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Charles F. Hall, Lynn R. Ansbaugh, John S. Koval,
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A COMPUTER-CONTROLLED SAMPLING SYSTEM FOR AIRBORNE PARTICULATES

Abstract

A self-contained, mobile, computer-controlled air-sampling system has been designed and fabricated that also collects and records the data from eight meteorological sensors. The air-samplers are activated automatically when the collected meteorological data meet the criteria specified at the beginning of the data-collection run. The filters from the samplers

are intended to collect airborne ^{239}Pu for later radionuclide analysis and correlation with the meteorological data for the study of resuspended airborne radioactivity and for the development of a predictive model. This paper describes the system hardware, discusses the system and software concepts, and outlines the operational procedures for the system.

Introduction

The Lawrence Livermore Laboratory (LLL) is currently conducting studies of airborne particulates in selected areas. The first such study at the Nevada Test Site (NTS) is an experimental program aimed at developing a model to quantify the hazard from ^{239}Pu resuspension.^{1,2} Such a model will permit prediction of air concentrations based on measurements of meteorological and other physical parameters.

Because of the extremely low plutonium levels in the air at NTS, a conventional air-sampler must be operated for as long as 30 days to

obtain enough PuO_2 for analysis. Due to the broad range of meteorological conditions experienced by a sampler over extended period of time, detailed correlation between weather conditions and airborne resuspension becomes virtually impossible. This report describes a computer-controlled sampling system (CCSS) designed to overcome both of these difficulties. Operating unattended in the field, the system monitors and records data from eight meteorological sensors and activates its air-samplers when the meteorological data meet the criteria specified at the beginning of the data-collection run. Thus, resuspension

activity can be correlated directly with specific weather conditions.

The next three sections describe the system hardware, the overall system concepts upon which the soft-

ware was designed, and outline the operational procedures necessary to use the system. The last section presents some preliminary results and some suggestions for future improvements.

System Hardware

GENERAL DESCRIPTION

The CCSS was designed around a Digital Equipment Corporation (DEC) PDP-12 minicomputer.* The computer and peripherals are installed in an air-conditioned truck. The eight meteorological instruments are mounted on a 10-m-high steel tower located 75 m from the truck (see Fig. 1). Signals from the instruments pass through a signal-conditioning unit located at the base of the tower. The air-sampler control unit is also located at the tower. The samplers themselves can be located up to 75 m from the tower.

The entire system can be powered by a generator, by line voltage, or by a combination of the two. The air-conditioning and heating units for

the truck require 208 V ac input and are on a separate line from the computer and instruments, which require 110 V ac. The 110-V line is regulated by an ac regulator and monitored by a strip-chart recorder. The temperature within the PDP-12 rack is monitored and the power to the computer is switched off when this temperature exceeds 90°F (32°C). Figure 2 is a block diagram of the CCSS and Fig. 3 is a photograph of the inside of the truck.

CENTRAL PROCESSOR AND MEMORY

The heart of the CCSS is a PDP-12 minicomputer, a 12-bit machine with a cycle time of 1.6 microseconds. It has two operating modes, LINC and PDP-8. The user can switch from one mode to the other at will. In the LINC mode, the PDP-12 operates as a LINC (Laboratory INstrument Computer) and can easily be interfaced to standard laboratory instrumentation, either analog or digital. In the

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research & Development Association to the exclusion of others that may be suitable.

Fig. 1. A pictorial representation of the computer-controlled sampling system as it would appear on location at the Nevada Test Site.

PDP-8 mode, the machine operates as a standard PDP-8/I computer. It uses the standard PDP-8/I instruction set and can be interfaced to any standard PDP-8 peripheral.

The LINC mode has its own instruction set which, among other things, (1) permits extended tape addressing, (2) gives immediate access to the A/D converter, the display, the relays, the sense lines, and the tape drives

via the I/O bus, (3) permits program traps, (4) speeds the sampling of analog inputs, and (5) permits the central processor to resume operation after initiating a tape transfer without waiting for transfer completion.

