarbons during the Blue Ridge flights (16 August 1988, flights 1 and 2). Again, location (latitude/longitude), time, temperature, dewpoint, and altitude were recorded on the flasks and in the in-flight log book.

## 4.12 Mohnen Slotted-Rod Collector (modified): Cloud Water Collection

We used a modified Mohnen slotted-rod collector for cloud water sampling (Kim, 1991). Samples were collected in clean, deionized-water-rinsed bottles that were attached to the base of the collector. Each sample was analyzed immediately after flight for pH; the remainder of each sample was divided for analyses for S(IV), $H_2O_2$, $O_3$, and principal ions. Brookhaven Laboratory and the NOAA Atlantic Oceanographic and Meteorological Laboratory (AOML) analyzed the water samples.

## 4.13 Particle Measuring Systems (PMS) Active-Scattering Aerosol Spectrometer Probe (ASASP): Particle Size

Principle of Operation: A 632.8-nm He-Ne laser is used to size particles in the 0.12-3.12 $\mu$m range using a single channel, with 15 size bins. Airflow is directed and constrained to a 150-$\mu$m-diameter stream, providing isokinetic flow for sampling. Particles are detected and sized by the amount of light refracted by the collecting optics aperture.

Specifications: Range: 0.12–3.12 $\mu$m (15 bins)
Accuracy: 99% +

Calibrations: No calibration is done onsite; the probe is calibrated by the manufacturer. The last calibration was performed 13 January 1987.

### 4.14 Particle Measuring Systems (PMS) Forward-Scattering Spectrometer Probe (FSSP): Particle Size

Principle of Operation: The FSSP is a one-dimensional probe that measures each particle's diameter as it passes through the sample area. Particles are sized by measuring the amount of light scattered into the collecting optics aperture. There are four overlapping size ranges, and each range is divided into 15 size intervals, providing 60 size channels in a 0.5–47 $\mu$m range; however, the instrument was set to Range 1, which measures 2–32 $\mu$m.

Specifications: Range: 2–32 $\mu$m (15 bins)
Accuracy: $\pm$10% or $\pm$2 $\mu$m (whichever is greater)

Calibrations: Calibration was performed by the manufacturer; the last calibration was on 2 May 1988. No calibration is necessary in the field.

### 4.15 Advanced Navigation Inc. (ANI) Long-Range Navigation (LORAN) System: Latitude, Longitude, Heading

Principle of Operation: The LORAN system is a pulse-type radio system with ground-based transmitters. A receiver in the aircraft precisely measures signals from each ground station, thereby fixing a line of positions for tracking. Latitude, longitude, and heading are read directly from the LORAN; wind direction and wind speed are calculated using LORAN input. Latitude and longitude are converted to decimal degrees; wind directions are in degrees, and wind speeds are in meters per second.

Specifications: Accuracy: Lat/Long—.002° (approx. 200 meters)
Heading—1.0° (with 1-min averages)
Wind Direction—1.0° (with 1-min averages)
Wind speed—1.0 m $s^{-1}$ (with 1-min averages)

Calibration: No calibration is required; however, a check was made of the system over the BAO on 13 October 1988, and the LORAN accurately received the tower's position.

## 5. DATA PROCESSING

Data were verified on site by a post-flight look at the 30-s grab-sample files. The cartridge tapes were shipped overnight to Boulder for processing. A series of steps was involved in developing the final usable data:

1. The data (both DAS-64 and LORAN) were written back to a hard disk on an HP-1000 system.

2. An HP program designed specifically for the Acid-MODES aircraft channel assignments was used to produce an averaged data file (user's choice of averaging time). This program integrates the LORAN data, so the final file has averaged chemical, meteorological, and position data.

3. The aerosol probe (ASASP and FSSP) data were processed separately, and an averaged file for each probe was produced.

4. Some data such as $SO_2$, $NO/NO_y$, $H_2O_2$, and filter-pack flows needed after-the-fact calibration coefficients applied. These data were initially analyzed for these adjustments and then reprocessed with the correction factors.

The dataset for Acid-MODES consists of 1-min-averaged and 10-s-averaged (one each per flight) ASASP, FSSP and chemical, meteorological, and LORAN (CML) files.

The ASASP final processed files have 19 columns of data:

Columns 1, 2. Beginning and ending times (of the average).

Columns 3-17. Bin values (particles $cm^{-3}$ $\mu m^{-1}$). The bin number listed at the top of the columns is the value at the center of the bin ($\mu m$). The ASASP has only one range with 15 bins. Table 2 lists the ASASP bin sizes.

Column 18. Average mass ($\mu g$ $m^{-3}$). The average concentration (particles $cm^{-3}$ $bin^{-1}$) is converted to mass based on 2 g $cm^{-3}$ density, then the average mass values are integrated across the bins.

Column 19. Average concentration (particles $cm^{-3}$). The value in each bin (particles $cm^{-3}$ $\mu m^{-1}$) is converted to particles $cm^{-3}$ $bin^{-1}$, then the average concentration values are integrated across the bins.

The FSSP final processed files also have 19 columns of data:

Columns 1, 2. Beginning and ending times (of the average).

Columns 3-17. Bin values (particles $cm^{-3}$ $\mu m^{-1}$). The bin number listed at the top of the columns is the value at the center of the bin ($\mu m$). When the concentration is greater than 5.0 particles $cm^{-3}$, the value shifts to liquid water content (g $m^{-3}$). The FSSP can be set to autoranging or to an individual range. During Acid-MODES, the instrument was on Range 1. Table 2 lists the FSSP bin sizes.

Column 18. Average mass ($\mu g\ m^{-3}$), based on 2 g $cm^{-3}$ density, except when the value is shifted to liquid water, then the standard density of water (1 g $cm^{-3}$) is used. As with the ASASP, the values are integrated across the bins.

Column 19. Average concentration (particles $cm^{-3}$). Concentration values are converted as with the ASASP: Particles $cm^{-3}$ $\mu m^{-1}$ to particles $cm^{-3}$ $bin^{-1}$, then integrated.

Table 2. ASASP and FSSP calibrated bin values

| ASASP-100X | | | FSSP | | |
|---|---|---|---|---|---|
| Channel | Size ($\mu m$) | Interval ($\mu m$) | Channel | Size ($\mu m$) | Interval ($\mu m$) |
| 1 | 0.120–0.145 | 0.025 | 1 | 2.00– 4.00 | 2.00 |
| 2 | 0.145–0.195 | 0.050 | 2 | 4.00– 6.00 | 2.00 |
| 3 | 0.195–0.270 | 0.075 | 3 | 6.00– 8.00 | 2.00 |
| 4 | 0.270–0.370 | 0.100 | 4 | 8.00–10.00 | 2.00 |
| 5 | 0.370–0.495 | 0.125 | 5 | 10.00–12.00 | 2.00 |
| 6 | 0.495–0.645 | 0.150 | 6 | 12.00–14.00 | 2.00 |
| 7 | 0.645–0.820 | 0.175 | 7 | 14.00–16.00 | 2.00 |
| 8 | 0.820–1.020 | 0.200 | 8 | 16.00–18.00 | 2.00 |
| 9 | 1.020–1.245 | 0.225 | 9 | 18.00–20.00 | 2.00 |
| 10 | 1.245–1.495 | 0.250 | 10 | 20.00–22.00 | 2.00 |
| 11 | 1.495–1.770 | 0.275 | 11 | 22.00–24.00 | 2.00 |
| 12 | 1.770–2.070 | 0.300 | 12 | 24.00–26.00 | 2.00 |
| 13 | 2.070–2.395 | 0.325 | 13 | 26.00–28.00 | 2.00 |
| 14 | 2.395–2.745 | 0.350 | 14 | 28.00–30.00 | 2.00 |
| 15 | 2.745–3.120 | 0.375 | 15 | 30.00–32.00 | 2.00 |

In the CML files, some data were left in the raw voltage state; however, most were converted (with calibrations) to engineering units. True air speed (TAS), wind speed, wind direction, $H_2O_2$ (ppbv), $SO_2$ (ppbv), NO (ppbv), and Noy (ppbv) were calculated and added to the processed CML files; each CML file has 30 columns in it. Table 3 lists the parameters in the final averaged CML data files.

