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The automatic methods of acquiring and reducing aerometric data, as described in this report, have proven to be feasible and cost effective. However, it has been found that much technical expertise is required to implement and maintain this equipment. There are still some basic problems associated with their general usage.

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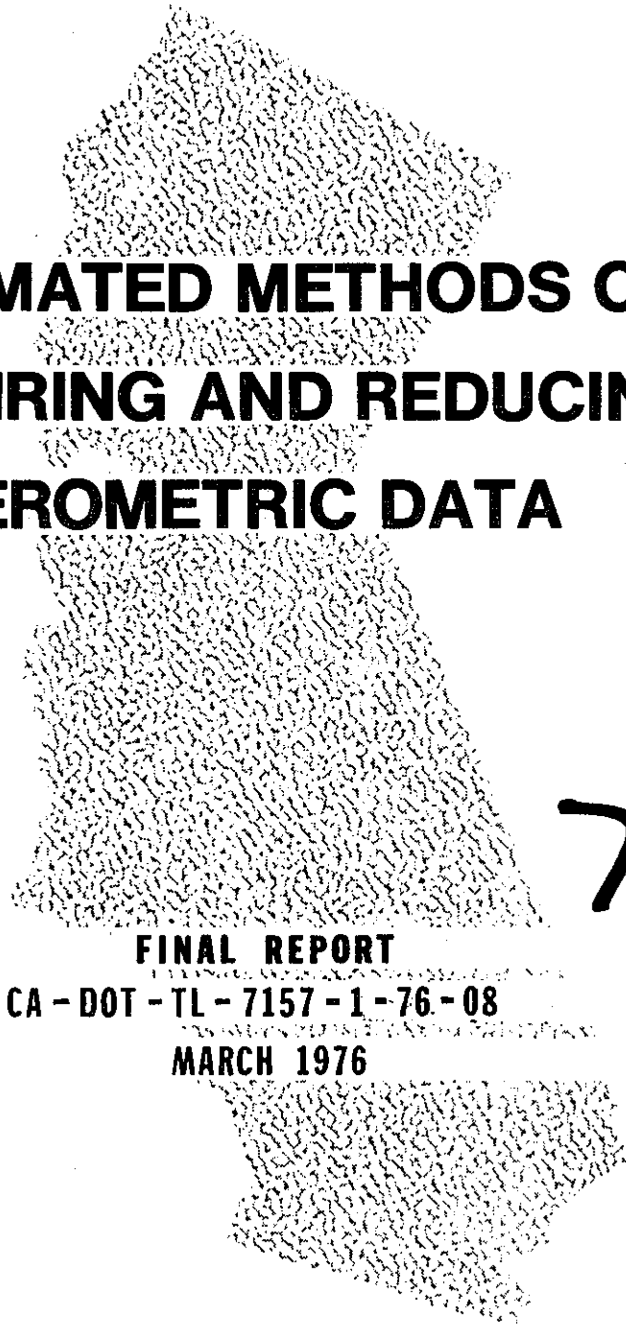

AUTOMATED METHODS OF ACQUIRING AND REDUCING AEROMETRIC DATA

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DIVISION OF STRUCTURES & ENGINEERING SERVICES
OFFICE OF TRANSPORTATION LABORATORY

March 1976

TL No. 657157

Mr. C. E. Forbes
Chief Engineer

Dear Sir:

I have approved and now submit for your information this final research project report titled:

AUTOMATED METHODS OF ACQUIRING AND REDUCING AEROMETRIC DATA

Study made by ....Enviro-Chemical Branch

Under the Supervision of ....Earl C. Shirley

Principal Investigator..................Walter A. Winter

Co-Investigator.........................Stephen J. Kassel

Report Prepared by ....Stephen J. Kassel
and
Walter A. Winter

Very truly yours,

GEORGE A. HILL
Chief, Office of Transportation Laboratory

Attachment

WAW:bjs

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The authors wish to express their gratitude to Messrs. Robert Donner, Leonard Alsop, and Roy Rounds of the Electronic Section whose assistance proved to be invaluable. Special appreciation is given to Chris Wyszynski for his tireless efforts in digitizing the strip charts and to Charles Frazier for his programming assistance.

The contents of this report reflect the views of the Transportation Laboratory which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

INTRODUCTION

Transportation Engineers are faced with the task of monitoring the environment in ever-increasing detail. This requires various systems that collect days, months, and even years of environmental data at a given location. This report discusses the collection and reduction of aerometric data. In particular, the report focuses on methods to reduce data from meteorological instruments and from analyzers which measure concentrations of various air pollutants.

Historically, these data have been recorded on strip charts. It has proven to be a time-consuming and tedious process to summarize and evaluate these data by hand. Therefore, this research was aimed at finding more efficient methods of obtaining and reducing these data. Two basic approaches were investigated. The first was to develop a more efficient method of reducing data from existing strip charts. The second was to develop a system to replace strip charts entirely.

This report presents the research project in two main divisions. The first discusses the semi automatic method of reducing data on strip charts from existing mechanical weather stations. The second discusses the development, and evaluation of a digital cassette based data acquisition system as a replacement for strip charts. Quality assurance of collected data is also discussed as are system feasibility and cost effectiveness. Various problems encountered under field operation are reported.

OBJECTIVES

The objectives of this project are three-fold:

1. Develop a semi automatic method of reducing data from analog strip charts made on existing mechanical weather stations.

2. Evaluate digital cassette-based data acquisition systems as a replacement for analog strip charts on existing and future environmental monitoring equipment.

3. Develop data handling capabilities to transmit collected data into the Department's computerized aerometric data base.

CONCLUSIONS AND RECOMMENDATIONS

Automatic methods of acquiring and reducing aerometric data have proven to be feasible and cost effective. They have also proven to require a great deal of technical expertise to implement and maintain and there are still some basic problems with their general usage.

The digitizer service has proven cost effective and produces a product superior to manual strip chart reduction. However, this type of system must be quite complex in order to perform adequately. Setting up this type of equipment is not recommended unless experienced mini computer programming and digital electronics expertise are available.

Data loggers also proved cost effective. Once data loggers are used to monitor environmental data, it is hard to imagine going back to strip charts; however, purchasing a data logger requires careful planning. The primary considerations are reliability and accuracy of the data. Quality assurance and maintenance programs should be planned before purchasing the data logger as the choice of a logger may well determine the ease of performing these functions.

There is another potential problem in reduction and analysis of the data. This may be no great problem if only one or two loggers are to be purchased. For larger numbers, however, one rapidly finds himself in the data processing business with all the trade-offs of equipment expense versus reduction and analysis speed. The most effective solution can only be predetermined if the volume of work is known in advance. In any case, it is advantageous to purchase a reduction system that is upward compatible in speed and perhaps also in output media.

The final consideration is the standardization of data storage media and format. This consideration is the only remaining obstacle to large scale use of the data loggers in Caltrans. If only one or two loggers will ever be used, then perhaps this is no problem. However, if one foresees expanded use of loggers for different applications, then he must consider the data reduction problems he will encounter when he has loggers in the field from several different vendors with incompatible data formats. This will probably mean that a separate cassette reader must be purchased for each brand of logger. In some cases, more than one reader may have to be purchased to handle different formats produced by a single vendor. Each of these readers must be interfaced to a computer or some other device which can accept and use these data. It is considered undesirable to be restricted to one vendor by the fact that he is the only one that can supply equipment compatible with an existing data reduction system.

Caltrans is currently looking for two or more established vendors who will establish a uniform data format, or a single vendor who can log data reliably and cheaply in one of the ANSI standard formats, or a cassette reader that can handle a variety of formats.

Until this last problem is resolved, Caltrans will be very conservative in its data logger purchases.