The standard configuration contains 4096 12-bit words of core memory. Our unit has been extended to 8192 words. The additional 4K of memory speeds up the assembly and compile operations

Fig. 2. A simplified block diagram of the hardware for the computer-controlled sampling system. This diagram outlines the data flow from the eight meteorological sensors to the PDP-12, the Central Processor and its associated peripherals.

Fig. 3. A picture of the hardware of the computer-controlled sampling system mounted in the van.

and optimizes the editing features of the service library. In addition, our system has a cathode ray tube display, a real-time clock, a power-fail restart circuit, an ASR-33 teletype, two LINC tape drives, a Kennedy incremental tape recorder with a READ/ WRITE interface, a relay buffer, and a multiplexed analog-to-digital converter. We are presently using the DIAL-MS and DEC SYSTEMS system software and service libraries.^{3,4}

CATHODE RAY TUBE DISPLAY

The cathode ray tube display has a 6.5 x 9 in. screen on which

individual points and whole characters can be displayed. Characters are plotted on a 4 x 6 point matrix. A full character can be displayed with only two instructions.

The display is used primarily for text and tape editing and addressing, but routines for plotting data, e.g., the power spectrum of an input signal are available.

REAL-TIME CLOCK

The real-time clock, a DEC KW12-C crystal clock, provides a 5-kHz timing pulse. Since the maximum sampling rate required by the CCSS is 10 Hz the timing pulse is reduced to 50 Hz by a hardware divide-by-100 circuit. This signal is fed to the interrupt-request bus of the computer, thus providing a 20- μ s delay between interrupts.

POWER-FAIL RESTART

The KP-12 Power-Fail Restart option automatically restarts the CCSS following a power failure. The time of failure is printed out on the teletype after the restart is accomplished. This feature prevents needless loss of data if the power is interrupted during unattended operation.

ASR-33 TELETYPE

The ASR-33 provides direct communication between the user and the

operating program. The unit contains a paper tape reader and punch as well as a printer. Our ASR-33 has been modified with an adjustable timer which turns off the motors 30 s after the last operation. A 'null' character and a carriage return precede all instructions to the teletype to 'wake-up' the unit. This configuration reduces motor wear when the system is left on during unattended operation of the CCSS.

LINAC TAPE UNITS

The two LINC tape transports are controlled by a fully-buffered tape processor. Once the processor is initiated by the LINC program, tape operations can be carried out independently of the central processor. Tapes are customarily written and read in standard LINC tape format; nonstandard formats and all DECtape formats, however, can be written and read via a hardware option which has been installed. The original version of the CCSS software used a LINC tape drive to store data on magnetic tape and filled a tape every 24 hr. The addition of a Kennedy incremental recorder (discussed in the next section) extended the capability for unattended operation to 10 days.

INCREMENTAL TAPE RECORDER

Data storage is increased and thus the operation time for the system is

extended by the addition of a Kennedy incremental Tape Recorder. The unit provides an IBM-compatible seven-track tape. A synchronous Read/Write interface provides the capability to read and write records and to record gaps and end-of-file gaps as well as to skip records, to skip files, to rewind, and to slew forward. The tape drive is completely controlled by the program via instructions responded to by the interface unit. Odd or even parity words can be written or read, and longitudinal as well as vertical parity checks are made. If a power failure occurs during a write operation, the service software reinitiates the operation to prevent loss of data.

RELAY BUFFER

A relay buffer consisting of six relays capable of switching 1 A at 110 V ac or 3 A at 28 V is mounted on the Data Terminal Panel of the PDP-12. The relays can be switched off or on by means of a LINC-mode instruction. They are used to start and stop the air-samplers. The status of the relays can be read back into the accumulator of the central processor. This allows software to monitor the condition of the relay buffer and make appropriate decisions based on its status.

MULTIPLEXER AND A/D CONVERTER

This unit is a 16-channel multiplexed 10-bit A/D converter with

sample and hold, overload protection, and differential input. The normal input voltage is 1 V full-scale. A single LINC-mode instruction samples any of the 16 channels. Eight of the inputs, taken from phone jacks mounted on the Data Terminal Panel, are fed through preamplifiers to the converter. The remaining eight channels are connected internally to 10-turn potentiometers mounted on the Data Terminal Panel.

