COO-2428-2

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

77 Massachusetts Avenue
Cambridge, Massachusetts 02139

M. Ruane, J. Gruhl, F. Schweppe, B. Green(ERT) and B. Egan(ERT)

AEC Report COO-2428-2

"THE DESIGN AND IMPLEMENTATION
OF A
DEMONSTRATION
SUPPLEMENTARY CONTROL SYSTEM"

February 1, 1974-July 31, 1974

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Principal Investigator

Fred C. Schweppe
Associate Professor

Interim Final Report

on

The Design and Implementation of a Demonstration

Supplementary Control System

AEC Document No. COO-2428-2

Abstract

This report documents the progress made during the six-month Phase I portion of a project to design and implement a Supplementary Control System on four coal-burning power plants in western Pennsylvania. Preliminary data collection and analysis, air quality modeling, meteorological forecasting, control strategy development and program definition are discussed. Coordination of Phases I and II is explained. Appendices include data on meteorology, the AIRMAP air quality monitoring system and plant and system parameters affecting control strategy design.

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1.0 INTRODUCTION

The Interim Final Report is submitted as one of the requirements for completion of contract AT(11-1)-2428. It covers the period from February 1, 1974 to July 31, 1974, and is a comprehensive report of the progress on tasks 1 through 5 of the original proposal, "The Design and Implementation of a Demonstration Supplementary Control System." The work described in this report is continuing and the project final report will be available August 1, 1975.

A Supplementary Control System (SCS), as an environmental control technology that takes advantage of the atmosphere as a time-varying resource, provides both environmental and economic benefit. It provides an immediate solution to the ambient air quality threats posed by the shortages and high costs of low sulfur fuels and the present unavailability of reliable, economic and environmentally sound flue gas desulfurization equipment. The use of SCS by isolated sources would be a step toward improved ambient air quality, clean fuel conservation, a more reliable electric energy supply and consumer savings.

SCS is an evolving technology that is based on the combination of several existing technologies. Its principal components are shown below:

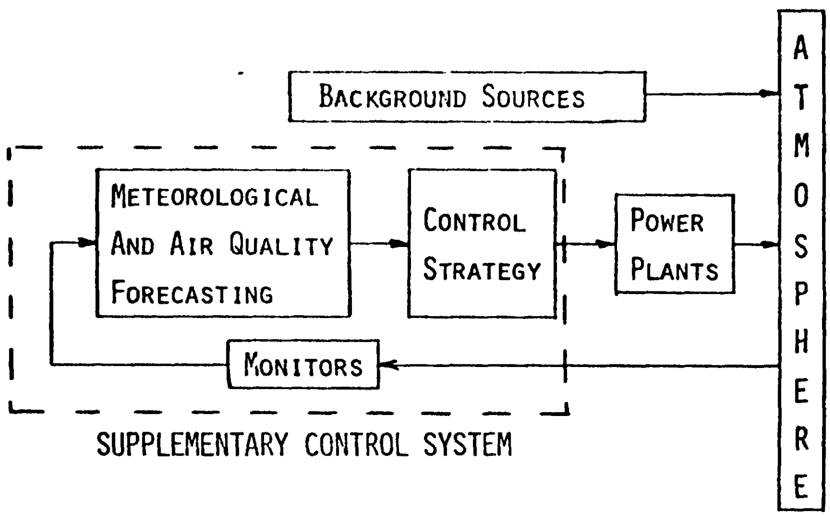


Figure 1.1

First generation schemes such as those at TVA [Montgomery, et al, (2) (3)] have demonstrated both economy and improvement of ambient air quality.

This project is implementing an SCS in western Pennsylvania on four coal burning power plants of the Penelec system which total 5,200 MWe. The relationships among the project participants are shown in Figure 1.2.

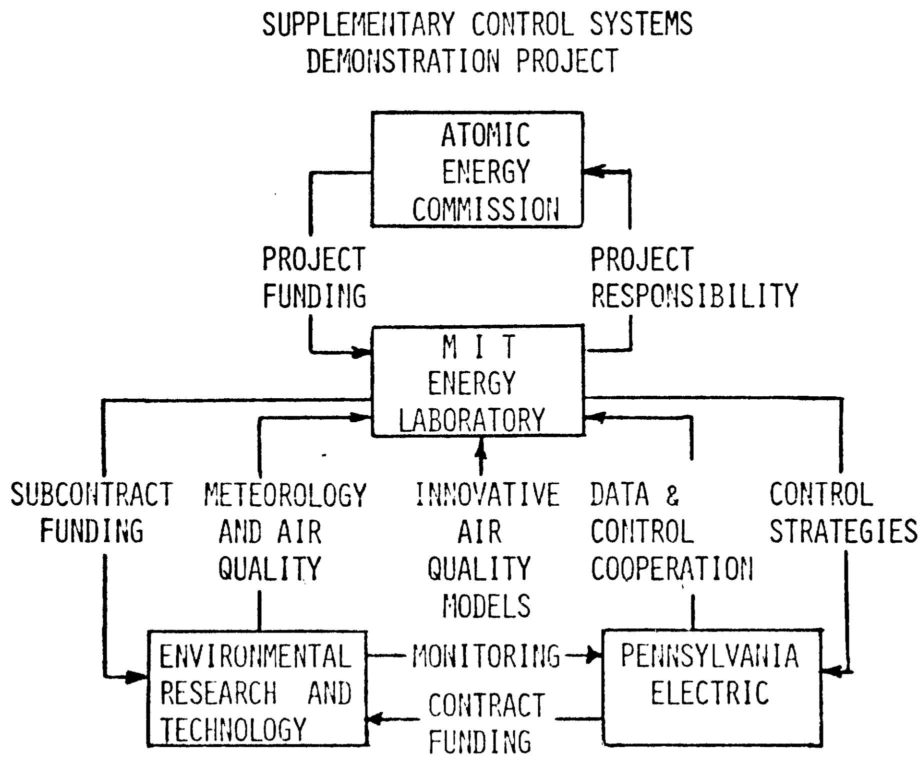


Figure 1.2

The demonstration SCS is a second generation design intended to provide improved reliability, increased objectivity of operation and easier regulation by state and federal agencies. The project includes a parallel effort on the development of a third generation SCS method with even greater reliability and objectivity in the air quality prediction process. The third generation design also provides a completely automatic means of regulation by appropriate agencies. For the immediate future, the main SCS role is in meeting existing SO_2 ambient air quality standards by means of presently available technology and fuel supplies.

Page 12 of the original proposal outlined five tasks for the Phase I period of the contract:

1) Preliminary Data Collection and Analysis
2) Air Quality Model Adaptation and Development
3) Forecast Model Adaptation and Development
4) Control Logic Adaptation and Development
5) Operational Program Definition.

After a summary, these five topics will be discussed individually and related to the work plan laid out in the original proposal. The coordination of the efforts of Phase I with those of Phase II will then be considered. The last section will include references and appendices containing data and other support information.

A topical classification of the work performed will frequently be mentioned. It includes:

1) Operational monitoring and air quality forecasting
2) Control strategy development
3) Innovative air quality modeling

These three topical groupings, in addition to a fourth, analysis, form the structural framework for the continuing Phase II effort and are mentioned in this report to facilitate the continuity of Phases I and II.

This report describes work supported by the United States Atomic Energy Commission, Division of Applied Technology, under contract number AT(11-1)-2428.

2.0 SUMMARY

2.0.1 Delays

Phase I was essentially a period of preparation for the actual demonstration SCS on the Penelec plants, which will occur in Phase II. The planned preparations were not completed, but the reasons for the delays were more human than technical. Union regulations affecting AIRMAP installation, bureaucratic tie-ups on the collection of Penelec and PJM (Pennsylvania-New Jersey-Maryland Interconnection) operating data, and administrative problems in contract funding and program definition for Phase II have all caused the technical program to be delayed. The delays that have occurred should not affect the final success of the project since they can be corrected during Phase II before the critical Exercise Control phase.

2.0.2 Data Sources

The available sources for air quality and meteorological data in the Penelec region are better than average due to recent EPA studies. However, they concentrate on relatively short periods of time during the day and year. Independently, they are therefore limited in their usefulness for validating real time models, and conclusive validation will have to await AIRMAP data. Plant and power system data has been available through Penelec and arrangements to get PJM data have been made. This has proven to be a slower process than expected.

2.0.3 Monitoring System

The AIRMAP real-time monitoring system is installed and tied in to the ERT data center in Lexington, Mass. One SO_2 monitor and one meteorological tower have been eliminated from the planned system because of siting problems. There remain sixteen SO_2 monitors and one meteorological tower. All of the SO_2 monitors became operational in the period from April to July. The meteorological tower did not become operational until mid-August.

2.0.4 Possible AQ Violations

Penelec's air quality performance has been good in the past, with no apparent violations of standards occurring. The AIRMAP system has observed concentrations during area-wide fumigations which indicate possible violations, as would possibly be expected to happen with a more extensive monitoring net. These initial results indicate the Penelec plants are not effectively isolated from upwind sources during a stationary inversion. Hence background concentrations may be more important than originally anticipated. In the event that no control is needed under SCS, an artificial standard may be set to test the system.

2.0.5 Control Options

Operating data from Penelec and PJM indicate that it is physically possible to change stack temperature, switch fuel and shift load. However, there exists significant economic incentive (up to $45,000/hr/plant) to control by plume temperature modifications. Economic and reliability comparisons of all control options, including scrubbers, have been planned.

2.0.6 Innovative Air Quality Modeling

Two basic state estimation formulations have been developed and a third physical model has been designed. This effort is parallel to the principal demonstration of SCS which applies standard ERT AQ models. Efforts at developing an efficient state estimator algorithm have been temporarily stopped. Instead, a general purpose estimator, GPSIE, has been chosen to develop numerical results. A test day, using EPA LAPPES data, has been chosen to begin a limited validation attempt while waiting for an AIRMAP data base to be established.

2.0.7 Phase II Prognosis

No significant unforeseen technical difficulties have developed in Phase I. It is expected that Phase II will be completed on schedule.

3.0 TASK AREAS

Phase I was intended to concentrate on tasks 1 - 5 of the original project proposal. Each of the following is discussed separately and in detail in the following subsections:

Task 1 Preliminary Data Collection and Analysis

Task 2 Air Quality Model Adaptation and Development

Task 3 Forecast Model Adaptation and Development

Task 4 Control Logic Adaptation and Development

Task 5 Operational Program Definition

The installation of the AIRMAP system, its maintenance and operation are not tasks funded by this project. That effort is undertaken through a contract between Penelec and ERT. Penelec has agreed to allow the use of its data in this project as well as allow the use of necessary, economic control action on its plants.

3.1 PRELIMINARY DATA COLLECTION AND ANALYSIS

This task was identified to establish the type and quantities of data available to the project. It was also hoped that analysis of the data would provide insight into potential problems (and their solutions) expected to occur in the demonstration phase. Phase I data collection fell into the following categories:

1) Topography
2) Meteorology
3) Air Quality
4) Chestnut Ridge AIRMAP Network
5) Fuel Characteristics
6) Operating Characteristics
7) Costs

The sources of this data are varied, but it is unlikely that other plants desiring to implement SCS would have difficulty in gathering this information. All of the plant and control related information should be available, since it is necessary for normal system operation decisions. Topographic and meteorological data can be obtained through the United States Geological Survey and the National Weather Service. Air quality data and source inventories are available through the state and federal EPA. The use of the Penelec plants as the subjects of an extensive five-year study by the EPA, the Large Power Plant Effluent Study (LAPPES), facilitated the collection of air quality data and meteorological information in this project. The LAPPES data has been used mainly in the development of innovative air quality models, and this type of data would not normally be needed to establish an operational SCS.

3.1.1 Topography

The four power plants of this study are located in the Chestnut Ridge area of the Allegheny Mountains, to the northwest of Johnstown, Pennsylvania, as shown in Figure 3.1.1. There is a general upward slope of the land to the east in this region and the most prominent features, Chestnut Ridge and Laurel Ridge, are oriented in a SW to NE direction. Laurel Ridge is the bigger, reaching a height of approximately 2,800 feet (854m) and being located between Johnstown and the Conemaugh and Seward plants. Chestnut Ridge has a maximum height of approximately 2,500 feet (762m) and lies between the Homer City plant and the Conemaugh and Seward plants.

The region is generally hilly with 300 feet to 500 feet (90m to 160m) being a typical distance from the valley floor to hilltop. Creeks and rivers are numerous with the Conemaugh River being the most prominent and cutting a 1,300 foot deep (400m) valley through Laurel Ridge.

The Seward plant is located in a valley along the Conemaugh River southwest of Seward, Pennsylvania. It is highly susceptible to terrain effects because of its short stacks (150 ft.) (45m) with a stack base elevation of approximately 1,090 feet (334m) above mean sea level (MSL). Within four miles to the east and south Laurel Ridge rises 1,500 feet (460m) above the stack tops. The Conemaugh River valley passes through Laurelridge nearby. To the north and west there are smaller hills which still rise several hundred feet above stack top, and about 7 miles (11km) further to the west Chestnut Ridge begins.

