Alberta Oil Sands Environmental
Research Program

POLLUTION DEPOSITION FIELD STUDY PLAN

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1 - INTRODUCTION

1.1 - Objectives

The following is a study plan report coupled with detailed cost estimates aimed at obtaining field data on scavenging of pollutants up to about 80 km from source. The program design is based on conclusions reached in "Literature Review on Pollution Deposition Processes" (LIROPP), as well as further evaluation of details in the literature. Discussions have also been held with AOSERP, Alberta Environment and Syncrude personnel, and other workers, e.g. Hales, who have carried out similar studies on deposition of pollutants from coal-fired generating stations.

The study will be covered in this report in 3 phases: concept and preliminary design, detail planning and start-up, and field operations. The logical order of this report is chronological and proceeds from general to specific details, therefore, some repetition may be encountered.

1.2 - Methodology

Each experiment may be conceived of as testing more than one deposition model with emphasis on different parameters. For example, an experiment might compare dry deposition velocities for a simple constant V_p model and, at the same time, accumulate information on particle size distributions as input to a more sophisticated model. It is felt that the best test or confirmation of a deposition model is obtained when the model is in "good agreement" under a wide range of conditions. "Good agreement" is defined by Dana et al (1973) for SO_2 concentration measurements to be within a factor of 2 with model predictions.

There are many different methods of estimating deposition parameters. Direct methods determine the flux and are dependent upon the precision of emission, transport, and chemical reactivity data and algorithms, in addition to the deposition algorithm. Indirect measurements compare atmospheric measurements to fluxes and/or deposition velocities, and are mostly independent of the other portions of the model.

All techniques of field measurement can have large inaccuracies in design and can lead to erroneous conclusions. Therefore, the best approach to design of a field program is to build in as many levels of redundant checking as are reasonably possible, and to carry out all of the measurements simultaneously. Hence, a few in-depth studies with internal checks are better than many uncontrolled analyses.

2 - PHASE I - PLANNING

2.1 - Program Design

The sampling area proposed is an arc-shaped area enclosing an angular spread of 60 degrees to the west and 60 degrees to the east of north, centered in the Syncrude plant site.

In this study area approximately 168 sites will be cleared for installation of rainfall samplers, spaced along arcs spaced at 6.7-km increments of radius. Sample sites will be cleared at intervals of approximately 6.8 km of chord length along these arcs, measured from a north/south line. This results in 12 sampler site arcs containing 2, 5, 7, 9, 11, 14, 16, 18, 20, 22, 24 and 26 sites.

This spacing ensures that even typically small, transient summer shower events will affect several sampling sites. Any given 60-degree arc in this study area contains approximately 90 sampler sites.

Specifications for Field Locations

These specifications apply to rainfall sites but not to Mildred Lake, Bitumont, McClelland Lake or Firebag. Specifications for these latter places will be drawn up separately. Consult the section on field instrumentation for details of individual instruments and collectors.

Each open site must be cleared to eliminate brush higher than 0.3 m (1 ft) in a minimum area of 60 m by 60 m. Actual clearing must consider the instrumentation siting and helicopter landing area, so that no interference results between helicopter and instrument locations. There must be ample room for the helicopter to land. Normally helicopters will land and take off from the downwind side (N); therefore, the site may be elongated in a N-S direction.

Distance between instrumentation and forest stand should be such that the angle between the forest height--sampler height line and a horizontal line is 30 degrees or less. Thus a minimum approach to forest stand will be 1.7 times the average height of the stand in all directions.

Instrument siting on ground and elevated within forest stands are considered separately.

Samplers and instruments will be sited normally 0.9 m (3 ft) above the ground in a level site. The instrument table is best constructed of Dexion or similar angular steel with a plywood top surface. Dexion steel allows easy attachment of support rods, etc, for securing instruments. Normally the platform will be 2 m (7 ft) long and 30 cm (1 ft) wide and will be oriented E-W or elongated at right angles to the prevailing wind. The narrow width of the platform minimizes splash and dust effects on samplers. The platform will be well secured to the ground.

The 2 gas samplers will operate from opposite ends of the platform and the collection cone will extend beyond the table. The SO_2 and $SO_4^=$ collectors will be clustered next to one another and be separated as far as possible from gas collectors and bulk rain collectors. Gas collectors will be secured with a springy band, and all other collectors will be secured by laboratory type

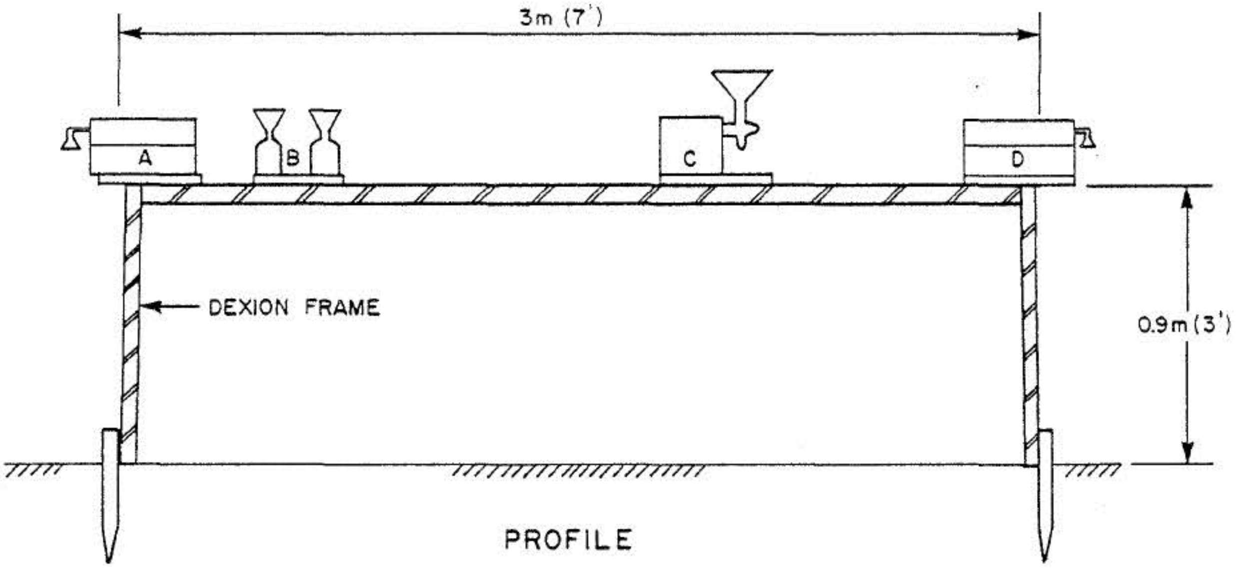
1/2-inch aluminum rods, clamps and rings. The rods will be attached via plates and screws to the plywood or Dexion steel. Plywood sections will be large enough only to support funnels, bottles, etc, so that a minimum amount of table surface is exposed to splash and reentrainment contamination. Figure 1 is a schematic diagram of the layout.

Site Selection

Number of sites and locations have been chosen on the basis of preparation time requirements, analytical requirements, prevailing wind trajectories, sophistication of measurement, ground terrain, and whether a rainfall or dryfall study. Each study is considered to be completed in the field in about 1 day.

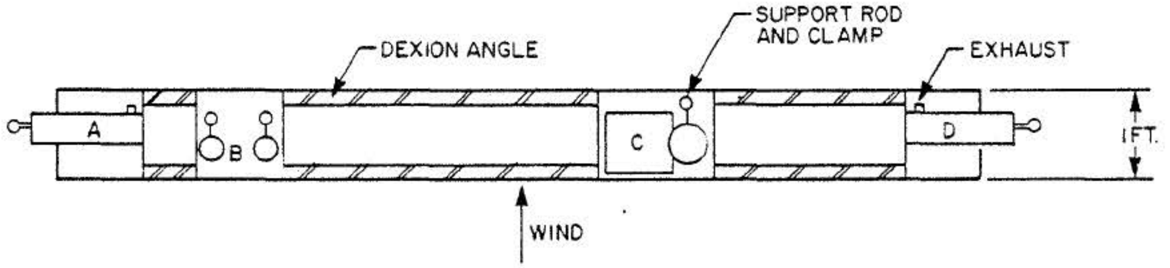
Dryfall studies, due to the detail and precision of measurement, will be carried out at 3 sites only, Mildred Lake Camp, Bitumont Tower and Firebag Tower. Access, towers, power and instrumentation in part are already available for these sites. Furthermore, they lie in the direction of prevailing winds for the study period and are the right distances from source (13 km, 46 km, 81 km) for the scale of the study. Furthermore, Bitumont will be instrumented for measurement of through forest dryfall.

Approximately 100 sites have been selected for rainfall measurements. This number was considered reasonable from preparation time requirements, analytical capabilities and cost. Initially 3 arcs, 10 km, 40 km and 80 km distant from source were chosen for sampling. However, due to the erratic depositional patterns in convective rainstorms,an approximate equal area sampling



PROFILE

A – SO_2 GAS, $SO_4^{=}$ AEROSOL PUMP
B – SO_2, $SO_4^{=}$ BOTTLES WITH PRESERVATIVE FOR RAINFALL
C – BULK COLLECTOR
D – NO_2, NH_3 AND AEROSOLS PUMP



PLAN

SCHEMATIC OF SAMPLING TABLE FOR RAINFALL

FIG. 1

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grid based on an arcuate pattern was chosen. In this way the probability of obtaining data for a rainfall is increased. Any sampling sector of 60 degrees within a 120-degree pattern laid out with Syncrude as the source and extending from N60°W to N60°E may be chosen. The pattern is constructed as a series of arcs equally separated and laid out with distances along each arc approximately equal to arc separations locating sampling sites. Further examination of maps and aerial photographs may alter positions slightly. The area of the 60 degree arc extending 80 km is calculated and the first estimate of area and station spacing is obtained (6.5 km) considering 80 stations. The number of arcs (12) is obtained using a 6.5-km spacing and 80-km maximum distance. This results in an actual spacing of 6.7 km. Table 1 gives details for locating all stations. This procedure results in about 87 stations for any 60-degree arc to be studied. Therefore, there are about 10 stations that can be considered standby or can be used for special purpose study such as forest canopy throughfall.

In addition to the above pattern, Mildred Lake, Bitumont and Firebag will be studied intensively during rain events.

Sampling equipment at the 87 equal area stations is as follows

- every location: collector for SO_2 in rain,
  collector for SO_2 + $SO_4^=$ in rain

- every third location: collector for SO_2 gas and
  $SO_4^=$ aerosol,

TABLE 1

DESIGN OF EQUAL AREA SAMPLING SYSTEM USING AN ARC GEOMETRY

Approximately 90 sampling stations are contained in any 60-degree arc. The basis for layout out of the system consists of 12 arcs (radius = x_1, x_2......bisected by chords of length r_1, r_2 etc). Values are as follows.

Arc Radius (km)	Chord Length (km)	No. of Stations (120 degrees)
6.7	7.35	2
13.4	7.09	5
20.1	7.08	7
26.8	7.02	9
33.5	7.02	11
40.2	6.5	14
46.9	6.5	16
53.6	6.5	18
60.3	6.6	20
67.0	6.65	22
73.7	6.71	24
80.4	6.74	26

Total stations for 60-degree arc = 87

collector for NH_3 and NO_2 gas
and aerosol,
bulk collector for H^+, Na^+, Ca^{+2},
Mg^{+2}, NH_4^+, $SO_4^=$, Cl^- and trace
metals.

Mildred Lake, Bitumont and Firebag would contain sampling gear as above, plus raindrop sizing, wind direction and velocity, rainfall intensity, high volume samplers, and continuous gas monitoring instrumentation.

All sites must be cleared sufficiently to enable helicopters to land and take off, and to ensure that there will be no interference with samplers from foliage, helicopter downwash, etc. This will be facilitated if landing sites are elongated somewhat to the north of the sampler location at each site.

Site Selection and Operations in Forests

The Bitumont site is proposed as the site for study of scavenging in a forest canopy. The site is at about the same elevations as the AOSERP camp and contains a dense deciduous forest from 10 - 15 m in height. Activity and portable power facilities are generally located at the site and to the north of the site. Therefore, both dry and wet canopy studies should be located to the south of the site whenever possible.

Following the study in Sweden by Richter and Granat (1978) of pine forest canopy throughfall measurements, a study area of approximately 50 m x 50 m of level terrain will be divided into 10-m squares, resulting in 36 possible sampling sites. Samplers will be placed 1 m from the surface, using the bench arrangement discussed earlier, or a simple modification thereof. Nine sites will be chosen randomly for gas analysis and 27 sites for SO_2, $SO_4^=$ and bulk rain collectors. The collectors will be the same as those used in open terrain, except that a coarse plastic screen will cover the funnels to exclude large debris. One additional site in an open clearing will serve as reference. Two types of samples are proposed: an "in the forest" sample, and an "under a well-shaped tree" sample. Multiple funnels leading to 1 collector are proposed for greater areal coverage. At least 1 rain event study will collect fractions of rainfall. Hopefully, analysis of fractions may suggest washdown of contaminants when compared with the open clearing reference sample.

Sample volume will be determined by weighing collectors, and this variation will be used as a statistical variation to relate to depositional measurements.

During dry deposition studies at Bitumont, the forest canopy study area will be monitored at ground level and at elevations on scaffolding for vertical and horizontal variations. It is hoped that using the scaffolding it will be possible to sample above the canopy for both wet and dry events so that both vertical and horizontal profile can be obtained. The canopy study area will be chosen by ground and aircraft study. Canopy characteristics will then be mapped using photography from air and ground, and light penetration.