METEOROLOGICAL SENSORS

The eight sensors in the CCSS are located at various heights on the 10-meter tower. Transducer outputs fall into three categories: variations in voltage, variations in frequency, and variations in resistance depending on the instrument. Therefore three basic types of signal-conditioning circuits which normalize all outputs to 1 V full-scale are required. These circuits are located in a unit at the base of the tower. The characteristics and functions of the eight sensors are summarized in Table 1.

Vertical wind-speed measurements are made by a single Gill propeller anemometer mounted 3 meters above the ground. A miniature dc generator produces an output voltage proportional to wind speed. This output voltage is fed first to a two-stage

differential amplifier that has a gain of 2.4 and then to the A/D converter.

A Geotech staggered-cup anemometer is used to measure horizontal wind fluctuations. A small light-chopper inside the sensor produces a pulse-train of frequency proportional to wind speed. These pulses are integrated and scaled to a full-scale reading of 1 V dc for 1315-Hz pulses (representing a wind speed of 50 m/s).

Wind direction is sensed by a 360° Climet wind vane. The transducer produces a dc voltage via a fixed reference voltage and a variable resistance dependent upon the angular position of the vane. The range of the output voltage is limited to 4.8 V by an internal zener diode. The same type of differential amplifier used for the Gill anemometer scales the wind-direction voltage before feeding it to the A/D converter.

Each of the two Climet anemometers (2-meter and 10-meter heights) incorporate a rotating magnet and small reed switch produces an output frequency proportional to horizontal wind speed. The two pulse-trains are fed to integrator and scaler circuits which produce a 1-V full-scale voltage with a 71.3-Hz input (again representing 50 m/s).

The two Climet aspirated thermometers are mounted at 2 m and 10 m to

Table 1. The eight sensors included in the CCSS system.

1	8	6	12	10	8	12
Sensor	A/D converter channel	Height (m)	Measurement	Range	Sampling interval (s)	Output
Gill propeller	10	3	Vertical wind	0.3-11 m/s	0.1	Voltage (dc) $\propto$ speed
Geotech anemometer	11	3	Horizontal wind fluctuations	0.2-40 m/s	1	Pulse output $\propto$ speed
Climet wind vane	12	2	Wind direction	0-360 deg	5	Variable resistance (function of wind direction)
Climet anemometer	13	10	Wind speed for Richardson No.	0.3-40 m/s	15	Contact closure (frequency $\propto$ wind speed)
	14	2	Same	Same	15	Same
Climet thermometer	15	2	Temperature for Richardson No.	-30 to +50°C	15	Variable resistance (function of air temperature)
	16	10	Same	Same	15	Same
Climet dew-point probe	17	10	Dew point	-30 to +45°C	60	Variable resistance (function of dew point)

provide a measure of temperature differential. A thermistor in each sensor is part of a resistance bridge circuit. This circuit provides a full-scale voltage-output range with an input corresponding to -50°C to +50°C. However, thermistor linearity limits the usable range to -30°C to +50°C.

The eighth sensor in the CCSS, a Climet dew-point probe, is coupled to the 10-m aspirator and exposed to part

of the air drawn over the 10-m temperature sensor. The dew-point probe is a thermistor housed within a tube wrapped with a cloth saturated with lithium chloride. Surrounding this cloth-covered housing is a bifilar winding of electrodes. Moisture in the air causes the chemical to absorb water; therefore, current through the electrodes increases and heats the tube containing the thermistor. The measurement of

increased temperature is read as an increase in dew point. The dew-point thermistor output is processed by a bridge circuit similar to the other temperature sensor circuits. The output of the bridge circuit is routed to the A/D converter.

