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INTEGRATED DATA ACQUISITION SYSTEMS FOR REAL-TIME METEOROLOGICAL MONITORING

By:

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ABSTRACT

Real-time meteorological monitoring data acquisition is routinely performed at a number of nuclear facilities within the USA. In these systems, meteorological sensors (wind speed, wind direction, temperature, etc.) on single or multi-level meteorological towers provide signals as input to the data system. The system then scans the input signals, digitizes the data values, adjusts the data to engineering units, and stores data averages. The data are then collected, validated, and provided for display and/or input to dispersion models. The data may then be archived into a database for future retrieval and reporting.

Since the meteorological towers are often remote from the reporting and display computer, current data acquisition and handling systems generally utilize distributed processing wherein a remote data logger acquires the data initially then passes the data to the central computer upon request.

This paper describes a number of approaches for integrated data systems for real-time meteorological monitoring ranging from simple PC-based systems to more complex designs utilizing redundant high-level minicomputers. System components (hardware and software) and their function in an integrated system are described. System features are discussed including advantages and disadvantages of the various designs. Features necessary to insure high data recovery and availability and the preservation of high quality database are included.

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1.0 INTRODUCTION

Meteorological monitoring is performed on a real-time basis at many installations within the USA and worldwide. Systems are currently in place at nuclear power plants, government laboratories involved in nuclear research or weapons production, air quality sites, or sites of unusual meteorological interest. The sensors involved in monitoring are usually those needed for the monitoring purpose. For dispersion modeling of radionuclied or air quality pollutants, parameters such as wind speed/wind direction (u, v, w), temperature (dry and wet bulb), dew point, relative humidity, barometric pressure, solar radiation, and total rainfall are often monitored. Sensors may be installed at single or multiple levels on meteorological towers (Figure 1).

In earlier times, data from sensors were logged by hand which limited data acquisition to the number and stamina of the data logging personnel. The advent of sensors that provided electrical outputs greatly improved the ability to archive information on recording devices such as paper strip charts. Unfortunately, these types of recording media still required conversion into digital values which could be averaged and from which associated derived parameters could be calculated. It was the advent of the digital computer and microprocessor-based recording in the 1960's that revolutionized data recording and calculation of derived parameters such as sigma theta and vector wind speed/wind direction. This capability was further enhanced by the growth of the minicomputer in the 1970's and the advent of the personal computer in the 1980's.

A working data acquisition system requires the successful integration of multiple components as follows:

1. Sensors
2. Front-End Data Collection Hardware and Software
3. Communications Media
4. Central Computer
5. Operating System
6. Central Applications Software

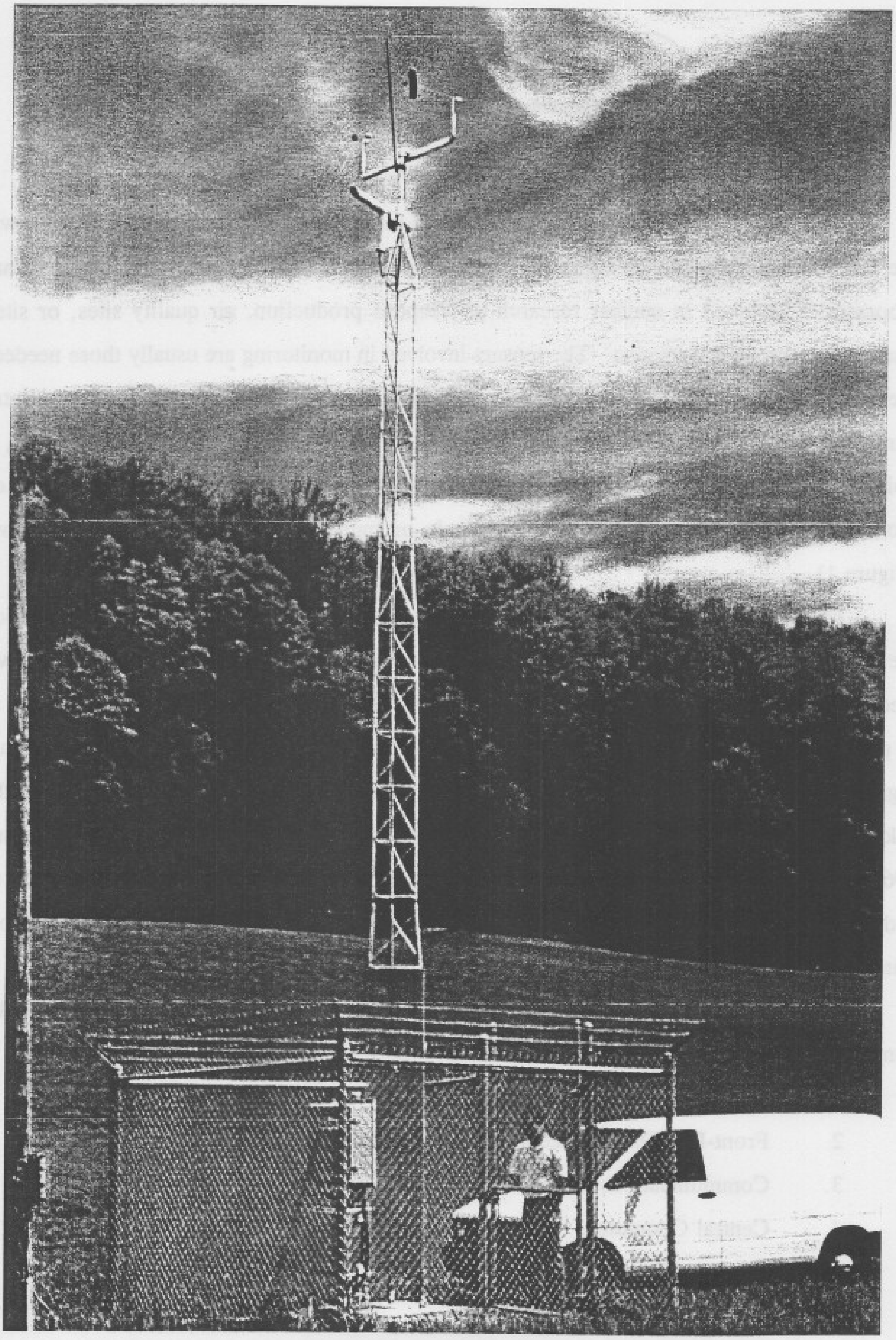


FIGURE 1 - SINGLE LEVEL MET SITE

In the following, common modern approaches to computer-based meteorological monitoring are described ranging from relatively simple Personal Computer-based system to more complex designs utilizing redundant high-level minicomputers. System components (hardware and software) and their function in an integrated system are described. Various data communication alternatives are described and system features are discussed including advantages and disadvantages of the various designs. Features necessary to insure high data recovery and availability and the preservation of a high quality database are included.