IMPLEMENTATION

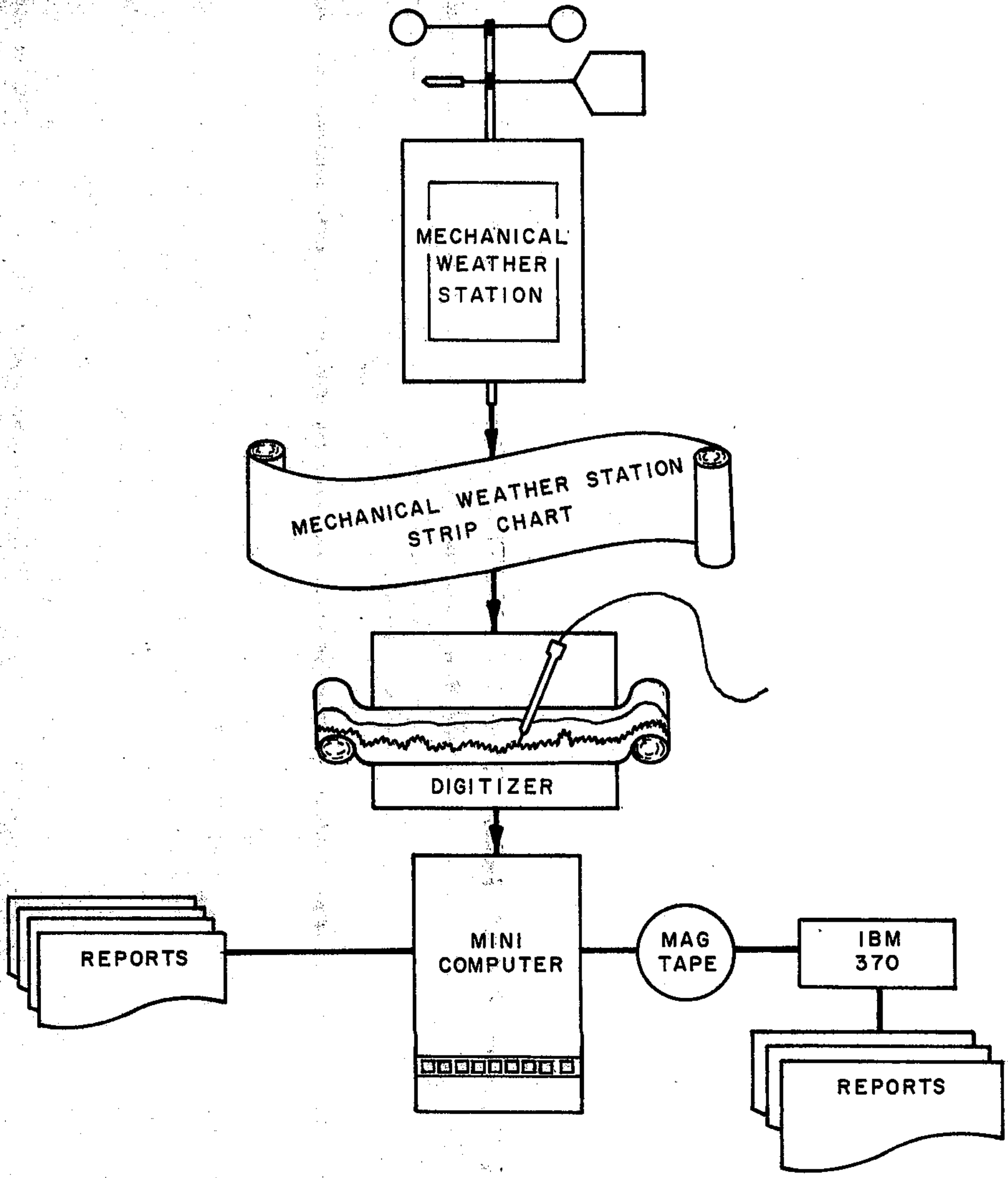
Conceptual Solutions

The first area of study involved the largest volume of environmental strip chart data within Caltrans. These data are generated by mechanical weather stations. Figure 1 illustrates the system concept developed to reduce these data. The strip charts from the mechanical weather stations are digitized as coordinate data using a high speed digitizer. These coordinate data are used by the minicomputer to compute hourly values for temperatures, average wind speed, and wind azimuth. Although these summarized data can be reported directly on the minicomputer's teletype, they are normally stored on magnetic tape for transfer to the Department's aerometric data bank.

The second area of study employs digital cassette-based data acquisition systems (data loggers). Figure 2 illustrates the system concept. It shows data being acquired directly on cassette tape from two existing and one future instrumentation packages. The data tapes are then taken from the loggers and read through a reader into a minicomputer. The minicomputer then calculates and reports a summary of data directly on the teletype. Large quantities of data will justify the future use of magnetic tape to transfer the data to the Department's aerometric data bank.

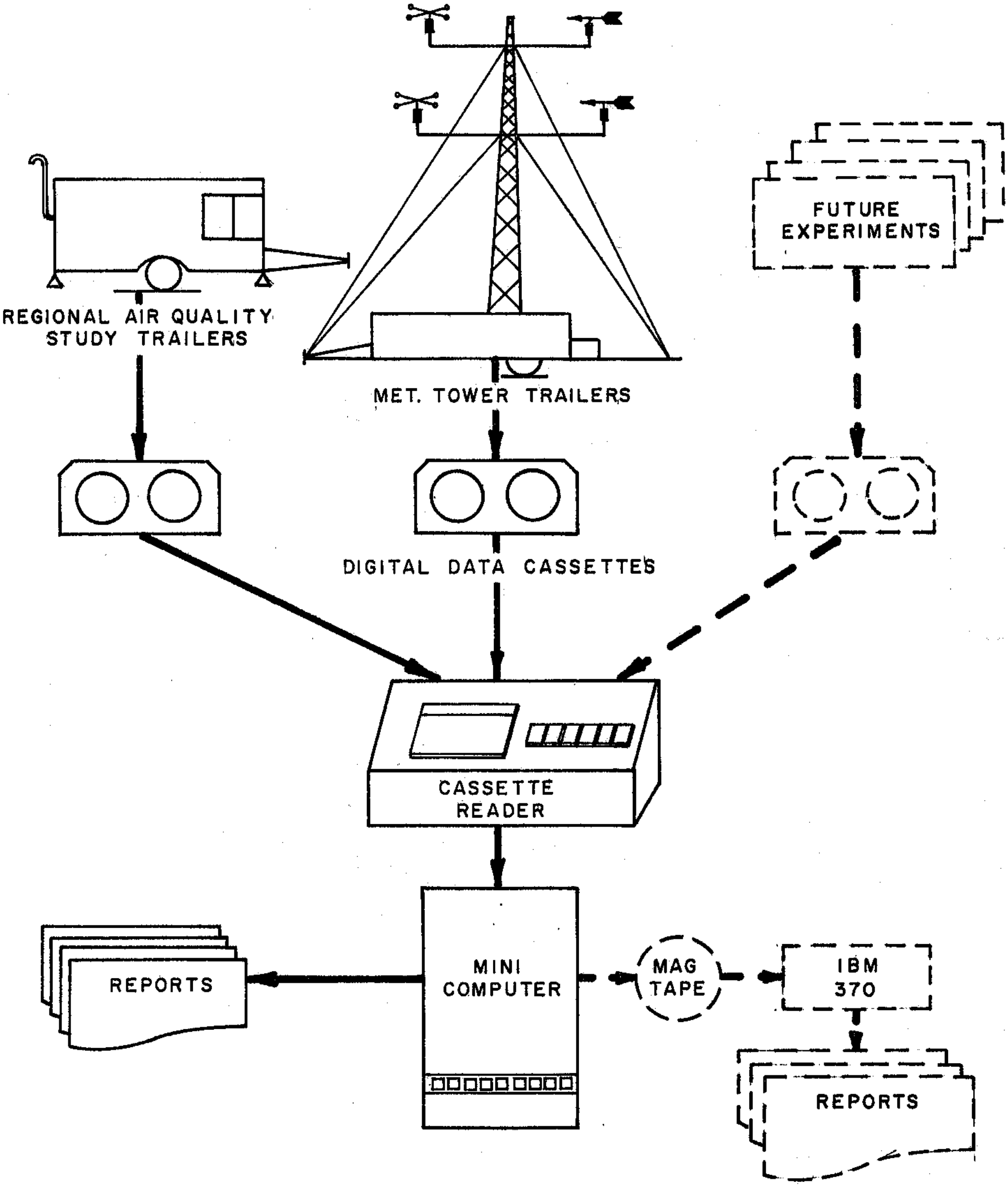
Practical Considerations

Strip charts historically have been used to capture environmental data. Their disadvantages are many and legendary. They waste paper, break down, run out of ink, and their accuracy is limited. But, most of all, strip chart data reduction is a tedious process. So much so, that it is rarely practical to extract all the information



DATA REDUCTION OF MECHANICAL WEATHER STATION STRIP CHARTS

Figure 1



DIGITAL CASSETTE BASED
DATA ACQUISITION AND REDUCTION
OF LOGGED DATA

Figure 2

on a strip chart. Even "eyeballing" summaries is a costly and uninspiring process.

As shown in the example of a mechanical weather station strip chart (Figure 3), one must average hourly traces for temperature, wind run (speed) and wind azimuth. Reducing this strip chart by hand is a tedious process for a month's period of data. Tracing the strip chart data with a digitizing pen is still a time consuming and costly process.

