With increased tightening of air quality regulations, more systems for monitoring air quality became necessary. The greater use of such systems further stimulated the development of sensor-based systems that require less programming effort. The goal was to have a practical, real-time system with the ability to change the configuration of the sensors without extensively modifying the associated software. Described is a prototypical system that avoids the necessity of reprogramming every time sensors are changed.

User-definable software applied to a real-time ambient air quality monitoring system

by P. Halpern and J. W. Rettberg

Real-time sensor-based applications require the monitoring or regulating of a network of distributed sensor points. The software for such an application must be capable of carrying out various functions throughout the network of points. However, these functions are dependent on the sensor or control point and use variables whose range of values are determined by the hardware located at the distributed points. The distributed hardware provides the analog and/or digital interface between the computer and the sensor. A characteristic of sensor-based applications is the need for a unique user interface to the computer system. One can think of the application program as having two basic parts: a configuration program and a monitoring program. The configuration program allows user selection of the desired functions, which are part of the monitoring program. It also permits the user to easily chain functions, thereby tailoring the monitoring program to the sensor hardware specifications. A typical configuration program supplies the following types of information:

- Scanning frequency
- Maximum and minimum scale readings
- Monitoring units
- Standards for alarm settings and printing summaries
- Hardware addresses
- Prioritizing of functions

required functions

The monitoring program supplies the software that links the computer, the sensor, and the analog or digital devices. Some required functions that the monitoring program must carry out are:

- Analog-to-digital conversion
- Limit testing and alarming of monitored data
- Conversion of readings to engineering units
- Printing of summary reports
- Addressing of hardware devices

The designer of the monitoring program should include the necessary functions to carry out all the sensor-based tasks required for the application. Generally, as soon as the initial design is complete and the software made operational, added functions will be required. Provided that careful design is followed, these new functions can easily be added to the monitoring program. Similarly, the necessary user interface can be included in the configuration program. In many sensor-based applications, although the functions may not change, the total number of sensor points usually increases. This type of growth can be easily handled by the configuration program. In effect, what we are describing is a file of switches, generated by the configuration program, which are interpreted by the monitoring program to customize it to the existing hardware sensor point network.

Guidance in the design of the configuration program comes from insight obtained from the users' discussions of the tasks they need to accomplish. Since the configuration program will be exercised infrequently, and by users with limited computer background, the interaction with the configuration program must use a natural language dialogue. The user is then able to respond to a series of queries that will step him through a configuration session. Such a session should have considerable redundant syntax since it will be used infrequently. One can consider two modes of execution for a configuration program. The first would be used to configure the monitoring program at installation time or when there are major additions to the monitoring network. The second mode would be used to edit an existing configuration file; e.g., for changing a scan frequency or an alarm setting.

Thus far we have discussed the general philosophy of designing sensor-based applications, with an emphasis on the user interface to the programs. The major portion of this paper discusses the application of this design philosophy to the sensor-based area of air quality monitoring. This particular application was chosen because it is representative of other sensor-based systems such as the monitoring and control of water quality and energy management.

Experimental ambient real-time air quality monitoring system

Air quality has been monitored by computer systems since the 1960s.[1] Such monitoring is usually one component of a program to prevent significant deterioration of air quality. The recording of ambient-level air pollutants and meteorological variables, as part of a program to prevent significant deterioration of air quality, belongs to the general class of computer applications called real-time monitoring. For air quality monitoring, the processor must respond to changes in the atmospheric motions and pollutant levels and record them at specific intervals of time. When preset pollutant levels, which are thought to be hazardous to health, are exceeded, a signal is activated by the computer indicating the need to begin procedures to correct these conditions. In addition to this immediate response for the activation of alarms, there is the need to collect data, which can be used after processing, for reporting and determining long-term air quality trends.

In the early 1960s, real-time air quality monitoring systems were one-of-a-kind facilities, usually operated by state or local governmental regulatory agencies. These systems required many man-years of implementation effort. The expenditure for the system software support quickly outstripped the cost of the hardware.