Provision has been made for a ninth sensor input to the signal-conditioning unit by adding an additional differential amplifier. A

spare pair of wires in the 75-m cable between the signal conditioner and Data Terminal Panel is connected to the output of this amplifier. Any transducer with a voltage output scalable to 1 V by this amplifier can be used as a ninth sensor. However, since the A/D converter can accept only eight external inputs, this additional signal would have to be substituted for the dew-point signal at the Data Terminal Panel.

System Concept

GENERAL

The CCSS has a three-fold function: to collect and process meteorological data, to control the air-samplers on the basis of the processed data, and to record the processed data and the status of the air samplers. A system flow diagram is shown in Fig. 4. Since the sampler-control concept determines how the data will be collected and processed, that portion of the system is discussed first.

SAMPLER CONTROL

The control of the air-samplers is based on a minimum time of fifteen minutes; that is, the decision to turn a sampler off or on is based on the data collected during the preceding 15-min period and is independent

of previous decisions. This 15-min period is subdivided into five 3-min intervals. During each 3-min interval, meteorological data are accumulated and six critical parameters are computed: (1) vertical wind speed rms value, (2) fractional standard deviation representing horizontal wind-speed fluctuation at 3 m above the ground, (3) mean wind direction, (4) mean dew point, (5) mean horizontal wind-speed at 2 m above the ground, and (6) Richardson number. These parameters are then compared to the corresponding criteria specified at the beginning of operation. Yes or no "votes" are then stored, depending on whether or not each parameter falls within its prescribed range. At the end of the 15-min period, the votes for each parameter are counted. If

Fig. 4. A simplified diagram of the system software flow, outlining the series of computations performed to accumulate and store the data obtained from each of the eight wind sensors and then to make the decision to turn the air-sampler on or off.

all six parameters register at least four out of five yes votes, the air sampler is turned on during the next 15-min period. The 4-of-5 scheme allows for some anomalous variation without upsetting the decision process. where

number referenced to the 2-m height is

$$Ri = \frac{g}{T_a} \left(\frac{\Delta T}{LZ} + DA \right) \left(\frac{\Delta u}{LZ} \right)^2$$

DATA COLLECTION AND PROCESSING

The analog signals from the eight sensors are sampled and converted to 10-bit digital words at various time intervals. These sampling intervals were selected to be at least one-half the time interval of the fastest anticipated change in the output of a particular sensor.

The two aspirated thermometers mounted at two and ten meters from the ground are sampled every fifteen seconds and a mean temperature is calculated for each thermometer every three minutes. These three minutes mean values are subtracted to form a three minute ΔT value. Similarly, three minute mean wind speed values are calculated for the two Climet anemometers also mounted at two and ten meters and these means are subtracted to form a three minute Δu value. These ΔT and Δu values are used to calculate a Richardson number once every 3 minutes. The formula⁵ for the computation of Richardson

g = acceleration due to gravity,

$T_a = T_a$ = temperature at 2 m, K,

Δu = difference in wind speeds between the two anemometers,

ΔT = difference in temperature between the two aspirated thermometers,

$LZ = 3.21888$ m, the natural logarithm of the ratio of the two measurement heights multiplied by the lowest measurement height,

$DA = -0.01$ deg/m, the dry adiabatic lapse rate.

The Richardson number Ri is a measure of stability at the 2-m level of boundary-layer flow. A negative Ri indicates an unstable condition; a positive Ri indicates an inversion and thus a stable condition. The 3-min means for both temperatures and wind speeds, and the Ri value, are stored in the tape buffer.

The wind direction and the dew point are sampled every 15 s. Three-minute means are calculated and stored in the tape buffer.

The vertical wind speed is sampled every 0.1 s and a cumulative sum of the absolute values of this wind speed is computed over each 3-min period.

The current value of the sum is stored in the tape buffer every 5 s. At the end of each 3-min period, the sum is divided by the total number of samples and stored in the tape buffer.