2.2 - Precipitation Event Sampling Program

During a given precipitation event only a 60-degree sector of sampling area, containing about 90 rainfall event sampling sites, will be utilized. The orientation of the sector chosen will depend on 24-h weather forecasts.

Every third location will contain portable sampling pumps for gases, and bulk collection for trace metals and major ions during wet deposition. All sites will sample for SO_2 and $SO_4^=$. Bitumont will contain about 10 complete units for canopy studies. This will result in about 100 sample sets of SO_2 and $SO_4^=$, and 40 complete sample sets per experiment. In addition background levels will be measured at remote locations to the northwest, for example, Namur Lake.

Details of Precipitation Chemistry Sites

At all sites

- SO_2 in Rain - 7.5-cm (344 cm^2) area polypropylene funnel in 250-mL polypropylene bottle at ground level. TCM solution is preservative.
- $SO_4^=$ in Rain - 7.5-cm polypropylene funnel in 250-mL teflon bottle at ground level. Hydrogen peroxide preservative results in the measurement of $SO_2 + SO_4^=$.

At every third site

- SO_2 Gas Analysis - 2-L/min pump with midget impinger containing 25 mL TCM preservative. SO_2 analysis sensitivity is 0.1 mol/L or time to obtain 16X sensitivity if

  $c = 0.02$ ppm, $t = 4$ h
  $c = 0.01$ ppm, $t = 0.7$ h

  These are ranges of SO_2 levels to be expected. Therefore a 3 - 4-h sampling will produce enough SO_2 for analysis.

- $SO_4^=$ Aerosol Analysis - Sulfate is typically about 1 percent of SO_2. The sensitivity for the methylthymol blue colorimetric method is 0.01 mg/L. Using a cleansed fluoropore filter, extraction into 5 mL of aqueous solution requires about 10 h sampling time. SO_2 gas and $SO_4^=$ aerosol are generally obtained from the same unit.

- NO_2 - NO_x values in the area range from 0.01 - 0.1 ppm or 0.02 - 0.2 mg/m^3. Sensitivity of the diazotization colorimetric method using triethanolamine and guaiacol, and sodium metabisulfate as collecting fluids is 10 μg N/L. Collection in a midget impinger containing 25 mL, with a pumping capacity of 2 L/min results in 1-h requirement for analysis.

- NH_3 - Ammonia is absorbed on an oxalic acid filter paper and then analyzed using a low-level Berthelot-indophenol method, having a sensitivity of 10 µg N/L. Using a background level of 0.008 mg NH_3/m^3, pumping rate of 2 L/min, and 10 mL of solution, the time required is 1 h.

  NO_2 and NH_3 would be sampled from the same pump.

- Bulk Sampler - A 20 cm (314 cm^2) area polyethylene funnel collects water in a 4-L polyethylene container for Ca^{++}, Mg^{++}, Na^+, K^+, H^+'NH_4^+, Cl^-, $SO_4^=$, specific conductivity, and Gran titration. For trace metals sample is acidified.

2.2 - Dry Sampling Program

Dry deposition requires more extensive study, resulting in meteorological instrumentation on towers or scaffolds of 4+ m on level grass or soil and water at 3 of the approximately 20 dry deposition sites.

In addition to instrumentation at existing meteorological towers at Mildred Lake, Bitumont and Firebag, there will be a tower on a raft in McClelland Lake.

Details of Dry Deposition Sites

Thermal and wind profile measurements along with concentration gradients are required, with a study period of 2 - 6 h. Details as follows

- SO_2, $SO_4^=$, NO_2, NH_3 collected at 3 sites at continuously varying elevations, by moving the gas intake elevation and continuous gas analyzers. Filter analysis from soluble K^+, Na^+, Ca^{+2}, Mg^{+2}, Cl^-, H^+, NH_4^+, NO_3^- and $SO_4^=$ at 3 sites at 4 fixed elevations corresponding to the elevations for the meteorological sensors. Dry fall collected at the 3 sites.

2.3 - Additional Measurements

High volume sampling, particle sizing, raindrop distributions and continuous gas monitoring are required for 3 distances from the source, since a typical experiment varies from 2 - 6 h. AOSERP Mildred Lake facility would be suitable for a 20-km site, Bitumont for a 40-km site, with 1 additional instrumented location needed for a 80-km site. Birch Mountain is the appropriate distance away, and might be suitable for obtaining background levels. Firebag would be a more suitable site for additional instrumentation along the 80-km arc, and in subsequent discussion this station is used.

Bitumont and McClelland Lake will have additional measurements. At McClelland Lake, wet collections will be obtained at 2 elevations, whereas at Bitumont, 10 ground level and 4 elevated samples will be obtained. Firebag will be more intensively instrumented also.

Surface character has a controlling effect on deposition velocities, therefore, 3 surface types will be examined.

Particle size analysis and continuous analysis for SO_2 and NO_2 will be carried out at 3 locations of Mildred Lake, Bitumont and Firebag. Details of SO_2 and NO_2 gas monitors are given in Section 3.2. Particle size analysis will be by hi-vol sampler with Anderson Cascade Impactor and Electrostatic Aerosol Sampler (details in Sections 3.1 and 3.4).

A decision to run a dry or wet sampling program will be made 24-h in advance, based on weather forecasts.

Samplers would be positioned as required with timers set to allow sufficient time to position all samplers and complete all preparations, and to turn on and off all samplers simultaneously. The professional men at Mildred Lake, Bitumont and Firebag would operate and monitor the more extensive instrumentation at these sites. The Bitumont site contains extra pumps and samplers to measure throughfall in a forest stand, and extra manpower may be required there.

A typical study will be from 2 - 6 h duration. Immediately after completion of a sampling period all samples would be picked up and delivered for analysis to the analytical laboratory at Mildred Lake.

2.4 - Meteorological Measurement Program

Meteorological information obtained from weather reports and existing instrumentation at Mildred Lake, Firebag and Bitumont meteorological towers will be supplemented by recording meteorological stations at 3 additional sites at locations approximately 20 km, 40 km and 80 km from the Syncrude source area on a heading at approximately northeast; these 3 sites and the existing meteorological towers cover effectively the permanent dry sampling site sector. At each site 4 stations on scaffolding will record meteorological parameters at 4 levels.

The meteorological and related measurements to be made at the 3 existing meteorological towers and at dry deposition measurement sites are

- wind velocity
- wind direction
- temperature
- precipitation rate
- relative humidity
- raindrop size frequency spectrum
- particulate size frequency spectrum.

Wind velocity, direction and temperature measurements will be made at a series of heights above the surface, so that vertical wind velocity and temperature gradients can be established.

Dispersion Models

Parameters for driving dispersion models require the calculation of wind direction, average wind velocity and atmospheric stability. Average wind velocity calculation requires the measurement of the vertical wind profile, while atmospheric stability requires the measurement of the vertical temperature gradient.

Atmospheric Chemistry

The oxidation rate of sulfur dioxide to sulfate, and many other relevant chemical and physical processes in the atmosphere, are dependent on temperature and the availability of moisture, indicated by the measurement of relative humidity

Wet Deposition

In order to calculate rates of deposition due to scavenging, precipitation rates and the raindrop size frequency spectrum must be measured in addition to measurements of gas and particulate concentrations in the atmosphere and the particulate size frequency spectrum.

Dry Deposition

The calculation of dry deposition velocity by the gradient method, which assumes essentially a common eddy diffusivity coefficient for chemical parameters, heat and momentum, requires the measurement of vertical temperature gradients and wind velocity profile, as well as the vertical pollutant concentration gradient, particulate size frequency spectrum and characterization of the deposition surface.

Another method of calculation of deposition velocities involves aircraft plume tracking. Integrated concentrations across 2 plume sections are determined, and it is assumed that the total mass difference is equal to the total deposition on the ground surface area between the 2 measured plume cross sections. With corrections for oxidation and the average wind velocity, the deposition velocity can be calculated.

2.5 - Helicopter Sampling Program

The use of a helicopter as a sampling platform allows the extension of temperature and concentration profile measurements to altitudes beyond the height of the existing meteorological towers at Mildred Lake, Bitumont and Firebag, and the scaffolding at the dry sampling sites.

Profiles will be flown at 4 altitudes at each site at 10 m, 30 m, 60 m and 90 m above the surface. A helicopter range of 6 - 7 h will allow profiles to be flown at 6 sites, corresponding to the meteorological towers at Mildred Lake, Bitumont and Firebag and the 3 dry sampling sites instrumented with recording meteorological stations. Runs will be made downwind and close to each station, and at a sufficient distance to ensure that downwash from the helicopter blades will not interfere with the ground based samplers and monitors.

The helicopter circles a station at each altitude for approximately 10 min to ensure a sufficient sample quantity. Approximately 5 min are required to move to the next altitude, and approximately 20 min for reaching the first site and returning to base from the last.

In addition to concentration and temperature profiles, readings will be taken to the northwest of the study area and downwind, close to the source area as background level and full-scale checks.

2.6 - Data Handling

Data Acquisition Equipment

Data will be acquired in essentially 3 modes. The first is for samples processed after the event has ended. These full-term samples will be conditioned for laboratory analysis. The end result is a single value or concentration for items such as particulate data, precipitation samples, etc.

The second type of acquisition will be to use strip chart recorders. These continuous measurements will be made for wind speed and direction, temperature, relative humidity and rainfall rate, where accuracy better than ±1 percent is not required, but more frequent sampling is necessary. The third method of acquisition will be by portable data logger. These units will be used where high accuracy and large volumes of data are anticipated such as the continuous SO_2 and NO_2 monitors. The units to be used are Metrodata 616 data loggers. They can scan up to 16 channels of analog data, convert to digital form and record on magnetic tape cartridges. The cartridges are then removed and processed using a Data General Nova 1220 computer system, equipped with a special reader. Outputs can include the instantaneous readings or conveniently average time intervals. The Metrodata 616 Data Logger is available in 2 alternative power source versions, 117 VAC, 50 - 400 Hz or 12 VDC. They fit a standard 19 in. rack mounting. Overall height is 7-3/4 in.

Data Processing

A good deal of thought will be necessary to design a flexible data storage and retrieval system for this project, such that the large number of data points can be analysed and compared. Data will be available for 3 different time durations, continuous data, 10-min data and sample period durations of between 2 and 6 h, and from many different sources. Much of these data will of necessity be stored on computers since the volume and variety of data and analyses will require this kind of resource. Other information may most conveniently be handled by the usual filing methods if it is of a more qualitative nature or if the volume is not sufficient to warrant the time to factor it into the data base.

Actually 3 interrelated data files are proposed, each representing a different time period, due to the different sampling methods utilized in the study.

- File No. 1, with a 10-min time base, is most suitable for storage of data obtained from helicopter sampling, such as temperature and gas concentration profiles.

- File No. 2 is an event duration file with a variable time base, up to the duration of the sample event. This file is suitable for storage of analytical results from the approximately 90 ground-based precipitation samples, etc.

- File No. 3 will store auxiliary data, such as recorded meteorological weather data, in the form of 10-min interval data and event duration reduced values.

Readings and analyses from Mildred Lake, Bitumont and Firebag will logically be divided between all 3 files.

Each data value will be stored with indexes to the source of the data (collection type, sampler location, time and collection interval), data type (SO_2 value, $SO_4^=$ value, etc) reliability, etc.

This scheme ensures easy data retrieval by type, source, time interval, etc, and simplifies both data archiving procedures, data retrieval for calculations and possible future expansion of the data archive.

Data Reduction

The basic calculations to be made are for the determination of deposition velocities and rainfall scavenging coefficients of sulfur dioxide and nitrogen oxide gases, and sulfate and nitrogen containing particulates.

In simple terms, determination of a washout coefficient requires the determination of suspended or gas phase pollutant concentration in the atmosphere, before and after a period of precipitation. The time, intensity of rainfall, the 2 atmospheric concentrations and the concentration in the rainfall, allow the calculation of a washout coefficient, units of time^{-1}, in terms of the rainfall rate or intensity.

Deposition velocity calculations require either effective mass balance measurements or gradient analyses. Mass balance measurements are measurements of the total deposition of atmospheric concentration at 2 different times or places. The difference allows the calculation of deposition velocity. This method requires extensive measurements, and produces an integrated value, suitable for the mean wind velocities and surface characters of the entire study region. The gradient method, suitable for calculation of deposition velocities at a point and time, and, hence, allowing correlation with surface characteristics, depends essentially on the measurement of the concentration profile above the surface. Also known as the resistance method, it can be considered to be a calculation based on the measurement of the resistance or assistance given to settling pollutants by the lower atmosphere. These calculations cannot be isolated from the total dispersion, alteration and deposition problem, and will be considered in conjunction with dispersion models and sulfur dioxide oxidation atmospheric chemistry.

2.7 - Analytical Program

For wet deposition, SO_2, NO_x, NH_3, soluble particulates, Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^-, $SO_4^=$, H^+, NO_3^-, NH_4^+ and trace metals will be measured.

Precipitation analysis will include SO_2, NH_4^+, Na^+, K^+, Ca^{+2}, Mg^{+2}, H^+, Cl^-, $SO_4^=$, NO_3^- and trace metals. SO_2, $SO_4^=$, NO_3 and NH_3 will be measured at all sites, and the other parameters, when considered significant (from SO_2 analysis), will be measured at every third site. Trace metals analyzed will include Cu, Pb, Zn, Ni, Cd, Mn and Hg.