In response to the tightening of air quality regulations in the early 1970s, many industries found it necessary to monitor ambient pollutant levels and related meteorological variables, thus increasing the demand for air quality monitoring systems. Simultaneously, computer hardware costs began to decrease markedly. The introduction of programs such as PROSPRO,[2] which use information supplied by the application user via standard computer-compatible forms, helped programmers to reduce the amount of programming effort needed. The completed forms contained the necessary information for defining the variables used by the application program. Further reduction in software effort was achieved with the introduction of host program preparation facilities. These facilities allowed the application program to be written, compiled or assembled, and debugged using the facilities of a large general-purpose computer. The executable form was then transmitted to the real-time computer. It should be noted that these aids still required that the application program be written, assembled, debugged, and transmitted every time the user wished to make a change in his monitoring system. Thus, with the decreasing cost of hardware, software development has become an ever-increasing portion of the price of the total system.

In air quality monitoring systems, instruments are often replaced, added, or moved to new locations. Each modification to the physical system requires changes to the software system. A practical real-time system is one which incorporates the ability to change the configuration of the monitoring hardware, without the need for an extensive modification to the monitoring software. As discussed above, a user might wish to replace existing sensors or add new ones to his monitoring system. If he could accomplish this, without rewriting the monitoring program, he would greatly reduce his software costs.

In this paper, we describe a prototypical hardware and software system that avoids the necessity of reprogramming each time the sensor configuration changes. The user makes the software cognizant of both the initial sensor configuration and any subsequent configuration through a simple dialogue with the computer via the configuration program. The data acquisition, analysis, and on-line report generation are all packaged in the monitoring program and are programmed in a high-level control language. The interface between the processor and sensors is provided by a distributed sensor link, which permits physically remote sensors to be polled by a centrally located processor. The data is recorded on a tape cassette, from which it can be transferred to a host computer. Once on the host the data can be included in the data base for access by various report and atmospheric modeling programs.

system requirements

The heart of a real-time monitoring system is a low-cost processor with the capability of communicating with a host computer. This processor should have a CRT (cathode ray tube) display, access to a hard-copy unit, and a secondary storage medium such as a tape or disk. The operating system should support data acquisition and control programs and provide a multiprogramming and multitasking environment. The Event Driven Executive (EDX)[3] operating system is an example of a system that provides these functions. It also supports a high-level language, EDL, for application program development. Syntactically, EDL is composed of a number of primitive macroinstructions (e.g., DO loops, IF and SBIO statements) that facilitate the writing of application programs.

One possible architecture for the interface between the sensors and the processor is a distributed sensor link. To minimize cabling, noise pickup, and cost, this type of sensor link is composed of plug-in function cards, physically packaged in modular units. The cards are designed to carry out specific functions, such as analog-to-digital conversion, multiplexing, analog-in, etc. The choice of card mix is determined by the application requirements.

Figure 1 Experimental air quality monitoring system

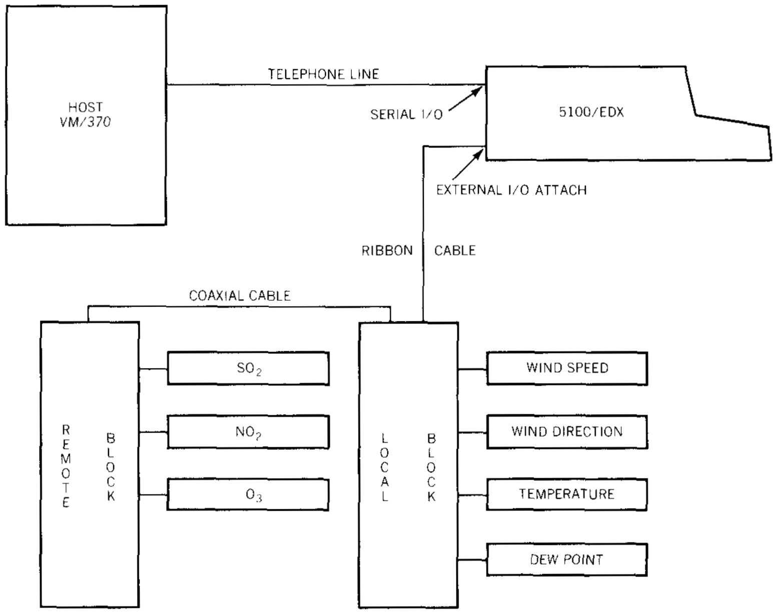

Figure 1 shows a schematic representation of an implemented hardware system for air quality monitoring. The group of cards packaged together is called a block. Figure 1 shows a local and a remote block. Each system must have a local block and may have up to 16 remote blocks. The blocks are chained together via 26-ribbon or coaxial cable. Briefly and schematically, the functions performed by the distributed sensor link start with a request initiated at the processor in order to poll a sensor attached to the local block. This request is routed to a predetermined channel on the multiplexor card. The requested analog signal from the sensor is transformed to a digital signal by the analog-to-digital converter card. This signal proceeds through a card that acts as the interface to the processor, and then across a data bus to the processor, where the data is analyzed and stored.