2.0 COMPUTER-BASED DATA ACQUISITION SYSTEMS (DAS)

Every computer-based data acquisition system starts with the same basic functions. A sensor yields a signal which varies in a unique way with the parameter being measured. A temperature sensor may consist of a resistor element whose resistance varies with temperature. If a current is applied to the element, the resulting voltage can be scanned and digitized. The digital value can then be scaled linearly or non-linearly to engineering units, validated, then recorded and displayed. Multiple scans can be averaged over known intervals (10-second, 1-minute, 15-minute, 1-hour, 24-hour, etc.) and the averages stored or displayed or provided as input into other software packages such as dispersion models. The data may then be archived into a database for future retrieval and reporting. An example list of parameters in a combined air quality/meteorology system is shown in Figure 2.

2.1 Data Acquisition at the Tower

Early computer-based meteorological systems generally consisted of a D/A device at the location of the sensor or sensor translator. The D/A performed a data conversion upon command from the Central computer but had no local memory. A central computer would then sequence through the individual D/A converters recording the values and performing the data processing using one CPU. The major disadvantage to this type of architecture (as shown in Figure 3) was that any disruption at Central or in the transfer medium resulted in data loss.

Since meteorological towers are often remote from the reporting and display computer, current data acquisition and handling systems generally utilize distributed processing wherein a remote data logger acquires the data initially then passes the data to the central computer upon request such as shown in Figure 4. The front-end data logger is generally a robust device with processing power to scan sensor inputs, validates the data based on other parameters, processes the digitized value calculating vector ws/wd, accounting for crossover points (360° or 540°), and stores the data in short term memory. Data sensors are generally scanned every second and stored

Computer Parameters

No.	Parameter
1	Sulphur Dioxide✓
2	Hydrogen Sulphide✓
3	Nitric Oxide✓
4	Nitrogen Dioxide✓
5	Nitrogen Oxides✓
6	Ozone✓
7	Non-Methane Organic Compounds✓
8	Carbon Dioxide✓
9	Solar Radiation✓
10	Precipitation✓
11	.5 cm Soil Temperature✓
12	-1 m Soil Temperature✓
13	-2 m Soil Temperature✓
14	Atmospheric Pressure✓
15	10 m Prevailing Wind Direction✗
16	10 m Vector Wind Direction✓
17	10 m Vector Wind Speed✓
18	10 m Mean Wind Speed✗
19	10 m Wind Gust ✗
20	10 m Sigma Theta✗
21	10 m Air Temperature✓
22	10 m Dew Point✗
23	10 m Relative Humidity✓
24	50 m Prevailing Wind Direction✗
25	50 m Vector Wind Direction✓
26	50 m Vector Wind Speed✓
27	50 m Mean Wind Speed✗
28	50 m Wind Gust✗
29	50 m Sigma Theta✗
30	(50 m - 10 m) Delta Temperature✓
31	90 m Prevailing Wind Direction✗
32	90 m Vector Wind Direction✓
33	90 m Vector Wind Speed✓
34	90 m Mean Wind Speed✗
35	90 m Wind Gust✗
36	90 m Sigma Theta✗
37	(00 m - 10 m) Delta Temperature ✓

Manual Parameters

No.	Parameter
1	Inhalable Suspended Particulates
2	Atmospheric Load
3	Evaporation