Table 3. Processed CML parameter files for Acid–MODES: Aug–Sep 1988, Harrisburg, PA

| No. | Parameter | Unit | Accuracy | Response Time | Precision | Comments |
|---|---|---|---|---|---|---|
| 1 | Begin time | hhmmss | ---- | ---- | ---- | From tape |
| 2 | End time | hhmmss | ---- | ---- | ---- | Computed value |
| 3 | NO | ppbv | ---- | ---- | ---- | Computed value |
| 4 | Noy | ppbv | ---- | ---- | ---- | Computed value |
| 5 | $H_2O_2$ background | mV | 0.1 mV | 2.5 min | 0.1 mV | $H_2O_2$ instrument |
| 6 | $H_2O_2$ signal | mV | 0.1 mV | 2.5 min | 0.1 mV | $H_2O_2$ instrument |
| 7 | $H_2O_2$ | ppbv | 0.1 ppbv | ---- | 0.1 ppbv | Flow corrected; not time corrected |
| 8 | Dynamic pressure | mb | 0.1 mb | 1 s | 0.1 mb | Pitot tube and static pressure port |
| 9 | Temperature | °C | 0.1°C | 1 s | 0.1°C | Wire |
| 10 | Dew point | °C | 1.0°C | 5 s | 0.1°C | Cooled mirror |
| 11 | $NO_y$ status | mV | ---- | ---- | ---- | $NO_y$ sample mode indicator |
| 12 | Dew point | °C | 1.0°C | 5 s | 0.1°C | Duplication for backup purposes |
| 13 | $SO_2$ | ppbv | 0.1 ppbv | 1 min | 0.1 ppbv | Pulsed fluorescence |
| 14 | Pressure | mb | 0.5 mb | 1 s | 0.1 mb | Static pressure |
| 15 | $NO_y$ signal | mV | 1.0 mV | 30 s | 1.0 mV | Raw voltages |
| 16 | Ozone | ppbv | 0.5 ppbv | 1 s | 0.1 ppbv | UV photometric detection |
| 17 | Latitude | deg | .002 deg | 1 s | ---- | LORAN-C |
| 18 | Longitude | deg | .002 deg | 1 s | ---- | LORAN-C |
| 19 | True air speed | $ms^{-1}$ | 1.0 $ms^{-1}$ | 1 s | 0.1 $ms^{-1}$ | Computed value |
| 20 | Heading | deg | 1.0° | 1 s | 1.0° | Gyrocompass |
| 21 | Wind direction | deg | 1.0° | 60 s | 0.1° | Computed value |
| 22 | Wind speed | $ms^{-1}$ | 1.0 $ms^{-1}$ | 60 s | 0.1 $ms^{-1}$ | Computed value |
| 23 | Solar radiation | $Wm^{-2}$ | ---- | ---- | ---- | Short-wave sun photometer |
| 24 | Filter flow | slpm* | 0.1 slpm | 1 s | 0.1 slpm | 1-in filter pack |
| 25 | Filter flow | slpm* | 0.1 slpm | 1 s | 0.1 slpm | 90-mm filter pack (total) |
| 26 | $H_2O_2$ flow A | slpm* | ---- | ---- | ---- | $H_2O_2$ airflow for signal |
| 27 | $H_2O_2$ flow B | slpm* | ---- | ---- | ---- | $H_2O_2$ airflow for bkgrd |
| 28 | Filter flow | slpm* | 0.1 slpm | 1 s | 0.1 slpm | 90-mm filter pack (separator) |
| 29 | $NO_y$ range | V | ---- | ---- | ---- | $NO_y$ range indicator |
| 30 | Spare | ---- | ---- | ---- | ---- | ---- |

*slpm is standard liters per minute.

## 6. DATA QUALITY

For three flights (22 August, flights 1 and 2; and 1 September, flight 2), the LORAN was completely inoperational. On two other flights (1 September, flight 1 and 4 September), the LORAN operated intermittently. In the processed CML data files, latitude, longitude, heading, wind speed, and wind direction are all incorrect whenever there is a LORAN malfunction.

A software problem that interfered with buffer storage caused random loss of data; however, it was not a significant amount. The values during that time were averaged over the amount of data that existed in that time frame, and the averages are accurate; however, the shorter the averaging time (i.e., 10 seconds), the greater amount of zeros. When a 1–min average is used, the data show no zeros for these short dropouts (which were usually less than 20

seconds). Some additional loss of in-flight data occurred when the cartridge tapes were changed (maximum 3 minutes). Table 4 shows the percentages of usable raw data per flight day. These percentages were obtained by including all possible losses.

Table 4. Percentages of usable data per flight

| Date of flight | Analog Channels | LORAN |
|---|---|---|
| 880816 (1) | 98.96 | 99.12 |
| 880816 (2) | 99.49 | 99.41 |
| 880818 | 89.07 | 99.38 |
| 880819 | 97.46 | 100.00 |
| 880820 | 97.93 | 100.00 |
| 880821 (1) | 98.50 | 98.50 |
| 880821 (2) | 97.30 | 96.68 |
| 880822 (1) | 98.43 | 0.00 |
| 880822 (2) | 98.97 | 0.00 |
| 880826 | 98.04 | 99.92 |
| 880829 | 99.26 | 100.00 |
| 880901 (1) | 98.55 | 21.32 |
| 880901 (2) | 98.92 | 0.00 |
| 880904 | 99.32 | 55.32 |

## 7. DATA AVAILABILITY

Processed aircraft data files (CML, ASASP and FSSP) are available in standard ASCII files on 9-track reel tape, 360-kilobytes or 1.2-megabyte 5.25-inch diskettes, and 720-kilobytes or 1.44-megabyte 3.5-inch diskettes. Copies of all original flight tapes, programs, graphs, and printouts, are maintained by NOAA/ERL/ARL/Aerosol Research Section. Requests for aircraft data may be directed to R.L. Gunter, J.F. Boatman, or S.W. Wilkison, NOAA/ERL/ARL/ARS, Mail Code R/E/ARx1, 325 Broadway, Boulder, CO 80303. Commercial phone number (303) 497-5130; FTS 320-5130.

## 8. ACKNOWLEDGMENTS

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APPENDIX: Pre-Flight, In-Flight, and Post-Flight Log Notes

**August 16, 1988**
**Blue Ridge Flight #1**

Pre-flight:

051000 $H_2O_2$ power to system, NOx on – 26 in. Hg (plugged filter inlet to keep it clean)
≈0557 Ground file started
061300 Power $SO_2$
061900 NOx 0.05 range, reads 20% FS
062130 $O_3$ on – sig inc. – Cal 800 sup 030? (Note: not 050 as per instrument who changed it?)
065200 CKT4 on
065520 NOx sig 598 – status 1.9 – range 922.0
065615 $SO_2$ to zero – pots: Z = 171; S = 740
070230 NOx 422
070530 NO mode (CKT3 off) T4 = 6.0
070700 $SO_2$ to span (zero at: 0.700 V) 2 l zero ccm span NOx 1350
072000 $O_3$ on
073000 $SO_2$ to 1/2 scale (2.0 l zero, 25.0 ccm) 7.8 V on full scale
074500 $SO_2$ 4.3 V @ 1/2 scale going to 1/4 (12.5 ccm)
075400 $SO_2$ 2.6 V – going to sample
075500 $SO_2$ to sample – troubleshooting NOx – Cal values very low
083100 NO cyl. on again – supp. at 020

FAST ANALOGS:
1 – Blank
2 – $SO_2$ ppbv = calculated
3 – $H_2O_2$ bkgd
4 – $H_2O_2$ – sig
5 – blank
6 – $\Delta P$
7 – T
8 – Td
9 – NOx status
10 – Td duplicate
11 – $SO_2$ – volts
12 – Pressure (mb)
13 – NOx signal
14 – $O_3$

SLOW ANALOGS:
A – Solar
B – FP flow 1"
C – FP flow 90 mm (TOT)
D – $H_2O_2$ flow A
E – $H_2O_2$ flow B
F – FP flow 90 mm (SEP)
G – NOx range
H – $H_2O_2$ in ppbv (calculated)

In-flight:

101700 Local time - taxi for departure - NOx cylinder may be bad?
Instrument is ok. All else running
102700 Both Algo's running - ASASP pump on
102800 Takeoff
103300 4800' MSL (dry layer, inversion, smoother)
103600 6500' MSL (very dry layer, big inversion, much smoother) clear skies, hazy below, not too hazy
104000 At 10500' MSL
104600 Winds 330/44, S of Scotia at 10000 ft.
105100 Descending to 6500' over Scotia
105400 At 6500' directly over Scotia
105700 Flask #750 exposed
105900 Descend to 3500'
110200 At 3500'
110300 Flask #754 exposed
110800 At 1900' level
111000 Flask #735 exposed at 1900'
111200 Climbing to 8500'
111900 At 8500' - going to Shenandoah
112000 $H_2O_2$ to cal 2 position
112200 NOx is zeroing (zero air pump on, circuit #3 & #4 on right now)
112500 Circuit #3 on & #4 off - still zeroing
112700 NO cal gas on now - Circuits #3 on & #4 off - span at 10 sccm
113500 NO and zero air both off - NOx back to sample mode
113600 $H_2O_2$ has completed a good cal cycle on cal #2
114900 Climb to 10500 over Shenandoah
115100 At 10500'
115400 Exposed flask #110 at 10500' over Shenandoah
115900 At 6300' over Shenandoah
120000 Flask #744 exposed at 6300'
120500 At 3850'
120700 Exposed flask #377
121000 Climb to 8500'
121600 Back to 8500' & level
122200 Algo tape one off - tape 2 on
130700 2 min from Whitetop at 10500 ft.
131000 Exposed flask #761
131500 At 8000' over Whitetop Mtn.
131700 Exposed flask #192 at 8000'
132200 At 5700'
132500 Flask #741 exposed at 5800'
135200 Landing
135500 TK/TM on both Algo's
141700 Replenished $H_2O_2$ fluids on ground - now doing a ground cal of $H_2O_2$
145300 Turned $SO_2$ to cal mode - NOx still getting only zero air
145700 End ground file