A signal from a sensor at a remote block follows a similar path. However, after being digitized it is sent to a card that converts the signal to a synchronous serial form. This signal passes over a coaxial cable to the local block, where it is deserialized and retransmitted in the same manner as signals from the local block.

An experimental version of the distributed sensor link was designed and built for use in a related application. It was modified and then used to form the nucleus of the experimental air quality monitoring system shown in Figure 1. A detailed discussion of the design and operation of the distributed sensor link is beyond the scope of this paper.

prototype system components

The IBM 5100 computer[4] was chosen as the processor to drive the system.[5] The 5100 is a desk-top computer equipped with a video display containing 1024 characters in 16 lines. It has a typewriter-like keyboard and an inboard tape unit, which uses removable tape cassettes, each with a capacity of 200 000 bytes. A maximum of 64 000 bytes of memory is available for application programs under normal operating circumstances. The 5100 user has a choice of two high-level computer languages: APL[6] or BASIC.[7] A companion bidirectional matrix printer, capable of printing up to 120 characters per second, provides hard-copy output.

In the present investigation, an experimental version of EDX was implemented on the 5100 and called EDX/5100. This effort was begun before EDX became available on the IBM Series/1 computer.[3] Once EDX/5100 is resident in the random access memory of the 5100 it has exclusive control of the processor. As part of the implementation, support for the keyboard, CRT display, printer, I/O facilities for the distributed sensor link, and utilities for host System/370 communications via the 5100 Serial I/O feature was achieved. The host system is assumed to be VM/CMS (Virtual Machine/Conversational Monitor System).[8]

Application programs are written on the host system, assembled by the H Assembler,[9] and sent to the 5100 (through the Serial I/O feature) where they are stored on tape cassettes. Data gathered by the monitoring system are stored on tape cassettes for future transmission to the host System/370. There the data may be kept resident on files for easy access.

Application software

The user supplies the attributes of his monitoring network and the electrical and mechanical attributes of the individual sensors through the configuration program. The monitoring program uses this information to poll the sensors, archive the recorded data on tape, activate alarms, and produce on-line reports. The sequence and form of the dialogue between the configuration program and the user were designed using established air quality conventions.

Configuration program

An air quality engineer will locate monitoring stations based on his knowledge of the interaction of the local meteorological conditions and emission source distribution. He often finds it necessary to add new stations or relocate established stations. The configuration program was designed to allow the air quality engineer to change the configuration of his sensing instruments without requiring any recoding.

The configuration program prompts the user, through a question and answer session, to describe his current sensor configuration. A file called the configuration file is created from this input.

The motivation for this approach is that it provides the user with the ability to quickly modify his monitoring software to reflect changes in the sensor network. Furthermore, through the use of a question and answer dialogue, the application user is led through a process that makes him familiar with his hardware and the underlying principles upon which the software is based.

data categories

The data supplied by the user via the configuration program can be categorized as follows:

Global parameters—These are related to the overall specifications of the system, e.g., location name, number of sensor stations, averaging time, etc.

Sensor type—Several types of sensors are common to real-time monitoring and can be classified according to the type of input and output they require. Most air quality sensors transform a physical quantity into an electrical output. This output must be converted by an analog-to-digital converter (A/D) to a form usable by the computer. Many sensors can be driven by digital input (DI) signals, e.g., for self-calibration.

Data attributes for each sensor—For this group, the user first specifies the physical quantity (e.g., wind direction, nonmethane hydrocarbons, etc.) and the frequency at which these quantities will be measured. Second, he supplies the maximum and minimum scale readings and the units in which the quantity is measured. Next, the hardware address of the sensor is specified, by the user, as a monitoring location number and a multiplexor line number into which the sensor is wired. Finally, the location on the block of the A/D converter card is supplied.

Output specifications—The time between printing summary reports on the hard-copy unit is determined by the user. He also may choose alarm settings that, when exceeded, result in either an alarm or a written record.