Dry deposition sites will concentrate on deposition of SO_2, $SO_4^=$, NO_2 and NH_3, and fine aerosols using the gradient technique. This technique assumes a common eddy diffusivity coefficient for chemical parameters, and heat and mechanical fluxes. This assumption is probably valid for gases and fine particles, but can be questionable for coarse particles. However, metals and other aerosols will be measured, and deposition fluxes will be estimated by collection and gradient techniques.

Wet deposition requires vertical gradients of composition in precipitation. SO_2, $SO_4^=$, precipitation chemistry at different elevations at 3 distance arcs, particle size, raindrop size, vertical profiles of wind velocity and direction, humidity and temperature must be obtained for wet deposition. Similar analyses, except for rain chemistry are required for dry deposition.

SO_2, NO_2, NO_3^-, NH_3, and $SO_4^=$ would be analyzed (in sequence given) using autoanalyzers at Mildred Lake. Standard addition technique would be used for $SO_4^=$ routinely and occasionally for others. Specific conductivity, pH and Cl^- would be measured on wet samples using electrodes. Trace metals would be acidified and other samples labeled and packed for later analyses off site.

Titration studies characterizing the acid will be carried out after other work is finished.

2.8 - Operational Manual

While the final report will present the essential details and reduced data and conclusions of the study program, operational manuals will be produced to cover all aspects of the program in fine detail. This procedure will enable the program to be repeated at a later date, and/or repeated with new personnel previously unfamiliar with the program, with a minimum of difficulty and a maximum level of efficiency.

2.9 - Operational Schedule

Ten weeks of field operation during the period July 15 - September 30, 1979 are proposed. Each sampling event, including preparation, field analysis, preliminary reduction of field data and preparation of samples for later analysis, would require about 1 week. Depending on frequency of plume trajectories in the selected sectors, some 6 - 8 complete field studies can be expected.

3 - PHASE 1 - INSTRUMENTATION

3.1 - Meteorological

Wind velocity, direction and temperature profiles, relative humidity, precipitation and precipitation rates will be measured by compact, selfcontained, electronic weather stations (Climatronics P/N 100243). Power requirements are standard lantern batteries. Sensors can be placed up to 300 m from the recorder without loss of accuracy to allow all recorders for instrumented towers to be placed together at ground level.

Windspeed is sensed by a photocell chopper using a solid state light source with a range of 0 - 55 m/s with an accuracy of ±.12 m/s. Distance or time constant is 2.5 m maximum and wind velocity threshold is 0.34 m/s. Wind direction is sensed by a 540-degree precision potentiometer, eliminating any areas of poor directional resolution. The range is a full 360°, with accuracy of ±1.5°. The damping ratio is adjustable between 0.4 and 0.6. Temperature is measured by a precision thermistor permitting a ±0.5°C accuracy recorded at a 0.5°C chart resolution, with a -30° to +50°C range, with a time constant of 10 s. The relative humidity sensor measures a full 0 - 100 percent humidity range with ±4 percent accuracy with a time constant of 10 s.

All data, except precipitation, are recorded as analog data on a crystal speed controlled drive chart.

A tipping bucket rain/snow gauge provides .22 mm precipitation increments, to an accuracy of ±1 percent, recorded as .25-mm event steps on a chart record.

All data are recorded on 1 chart.

Particulate size frequency spectrum will be measured with Anderson Cascade Impactors driven by standard high volume air samplers. This is an 8-stage, multi-jet cascade impactor which automatically separates particles into 8 fractions from 11.0 μ and above, down to 0.4-μ diameter. A backup filter provides absolute collection of the remaining submicron particles.

The raindrop size frequency spectrum may be measured by very complex or very simple means. A very complex method (in practice) is the measurement of the impact of each raindrop using an electromechanical momentum sensor. A very simple method is to allow some raindrops to fall for a few minutes upon sheets of filter paper tinted with dye. The filter papers must be first calibrated with drops of known sizes.

Raindrop size frequency spectrums obtained by both methods match closely (Vali, 1974). Therefore, the calibrated filter paper method will be used to obtain raindrop size frequency spectrums.

3.2 - Monitoring and Sampling Instrumentation

Continuous Gas Monitors

The following sections describe equipment and design which meet the requirements for ground-based and helicopter-based sulfur dioxide and nitrogen oxides sampling and calibration. Where appropriate, we have also included alternatives which we feel would improve system operation, minimize maintenance or allow for better achievement of the objectives of the program.

A wide range of monitors is available from various manufacturers. In order to limit the number of choices Acres has selected instruments with which we are experienced and which have EPA approval as equivalent sampling methods.

It may be desirable to purchase all instrumentation from one manufacturer as this would eliminate possible interfacing difficulties such as ground loop problems or signal levels which may arise from combining instruments from different manufacturers.

Listed below are instruments Acres recommends with a brief discussion on each.

- <u>Sulphur Dioxide</u> - Two methods of sulfur dioxide detection which have been certified by the U.S. EPA are discussed below. These are flame photometric and fluorescent detection techniques.

  - The flame photometric method provides dry analysis of sulfur in air samples. The operating principle utilizes the photometric detection of the 394 nm-centered band emitted by sulfur-containing compounds in a hydrogen-rich air flame. This method is not specific to sulfur dioxide and, therefore, requires the addition of a hydrogen sulfide removing scrubber.

  - The fluorescent technique of detection is based on the measurement of the fluorescence of sulfur dioxide produced by its absorption of ultraviolet radiation. Sulfur dioxide molecules are excited by ultraviolet radiation in the 230 - 190-nm wavelength. This region has been found to be free of quenching by air and most other airborne materials. The fluorescent radiation impinging upon a detector is directly proportional to the concentration of sulfur dioxide providing the basis for direct measurement.

In both methods discussed above a sensitive photomultiplier observes the reaction and transforms it into a voltage which is in proportion to the concentration of sulfur dioxide in the sample stream being analyzed.

The initial cost of the flame photometric analyzer is less than the fluorescent; however this differential is offset by the additional operating cost and inconvenience of supplying hydrogen for the flame photometric analyzer and replacement of the hydrogen sulfide scrubber. Use of flame photometric analyzers in a small aircraft is especially inconvenient due to both the sensitivity of the instrument to air pressure, the extra space requirement for the hydrogen gas, and the necessity of acquiring MOT approval for carrying hydrogen. Flame photometric units are manufactured by Meloy Laboratories and Monitor Laboratories (Meloy SA285E, Monitor Labs 8450E). Fluorescence units are made by both TECO and Beckman Instruments (Beckman 953, TECO 43).

Historically, Acres has had excellent cooperation with all the above. We have found the equipment to be reliable, accurate and maintainable under typical operating conditions. Acres considers that the products of all 4 manufacturers are capable of meeting the objectives of the program. Since the cost differential is small, final selection of instruments will be based on convenience, measurement sensitivity and opinion of relevant scientific authority. This selection will be made in consultation with AOSERP in the first stages of the contract.

- Nitrogen Oxides - The principal of operation for the detection of oxides of nitrogen will be the chemiluminescent reaction of nitric oxide and ozone.

  When nitric oxide reacts with ozone, some nitrogen dioxide decays to its ground state, giving off a photon of energy. When this emitted reaction is monitored, it becomes a sensitive measure of the nitric oxide in the reacting sample.

  The sample is divided into 2 paths, one leading to a catalytic converter to reduce nitrogen dioxide to nitric oxide, while the other bypasses the converter. Both samples reach a reaction chamber where nitric oxide is detected by its chemiluminescent reaction with ozone. A sensitive photomultiplier observes the reaction and provides a voltage which is in proportion to the concentration of nitric oxide in the sample. Any difference between the 2 readings is nitrogen dioxide.

  Here again there are a variety of manufacturers and models. The Teco model 14D, the Monitor Laboratories Model 8440, the Beckman 952A, the Meloy Laboratories Model NA530R, are monitors which have been U.S. EPA approved and would be suitable in this application.

Acres has had previous favorable experience with the Teco Model 14B, an early version of the Model 14D, but again we suggest that final instrument selection be made in consultation with AOSERP.

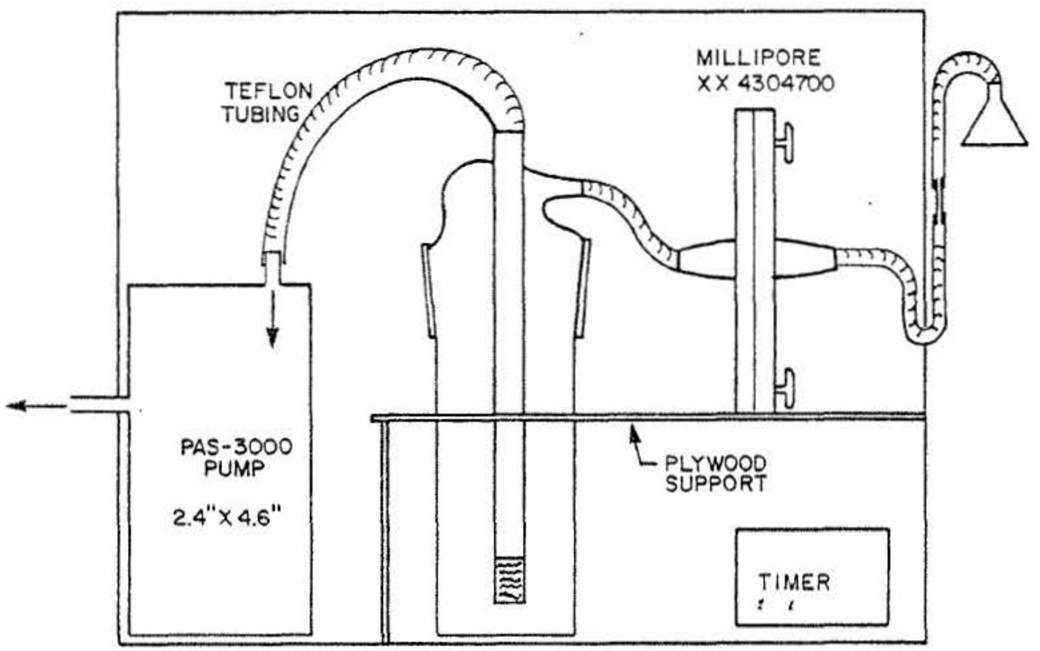
- Suspended Particulates - Standard high-volume sampler pumps will be used at Mildred Lake, Bitumont and Firebag. For particulate analysis either Whatman 41, or better, Fluoropore, is desirable as the filter paper with the lowest metal, sulfur and nitrogen background.

  Size distributions can be obtained by using an impactor head or by sizing using electron microscopy. For electron microscopic methods, Nucleopore or Millipore filter papers are more suitable. Smaller size filters (47 mm) in combination with portable pump units (Figure 2) are suitable for these samples.

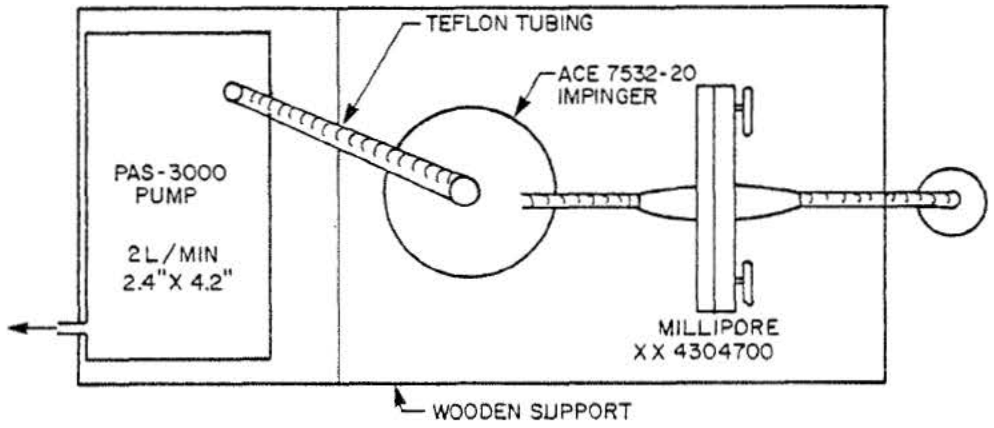
- Portable Samplers: Gas - For other locations than Mildred Lake, Bitumont and Firebag, portable gas samplers consisting of filter(s), impinger(s) and battery operated pump with delay and internal timer are used. Figure 2 is a schematic of the aerosol/gas sampler. The unit is modeled after the system used by Batelle-Northwest in studies of scavenging of power plant plumes.