East of New Florence, Pennsylvania, about two miles southwest of the Seward plant and also on the Conemaugh River is the Conemaugh station. This plant also is susceptible to topographic influences, despite its 1,000 foot (305m) stacks. Stack base elevation is 1,090 feet MSL (334m) so that within four miles (6.4km) to the east and south Laurel Ridge rises over 500 feet above stack top.

The Homer City plant, located about three miles (5km) southwest of Homer City, Pennsylvania, is on a plateau. Stack base elevation is approx- 1,220 feet (371m) MSL and much of the terrain to the north, west and south is about the same elevation, although slightly hilly. Chestnut Ridge lies two miles (3.2km) to the east but only rises to about 1,800 feet (550m), or approximately mid-stack. Stack heights are 800 feet (244m). A narrow river valley is between the plant and Chestnut Ridge, causing the terrain to drop off about 220 feet (65m) temporarily. In the region to the east of the plant there exists a plateau at elevation 1,300 feet (397m) after

Chestnut Ridge. Beyond the plateau, about ten miles (16km) from the plant, Chestnut Ridge rises to about 2,000 feet (610m) again.

The Keystone plant is in a shallow valley about two miles west of Shelocta, Pennsylvania. Stack base elevation is approximately 1,000 feet MSL (305m) with stack heights of 800 feet (244m). The surrounding countryside is hilly and the highest peaks reach about mid-stack height. Several rivers and creeks pass nearby, forming valleys about 300 feet (92m) below the hilltops.

The plants lie in an approximate straight line running southeast to northwest with about 25 miles (40km) separating the Keystone plant from Connemaugh and Seward. Pittsburgh lies about 40 miles (64km) west of Connemaugh and 35 miles (56km) southwest of Keystone.

3.1.2 Meteorology

Meteorological data for the Penelec region was collected in order to establish an understanding of the historical patterns of atmospheric behavior in the area, and to identify data sources which could be useful during the demonstration phase. In addition to searching through printed sources of past meteorological data, daily U.S. National Weather Service data from the region has been collected since mid-June as part of the ERT forecasting effort. This includes both teletype and facsimile data.

The plants are located in rural areas and all have begun operation in the last decade except Seward. Thus no site-specific meteorological data base exists for the plants. There are several small airports in the region and Pittsburgh is relatively close. The airports [Blairsville, Johnstown, Altoona and Allegheny County] provide records of surface wind speed and direction, temperature, pressure, relative himidity, precipitation and cloud cover. In addition Pittsburgh also supplies data on upper atmosphere winds and vertical temperature soundings, using a slow-ascent EMSU unit, and is the closest station with this information. Pittsburgh also has stability wind rose data compiled, as does Altoona and Philipsburg.

The best, though limited, source of on-site meteorological data is the four-volume Large Power Plant Effluent Study (LAPPES) which was conducted over a period of four years by the EPA. The limitations arise because LAPPES concentrated only on morning phenomena and because LAPPES was not a continuous study. It followed the completion of the construction of the large plants and provides data for the following periods:

October 13 - 31, 1967	April 8 - May 10, 1969
March 14 - April 12, 1968	October 9 - November 7, 1969
May 5 - June 1, 1968	April 20 - May 15, 1970
June 25 - July 23, 1968	October 14 - November 16, 1970
October 15 - November 7, 1968	April 21 - May 20, 1971

October 18 - November 17, 1971

Surface meteorology data from Jimmy Stewart was supplemented with an insolation monitor in LAPPES. Pilot balloons and radiosondes were released and tracked and instrumented helicopters were used to record the atmosphere's vertical structure. Unfortunately this data was generally taken only at one plant in any study period.

The following summary of regional climatology has been taken from the LAPPES report:

> The area of study has a humid, continental type of climate modified slightly by its nearness to the Atlantic Seaboard and the Great Lakes. Summers are mild but frequently humid because of invasions of air from the Gulf of Mexico. Winters are reasonably brisk with occasional periods of extreme cold; spring and fall months have moderate to cool temperatures. Precipitation is well distributed throughout the year, with appreciable snowfall in winter and the maximum frequency of thunderstorms in early summer.

> Surface inversions are relatively frequent during the warmer months of the year; in winter, however, cloudiness persists because of this area's proximity to the track of west-east migratory storms and the frequent showery weather associated with north-west winds across the Great Lakes. Cold air drainage induced by the many hills leads to frequent formations of early morning fog, which may be quite persistent in the deeper valleys during the colder months. The study area is also subject to relatively frequent occurrences of stagnating anticyclones, a condition conducive to high, ambient pollution levels because of the resulting poor ventilation.

Stability wind roses from Pittsburgh, Altoona and Philipsburg are included in the Appendix. Also included are tabulations of Pittsburgh's seasonal and annual mixing depths and average wind speeds through the mixing depth, which are measures of regional ventilation of pollutants. The interaction of winds and topography are discussed in the next section on Air Quality, while the meteorological monitors used in the Chestnut Ridge Airmap System are described in section 3.1.4.

Meteorological forecasting at ERT in Phase I has been based on the airport data mentioned above and National Weather Service data. A forecasting record of predicted and actual values of surface wind speed and direction, precipitation, and stability class at the four airports has been maintained since forecasting began in mid-June.

3.1.3 Air Quality

The interaction of the mesoscale winds with the topography in Penelec produces channeling and downwash effects on the SO_2 plumes which in turn affect the patterns of SO_2 concentrations at ground level. The effects are greatest at Seward and Conemaugh, which are in a valley between Chestnut and Laurel Ridges, and least at Keystone, which is in hilly countryside. The Homer City plume exhibits a downwash in the lee of Chestnut Ridge onto a plateau. An illustration of channeling which is typical of this region is shown in the Appendix. The wind roses of Philipsburg and Altoona (Blair Country Airport) which are 40 miles apart and under the influence of the same mesoscale winds, exhibit differences in wind direction frequencies characteristic of the SSW-NNE valley influence in Altoona. The LAPPES data reflects the downwash phenomenon through records of increased concentrations in the lee of Laurel Ridge and in observations of pilot balloon subsidence. These phenomena indicate a need for three-dimensional wind field modeling.

The historical air quality performance of the Penelec plants with tall stacks has been good. No violations of standards have previously been detected by the State of Pennsylvania, or by the monitoring system which Penelec had in operation before installing AIRMAP. According to Penelec environmental engineers, only once, during an episode condition, were any of the plume reheating devices used in an attempt to reduce concentrations. Seward, however, has had to install coal cleaning facilities because of its poor performance, and Penelec has plans to construct a new stack. The Penelec plants appear to satisfy the EPA draft requirement that SCS be applied only to isolated sources. The nearest SO_2 source of any magnitude is a Bethlehem steel plant in Johnstown. Pittsburgh and Allegheny County have a large number of significant SO_2 sources, and under certain conditions, i.e., stagnating high pressure and light winds, their emissions affect the Penelec region near Chestnut Ridge. It will be necessary to reflect this possible contribution to the background concentration from Pittsburgh during operational forecasting.

The air quality data from the AIRMAP network in Chestnut Ridge region was collected in real time during the month of July. One-hour average SO_2 values for the month are tabulated in the Appendix.

The highest one-hour average SO_2 concentration monitored during July was the 0.478 ppm recorded at the West Fairfield (C1) station between 0300 and 0400 EST on 12 July. This station-hour was also the beginning of the period that had the highest three-hour average (0.327 ppm) observed during the month. The Pennsylvania three-hour standard is .500 ppm.

On this date a high-pressure area was centered over Lake Erie. Winds were generally very light with a northerly component. Allegheny County Airport and Philipsburg reported calm for hours 0400 and 0500. All SO_2 monitors except that at West Fairfield were recording very low values. This implies that a local source was responsible for the high concentrations measured at West Fairfield. It is reasonable to assume that the wind was channeled southwest between Chestnut and Laurel Ridges from the Conemaugh and Seward power stations, which are respectively 5 and 8 miles to the northeast of the West Fairfield monitor, and that the high SO_2 readings were due to one or both of these power plants. By 0800 the winds had increased to more than six mph from the northeast at both Blairsville and Johnstown, and the combination of increased ventilation and decreasing stability as the sun heated the ground reduced the SO_2 concentration reported by the West Fairfield monitor to more normal levels by 1000. The data for this period are given in Table 3.1.1.

TABLE 3.1.1

Data for Morning of 12 July, 1974

Hour EST	BSI Wind Degrees	BSI Wind Kts	JST Wind Degrees	JST Wind Kts	AGC Wind Degrees	AGC Wind Kts	W. Fairfield SO_2(ppm)
01	No Report		No Report		20	6	.036
02	No Report		No Report		10	5	.087
03	No Report		No Report		90	3	.145
04	No Report		No Report		Calm		.478
05	70	8	No Report		Calm		.295
06	60	10	Calm		90	3	.209
07	40	7	Calm		10	4	.131
08	50	6	60	6	40	6	.079
09	20	6	310	7	70	7	.114
10	40	6	350	9	70	5	.154
11	40	6	360	8	350	3	.035
12	30	9	360	7	020	5	.002

Notes: (1) BSI = Blairsville, JST = Johnstown Airport, AGC = Allegheny County Airport south of Pittsburgh

(2) The SO_2 concentrations are listed for the hour at which the average ended.

The highest stationary monitor (bubbler) reading during the LAPPES study for a three-hour average was 0.230 on March 25, 1968. At that time there was a large high-pressure area over the Gulf of Mexico with a ridge extending to Lake Ontario. Winds were light and from the west southwest and the highest concentration occurred 9 km from Keystone. Several other monitors in the same region also registered high values during the same time period.

The 24-hour standard of 0.14 ppm was reached at the Luciusboro (P3) monitor between 1100 July 13 and 1000 July 14. During the afternoon of the

13th, several other monitors also recorded high values, notably stations P4 (Armagh), P5 (Florence Sub) and K2 (Parkwood). Station P3 reported its highest one-hour average (0.378 ppm) from 1300 to 1400 on July 13, station P4 its highest three-hour average (0.166 ppm) between 1300 and 1600, stations P5 and K2 their highest one-hour averages (0.324 and 0.260 ppm respectively) between 1200 and 1300 and station K2 its highest three-hour average (0.184 ppm) between 1200 and 1500.

During this period an almost stationary high-pressure area was centered over West Virginia and southwestern Pennsylvania. Winds were calm at Allegheny County and Johnstown Airports for several hours prior to 1000 on July 13. Scattered to light broken clouds prevailed at 25,000 feet until midnight. SO_2 concentrations increased rapidly as the wind picked up in the morning. Wind directions at Blairsville, Johnstown, and Allegheny County were general west-southwesterly (at Allegheny County; Johnstown and Blairsville do not report at night). The following morning, winds continued southwesterly, and the SO_2 concentrations at Luciusboro decreased gradually as the wind increased in advance of a cold front approaching from the northwest. The data from Luciusboro and the reporting weather stations are listed in Table 3.1.2.

It would appear from this data that the high SO_2 concentrations recorded were due to the Homer City Station, at least until sunset on the 13th, and advection from the Pittsburgh area.

Advection of SO_2 from Pittsburgh appeared to be a problem also on the morning of July 9, when seven monitors in the southern part of the network recorded values over 0.10 ppm during some part of the period 0500-1100. Winds were light from the southwest to west, and the ground fog and haze reported by

T A B L E 3.1.2

Data for Period 1100 13 July 1974 to 1000 14 July 1974

	HOUR EST	BSI Wind Degrees	BSI Wind Kts	JST Wind Degrees	JST Wind Kts	AGC Wind Degrees	AGC Wind Kts	Luciusboro SO_2 (ppm)
7/13	11	250	6	270	7	330	6	.032
	12	-	-	Calm		280	6	.149
	13	300	7	290	10	260	4	.213
	14	300	8	310	7	250	6	.378
	15	300	8	310	8	310	5	.336
	16	-	-	310	10	280	5	.181
	17	300	9	310	12	280	5	.135
	18	-	-	330	12	250	7	.083
	19	300	6	310	10	230	6	.076
	20	260	6	300	7	240	6	.045
	21	-	-	290	6	230	6	.055
	22	-	-	290	7	220	6	.090
	23	-	-	-	-	210	7	.090
7/14	00	-	-	-	-	-	-	.048
	01	-	-	-	-	220	6	.057
	02	-	-	-	-	230	6	.104
	03	-	-	-	-	210	6	.140
	04	-	-	-	-	200	6	.187
	05	230	9	-	-	200	6	.190
	06	230	10	-	-	180	5	.175
	07	290	7	240	12	190	7	.162
	08	230	10	270	12	200	5	.130
	09	220	11	270	14	210	6	.126
	10	240	10	270	10	180	8	.114

(Notes for Table 3.1.1 pertain to this Table also)

NWS observers indicated stable stratification. A broad diffuse high pressure area lay to the south and gradients were very light. The highest values at Penn View (H2) and Laurel Ridge (C2) were measured between 0700 and 0900, while the highest values at the less elevated stations occurred an hour or so later. This behavior is suggestive of the fumigation of a broad elevated plume such as would be caused by the industry in Allegheny County. The air cleared up somewhat after 11:00, when the wind became more northwesterly. Meteorological data for this period are given in Table 3.1.3.