The configuration program as designed for our prototypical system can be operated in one of two modes. The *creation* mode is used either when one is installing the monitoring network for the first time, or when one wishes to radically alter an existing configuration file, e.g., if one wishes to add an additional sensor or station to the network. To change the attributes of an existing sensor, one executes the configuration program in the *modify* mode. This mode provides the configuration program with an elementary editing facility.

Table 1 Quantities monitored

0	Temperature
1	Dew point, relative humidity, or wet bulb temperature
2	Wind speed (monitored with wind direction)
3	Wind direction (monitored with wind speed)
4	Atmospheric pressure
5	Net solar radiation
6	Temperature lapse rate
7	Sigma theta (horizontal turbulence parameter)
8	Sigma phi (vertical turbulence parameter)
9	Reserved for future use
10	SO_2
11	CO
12	Oxidant
13	NO
14	NO_2
15	NOX
16	Nonmethane hydrocarbons
17	H_2S
18	Total suspended particulates
19	Lead

configuration program dialogue

The following discussion of the configuration program dialogue is restricted to air quality monitoring but is easily extendable to related monitoring applications. The Appendix shows an example of the dialogue between the user and the configuration program when a new monitoring network is being installed. We have assumed that the sensors are analog and that the block hardware addresses are predetermined. The request for the averaging time in seconds refers to the length of time during which readings are collected before they are averaged. Each physical quantity can be sampled at its own scan rate, but only one averaging time is allowed.

The averaged values are stored on a tape cassette data file. This stored data can be transferred to a large host computer. The station number corresponds to the hardware block address. Each station must be either a meteorological or an air quality station. The meteorological and air quality quantities monitored by the prototypical system are presented in Table 1. For each quantity measured, the user must supply all the relevant attributes. Table 2 contains a list of the attributes and their definitions.

Following completion of the configuration session, the user can examine and/or modify the results of his session by using the configuration program modify mode. At this point, any of the attributes or global parameters can be changed. This point is also where the user would enter the configuration program if he had begun the session with a configuration file already established. Figure 2 shows the result, on the printer, from defining a configu-

Figure 2 Example of output from configuration file

THIS CONFIGURATION WAS FOR PALO ALTO AND CREATED ON 06/20/80 AT 14:00:00

AVERAGING TIME IN SECONDS: 3600

NUMBER OF STATIONS: 1

STATION NUMBERS: 0

ATTRIBUTES OF EACH QUANTITY MEASURED:

QUANTITY: TEMPERATURE
STATION NUMBER: 0

1:	SCAN TIME IN SECONDS	:	30.00
2:	MIN RECORDABLE VALUE	:	−30.00
3:	MAX RECORDABLE VALUE	:	50.00
4:	MIN OUTPUT OF A/D CONVERTER	:	4095.00
5:	MAX OUTPUT OF A/D CONVERTER	:	2048.00
6:	0=DEG C, 1=DEG F	:	0.00
7:	LOWER RATE-OF-CHANGE ALARM	:	0.00
8:	LOWER ALARM TIME IN HOURS	:	1.00
9:	UPPER RATE-OF-CHANGE ALARM	:	30.00
10:	UPPER ALARM TIME IN HOURS	:	1.00

Table 2 Attribute definitions

SCAN TIME IN SECONDS: The time interval between successive samplings.

MIN RECORDABLE VALUE: The lowest value of a sensor's range.

MAX RECORDABLE VALUE: The highest value of a sensor's range.

MIN OUTPUT OF A/D CONVERTER: The output, in decimal, of the A/D converter corresponding to the minimal analog input.

MAX OUTPUT OF A/D CONVERTER: The output, in decimal, of the A/D converter corresponding to the maximal analog input.

UNITS: The units of the sensor.

LOWER RATE-OF-CHANGE ALARM: The sum of the hourly average values, collected during the period given by the next attribute, must exceed this value or this alarm is activated. This will happen if the sensor fails.

LOWER ALARM TIME: The period referred to directly above.

UPPER RATE-OF-CHANGE ALARM: The difference between two successive hourly averages must not exceed this value. This alarm is activated if the output of the sensor is changing dramatically.

UPPER ALARM TIME: Must be set to one hour.

NAQS X HOUR ALARM: National Air Quality Standard Alarms.

ration with one station sensing one physical quantity. Such a printout can be obtained by the user during his dialogue with the configuration program.

Monitoring program

The monitoring program is stored on a tape cassette data file. After the user loads the monitoring program, a second tape cassette containing two files is inserted into the tape drive. The first file contains the results of the user's dialogue with the configuration program. A time stamp, station numbers, identifiers for the quantities monitored, and the quantities averaged over the specified period of time are stored on the second file. The monitoring program is organized into the main driver task and subtasks reserved for each measurable physical quantity.