  After evaluation of components available, the following are recommended

  - Spectrex PAS-3000 pump: flow rate adjustable from .005 - 2.7 L/min. To be run normally at 2 - L/min. Servo control for flow within 5 percent for 0 - 10 in. H_2O vacuum at 2L/min; 8 - 10 h



PROFILE



PLAN

1 SPECTREX PAS-3000 BATTERY PUMP 2L/MIN (5% OVERALL CONTROL) 16 HRS MAXIMUM RUN
2 ACE 7532-20 30mL IMPINGER FLOW < 3L/MIN
3 MILLIPORE XX4304700 47mm FILTER PAPER HOLDER
4 TIMER: MICROPROCESSOR CONTROLLED: START TIME AND INTERVAL. MAXIMUM 24 HRS
5 a TEFLON TUBE CONNECTIONS
  b GLASS INVERTED CONE

SCHEMATIC PORTABLE AEROSOL/GAS SAMPLER

FIG. 2

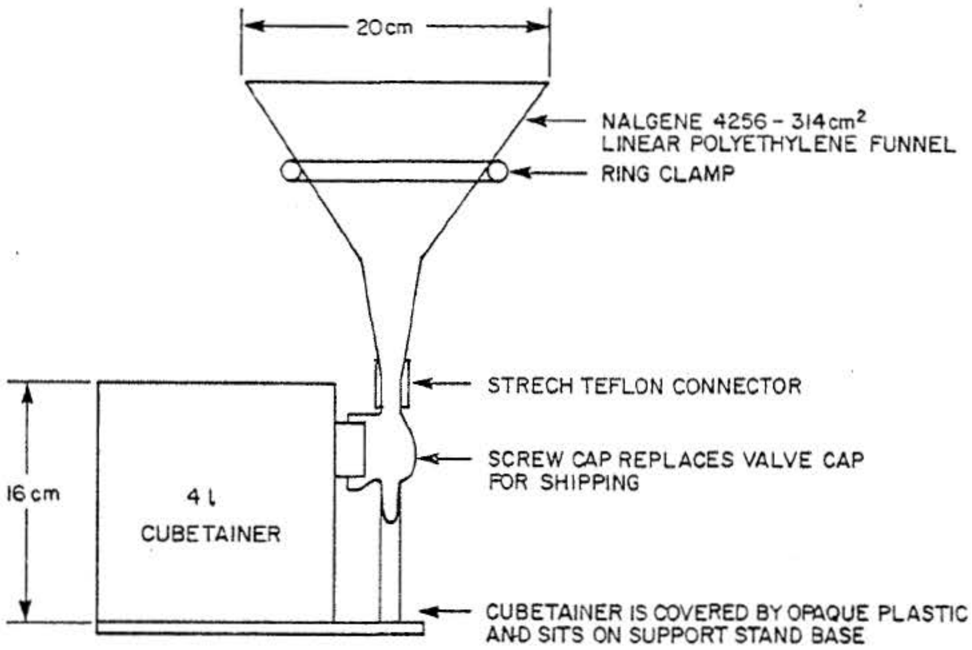
ACRES

battery life at 2 L/min. Batteries rechargable over 16 h. Low flow detection device. Size 4.2 x 4.6 x 2.4 in. fits in plastic lunch-bucket container.

- Impinger: Ace Glass midget No. 7532-20, 30 mL impinger for flows less than 3 L/min, with fritted glass diffuser. Normal solution volumes will be 25 mL.
- Filter holder: Millipore XX4304700 plastic holder for 47-mm diameter circular filter paper. Will accommodate a wide variety of common filter paper types.
- Timer: Micropressor chip to delay starting time and set sampling interval.
- Other: Container, a standard plastic lunch-bucket; Plywood frame to hold impinger and filter holder; teflon shink-fit tubing; tubing plugs for transport; inverted glass funnel for sampling cone; spring-loaded belt to secure unit to sampling table; exhaust line of pump remote from sampler.

- <u>Precipitation Collectors</u> - Two units are planned. One collects a bulk sample of greater than 300 mL and is designed to measure common ions (Na^+, K^+, Ca^{+2}, Mg^{+2}, NH_4^+, H^+, Cl^-, $SO_4^=$, NO_3^-), specific conductance and trace metals. This unit is shown in Figure 3. The unit consists of

  - funnel: 20-cm diameter Nalgene 4256, held in position by standard laboratory ring clamp and stand



FOR TRACE METALS, CONTAINER IS ACIDIFIED
TO FINAL 0.1 N HNO_3

N.B.
ADDITIONAL FUNNEL AND NALGENE 6151 - 1 CONNECTOR
CAN BE ADDED TO OBTAIN LARGER VOLUMES OF SAMPLE

BULK RAIN COLLECTOR FOR PARAMETERS
OTHER THAN SO_2 & $SO_4^=$

FIG. 3

- bottle: a 4-L cubitainer covered with opaque plastic and with a value cap for collection of rain from funnel

- teflon connection tubing

For trace metal sampling, aliquots of high purity HNO_3 acid will be available.

The second collector unit is designed for sampling and analysis of specific ions requiring preservatives. SO_2 will be measured in rainfall by preserving with TCM and $SO_4^=$ will be preserved (SO_2 + $SO_4^=$) in H_2O_2. A smaller collection system is needed. Figure 4 is a sketch of this system. This collection system consists of

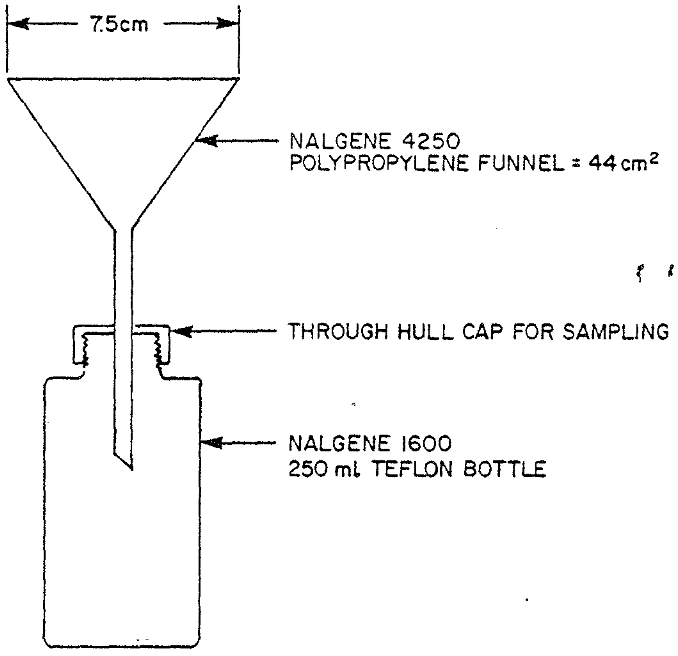
- 250 mL teflon (Nalgene 1600) bottle

- 7.5-cm diameter polypropylene (Nalgene 4250) funnel with O ring seal cap.

The unit is held in place using a standard laboratory ring stand and clamp.

3.3 - Laboratory Instrumentation

To the extent possible, chemicals will be preweighed and packaged, bottles, filters, etc, cleansed and packaged before field operations begin. This prepackaging will reduce field laboratory operations and should keep contamination problems to a minimum.



BOTTLE IS HELD WITH A CLAMP

SO_2 AND $SO_4^=$ RAIN BOTTLES

FIG. 4

ACRES

Three instrument units will be used at Mildred Lake laboratory for field operations. They are as follows.

- 2 - 3 Technicon autoanalyzers with a Gilson 200 automatic sample changer. The autoanalyzers will be used to measure SO_2, $SO_4^=$, NO_2, NO_3^- , NH_3-NH_4^+ using most sensitive techniques. Figure 5 summarizes the SO_2 manifold; Figure 6 summarizes the $SO_4^=$ manifold; Figure 7 summarizes the NO_2-NO_3^- manifold; and Figure 8 summarizes the NH_3 manifold.

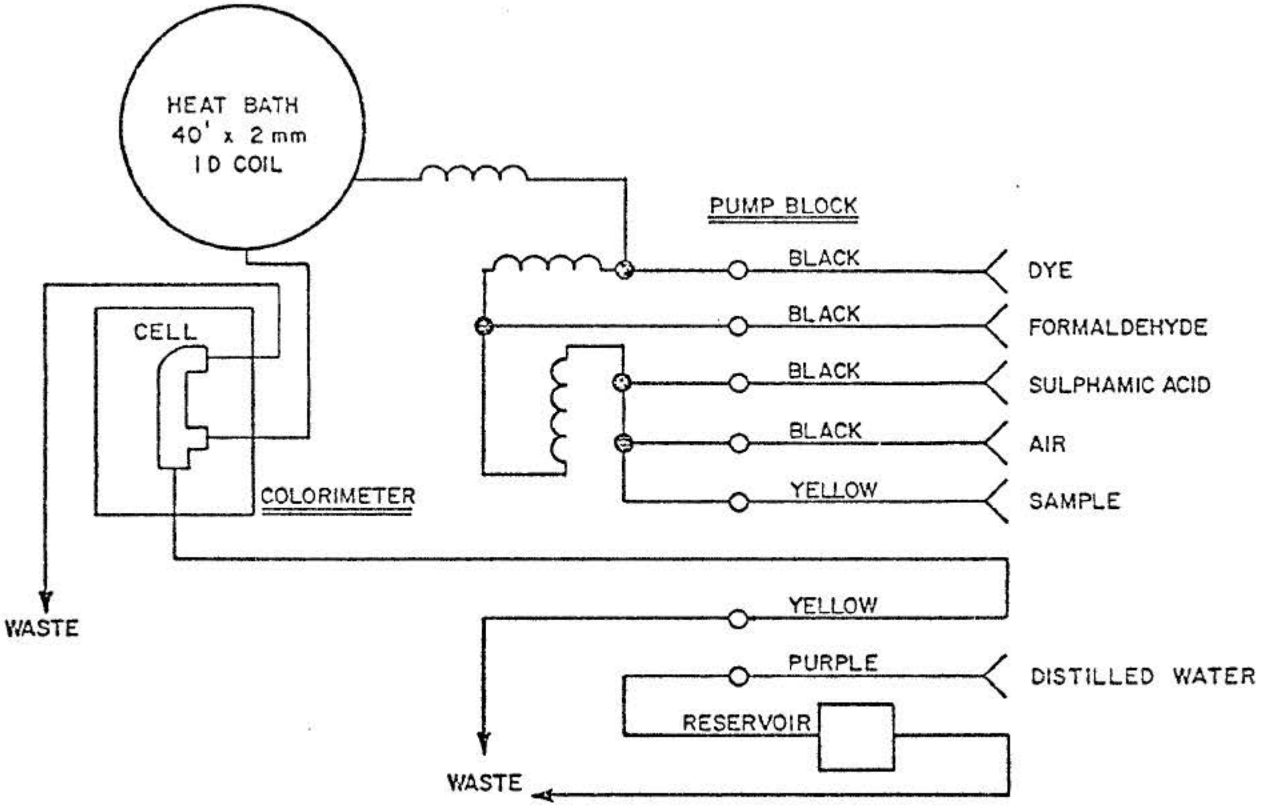
- a digital pH meter sensitive to 0.01 pH units. This unit with gel-reference combination pH electrodes will be used to measure pH and Cl^- using a specific ion electrode and standard addition techniques.

- Top-loading balance: 1 000-g capacity sensitive to 0.01 g for all weighings, dilutions, etc.

Other items required will be a fume cupboard or equivalent, conductivity meter, good quality water still and deionizer columns. Expendable supplies including glassware, micropipets and tubing are also required. Ample storage for bottles, etc, will be needed. For example, 8 rain experiments will require about 300 4-L cubitainers, or about 100 cu ft of storage space. Furthermore, space for charging batteries and preparing field samples is required.

Trace metal analysis and common ions will be measured after the field study is complete.

Applied Earth Science Consultants has had extensive experience using the above equipment in field laboratory conditions. With proper care, results obtained have equaled or bettered those of established laboratories. Previous



DYE:

STOCK 0.2 g PARAROSANALINE IN 100 ml H_2O, LET STAND 48 h.
FILTER THROUGH No. 42 WHATMAN.
TAKE 20 ml OF STOCK, ADD 50 ml OF CONCENTRATED HCl, LET STAND
5 MINUTES AFTER MIXING AND DILUTE TO 1000 ml WITH D. H_2O.

FORMALDEHYDE:

DILUTE 5 ml OF 37% FORMALDEHYDE TO 1000 ml WITH DISTILLED WATER.

SULPHAMIC ACID:

MIX AND DILUTE 1.725 g IN 1000 ml D. H_2O. FORMALDEHYDE AND SULPHAMIC ACID MAY BE KEPT FOR 7 - 10 DAYS. STORE ALL DYE SOLUTIONS IN DARK, PREFERABLY COLD. WORKING SOLUTION IS GOOD FOR 3 DAYS IF KEPT IN THE DARK. STOCK SOLUTION IS GOOD FOR SEVERAL MONTHS STORED IN A REFRIGERATOR.