The Geotech anemometer output is sampled at one second intervals. Every 5 s the sum of the Geotech samples accumulated to that point during a particular 3 minute period is deposited in the tape buffer. At the end of the three minute period the horizontal wind fractional standard deviation (FDS) is calculated by

$$\text{Horizontal wind FSD} = \frac{s}{\bar{X}} = \frac{\sqrt{\frac{1}{N} \sum (X_i - \bar{X})^2}}{\bar{X}}$$

where

X_i = the i th Geotech sample during a 3-min period,

$\bar{X}$ = the 3-min mean horizontal wind,

s = the standard deviation of the 3-min mean value of the horizontal wind,

N = the number of samples in a 3-min period.

At the end of the 3-min period, the computed horizontal wind fractional standard deviation is stored in the tape buffer.

At the end of each 3-min period the critical parameters are checked and votes are cast as described in the previous section. The six votes and the present status of the samplers (off or on) are stored in the tape buffer. The entire tape buffer is then written onto magnetic tape.

DATA RECORDING

Two types of records are written onto magnetic tape via the Kennedy incremental recorder. The first type is a "header" record, written once at the beginning of each run. This record contains the start date and time, the operator number, and the minimum and maximum acceptable values for each of the six critical parameters. The other type of record, a "data" record, is written every 3 min; it contains all of the information stored in the tape buffer during the previous 3 min of operation. The formats for these two data records are shown in Tables 2 and 3.

Table 2. header record format.

Octal word		Octal word	
0	ASCII date	27	High Richardson number
1		30	
2		31	
3	start-time	32	Low vertical wind
4		33	
5		34	
6	ASCII operator	35	High vertical wind
7		36	
	The remainder of the record is written		37
	in floating point format		40
10	Low wind speed (2 m)	41	Low horizontal FSD
11		42	
12		43	
13	High wind speed (2 m)	44	High horizontal FSD
14		45	
15		46	
16	Low wind direction	47	Low dew point
17		50	
20		51	High dew point
21		52	
22	High wind direction	53	Low Richardson number
23			
24	Low Richardson number		
25			
26			

Table 3. Data record format.

Octal word		Octal word	
0	Start-date ASCII	{ Year (2 digits)	26
1		{ Month "	27
2		{ Day "	30
3	Current-run hour (ASCII 2 digits)	31	Mean temperature (10 m)
4	Current-run Minute "	32	
5	Power-failure hour "	33	
6	Power-failure minute "	34	Mean temperature (2 m)
7	Cumulative sampler on time	35	
10	Votes for this 3 min (bits 6-11)	36	
11	Vote for last 15 min (bits 6-11)	37	Dew point mean
	The remainder of the record is written	40	
	in floating point format	41	
12	Mean vertical wind speed magnitude	42	Wind speed mean (3 m)
13		43	
14		44	
15	Horizontal wind FSD	45	Richardson number
16		46	
17		47	
20	Wind direction mean	50	Vertical wind
21		51	5-s value
22		52	
23	Wind speed mean (10 m)	53	Horizontal wind (3 m)
24		54	5-s value
25		55	

Words 56 thru 377 contain alternate 5-s values.

System Operation

The truck, the air-samplers, and the instrument tower are so placed relative to each other as to minimize wake effects within the area being monitored. The eight sensors are mounted on the tower and the signal and power cables are connected. Once the instruments are set up, power is applied and they are calibrated following the procedures outlined in Appendix A.

To initiate a sampling run, the operator loads the system software via a LINC tape and places a fresh magnetic tape on the Kennedy recorder.

Then, using the teletype, he initiates the run by specifying date, time, and sampling criteria as requested by the CCSS. A typical sequence is shown in Fig. 5.

Once the program is running, the data are recorded on tape and the samplers are turned off and on automatically. In addition, a hard copy of the date, the time, the eight sensor means, the Richardson number, the votes, the status of the sampler (off or on), and the cumulative on-time of the sampler can be obtained every 3 min or every 15 min. A sample printout is shown in Fig. 6.

HELLO AND WELCOME TO ANOTHER FUN-FILLED DAY AT NTS.

LOAD TAPE ON KENNEDY, THEN PRESS "RETURN"

DATE: 751009
TIME: 1530
OPERATOR: 855425

SELECTION OF SAMPLING CRITERIA---TYPE IN LOWER LIMIT FIRST.