Following the start of the monitoring program, the configuration file is read by the main task. This task then attaches subtasks for each physical quantity sensed by the monitoring network. The attributes entered during the dialogue session with the configuration program tailor each subtask to the hardware sensor. These subtasks are activated and deactivated from the main task by reading the system clock and using the scan time attribute. The number of tasks and the number of stations are restricted only by the memory of the IBM 5100 computer. With only 60 000 bytes available, the current monitoring program can support five stations, each having up to 16 channels for data entry; for air quality monitoring at typical industrial sites, this amount is adequate.

As each task is attached, a message to that effect appears on the CRT. When a data reading is not taken because of a hardware failure, a message indicating the absence of the reading is printed. With the use of the sensor attributes, errors generated by out-of-range data and alarms are recorded on the printer. Data is written to tape after the averaging period is complete. Under normal conditions, the monitoring program can run for about a month before the tape cassette is full. Upon completion, each subtask is detached and the appropriate message printed.

The report generated by the monitoring program consists of an hourly review of the averaged values of the monitored quantities. In addition, a 24-hour summary table of the averaged values of the previous day is printed. Figure 3 and Figure 4 show examples of the hourly and 24-hour summary tables, respectively.

alarms

There are two groups of alarms that can be activated by the monitoring program. Members of the first group are tripped if the ambient air quality exceeds any of the federal and state ambient air quality standards. The user supplies these standards during the dialogue with the configuration program.

Figure 3 Example of hourly reports from monitoring program

```
        HR.    STA.    WIND
         4      0       4.2  (MPH)            44.0  (DEG.)
-----------------------------------------------------------
        HR.    STA.    SO2
         4      1      .11  (PPM)
-----------------------------------------
*****   24 HR. AVERAGE CONTAINS MISSING DATA: STA. =  1 *****

  6/19/80                              5:38:17
 ------ HOURLY AVERAGE VALUES ------
        HR.    STA.    TEMP.
         5      0       9.2  (DEG. C)
-------------------------------------------
        HR.    STA.    HUM.
         5      0       5.6  (DEG. C)
-------------------------------------------
        HR.    STA.    WIND
         5      0       4.6  (MPH)            50.0  (DEG.)
-----------------------------------------------------------

    6/19/80                      5:38:28
 **** AVERAGE LESS THAN LOWER RATE-OF-CHANGE ALARM ****
   STA. NUM. =    1
     SO2 (PPM)         HOUR
       .11               1
       .11               2
       .11               3
       .11               4
       .11               5
****************************************************************

        HR.    STA.    SO2
         5      1      .11  (PPM)
-----------------------------------------
*****   24 HR. AVERAGE CONTAINS MISSING DATA: STA. =  1 *****
-----------------------------------------------------------
```

The second group of alarms is relevant to all monitored quantities. These are the rate-of-change alarms. Some of these alarms are activated when the difference between the previous and current averaged value is greater or equal to a user-determined value, and they are useful in checking the consistency of the monitoring instrument. They can also be used to sense any sudden changes in the prevailing atmospheric condition. The number of values is set by the user during the dialogue with the configuration program. When an instrument fails, an alarm is issued specifying the instrument, instrument location, and the time when the failure initially occurred. Figure 5 and Figure 6 show examples of these alarm messages.

It is often necessary to interrupt the monitoring program in order to accomplish a limited number of tasks. For example, the user might wish to limit hard-copy printout to alarm messages only. This limitation is desirable when the system runs totally

Figure 4 Example of summary table for temperature from monitoring program

```
        6/19/80                        0:38:20
─────────── TEMP. : SUMMARY TABLE OF VALUES ───────────
                               SITE: PALO ALTO
                                     STATIONS
                                        0
        HOUR
          0                          9999
          1                          9999
          2                          9999
          3                          9999
          4                          9999
          5                          9999
          6                          9999
          7                          9999
          8                          9999
          9                          9999
         10                          9999
         11                          9999
         12                          9999
         13                          9999
         14                          9999
         15                          24.9
         16                          21.9
         17                          20.4
         18                          19.0
         19                          16.8
         20                          15.5
         21                          14.6
         22                          13.5
         23                          12.1
────────────────────────────────────────────

      HR.    STA.    HUM.
       0      0        5.9  (DEG. C)
────────────────────────────────────────────

   6/19/80                              4:38:18
─────── HOURLY AVERAGE VALUES ───────
      HR.    STA.    TEMP.
       4      0       10.1  (DEG. C)
────────────────────────────────────────────

      HR.    STA.    HUM.
       4      0        6.4  (DEG. C)
────────────────────────────────────────────

   6/19/80                              4:38:25
 **** AVERAGE EXCEEDS AVERAGE RATE-OF-CHANGE ALARM ****
STA. NUM. =    0
WIND (DEG.)        HOUR
  344.0              3
   44.0              4
**********************************************************************
```