**August 16, 1988**
**Blue Ridge Flight #2**
**(to Roanoke, VA)**

Pre-flight:

No change in slow or fast analog channels - no $H_2O_2$ values; $SO_2$ = .7 zero

In-flight:

145700 Started flight file for flight #2 - $SO_2$ on span - NOx on zero
150430 Both algo's on & running
150700 Takeoff
151100 6500' MSL base of dry layer - passed by some shallow Cu - turbulence ends - haze diminishes
152100 Stay at 10K for 4 min
152200 Exposed flask #756 at 10.5K above Mt. Mitchell
152700 At 8500' - stay for 4 min
153000 Expose flask #137 above Mt. Mitchell - Cb's nearby
153300 At 7200' over Mt. Mitchell
153600 Flask #759 exposed at 7200'
154200 At 5000'
161300 $H_2O_2$ to cal cycle #2
162100 4 more min at 10500' near Brasstown
162300 Exposed flask #T29
162900 At 7500' & level
163000 Exposed flask #764 at 7500' over Brasstown
163500 At 5300'
163600 Exposed flask #762 at 5300'
164200 Climbing now to 9500' over Brasstown
164600 Over Brasstown at 10500'
165300 NO to span at 10 sccm
165700 Algo tape change
170100 NOx returned to sample mode
172700 Over Mt. Mitchell at 10500' - clear skies again
174800 Over Whitetop Mtn. at 10500'
180300 Descending to Roanoke
182208 Both algos off after landing
≈204500 Landed Capital City

**August 18, 1988**
**Cloud Water Flight**

In-flight:

[GMT]
101900 NOx has been running for about an hour - zeroing at C#4 on
102100 Reading = 1906 mV (NOx)

102400 Reading = 1828 mV (NOx)
105000 $SO_2$ to zero - NOx reading 1100 mV
110400 NOx reading 838 mV - $SO_2$ 0.7 V
110500 $SO_2$ to span fullscale (2 1 zero; 50 ccm span)
111600 $SO_2$ = 8.2 V, NOx = 662 mV
111800 NOx = 634
112000 $SO_2$ change to 25 sccm; NOx = 594; .05 range
112300 NOx = 596 mV changed to span at 10 sccm
113100 NOx = 2836 & stable - going to 5 sccm
113500 NOx = 1780 mV
113700 NOx = 1728 mV
113900 $SO_2$ @ 4.6 V
114000 $SO_2$ to 1/4 scale 12.5 ccm
114100 NOx = 1688 and nearly steady - going to zero mode & programming chrontrol
114800 $SO_2$ @ 2.8 V
114900 $SO_2$ to zero
122200 Turned ground file off - started flight file - algos not on yet
122400 Taxi out
122800 Runup - ASASP pump on
122900 Algos for DAS on
123100 Algo for LORAN on
123200 Takeoff
123500 Base of low clouds at 4500'
124600 $SO_2$ to sample
125100 Cloud deck below us with tops at about 8000'
125300 Tops of some clouds at 9500'
130000 Collecting water
130200 Removed bottle #1
130300 Put bottle #2 on
130735 Bottle #2 off
130900 Bottle #3 on
131740 #3 off
131920 #4 on
133400 #4 off
133515 #5 on
135130 #5 off
135500 At 10K ft. over Scotia - stay 4 min (clear air sounding 1355-1426)
140500 At 6.5K ft over Scotia
141900 At 1700' near Scotia
142600 At 5500' back to Harrisburg
142800 NOx cal at 10 sccm begun - $H_2O_2$ cal 2 begun
143900 Tape change
144200 Landing
144330 Algo TK/TM

**August 19, 1988**
**Cloud Water Flight**

Pre-flight:

NOx & rest of cals begun at 0700

095700 NOx suppression change from 020 to 015 - to shift the 0 up a little - $SO_2$ spanned at ≈8.2 V and 0'd at ≈0.6 V - NOx 0 ≈ 150 mV

No change in fast or slow channels - no $H_2O_2$ values given - $SO_2$ = .7 zero

In-flight:

[GMT]
141800 $SO_2$ to span
141900 Engine start - power cart loss right after engine start - no loss of instruments
142600 Taxi out for run-up
143300 DAS & LORAN tapes on - DR2 - FSSP on R1 - ASASP on
144015 ASASP pump on - taxi-ing for T/O
144140 T/O
144230 Broken layer ≈2500
144500 Layer beg 3500-4000
144525 In cloud - precip
144700 $H_2O_2$ to cal 2 red button) for this flight; top of layer @ 5800' - out now
145000 Holding @ 8K' for a while - traffic; in between layers here - clear
145230 Up to 10K now
145500 @ 10K' - $SO_2$ to sample - in rain - not cloud
145700 Descending to 5K after clearance - to clouds - on airway heading SW
150100 Cleared for 5K' - descending
150600 Clouds are lower here 5K' not in cloud - getting clearance - clear & sunny @ 5K'
150900 Cleared to 4500' - not in clouds yet - can't go lower until after Hagerstown
151400 Dulles couldn't approve low in BWI area - clouds are 3500' or so - going back to Hagerstown & Harrisburg where clouds are
152100 Having to go to 5K'
152800 Going to 4K' - clouds are getting thicker now
152900 Bottle #1 installed - 4000' - breaker popped on HS's pump
153600 End #1
153635 #2 on - CB keeps popping - will check - was on exhaust not suction?
154200 Lite precip on window
154400 #2 off - #3 on
155330 #3 off - #4 on
160300 #4 off - #5 on
160400 NOx to zero
161200 NOx to span
161800 #5 off - #6 on

161900 Span on NOx lower than zero!! chrontrol shows #3 & #4 on
162000 Now its changing to a higher value
162200 DAS #1 off - #2 on - TK'TMd Algo
162300 Dropping to 3800' - @ 4K was thinning - 3700' was thin also
162500 NOx to zero
162900 Clouds are thinning
163300 #6 off - lite sample - almost not worth it - going to a different location
163500 NOx to sample - zero & span didn't look good to me at all
163645 #7 on - 40°06/77°05 - heading SE from Harrisburg - still @ 3800'
164000 Going up to 4000' now - thinning - oops! out for a sec @ 4 - back down to 3900' - only 2-300' layer - pretty thin
164800 Back to 3800'
165500 #7 off - N for Harrisburg now - #8 on
170100 Up to 4000' - was thinning - now back in it
171100 #8 off - #9 on
173000 #9 off - #10 on
175100 #10 off - going back - almost on approach
175630 Landed
175700 Alt F10/all off

**August 20, 1988**
**Cloud Water Flight**

Pre-flight:

[GMT]
113400 DAS turned on
114000 NOx on & cooling since 1115 GMT - turning on vacuum pump & zero air
115800 NOx range on .05 - cool down nearly complete - turning $O_3$ on now - increase in signal to about 1/2 scale
124700 NOx = 678 - may still be going down some - C #4 was off - now turning C #4 on
125800 $SO_2$ zero = 0.7 V - NOx 0 with C #4 on = 608 mV - C #4 to the off position
130400 NOx zero = 594 mV
131300 NOx span = 2670 - change to span = 5 sccm
131500 $SO_2$ to 1/2 scale (25 ccm)
133300 NOx = 1794 at 5 sccm, $SO_2$ = 4.6 V at 1/2 scale
133400 NOx set to zero - C #4 off
134600 NOx zero = 632 mV - C #4 off - C #4 turned on
135900 NOx programmed & running

No analog channel changes - no $H_2O_2$ values given - $SO_2$ = .7 V zero

In-flight:

[GMT]
142900 Engine start

143230 Taxi out for run-up - FSSP on R1 - ASASP on
143600 DAS & LORAN on - DR2
144030 ASASP pump on
144140 T/O (same exactly as yesterday) going to 10K'
145300 Holding @ 8K for a bit - waiting for clearance to go higher
145500 $H_2O_2$ to cal - cal 1 - values are low
145600 Up to 10K'
145900 @ 10K' - T = 6.5°C - $T_d$ 4.9°C - $SO_2$ to sample - NOx to zero so zero air gen still on - in cloud haze - as soon as NOx is done will begin sample of water
150400 NOx to span
150900 NOx to zero
151400 NOx to sample - zero air gen off - going to 9000' - clouds too thin
151700 Going S is getting too thin - heading around back N and having to go lower (oops not yet) - waiting for clearance
152200 Going to 7K' - 8K' too thin - heading NE
152515 Bottle #1 on - nothing going in it so far
153000 Took #1 off - rinsed out with DI - no precip in it at all - only air had been in it - took probe out and rinsed - we are now out of cloud totally - trying another area
153400 Going to 6K'
153630 @ 6K' - looks good
153720 Bottle #1 on - taking water
154030 #1 off - #2 on
154600 #2 off - #3 on
154700 $SO_2$ way off scale!?! - changed to 100 range
154724 Up to 200 range
154900 $SO_2$ to 10 range
155300 #3 off - #4 on
155700 #4 off - going to 5K'
155830 @ 5K'
155900 #5 on
160500 #5 off - #6 on
161200 #6 off - #7 on
161630 2.2 l/min seems good value - shows up as 6 lpm on "Dwyer" meter
161800 End DAS #1 - begin DAS tape #2 - TK'TM'd
162000 #7 off - going to 4K'
162115 @ 4K'
162130 #8 on
162330 $SO_2$ close to offscale on 10 range - $H_2O_2$ very low
162420 $SO_2$ back to 10 range
162600 #8 off - great collection!! #9 on - great cloud!!
162700 $SO_2$ close to offscale again - switching to 20 range to prevent it - very low $H_2O_2$
163000 $SO_2$ to 10 range again - $SO_2$ decreasing
163200 #9 off - #10 on
163700 #10 off - done!! and such a good job!!!! going back
164500 Clear layer between 2500' down to ≈1800' - broken to ground - very hazy - next to nil vis
164745 Missed approach - up to 4K' to try again
170900 Landed
171000 Alt F10 - all off

August 21, 1988
Zipper Flight

Pre-flight:

[GMT] (local time = GMT - 4 hrs)
110500 NOx to zero C#4 on
111400 NOx 570 mV on zero mode and zero air
111500 NOx zero air only (C#4 off) 1.5 slpm
112000 NOx 528 mV zero air
$H_2O_2$ zero sig 52; bkgd 51
112600 NOx 450 mV zero air
$H_2O_2$ Std #1 (no cat) sig 223; Bkgd 231
reduce HV(B) 478 V
112900 NOx switch to NOx mode - zero air
113000 $SO_2$ on - zero air on /note: 50 sccm bled thru span line
113100 NOx NOx mode - zero air 386 mV

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 113200 | warmup | 0.05 range<br>354 mV NOx zero | zero sig 52,bkgd 52 |
| 113600 | $O_3$ on | 324 mV - switch to NO mode | Std #1 sig 223,bkgd 223 |
| 113900 | $SO_2$ to 100 ppb zero mode | 314 mV NO/zero | zero sig 56,bkgd 56 |
| 114400 | 10 ppb range zero mode | 278 mV NO/zero | catalase now |
| 114500 | 0.6 V on zero | 1.5 slpm air | HV(A) = 526; HV(B) = 478 |
| 114800 | | ozonizer on!<br>zero air | |
| 115200 | 0.7 V | 804 mV zero air | |
| 115600 | 0.6 V | 692 mV zero air | zero sig 58, bkgd 58 |
| 115900 | 0.7 | 668 mV [NO] zero mode and zero air | |
| 120200 | 0.6 | 682 mV /zero mode off | sig = 58, bkgd = 58 |
| 120300 | | NO cal - [NO]<br>10 sccm + 1.5 slpm air | |
| 120700 | 0.6 | 2854 mV | Std #1 sig = 214,<br>bkgd = 60 |
| 121100 | zero 171<br>span 740<br>cal at 6.1 ppb<br>50.0 sccm/<br>2.0 slpm air<br>015,800 | cal at 10 sccm<br>1.5 slpm air | zero sig 60;bkgd 60 |
| 121500 | 0.6; 3 ppb $O_3$ | 2792 mV NOx mode | Std #1 sig 208, bkgd 62 |
| 122000 | $SO_2$ cal span | 2800/NOx off<br>zero mode on | start 2 pt cal |

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 122300 | 7.3 V | 578 mV NO cal and zero mode | s = 63, b = 62 |
| 122800 | 8.6 V | 550 mV NO cal and zero mode | Std #1 sig 204, bkgd 65 |

Take off delayed from 9:00 to 10:30 am (Local) - time for extra calibration.

| | | | |
|---|---|---|---|
| 123000 | 8.6 V | zero mode off up 2234 mV | Std #2 sig 351, bkgd 70 |
| 123300 | 8.6 | 2718 mV NO cal | repeat |
| 123500 | 8.7 | 2744 mV NO cal increase cal flow #2 pt 4668 mV | |
| 123600 | 8.6 | 20 sccm cal | s = 67, b = 67 |
| 123900 | 8.6 V cal flow | 4696 mV Cal #2 | s = 67, b = 67 |
| 124300 | 4.9 V cal #2 | 4648 mV Cal #2 | Std #1 sig 197,bkgd 69 |
| 124600 | 4.7 cal #2 | 4680 mV NO mode and zero mode + cal 2 | Std #2 s = 347, b = 71 |
| 124800 | 4.7 cal #2 | 526 mV zero mode and NO cal 2 | sig 352, bkgd 73 |
| 125000 | 4.7 | 522 mV, 512 mV 504 mV, 508 | |
| 125145 | zero mode on | 514 mV zero mode NO cal 2 | ambient air sampling s = 91, b = 76 |
| 125300 | 1.6 down $O_3$ = 13 | zero mode off/ NOx mode on | s = 91, b = 76 |
| 125700 | 0.6 V zero 10 ppb range | 4808 mV NOx cal 2 | s = 91, b = 78 |
| 130000 | 0.6 V and then 20 ppb range change | 4854 mV NOx cal 2 | |
| 130300 | 0.1 V zero 20 ppb range | 4810 mV NOx cal 2 | |
| 130900 | 0.1 and change to 50 ppb range | 4816 mV zero mode on + NOx + cal 2 | |
| 131100 | -1.2 V zero 50 ppb range | 486 mV zero mode, NOx, cal 2 | s = 86, b = 72 |
| 131400 | -1.4 zero 50 ppb range | 492 mV zero mode, NOx, cal 2 | |
| 131600 | -1.4 and return to 10 ppb range | 504 mV + cal off! | |
| 132100 | 0.6 V zero 10 ppb range | 516, 514, 524 NOx zero air, zero mode | |
| 132200 | span 50 sccm | 514 + zero mode off! | |
| 132400 | 6.2 up span 50 sccm | 604 mV NOx + zero air | |

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 132600 | 8.4...8.5 V span | 604 NOx + zero air | |
| 133000 | 8.6 span | 580 mV + NOx off | s = 85, b = 69 |
| 133300 | 8.7 V 50 sccm span | 552 mV zero air NO mode | ambient air |
| 133500 | 8.7 and 35 sccm $SO_2$ | 550 mV + NO cal on 10 sccm | |
| 134100 | 6.4 V 35 sccm $SO_2$ | 3018 mV 10 sccm NO cal | |
| 134500 | 6.4 and change to 20 sccm | 2952 mV + change to 7 sccm cal | |
| 135000 | 4.1 V/20 sccm | 2238 mV 7.0 sccm cal | |
| 135300 | 4.1 and change to 10 sccm | 2238, 2246, 2234 + change to 4.0 sccm | |
| 140000 | 2.5 V/10 sccm | 1638 mV 4.0 sccm cal | |
| 140400 | to zero air mode | 1610 + change to 20 sccm | |
| 140600 | 0.7 V zero | 5038 mV 20 sccm | |
| 140800 | 0.7 V zero span at 50 sccm for flight | 4896 mV + change to 10 sccm 10 sccm for inflight cal | |

no channel changes - $H_2O_2$: 67, 67, 10, 1.02; $SO_2$ = .7 V zero
For flasks: HW = Hal Westberg; DB = Don Blake

In-flight:

[GMT]
141900 Engine start
142000 NOx & $SO_2$ on span for T/O and climb
142300 Taxi out for runup
143000 DAS & LORAN tapes on - DR2 - FSSP on R1 - ASASP on
143300 ASASP pump on
143415 T/O
143500 Slightly hazy - 1500'
143900 BL irregular 3500-4500' layered
144200 @ 5500' - almost to top - several small layers on top still
144300 Another layer at 7500' - going to 8500'
145200 Holding @ 12.5 still in BL - calling CCVV
145300 Descending to 6500' - $SO_2$ to sample - NOx to sample
145900 @ 6500' - flushing HW flasks - above majority of BL
145900 Begin flushing HW flask #123
150200 HW Flask #123 - 6500' - +7.7°C; DB flask T-25 - 40°45/77°55
150300 End flasks - over Scotia - descending & turning - relatively clear
151000 Begin flushing HW flask #114 - @ 3000'
151200 HW flask #114 - 3000' - DB flask #755 - over Scotia
151300 End flasks - mostly clear