ABSORBING REAGENT:

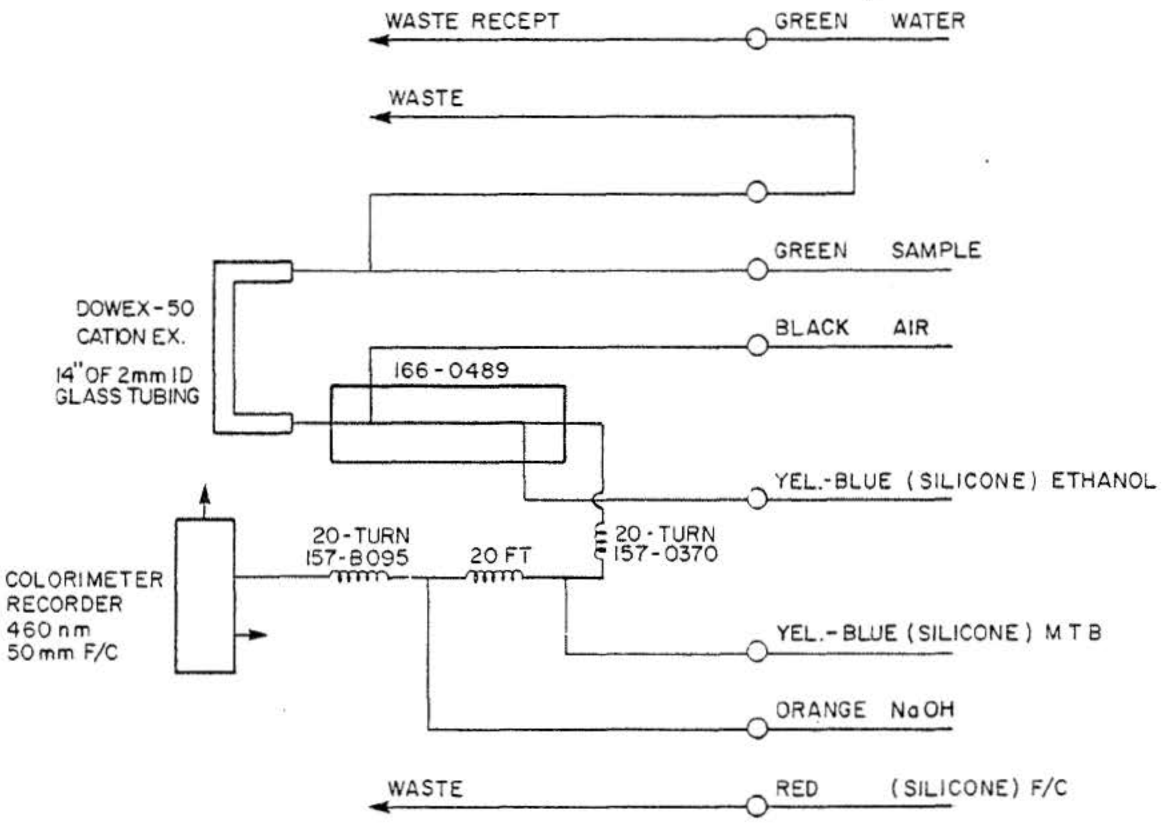
2.34 g NaCl AND 5.44 g (S - FREE) $HgCl_2$ TO 1000 ml AND MIX WELL.

STANDARD ADDITIONS TECHNIQUE (ADDITION OF KNOWN $Na_2S_2O_5$) SHOULD BE CARRIED OUT IF VARIABLE AMOUNTS OF ABSORBING REAGENT ARE USED. FILTER AT 560 μm. USE PLAIN, SOLVOFLEX, AND ACIDOFLEX TUBING.

Schematic of an auto-analyzer procedure for SO_2, using the West-Gaeke procedure

FIG. 5

ACRES



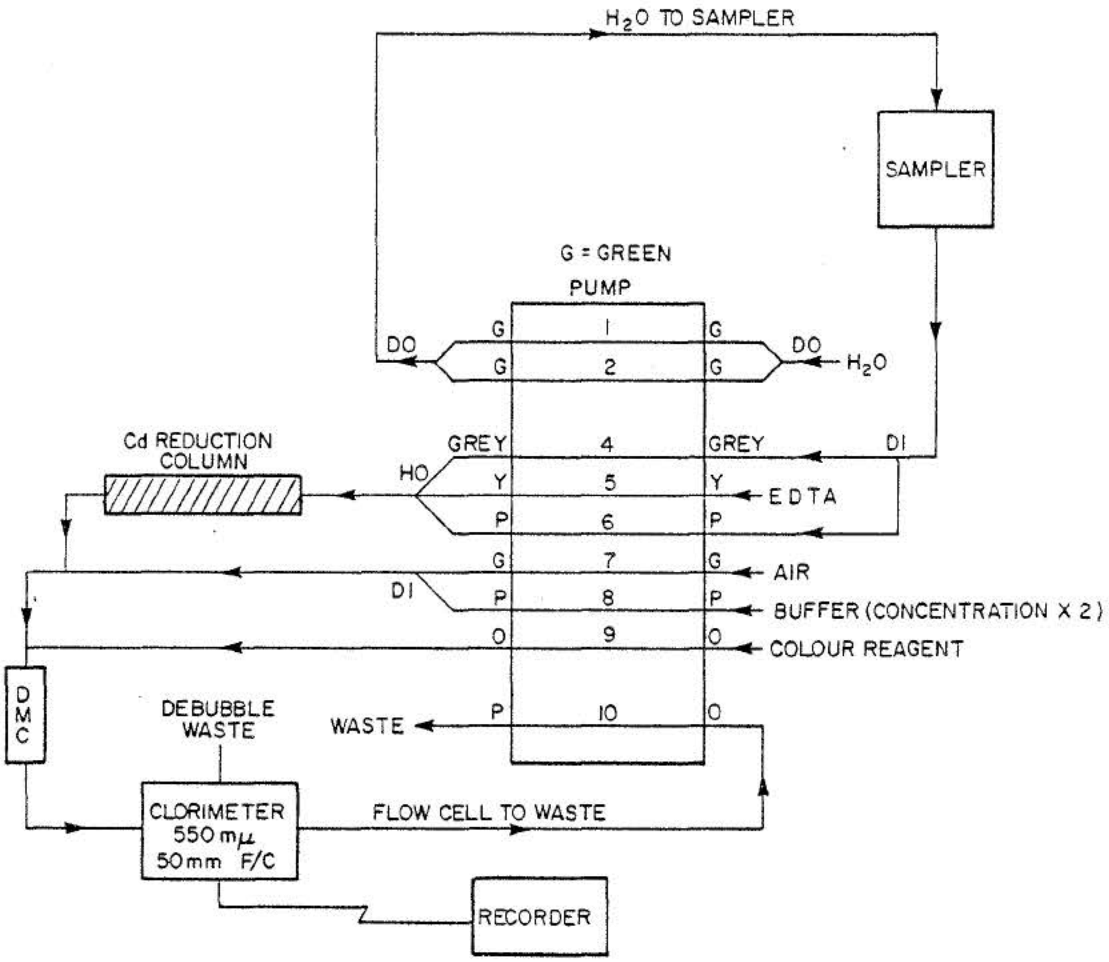
DETECTION LIMIT: 0.01 mg/L SAMPLE CONSUMED 5 mL
ETHANOL: 95%
BARIUM CHLORIDE STOCK 1.526 gm DIHYDRATE IN 1 L, ADJUST TO EQUIV. OF 5 mg/L $SO_4^{=}$
METHYLTHYMOL BLUE (MTB). SEE M. W. ON BOTTLE.
DISSOLVE FOR EQUIV. MOLAR Ba CONC. IN ETHANOL, ADD Ba STOCK SOLUTION,
4 mL 1.0 N HCL AND DILUTE WITH ETHANOL, NaOH 7.2 gms IN 1 L H_2O
N.B. ETHANOL LINE MAY BE DOUBLED FOR GREATER SENSITIVITY

$SO_4^{=}$ MANIFOLD USING Ba - METHYTHYMOL BLUE TECHNIQUE

FIG. 6

ACRES

SENSITIVITY 10$\mu g/l$
SAMPLE: 5 ml



COLOUR REAGENT:

a) 2.5 gm SULPHANILAMIDE IN 18 ml CONC. HCL AND 70 ml H_2O. MIX WELL DILUTE TO 100 ml.

b) 0.5 gm 1-NAPHTHYLAMINE HYDROCHLORIDE IN 90 ml H_2O & 10 ml ACETONE. (STABLE FOR 2 WEEKS. NO GOOD IF BROWN) MIX a & b, GOOD FOR 50 SAMPLES

EDTA:

DISSOLVE 10 gm Na-EDTA IN 500 ml H_2O, ADD 25 ml STOCK BUFFER, DILUTE TO 1000 ml.

BUFFER:

MIX 300 ml EACH OF a & b, DILUTE TO 1 l

a) 450 ml GLACIAL ACETIC ACID TO 2 l

b) STOCK BUFFER: 207g OF Na-ACETATE TRIHYDRATE IN 100 ml OF GLACIAL ACID. DILUTE TO 2 l.

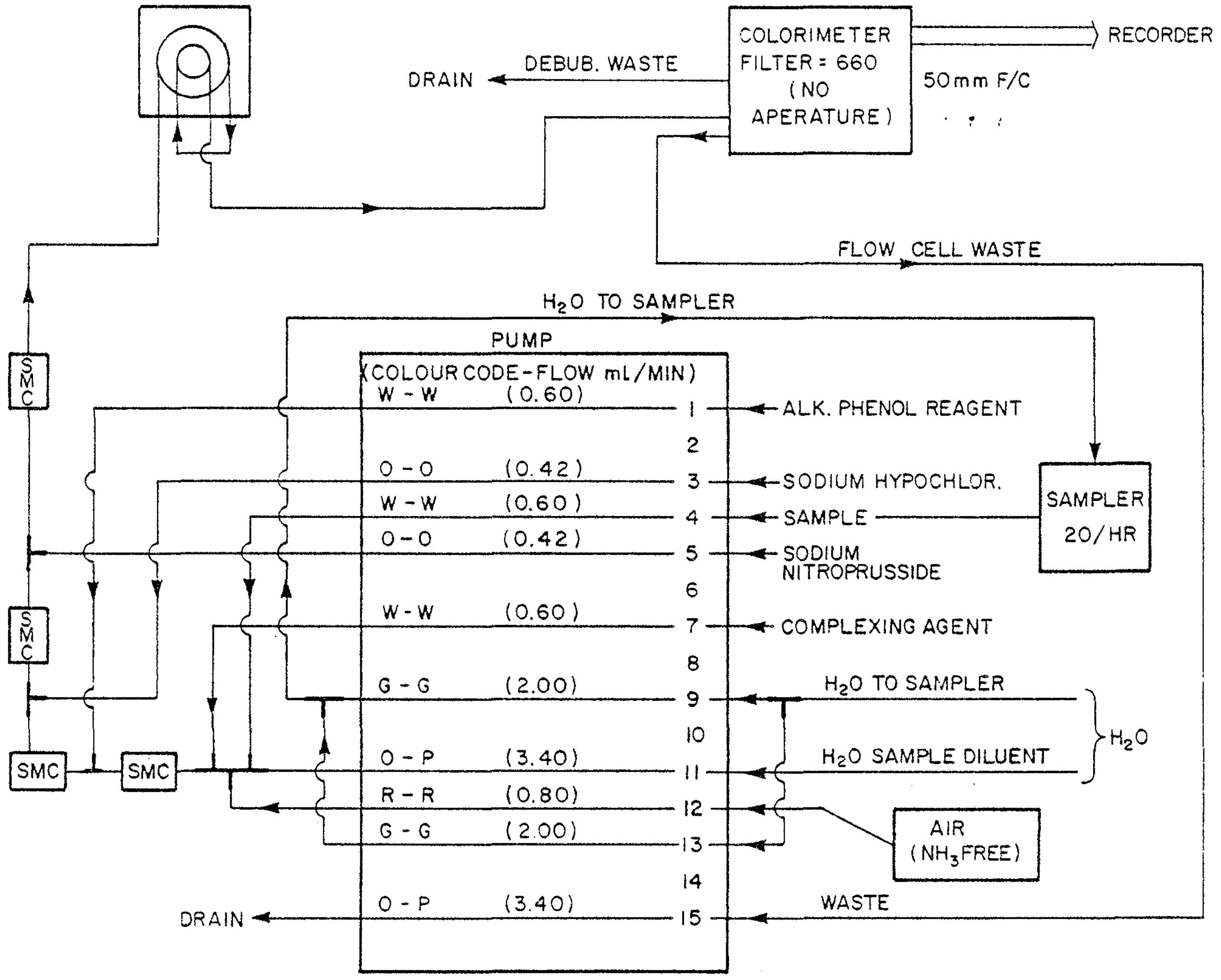
NO_2 AND NO_3^- MANIFOLD

FIG. 7

ACRES

SENSITIVITY 5 ug/L

SAMPLE: 5 -10 ml



N. B.

ODD NUMBERS CORRESPOND TO LOWER LAYER OF TUBES, EVEN NUMBERS TO UPPER

AMMONIA ANALYSIS MANIFOLD

FIG. 8

Figure 8 (Cont'd)

STANDARDS

Primary Standard - Dissolve 1.9095 g NH_4Cl in 500 ml.
- This solution is 1,000 mg/L (ppm) NH_3-N.
- Note: Predry NH_4Cl overnight at 105°C.

Working Standards - Prepare working standards by dilution of Primary Standard using same dilution scheme as for NO_3^- standards.

REAGENT PREPARATION

Complexing Reagent - Dissolve 1.65 g potassium sodium tartrate and 1.2 g sodium citrate in 950 ml H_2O; adjust pH to 5.0 with dilute H_2SO_4 (pH meter) and make up to 1 L.

Alkaline Phenol - Mix 21 g of phenol with 50 ml H_2O; cautiously add 180 ml of 5 percent w/v NaOH; dilute to 1L.

Note: Avoid breathing phenol vapor and allowing phenol to contact skin.

- 5 Percent w/v NaOH - Dissolve 25 g NaOH in 500 ml H_2O.

Sodium Hypochlorite - Dilute 50 ml of stock hypochlorite solution having 5.5 percent available chlorine to 1L with H_2O.

Sodium Nitroprusside - Dissolve 0.25 g sodium nitroprusside in 1L H_2O.

5 N H_2SO_4 - 270 ml H_2O plus 45 ml H_2SO_4 (conc). All air bubbled into the system must be scrubbed of NH_3. This is achieved by bubbling H through 5 N H_2SO_4 before allowing it to enter the system.

experience has shown that the main problem that can arise in field laboratories results from an unstable power supply.