unattended. The ability to initiate a limited number of keyboard tasks increases the flexibility of the system. In the current implementation, the user can issue commands that will curtail printing to alarm messages. With another he can resume normal printing. The user may wish to remove from the polling sequence an instrument that is not functioning properly. Once that instrument has been repaired, the user can reset it into the scanning cycle

Figure 5 Example of ambient air quality alarm messages for SO_2 from monitoring program

```
        6/19/80              6:38:17
------------ HOURLY AVERAGE VALUES ------------
     HR.       STA.       TEMP.
      6          0          9.0  (DEG. C)
-----------------------------------------------

     HR.       STA.       HUM.
      6          0          5.5  (DEG. C)
-----------------------------------------------

     HR.       STA.       WIND
      6          0          4.2  (MPH)   50.0  (DEG.)
------------------------------------------------------------------------

        6/19/80              6:38:28
**** AVERAGE LESS THAN LOWER RATE-OF-CHANGE ALARM ****
    STA. NUM. =          1
      SO2 (PPM)               HOUR
         .11                    2
         .11                    3
         .11                    4
         .11                    5
         .11                    6
****************************************************************************************************

     HR.    STA.    SO2
      11      1     .89  (PPM)
-------------------------------------------------------

***** 1 HR. SO2 (PPM) NAQS IS EXCEEDED: STA. = 1, AVG. = .89, STD. = .50 *****
****************************************************************************************************

***** 3 HR. SO2 (PPM) NAQS IS EXCEEDED: STA. = 1, AVG. = .62, STD. = .50 *****
****************************************************************************************************

***** 8 HR. SO2 (PPM) NAQS IS EXCEEDED: STA. = 1, AVG. = .32, STD. = .25 *****
****************************************************************************************************

***** 12 HR. SO2 (PPM) NAQS IS EXCEEDED: STA. = 1, AVG. = .25, STD. = .25 *****
****************************************************************************************************

             ***** 24 HR. AVERAGE CONTAINS MISSING DATA: STA. = 1 *****
------------------------------------------------------------------------
```

without bringing the entire system down; he can do the removal and reset operations via keyboard command. Finally, the execution of the monitoring program can also be immediately halted with a keyboard command because all keyboard tasks are assigned the highest priority.

Conclusions

We have developed and successfully tested a compact, flexible, and easy-to-install air quality monitoring system. The application software is constructed so as to avoid the necessity of reprogramming the software every time the sensor configuration changes or attributes of a sensor are altered. The user describes and/or changes his sensor configuration and communicates these mes-

Figure 6 Example of rate-of-change alarms for wind direction and SO_2 from monitoring program

```
        HR.    STA.    SO2
        20      1      .11  (PPM)
---------------------------------------------

*****    8 HR. AVERAGE CONTAINS MISSING DATA: STA. =   1 *****
*****   12 HR. AVERAGE CONTAINS MISSING DATA: STA. =   1 *****
*****   24 HR. AVERAGE CONTAINS MISSING DATA: STA. =   1 *****

          6/18/80          21:38:18
-------  HOURLY AVERAGE VALUES  -------
        HR.    STA.    TEMP.
        21      0      15.5  (DEG. C)
---------------------------------------------

        HR.    STA.    HUM.
        21      0       5.9  (DEG. C)
---------------------------------------------

          6/18/80          21:38:25
**** AVERAGE EXCEEDS AVERAGE RATE-OF-CHANGE ALARM ****
  STA. NUM. =   0
  WIND (DEG.)          HOUR
       72.0             20
      218.0             21
************************************************************************

        HR.      STA.      WIND
        21        0          .5  (MPH)   218.0  (DEG.)
------------------------------------------------------------

          6/18/80          21:38:35
**** AVERAGE LESS THAN LOWER RATE-OF-CHANGE ALARM ****
  STA. NUM. =   1
    SO2 (PPM)          HOUR
       .11              17
       .11              18
       .11              19
       .11              20
       .11              21
************************************************************************
```

sages to the system through a question and answer interactive session with the configuration program. The monitoring program performs the data acquisition, analysis, and report generation based on input from the configuration program. The general approach demonstrated for air quality monitoring could be expanded into related real-time monitoring applications such as water quality.