WIND SPEED (2M) BETWEEN M/SEC: 5
AND M/SEC: 10

WIND DIREC (2M) BETWEEN DEGREES: 160
AND DEGREES: 200

RICHARDSON NUMBER BETWEEN: -0.2
AND: 0

VERTICAL WIND BETWEEN M/SEC: 0.5
AND M/SEC: 1

HORIZ WIND FSD BETWEEN: 0
AND: 0.5

DEW POINT TEMP BETWEEN DEGREES C: 5
AND DEGREES C: 10

IF YOUR INPUT IS GOOD ENOUGH TO SAVE ON TAPE, PRESS "CTRL-S".
OTHERWISE, TO RUN INPUT PROGRAM OVER AGAIN, PRESS "CTRL-R".

SET SSW 0 IF PRINTOUT IS DESIRED. PRESS "LINEFEED" TO GET THINGS GOING.

Fig. 5. A typical sampling parameter input sequence as it would be entered by the operator at the beginning of a data run. These meteorological sampling parameter inputs establish the sampling "windows" within which the air-sampler will be allowed to be turned on.

HRS MIN	DIR	RICH#	U2M	VERT	HORIZ	DEWPT	T2M	VOTE	SAMP HRS
+0 +3	+235	-0.172	+6.28	+0.32	+0.32	+0.18	+22.87	OFF	+0.00
+0 +6	+237	-0.277	+6.07	+0.33	+0.32	+0.18	+22.65	OFF	+0.00
+0 +9	+232	-0.194	+5.72	+0.37	+0.21	+0.23	+22.99	OFF	+0.00
+0+12	+232	-0.297	+7.18	+0.31	+0.26	+0.35	+23.03	OFF	+0.00
+0+15	+226	-0.274	+6.44	+0.39	+0.35	+0.32	+22.36	OFF	+0.00
+0+18	+236	-0.166	+6.56	+0.36	+0.31	+0.35	+22.56	ON	+0.00
+0+21	+232	-0.331	+7.12	+0.37	+0.28	+0.35	+22.47	ON	+0.00
+0+24	+227	-0.185	+7.49	+0.34	+0.51	+0.35	+22.27	ON	+0.00
+0+27	+221	-0.303	+6.36	+0.30	+0.62	+0.50	+21.93	ON	+0.00
+0+30	+236	-0.182	+6.17	+0.42	+0.36	+0.50	+22.34	ON	+0.00
+0+33	+230	-0.313	+7.06	+0.36	+0.26	+0.62	+22.62	ON	+0.25
+0+36	+232	-0.129	+6.43	+0.35	+0.41	+0.68	+23.12	ON	+0.25
+0+39	+235	-0.130	+7.00	+0.40	+0.21	+0.73	+22.91	ON	+0.25
+0+42	+232	-0.275	+6.90	+0.32	+0.31	+0.73	+23.15	ON	+0.25
+0+45	+223	-0.373	+7.28	+0.29	+0.35	+0.79	+23.20	ON	+0.25
+0+48	+223	-0.526	+6.96	+0.31	+0.31	+0.79	+23.49	ON	+0.50
+0+51	+212	-0.222	+7.66	+0.31	+0.33	+0.85	+23.55	ON	+0.50
+0+54	+216	-0.118	+7.02	+0.30	+0.36	+0.88	+23.29	ON	+0.50
+0+57	+216	-0.127	+9.09	+0.30	+0.23	+0.82	+23.03	ON	+0.50
+1 +0	+215	-0.115	+7.49	+0.34	+0.40	+0.70	+22.68	ON	+0.50
+1 +3	+218	-0.183	+8.35	+0.33	+0.22	+0.82	+22.76	OFF	+0.75
+1 +6	+220	-0.137	+8.41	+0.40	+0.20	+0.76	+22.48	OFF	+0.75
+1 +9	+219	-0.081	+8.15	+0.40	+0.31	+0.88	+22.12	OFF	+0.75
+1+12	+221	-0.232	+7.97	+0.41	+0.26	+1.06	+22.18	OFF	+0.75
+1+15	+221	-0.151	+8.06	+0.35	+0.27	+0.91	+21.99	OFF	+0.75

Fig. 6. A typical abbreviated data output as it would be printed on the teletype if so requested by the operator. This abbreviated output serves to keep the operator informed of the critical meteorological parameters used to determine whether to turn the air-samplers on or off.