3.4 - Helicopter Instrumentation

In addition to standard navigation instrumentation required to fix time, altitude, location, speed and direction of the aircraft, meteorological and pollution parameters must be measured.

Meteorological Parameters

Meteorological and pollution parameters to be measured are temperature, humidity, particulate size spectrum, precipitation chemistry, SO_2 and NO_x gas analyses.

Temperature and humidity measurements will be made by Airflow Development Remote Reading Air Temperature System 3015, with a temperature range of $-35^{o}C$ to $+50^{o}C$, and Airflow Developments Remote Reading Relative Humidity System 3013 (Texas Electronics Inc. Models 2015 and 2013) or equivalent.

Pollution Monitoring Equipment

Particulates will be collected and size frequency spectrum analyzed by Anderson Impactor and High Volume Air Sampler, and TSI Inc. Model 3100 Electrostatic Aerosol Sampler. This device uniformly collects particles in the 0.02 - 10-μ diameter range. Its electrostatic mode of operation is ideal for collection of samples for visual or electron microscope examination since particles may be deposited directly onto glass slides or coated electron microscope grids. Measurable concentrations range from 0 - 5 mg/m^3 at air flow rates between 4 and 10 L/min.

High volume samplers for particulates, aerosol and gaseous $SO_4^=$, H_2SO_4, SO_2, NH_4^+ and NO_2 will be collected on chemical impregnated filters, using portable ground instruments.

Suitable gas analyzers are Beckman Model 953 for SO_2 and Model 952-A for NO_x. Details are discussed in Section 3.2.

The SO_2 gas analyzers work on the fluorescence principle, and the NO_x gas analyzers on the chemiluminescent method. The SO_2 concentration measurement ranges are up to 2 ppm, at a precision of 0.005 ppm. Lower detectable limits are 0.001 ppm. The NO_x concentration measurement ranges are up to 25 ppm at a precision of ±1 percent. Minimum detectable sensitivities are 0.001 ppm. All these instruments meet EPA standards for detection levels and sensitivity.

Dissolved sulfate, nitrate, ammonium and other ions in precipitation will be sampled by an isokinetic rain scoop. This is a scoop structure designed to collect air volume samples without creating high or low pressure zones in the entrance area to the scoop. Such areas would divert particulates and raindrops, and produce false air volume flow readings for flow through the sampling instruments. Precipitation samples collected will be analyzed back at base camp.

Samples will be taken from the airflow through a 5-cm teflon tube extending forward of the aircraft approximately 1 m to clear the rotor downwash. Gas sampling will be by isokinetic probes inside the 5-cm teflon tube at a point as close as possible to the gas monitors.

A Metrodata 616 data logger will be used to maintain a continuous record of the measurements. Up to 16 channels can be scanned and recorded in digital form on magnetic tape. Power requirements are 12 VDC for portable or unattended operation.

Some of these instruments are available in 24 - 36-VDC driven modifications, but the gas analyzers require 110-VAC 60-Hz power, hence a reasonably high quality electronic power inverter will be required. The power requirement, if all instruments must be operated simultaneously, is approximately 1 000 - 1 500 watts. The range of power requirements is dependent on the gas analyzers chosen.

A suitable static inverter, converting 28 VDC to 110 VAC at 60 Hz has been examined. To meet the considerable power requirements of the instrumentation 4 or more inverters can be connected in parallel. Total weight of instrumentation and inverters will be approximately 145 kg to 180 kg, and should present no serious difficulty in terms of volume space occupied. The data logger requires approximately 0.18 m^3, while the 2 gas analyzers, aerosol sampler, temperature and humidity readouts, require a rack approximately 0.5 x 0.6 x 1.5 m in width x depth x height, or 0.45 m^3. The power inverters are approximately 30 x 20 x 10 cm in width x depth x height. Vacuum pump and impingers require roughly an additional 0.2 m^3 plus storage. Space requirements, therefore, may be a critical factor. A Bell Jet Ranger 206B (long-range version) is of a suitable size.

3.5 - Calibration

Both the sulfur dioxide and the nitrogen oxides continuous monitors require initial calibration and periodic recalibration. This will be achieved by the permeation tube principle for sulfur dioxide and for nitrogen dioxide. The basic principle involved in this method of calibration is that gas will be evolved from a surface on which it is adsorbed at a rate depending reliably on temperature. NBS certified permeation tubes for the 2 gases of interest are heated to a precisely regulated temperature in a carefully controlled clean air flow, hence, the concentration of the pertinent gas in air will be precisely known.

Suitable units for calibration of sulfur dioxide monitors are Meloy CS10-2, Teco 143 and Monitor Laboratories 8500-R. Suitable for both SO_2 and NO_2 calibration (as well as O_3, which is not required for this study) is the Meloy CNOS40.

Calibration from NO and NO_x requires the utilization of gas phase titration and a nitrogen oxide gas supply. Suitable calibration units for NO-NO_2-NO_x measuring instrument calibration are the Teco 101N and Monitor Laboratories 8500-R, the latter including SO_2 and O_3 calibration capabilities. The Monitor Laboratories 8500-R is the most versatile of the several calibration units examined and is recommended as capable of calibrating all 4 measuring capabilities of the gas monitoring instruments (as well as an O_3 calibration capability for possible future expansion of the program).

3.6 - Spares

In any complex instrument some components have longer reliable lifetimes than others. Spares should be stocked of these shorter-life components or maintenance items. These include items such as photo-tubes, lamps, fuses, etc. Other items requiring spares are any critical components that, while normally reliable, are difficult to replace on short notice.

3.7 - Transportation

Delivery to Fort McMurray will be by rented trucks; 2 16-ft vans are estimated to have sufficient volume and load capacity to transport all meteorological, monitoring and analytical laboratory equipment.

4 - SUMMARY

4.1 - Chemical Measurement Program

The sampling program requires the following.

- Wet deposition analysis over 60 degrees, requiring 90 sites for SO_2, $SO_4^=$, NO_3 and NH_4^+ in precipitation. Complete sampling every third site for a total of 30 sites. Additional continuous sampling, intensive analysis at Mildred Lake, Bitumont and Firebag.

- Dry deposition at Mildred Lake, Bitumont and Firebag, plus vertical gradient measurements at 3 additional sites at 4 heights above ground

- Aircraft (helicopter) sampling and analysis at 6 sites at 4 elevations for continuous gas analysis, precipitation chemistry scoop, particle size analysis and meteorological parameters.

4.2 - Precipitation Chemistry Sites

Summary of details of precipitation chemistry sites is as follows

- 90 sites contain 3 funnel bottles for SO_2, $SO_4^=$, NO_3 and NH_3

- 30 sites contain SO_2-$SO_4^=$ pump, NH_3-NO_2 pump and funnel collector for other constituents

- 15 sites contain separate SO_2 and NO_2 pumps

- Mildred Lake, Bitumont and Firebag stations will have continuous SO_2 and NO_2 monitoring in addition to the above,plus raindrop analysis and vertical profiles of rain and gases, with large volume collection for titration and Gran analysis and for trace metals.

- 10 collectors at Bitumont forest site.

4.3 - Dry Deposition Sites

Collections will be made at 18 sites in addition to Mildred Lake, Bitumont and Firebag; which are instrumented for collection at 4 levels.

4.4 - Meteorological Measurements

Meteorological instrumentation will be added to existing instrumentation at Bitumont, Mildred Lake and Firebag as required. Raindrop size frequency spectrums and particulate size spectrums will be measured at these sites.

Meteorological parameters will be measured at 4 levels at 3 additional sites during each rainfall event. These sites will correspond to dry deposition sites.

Meteorological parameters measured at dry deposition sites are

- wind velocity and direction
- temperature
- precipitation rate
- relative humidity
- particulate size frequency spectrum.

5 - PHASE II - FIELD PREPARATION

The field preparation phase commences when a go-ahead order is received regarding the program of study. It consists of equipment tenders, ordering equipment, site selection, construction, setup and installation.

This section of the report will follow through the field preparation phase in roughly chronological order.

5.1 - Instrumentation Acquisition

- Equipment Tenders

  The manufacturers of the relevant meteorological, air monitoring and sampling, recording and analytical instrumentation, as outlined previously, as well as manufacturers of auxiliary equipment and supplies, will be approached. Suppliers will be chosen, taking into account cost, delivery schedule and Canadian supplier, as well as suitability of the instrumentation supplied.

- Instrumentation

  All instrumentation will be ordered by May 1, 1979

  All basic analytical instrumentation is now available for field operations. Extra parts will be obtained for portions of the system known to wear out. An inventory of extra parts will be maintained.

5.2 - Sampling Sites

- Site Selection

In the planning phase, ideal site locations were selected from maps, air photographs and satellite imagery. In order to check the suitability of these site locations to specify requirements for clearance, etc, an examination will be made in the field. A helicopter flyover will, in most cases, be sufficient to assess the suitability of a site. Landings will be made as required. Suitable sites will be marked and logged, with recommendations for the subcontractor who will clear the site. Alternative sites, as close as possible to the planned location, will be selected and marked as required.

Three locations for scaffolding for the additional meteorological instrumentation will be examined and marked. If required, three additional sets of scaffolding will be constructed at Mildred Lake, Firebag and Bitumont meteorological tower sites. The forest throughfall site at Bitumont will be examined and marked.

- Site Designation

Subcontractors will clear the sites, as specified previously, sufficient for helicopter landings and to prevent vegetation from interfering with the samplers and meteorological instrumentation. Sites must be marked for easy identification from the air (large day-glow painted numbers, etc), and must be surveyed to establish exact headings and distances from the study area emission source location at the Syncrude plant.

Each designated site will have a preplanned number, based on its distance from the source and its position in its arc.

Every third station in each arc, also designated, will be marked to indicate that it will contain a pump set. (Pump locations are fixed, and will not shift with the 60-degree sector chosen for a given event sampling program).

Scaffolding for the 3 recording meteorology stations must be erected at the specified locations; raft and tower constructed on the proper site, and forest throughfall scaffold constructed as required.

- Two additional sites outside the study area will be designated as background level sites. Possible sites would be at weather towers to the north and west of the study area, such as Richardson, Buckton, Edra, Namur Lake and Legend. The 2 sites chosen will be cleared, if required.

  Further inspections and alterations will be made if necessary.

  Sites will be ready for instrumentation by July 1979.

5.3 - Equipment Checkout

One prototype unit of each portable field sampler will be obtained by fastest means. This includes the portable unit and the rainfall collectors. These units will be assembled at once and tested under close scrutiny for operational characteristics. Furthermore, sampler handling, calibration and transport will be carried out under various conditions which may be encountered in the study. Modification in manuals will be made from this study.

All sampling bottles, funnels, etc, will be fully assembled upon receipt. Then they will be broken down, and all apparatus cleaned and packaged to avoid contamination. All filters will be cleaned and individually packaged.

All portable aerosol/gas samplers will be fully assembled and operated for the equivalent duration of 2 experiments (24 h). Close attention to pump rate control and impinger operation will be noted. All pumps will be calibrated to 2 L/min. All samplers will be labeled to coordinate to specific site locations.

Chemicals required in the field and in the laboratory will be prepared and packaged to the limit possible. This packaging will require only simple mixing or dilution operations in the field. Enough units for 15 studies will be prepared, labeled and boxed.

All analytical equipment will be made fully operational, and actual analyses will be carried out on 1 or 2 sample sets obtained from testing of equipment.

An inventory of all chemicals, samplers, filters, spare parts, etc, will be maintained. When pertinent, procedural manuals will be annotated with changes, cautions, etc.

Instruments will be received during the month of June 1979. All instruments will be immediately checked for damage, missing components, wrong orders, etc, and steps taken to correct any problems.

Technical personnel will take seminars and refresher courses in the operation and maintenance of all new instrumentation to ensure that optimum program efficiency will be maintained.

Attention will be paid to possible interferences of various equipment and other operations, and adjustments will be made to the program.

Ground to air communication will be important to coordinate ground and air profiles and sampling times. Each study should occupy 10 - 60 min.

A large number of samples must be emplaced and recovered for a precipitation event. Timing, sample handling, aircraft utilization, recovery and deployment of personnel are key factors to the success of the study. Special note of aircraft access to sampling site and possible site contamination due to aircraft will be noted.

5.4 - Transportation

All instrumentation will be packed and transported to Fort McMurray by Acres personnel to ensure against loss, damage or delay.

All packed equipment will be accompanied by contents lists and manuals to minimize unpacking and setup time. All analytical supplies will be, as much as practical, packed in "per analysis modular units" (Section 3.3).

5.5 - Program Setup

- Analytical Equipment and Laboratory

  It is proposed that the field analytical laboratory be established at AOSERP Mildred Lake laboratory facility. Three components to laboratory work are involved

  - sample and equipment storage
  - sample preparation
  - analysis.

  A clean, preferably unused, location of approximately 8 x 10 ft is required for storage of containers, samples and equipment parts. This may be a fixed building, or a trailer. Similarly sample preparation requires an area contamination-free from dust and other chemicals. For some operations, the sample storage location can be used, but in dispensing and weighing chemicals an analytical laboratory with fume cupboard and top-loading balance is required.

The analytical laboratory requires a fume cupboard or exhaust system, a good distilled water supply, laboratory bench space at least 10 ft long and a working area of about 150 - 200 sq ft. The area should be draft free so that routine volume measurements using a top-loading balance can be carried out. Various modifications can be made to an existing design as long as minimum area, draft free, and with fume cupboard and distilled water supply are available.