Appendix: User dialogue with configuration program

```
S.   CONFIG PROGRAM—3/23/79
S.   RESPOND Y/N, WITHOUT DEPRESSING THE EXECUTE KEY,
S.   TO ALL YES/NO QUESTIONS. NUMERICAL INPUT AND
```

```
S.      TEXT STRINGS MUST BE TERMINATED BY DEPRESSING
S.      THE EXECUTE KEY. YOU MAY DEPRESS THE ATTN KEY,
S.      AT ANY TIME, AND THEN ENTER THE FOLLOWING TWO
S.      CHARACTER CODES TO GET THE RESULTS INDICATED.
S.      AB—ABORT SESSION
S.      RE—RESTART SESSION
S.      THE ATTRIBUTES OF EACH SPECIES MAY BE ENTERED
S.      IN FLOATING POINT FORMAT.

S.      HAS TAPE ONTO WHICH CONFIG FILE WILL
S.+U.   BE WRITTEN BEEN INSERTED INTO THE 5100? Y

S.+U.   DO YOU WISH TO CREATE A NEW CONFIG FILE? Y

S.+U.   ENTER THE NAME OF YOUR LOCATION: PALO ALTOexec

S.+U.   ENTER DATE (MM/DD/YY): 06/20/79exec

S.+U.   ENTER TIME (HH:MM:SS): 14:00:00exec

S.+U.   ENTER AVERAGING TIME IN SECONDS: 3600exec

S.+U.   ENTER TOTAL NO. OF STATIONS: 1exec

S.      YOU HAVE ENTERED THE VALUE:   1

S.+U.   IS THIS VALUE CORRECT? Y

S.+U.   ENTER STATION NO.: 0exec

S.+U.   IS THIS A METEOROLOGICAL STATION? Y

S.      IS TEMPERATURE
S.+U.   TO BE MEASURED? Y

S.+U.   SCAN TIME IN SECONDS          :    30exec

S.      YOU HAVE ENTERED THE VALUE    :    30.00

S.+U.   IS THIS VALUE CORRECT? Y

S.+U.   MIN RECORDABLE VALUE          :    −30

S.      YOU HAVE ENTERED THE VALUE    :  −30.00

S.+U.   IS THIS VALUE CORRECT? Y

S.+U.   MAX. RECORDABLE VALUE         :    50exec

S.      YOU HAVE ENTERED THE VALUE    :    50.00

S.+U.   IS THIS VALUE CORRECT? Y

S.+U.   MIN OUTPUT OF A/D CONVERTER   :    4095exec

S.      YOU HAVE ENTERED THE VALUE    :  4095.00

S.+U.   IS THIS VALUE CORRECT? Y

S.+U.   MAX OUTPUT OF A/D CONVERTER   :    2048exec

S.      YOU HAVE ENTERED THE VALUE    :  2048.00
```

```
S.+U.  IS THIS VALUE CORRECT? Y

S.+U.  0=DEG C, 1=DEG F              :     0exec

S.     YOU HAVE ENTERED THE VALUE    :     0.00

S.+U.  IS THIS VALUE CORRECT? Y

S.+U.  LOWER RATE OF CHANGE ALARM    :     0exec

S.     YOU HAVE ENTERED THE VALUE    :     0.00

S.+U.  IS THIS VALUE CORRECT? Y

S.+U.  LOWER ALARM TIME IN HOURS     :     1exec

S.     YOU HAVE ENTERED THE VALUE    :     1.00

S.+U.  IS THIS VALUE CORRECT? Y

S.+U.  UPPER RATE OF CHANGE ALARM    :     30exec

S.     YOU HAVE ENTERED THE VALUE    :    30.00

S.+U.  IS THIS VALUE CORRECT? Y

S.+U.  UPPER ALARM TIME IN HOURS     :     1exec

S.     YOU HAVE ENTERED THE VALUE    :     1.00

S.+U.  IS THIS VALUE CORRECT? Y

S.     IS DEW PT, REL HUM OR WET BULB
S.+U.  TO BE MEASURED? N

S.     IS WIND SPEED
S.+U.  TO BE MEASURED? N

S.     IS WIND DIRECTION
S.+U.  TO BE MEASURED? N

S.     IS PRESSURE
S.+U.  TO BE MEASURED? N

S.     IS NET SOLAR RADIATION
S.+U.  TO BE MEASURED? N

S.     IS TEMPERATURE LAPSE RATE