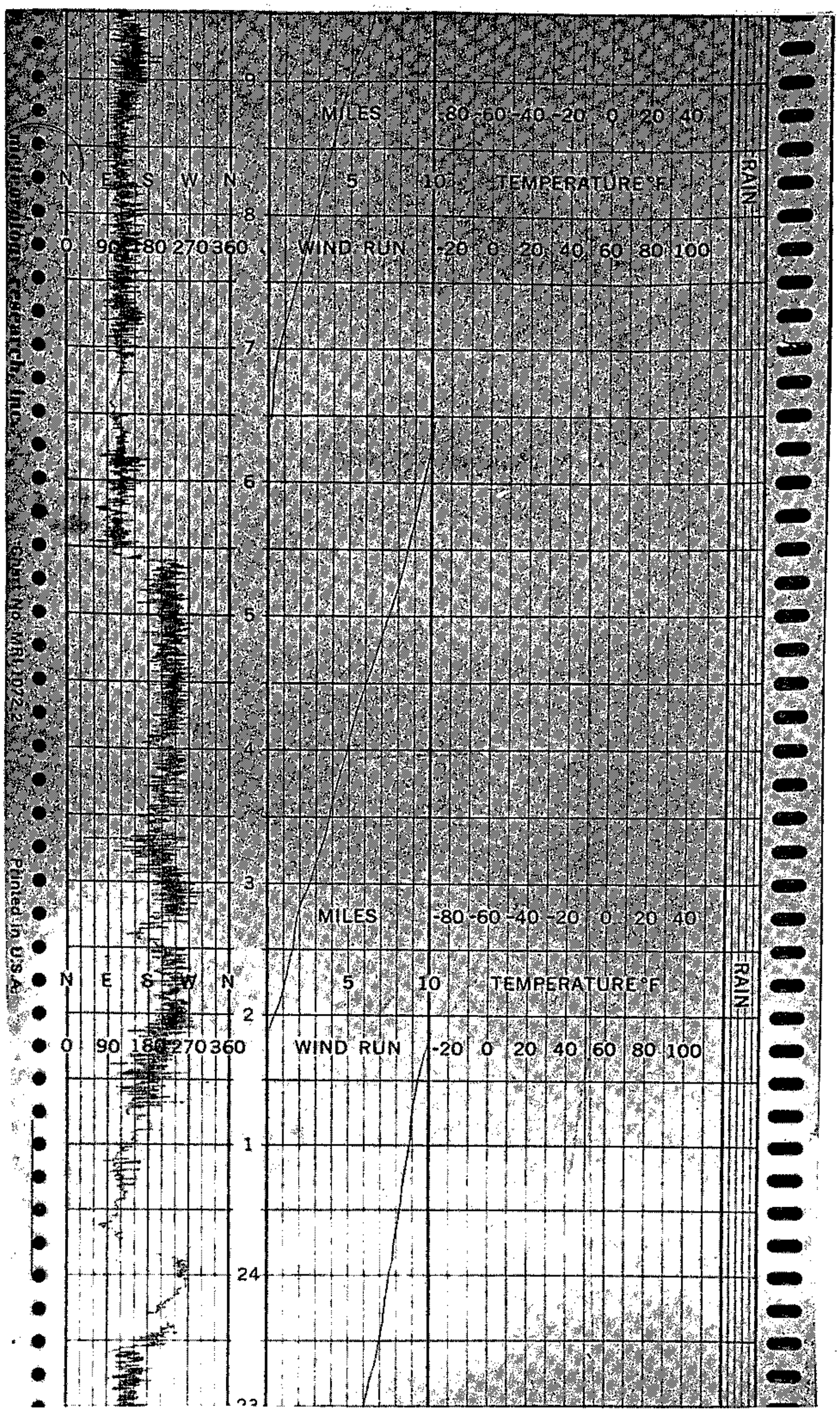


FIGURE 3

MECHANICAL WEATHER STATION
STRIP CHART

However, strip charts do have advantages: They are inherently insensitive to high frequency noise, they are relatively cheap, and they give an instantaneous visual check of the entire monitoring system. Above all, strip charts are conceptually and mechanically simple. One does not have to be a computer expert and electronics engineer to make them run and have some confidence that they are running correctly. This is a very important consideration. It is recommended that considerable thought be given before the strip chart is replaced by an automatic data acquisition system which may require that the strip chart reducing technician later be replaced by an electronics engineer.

Semi-automatic reduction can reduce the cost and tedium of reducing strip charts. However, the setup cost and level of technical sophistication required to automatically reduce strip chart data are definite factors. Hardware is expensive ($15,000 - $25,000) and programming can be time consuming, if indeed it ever is completed to everybody's satisfaction. Our efforts proved successful, but we found it necessary to tap resources which will not be available to everybody with a data reduction problem.

Data loggers are the wave of the future. They collect. at a reasonable cost, mountains of data which can be reduced, summarized, analyzed and reported without ever being touched by human hands. But, it takes a good deal of technical sophistication to obtain and install a data logging system that will automatically monitor a process and still provide confidence in the quality of the collected data. We will dwell on the subtleties within the report, but the major problems revolve around the fact that one cannot just look at a data logger in operation and determine if it is indeed collecting reasonable data.

Choice of Method

The need for a more efficient method of reducing strip charts was realized when it was projected that approximately 100 mechanical weather stations were to be operated within the State. Three methods of approach were conceptualized. The first would be to replace the strip charts with a machine readable data capture device. The second was to optically scan the strip charts. The last was to manually digitize the strip charts.

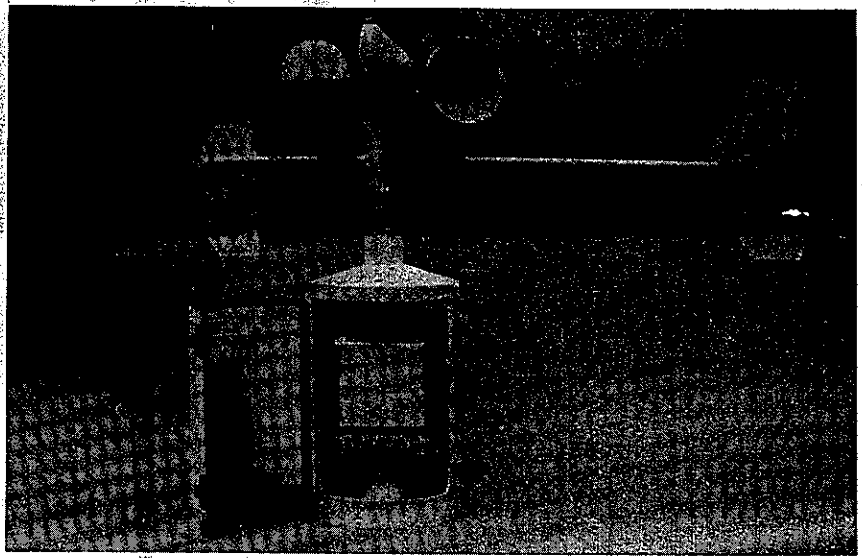
It was decided that replacing the strip charts would be prohibitively expensive even if an acceptable product were on the market.

A search was conducted for a service that could optically digitize the charts. The faintness of the traces made by the styli on the pressure sensitive paper proved to be an insurmountable obstacle to optical scanning. In addition, setting up this type of operation would be expensive, complex, and time consuming with no assurance that the outcome would be successful.

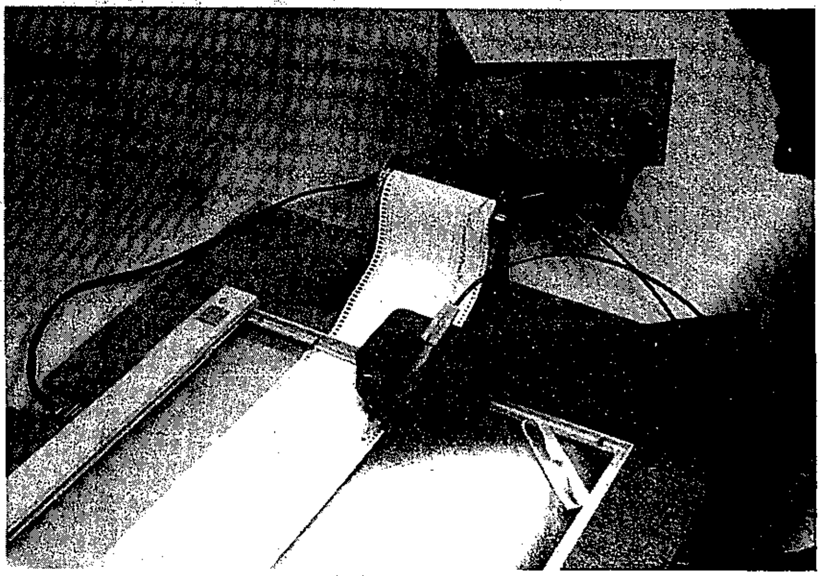
The decision was then made to use the semi-automatic method of manually digitizing the strip charts. It was decided that an existing minicomputer with an IBM compatible magnetic tape transport could be used to develop the system. The Graf Pen Sonic digitizer was chosen from the available instruments on the basis of speed, flexibility and cost.