In addition, a battery recharge area for portable gas/aerosol pumps is needed. It is quite possible a master recharge panel and space can be accommodated in a storage area.

The analytical equipment and laboratory will be set up during June to be ready for operational phase by July 15.

- <u>Field Equipment</u>

  - Platforms for rainfall samplers and pumps will be constructed and placed during this time period.

  - Recording meteorological station sensors will be installed at the required four elevations on the scaffolding at three sites, recording modules on the ground hooked up to the sensors, systems checked out, batteries changed, etc.

  - Monitoring instrumentation at the meteorological towers at Mildred, Bitumont and Firebag will be installed and checked out.

- The equipment package for helicopters will be constructed and mounted in the aircraft, permanent installation (of 5-cm teflon pipe, etc) made and the system checked out.
- During this phase, program adjustments will be made as they are required.

  All steps, changes and adjustments in this phase will be logged as the basis of operational manual sections on program setup.

Field equipment will be in place and operational by mid-July.

- Shakedown

Included as part of the setup and checkout phase will be complete sampling runs for both a rainfall event and a dry sampling period. This will familiarize personnel with their tasks, ensuring greater efficiency during the operational phase, and will serve to locate any possible problem areas. Adjustments to the program will be made as required. Any data recovered will be examined for reliability and added to the total data base in the data reduction phase if suitable. Shakedown runs should take place near the middle of July 1979.

6 - PHASE III - FIELD OPERATIONS

Field operations will commence by mid-July and continue until mid-September. Six to eight complete sampling programs are anticipated.

This phase will be covered in this report as scenarios for a wet and a dry sampling run.

6.1 - Atmospheric Chemistry

- Preparation

  All analyses from previous sampling periods must be completed, equipment cleaned, maintained and recalibrated (if required) before the next sampling period can be decided on. These operations will require approximately 1 week. During this period preliminary data reduction from the previous sampling period may indicate the necessity for modifications in subsequent sampling programs.

- Preparation and Operation of Portable Instruments and Rainfall Collectors

  Most measurements will be made at the limit of detection for a given parameter. Therefore, it will be very easy to contaminate sample containers, preservative solutions and funnels unless extra care is taken. Avoiding contamination must be given top priority. Since a laboratory contains chemicals, it is the most probable location where contamination will occur if precautions are not taken.

  The following treats each collector or sampler separately.

- $SO_4^=/SO_2$ Gas/Aerosol Pump

In normal operation, the filter consists of a Millipore Fluoropore FA (1.0 m) or FH (0.5 m) filter. These filters should have been prewashed with double distilled water and packaged individually and sealed in disposable Petri dishes. The filters are to be handled at all times only with the special tweezers provided. In the laboratory, the filter holders are to be loaded for the $SO_2/SO_4^=$ samplers (so designated) as follows. Open the white plastic holder (Millipore XX4304700) by loosening the three thumb screws. Open the holder and remove the O ring seal using tweezers. Lay on a clean surface. Place the Fluoropore filter in the holder, carefully centering, and replace O ring, making sure there are no dust particles on the O ring. Reassemble the holder. The holding screws should not be overtightened but tightened evenly. If the holder is not to be put on-line, place tabs over the intake and outlet to prevent contamination.

It is best to prepare all filters at one time for an experiment. When finished, seal and store them temporarily in a clean plastic bag.

The midget impinger is filled with sodium tetrachloromercurate (TCM) preservative. The preservative should be prepared in bulk for an experiment. Its preparation is as follows.

Take 2.34 g of NaCl and 5.44 g (S-free) $HgCl_2$ in 1,000 g of double distilled water and mix well. Carry out mixing in a closed container and use preweighed NaCl and $HgCl_2$ units, making sure that they are washed out two to three times.

Add the TCM solution in 25 g amounts to each impinger, using a top loading balance. Record flask and solution weight. Seal the impinger and make sure inlet and outlets of the impinger are plugged. Store in appropriate "lunch bucket" gas sampler box.

Make sure the pump has been recharged and calibrated if required.

Distribute filter holders among samplers. Connection between filter holder outlet, impinger inlet, impinger outlet, pump inlet and internal intake and filter holder inlet may be made at this time. The inlet tube outside the sampler should be plugged and remain plugged until the inverted sampling cone is installed in the field. Caution - the sample box must remain upright at all times so that the preservative solution does not spill over into either the pump or the filter. If there is a possibility of mishandling of the pump unit, leave the impinger plugged and separate and make connection along with sampling cone at the field site.

- Ammonia - NO_2 Gases and Aerosols

The same general procedure for assembly of the ammonia/ NO_2 aerosol/gas unit is carried out as for the $SO_2/SO_4^=$ unit, except that two gas lines are used (and two impingers with different preservatives and filter papers). Refer to the separate section on pump care and calibration.

Both air lines are prefiltered with Fluoropore filter paper (FA). These papers (along with the $SO_4^=$ line paper) are later leached to obtain aerosol estimates for NH_4^+, NO_3^-, $SO_4^=$, and H^+.

The impinger for the ammonia determination is filled with 25 g of high purity 0.02 NH_2SO_4. This solution is obtained by making an 1,800-fold dilution of high purity 36 N H_2SO_4. Dilute the vials of H_2SO_4 provided to 1,000 g, using a top loading balance. Warning - laboratory air and human contact can readily contaminate the solution with ammonia. Furthermore, levels to be estimated are very low. Work only with fresh distilled water and with closed containers.

Nitrogen oxide preservative consists of TG solution. This solution is stable for 7 days only, including analysis time. Therefore, this solution should be one of the last units prepared. To make up a solution and transfer 25 g, mix 20 g of Triethanolamine and 0.5 g of guaiacol and make up to 1,000 g with freshly distilled water. Add 25 g to each impinger and seal intakes and outlets.

Follow the same procedures for connection of the pump, impinger and filter holders. A Y connector is used to join the lines to the pump.

- Bulk Collector

The 4-L cubitainer bulk collectors are precleaned and need no further preparation. If trace metal preservation is to be carried out, add 10.0 g of high purity HNO_3 labelled "Trace Metal Preservative". This will provide the right acid strength for 1 cm of rain (314 g rain plus 10 g of HNO_3). Depending on actual rainfall, add more acid if required.

Assemble the funnel and container in the field. Before proceeding to assemble, wash the collecting funnel with distilled water.

- $SO_2/SO_4^=$ Rainfall Bottles

Teflon collection bottles of 250 ml are used for sampling SO_2 and $SO_4^=$ in rain.

Use TCM solution for SO_2 made up as for gas sampling but at double strength to account for rain dilution. Take 4.68 g NaCl and 10.88 g (S-free) $HgCl_2$ in 1 000 g water. Transfer 44 g of this solution to each SO_2 teflon bottle. For 1 cm of rain, 44 g will result in the proper preservative concentration. Cap the bottle, weigh, and assemble filter to bottle in the field.

$SO_4^=$ in rain measures SO_2 plus $SO_4^=$ by oxidation of SO_2 to $SO_4^=$. This is carried out in a 1-percent H_2O_2 solution. Make up a fresh 2-percent w/w solution of H_2O_2 and keep in a dark bottle. Add 44 g to each $SO_4^=$ 250-ml teflon container. Weigh, cap and store in the dark. Assemble funnel in the field. When 1 cm of rainfall is collected, 44 g of 2-percent H_2O_2 results in a 1-percent H_2O_2 solution . After collection, the sample may be stored for extended periods before analysis.

6.2 - Weather

Daily weather forecasts will be followed closely, so that conditions suitable for a precipitation event sampling program can be determined with a 24-h lead time.

At least 24 h in advance, a decision must be made if a wet sampling program is to be executed. A dry sampling program is the default case, and in general is less critical in terms of lead time.

6.3 - Precipitation Event Program

Long-term preparation, cleaning, calibrating of instruments, preparation of prepackaged and preweighed filters, reagents, preparation of pump units, bulk sample units, etc, will be completed before a decision to go is made.

Short-term (24-h) preparations consist of a decision as to which sites (in a 60-degree sector determined by predicted wind headings) will be utilized for the precipitation event program, setting out samplers in the proper sites, preparing the helicopter to fly profiles, preparing recording meteorology stations, and preparing equipment at the meteorology towers and at the forest through-fall site.

The sector chosen will be designated by compass headings and site numbers, and the appropriate samplers and pump assemblies prepared and loaded. Short-term preparation consists of checking batteries, etc, and setting timers. Samplers will be numbered or otherwise designated as to the proper sites to which they belong. While this will require extra planning steps in loading helicopters for set out and flight plan, it will ensure maximum speed and efficiency in the chemical analysis phase of the program.

At each site with pumps, the appropriate unit is secured on the sampling site frame and the timers activated; protective caps, etc, are removed. Pilot must take care to avoid contaminating bulk sampler, etc, with dust from the helicopter rotor downwash.

At sites with recording meteorological stations the recorders are turned on.

If not already in place, the helicopter air monitoring instrumentation package is mounted, connected up and checked out. Portable pump units with their required supply of filters and storage containers, etc, are loaded on board. All miscellaneous supplies required will be checklisted and marked off as loaded.

Monitors, equipment, prepackaged filters, etc. to be prepared at the 3 meteorological towers and at the Bitumont forest stand as required. Technicians will make some preevent measurements to ensure data continuity and as a final check.

All set-out and profiles can be completed with 1 helicopter and 2 men, but additional helicopters, if available, will facilitate the operation.

Analytical Laboratory

On receipt of samples, there will be 2 or 3 personnel ready to carry out the following operations

- log in all samples and assemble in order; SO_2, $SO_4^=$ and bulk samples will be weighed to determine amount of sample
- SO_2 and NO_2 impingers will be weighed to determine change in adsorbing solution
- individual filters will be removed and placed in plastic dishes and sealed, or placed in extraction vessel
- specific conductance, pH and Cl^- will be measured on 25 g aliquot using electrodes
- autoanalyzer sample chamber will be loaded with standards and samples to measure in sequence

  NO_2-impinger

  SO_2-rain

  $SO_4^=$ + SO_2-rain

  NO_3, NH_3-bulk sampler-bulk sampler, and

  $SO_4^=$-bulk sampler

  extracted filters will be analyzed for NH_3 and $SO_4^=$ aerosol

- portions of hi-volume filters are extracted and pH, $SO_4^=$, Cl^-, conductivity, NH_4^+ and NO_3^- are measured

- pumps checked, recharged and recalibrated

- bulk samples and filters are marked, logged and stored for later analyses

- impingers are cleaned, filter holders are cleaned and new adsorbing solutions added and weighed

- $SO_2/SO_4^=$ bottles are cleaned; new adsorbing fluid added and bottles are weighed

- data are summarized and reviewed; initial calculations and isopleth maps are made; modifications and replacements to equipment are made as required

- time permitting, base titration of 100 mL of bulk precipitation and Gran analysis are carried out.

6.4 - Precipitation Event Start

- The program will begin at the time previously set and run from the previously set time period, although all sites may not be involved in precipitation activity.

- At the preselected time, timers automatically start pumps etc, and sampling begins.

- Technicians at meteorological towers at Mildred Lake, Firebag and Bitumont begin to take readings, start hi-vol samples, start pumps, etc.

- Technicians duties include continuous monitoring SO_2 and NO_x at different elevations, hi-vol particulate samples at 4 elevations several times during the event, bulk rainfall sampling, and auxiliary meteorological parameter measurements, including raindrop size spectrum analysis at the onset of the event, near the forecast halfway point of the sample period and near the end of the sample period.

- Most data will be logged automatically by digital data loggers. Records of sampling periods for hi-vol filters, pump units, bulk samplers, raindrop size spectrum analysis filter papers, etc, must be logged by hand.

- All automatically recorded data will be checked by taking periodic instrument readings (3 or more times during the event)

Helicopter Temperature and Concentration Profiles

The helicopter will be aloft with sufficient lead time to make last minute checks and adjustments, to begin monitoring SO_2 and NO_2, and to be over the first profile flight site when the pumps turn on. At this time the helicopter begins precipitation and particulate sampling. The helicopter remains approximately 10 min at each altitude to be measured in the profile program, and moves to the next site. Profile flights will be near, but slightly downwind of the sites to avoid possible influences of rotor downwash. Between altitudes and sites, filters, samplers, etc, will be changed as required. To fly profiles over 6 sites, plus taking background readings over 2 sites beyond the study are to the north and west, will require approximately the 6-h duration of the event period.

For the wet event sampling program the 6 locations may vary, depending on the 60-degree sector chosen, and the location of actual rainfall activity. At least three, and ideally all, profile sites will correspond to meteorological measurement sites on the ground (the 3 recording meteorological station sites and the meteorological towers at Mildred Lake, Bitumont and Firebag).

Monitored data will be recorded by a data logger, but periodic readings (at least once per station and altitude) must be taken and logged as a backup check.

Data Collection

- Helicopter returns to base and delivers samples collected and logged data, etc, to analytical laboratory, etc.

- All pumps will be shut off by timers, but bulk samplers, funnels, bottles, etc, will remain open and collecting dust. Therefore, the quicker all sampler can be collected and delivered to the analytical laboratory, the better the analytical results will be.

  The helicopter will collect all samples. If space in the helicopter is at a premium, the profile monitoring package must be demounted before collection can begin. Additional helicopters will greatly facilitate sample collection.