TABLE 3.1.3

Meteorological Data for Morning of 9 July, 1974

HOUR	BSI Wind		JST Wind		AGC Wind	
EST	Degrees	Kts	Degrees	Kts	Degrees	Kts
04	-	-	-	-	200	3
05	260	7	-	-	210	4
06	240	8	270	6	190	5
07	240	7	250	8	210	5
08	250	9	160	9	210	5
09	250	9	300	10	230	5
10	240	10	320	10	250	5
11	290	8	330	12	270	7
12	260	9	350	10	230	7

In contrast to the periods of high concentrations described above, July 21 was a day on which all stations averaged well below their monthly average values. A high pressure area was centered over Michigan; the day was clear and cool with fairly light and variable winds in response to the gentle gradient. The only high SO_2 concentration recorded was the 0.144 ppm at West Fairfield between 1100 and 1200. This anomalous value may have been due to the apparent passage of the wind direction through north during that hour. The meteorological data for the day are given in Table 3.1.4. Note that no reported wind direction would produce advection from the west.

The monthly averages for July at four stations (Gas Center P1, Luciusboro P3, Brush Valley H1, and Penn View H2) are higher than the annual standard of 0.03 ppm. Because background value should be minimal during this month, it is possible that the annual standard may be in jeopardy in the Chestnut Ridge region.

This preliminary examination of the air quality in the Penelec area indicates that advection of SO_2 from industrial and background sources to the south-west and west has a major impact and will have to be modeled operationally.

Mr. Richard Johnson of the Pennsylvania Bureau of Air Quality and Noise Control reports that stack and emission data for the major industrial sources and SO_2 emissions for important area sources is available from his office. It will be obtained early in Phase II.

TABLE 3.1.4

Meteorological Data for 21 July 1974

HOUR	BSI Wind		JST Wind		AGC Wind	
EST	Degrees	Kts	Degrees	Kts	Degrees	Kts
01	-	-	-	-	50	4
02	-	-	-	-	40	5
03	-	-	-	-	50	4
04	-	-	-	-	70	5
05	120	7	-	-	50	6
06	110	10	-	-	60	5
07	120	9	60	5	60	5
08	120	8	70	5	80	6
09	120	8	90	5	80	5
10	350	7	100	5	80	5
11	40	4	360	9	60	7
12	70	9	120	10	80	6
13	20	3	80	12	80	7
14	110	8	120	8	60	8
15	80	9	150	10	90	6
16	180	4	120	9	110	4
17	90	8	140	12	30	4
18	70	7	130	12	110	5
19	-	-	120	7	Calm	
20	-	-	130	6	-	-
21	-	-	120	8	-	-
22	-	-	90	7	Calm	
23	-	-	-	-	90	5
00	-	-	-	-	110	4

3.1.4 Chestnut Ridge AIRMAP Network

A description of the AIRMAP network is provided in the Appendix. Hourly average SO_2 data for the month of July is also tabulated in the Appendix, as are examples of the two minute output which is available. Under normal operation the hourly average data is automatically logged and the two minute data destroyed. At the option of the computer operator two minute data can also be recorded.

A discussion of the significant aspects of the July AIRMAP data is included in section 3.1.3. It should be noted that AIRMAP routinely monitors several pollutants and meteorological quantities, although only SO_2 is of interest in this SCS project.

3.1.5 Fuel Characteristics

Most of the information on fuel characteristics can be found in the Appendix on CONTROL. Generally, the type of coal burned at the plants at any given time could be quite different from coals burned at other times. On the average, though, the coal has the characteristics:

Moisture	4%
Volatile Matter	30%
Fixed Carbon	48%
Ash	17%
Sulfur	2.2%
Btu per lb.	12,000
Calories per gram	6,600

Some of these characteristics can vary by significant amounts. For example, sulfur content can vary from 1.6% to 6.0%, and in a single batch can vary from say 1.6% to 3.2%. Grab samples are made of all the truckloads that come in, being analyzed daily for each shipping company. The conveyor belt is sampled by an automatic cutter, and analyzed daily.

3.1.6 Operating Characteristics

The facilities in this study are base-loaded facilities. Being once-through supercritical devices, they are generally forced out of service due to failures several times a month. This will considerably help the control simulations by providing emission reductions which can be used to analyze air quality improvement in the area.

The incremental heat rate of these large plants ranges from about 7,300 Btu/net KWh at the lower end to about 8,500 Btu/KWh near full load.

The nominal startup-shutdown rate is 5MW/minute, which for one of the 900MW units would mean about 3 hours to completely change the unit from on to off, or off to on.

A larger sample of the information on operating characteristics is contained in the CONTROL Appendix.

The load on this system has an annual peak to annual minimum ratio of 32%, and a 7% per year growth rate.

3.1.7 Control Options

Load shifting has large economic penalties for the plants involved, with 5-6 mills/KWh efficiency compared to 10 to 55 mills/KWh for replacement power. Thus, load shifting would preferably have to be done offpeak, and would require the consent of all the part owners.

Fuel switching would require about a 6-hour lag to implement, with about $10 per ton additional cost for 1.25% sulfur coal (instead of 2.4% sulfur coal). A coal cleaning facility could be set up on the system. For about 10¢/MBtu and a loss of about 10% of the Btu's, a few tenths of a percent could be removed from the sulfur content of the coal.

Increasing stack gas temperature from 290° to 600°F could be accomplished by 3 men in about 1 hour. The penalty is 1% loss in efficiency per each 40°F temperature change. The effectiveness is about a 7% reduction in groundlevel concentrations (for full implementation).

Simulated controls will be possible at many times due to the large number of forced outages that occur on the plants involved (up and down several times a month).

Penelec would like to exercise an SCS control for several reasons. First, it is in their operating license to have such a control procedure. They also believe there could be long-term gains in air quality, for use on SO_2, SO_4 and any other pollutants. They need an interim control for Homer City which will miss the 6/1/75 emission standard by about 1 to $1\frac{1}{2}$ years. And, finally, they would like to have a control mechanism as an interim measure until better scrubbers are available.

3.1.8 Costs

The costs of coal are difficult to determine due to the blending of several spot sources with long-term, and "owned" supplies. The prices will generally vary from about $15 to $30 per ton. Transportation costs run around $2.50 per ton. Most of the coal used has a Btu content of about 12,000 Btu/lb. With this figure in mind, and assuming a cost of $24 per ton, the startup cost for these plants is about $4,220, and to maintain the plant on spinning reserve costs $610/hr.

The bus bar cost of these larger units is between $5.22 and $6.10 per net MWh, compared with replacement costs of power on the system ranging from (depending on time of day) $10 to $55 per net MWh.

More detailed costs of scrubber systems will be available to Penelec soon. They presently estimate costs around $2 to $4 per MWh and $50 to $60 per installed KW. Additional data is displayed in the CONTROL Appendix.

3.2 AIR QUALITY MODEL ADAPTATION AND DEVELOPMENT

This task was identified with two goals in mind: operational air quality forecasting and innovative air quality modeling. Operational air quality forecasting is that part of the SCS which takes emissions, terrain, meteorology and monitor data and develops predictions of air quality in time and space. Innovative air quality modeling is an attempt to improve upon the present generation of air quality models.

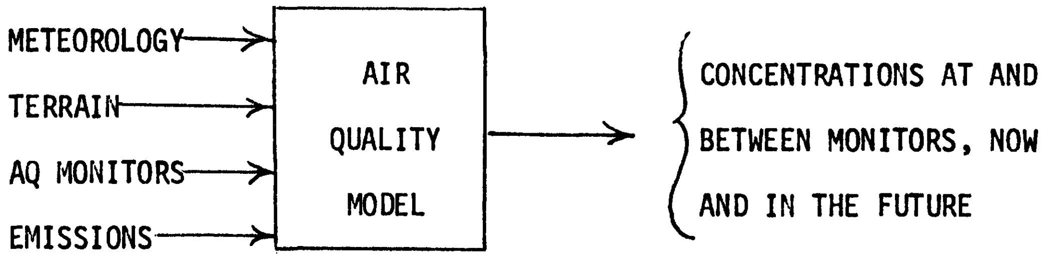


Figure 3.2.1 Air Quality Forecasting

Two separate techniques were to be used by MIT and ERT to meet the two separate goals.

ERT was to modify their existing air quality models to adapt to the special needs of the Penelec region and sources. This was to provide an operational tool to be used by ERT forecasters in preparing the forecast of air quality which would trigger any necessary control strategy decisions. MIT, with modeling assistance from ERT, was simultaneously to be pursuing the longer range goal of developing an innovative method of forecasting air quality which would then be tested against the ERT state-of-the-art model. The progress of each of these efforts is described in the following.

3.2.1 Operational Air Quality Forecasting

Operational air quality forecasting is provided by ERT using standard existing model techniques. The basic models have required adaptation to reflect the characteristics of the Penelec Chestnut Ridge region. Model development and adaptation have proceeded at ERT on two fronts, diffusion modeling and wind field modeling. Early in June the decision was made by Dr. Schweppe of MIT AND Elliot Newman of ERT to use for this project the diffusion model then under development for an SCS system being installed at an industrial plant in the Midwest. This model is a modified Gaussian plume point source model.

Although this model did not include any representation of topographic effects and had a receptor array limited to 128 points, it was decided that these disadvantages were outweighed by its virtues of keeping track of 3- and 24-hour average concentrations at each receptor, using Briggs' plumerise estimates and automatically adjusting emissions of heat and SO_2 in plumes according to the load projected on individual units. Furthermore, the major model development costs were already being absorbed by the industrial client. The model was to be implemented by mid-July for that client and is now operational. ERT intended to use the model without terrain adjustments for operational forecasting at Penelec as soon as possible and to add the terrain refinement subsequently with the assistance of the operational experience.

The fact that the model was not implemented until August 1, resulted in no forecasting being done with it during Phase I. Inclusion of the vertical modification of plume trajectory resulting from topography has been initiated, and the changes necessary to make the receptor array more suitable to the multiple-source Chestnut Ridge environment will be completed early in Phase II. Implementation of this model on the MIT computer will be straightforward and will be completed early in Phase II. This implementation is required to facilitate control simulations at MIT.

ERT's three-dimensional experimental potential flow model for wind trajectories has been run for the wind over Chestnut and Laurel Ridges. The maximum change in wind speed generated was approximately ten percent, and the maximum deformation of the wind direction was only ten percent. These results indicate that this model, which lacks any consideration of thermal stratification, is insufficient to model the sorts of flow deformation observed in such areas. Consequently work has proceeded on development of improved windfield models incorporating density stratification. A working model is not expected to be available until November. The major burden of the costs for this development effort is not being charged to the SCS contract but to other programs at ERT.

3.2.2 Innovative Air Quality Modeling

The goals of the innovative air quality modeling effort can be stated as:

-- the prediction of spatial and temporal concentrations of SO_2

-- the incorporation of uncertainty into the modeling process

-- the demonstration of real-time model operation

-- the verification of model results

To meet these objectives, the efforts in this area were separated into five tasks:

a. The exploration of general physical models to represent the process of atmospheric transport.

b. The identification and incorporation into the physical model framework of the uncertainties involved in the determination of air quality.

c. The development of algorithms to adapt the models to the available field data.

d. The adaptation of the model structure to the Penelec terrain.

e. The validation of model operation, offline from the demonstration SCS, using actual field data from the monitoring system or other sources.

The present status of this effort is that a general formulation of the model has been completed (tasks a and b); the algorithms for data application have been identified (task c); and a source of validation data has been identified (task e).

3.2.2.a Physical Models

Considerable simulation experience in air quality modeling had been gained prior to this project, but it is not directly applicable to the Penelec region because of terrain effects, magnitude of the sources, and the necessity of developing a real-time modeling capability. It was decided, therefore, to develop the new air quality models by starting with the fundamental processes involved, rather than attempting to adapt the simulation models directly. The techniques for adapting the models to the data, called state estimation, are the same ones used in the simulations.

Physically meaningful models are desirable in an SCS for two reasons. First, SCS must operate in real time, directing control actions on a time scale compatible with the dynamics of the source and atmosphere. The sources involved in this project have several control actions available, with required lead times for control implementation varying from minutes to six to eight hours. They are required to meet standards which consider three and twenty-four hour averaging periods. In addition, the atmosphere exhibits time constants ranging from minutes to hours, or even days, which affect the maintenance of air quality. Clearly, statistical models cannot reflect this important time structure adequately for the real-time control needed in SCS, and an explicit representation of atmospheric dynamics is needed.

Second, an SCS must be capable of improving its performance with time. Physical models are advantageous because their performance can be analyzed component by component through sensitivity studies, and the weakest components improved by increased data collection or new submodels. The correspondence between atmospheric quantities and model quantities also simplifies interpretation of the model results and behavior.