Equipment

Mechanical Weather Station (MRI - Model 1071) is illustrated in Figure 4. The self-contained mechanical weather station is equipped to measure and record wind direction, wind run (speed)



Mechanical Weather Station
Figure 4

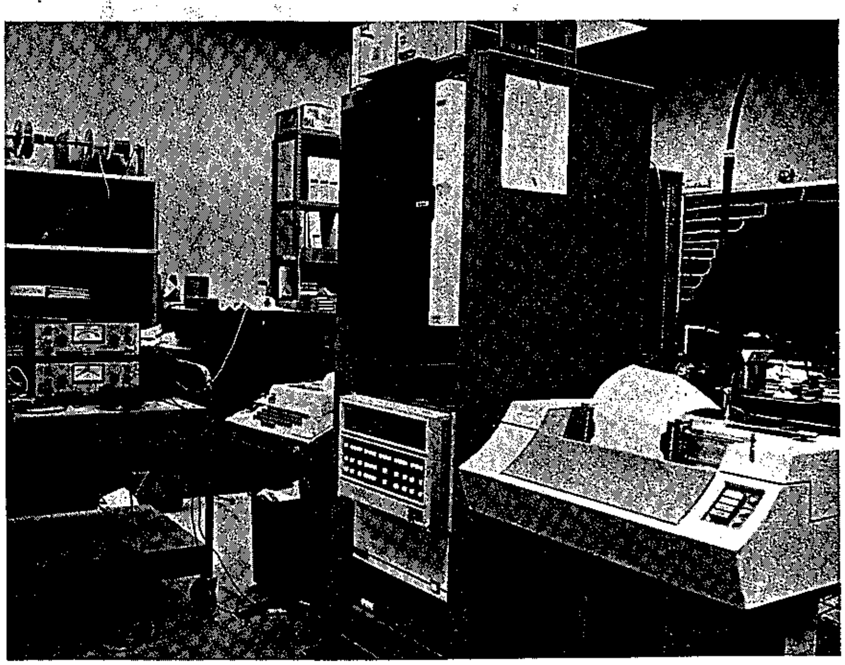


Sonic Digitizer
Figure 5

and temperature. Wind direction is sensed by the vane. Wind run is sensed by a cup anemometer which has a threshold speed of 1/2 mph. Temperature is sensed by a shielded spiral bimetal element. The recorder is battery wound with a chart speed of 20 mm/hr and a record span of approximately 30 days.

A Graf/Pen Sonic Digitizer (SAC-Model GP-2 system) is shown in Figure 5. The digitizer is a device for obtaining (x,y) coordinates in digital form which can be entered automatically into a data processing system minicompcomputer. The digitizer is used to reduce the mechanical weather station strip chart data by digitizing the tracings inscribed on the chart. The digitizer includes three basic components - a tablet, a stylus, and a controller. The tablet's active area is 14 inches square with microphone sensors mounted along two adjacent sides. One linear microphone represents the x-axis, the other the y-axis. A hypersonic sound wave, created by a spark emitted from the stylus tip, is measured (timed) between the stylus and microphones. Thus, any location on the tablet can be measured and recorded as a digital word pair displayed in a binary form on the controller panel. From the digitizer controller these data are passed to the minicomputer.

A Hewlett Packard Minicomputer data processing system is shown in Figure 6. The system includes the computer with 16,384 sixteen-bit words of core memory, an IBM compatible digital tape drive, a teletype terminal and a high-speed paper tape reader.



Mini-Computer
Figure 6

Strip Chart Viewer
Figure 7

Strip Chart Handling Equipment is used to inspect and rewind the strip charts. Equipment includes a power driven strip chart viewer and a hand roller. The automatic strip chart viewer is shown in Figure 7 and is used to spot check strip charts for mechanical weather station malfunctions. The hand roller is attached to the digitizer tablet (Figure 5) and is used to advance and rewind the chart during the digitizing operation.

Materials include computer compatible magnetic tape, teletype paper, and strip chart reduction forms. A strip chart reduction form (Figure 8) is used by the operator to format necessary strip chart heading information onto magnetic tape. Teletype paper and magnetic tape are used to output and store the summary data from the strip charts.

Minicomputer Programming for Digitizing

The programs within the minicomputer were written to be interactive with the digitizer and also fairly fast. It was assumed that the system would have a lot of usage, so operator convenience and interactive error detection and correction were incorporated wherever possible. The bulk of the programs were written in Fortran II. The equipment drivers were written in assembly language as were a couple of short routines for code conversion and re-entering a Fortran program at a pre-determined location.

A feel for the interaction of the program and the hardware can be obtained by referring to Appendix B "Operative Procedures - Digitizing Services". There are also several error detection

MECHANICAL WEATHER STATION
STRIP CHART REDUCTION
INPUT INFORMATION

Master File Identification

Saroad Record Information

State		Area				Site			Agency	Project	

Time Control Information

Enter first Hour, Day, Month, and Year on strip chart

☐☐, ☐☐, ☐☐, ☐☐

Enter last Minute, Hour, Day, and Month on strip chart

☐☐, ☐☐, ☐☐, ☐☐

Enter actual Minute and Hour corresponding to the end of chart

☐☐, ☐☐

Site Description:

____

Chart Received by:__________Date:______.Chart Returned by:______Date______

Chart Reduced by:__________Date:______.

Comments:______________________________________

Figure 8

routines that print error messages where digitizer errors are sensed. Error messages are also printed when a point is digitized which is beyond the limits of the trace or the first point digitized on a trace is past the starting of the first form. An abort option can be triggered by digitizing a point within a square marked on the digitizer surface. This aborts the 12 hour segment being digitized and requests that it be started again.

The end result is a system which can be used to digitize a 12 hour segment in less than a minute. A normal strip chart covers one month so it contains about 60 such segments and takes about one hour to digitize.

The task is quite repetitive, however, and it is necessary to intersperse other duties in the operator's work day. The maximum production expected from one operator is four charts per day, or approximately four months worth of data.

Quality Assurance of Digitized Data

It is essential that quality of mechanical weather station data be assured. Procedures were developed to accomplish this.

The operator inspects incoming charts for any bad traces resulting from mechanical weather station malfunctions. This is done as the chart is being rewound to its start. If the strip chart is legible and apparently correct, the operator proceeds to digitize the strip chart. If not, he notifies the mechanical weather station user of the malfunction and returns the strip chart. The strip charts are digitized and hourly summary information is written to a magnetic tape which is, in turn, read into a large computer for storage in a computerized data base. See "Operating Procedures - Digitizing Service" in Appendix B.

A list of each hourly value is printed out as the tape is being read into the data base.

This output is returned to the digitizing operator who spot checks it against the strip charts to assure that all aspects of the digitizing process were functioning properly.

Periodically, the digitizer tablet is checked for coordinate accuracy to assure that the correct coordinate interpretation of the strip chart is being achieved.

AUTOMATIC DATA ACQUISITION

Choice of Method

It was realized that even automated reduction of strip charts would be expensive and time consuming. A more desirable solution would be to capture data directly on a machine readable media. Several such media were evaluated.

Perforated paper tape was considered but was discarded because of its excessive use of power and its relative difficulty of handling. This is not to imply that perforated paper tape is no longer a valuable alternative for environmental data capture. It still has many advantages that should not be discounted.

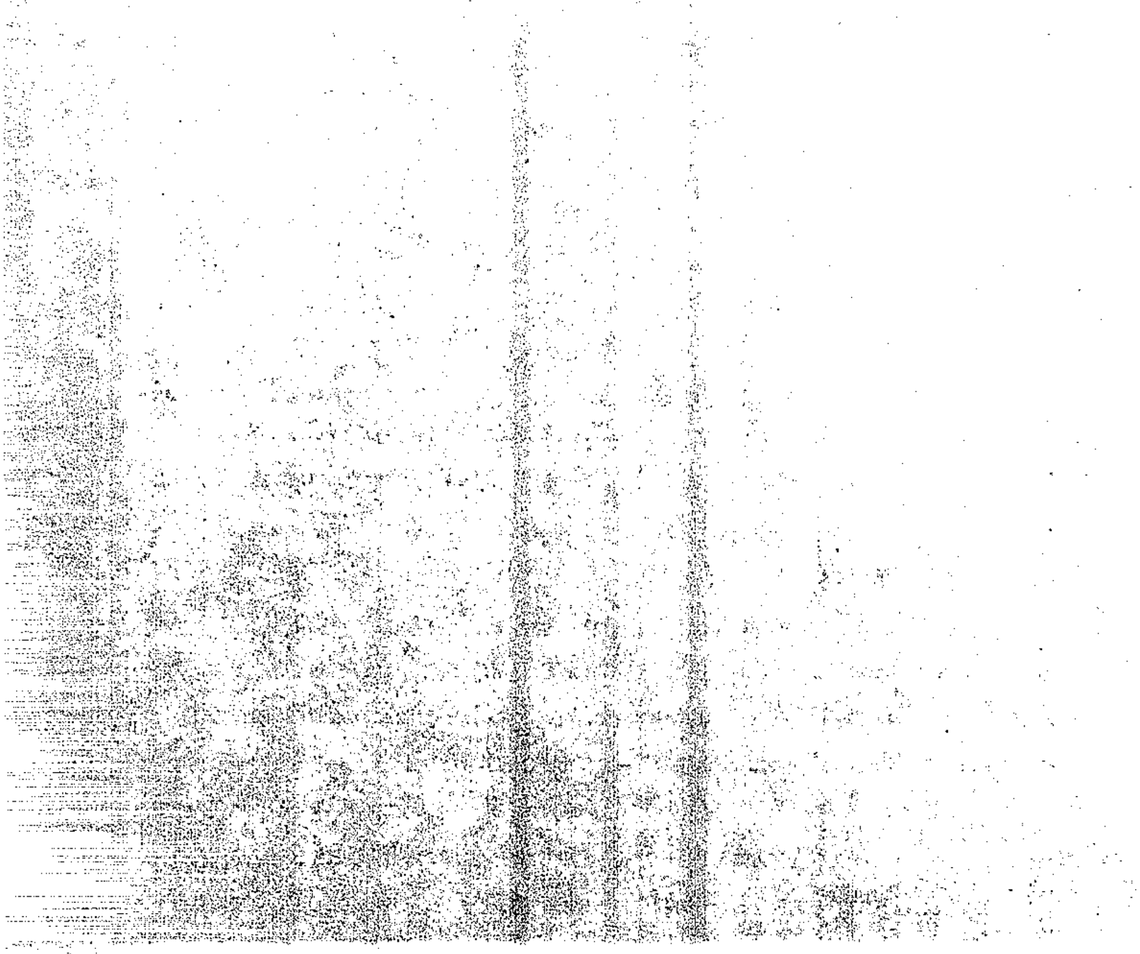
Several magnetic media were considered including floppy disks, magnetic cards, etc. There were no data logging devices available which used these media and the use of non standard media was considered something to be avoided.