- At the 3 recording meteorological station sites the chart records will be collected and the station turned off.

- Samples and data collected from the meteorological tower sites at Mildred Lake, Bitumont and Firebag and from the forest stand site at Bitumont.

- Irregularities at the sites will be noted, such as debris in the sample containers, indications of splashing or excessive dust from rotor downwash. Any maintenance requirements to be done during the succeeding between-events period will be noted.

6.5 - Dry Sampling Program

- The preparation, preevent, sampling and sample data collection aspects of the dry sampling program are simplication of the rainfall event program. Rainfall samplers are eliminated, rainfall data are not obtained.

  Event time can be fixed. Pump timers are set to begin sampling in 24 h, and to shut off after a sufficient sampling period, allowing sufficient daylight for sample and data collection.

- Procedures are similar to those in Section 6.1 and 6.4 except no bulk rain sample, SO_2 - rain or $SO_4^=$ - rain samples are obtained. On the other hand, large numbers of hi-volume samples will be processed, and analysis of extracts carried out.

- Decision to go with a dry sampling program depends primarily on wind direction. Whereas for the wet sampling program the 60 degree sector utilized could be shifted to match the predicted wind heading, for a dry sample program we must wait until we can predict that the wind will blow the Syncrude plume through the N to N60°E sector. The sector remains fixed because the existing meteorological towers at Mildred Lake, Bitumont and Firebag, and the 3 additional recording meteorological station sites remain fixed in this sector, the sector estimated to have the greatest chance of accommodating the Syncrude plume during the late summer and early fall. While for wet studies the primary meteorological parameter required to calculate the washout coefficient is the rainfall rate, which can be measured on the ground, the gradient method of calculating deposition velocities, requires the characterization of the temperature, concentration and (ideally) the wind velocity profile.

Surface character is also important to the determination of the deposition velocity. Therefore, the decision was made to characterize the deposition velocity at a series of fixed locations rather than to attempt to determine an overall deposition velocity for the entire study area.

- Helicopter concentration and temperature profile runs will be made at the 6 fixed meteorological sites, to extend the ground-based measurements of the profiles to an altitude of approximately 100 m.

- Procedures for data and sample collection are the same as for the wet event sampling program.

- Between sampling periods, constant checks regarding instrument calibration and contamination are to be carried out. Extraction studies on filter blanks, analysis of distilled water, impinger fluid, and standard addition studies as well as replacement of tubing, exchange columns and chemicals in autoanalyzer pumps will be carried out.

Review of maintenance and calibration logs to see patterns in analytical problems will be beneficial.

Samples, especially of rain samples, will be assembled and shipped so that the rest of analyses may be started.

- Data Reduction

  - The initial data reduction step will be the calculation, examination and recording of routine statistics, including averages, standard deviations, correlations, and coefficients, etc, for all data terms of chemical species, site, altitude, event, etc.

  - Calculations, theoretical and measured values for deposition velocities, scavenging coefficients, oxidation rates, dispersion models, etc, are outlined in detail in "Literature Review on Pollution Deposition Processes". All calculations will be in accordance with the recommendations of this document.

    The primary calculations to be made are for deposition velocities of gases and particulates by the gradient method, and the calculation of gas aerosol and particulate rainfall scavenging coefficients.

    These calculations cannot be considered in isolation, but must be considered in the context of the entire system. Other aspects of the system that will be examined are atmospheric chemistry, primarily oxidation rates for the oxidation of sulfur dioxide to sulfate, and the modeling of atmospheric dispersion and transport.

    Initial calculations will be estimates based on updated overall averages. These will constitute a check on subsequent calculations based on individual sites, etc.

- Data Handling - All data will be recorded with reference to sampler site number, type of collection, time, etc. Data and samples from the meteorological towers or scaffolds will also be referenced as to altitude at which observations or collection were made. Helicopter observation will be so referenced and recorded with reference to altitude.

- Field Data - All data recorded by data loggers will be printed to paper and compared to backup chart records and readings taken by technicians. Data will be examined for agreement with previously known lapse rates and wind profiles. Subsequent use of data will depend on the consistency of the data.

  Gas analyzer and meteorological recorders will be examined for continuity. Any abrupt change in values, temporally or spatially, will be grounds for suspicion.

- Analytical Results - All analytical results will be examined using the same criteria as for field data. Analytical data and field data will be compared for consistency and continuity.

- Archive - All field data and analytical results will be archived on magnetic tape in a consistent data storage format. The system is simple, readily expandable and flexible.

  The archive (together with filed data log sheets, original notes, data and magnetic tape) will form the permanent backup data file for all subsequent calculations and data manipulation.

7 - REPORTING

Final reporting will be of 3 main types

- a report
- working manuals
- a data archive.

Report

The final report will outline all phases of the program in detail, including typical wet and dry sampling program scenarios, appropriately reduced data, calculations and results, and conclusions and recommended actions.

Observations and results of calculations will be compared with theoretical and measured values in the literature, and conclusions made as to the usefulness of the exercise. Recommendations for expansion, continuation or modification of program will be made.

Working Manuals

This study is a large and complex operation, presenting many logistical problems. Therefore, in order to facilitate the transfer of the program to new personnel, and to aid in setting up new programs of this nature, our experience will be outlined in the form of minutely detailed working manuals. These manuals will cover the planning, field preparation, operational and reporting phases of the program.

Data Archive

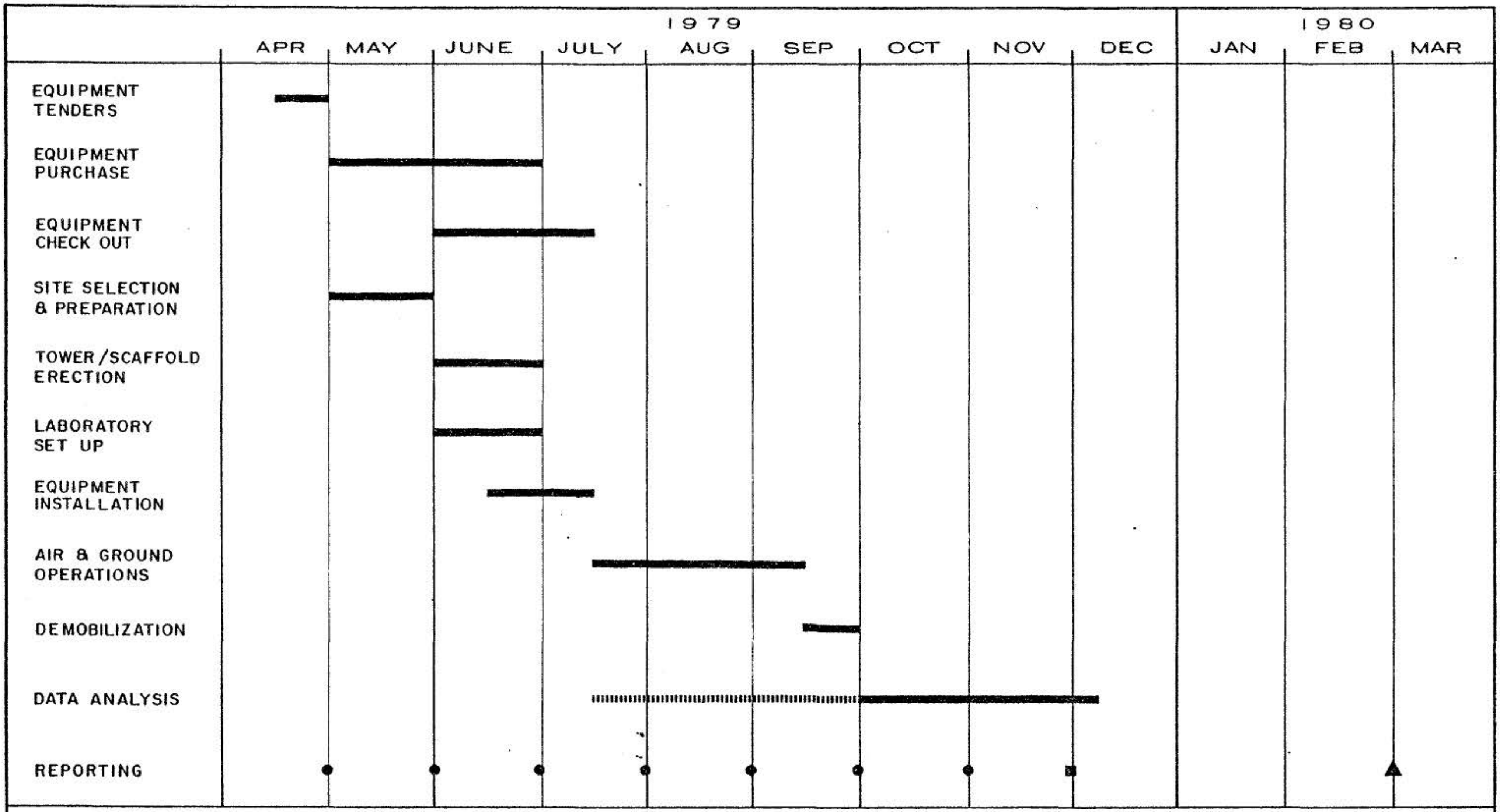
A magnetic tape archive containing all the field and analytical data in a usefully reduced and accessible form will be included as a part of the final report.

8 - STUDY TEAM

This project will be managed and professionally directed by Paul Denison, Environmental Research Executive, Acres Consulting Services Limited. He will be responsible for the overall performance of the work program, technical content of the report on project results, liaison with the client, and budget and schedule conformance. His principal technical contribution will be in the design of the meteorological program and interpretation of atmospheric physics measurements. Assisting him will be James Kramer, Principal, Applied Earth Science Consultants Inc., whose principal contribution will be in the gathering and interpretation of atmospheric chemistry measurements. Frank Huhn, Atmospheric Physicist, Acres Consulting Services Limited, will act as project coordinator for both office and field work. During the installation and operation of the field program, he will be assisted full time by two senior instrument technicians of Acres and two senior chemical technicians of Earth Science. Paul Denison will spend approximately 5 weeks, and James Kramer approximately 8 weeks in the field during the installation and operation phases of the project. The Acres technicians will be experienced in the operation and maintenance of meteorological and air quality monitoring equipment, and the Earth Science technicians will be experienced in the operation and maintenance of atmospheric chemistry monitoring and analytical chemistry equipment.

9 - SCHEDULE

The work program can be arranged according to 3 major tasks; viz, selection - purchase - commissioning of equipment, data gathering in the field, analysis and interpretation of data. Figure 9 shows the timing and sequencing of tasks.



● PROGRESS

■ DRAFT

▲ FINAL

FIG. 9

SCHEDULE

ACRES

10 - COST ESTIMATE

10.1 - Fees

Installation and Commissioning	
Helicopter - 150 h	
150 man-days at $300 per diem average	$45,000
Field Program	
Helicopter - 500 h	
360 man-days at $230 per diem average	83,500
Data Analysis and Reporting	
160 man-days at $270 per diem average	43,200
Management	
40 man-days at $375 per diem average	15,000
Total Fees	$186,700

Note: Living costs at Camp Mildred assumed free.

10.2 - Disbursements

Structures

3 Scaffolds	$ 1,600
Raft and tower	600
75 (est) site clearances	24,000
1 trailer rental	1,287
2 truck rental	4,422
	31,909

Meteorological Instruments

9 recording meteorological stations	49,519
3 units as above plus precipitation and humidity sensors	20,166
	69,685

Aircraft Instrumentation

Temperature	623
Humidity	1,351
Particulates	
Hi-vol and impactor	3,223
Electrostatic sampler	7,007
Gas analyzers	
Sulfur dioxide	12,949
Nitrogen oxides	10,580
Power supply	5,894
	41,627

Ground Instrumentation

80 pump units	76,240
Parts ($853)	
Labor ($100)	

100 Bulk samplers 2 $SO_2/SO_4^=$ samplers, all parts $122	$ 12,200
3 SO_2 monitors	40,789
3 NO_x monitors	33,327
3 Hi-vol samplers and impactors	7,627
1 Calibrator for SO_2/NO_x	7,367
Miscellaneous plumbing	630
	178,180

Chemical Analyzer

Offsite for trace metals, common ions, particulates, 2,700 analyses at $10 each	27,000
Expendible supplies (filter paper, AA-tubing, chemicals, glassware, etc)	4,000
Rental (sample changer, 2 autoanalyzers balance,pH meter)	2,000
	33,000

Data Evaluation and Reporting

Report printing	4,500
Computer time	2,500
	7,000
TOTAL DISBURSEMENTS	$353,482

11 - BASIS OF REIMBURSEMENT

We propose the following per diem rates for personnel assigned to this project. During the field program phase we anticipate that some overtime hours will be required primarily in setting up for monitoring through, and collecting samples after, both wet and dry events, as well as in the subsequent chemical analyses. For this reason we have estimated fees on the basis of 6-day work weeks during the 10-week field program.

A normal work week consists of 5 8-h days.

Function	Per Diem Rate
P. J. Denison	$375
J. R. Kramer	$350
F. J. Huhn	$250
Computer Programmers and Data Handlers	250
Equipment Technicians	200
Laboratory Technicians	200
Draftspersons	175
Secretaries	125

Disbursements for travel from Edmonton, living expenses computer time, communications, reproductions, report printing, air and ground vehicle leasing, equipment purchase and or leasing will be billed at cost plus 5 percent for G and A.

12 - REFERENCES CITED

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