151700 @ 1700'
151800 Begin flushing HW flask #38
152000 HW flask #38 - 1700' - DB flask #731 - over Scotia
152100 End flasks - mostly clear - up to 4500' - thank goodness!!
152600 Lots of water in FP system
152800 FP 90 mm #1 on - flow 167 lpm
153000 Winds 330/12 - bumpy ride! - just below cloud base
154800 Coming into more clouds - rougher ride - may have to descend to avoid clouds
160500 $H_2O_2$ to cal 1
160800 Clouds clearing out
161200 Over Geneseo airport - turning to Sparta
162000 End DAS tape #1 - begin DAS tape #2 - TK'TM'd
162500 Contact with German aircraft (Hawker) they're going to Lexington, KY
162800 End FP #1 90 mm off - flow 170 lpm
163000 FP #2 90 mm on - more clouds now
163500 NOx to zero
164100 NOx to span
164900 NOx to zero
170000 NOx to sample
171500 Turning near SAX (Sparta) heading to SLK (Saranac Lake) crappy ride!!! turbulent
173000 90 mm #2 off
173100 90 mm #3 on - flow 184 lpm-clouds all around-very rough-terrain rising
173900 Going to 5500'-6500' would put us in clouds - still @ cloud base
181700 End DAS tape #2 - begin DAS tape #3
183100 90 mm #3 off
184100 Landed Saranac Lake - they have power ready - maybe they can shoot me now so I can die fast - restarted UPDAS - refreshed chemicals - Cal 1 on $H_2O_2$ - $SO_2$ & NOx put to zero - leaving same UPDAS going for in-flight file also - its cold up here @ SLK 12.5

**August 21, 1988**
**Zipper Part 2**

<u>In-flight</u>:

Note: Whiteface Mtn 44°21', 73°54'
TAS not changing - whole flight

193800 $SO_2$ & NOx to span for T/O
194900 DAS & LORAN tapes on - FSSP on R1 - ASASP on
195300 ASASP pump on
195400 T/O - going to Whiteface Mtn. and 10K'
200200 @ 10K' - $SO_2$ & NOx to sample - zero air gen off
200815 DB flask #119 - T = -2.8°C; $T_d$ -19.2°C - over Whiteface Mtn. - clouds below; clear above - 10K'
201130 @ 8000' - 7K would put us in clouds - going to 6K
201300 Can't do 6K - clouds - going back to 8K' - D.B. will have to like it

201700 Heading back to WFM after climb back and another turn - $H_2O_2$ still doing cal mode??! after renewing solutions I only hit Cal 1 (red button once to cal it) when I'm doing with this flask will check
201900 DB flask #362 - 8000' - T = 1.7°C - $T_d$ -18.0°C - over Whiteface Mtn. clouds below - clear above
202300 @ 5300'
202400 DB flask #379 - 5300' - over Whiteface Mtn. - T = +2.1°C - $T_d$ -.2°C clouds above - just at bases - clear below
202600 @ 5500 - heading direct to Cap City
202800 Going to 4500' - clouds @ 5500 now - can clear terrain here
203000 FP 90 mm - blank - 4500'
203200 FP 90 mm #4 on - flow 172 lpm
203300 Had to "reset" the "run" $H_2O_2$ - cal was continuous
213700 End DAS tape #1 - begin DAS tape #2
214200 LORAN has been out for ≈15 or so min
215200 FP 90 mm #4 off
215500 NOx & $SO_2$ to zero - on descent - don't want to "crud" up instruments
215800 Still no LORAN - test indicate poor geography, low signal problem as opposed to hardware failure
220500 Landed
220600 Alt/F10 - all off

**August 22, 1988**
**REME Box W/IC**

Pre-flight:

Notes: LORAN tape was put on just in case LORAN came back on - so far no LORAN for this flight

TAS not updating on screen

no channel changes

061500 Power on

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 061700 | | power on | power on |
| 104900 | | vac pump on | |
| 105400 | $SO_2$ power on | 1412 mV - cooling | |
| 110400 | 0.7 V | ozonizer on 1140 mV | lamp on - 4.52 V |
| | | 0.05 range | zero started |
| 111800 | 0.6 zero | 528 mV zero air/NO | |
| 112300 | 0.6 | 418 mV zero air/NO | |
| 112900 | 0.6 | 324 mV zero air/NO | zero ? s = 139, b = 142 |
| 113400 | 0.6 | 278 mV zero air/NO | adj suppression |
| | | | bkgd is higher today |

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 113600 | 0.6 | 250 zero mode on | zero sig 51 bkgd 50 |
| 113900 | 0.6 | 228 zero air + zero mode | |
| 114900 | 0.5 | 152 mV zero air/back to zero air only | ambient 59 62 |
| 120200 | 0.5 | 92,100 zero air + start NO cal | zero sig 51 bkgd 50 |
| 120400 | 50 sccm span | 10 sccm span | |
| 120700 | 7.7 V span | 2540 mV 10.2 sccm NO cal/NO | std#1 (adj 480 V) sig 201 198 |
| 121000 | 8.2 span | 2512 10.2 sccm NO cal/NO | |
| 121900 | 8.3 | 2496 + NOx mode on NO cal | zero sig 51 bkgd 52 |
| 122300 | 8.3 | 2492 10.2 sccm NO cal/NOx | |
| 122700 | 8.3 | 2518, 2542, 2500 2462, 2448, 2476 | std#1 s 190 b 189 |
| 122900 | 8.3 | NOx NO cal zero mode | |
| 123400 | 8.3 | 30, 32, 22, 30, 28 24, 20, 16, 8 | catalase - start zero |
| 123700 | | zero off NO cal/NOx | |
| 123800 | 8.3 and back to zero | 2468 mV + NO cal off, NOx off | |
| 124300 | 0.8 zero | 60 down zero air only NO | zero s 49 b 49 |
| 124800 | 0.6 | 48, 46, 38, 60, 58, 52 52, 50, 48, 46 | |
| 124900 | 0.6 | adj zero suppression to 012 | 2pt cal |
| 125200 | span at 50 sccm | 442, 464, 446, 452, 472, 482, 488, 502, 502, 502, 488, 496, 492, 490, 482, 458, 444, 448, 458, 458, 470, 474, 480 | std#1 176 46 |
| 125600 | 8.2 span | 466, 448, 424, 414, 434, 472 zero air | |
| 125700 | 8.3 | zero mode on | std#2 318 47 |
| 130000 | 8.4 | 270, 258, 250, 240, 232, 236, 230 | s 339 b 48 |
| 130300 | 8.4 | 654, 644, 662, 678, 688, 716, 712 | |
| 130600 | 8.4 | 768, 726, 614, 408, 350, 308, 358, 418 | zero 47 47 |
| 131100 | 8.4 | 446, 432, 442, 448, 472, 480, and zero mode off | std#1 s 168 b 47 |
| 131500 | 8.4 | 576, 552, 544 | std#2 323 47 |
| 131500 | | zero air only | |

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 131600 | span to 25 sccm | NO cal at 10 sccm | |
| 132400 | 4.7 span | 2562, 2594 NO cal/NO | std#1 155 47 |
| 132800 | 4.7 | 2618, 2600, 2620 NO cal/NO | std#1 158 46 |
| 133000 | to zero | to NO cal/NOx | |
| 133200 | 1.1 | 2592, 2600, 2618, 2624 NO cal/NOx | std#2 308 153 |
| 133500 | 0.7 zero | 2620, 2616, 2634 and zero mode on | ambient 110 60 |
| 133800 | 0.6 | 322, 324, 322, 314, 312, and NOx off | reprogrammed micro-meter |
| 134400 | 0.6 | 342, 340, 336, 344, 346 zero air/zero mode | 104 60 |

$H_2O_2$ factors: 50, 50, 11, 1.02
$SO_2$: .7

In-flight:

141800 Engine start - $SO_2$ & NOx are in cal mode
142000 Taxi out for run-up
142600 DAS & LORAN tapes on - FSSP on R1 - ASASP on
142740 ASASP pump on
142830 T/O - going to 7.5K'
143200 Crud layer @ 4-4200'
143300 BL @ ≈6000'
143500 @ 7500 - definitely out of mixed layer - $SO_2$ & NOx to sample
143800 Contact with G-1 - IC will be @ 4000'
144000 Starting descent into St. Thomas for IC - going to 5500'
144500 @ 5500' - crud layer right here - waiting for 4000'
144700 Both aircraft in site
145000 Descending to 4000' - speeding up to 180 kts
145200 IC beginning - both planes along on our right
145800 This is pretty neat! sure wish I had my camera
150400 Done with IC - climbing to 7500'
150500 Flushing FP system - @ 6000'
150700 @ 7500' - begin circuit 1 of box 40°36'/77°24' - heading 020 +7.2°C $T_d$ -25°C
150800 FP #1 - 90 mm on - flow 159 lpm
151700 $H_2O_2$ to cal 1 (red button)
152800 NOx to zero
153500 NOx to span

153730 Turning around - end of leg 1 - turn point 42°02/76°46 - will be heading 175
154000 On heading 175 - to Pottsville