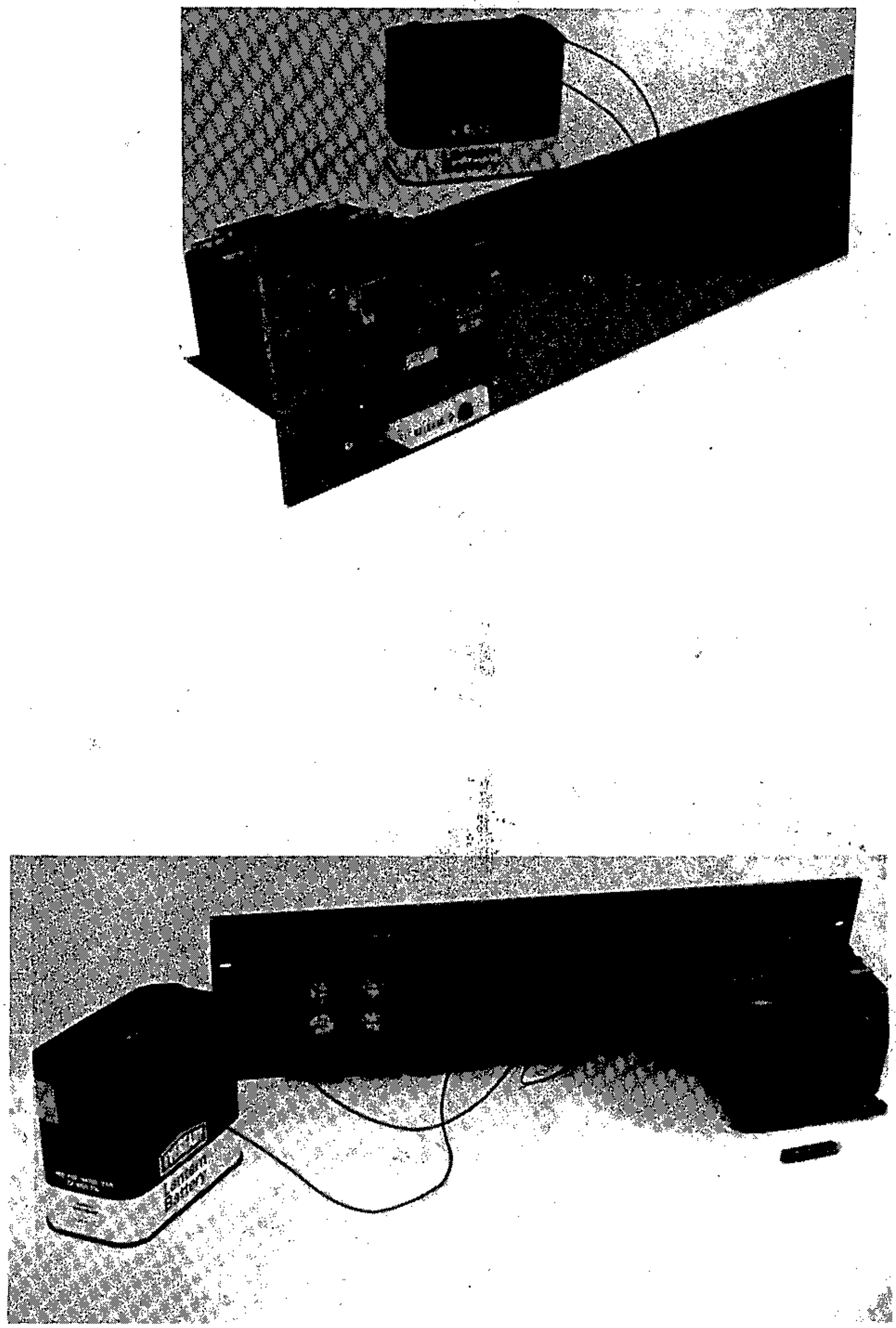
Computer industry compatible magnetic tape was considered. There are many advantages to this media. The main problems were cost, power usage, and sensitivity to extreme environments.

The final decision was to use digitial cassette based data loggers. The Datel system which was purchased was the only system found that had low power drain and appeared to be designed and assembled with a reasonable amount of care. It did have several drawbacks. It required the addition of timing and control circuitry as well as power supply, enclosure etc. It wrote data in a nonstandard format and the available cassette reader was slow by computer standards and difficult to control remotely.

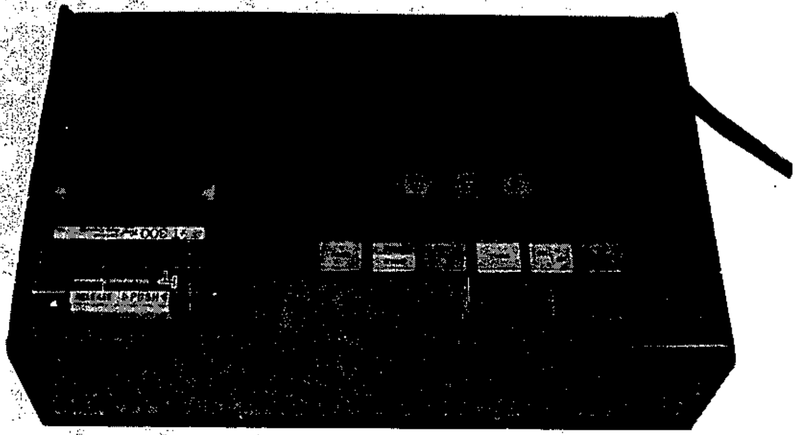
Equipment

The Data Logger System is shown in Figure 9. The system includes the basic data logger unit, a front panel designed for rack mounting and a control circuit board which includes circuitry for logger timing and input channel selection.





Data Logger
Figure 9



Data Cassette
Reader

Figure 10

The Data Logger Unit contains an analog multiplexor (switching device), an analog to digital converter (volt meter) a data formatter, a cassette tape transport with necessary drive electronics and logger control circuitry. The analog (voltage) data inputs are sequentially selected, converted into digital form, formatted and stored on cassette tape.

The Control Circuit Board mounted on the back of the front panel, contains the necessary circuitry for the selection of the desired number of channels to be scanned and the desired sampling rate. It also contains circuitry for control of various logger operations necessary for proper startup and shutdown of the system.

Four rotary decimal switches, soldered onto the board, can be set to provide any desired scanning rate, from one scan per second to one scan every 9,999 seconds (2 hr 46 min). A hexidecimal switch provides the capability of selecting from one to 15 channels of input data per scan. A circuit diagram of the control board is included in Appendix A.

The Front Panel was designed for rack mounting and supports the logger and control board. It displays the cassette transport, a data logger on/off switch and end-of-data gap light and button. The reason for the gap light and button is given later in this report.

The Cassette Reader is shown in Figure 10. The reader is designed to read logger cassette tapes and present the data output in a format that will be accepted by the minicomputer. It consists of a tape read transport (similar to the data logger's write transport) which is mounted in a cabinet with power supplies and controls. The tape is read at a rate of 2.75 inches per second.

The computer has only limited control over the reader by signaling a command to read the next block of data. The computer must be ready to accept one block of data at the rate that the reader presents it or data will be lost.

Minicomputer Reduction of Logged Data

It was decided early in the project that it would be virtually impossible to predetermine the number and types of signals that the loggers were going to be asked to monitor, let alone their calibration characteristics. It was also considered impractical to predetermine report algorithms and formats.

For these reasons, it was decided to write an assembly language overlay to the BASIC interpreter to allow the interactive development and modification of data reduction programs. It was later found desirable to overlay the interpreter with a formatter so that reports could be produced in a more readable form. Additional overlays were written to allow outputting to a high speed printer and an IBM compatible magnetic tape transport.

This resulted in a highly flexible system that is relatively slow in processing. The reader itself is slow in comparison to normal computer peripherals. It takes more than 20 minutes to read a standard 300 foot cassette. Programs run with the BASIC interpreter are also slower than similar programs written in FORTRAN, and take about as long to reduce as the reader takes to read them. The BASIC used was not set up to use the interrupt system, so no computations are performed as data are being read. A FORTRAN program would run faster and probably concurrently with the data input. Output would also run concurrent with the input. Rewriting the reduction programs in FORTRAN would, therefore, cut the reduction time approximately in half. Obtaining a higher speed reader would allow some dramatic time savings.

These problems are not critical with a low volume of work. The cassettes can be reduced during slack periods on the computer by existing personnel. If the use of cassettes is expanded, then the time required to read the cassettes would tie up the facility to an unacceptable degree and an additional facility with an operator would have to be obtained. The additional facility would either be much less flexible or very expensive. Complete duplication of the existing facility would cost well over $20,000.