Five physical model structures have been considered and their equations are given below:

1) Sutton Model (Gaussian plume)
2) Dynamic Advection-Diffusion PDE (Tracer Equation)
3) Static Advection-Diffusion PDE
4) Pure Advection PDE
5) Weil-Hoult Model (Atmospheric Energy Balance)

Sutton Model (Gaussian Plume)

$$C(\underline{s}) = \frac{Q}{\pi\, u\, \sigma_y\, \sigma_z} \exp\left[-1/2\left(\frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_y^2}\right)\right] \qquad (3.1)$$

Dynamic Advection-Diffusion PDE (Tracer Equation)

$$\frac{\partial C(\underline{s},t)}{\partial t} = -V(\underline{s},t) \cdot \nabla C(\underline{s},t) + \nabla K(\underline{s},t) + Q(\underline{s},t) \qquad (3.2)$$

Static Advection-Diffuse PDE

$$\text{Define } \tilde{C}(\underline{s}) = \frac{1}{T}\int_0^T C(s,\tau)\, d \qquad T = 1 \text{ to } 3 \text{ hours} \qquad (3.3)$$

$$0 = -V(\underline{s}) \cdot \nabla\tilde{C}(\underline{s}) + \nabla K(\underline{s})\nabla\tilde{C}(\underline{s}) + Q(\underline{s}) \qquad (3.4)$$

Pure Advection

$$0 = -V(\underline{s}) \cdot \nabla\tilde{C}(\underline{s}) + Q(\underline{s}) \qquad (3.5)$$

Weil-Hoult

$$\overline{C}_{max} = K_1 \frac{Q_i}{vh_e2} \quad L > h_e, \quad \overline{C}_{max} \approx 0 \quad L < h_e \tag{3.6}$$

Symbols

$\underline{s}$ - spatial coordinate vector

L - time

C - concentration

C_{max} - maximum ground level contration

Q - emission rate

y, z - cross wind and downwind distances

σ_y, σ_z - plume spread coefficients

u - downwind speed

V - wind vector - three dimensional

K - turbulent diffusion coefficients - three dimensional

Q_i - mass flow rate of effluent

K_1 - empirical proportionality constant (dependent on sampling time)

h_e - effective stack height

L - mixing depth

These general equations conceal a series of secondary modeling issues regarding parameters such as wind velocities, diffusion coefficients, emission behavior, effective stack height, etc. In order to proceed to the other tasks, it was decided not to concentrate on all physical structure models at once.

Physical model 3, the static advection-diffusion model, was chosen as a physical model structure to be further investigated with state estimation techniques and field data. The choice was made after comparing the various models on a basis of their physical assumptions, mathematical form, compatibility with the planned uncertainty models, and expected computer efficiency. This model has been expressed in a state space formulation as described below, with the concentrations in a rectangular three-dimensional grid cell representing the system states. Physical model 5, the Weil-Hoult approach, has been studied simultaneously with the static advection-diffusion model and is discussed in detail in section 3.2.2.e.

STATIC MODEL STATE SPACE FORMULATION

Define

$$c(\underline{s}) = \frac{1}{T}\int_0^T c(\underline{s},T)dt \qquad T = 1 \text{ to } 3 \text{ hours} \tag{3.7}$$

Then

$$0 = -\underline{v}(\underline{s})\nabla c(\underline{s}) + \nabla K(\underline{s})\nabla c(\underline{s}) + Q(\underline{s}) \tag{3.8}$$

Define

$\underline{C}$: K_1 vector of $c(\underline{s})$ at K_1 values of $\underline{s}$

Then (3.8) becomes

$$0 = [\underline{V} + \nabla\underline{K}]\ \underline{D_1 C} + \underline{K}\ \underline{D_2 C} + \underline{B}\ \underline{Q} + \underline{d} \tag{3.9}$$

$\underline{V}$ - matrix of winds

∇K - matrix of dispersion gradients

K - matrix of dispersion coefficients

$\underline{D_1 C}$ - finite difference approximation to $\nabla c(\underline{s})$

$\underline{D_2 C}$ - finite difference approximation to $\nabla^2 c(\underline{s})$

$\underline{B}$ - injection matrix (0-1 matrix)

$\underline{Q}$ - vector of emissions

$\underline{d}$ - boundary conditions

Define

$\underline{m}$ - vector of meteorological parameters (i.e., those that specify $\underline{\nabla}V$, $\nabla\underline{K}$, $\underline{K}$, boundary conditions)

Define

$$-\underline{A} = [\underline{V} + \nabla\underline{K}]\ \underline{D}_1 + \underline{K}\ \underline{D}_2 \qquad (3.10)$$

then (3.9) becomes

$$\underline{A}(\underline{m})\ \underline{C} = \underline{B}\ \underline{Q} + \underline{d}(\underline{m}) \qquad (3.11)$$

3.2.2.b Uncertainty Representation

The innovative aspect of the new air quality models tied to state estimation is their treatment of the process uncertainties associated with air quality monitoring and prediction. The uncertainties which are included in the state space model are represented by three groups: SO_2 measurement uncertainty, emissions uncertainty, and meteorological parameter uncertainties. The uncertainty, or error between model prediction and field measurement, is represented by the following formulation:

Define

$\underline{z}$ - ambient SO_2 measurements

$$\underline{z} = \underline{H}\underline{C} + \text{error} \qquad \text{H is 0-1 matrix} \qquad (3.12)$$

$\underline{z}_Q$ - knowledge of emissions

$$\underline{z}_Q = Q + \text{error} \qquad (3.13)$$

$\underline{z}_m$ - measured meteorological parameters

$$\underline{z}_m = \underline{m} + \text{error} \qquad (3.14)$$

From (3.11)

$$\underline{z} = \underline{H}(\underline{m})Q + \underline{b}(\underline{m}) + \text{error} \qquad (3.15)$$

$$\underline{H}(\underline{m}) = \underline{H}\ \underline{A}^{-1} \qquad \underline{b}(\underline{m}) = \underline{H}\ \underline{A}^{-1}(\underline{m})\ \underline{d}\ \underline{m} \qquad (3.16)$$

$\underline{A}(\underline{m})$ large sparse matrix

$\underline{H}(\underline{m})$, $\underline{b}(\underline{m})$ - obtained using sparsity programming

Define

$\underline{R}_z$ - covariance matrix of $\underline{z}$ errors

$\underline{R}_Q$ - covariance matrix of $\underline{z}_Q$ errors

$\underline{R}_m$ - covariance matrix of $\underline{z}_m$ errors

The covariance matrices are determined from engineering judgment and past data on sensor performance and sensitivity, process control accuracy and meteorological forecasting accuracy. The algorithms of state estimation automatically use the field data to improve (i.e. make consistent with the available data) these initial covariance estimates. A standard static state estimator will be used with this formulation to yield the estimate of the state having the smallest covariance matrix. This will represent the most accurate estimate possible given the available data and its uncertainty. The covariance matrix also represents the confidence bands associated with the estimate. Since the state is the concentration in each grid cell, this approach yields the most accurate estimate of the concentration in each cell over the whole region and an accompanying measure of the confidence to be associated with that estimate.

3.2.2.c Algorithmic Development

Initially it was inteded to choose a physical model structure and develop algorithms to perform estimation of air quality using that model. The advantage of developing algorithms for a specific physical model of air quality is that one can usually produce efficient computational schemes by taking advantage of the particular mathematical properties of the problem. The trade-off is that more development time is necessary.

Due to this trade-off, the algorithmic development was delaying the state estimation process and it was decided to postpone the search for efficiency in computation in order to obtain numerical results with the physical models.

This decision was influenced by the recent availability of an MIT code, GPSIE (General Purpose System Identifier and Evaluator). GPSIE uses very straightforward techniques, but can easily be applied to nearly any model adaptable to a state space formulation. This includes the static advection-diffusion model.

No numerical results were obtained in Phase I using GPSIE, but they will be available early in Phase II. As is described in the next section, a sample LAPPES day has been chosen for the initial numerical studies.

3.2.2.d Model Adaptation and Verification

Topographic maps of the Penelec region were obtained and studied. The location of plants and monitors encompasses a region of over 1200 square miles. This would require a grid of nearly 5000 cells if vertical spacing of 100, 200, 500 and L-800 meters (L is mixing height) is used, with a square mile surface grid. Fortunately, most of such a grid would not be utilized at any one time. Also, the plants are sufficiently distant that it appears that they will interact significantly only under infrequent meteorological conditions when the winds are from the Northwest or Southeast. Prevailing winds are from the Southwest. Numerous alternatives exist to dealing with a 5000 state system, including subgrids, plant-centered grids, or varying grid sizes.

For the initial numerical studies a single day from the LAPPES study has been chosen. The analysis will concentrate only on the Homer City plant, and the day was chosen so as to have a good combination of data availability and independence from topography. The independence of the data from topographcial effects was accomplished by choosing a day when the plume trajectory was parallel to Chestnut Ridge. A 714 cell grid system covering approximately

120 square kilometers has been designed to cover the region for which SO_2 data is available. The grid cells are 1 square kilometer at their base and vary in height by layer. The layers nearer the ground are "thinner" and terrain effects are discretized by the grid at the surface. Normally there are four layers in the grid, but terrain may cause one or more lower cells to be added or removed. A further discussion of the grid is in the Appendix.

Although the LAPPES helicopter data is virtually instantaneous, it was assumed that the helicopter data and the bubbler data (.5 hr average) are compatible and that estimation will occur on a .5 hr time step. Wind data also has been extended to a .5 hr averaging period. This data will be used with an assumption of constrant plant emissions during each 1 hour period of plant emission data. The defined data set will be tested in Phase II using the static advection-diffusion model to determine concentrations at and between the monitors as a function of wind and emissions.

3.2.2.e Weil-Hoult Model Structure

The Weil-Hoult model can be separated into three parts: 1) Plume rise equations, which are used to determine the effective stack height under various meteorological conditions. 2) Diffusion near the stack exit which produces the maximum ground level concentration, C_{max}. 3) Diffusion far downwind from the stack exit which is used to determine the background concentrations produced by upwind sources.

1) Plume Rise

Stable conditions ($\frac{\delta\theta}{\delta z} > 0$) occur during the early morning and at night. During stable conditions the plume entrains cooler air near the ground so that it reaches thermal equilibrium with its surroundings at some height above the stack exit. The plume equilibrium position during stable conditions is dependent on the vertical temperature gradient, $\frac{\delta\theta}{\delta z}$, the wind speed, u, and the plant operating conditions $u_i b_i^2 \Delta T$.

$$h = 2.3 \left(\frac{u_i b_i^2 \Delta T}{v \; d\theta/dz}\right)^{1/3} \quad (3.17)$$

Neutrally stable conditions occur during the day when the plume rise takes place in the mixing layer which is created by solar heating. The temperature gradient in the mixing layer is adiabatic, $\frac{d\theta}{dz} = 0$, so the plume never reaches thermal equilibrium in the mixing layer. The convective eddies in the mixing layer break up the coherent nature of the plume when the convective eddy velocity becomes equal to the plume rise velocity. The effective stack height during neutrally stable conditions is the height at which the plume loses its coherent nature and the effluent is dispersed by the convective eddies. The intensity of the solar insolation, Q_r, and the mixing depth, L, are used as a measure of the convective eddy velocity:

$$\Delta h = 5.6 \; \frac{u_i b_i^2 \Delta T}{v} \; \left(\frac{g}{T}\right)^{1/3} \left(\frac{Q_r L}{\rho_0 c_p}\right)^{-2/3} \quad (3.18)$$

2) Diffusion Near the Stack

The effluent from tall stacks, such as those in the Penelec region, is released above the region where there is strong diffusion caused by mechanical turbulence. The only mechanism which will bring the buoyant pollutants down to ground level is the diffusion produced by the convective eddies in the mixing layer. When the plume rise takes place above the mixing layer none of the effluent reaches ground level.

$$\text{When } L < h_s \qquad C_{max} = 0 \quad (3.19)$$

When the plume rise takes place in the mixing layer the ground level concentration is dependent on the pollutant flux, the wind speed, and the effective stack height $h_e = h + h_s$.

When $L > h_s$ $$C_{max} = \frac{K_1 Q_i}{v h_e^2} \tag{3.20}$$

For a 15-minute sampling period $K_1 = .21$

3) Diffusion far Downwind of the Stack

In the manner of Holzworth it is assumed that far downwind of the stack the pollutants which reach equilibrium in the mixing layer will be uniformly distributed between the top of the mixing layer and ground level. When the mixing layer is below the effective stack height the concentration far downwind will be negligible. When the mixing layer is above the effective stack height, all the pollutants emitted by the plant are trapped in the mixing layer.

When $L < h_e$ $$C_{downwind} \approx 0 \tag{3.21}$$

The limited number of observations of concentrations produced ten kilometers or more downwind from isolated sources suggest that the plume width increases linearly with downwind distance, x, and the concentration decreases as 1/x. The following equation is expected to be valid for $x > 3L$. It is certainly correct in the region of 20 kilometers where the Penelec plants will begin to interact with each other.

When $L > h_e$ $$C_{downwind} = \frac{K_2 Q_i}{x v L} \tag{3.22}$$

4) Meteorological Parameters

Wind speed (v), ambient temperature (T), and solar insolation are measured at the meteorological tower. The relationship between the atmospheric energy budget and the solar heat flux (I_0) determines the mixing depth, L.

$$L = 36 \frac{I_o}{\Delta T} \tag{3.23}$$

$(I_o = \int_o^t Q_r dt$ and has the dimensions of $cal/cm^2)$

There is not enough information available at Penelec to determine the lapse rate in the early morning. Examination of LAPPES data revealed that the range of values observed for the lapse rate will produce a variation of ± 10% in the plume rise because the plume rise is proportional to $(\frac{d\theta}{dz})^{-1/3}$. A value of $\frac{d\theta}{dz} = 10^{-2}$ $^oC/m$ is suggested for use in the equation

The variation of the insolation, Q_r, during the early morning can be used to predict I_o and L for the rest of the day to within ± 50%. This estimate could be improved by a more extensive data effort which would include vertical T soundings.