FIGURE 2

EXAMPLE PARAMETER SET FOR AIR QUALITY/METEOROLOGY SITE

MINI COMPUTER BASED DATA SYSTEM

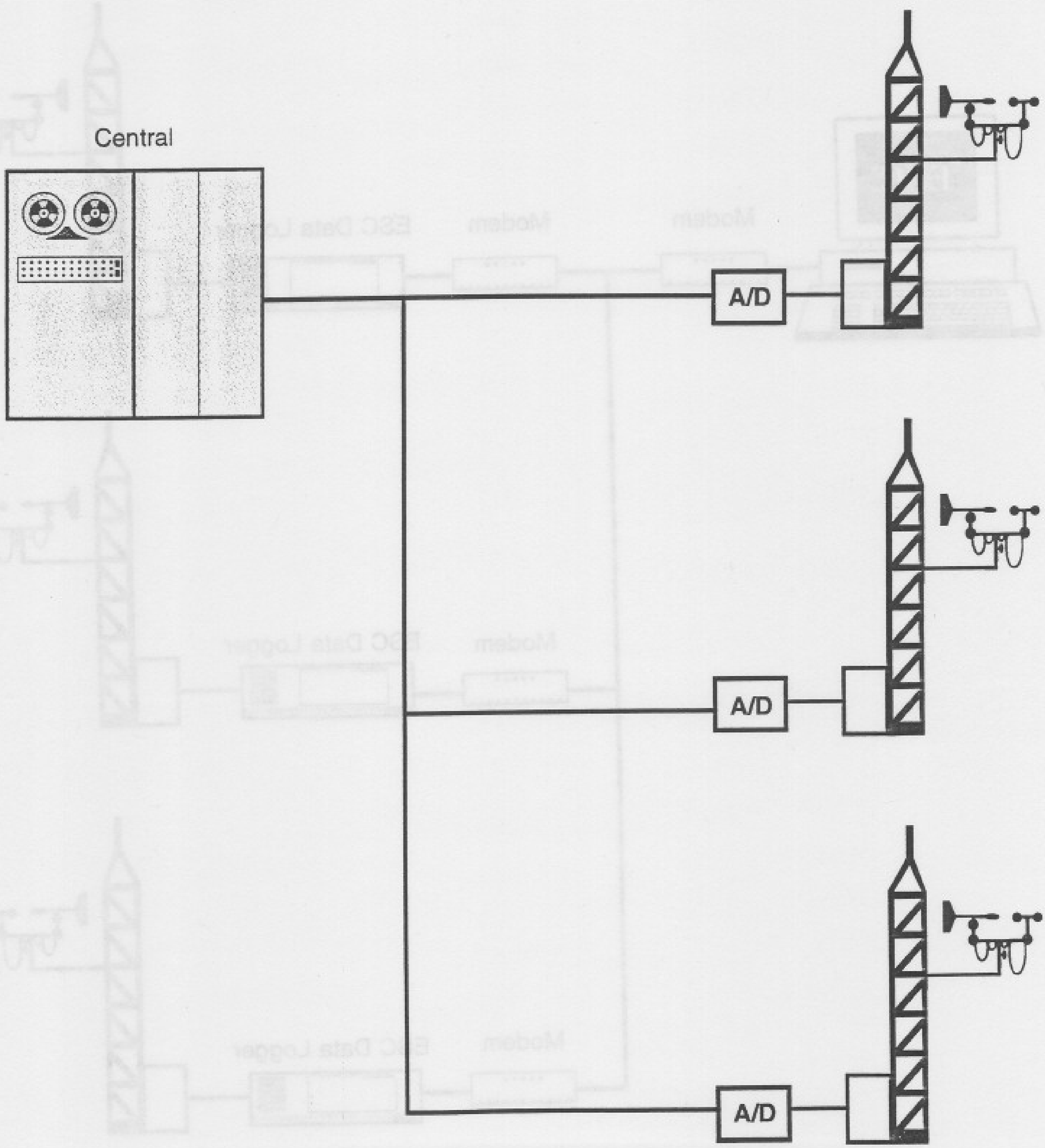


FIGURE 3

PERSONAL COMPUTER-BASED DAS

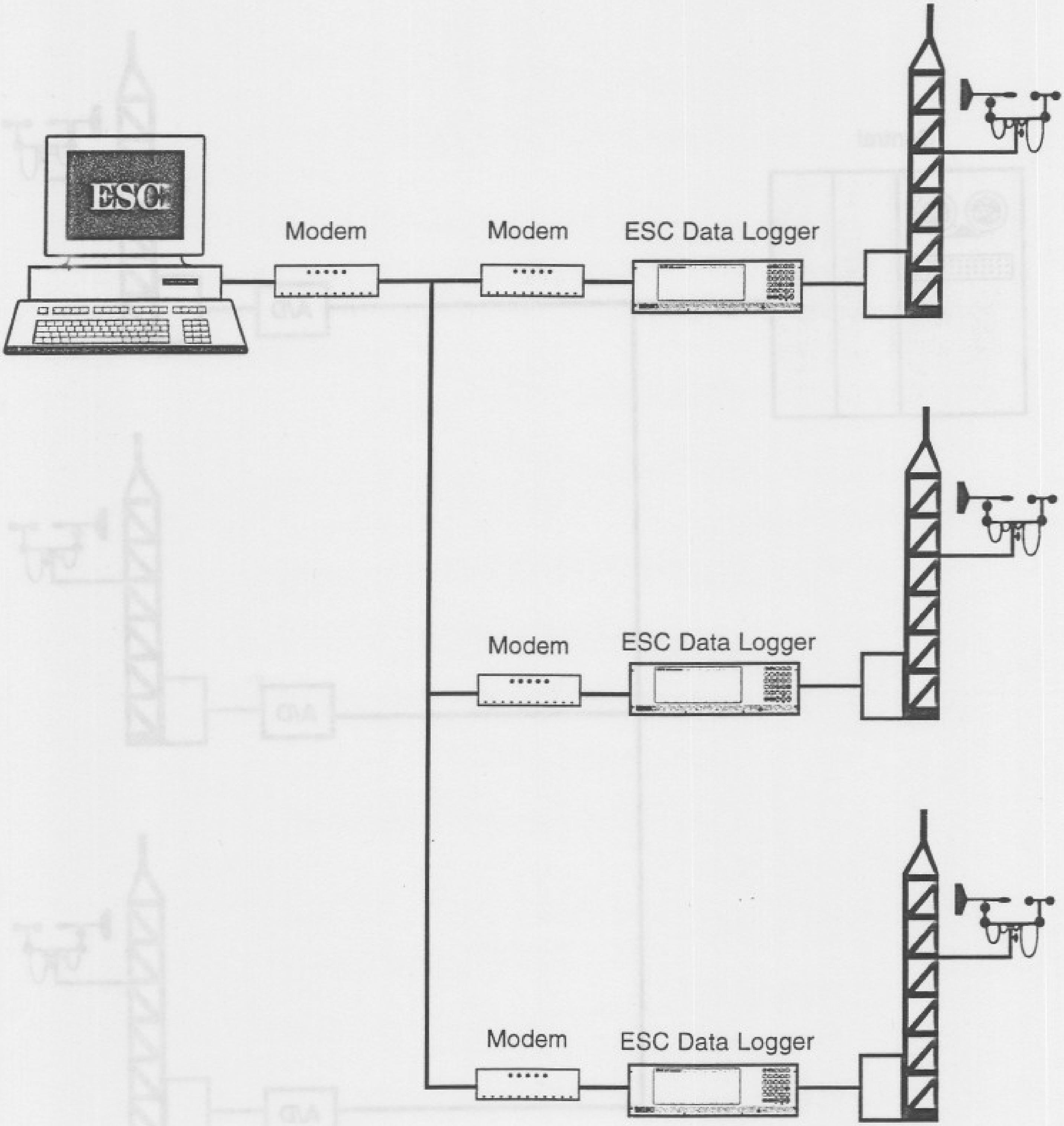


FIGURE 4

as one-minute, 15-minute, or hourly values. An example data logger routinely used in meteorological monitoring is shown in Figure 5. In some cases, personal computers have been employed for this purpose by utilizing A/D boards connected serially or through the PC data bus. In general, however, the PC operating systems and environmental extremes associated with a meteorological tower enclosure have required devices which can operate reliably in a multi-user mode under substantial temperature extremes. Current off-the-shelf personal computer operating systems have not demonstrated the reliability for continuous long term 24 hour x 7 day operation.

Software for meteorological data loggers is generally embedded into the system and stored in a non-volatile format. Modern systems allow the values describing the sensors connected to the logger (i.e., sensor range, parameter type, etc.) to be entered into configuration files. The loggers typically will scan the data on at least a one-second interval and utilize averaging routines to form longer term averages. Data may also be validated and a validation or information flag stored with the data point together with a time-tag identifying when the data was acquired or averaged. Time-tagging is accomplished with a battery-backed real-time crystal-based clock. Example flags are shown in Figure 6.

The remote data logger will also retain short-term data (generally up to a few hours or days) which can be reviewed by the site operator or which may be back-polled should a problem with the Central data retrieval computer occur.