Proposed Improvements

The CCSS has been tested at the Lawrence Livermore Laboratory. All segments of the software have been verified and data from a short preliminary test indicate that the system is functional. The system will be moved to NTS during December 1975. It is anticipated that once the system is operational at NTS some minor changes may be necessary. For example, extended testing may indicate that one or more of the sampling intervals should be changed. Also, the 15-min air-sampler on time with five 3-min data-collection intervals was a judgmental choice; experimental results may point to optimal time periods. Changes of this kind can be implemented with relative ease because of the flexibility of the operating system.

After any operational changes have been made, several additional improvements are planned. The first is the addition of another set of air-samplers controlled by a separate set of meteorological criteria. This will permit sampling operations from different wind directions or at different wind speeds. Another is the replacement of the dew-point temperature sensor with an MRI integrating nephelometer. This instrument uses a light source and photomultiplier tube to determine the

scattering coefficient of the atmosphere. Scattering can be related to the amount of dust or soil particulates in the air. Since the output of this unit is a dc signal proportional to scattering, it is easily handled by the ninth sensor input channel discussed above.

We plan also to interface a particle analyzer to the system. Initially, the CCSS will only write the output of this unit onto LINC tape; the data will then be analyzed "off-line".

One major software concept change is being considered - the addition of trend analysis to the sampler-control routines. This type of analysis would predict whether a parameter would fall outside of the acceptable range and could be used for more positive control of sampler on time.

When these changes have been made and the system software has been definitively established, new system hardware can be selected and/or designed on the basis of minimum power and size and maximum portability. The relatively low sampling rates and simple software make micro-processors an attractive solution to the new hardware design.

Conclusions

This paper describes a computer-controlled sampling system that can be used for a more exact sampling of atmospheric pollutants, particularly those resuspended from contamination sources on the ground. The system has been tested and is operational. The flexibility obtained through the use of a standard minicomputer with system software, including Basic, FOCAL, and Fortran compilers, permits

easy modification of the basic program for sensor-monitoring and air-sampler control. The data obtained from this system can be applied to test and validate predictive resuspension models which, together with an understanding of local meteorological conditions and soil surface characteristics, will allow assessment of potential resuspension hazards.

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Appendix

This appendix describes the calibration and scaling factors peculiar to each of the meteorological sensors. All calibrations are based on a ± 1 -V range for the A/D converter.

GILL PROPELLER ANEMOMETER

This sensor has a nominal 500-mV output at 1800 rpm. For vertical wind-speed measurements 1800 rpm represents 26.6 mph (11.89 m/s). Letting 1 V at the A/D converter represent 10 m/s, the scale factor becomes

$$\frac{11.89}{10.00} = \frac{499}{x}$$

or

$$x = \frac{(10.00) \times (499)}{11.89} = 419.68 \text{ mV,}$$

where 499, the actual output of our unit, has been used in lieu of the nominal 500-mV value. Thus, the signal-conditioning amplifier must produce an output of 1 V with an input of 0.41968 V. The required gain is therefore

$$\frac{1.000}{0.41968} = 2.383.$$

To calibrate the amplifier, -1 V is applied to the input and the gain is adjusted for an output of -2.383 V.

GEOTECH ANEMOMETER

The output frequency of the Geotech anemometer is defined as

$$f = 18.82 (W - 0.63) \text{ Hz,} \quad (\text{A-1})$$

where W is wind speed in miles per hour. When W is in meters per second, Eq. A-1 becomes

$$f = 26.44 (W - 0.282) \text{ Hz.} \quad (\text{A-2})$$

Assuming a full-scale value of 50 m/s,

$$f = 26.44 (50 - 0.282) = 1315 \text{ Hz.}$$

To calibrate the integrator card, pulses of 1315 Hz are connected to the input and the output is adjusted for + 1 V.