Validation

The plume rise equations and the diffusion near the stack has been correlated with LAPPES data by Weil and Hoult. The ground level concentrations and plume centerlines observed on eighty helicopter flights were used to establish equations (3.18) and (3.20). The empirical constant, K_2, used in equation (3.22) needs to be established with ERT monitoring data. The LAPPES data was only taken in the morning so that L is rarely greater than the effective stack height and K_2 cannot be determined accurately.

The variation of $\frac{d\theta}{dz}$ was obtained by examining the vertical temperature profiles on one hundred different days. The variation of Q_r during the day was examined for 50 sample days. The variation of L was examined from 33 sample days of the LAPPES data.

3.3 Forecast Model Adaptation and Development

This task was undertaken to provide experience for the ERT forecasters in forecasting the parameters needed to predict air quality in the Penelec region. The task title is a misnomer insofar as there is not a "model" per se which translates the AIRMAP met tower data and National Weather Service data into parameter predictions. The translation is performed by experienced air quality forecasters using standard forecasting techniques combined with a familiarity with the region. The Phase I adaptation and development effort was intended to provide forecasting experience for the ERT meteorologists to establish and increase this regional familiarity.

It became apparent in early June that the meteorological tower at the Penn View site would not be operational until late in the month at the earliest. (The extent of the delay caused by the problem of installing the cable from the base of the tower to the instrument shelter could not be fully evaluated at that time, so that the forecasts of when the tower would be functioning in real time were still optimistic.) Consequently it was decided that ERT forecasters should gain experience in forecasting wind speed and direction, stability, and mixing depth for the Chestnut Ridge region by attempting to predict these parameters for the National Weather Service reporting stations at Blairsville, Allegheny County Airport, Johnstown Airport, and Altoona (Blair County) Airport. This forecasting began routinely on June 21, 1974, at midnight, 6 A.M., and noon EDT. Verification of the forecasts has not yet been completed. On August 13, forecasting of wind speed and direction and temperature gradient on the Penn View tower was initiated also. A forecast and verification form is presented in Figure 3.3.1.

Figure 3.3.1

CHESTNUT RIDGE FORECAST AND VERIFICATION FORM

FORECAST DATE:__________ FORECASTER:__________ DATE:________ TIME:________

FORECAST PERIOD	HOUR	STABILITY		AGC		BSI		AOO		JST		PIT	PENN VIEW TOWER				
		AM	TP	WD	WS	WD	WS	WD	WS	WD	WS	DMX	WD	WS	ΔT	BIVT	BIHR
T + 6																	
T + 12																	
T + 18																	
T + 24																	
T + 30																	
VERIFICATION																	
T + 6																	
T + 12																	
T + 18																	
T + 24																	
T + 30																	

VERIFYING METEOROLOGIST:__________ DATE:________ TIME:________

STAB: "AM" is ERT air mass classification of stability
"TP" is Turner-Pasquill stability class (1 to 5)

WD: Wind Direction in tens of degrees

WS: Wind Speed in knots (mph)

ΔT: Temperature Difference in °F top-bottom of tower

BIVT: Standard Deviation of Vertical Wind Angle in Degrees

BIHR: Standard Deviation of Lateral Wind Angle in Degrees

DMX: Mixing depth in 100's of meters

3.4 Control Logic Adaptation and Development

To place this portion of the overall effort in proper perspective it is useful to examine the block diagram of information flow for the entire system.

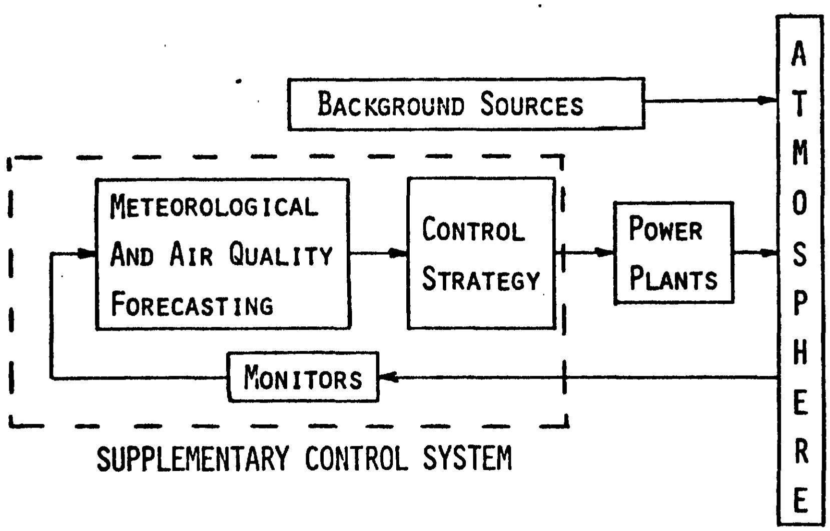


Figure 3.4.1

The control strategy is that portion of the SCS which takes the atmospheric models (and predictions) and uses the models of the power system to develop the costs and effects of all alternative pollution control measures.

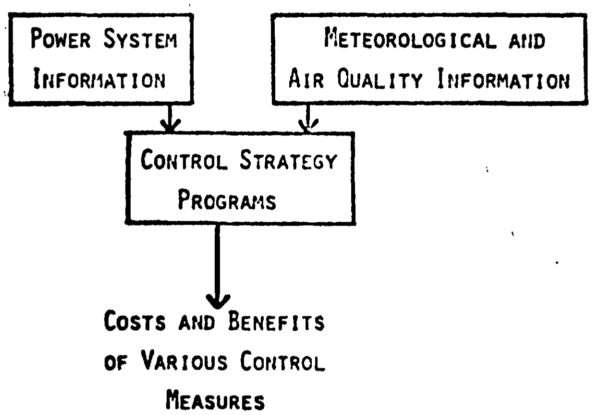


Figure 3.4.2

The goals of the control strategy programs can be stated as:

-- the evaluation of the ability of the various control measures to maintain ambient air quality standards

-- the demonstration that an SCS is workable in real time

-- the substantiation that the operation of an SCS will not reduce the reliability of the power system, and that it will not disrupt system operation procedures

-- the comparative display of the economic, environmental, reliability, and other ramifications of all the possible pollution control procedures.

To meet these objectives the thrust of this effort has been separated into four closely coupled tasks:

1. A theoretical formulation of the strategy must be made which meaningfully incorporates the uncertainties of the problem and which facilitates the easy transfer of this technology to all other systems.

2. The control strategy will be exercised, first in a simulation, then on "mock" and real events.

3. Simulations will be made of the long-range maintenance planning possibilities under an SCS; and the ramifications to the minute-by-minute dispatch problem will be evaluated. These studies will cover the SCS implications to the neighboring (slower and faster) controls in the power system operation hierarchy.

4. The final task will be analysis and evaluation of all the pollution control possibilities and their costs, implications, and effectiveness, The possibilities to be studied will include the effects of:

   -- fuel switching (to lower and/or higher sulfur contents)

   -- stack gas temperature modification

   -- shifting the load to other plants (including use of pumped storage to effectively shift load in time)

-- changes in the regulations on allowable sulfur content of fuel

-- tightening or loosening of existing 3- and 24-hour ambient standards

-- use of scrubber systems without any by-pass

-- intermittentuse of scrubbers according to control strategy

-- addition of hypothetical standards, specifically 1-hour SO_2 standards, and sulfur times particulate standards (as discussed in several sources)

The most pervasive factor in determining the type of decisions that a control strategy must make is the time scale over which the strategies must be developed. This time scale in turn is determined by the available weather forecasting capabilities about which two presumptions can be made:

(1) everything to be known about the weather one minute from now, is already known, and

(2) nothing can be predicted about the change in climate from one year to the next.

Thus, there is no possibility for changing control strategies faster than every minute or slower than every year. Between these bounds, the heart of the weather forecaster's capabilities falls in the 6-hour to 4-day look-ahead range.

On the following page is a chart of the hierarchy of power system control levels as a function of the time scales involved. From the previous arguments it can be seen that the heart of the SCS must lie in the Unit Commitment level, with peripheral assignments given to Economic Dispatch and Maintenance Scheduling.

We will now briefly go through the types of decisions made at these three power system operating levels, and then close this section with a brief over-

TABLE 3.4.2

	PROBLEM	TIME SCALE
MAINTENANCE SCHEDULING - NUCLEAR REFUELING	Determine 2-week to 2-month outage period for each plant for each year	1) Plan ahead for 1-2 years 2) Redo as conditions change
UNIT COMMITMENT	Determine hour-by-hour strategy for which plants will be committed (at what level) for next week. Constrained by "Maintenance-Scheduling"	1) Overall plan ahead for 1 week 2) Detailed plan for each day 3) Redo as conditions change
ECONOMIC DISPATCH	Determine minute-by-minute scheduling for each plant. Constrained by "Unit Commitment"	Redo every 5 minutes
AUTOMATIC GENERATION CONTROL (LOAD FREQUENCY CONTROL)	Adjust generation level to maintain system frequency and tie line flows at desired levels. Constrained by "Economic Dispatch"	2 - 10 second time constant

Factors which complicate solution:

1) pumped storage
2) fixed nuclear refueling scheduling
3) gas-oil contracts
4) interruptible loads
5) transmission line losses
6) ability to buy from neighbors
7) start-up cost and time-varying costs, maximum rate of change, maximum and minimum up and down times

Outages:

1) forced out
2) rescheduled maintenance
3) generation reserve

view of the literature to date in these environmentally constrained operating problems.

3.4.0.1 Maintenance and Production Scheduling

The use of scheduling and planning methods with horizons of a few years has been an important tool both in the operation and the management of power systems. Some of the major questions addressed by these mid-range schedulers are:

(1) timing and duration of maintenance outages,

(2) timing and batch sizes of nuclear refuelings,

(3) inputting operating information to long-range simulations,

(4) commitment of interutility power sales and purchases,

(5) providing information for fuel budget studies,

(6) developing weekly production schedules for the optimal utilization of fixed batches of nuclear, fossil, and hydro energy, and

(7) forecasting, contracting and leveling of maintenance and refueling manpower.

Ideally, all of these tasks must be performed under the requirements of maintaining system reliability and minimizing all expenses.

Figures 3.4.3 and 3.4.4 show approximately how tasks are divided into the general, mid-range, generation planning and operations areas.

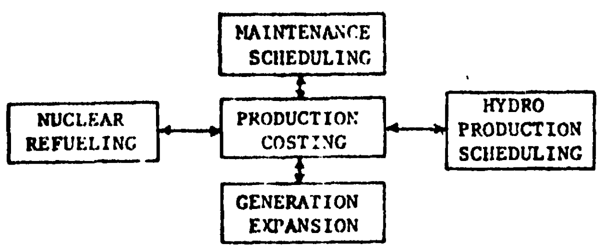


Figure 3.4.3 Mid-range Generation Planning Problem

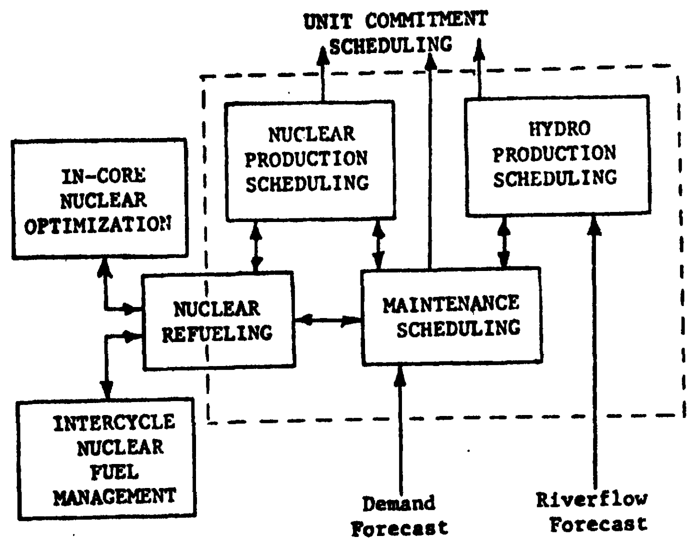


Figure 3.4.4 Components of the mid-range generation wcheduling problem.

Historically, maintenance scheduling has been manually performed using "fill-in-the-valleys" techniques, that is, fitting the largest plant in the largest hole in the schedule, see Figure 3.4.5. There exist several other criteria, and some computerized programs, but these are not in general use (it is a manual process for the PJM coordinator covering the Penelec region.)