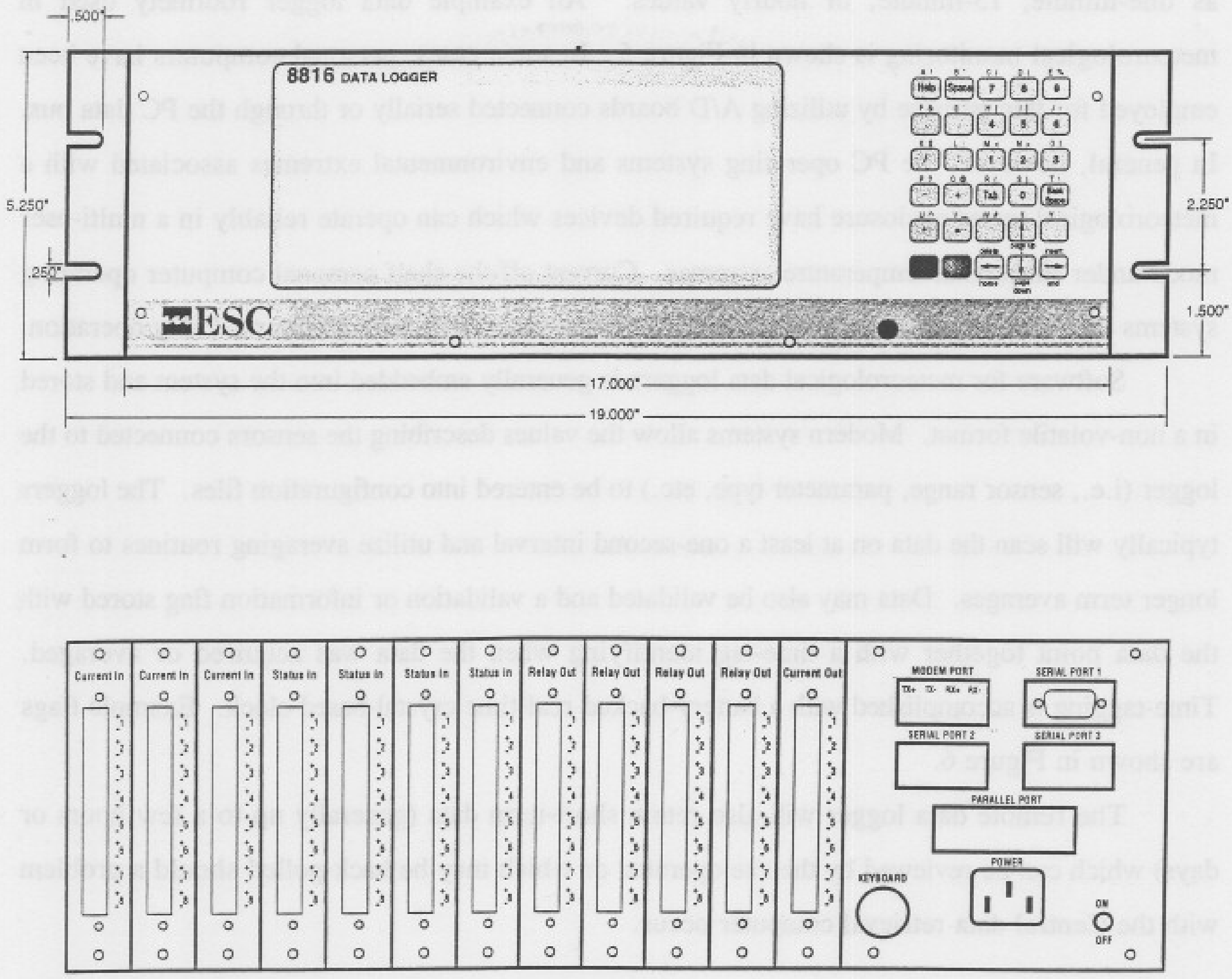


FIGURE 5 - ESC 8816 DATA LOGGER

TABLE OF ESC 8816 FLAGS

FLAG	CONDITION	TYPE
P	Power Failure	Validation
D	Channel Disabled (marked off-line)	Validation
T, t	Out-of-Control Tolerance Exceeded (calibration data)	Validation
F, p	Boiler Off-line	Validation
B	Bad Status Detected	Validation
C	Calibration	Validation
M	Maintenance	Validation
O	Analog Overrange	Validation
U	Analog Underrange	Validation
A	Arithmetic Error (math calculation error)	Validation
+	Maximum Exceeded	Validation
–	Minimum Exceeded	Validation
R	Rate of Change Limit Exceeded	Validation
Alarm & Info Flags - data included in averages		
H	High-High Alarm Limit Exceeded	Alarm
h	High Alarm Limit Exceeded	Alarm
L	Low-Low Alarm Limit Exceeded	Alarm
l	Low Alarm Limit Exceeded	Alarm
J	High Rate of Change Alarm Limit Exceeded	Alarm
j	Low Rate of Change Alarm Limit Exceeded	Alarm
f	Floor Limit Exceeded	Information
V	Digital Information Status #1 Detected	Information
W	Digital Information Status #2 Detected	Information
X	Digital Information Status #3 Detected	Information
Y	Digital Information Status #4 Detected	Information
Z	Digital Information Status #5 Detected	Information
>	Some missing data, but meets requirement for valid average	Data Capture
<	Does not meet requirement for valid average	Data Capture
<blank>	No missing data	Data Capture

FIGURE 6

2.2 Central Computer Hardware and Operating System Types

Current meteorological data systems utilize a range of hardware and software systems which make up the central computer. This central computer retrieves data from the remote site units, archives the data in a database, provides reports and displays, and provides user services. These computers generally consist of two types depending on capabilities required and budget available.

Minicomputer Platforms - Minicomputers such as the Digital Equipment Corporation VAX and Alpha (running VMS) or Hewlett Packard D or K series running HPUX offer stable and reliable platforms that provide multiple-user capability. Systems such as these are currently in place polling 3,000 parameters over leased phone lines every five minutes with retry and back poll capability in the event of a communication problem. The primary downside of the systems is the lack of visual programming languages and GUI's (graphical user interface) without the investment of significant resources.

Personal Computer (PC) Platforms - The advent of the personal computer, generally thought of as the IBM PC-compatible Intel CPU device originally running DOS and now Windows (apologies to Apple) has revolutionized data acquisition as well as computing. In meteorological monitoring, we have seen five (5) operating systems utilized on personal computers as shown in Figure 7. This figure, also indicates from our experience, the relative stability of the personal computer and minicomputer systems in single non-redundant applications. The advantage of the PC platform is low cost with the addition of Graphical User Interface (GUI) interaction with the operator. The primary disadvantage is the lower reliability of these systems in continuous DAS operation compared with traditional minicomputer platforms.

The choice of use of a minicomputer is often based on budget available as well as the experience base of the anticipated system user. Over the past few years, personal computers have been favored in single-user or networked applications.