Logger Temperature/Humidity Sensitivity

After the data loggers were bench-checked, they were tested under various temperature and humidity conditions to determine their tolerance to the environmental changes to which they might be subjected in the field. The tests showed that they were sensitive to heat and moisture.

The tests were made in an environmental chamber capable of being varied between 14°F and 140°F. A different reference voltage was applied to each of the data logger's input channels. The loggers recorded the input voltages accurately at temperatures of about 14°F. As the chamber temperature was raised, moisture condensed on the data loggers. Write errors occurred and the loggers often malfunctioned. Under temperatures of 140°F the data loggers again recorded accurate data; however, some write errors did occur.

It was hypothesized that the write errors were caused by failure of the cassette tapes and not the loggers. We were not, however, able to substantiate this hypothesis. Using manufacturer recommended tapes at normal room temperature, the reused tapes eventually began to give write errors. We found it necessary, therefore, to use only new cassette tapes for the remainder of our testing. Later we employed this practice with all of our data collecting operations.

Installation of Gap Button

During laboratory testing, the data loggers were consistently writing errors on the cassette tape for the first and last readings. It was later found that "power on" and "power off" to the loggers caused a change in flux in the writing head, which was recorded as erroneous data on the tape.

The first reading error was remedied by setting a 90 second "load forward" delay in the control circuitry immediately after power on. This allowed the power to be turned on while the head was positioned in the clear Mylar leader (unwritable portion) of the tape, and the first data were then written after a 90 second gap on the write portion of the tape. The last reading, however, presented a problem.

There was no way to eliminate the power off error. It was necessary to incorporate into the control circuitry a tape advance circuit which would allow a "power-off" error to occur well after the last data entry on the tape. To do this a 30 second tape advance was built into the control circuitry utilizing a panel "gap button" and "end-advance light". Pressing the button after the last desired data entry caused the light to go on and the tape to advance. Thirty seconds later the tape stops, and the panel light goes out indicating that the logger power may now be shut off. The result is a 30 second "load forward" gap before the power off error. The tape reader system is programmed to consider a gap of that length as the end of data.

Field Operation

After functioning satisfactorily in the laboratory, the data loggers were tested for field operation. They were installed in two aerometric data collecting systems, a meteorological tower trailer and an air pollution monitoring trailer. Both systems contained strip chart recorders whose output could be easily compared with logger collected data.

Meteorology Tower

The first attempt at collecting data using the loggers in the field made use of the mobile meteorological tower equipped with six wind and temperature sensing devices. These aerometric sensing devices are attached to the tower and work in conjunction with a signal conditioning device mounted at the tower base. A current ranging from zero to one milliampere is sent from the signal conditioning unit to a panel of strip chart recorders. Each recorder receives a signal corresponding to a particular wind or temperature instrument and records its level on the strip chart. All instruments are powered by a heavy duty truck battery mounted at the rear of the tower trailer.

Besides providing an output to the strip chart recorders, the signal conditioning device produces a parallel voltage output (zero to five volts full scale). Since the loggers are sensitive to a minus five to plus five volt range, they could be easily tied to this output. Linking the data logger to the voltage output would also provide a double means of recording data, one using the logger and the other utilizing the strip charts.

Tower Installation

A data logger was then installed into the meteorological tower system employing the voltage output from the signal conditioning device (see Figure 11A). A wiring harness was built to carry the six channels of input signals from the back of the signal conditioner to the data logger input conector. Due to problems that will be discussed later, a twelve volt lantern battery was installed to power the logger. The data logger was then set to collect data from the six input channels, once every minute.

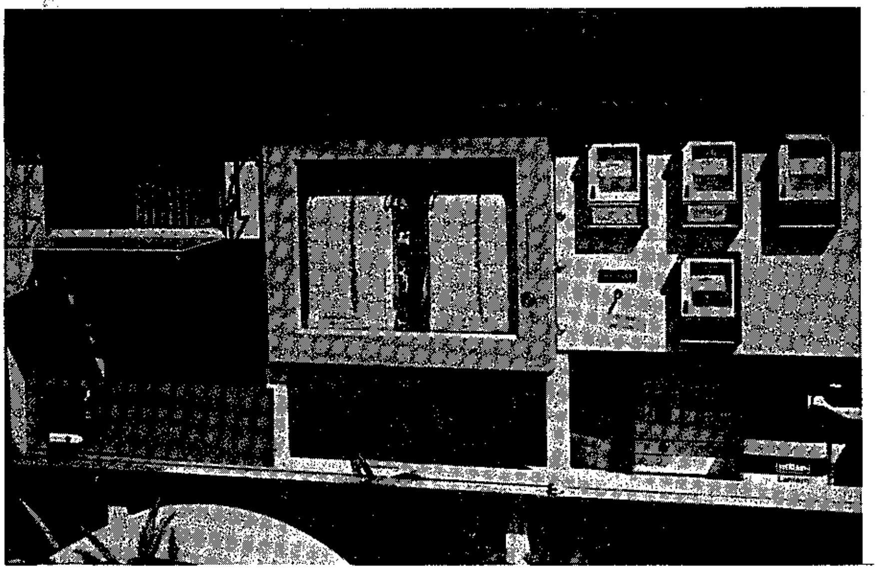
After placing a new tape cassette into the logger, the logger was ready for operation. The meteorological tower instruments were calibrated, the strip charts were adjusted, and batteries were checked. The system was then operational.

Air Pollution Monitoring Trailers

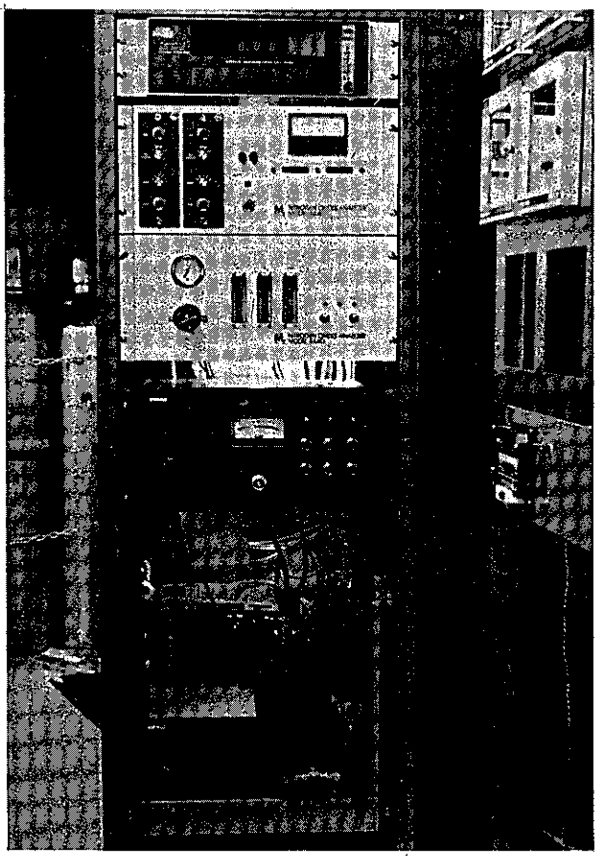
In addition to the meteorological tower, the loggers were field tested in three identical air pollution monitoring trailers that were in use in the Sacramento area. The equipment in each of the trailers was AC powered from commercial power. Each trailer had analyzers which gathered air pollutant concentration data for eight pollutants and recorded the resulting data on strip charts. All analyzers provided voltage signal outputs of either zero-to-one volts or zero-to-100 millivolts (full scale) to their recorders.

Trailer Installation

The data loggers were mounted in each trailer in the strip chart recorder rack adjacent to the analyzers (see Figure 11B). Logger power was provided by a twelve volt lantern battery that was secured at the base of the recorder rack. A uniform zero-to-one volt signal was achieved for all logger input channels. This required connecting five sets of logger input leads to the five recorders that received a one volt (full scale) signal. For the analyzers that sent a 100 millivolt (full scale) signal to their respective recorders, logger input leads had to be run directly to the analyzer where zero to one volt outputs were available. The logger was then set to collect data from eight input channels at a rate of one complete scan every minute. The analyzers and recorders were calibrated and a new cassette tape was installed. The pollution monitoring system was then operational with the ability to collect data on both the strip charts and the cassette tapes.