NOTE: LORAN might be antenna - other problems in addition to LORAN out however

154200 NOx to zero - NOx inc after shutting cyl off?
154900 NOx to sample - peaked slightly after zero shut off?
155400 Power plant off to our right - we will be intercepting its plume maybe; winds out of west
160300 Didn't intercept plume - too far above BL I guess - it looked like it was coming out and above
160700 Turning around @ Pottsville - turn point 40°37/76°06 - end of leg 2 - heading to Hancock
161600 End DAS tape #1 - begin DAS tape #2
161900 On heading 025 to near Hancock VOR
164000 Turning - end of leg 3 - heading 262 to 41°35/77°22 - turn point 42°02/75°28
165300 End FP #1 90 mm - flow 163 lpm
165400 FP #2 90 mm on - flow 171 lpm
171600 Turning - end of leg 4 - turn point 41°35/77°22 - heading 120 - 41°05/75°28
174300 Turning - end of leg 5 - turn point 41°05/75°28 - heading 262 to Mifflentown VOR - may not be able to make it all the way - may have to cut short & go direct to CXY we'll see
180600 End DAS tape #2 - begin DAS tape #3 - TK'TM
181500 Turning to Cap City - end leg 6
181800 End FP #2 90 mm - flow 166 lpm
181830 FP #3 - blank - 90 mm
182030 NOx & $SO_2$ to zero - descending into Cap City
183000 Landed - only stopping UPDAS - power on

**August 22, 1988**
**Box Part 2**

Pre-flight:

Between Flight Calibrations 880822_2G

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 184300 | zero | on zero air | start 2pt cal |
| 184500 | 0.8 V zero | 540, 538 zero air | flow a = 220, b = 1.95 adj to 2.0 A&D |
| 184800 | 0.8 | 548, 550 zero air | ambient 555 b 41 std#1 |
| 185400 | 0.8 | switch to NOx mode 628, 622, 620 | s 107 b 38 std#2 |
| 185600 | 0.8 V to span 50 sccm | NO cal on 10 sccm | s 218 b 38 |
| 185800 | 4.9 up | 3046, 3100, 3102 3118 NOx mode NO cal | |
| 190200 | 8.1 V span $O_3$ = 35 | 3046, 3036, 3024 NOx mode off | |

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 190500 | 8.3 span | 3030, 3050, 3064, 3042 NO mode, NO cal | |
| 191000 | 8.3 span | 3058, 2986, 2994, 3008 and switch to zero mode | zero s 38 b 39 |
| 191100 | span to 25 sccm | 660 NO cal zero mode | |
| 191300 | 5.4 | 600, 598, 602, 610, 622 zero mode | std#1 105 39<br>std#2 196 40 |
| 191600 | 4.8 | NOx mode on NO cal zero mode | |
| 191800 | 4.7 | | 195 49? |
| 192000 | 4.7 | 606, 610, 612, 622, 616, 610 | |
| 192400 | back to zero 2.7 V | 608, 618, 620 and NO cal off | |
| 192800 | 0.8 zero | 634, 628, 632 NO off NOx, zero mode | new solutions<br>zero 9 8 |
| 193000 | 0.8 | | std#1 128 10 |
| 193100 | 0.8 | 636, 646, 650, 646 NO zero mode | std#1 130 10 |
| 193400 | 0.8 | 652 and zero mode off | std#2 270 11<br>adj zero offset up |
| 193700 | 0.8 | 688, 680, 686, 688, 700 | zero sig 54 bkgd 54 |
| 194500 | 0.8 | start cycle program | zero sig 54 bkgd 55 |
| 194900 | 0.9 | | std#1 176 50 |
| 155700 | 0.9 | | std#? 178 54 |
| 155900 | | | zero 57 54 |
| | | | std#1 168 55 |
| 200400 | | | std#1 171 55 |

$SO_2$ = .9; $H_2O_2$ factors: 57, 54, 11, 1.02
No LORAN for this flight – TAS not correct

In-flight:

[GMT]
201300 Engine start – $SO_2$ & NOx in span mode
201500 DAS & LORAN on – FSSP on R1 – ASASP on (LORAN on just in case it wants to work)
202100 ASASP pump on – NOx cycled to zero mode
202200 T/O – going to 10K' and the Scotia site
202800 BL ≈6000' – hasn't changed much – not as cruddy looking as this morning
202900 $H_2O_2$ flow A really low on climb – will adj when we level off
203300 @ 10K' – $SO_2$ to sample – NOx to sample
203500 Aircraft LORAN was turned off by pilots – so I turned recording of it off
203830 Descending to 6500'

204200 @ 6500'
204300 Begin flushing HW flask #106
204600 HW flask #106 - 6500' - over Scotia - T = 8.9°C - $T_d$ -9.2°C - slight haze below; clear above
204700 End flask
205100 Descending to 2500'
205400 @ 2500 - begin flushing HW flask #87
205500 Really begin - valves stuck
205630 HW flask #87 - 2500' - T = 19.2°C - $T_d$ .3°C - slightly hazy below; clear above
205710 End flask
210200 @ 1700' - begin flushing HW flask #35
210600 HW flask #35 - T = 21.1°C - $T_d$ 2.1°C - clear lite haze to ground
210700 Done with flasks - up to 10K'
211000 Contact with G-1 and HS - they are just airborne heading to sample site
211630 @ 10K'

Note: Check about turning circuits off/on during flights

211900 Over Mifflentown - turning for leg 1 - FP 90 mm #1 on - flow 134 lpm
212000 [G-1 & HS just arrived at beginning sample point also] we're heading 029
213500 $H_2O_2$ to cal 1 (red button)
213600 NOx to zero
214100 Not zeroing very well - it went up then down, then peaked?
214400 NOx to span
214800 NOx to zero - it peaked when I shut cylinder off
215600 NOx to sample
221415 End DAS tape #1 - begin DAS tape #2
221500 Turning - end of leg 2 - now heading 028
224500 Turning - end of leg 3 - heading direct now to Cap City - still @ 10K' - 220 heading - FP flow is now 150 lpm
231900 FP #1 90 mm off - flow 149 lpm
232000 FP #2 blank 90 mm - start descent into Cap City
232200 $SO_2$ & NOx to zero
232930 Landed
233000 Alt/F10 all off

**August 25, 1988**

The flight was canceled; therefore, none of the pre-flight preparation log notes were entered here. The only notes of interest are that the $O_3$ instrument's optical tubes were cleaned, and the $H_2O_2$ instrument was flushed with HCl solution and deionized water.

**August 26, 1988**
**IC Flight with G-1 & HS**

Notes: $H_2O_2$: 47, 46, 6.6, 1.02
$SO_2$: .8 V - channel 10 now blank (not "blank" - showing -75.0) causing "**s" in data.

Pre-flight:

| [GMT] | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 122800 | Power on | | |
| 125200 | 0.6 V zero<br>$O_3$ on | start vac 2900 mV<br>0.05 range zero air | 50, 50, 6, 1.02<br>UPDAS $H_2O_2$ factors |
| 131100 | $O_3$ in error off then on again | 1586 mV zero air | no solutions yet |
| 132200 | 0.5 V zero | 1276 mV zero air | |
| 133300 | 0.5 V zero | 1040 zero air | solutions in - zero lamp on |
| 133800 | span at 50 sccm | 976 zero | lamp voltages still increasing |
| 134400 | 8.5 V span | 956 zero | zero s 49 b 50 |
| 134900 | 8.6 V span<br>$O_3$ = 23 | 886 zero and NO cal on | zero s 47 b 49 |
| 135300 | 8.5 | 3284, 3322, 3352 3388 NO cal/NO 10.2 sccm | std#1 s 318 b 316 |
| 135800 | 8.6 V | 3446, 3412, 3438 NO cal/NO 10 sccm | |
| 140800 | 8.6 | 3404, 3408, 3410 10 sccm | |
| 141000 | span to 25 sccm | NOx mode NO cal 10 sccm | catalase added |
| 141700 | 4.8 V | 3466, 3480, 3494, 3508 and zero mode | adj zero s 46 b 47 |
| 142200 | 4.8 | 812, 806, 824, 836, 844, 856 NO cal NOx zero | |
| 142300 | 4.8 and back to zero | NO mode zero | |
| 142700 | 1.0 zero | 828, 822, 820, 824, 843, 838 NO zero w/ NO cal | zero 47 46 |
| 142900 | 0.7 zero | NO cal off | std#1 s 310 b 50 |
| 143400 | 0.7 | zero air only 834, 866, 864 | zero s 47 b 46 |
| 144100 | 0.7 | 882 programmed and ready to start | std#1 s 309 b 49 |

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 145000 | 0.8 | auto cycle with zero air | zero 47 46<br>std#1 303 48 |
| 145500 | 0.8 | | std#2 478 66 |
| 150900 | 0.8 | | std#1 s 299 b 47 |
| 162300 | waiting for 1645 takeoff | NOx on auto | |
| | ground file stopped | | micrometer re-programmed |