	Example Computer Operating Systems	Type	Hardware Platform
Stability	VMS, RSX-11M (obsolete) HPUX	Multi-user	Minicomputer (VAX, PDP, HP)
↑	SCO UNIX	Multi-user	Personal Computer (Intel)
	Windows NT	Multi-Tasking Client/Server	Personal Computer (Intel)
	DOS (obsolete)	Single-Tasking	Personal Computer (Intel)
	Windows 95	Multi-tasking	Personal Computer (Intel)
	Windows 3.1	Multi-tasking	Personal Computer (Intel)

FIGURE 7

High-Availability Systems

In an application utilizing personal computers and a high-reliability front-end, data recovery can be reasonably assured at the 95% level or above, with certain obligations imposed on the user/operator of the system. For example, in the event of a primary data acquisition component failure of the DAS (typically the data logger front-end), the user would be expected to replace the failed component within a few hours of system notification of the failure in order to meet an availability guarantee. A failure of the Central reporting computer can take longer than a few hours to repair if only data recovery is the issue, but oftentimes the system has a requirement for high availability, that is, the availability of displays and alarms to an operator.

For high system availability requirements, that is, greater than 99% (i.e., allowing 3.7 days of downtime per year on a continuing basis, a high-reliability redundant system should be utilized with automatic failover built-in to either the hardware or software. Redundancy can also be built into the remote site (Figure 8) and if other elements are prone to failure, duplicate modems, communication media, and sensors may be employed.

REDUNDANT DAS

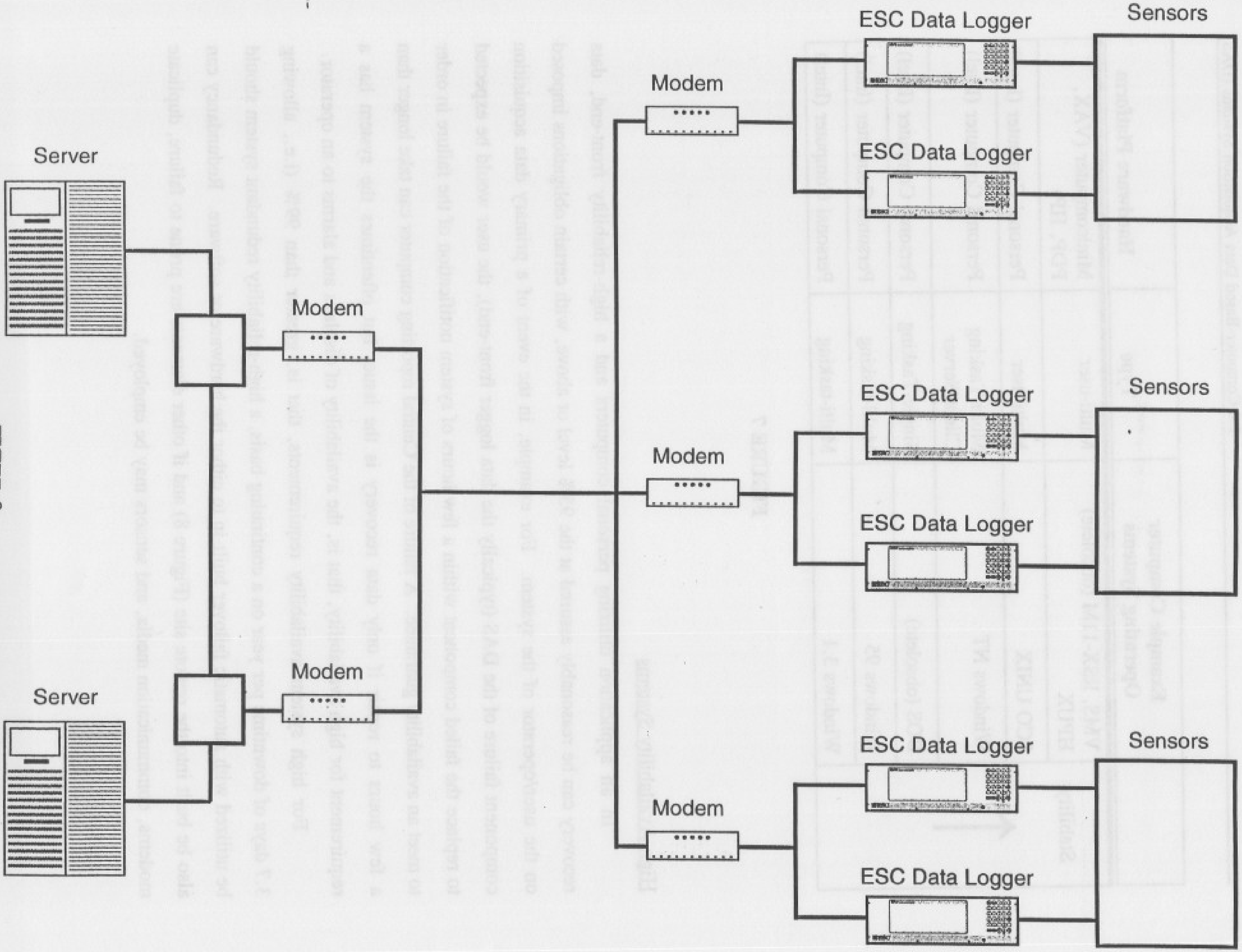


FIGURE 8

2.3 Data Communication Media

Since meteorological towers and their sensors are often remote from the Central computer, some form of communication media is required for signal transmission from the front-end data collector to the central computer. Common forms of transmission media are as follows (see Figure 9):

Telephone Line - Both Dial-up (Switched) and Leased telephone lines are often utilized in meteorological monitoring. Dial-up lines utilize the Public Switched Telephone Network and commonly available dial-up modems. Although this medium is very cost effective for sites which are hundreds of miles from the Central, the act of dialing and the per minute costs for line use are usually prohibitive for real-time monitoring. Leased telephone lines (conditioned) provide an open wire for communications and are commonly used for real-time monitoring since the communication line is always open. Modems for leased lines can cost ten times that of dial-up ($2,000 vs $200) because of the lower production levels. Modems are also available for direct-wired unconditioned line (twisted pair) if a distance of only a few miles is required.

Fiber-Optic Line - Fiber-optic lines are finding increased usage in short distance communications (few thousand feet). They offer excellent electrical noise immunity, high-reliability if installed correctly, and low cost compared to copper.

Cellular Phone - Cellular phone coverage across the USA has increased significantly over the past few years. If a dial-up connection can be tolerated, cellular phones can offer a data retrieval option that can cost significantly less than running cable to a remote application.

Radio - UHF, VHF, and Microwave Radio has been utilized for years for real-time data communications where licensing could be obtained. The advent of Spread Spectrum Radios which do not require licensing but are effective out to 20 or 30 miles has lead to an increased use of radios for data applications.