Data Logger/Tower Installation
Figure 11A



Trailer Installation of Data Logger
Figure 11B

DATE 02/15/75

START TIME	CUP1 MPH	CUP2 MPH	AZI1 DEG	AZI2 DEG	TEMP C	DLTT C	R. NO	R. B. NO 1/M^2	BATT VOLTS
0000	10. 4	11. 8	315	318	7	-5. 46	-2. 75	-0. 00	4. 0
0100	10. 9	12. 7	309	317	6	-5. 46	-1. 62	-0. 00	4. 0
0200	13. 3	14. 9	311	318	6	-5. 45	-2. 00	-0. 00	4. 0
0300	11. 5	13. 0	313	316	5	-5. 45	-2. 35	-0. 00	4. 0
0400	10. 4	12. 3	331	317	5	-5. 45	-1. 38	-0. 00	4. 0
0500	8. 1	9. 5	272	311	4	-5. 45	-2. 62	-0. 00	4. 0
0600	10. 5	12. 0	315	318	4	-5. 45	-2. 10	-0. 00	4. 0
0700	9. 4	10. 5	320	323	4	-5. 45	-3. 98	-0. 00	4. 0
0800	10. 1	11. 0	320	324	5	-5. 45	-5. 35	-0. 00	4. 0
0900	12. 2	13. 7	322	325	8	-5. 46	-2. 17	-0. 00	4. 0
1000	11. 9	12. 8	318	319	9	-5. 46	-6. 45	-0. 00	4. 0
1100	9. 4	10. 0	306	305	11	-5. 46	-14. 59	-0. 00	4. 0
1200	7. 5	8. 3	294	299	12	-5. 46	-8. 00	-0. 00	4. 0
1300	6. 3	6. 9	294	300	13	-5. 46	-13. 46	-0. 00	4. 0
1400	7. 4	8. 0	302	303	13	-5. 46	-14. 76	-0. 00	4. 0
1500	5. 5	5. 6	227	222	13	-5. 46	-365. 55	-0. 01	4. 0
1600	3. 6	3. 8	114	98	13	-5. 47	-206. 11	-0. 01	4. 0
1700	5. 7	6. 1	136	134	12	-5. 47	-24. 04	-0. 01	4. 0
1800	5. 3	6. 1	152	153	11	-5. 46	-6. 64	-0. 01	4. 0
1900	4. 2	4. 9	143	145	10	-5. 46	-9. 29	-0. 01	4. 0
2000	5. 0	5. 9	143	145	9	-5. 46	-5. 92	-0. 01	4. 0
2100	6. 8	8. 1	125	126	8	-5. 46	-3. 04	-0. 00	4. 0
2200	8. 0	9. 1	112	111	7	-5. 46	-4. 58	-0. 00	4. 0
2300	7. 1	7. 5	132	135	6	-5. 45	-31. 13	-0. 00	4. 0

Summary of Meteorology Tower Logged Data

Figure 12

1	4.998	2	2.000	3	4.998	4	1.580	5	3.052	6	2.488	7	0.000
1	3.787	2	2.124	3	3.059	4	1.545	5	3.044	6	2.517	7	0.000
1	2.961	2	1.892	3	4.392	4	1.501	5	3.047	6	2.468	7	0.000
1	4.504	2	1.904	3	3.987	4	1.545	5	3.025	6	2.490	7	0.000
1	3.240	2	2.021	3	3.662	4	1.545	5	3.037	6	2.480	7	0.000
1	3.870	2	1.938	3	4.111	4	1.675	5	3.025	6	2.517	7	0.000
1	2.634	2	1.931	3	3.018	4	1.543	5	3.030	6	2.517	7	0.000
1	3.042	2	2.117	3	3.682	4	1.709	5	3.040	6	2.520	7	0.000
1	1.985	2	2.175	3	2.009	4	1.912	5	3.052	6	2.585	7	0.000
1	1 526	2	2.200	3	1.997	4	1.519	5	3.069	6	2.520	7	-0.002
1	4.426	2	1.724	3	4.316	4	1.514	5	3.027	6	2.476	7	0.000
1	2.678	2	1.843	3	2.842	4	1.582	5	3.018	6	2.502	7	0.000
1	3.325	2	2.156	3	3.833	4	1.726	5	3.027	6	2.542	7	0.000
1	3.911	2	1.753	3	3.652	4	1.462	5	3.022	6	2.517	7	0.000
1	3.391	2	1.704	3	4.319	4	1.448	5	3.025	6	2.502	7	0.000
1	2.883	2	1.941	3	2.893	4	1.438	5	3.015	6	2.537	7	0.000
1	3.757	2	2.136	3	3.596	4	1.440	5	3.015	6	2.512	7	0.000
1	2.197	2	2.031	3	2.554	4	1.946	5	3.022	6	2.476	7	0.000
1	3.696	2	1.921	3	3.577	4	1.587	5	3.020	6	2.520	7	0.000
1	3.711	2	1.987	3	4.736	4	1.606	5	3.015	6	2.490	7	0.000
1	3.877	2	2.090	3	3.855	4	1.682	5	3.005	6	2.522	7	0.000
1	4.590	2	1.978	3	4.812								

STOP

Voltage Values for Seven Channels

Figure 13

Quality Assurance of Logged Data

After the data cassette tapes have been returned to the laboratory for reduction, it is essential that they be checked for unreasonable data values, possibly resulting from logger or analyzer malfunctions. Methods have been developed to accomplish this.

From our data summary program that has been developed to print hourly averages of data (Figure 12), we can read our cassette tapes and compare the resulting analyzer data averages to the analyzer strip chart data. A second check is made periodically on the cassette data using a different program which prints individual voltage values for individual readings of input data. With these voltage data we can determine analyzer malfunctions that would not normally be found using the summary program.

Logger Field Problems

Various electrical problems were encountered during the installation and operation of the data loggers in the field. Since the problems were common to both the meteorological tower and the air pollution study trailers, emphasis is given to logger installation in the simpler system, the meteorological tower. The meteorological tower was the first system to be used with a logger and most of the electrical "bugs" were remedied before the loggers were installed in the air pollution monitoring trailers.

Noise in Logger Power Supply

The first problem occurred when the data logger was connected to the heavy duty battery on the tower trailer. This battery was the sole power source for the entire tower system. Reduction of data from the first logger data tape showed large deviations from strip chart data. It was found that the signal conditioning unit was "loading down" the battery which resulted in electrical "noise". Apparently this caused problems with the data logger. The situation was remedied by powering the logger by a separate twelve volt lantern battery.

Excessive Battery Drain

The second problem occurred when the supply voltage was monitored. Since the logger was inoperable when its supply voltage fell below ten volts, it was decided that one data channel could be used to monitor the supply voltage. In order to monitor the twelve volt lantern battery with a five volt logger, a series of resistors (a voltage divider) was wired between the battery and logger input connector. This voltage divider reduced a zero-to-twelve volt input signal to a zero-to-four volt signal. The divider was installed and the logger functioned properly for only a short period of time. It was discovered that the voltage divider "loaded" the battery down below ten volts in a very short period of time and had to be eliminated from the system. The automatic battery check was replaced by a periodic volt meter check. This prolonged the life of the logger battery considerably.

Common Signal Grounds

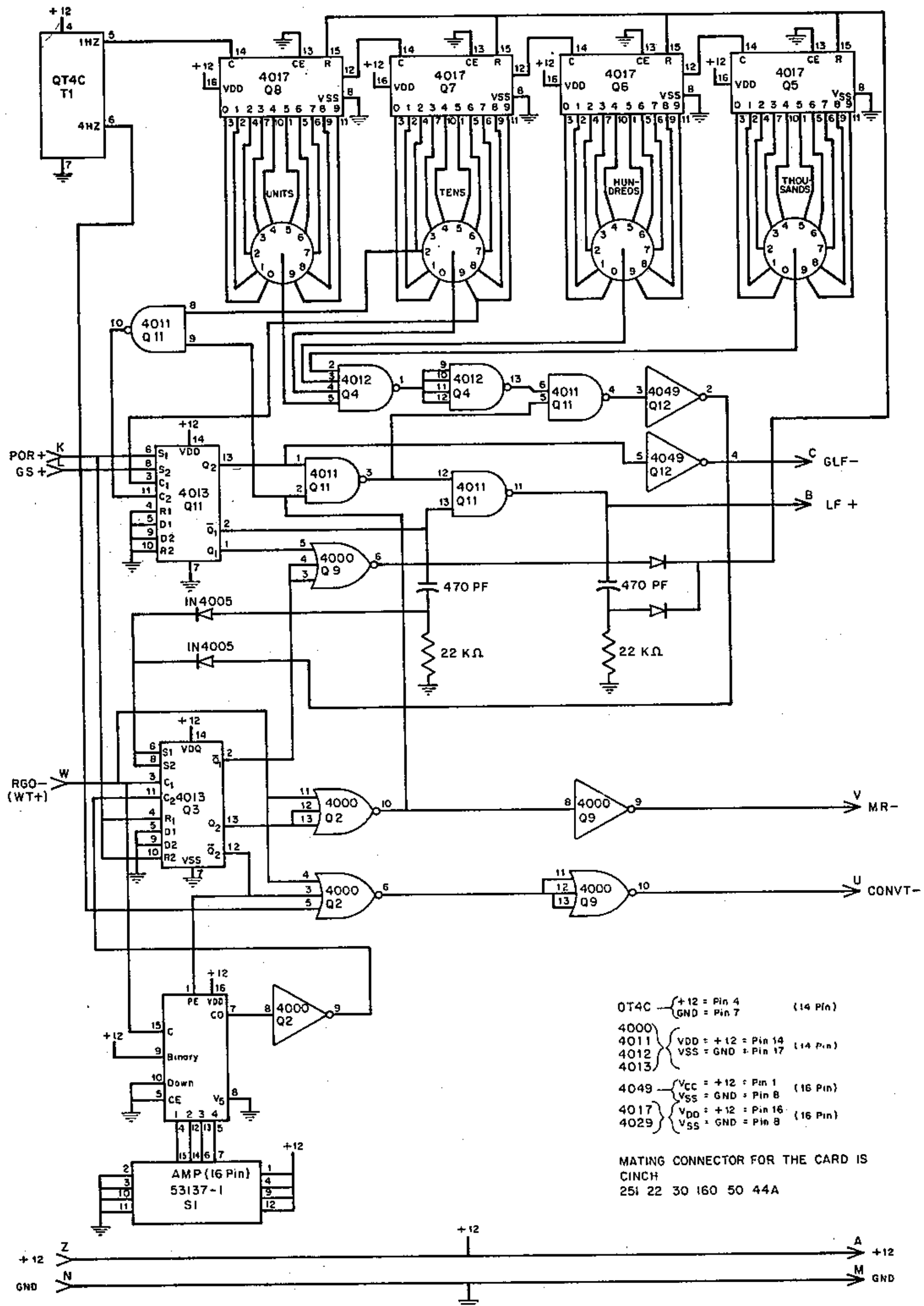
There is a third potential problem which exists within the logger itself. The logger is designed to internally tie all signal commons together. This has the potential of causing a wide variety of problems within the analyzers themselves. This effectively defeats the signal isolation of the analyzers and may set up "ground loop" problems. These problems may not be trival and could require the addition of costly isolation amplifiers, etc.