In-flight:

164800 Engine start - $SO_2$ to span
165100 Taxi-out for runup - $H_2O_2$ to cal 1 (red button) - FSSP on R1 - ASASP on
165700 DAS & LORAN tape on - DR2
165930 ASASP pump on
170020 T/O - going to 10K' and Scotia site - hazy
170700 @ 6500' - top of clouds - small to med layer of haze still above
170900 @ 9K' - still not above second layer
171100 @ 10K' - still not out - will level out here - $SO_2$ to sample - NOx to sample - zero air gen off
171300 In clouds at 10K' as we head for Scotia dropping a little to stay out
171500 Descending to 7500' - maybe if it doesn't put us in clouds
171800 @ 8500' - 7.5 & 8 would get us in clouds up here - will do 1st Scotia level here
172300 Begin flushing HW flask #P-20
172600 Begin sample flask #P-20 - 8500' - T = 7.1°C - $T_d$ -18.6°C - broken clouds below - clear above
172700 End sample
173000 Descending to 3500'
173500 @ 3500'
173610 Begin flushing HW flask #122
173715 Begin sample flask #122 - 3500' - T = 16.0°C - $T_d$ 3.3°C
173815 End sample - scattered clouds above - clear below
174300 Begin flushing HW flask #P-39
174500 Begin sample flask #P-39 - 1900' - T = 21.2°C - $T_d$ 5.5°C - scattered clouds above - clear below (500 AGL)
174600 End sample
174800 Ascending - going to St. Thomas VOR
175200 NOx to zero - @ 6500' for ride out
175500 $H_2O_2$ to cal 1 (red button)
175700 NOx to span
175800 Descending to 4500' - clouds
180000 $SO_2$ offscale - putting it on 200 range
180200 Back to 10 range ($SO_2$) still very high - $O_3$ still looks noisy
180400 Meeting with G-1 and HS now - going to 4500'
180700 NOx to zero
180900 Begin 90 mm FP #1 - flow 160 lpm - 4500'
181200 NOx to sample - zero air gen off

181700 $SO_2$ on 20 range - offscale +10 ppbv
181900 G-1 reading same high levels of $SO_2$ - now back on 10 range
185000 End DAS tape 1 - begin DAS tape 2 - TK'TM
185300 Choppy ride - in fact I was just bounced out of my chair - hit the ceiling
190930 90 mm FP #1 off
191640 90 mm FP #2 on - flow 172 lpm
201615 90 mm FP #2 off
201740 90 mm FP #3 - blank
203600 $SO_2$ & NOx to zero
203800 Landed
203900 All off Alt F10

Note: $SO_2$ on & offscale @ 10 range setting

**August 29, 1988**
**Cloud Water Collection**

Pre-flight:

061500 Power on

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 112300 | | vac pump on<br>zero air on<br>0.05 range | |
| 113300 | both on | | |
| 114300 | zero cal | ozonizer on | |
| 114800 | 7.4 V | circuit #4 on | |
| 115500 | 0.6 V | circuit #4 off<br>1460 mV | |
| 120500 | cal/span @ 50 | span mode 1346 mV<br>10 tylan #3 | power/lamp on<br>in zero mode |
| 121400 | | 4296, 4310 NO cal | zero sig 55 bkgd 55 |
| 121700 | | 5.0 tylan #3 | |
| 122800 | | 2700, 2666 | |
| 123000 | cal/span @ 25 | circuit #4 on<br>NO cal off zero mode | |
| 123700 | 4.5 V | 1000, 1016, 1026 mV | std#1 s 288 b 288 |
| 123900 | | circuit #4 off<br>zero air only | zero 52 52 |
| 124300 | 4.5 V | 986, 988 | catalase in B now |
| 124600 | cal/span @ 50 | | |
| 125600 | 8.3 V | auto cycle started | zero 48 48 |
| 130500 | 8.4 V | | std#1 s 290 b 55 |
| 131200 | 8.4 | | zero 49 49 |
| 131500 | 8.4 | | std#2 285 54 |
| 131600 | stop DAS | | micrometer re-programmed |

Notes: Channel 10 now showing volts only
$H_2O_2$ = 49, 49, 7.3, 1.05
$SO_2$ = .7
TAS not updating on screen

In-flight:

134000 Engine start
134100 NOx & $SO_2$ to span
134300 Taxi out for runup
134500 On span $SO_2$ is almost offscale?? $H_2O_2$ very high also
134700 DAS & LORAN tapes on - DR2 - FSSP on R1 - ASASP on
135100 ASASP pump on
135315 T/O
135900 6500' - in cloud now - precip.
140100 7500' - out now - in between layer - thin now in/out
140330 @ 10K' - $SO_2$ to sample - NOx to sample - zero air gen off
140900 Waiting for clearance to go down
141400 Going to 8K'
141600 @ 8K'
141700 Bottle #1 on - 8000' - +10°C
142000 $H_2O_2$ to span
142300 NOx to zero
142600 #1 off - #2 on - 8000'
142700 NOx to span
143100 NOx to zero
143500 #2 off - #3 on - 8000'
144100 NOx to sample
144500 #3 off - going to 6K'
144730 @ 6K' - too much rain - must be bases
144900 @ 6500' - bottle #4 on @ 6500' - going to 7K' - too thin too rainy
145000 @ 7000' - finishing #4 here
145900 #4 off - #5 on - lite turbulence - 7000'
150900 #5 off - #6 on - 7000'
151900 #6 off
152515 #7 on - 5000'
153200 DAS tape #1 off - #2 on - TK/TM
153500 #7 off - going to 6K' - too turbulent - winds 210/54
153700 #8 on - 6000'
154500 #8 off - #9 on
155600 #9 off - #10 on
160000 Into thin clouds - occasionally out but in haze/thin cloud - turning back to them
160300 Back in clouds now
160800 #10 off - back to CXY
162300 In turbulence and heavy rain now
164600 Landed
164700 Alt F10 - all off

**August 30, 1988**

Pre-flight calibrations were started for this date; however, the flight was canceled, so none of the notes are entered here.

**September 1, 1988**
**High Resolution Box - Part 1 w/IC**

Pre-flight:

[GMT]
111500 start ground file
111700 NOx to C#4 (elec zero) on 914 mV
112300 NOx to zero air
≈1125 UPDAS hung up ? - DAS hung up ? - stopped/restarted - seems OK now
113900 NOx zero = 585 mV; NOx to span
115200 NOx span = 3140 mV; NOx to zero
115300 $SO_2$ on - zero mode
115300 $H_2O_2$ - zero sig 43 bkgd 45
120200 NOx zero = 388 mV - to span

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 121300 | 0.6 V zero | 2882, 2898, 2880 NO cal 10.2 sccm | zero sig 46 bkgd 47 |
| 121600 | 0.6 V | 2786, 2760, 2766, 2786 mV 10 sccm | zero 45 45 |
| 123000 | 0.6 | NOx mode on | span std#1 275 275 |
| 123400 | to span 50 sccm | | catalase to B |
| 123700 | 8.4 V span | 2772, 2794, 2798, 2804 NOx NO cal | |
| 124000 | 8.7 V span | 2764, 2760 and zero mode on | zero sig 41 bkgd 41 |
| 124700 | 8.6 V span | 356, 328, 304, 296, 284 and NOx off zero off | zero 40 40 |
| 125100 | 8.6 V and span at 25 sccm | NO cal off | std #1 273 51 |
| 125700 | 4.7 V | 332, 334, 332 zero air only | zero 42 40 |
| 130000 | 4.7 V $O_3$ = 8.5 | start auto cycle | std#1 270 49 |
| 130300 | zero mode and (test) HV = 972 | | zero 42 40 |
| 130900 | 0.7 V zero | | std#1 270 47 |
| 131500 | 0.5 V zero | | std#2 519 59 |
| 131900 | 0.5 V zero | | |

$H_2O_2$: 42, 40, 7.32, 1.02
$SO_2$: .5 V
No additional channel changes

In-flight:

133900 Engine start
134300 Taxi out for run-up - NOx & $SO_2$ on span
134700 DAS & LORAN tapes on - DR2 - FSSP on - ASASP on
134900 ASASP pump on
135000 T/O - going to 10'K - hazy on climbout
135500 Very dirty layer at 5000'
135800 @ 8000' - several layers above still - majority of mixed layer <7K' however
135900 9500' - definite top of BL
140100 @ 10K' - $SO_2$ to sample - NOx to zero
140200 $H_2O_2$ to cal
140600 Spike in NOx?
140700 NOx to sample - zero air off - descending to 4500'
142200 G-1 and HS in sight over VOR
142600 Starting IC time - both A/C in proximity - G-1 agrees
142800 $O_3$ = 58 ppbv - $SO_2$ = 4.8 ppbv - $H_2O_2$ = .5 ppbv - T = +10.6°C $T_d$ +3.4°C - NOx = 1.9 V
143600 $SO_2$ 1.5 ppbv - $O_3$ = 50 ppbv - T = 10.2°C - $T_d$ 3.7°C
143800 End IC - ascending to just > mixed layer
144100 LORAN out
144500 Boundary layer is very high - G1 going to 10.5 - verified we were to go to just above BL - I thought they were to do 4500?
144900 @ 9500 top of BL
145000 Begin FP #1 - flow 159 lpm
150900 Just skimming the BL up here - 3 min from turning
151200 Turning - heading 170
151400 NOx to zero
151800 NOx to span
152200 Flow A on $H_2O_2$ way low - adj'ing
152600 NOx to sample
152700 Now NOx to sample - zero gen off - ≈1 min zero air then into elec zero mode
153000 Pilots turned LORAN off
154000 Sloping BL - changing as we go N/S - 9500 is keeping us just above in some places
154100 Turning - heading now ≈028
154300 End DAS tape #1 - begin DAS tape #2 - E/T
161500 End 90 mm FP #1 - flow 159 lpm - turning - heading 262
161515 G-1's time check shows 161545 - water in FP system again? Was plugged prior to T/O???
161700 Begin 90 mm FP #2 - flow 163 lpm
163700 Going to 9700' - BL inc - we were getting into the crud a little
164400 Turning - heading 119
171400 Turning - heading 261 - on last leg
173200 $SO_2$ = .2 ppbv; $O_3$ = 41 ppbv; $H_2O_2$ = 1.0 ppbv; T = +3.6°C; $T_d$ -15°C; NOx = .8 V

173400 End DAS tape #2 - begin DAS tape #3
174400 End FP 90 mm #2 - flow 159 lpm
174500 90 mm #3 - blank
174600 Begin descent into Cap City
175900 Landed - shutting off only UPDAS - will remain on grd power
180000 Alt F10 - NOx & $SO_2$ to zero

TAS not updating on screen. Only hour of LORAN data - LORAN "belly-up" on 1347, off 1441, TK/TM'd 1530

**September 1, 1988**
**High Resolution Box - Part 2**

Pre-flight:

No LORAN - no channel changes
$SO_2$ - .8 V
$H_2O_2$ - 38, 37, 7.3, 1.03

| | $SO_2/O_3$ | NOx | $H_2O_2$ |
|---|---|---|---|
| 182400 | zero 0.7 | zero air | flows A = 2.03 B = 1.88 |
| | | 420, 428, 416, 424 | adj flows to 2.0 |
| | | parked chan # 3 & 4 | start 2pt cal |
| 182800 | to span 50 sccm | to span NO cal | zero sig 38 bkgd 37 |
| | | 10 sccm | |
| 183200 | 7.6 span | 3010, 3000, 3016 | 37 37 |
| 183800 | 8.1 | 3028, 3034, 3000 | std#1 275 40 |
| 184000 | 8.2 | 3026, 3058, 3050, 3032 | std#2 527 46 |
| 184600 | 8.4 | 2960, 2982, 3004 and zero mode on | start 2nd 2pt cal |
| 185300 | 8.5 V | 522, 530, 536 NO cal zero | zero 38 37 |
| 185400 | 8.6 | NOx mode on | |
| 185700 | 8.6 V | 538, 530, 536, 548 and NO cal off | std#1 sig 267 bkgd 40 |
| 190200 | 8.5 | 556, 558, 550, 564 NOx and zero air zero mode | std#2 518 46 |
| 190400 | 8.5 | auto cycle started | end of cal |
| 190500 | zero mode leave $SO_2$ flow on | | |
| 191000 | 0.9 zero | | |
| 191400 | 0.8 zero | | |

191500 stop DAS - copy file - micromaster set to go

In-flight:

193700 Engine start – $SO_2$ & NOx on – span already
194000 Taxi-out for run-up
194300 DAS tape on – no LORAN – FSSP on R1 – ASASP on
194600 ASASP pump on
194700 T/O – going to 10.5K'
195400 @ 7000' – cloud base – still in crud layer
195900 @10500' – $SO_2$ to sample – NOx to zero
200300 FP 90 mm #1 on – flow 159 lpm
201100 NOx to span – $H_2O_2$ to span
201600 NOx to sample – zero air off – C #4 on – elec zero going on
203200 Turning – hdg ≈170
210100 Turning – hdg ≈020
213100 Turning – hdg direct to Cap City
213300 End DAS tape #1 – begin DAS tape #2 – TK/TM'd
220300 FP #1 90 mm off – flow 151 lpm
220400 FP #2 90 mm – blank – starting descent into Cap City
221400 $SO_2$ & NOx to zero
221800 Landed
221900 All off

**September 4, 1988**
**Cloud Water Flight**

Pre-Flight:

[GMT]
111000 Power-up ($H_2O_2$ sys; NOx on)
113000 NOx vacuum pump & zero air on
114700 Ozone (NOx) on
114900 "UPDAS" started
120000 NOx C #4 on – reads 2200 mV – not stable yet still
120500 NOx elec zero -1960 mV – going to zero air
120600 NOx C #4 off – zero air
121800 NOx zero = 1460 mV – going to span
122700 NOx span = 3832 mV – going to zero
122800 $SO_2$ & $O_3$ inst on
125000 $SO_2$ = .6 V – going to span; NOx = 930 mV – going to span
130500 $SO_2$ to zero
132500 Not yet zero still
132800 NOx to zero
133800 $SO_2$ to 1/2 scale span
135000 $SO_2$ 1/2 scale = 5.0 V going to zero
135200 $SO_2$ to zero – NOx programmed

$H_2O_2$ = 38, 36, 7.4, 1.04
$SO_2$ = 6.0, .7

In-flight:

[GMT]
142700 Engine start - lost power cart on start-up? $SO_2$ & NOx on span
143500 DAS & LORAN tapes on - FSSP on R1 - ASASP on
143900 NOx went to elec zero during span
143830 ASASP pump on
144100 T/O - going to 10K'
144100 8-900' - cloud base
144600 Between layers at 5300'
145100 @ 10K' - $SO_2$-NOx to sample
145800 $H_2O_2$ to cal 1 (red button) not quite in clouds here - going further west then maybe descend a little
150000 Descending to 9000'
150200 @ 9000' - looks good
150300 Bottle #1 on - 9000' - some holes at this level trying to stay in
151500 Changing direction - clouds here getting thin - going NW of Harrisburg
152300 #1 off - #2 on - in/out rain - going back to west of Harrisburg not any better up north for clouds
153200 NOx to sample - forgot to turn zero gen off so NOx was zero-ing all this time - will span in a min or two
153700 #2 off
154200 NOx to span - zero air gen back on
154500 Span (NOx) acting strange - big spike
154900 #3 on - east of Harrisburg now
155000 NOx to zero - descending to 8000' - too thin here - nothing in bottle yet
155300 Heading N/NE - clouds look thicker there
155500 NOx to sample
160300 Real good cloud 19 mi NE Harrisburg - holding here for awhile
160800 #3 off - #4 on - 8000'
162000 #4 off - #5 on - 8000'
162500 DAS tape #1 off - #2 on - TK/TM'd
163500 #5 off - descending to some level - will decide on cloud
163800 @ 6000' - looks good
163830 #6 on
134600 @ Selinsgrove VOR - turning to Harrisburg - LORAN out - don't know when it went - receiver tests ok - still indicates winds??
164900 In/out thin - clouds are intermittently thin - convective system - nothing really uniform here
165400 #6 off - descending to 5000'
165600 #7 on - @ 5000' - too thin - dropping to 4000' - just hitting tops
165830 @ 4K' - in cloud continuing with #7 - 4000'
170000 6 mi NE Harrisburg on 026 radial - no LORAN still - just turned to this 026 heading
171100 28 mi NE Harrisburg on 026 radial - just turned back to Harrisburg popped out of cloud
171900 #7 off - 4000' - going over to Lancaster area - maybe climbing for that (maybe)

171915 #8 on – not going to Lancaster now – this area improved – 14 mi NE of Harrisburg – turning hdg toward HAR – the clouds seem to be spanning 14–24 mi NE of Harrisburg
173000 #8 off – #9 on – 4000′
173030 15 mi NE of Harrisburg – turning away from Harrisburg now – still on 026 radial – still no LORAN
173700 Turned to Harrisburg – 2 mi from Selinsgrove
174500 #9 off – turning away from Harrisburg
174600 #10 on
175200 Clouds seem to be increasing to NE – will continue further instead of turning toward HAR
175400 10 mi N of Selinsgrove on V31 – turning toward Har.
180400 #10 off – 4000′
180500 Heading home – 20 mi N of VOR – LORAN still out (N of airport) – clear at this level just after #10 came off – broken layer @ ≈3000′ – maybe 2000′ – ovc ≈5000′ or so – hard to tell – variable
182200 1200′ base over Cap City
182500 Landed
182600 Alt F10 – all off



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