S.+U.  TO BE MEASURED? N

S.     IS SIGMA THETA
S.+U.  TO BE MEASURED? N

S.     IS SIGMA PHI
S.+U.  TO BE MEASURED? N

S.     YOU HAVE NOW CONFIGURED SYSTEM. DO YOU
S.+U.  WISH TO EXAMINE AND/OR MODIFY THIS FILE? Y

S.     DO YOU WISH TO PRINT A COPY OF YOUR
S.+U.  CONFIGURATION ON THE LINE PRINTER? Y
```

```
S.      THIS FILE WAS CONFIGURED FOR PALO ALTO
S.      ON 06/20/79 AT 14:00:00

S.+U.   DO YOU WISH TO CHANGE THE NAME? N

S.+U.   DO YOU WISH TO CHANGE THE DATE? N

S.+U.   DO YOU WISH TO CHANGE THE TIME? N

S.      AVERAGING TIME IN SECONDS: 3600

S.+U.   DO YOU WISH TO CHANGE AVERAGING TIME? N

S.      NUMBER OF STATIONS:    1

S.      STATION NUMBERS:    0

S.+U.   DO YOU WISH TO CHANGE A STATION NUMBER? N

S.+U.   DO YOU WISH TO EXAMINE THE SPECIES MEASURED? Y

S.      ATTRIBUTES OF EACH SPECIES MONITORED:

S.      SPECIES: TEMPERATURE
S.      STATION NUMBER:    0

S.              1: SCAN TIME IN SECONDS           :   30.00
S.              2: MIN RECORDABLE VALUE           :  -30.00
S.              3: MAX RECORDABLE VALUE           :   50.00
S.              4: MIN OUTPUT OF A/D CONVERTER    : 4095.00
S.              5: MAX OUTPUT OF A/D CONVERTER    : 2048.00
S.              6: 0=DEG C, 1=DEG F               :    0.00
S.              7: LOWER RATE OF CHANGE ALARM     :    0.00
S.              8: LOWER ALARM TIME IN HOURS      :    1.00

S.+U.   DO YOU WISH TO CHANGE ANY OF THESE VALUES? N

S.+U.   DO YOU WISH TO CONTINUE EXAMINING SPECIES? Y

S.      SPECIES: TEMPERATURE
S.      STATION NUMBER:    0

S.              9: UPPER RATE OF CHANGE ALARM     :   30.00
S.             10: UPPER ALARM TIME IN HOURS      :    1.00

S.+U.   DO YOU WISH TO CHANGE ANY OF THESE VALUES? N

S.+U.   DO YOU WISH TO CONTINUE EXAMINING SPECIES? Y

S.      YOU HAVE EXAMINED ALL THE SPECIES ENTERED.
S.      DO YOU WISH TO EXAMINE AND/OR MODIFY THIS
S.+U.   FILE AGAIN? N

S.+U.   DO YOU WISH TO WRITE CONFIG FILE ONTO TAPE? Y

S.      CONFIG FILE HAS BEEN WRITTEN SUCCESSFULLY.
S.      DO YOU WISH TO EXAMINE AND/OR MODIFY THIS
S.+U.   FILE AGAIN? N

S.+U.   DO YOU WISH TO RESTART THIS SESSION? N
```

S.+U. DO YOU WISH TO TERMINATE THIS SESSION? Y

S. CONFIG ENDED

exec—depress the EXECUTE key

CITED REFERENCES AND NOTE

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4. *IBM 5100 Portable Computer*, Systems Library, G280-00181-1, IBM Corporation; available through IBM branch offices.
5. The prototypical equipment described in this paper is not available outside of IBM.
6. *IBM 5100 APL Reference Manual*, Systems Library, SA21-9213-0, IBM Corporation; available through IBM branch offices.
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The authors are located at the IBM Palo Alto Scientific Center, P.O. Box 10500, Palo Alto, CA 94304.

Reprint Order No. G321-5142.