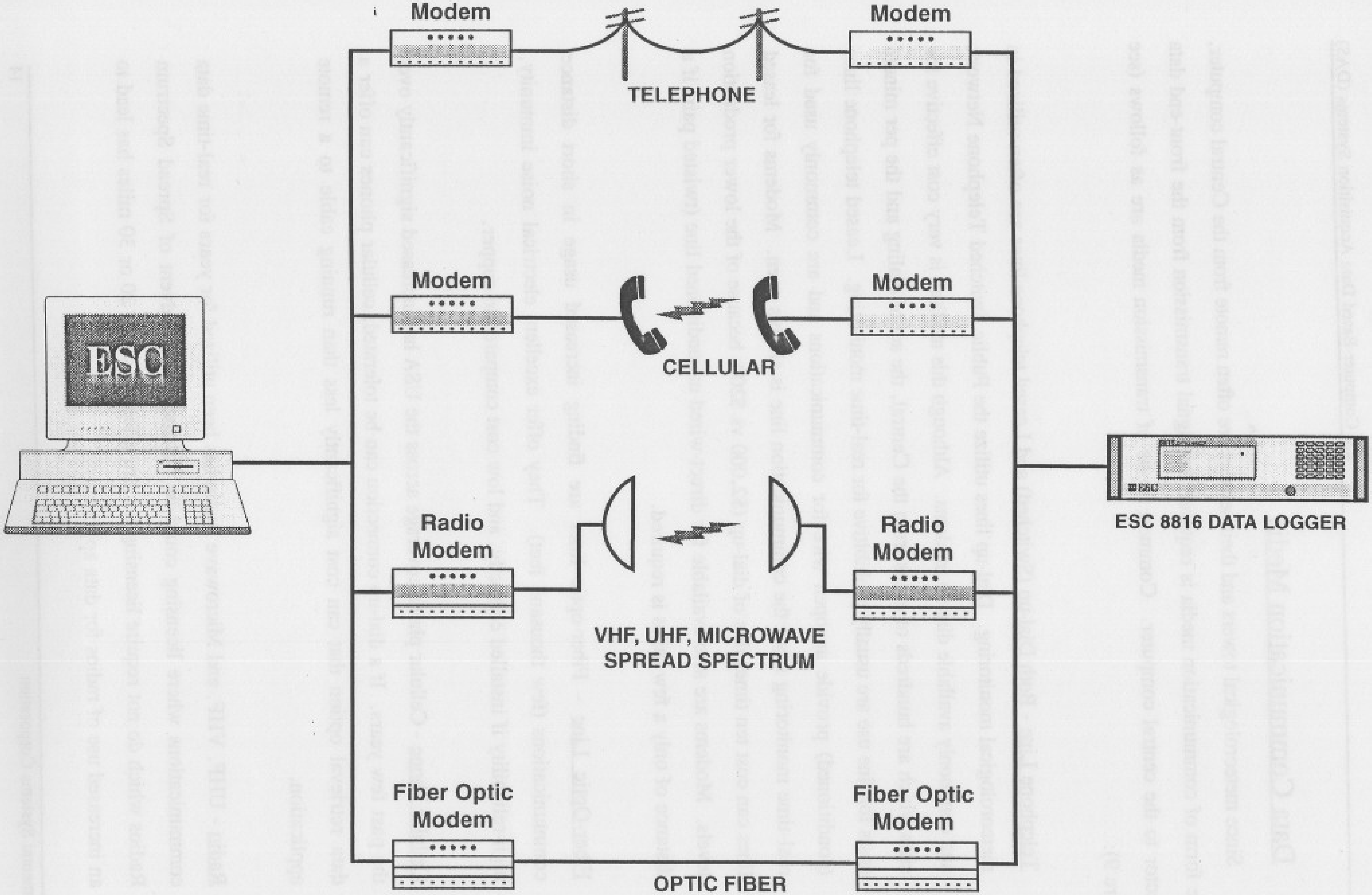


FIGURE 9

DATA COMMUNICATION MEDIA

Internet - Although, to our knowledge, no current meteorological data acquisition systems utilize the Internet, the prospect of low cost communications worldwide (where ISP's are available) is sure to be exploited in coming years.

2.4 Central Applications Software

The Central Applications Software in a meteorological monitoring system is one of the most important elements in the system. Besides the requirements that the software function with the hardware and operating system of choice, this package provides the following tasks:

1. Storage And Editing of Configuration (i.e., number of sites, number and type of parameters)
2. Automatic Data Retrieval (Polling) From The Remote Data Collectors on Command, Together With Catch-up Polling If Needed.
3. Real-time Displays That Are Automatically Updated After Polling.
4. Data Insertion And Editing of Data in The Database
5. Data Reporting
6. Data Transfer to Other Software (such as dispersion models)
7. Data Backup and Archiving (to tape or optical disk)

Each of these tasks must be accomplished so as to complement the other tasks or supply requested information as needed. If redundant computers are utilized, the software on one machine may need to interact with software on the backup computer in the event of a failure of some component.

In order to insure high quality data, the Central must retrieve and store flags from the front-end collector and provide error-checked data communications to prevent noise corruption. In database storage, it is highly recommended to retain both raw and editable database so that data can always be recovered if an editing error is made.

The Central Software also provides the primary user interface to the system operators so it is the component with which the data users interact. It is important that the interface is designed to maximize the efficiency of the operation. The use of Windows-based software with development tools that facilitate GUI programming allows the interface to be easily structured for intuitive interaction.

Common displays and reports are shown in Figures 10, 11, and 12.