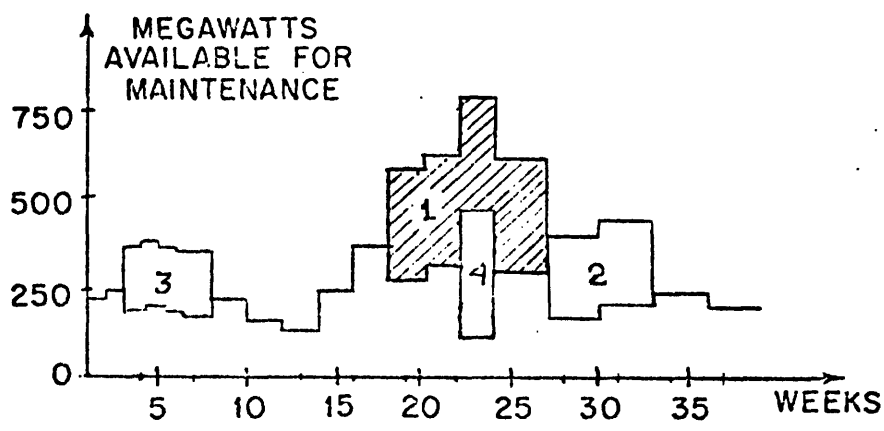


Figure 3.4.5 Maintenance Availability Curve.

At the MIT Energy Laboratory there is a maintenance scheduling computer program which will be used on simulations, and then hopefully as a real scheduler, to take advantage of the economic and environmental gains in production scheduling. The SCS-type environmental gains at this scheduling level have not been explored anywhere else; the gains that are possible will depend directly on the extent of seasonal variation of the climate and the amount of freedom available in the scheduling process.

All the information required for this simulation is available, with the only environmental data being the climatological data of such things as inversion probabilities and stream temperatures during times of possible scheduled outages. Figure 3.4.6 shows one example of the type of economic and environmental trade-offs that can be made on this time scale (the point marked X represents the schedule developed by one of the more advanced computerized scheduling devices currently being used).

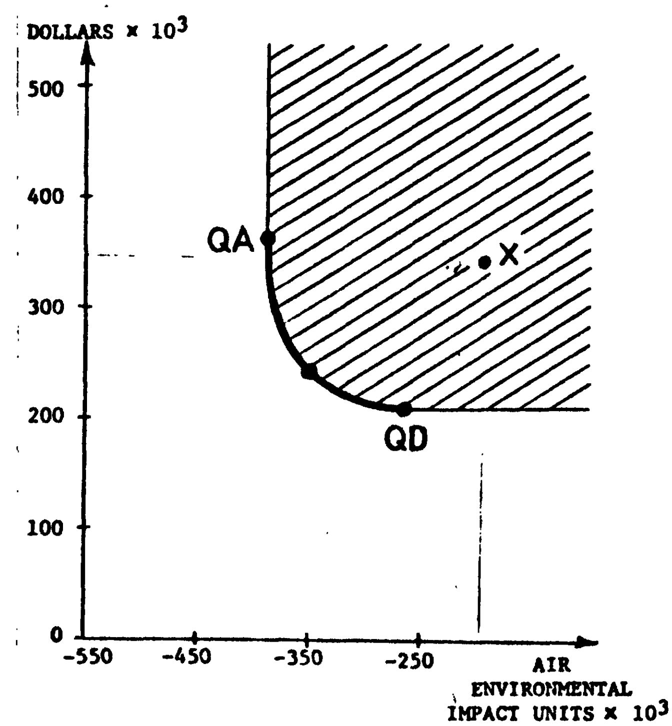


Figure 3.4.6 The area representing all possible consequences of 'dollar and air pollution' maintenance strategies at a standard reliability level (the negative values on the air impact axis result from a convention of rewarding plants as a function of the time of year they are scheduled out for maintenance).

3.4.0.2 Unit Commitment Scheduling

Basically, the unit commitment scheduler makes hour by hour decisions on which plants will be operating and at approximately what levels they should be loaded. The horizon time for these schedulers is generally one week. Although there are computerized schedulers, many systems still operate manually (Penelec is in a system which operates manually).

The purpose of the unit commitment scheduler is to turn plants on and off to follow the load demand, see Figure 3.4.7.

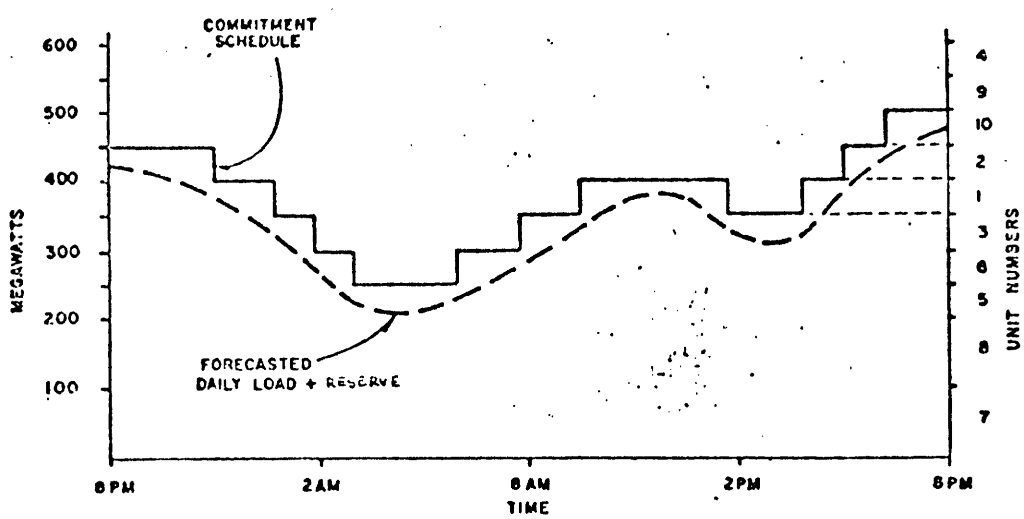


Figure 3.4.7 Graph showing the removal of units on a priority system so that the load can be followed.

Since the heart of the SCS is in the unit commitment time scale, much more of this level of operation will be described later. It is, however, important to have a general idea of what is occurring, in particular:

1. Operating considerations

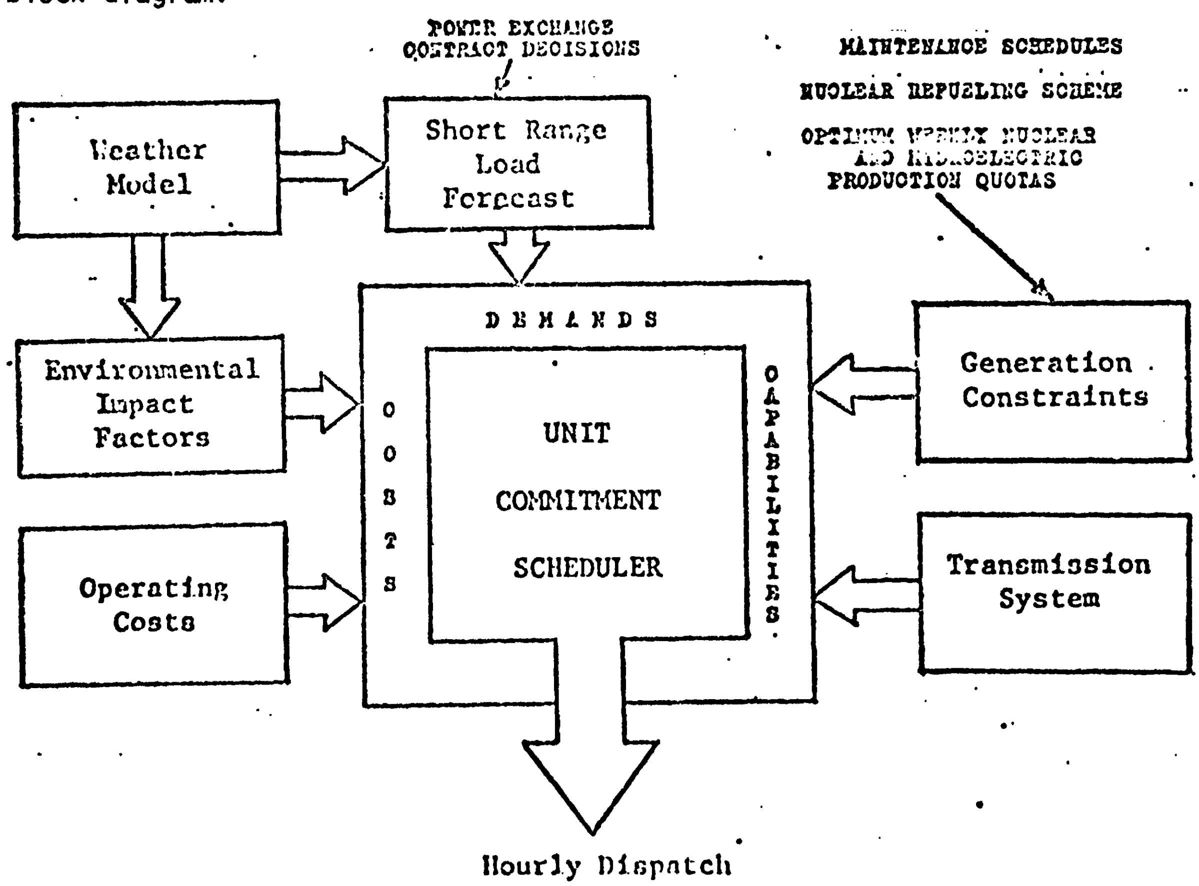
- Demand for power
- Sufficient reliability - reserves
- Hydro, nuclear, gas consumption quotas
- Pumped hydro scheduling
- Reservoir limitations
- Min., max. up and down times for many plants

- Maximum startup and shutdown rates
- Geographic limitations
- Capacity limitations on plants (variable)
- Startup costs varying with down times (nonlinearly)

2. <u>Performance Measures</u>

- Dollar costs
- Reliability

For SCS use, environmental factors will also affect the generation capabilities, and possibly will be used as performance measures in the system (e.g. a measure of interregional "fairness" to avoid pollution exporting). The coordination of information is displayed in the following block diagram.



<u>Figure 3.4.8</u> Block Diagram Representation of Unit Commitment in an SCS

3.4.0.3. Dispatch Techniques

The dispatch (or economic dispatch) is the minute by minute scheduling of system operations. The dispatch schedulers are universally computerized and act strictly to minimuze the incremental cost of producing power. An operating SCS would have some troublesome ramifications on the dispatch operation. Since dispatchers are currently operated only for economic incentive, they would require some environmental constraints if they are not to work contrary to some of the pollution limiting decisions of the unit commitment scheduler. There are apparently several theoretical possibilities for handling this type of "conflict of interests," such as bounding operations of particular plants or developing pseudo-incremental costs. Probably the best technique would involve constraining the weighted sum of generation from particular facilities. The usefulness of this method will, of course, depend upon the possibilities for modifying the existing computerized dispatch programs.

3.4.0.4 Literature Relevant to SCS

Very briefly, most of the literature on environmental operating constraints for power systems lies in the area of the dispatch techniques. Most of these schedulers (see References: Gent, Lamont, Delson, Finnigan) minimize tons of SO_2 emitted on an incremental basis identical to current dollar incremental cost techniques. One (Sullivan) attempts crudely to relate emissions to pollution concentrations at one prespecified ground-level point. These dispatch studies are inappropriate for use as an SCS because they attack the problem at the wrong time scale.

The right time scale is, as was mentioned, the unit commitment level, and several studies have addressed this problem (see References: TVA, ERT, MIT studies). The most sophisticated of these studies were done at MIT, setting up constraint sets representing the system's limitations;

$$\underline{A}\ \underline{x} < \underline{b} \tag{3.25}$$

and using performance measures of the form

$$\min \quad \underline{c}\ \underline{x} \tag{3.26}$$

where $\underline{c}$ is parameterized. The maintenance and production schedulers use the same basic concepts as the unit commitment devices. Ample documentation of these methods is available.

3.4.1 Control Measures

This section deals with the physically possible methods of controlling pollution. The specifics and data relating to the Penelec situation are left to the Appendix entitled CONTROL. This section, then, is a brief outline of the possibilities.

Fuel switching is the most easily understood of the pollution control measures. It involves the storage of two grades of fuel (at Penelec these are typically 2 to 2.4% sulfur and 1 to 1.25% sulfur coal) plus a time delay of about 6 hours before the emissions reflect the switch. There is a substantial additional cost for this cleaner coal, about $10 per ton on top of the $15 to $20 per ton current costs. A facility such as Homer City, which consumes about 600 tons of coal per hour at 1800MW full load, could switch fuel for about $6,000 per hour. There are a number of issues which must be completely modeled to fully describe the fuel switching alternatives:

-- cost of fuel (which can change daily)

-- Btu content of fuels (also changes)

-- sulfur contents of fuels (is monitored daily)

-- time lag for control action

-- additional labor costs

-- additional maintenance costs of inefficiencies due to increased clinker buildup

-- whether or not fuel costs can be included in the rate base

-- loss of particulate precipitator efficiency with low-sulfur fuels.

The effect of fuel switching on pollutant concentrations is obviously very important, e.g. half the sulfur content in the fuel means half the ground level concentrations (neglecting slight changes in heat content on fuels). A recent report by ERT (ERT, 1974, Table 5.3) demonstrates roughly the effect of fuel switching on frequency of violations.