Logger Sensitivity

The last problem encountered was inherent to the air pollution study trailers. Unlike the meteorological tower systems that use five volts (full scale), the air pollution trailer analyzers used only one volt full scale. When the analyzers were set to measure a wide pollutant range, the required data precision approached the resolution of the data logger. In other words, the smallest pollutant concentration to be measured was smaller than the smallest increment that could be detected by the logger. This was remedied by setting the analyzers to a more sensitive scale.

APPENDIX A

CIRCUIT DIAGRAM OF LOGGER CONTROL BOARD



TIMING AND CHANNEL SELECTION CIRCUITRY

APPENDIX B

OPERATING PROCEDURES - DIGITIZING SERVICE

1. A Strip Chart Reduction Sheet will be prepared by the service operator prior to the reduction of the strip chart. The service operator must extract the starting time and date from the strip chart, the time and date when the chart was removed from the mechanical weather station, and the time location of the stylus on the strip chart when the chart was removed. He must then record this along with accounting, necessary data center, and site description information on the reduction form.

2. Upon preparing the initial information from the district, the service operator will then be responsible for checking the chart (for obvious mechanical weather station malfunctions and chart time errors) and rewinding the chart to the starting hour. He will be responsible for maintaining a notebook for the reduction input forms as they are received from the districts. He will date and make any necessary comments on the input forms regarding chart errors, etc. The service operator will then perform the actual chart reduction operation.

a. Load the strip chart onto hand roller and feed across the digitizer tablet to the opposite roller.

b. Turn on the digitizer power. Switch the "Operator" switch to the "Right-Hand" position. Switch the mode switch to the "Remote" position.

c. Turn on the computer system power. Assure that computer paper tape reader and tape drive are ON, and teletype is on "line". Load the paper-tape bootstrap (very high binary tape to "read" magnetic tape) using the absolute binary loader. Load the program tape onto the magnetic tape drive, load the beginning address, and execute the operation to read the magnetic tape program into the computer. Then, set address to execute the digitizer program, and begin operation. At this point, the operator should type into the computer (on the teletype) the information on the Reduction Form.

The charts are digitized in twelve hour segments from midnight to noon or noon to midnight. Each segment is oriented by digitizing the point at the bottom of the azimuth regions at the exact beginning of the 12 hour segment. (Note: This is either 24:00 or 12:00 with no exceptions for charts starting or ending within the segment.) This first point defines the beginning coordinate of the chart. One more point is digitized along the base of the azimuth region to give the chart angular orientation.

The teletype bell will ring when the orientation is complete.

The temperature trace is first digitized. Enough points are digitized along the temperature trace so that a straight line drawn between these points adequately describes the temperature trace.

The teletype bell will ring when the temperature is finished.

The wind-run trace is digitized next. A point at each left and right boundary (where each line segment meets the boundary) must be digitized. Additional intermediate points are usually necessary to adequately define the wind run trace.

The teletype bell will ring when the wind run trace is finished.

The azimuth is digitized last. The azimuth line is continuously digitized (traced) from the start to the end of data within the segment. The pen will continuously spark during this operation. If, however, a point is missed, the pen will stop sparking and will not continue to spark freely until it is moved back to the location of the missed data.

The teletype bell will ring when the azimuth line has been digitized.

d. When the digitizing operation is complete, shut OFF all computer systems (teletype, tape drive, paper-tape reader and computer) and switch OFF the digitizer.

4. The magnetic tape, input forms and strip charts are filed by the service operator. He prepares the job control form for submittal to the data center. He also decides if a sample chart is to be retained by the laboratory for a quality control spot check. He then transmits the data tape and job control form to the appropriate data guidance unit within the Department's computer data center.

Next, the Service Operator makes necessary comments on the Strip Chart Reduction Form pertaining to a possible Mechanical Weather Station malfunction or poor adjustment. A copy of the Strip Chart Reduction Form should be retained and the original sent back to the district with the strip chart. This informs the district that the chart has been digitized and to expect printout from Computer Systems.

APPENDIX C

OPERATION PROCEDURES FOR DATA LOGGER

1. Cassette Tape Preparation

a. Degauss the cassette tape using the TD-1A cartridge eraser following the instructions on the casing.

b. Rewind the cassette tape using the cassette reader: Set cassette into the reader with exposed tape at top and Side 1 up. Do not clamp down the reader head bar. Push the power button to on and then push the rewind button.

c. Load forward the cassette tape by clamping down reading head bar and then pressing the EOT-S-BOT button down for 5 seconds. (If the EOT-S-BOT button light goes out, rewind the tape and load forward again; this time holding the EOT-S-BOT down just long enough so that the light does not go out.)

d. Press power button to off. (The tape is now ready for the data logger.)

2. Data Logger Operation

a. Insert cassette tape into logger and clamp down writing head bar.

b. Flip panel switch up (on). (The cassette tape will advance for 90 seconds and then it will begin to collect data.)

c. When all data has been collected, press the red panel gap button immediately after the last segment of data has been written on the cassette tape. (This will put a 30-second gap on the cassette tape.)

d. When tape has stopped advancing (part c), immediately flip panel switch down (off).

3. <u>Data Reduction</u>

a. MINI: Turn power on, press "HALT/CYCLE".

b. TTY: Turn "LINE OFF LOCAL" switch to "LINE".

c. LINE PRINTER: Depress "ON/OFF" and "SELECT" so that the switches are lit.

d. TAPE READER: Turn power on by depressing "POWER" switch.

Press "LOAD".

Place Tape #1 (16K BASIC LP 14B, TTY 15B, PR 16B, CASSETTE 20B) into tape reader.

Press "READ"

e. MINI: Press "S" switch.

Press "CLEAR DISPLAY" switch.

Press "P" switch.

Press "CLEAR DISPLAY" switch

Press the following Display Register Switches: "13, 12, 11, 10, 9, 8, 7, 6" (037700_8)

Press "EXTERNAL PRESET"

Press "INTERNAL PRESET"

Press "LOADER ENABLE"

Press "RUN"

Paper tape should now start loading. At the completion of the paper tape loading the CPU shall halt (HALT/CYCLE light lit) and the display register should have the following switches lit: "15, 10, 5, 4, 3, 2, 1, 0". (102077_8)

f. TAPE READER: Press "MANUAL ADVANCE" to remove paper tape.

Press "LOAD" rewind tape #1 and return to storage.

Place Tape #2 (*BASIC* Hourly Summary w/ Z from cassett) into tape reader.

Press "READ"

g. MINI: Press "S" switch

Press "CLEAR DISPLAY" switch.

Press "P" switch.

Press "CLEAR DISPLAY" switch

Press "DISPLAY REGISTER SWITCH '6'" (000100_8)

Press "EXTERNAL PRESET".

Press "INTERNAL PRESET".

Press "RUN".

h. TTY: TTY will print out "READY"

Type in "PTAPE", press "RETURN"

Paper tape should load and TTY will print "READY"

i. CASSETTE READER: Turn power on and rewind cassette with reader head bar up. Clamp head down, and press EOT-S-BOT button down until light goes out.

j. TTY: Type "RUN", press "RETURN"

TTY prints out "INPUT START DATE" - Mo., Day, Yr.

Type in "_ _, _ _, _ _" Press "RETURN".

TTY prints out "INPUT START TIME" (4 digit military).

Type in "- - - -" press "RETURN".

TTY prints out "SET SWITCH REGISTER BIT 15".

Immediately press CPU DISPLAY REGISTER SWITCH "15".

Hourly Summary will start being printed out on the line printer. At the end of data on the cassette, the line printer will print "***** End of Data *****" and the TTY will print "READY".

If no more cassettes are to be read, type "BYE" on the TTY, push "RELEASE" button on cassette, press "REWIND" button and when cassette has rewound, remove.

If more cassettes are to be read, insert next cassette and repeat from Step i.