CLIMET WIND VANE

The sensor produces a voltage output range of 0 to 4.8 V, corresponding linearly to a direction of 0 to

360 deg. Letting 1 V at the A/D converter represent 500 deg,

$$\frac{500 \text{ deg}}{1 \text{ V}} = \frac{360 \text{ deg}}{x}$$

or

$$x = \frac{360}{500} = 0.72 \text{ V.}$$

Thus, the gain of the signal conditioner must be

$$\frac{0.72}{4.8} = 0.15.$$

When the wind vane is calibrated, a -1-V input should produce an output of -0.15 V. The calibration can be verified with the sensor connected, by aligning the two marks on the wind vane and its shaft. This is an orientation of 180 deg; therefore, the output of the signal-conditioner amplifier should be 0.36 V.

CLIMET ANEMOMETER

The procedure for calibrating the Climet anemometer is similar to that for the Geotech anemometer. In this case

$$f = 1.432 (W - 0.232) \text{ Hz} \quad (\text{A-3})$$

when W is in m/s. In this case, the

frequency required for an output of 1 V when the wind speed is 50 m/s is

$$f = 1.432 (50 - 0.232) = 71.3 \text{ Hz.}$$

CLIMET THERMOMETERS

Both temperature sensors have YSI #44203 linear thermistors. When they are shunted by an 18.7-k Ω resistor and connected to a bridge circuit, the output of the bridge is defined as

$$E_{\text{out}} = E_{\text{in}} (-0.0067966 T + 0.65107) \text{ V,} \quad (\text{A-4})$$

where T is the temperature in $^{\circ}\text{C}$.

Letting $E_{\text{in}} = -1 \text{ V}$ and the temperatures 0°C and 50°C correspond to 0 and +1 respectively, we get

$$F_{\text{out}} (0^{\circ}\text{C}) = -0.65107 \text{ V}$$

$$E_{\text{out}} (50^{\circ}\text{C}) = -0.31124 \text{ V.}$$

The nodal equations for the negative input of the operational amplifier were used to determine the resistive values necessary for a -0.65107 V offset input from a -1-V source. Thus, when a -0.65107-V signal from the sensor appears on the positive input, the output is 0 V. The gain of the amplifier was set to give a +1-V output with -0.31124 V connected to the

positive input. The circuit is calibrated by connecting precision resistors, representing the thermistor at specific temperatures, across the input of the bridge circuit. A 34.89-k Ω resistor is used for 0°C and an 8.45-k Ω for 50°C. With the 34.89-k Ω resistor connected, the amplifier offset is adjusted for 0 V out. The gain is adjusted for a 1-V output with the 8.45-k Ω resistor connected to the input.

where T is the temperature inside the probe. This temperature is related to the dew point by the expression

$$T = 1.3467 T_d + 35.40, \quad (A-6)$$

where T_d is the dew point and both temperatures are in °C. For zero and full-scale dew points of 0°C and 45°C, thermistor temperatures of 35.4°C and 96°C are calculated. With $E_{in} = -1$ V,

$$E_{out} (35.4^\circ\text{C}) = -0.67574 \text{ V}$$

and

$$E_{out} (96^\circ\text{C}) = -0.35163 \text{ V}.$$

CLIMET DEW-POINT PROBE

The dew-point probe contains a YSI #44201 thermistor. Components for the bridge and operational amplifier cord are selected in the same manner as those for the other two temperature sensors. In this case

$$E_{out} = E_{in} (-0.0053483 T + 0.86507) \text{ V}, \quad (A-5)$$

Calibration of this signal conditioning circuit is accomplished in the same manner as for the temperature circuits. A 6.69-k Ω resistor is used for the 0-V output and a 1.735-k Ω resistor is used to check the 1-V output, representing dew points of 0°C and 45°C, respectively.