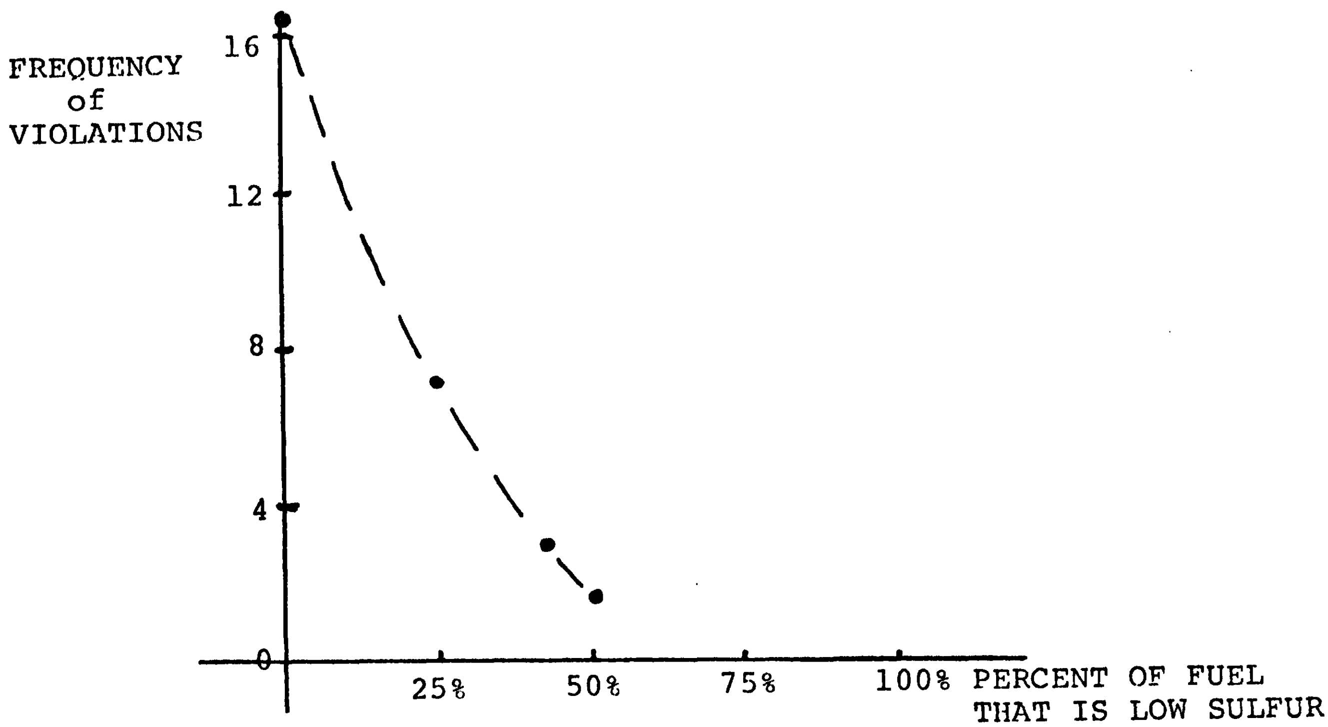


Figure 3.4.9 Effectiveness of fuel switching for reducing violations (adapted from ERT, 1974, table 5.3)

Stack gas temperature modification is a control measure which is effected by changing the operation of an air preheater. The economics of the process is considered to be minor; three men are required and the change in temperature ΔT can be as much as 310°F (from 290°F to 600°F at Homer City and Conemaugh, ΔT = 150°F at Keystone). Using the standard plume rise formula (G.A. Briggs, 1969) the increase in effective stack height could be about 12% and the resultant maximum concentration (using the standard Gaussian formula) would be 93% of the original. Although it is possible to operate the preheater at fractional decreases, it appears that those costs would not vary significantly from full reduction and thus full reduction will be the only considered control measure. The economic ramifications of changing stack gas temperature will be explored fully.

Shifting the load to other plants has perhaps the greatest potential as a pollution control measure. A number of simulations (see for example Gruhl, 1973; Eisenberg and Vertis, 1973; Gruhl, 1972) support the intuitive reasoning that a great potential effectiveness exists. In a power system which often operates from 1/3 to 1/2 of its capacity, decisions of which plants to shut down are made on a very small difference of marginal cost. Since these plants cover the whole spectrum of pollutant outputs (for SO_2: nuclear, hydro and gas turbines have negligible pollution) consideration of pollutants can give large environmental gains at low costs.

Load shifting can take advantage of the following situations:

- -- variations in the pollutant outputs of plants on system
- -- variations in background concentrations and/or dispersive potential in different airsheds over the system
- -- variations in emissions per megawatt at the upper and lower ends of each plant's loading curves
- -- possible storage of energy at pumped storage facilities for use at times of higher predicted concentrations.

For Penelec, the plants considered can switch load at a rate of about 1.3% per minute. However, because these plants are very, very efficient the cost differential between these facilities and many of the older units makes the load shifting uneconomical for this situation (as much as $45,000 per hour to completely replace one facility). Therefore, load shifting may have to be simulated using the high outage rates of these facilities as pretensions of SCS exercises.

Scrubbers with no By-pass are the fourth alternative. Some states, for instance New Jersey, are presently not planning to allow for the by-pass of the scrubber systems that are installed. In this type of system a failure of the stack gas desulfurization equipment will cause an outage at the power facility. Such designs have severe economic and reliability implications (as well as potential environmental consequences of bringing online older plants to provide replacement power). Simulations will be made of this type of pollution control measure as soon as adequate data is accumulated on the costs and performances of various scrubber systems (in about 3 months).

Intermittent Scrubber operation is the final control strategy possibility. This will involve the simulation of noncontinuous operation of stack gas desulfurization equipment. Here, again, simulations must await the compilation of realistic, actual scrubber operation data. There are really two types of intermittent scrubber operation that can be studied. One is the by-pass of scrubbers only to avoid power plant outages. The other is the possibility of operating scrubbers only at times when it is economically and/or environmentally advantageous. For instance, where stack gas temperatures cause sufficient buoyancy to put the plumes above inversion layers (resulting in pollution-free operation), it could be environmentally harmful to scrub out much of the SO_2 with the resultant tremendous temperature reduction in the plume which might not then allow that plume to push through the inversion layer.

3.4.2 Control Strategies

Most of the control action for an SCS will take place at the unit commitment level, that is, the hour-by-hour scheduling to a one week horizon. The information flow of a unit commitment schedule is shown in Figure 3.4.10. For an SCS which is responding to 3- and 24-hour standards the flow of information can be seen in Figure 3.4.11 . For a very short description of some of the control strategy work consider the following symbols:

t = time

c = pollutant concentration

Q_i = emission rate of source i

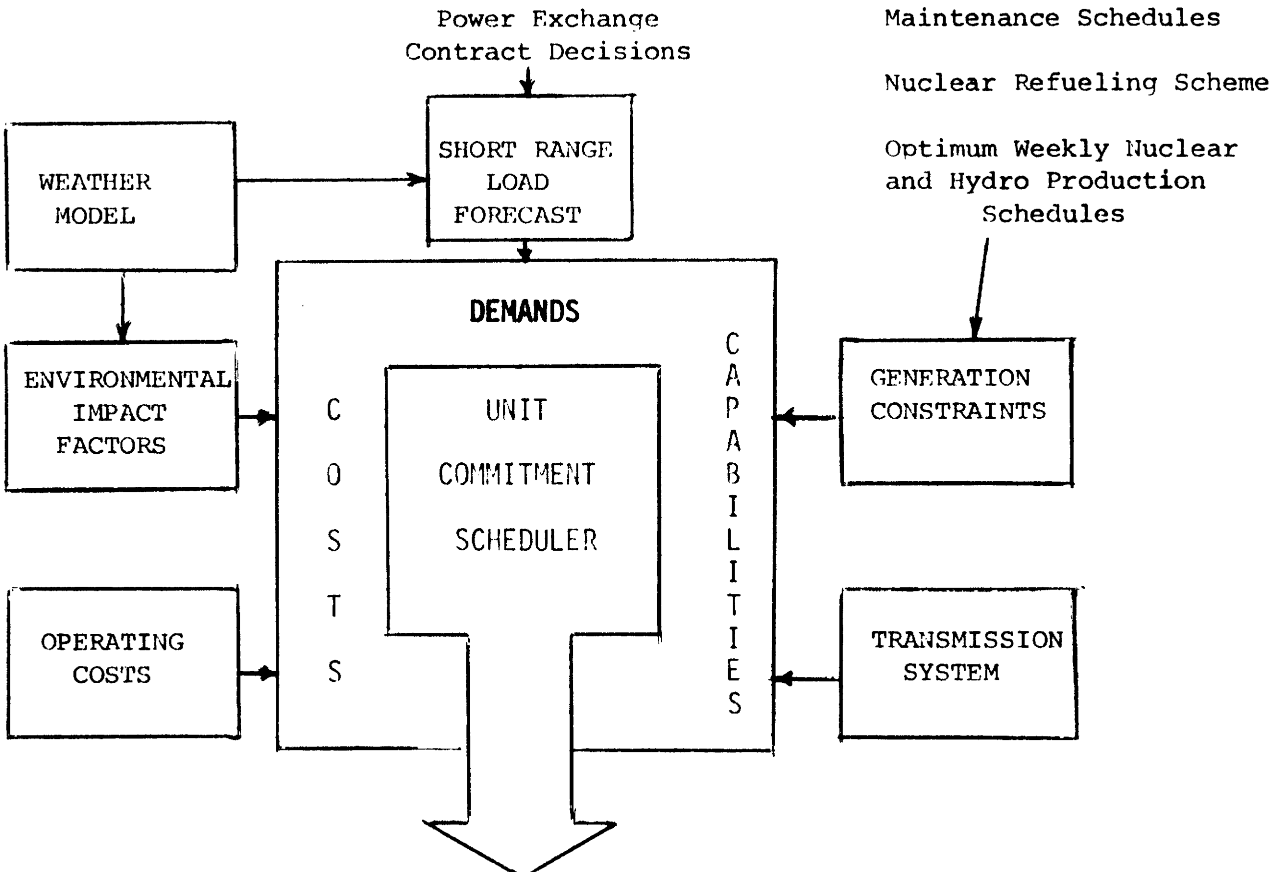


Figure 3.4.10 Hourly Dispatch

Each of the control measures will be evaluated separately (and in predetermined combinations) on a case by case basis. To demonstrate some of these calculations consider first a simple load shifting model for meeting the 24-hour standard. Suppose that the standard is violated in one particular cell of the grid of concentration, and that the violation is isolated in time from other violations, simplifying the scheduling problem to a static-type dispatch technique. The problem can be expressed as [where everything is known but $\Delta P_i(t)$]:

$$\min \sum_i \sum_t [\lambda_s(t) - \lambda_{c,i}(t)] \Delta P_i(t) \quad (3.27)$$

$$\text{where } \sum_i \sum_t \lambda_{p,i}(t) \cdot \Delta P_i(t) + 24P_b < 0 \quad (3.28)$$

$$\text{and } \Sigma \Delta P_i(t) = 0 \quad (3.29)$$

with $\lambda_{p,i}(t)$ as the incremental addition to pollution from plant i at time t

$\lambda_{c,1}(t)$ is the incremental cost of i and time n (this will vary as the operating point varies)

$\lambda_s(t)$ is the system-wide incremental cost at n

$\Delta P_i(t)$ is the change in the output (MW) of i at time t and P_b is the extent to which the 24-hour standard is broken.

The equations can simply be expressed as the minimization of the replacement power cost required to bring the cell under the standard. Both λ_s and $\lambda_{c,i}$ are available information. However, each $\lambda_{p,i}(n)$ must be computed from the equation which relates the concentrations c(s,t) and the emissions $Q_i(t)$.

As another example of the formulation of the control strategy equations consider the modeling of the stack gas temperature change required to meet a 3-hour standard. Ahead of the strategy computation is the determination of the concentrations modes in (and near) the violation areas.

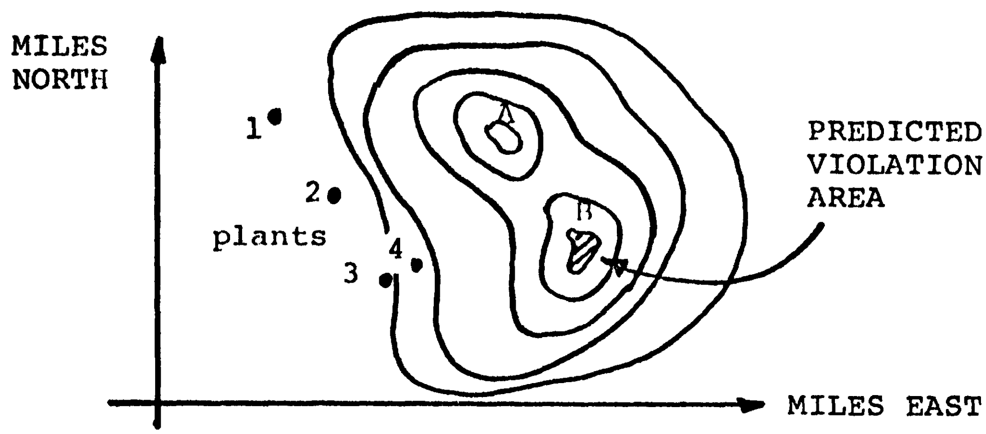


Figure 3.4.11 Predicted Violation Modes

The controllable sources are plants (units) 1, 2, 3, 4; the mode in the violation area is B and a mode in a near-violation area is A.