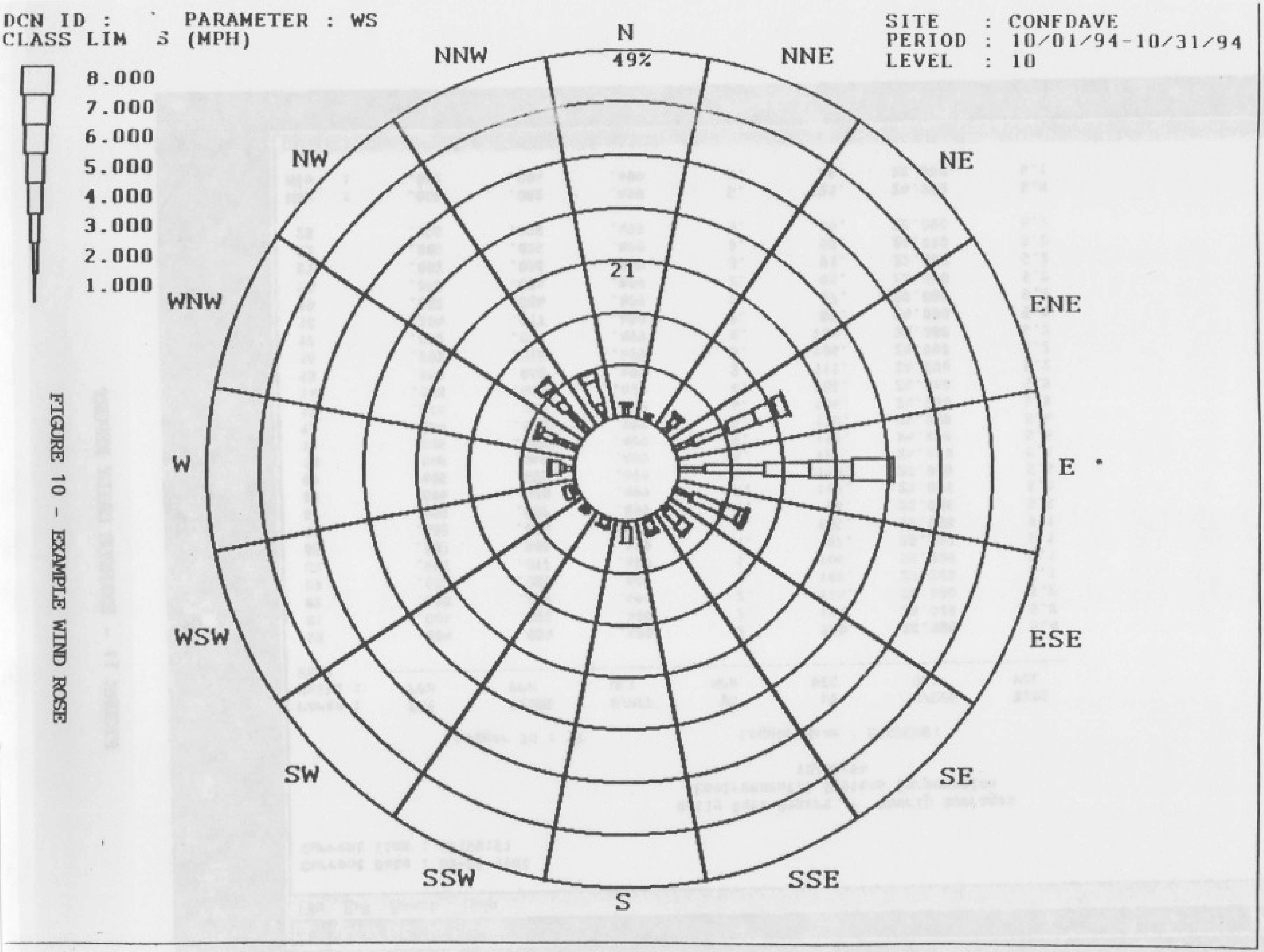
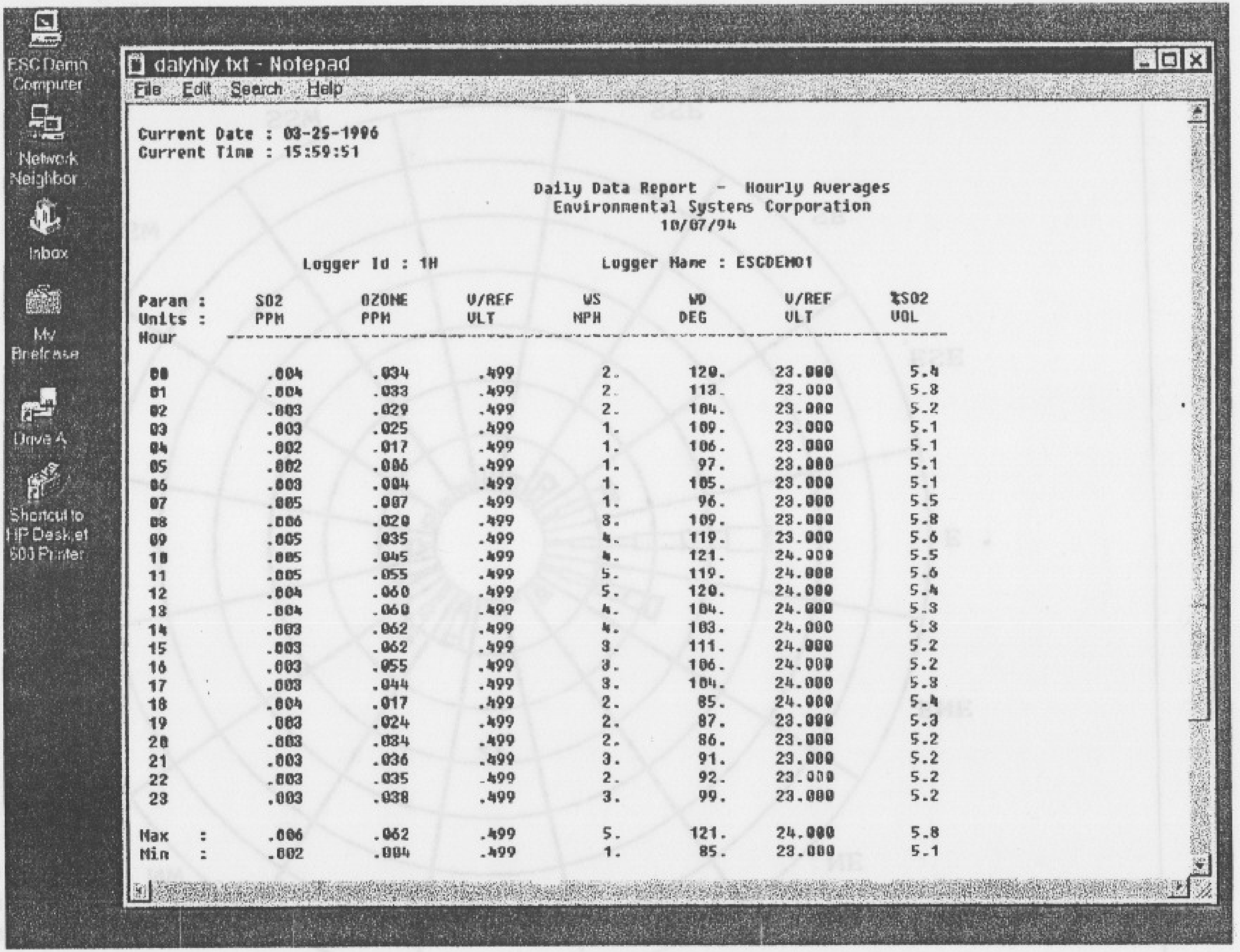


FIGURE 10 - EXAMPLE WIND ROSE



Current Date : 03-25-1996
Current Time : 15:59:51

Daily Data Report - Hourly Averages
Environmental Systems Corporation
10/07/94

Logger Id : 1H Logger Name : ESCDEM01

Param :	SO2	OZONE	V/REF	WS	WD	V/REF	%SO2
Units :	PPM	PPM	VLT	MPH	DEG	VLT	VOL
Hour							
00	.004	.034	.499	2.	120.	23.000	5.4
01	.004	.033	.499	2.	113.	23.000	5.8
02	.003	.029	.499	2.	104.	23.000	5.2
03	.003	.025	.499	1.	109.	23.000	5.1
04	.002	.017	.499	1.	106.	23.000	5.1
05	.002	.006	.499	1.	97.	23.000	5.1
06	.003	.004	.499	1.	105.	23.000	5.1
07	.005	.007	.499	1.	96.	23.000	5.5
08	.006	.020	.499	3.	109.	23.000	5.8
09	.005	.035	.499	4.	119.	23.000	5.6
10	.005	.045	.499	4.	121.	24.000	5.5
11	.005	.055	.499	5.	119.	24.000	5.6
12	.004	.060	.499	5.	120.	24.000	5.4
13	.004	.060	.499	4.	104.	24.000	5.3
14	.003	.062	.499	4.	103.	24.000	5.3
15	.003	.062	.499	3.	111.	24.000	5.2
16	.003	.055	.499	3.	106.	24.000	5.2
17	.003	.044	.499	3.	104.	24.000	5.3
18	.004	.017	.499	2.	85.	24.000	5.4
19	.003	.024	.499	2.	87.	23.000	5.3
20	.003	.034	.499	2.	86.	23.000	5.2
21	.003	.036	.499	3.	91.	23.000	5.2
22	.003	.035	.499	2.	92.	23.000	5.2
23	.003	.038	.499	3.	99.	23.000	5.2
Max :	.006	.062	.499	5.	121.	24.000	5.8
Min :	.002	.004	.499	1.	85.	23.000	5.1

FIGURE 11 - EXAMPLE DAILY REPORT

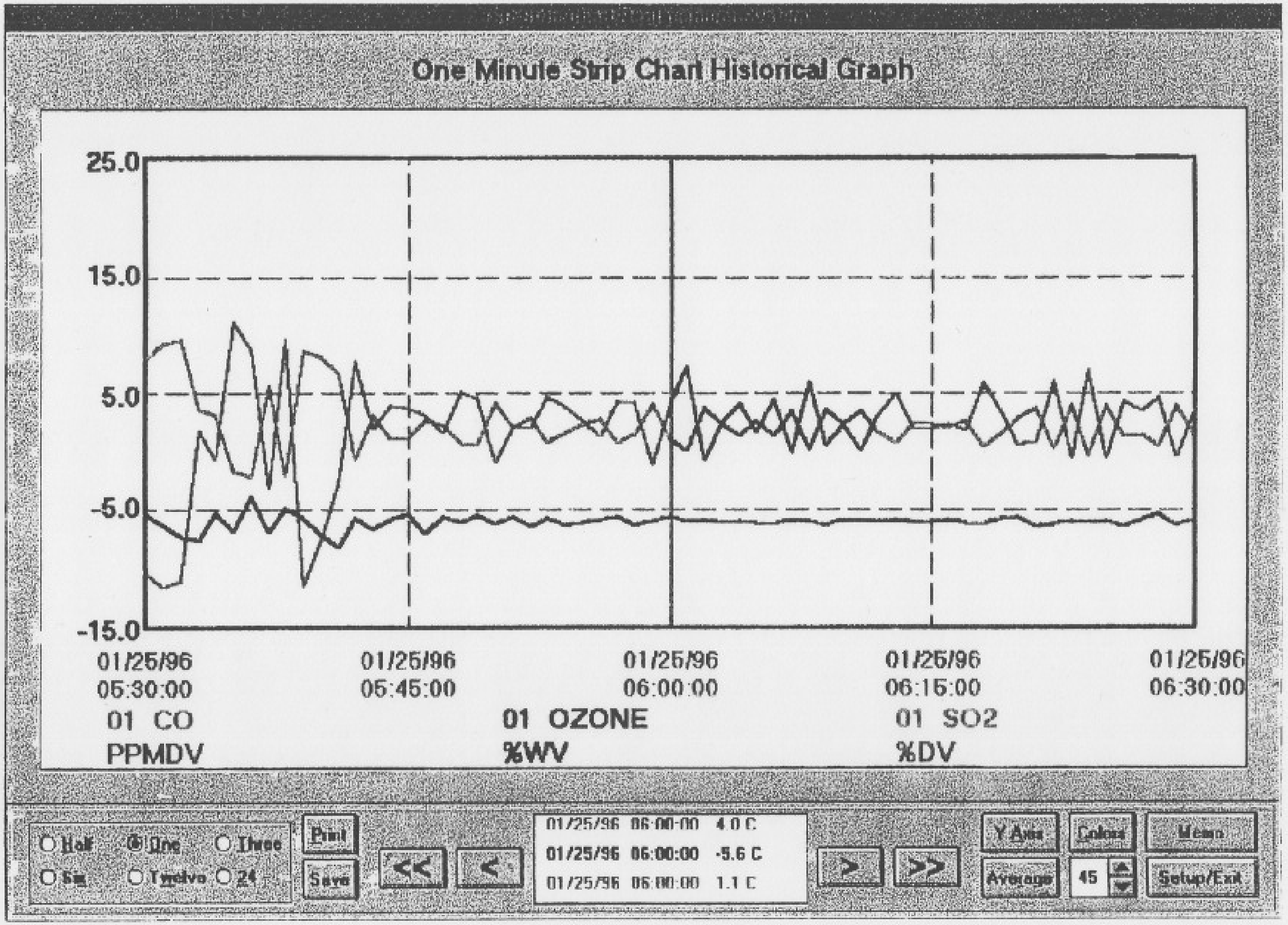


FIGURE 12 - EXAMPLE TRENDING DISPLAY

3.0 CONCLUSION

The integration of multiple components is the key to successful data acquisition for meteorological monitoring. As computers have offered more power for lower cost over the last ten years, the capability of these data systems has substantially increased. New developments in microprocessors (Pentium, Pentium II), operating systems (Windows NT), and communication media (fiber-optic cable, spread spectrum radios) have facilitated the developers ability to integrate these systems and provide greater value than in the past. As this trend continues and new DAS components are developed or enhanced, the power of these systems and their use in meteorological monitoring will continue to grow.