Also ahead of the strategy development is the computation of coefficients from the controllable source contributions to mode concentrations.

c_B = concentration predicted at B

c_A = concentration predicted at A

$c_{A,backgd}$ = background concentration at A

H_{A1} = contribution of unit 1 to concentration at A

H_{A2}, H_{A3}, H_{A4}, H_{B1}, H_{B2}, H_{B3}, H_{B4} likewise (contributive factors)

Q_1, Q_2, Q_3, Q_4 = emissions from units 1, 2, 3, 4

where

$$\sum_{i=1}^{4} H_{Ai}Q_i = c_A - c_{A,backgd} \qquad \sum_{i=1}^{4} H_{Bi}Q_i = c_B - c_{B,backgd}. \tag{3.30}$$

Assuming this 3-hour violation (predicted) is isolated in time from other violations, the strategy is to effect a least cost $\Delta Q_i'$ sufficient to drop the predicted violation below the standard. In different form

$$\sum_{i=1}^{4} H_{Ai}\ Q_i' < S - c_A \qquad \sum_{i=1}^{4} H_{Bi}\ Q_i' < S - c_B \tag{3.31}$$

where S represents the standard concentration. In this equation the four changes in emission rates, $\Delta Q_i'$, are variables.

Representing the cost of stack gas change in terms of a linear coefficient D_i then the cost of control can be

$$\sum_{i=1}^{4} D_i \Delta Q_i' = \text{cost of control (direct)} \tag{3.32}$$

Another cost of control (which is indirect) results from the slight loss in efficiency on the units controlled (including power to the air preheaters) E_i; then $\sum_{i=1}^{4} E_i \Delta Q_i'$ = cost of power lost. (3.33)

The effective emission reduction ΔQ_i from the increase in emission temperature is probably best broken up into two quantities, X_i = the fraction of control exercised (0 to 1, fractional values would indicate exercising the control measure over fractional portions of the 3-hour interval) and Q_i^i = the effective emission reduction assuming full operation of control measures (will depend on the level of plant operation, and sulfur content of fuel) then Q_i^i is replaced by $X_i \cdot \Delta Q_i$.

Now (if the loss of power due to control is not dependent on level of plant operation then E_i can be time constant, otherwise it must be computed from the power levels):

$$\min \sum_{i=1}^{4} D_i X_i + \sum_{i=1}^{4} E_i(P_i) X_i \tag{3.34}$$

where

$$\sum_{i=1}^{4} H_{Ai} \Delta Q_i (P_i F_i) X_i < S - c_A \tag{3.35}$$

$$\sum_{i=1}^{4} H_{Bi} \Delta Q_i (P_i, F_i) X_i < S - c_B \tag{3.36}$$

where P_i is the operating level of the unit, and F_i is the sulfur content of the fuel.

As in the case with all uncertain processes, measurements of the levels of certainty associated with predictions are at least as important as the predictions themselves. Since the air quality standards are specified in terms of levels which are "not to be exceeded more than once per year" it is natural to develop probabilistic measures of air quality.

A lengthy document on reliabilities of SCS's has been developed by ERT (Document P-669, February 1974) thus only a brief overview will be presented here.

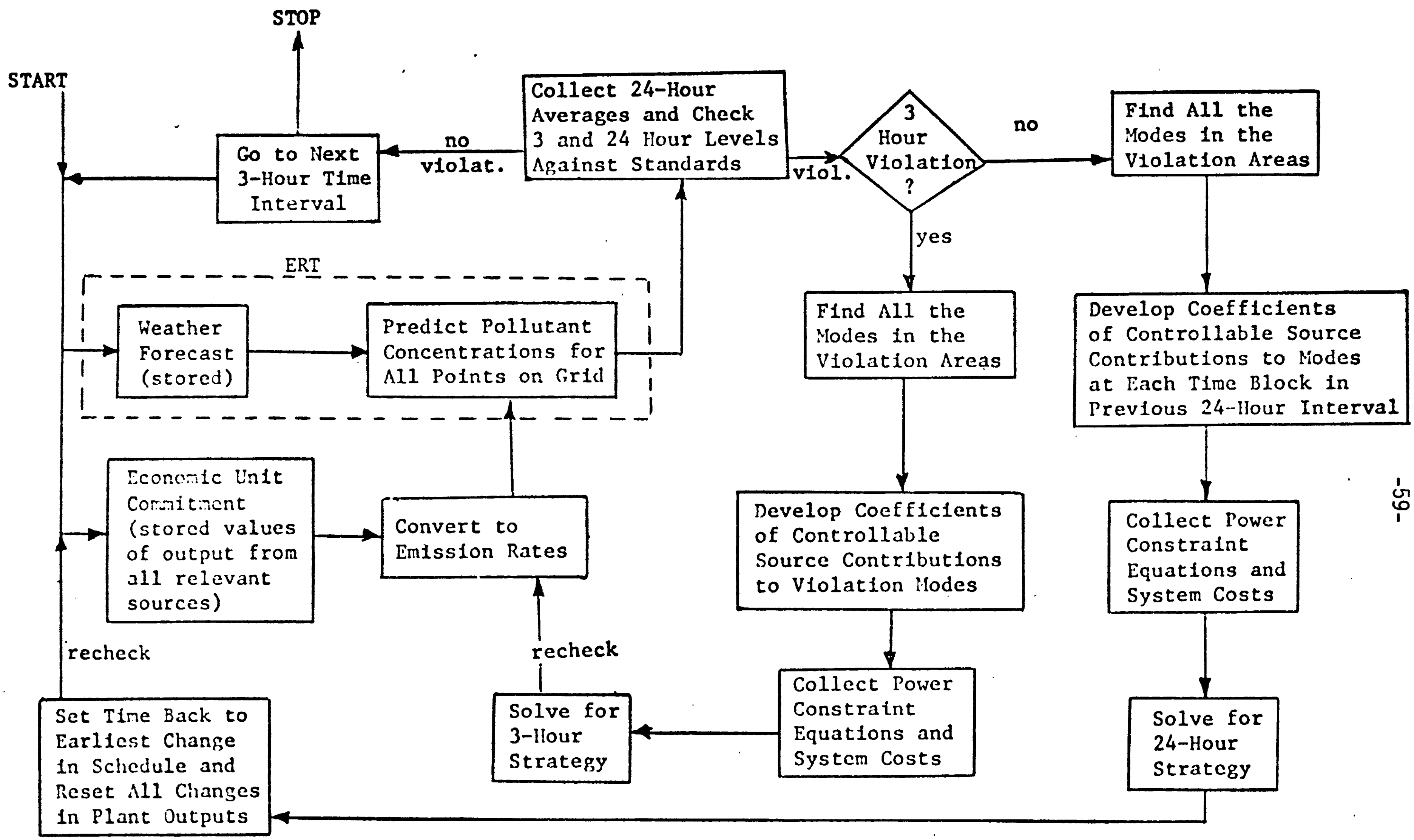


Figure 3.4.12

Tentative Representation of Control Strategy for Penelec SCS

Consider the following definitions relevant to understanding the probabilistic model:

$c(x,t)$: concentration at time t and location x

$C(t)$: max $c(\underline{x},t)$; maximum concentration over all x locations at time t

$\underline{x}$: downwind location of $C(t)$

$Q(t)$: emission rate without SCS

$M(t)$: meteorological function relating the maximum concentration $C(t)$ to source emission rate $Q(t)$ which will include the effects of stack height, wind conditions, mixing depths or any other pertinent meteorological inputs

$R(t)$: the error ratio of concentration prediction defined as follows:

With or without an operating SCS, the observed maximum concentration C_o is related to the actual emission rate Q through the meteorological function M as follows:

$$C_o = Q \cdot M \text{ at time } t \tag{3.37}$$

With an operating SCS, the corresponding maximum predicted concentration is related to the actual emission rate Q and the meteorological function M (defined above) through the Error Ratio R as follows:

$$C_p = Q \cdot M \cdot R \text{ at time } t \tag{3.38}$$

From the above, the error ratio can be defined as

$$R = Cp/C_o \; . \tag{3.39}$$

Assume that there exist probability density functions for M and Q, and we wish to generate a frequency distribution for C when no SCS is operating. If A is any concentration value, Q and M are independent of each other and random variables, then

$$P_C(C = A) = [P_Q(Q = \varepsilon) \cdot P_M(M = A/\varepsilon) + + P_Q(Q = 2\varepsilon) \cdot P_M(M = A/2\varepsilon) +--- + P_Q(Q = n\varepsilon) \cdot P_M(M = A/n\varepsilon) +--- + \Delta\varepsilon \quad (3.40)$$

or, in the limit as $\Delta\varepsilon$ approaches 0

$$P(C = A) = \int_0^\infty P_Q(Q = \zeta) \cdot P_M(M = A/\zeta)d\zeta \quad (3.41)$$

or

$$P_C(A) = \int_0^\infty P_Q(\zeta) \cdot P_M(A/\zeta)d\zeta \quad (3.42)$$

Expressing the operator above by *,

$$P_C = P_M * P_Q \quad (3.43)$$

This equation states that the probability density function for maximum ground-level concentrations can be derived from the convolution of the probability density functions for M and Q. Therefore, the frequency distribution of ground-level concentrations for an uncontrolled plant can be determined from determinations of M and Q.

Consider next the case when the SCS is operating. In this case $C_c = Q_c \cdot M$ where subscript c denotes the functional value when the SCS is operating. Q_c is no longer independent of meteorology since the operation of the SCS depends on meteorological forecasting.

P_Q will, therefore, also be generally dependent upon P_M and will vary for different control strategies. For computer solutions to the correlated integration, the dependence of these quantities upon each other can be readily simulated.

Assuming that the error ratio R is independent of M and of Q and given P_R, P_M, and P_Q it is possible to use control strategy rules for determining Q_c to numerically evaluate P_C under the SCS control.

In this case $C_p = M \cdot Q \cdot R$. The value of Q_c is determined in each case from the predicted value of concentration Cp and from the strategy used. From the resulting distribution of Q_c, the value of P_{Cc} is easily obtained from the equation

$$P_{Cc} = P_{Qc} * P_M \tag{3.44}$$

Note the parallel nature of this equation and the equation for P_C.

This means that the existing frequency distribution of ground level concentrations for a plant can be determined from archived measurements of Q and M, and from records of air quality forecasting accuracy during operational use of the SCS to determine R. R is a function which contains contributions from all sources of error and uncertainty which prevent a perfect air quality forecast (that is, $C_p = C_o$). These sources of uncertainty arise from each component of the SCS -- meteorological forecasting, emissions forecasting, and air quality modeling. R has the following form:

$$R = R_q \cdot R_w \cdot R_m \tag{3.45}$$

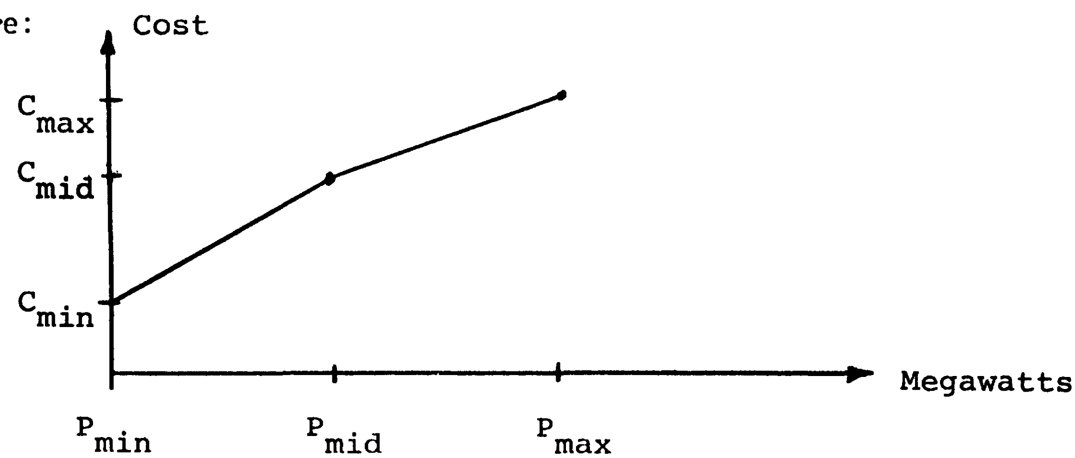
where R_q, R_w, and R_m are the error ratios for emissions prediction, meteorological (weather) forecasting, and air quality modeling respectively.

This probabilistic-reliability formulation, as it has been presented, would pose computational problems due to its complexity and often repeated usage. Fortunately there is a widely used and often substantiated simplifying assumption which can be invoked, and that is that the probabilistic distribution of pollutant concentrations at any one point in time and space is log normal in shape. This log normality assumption enables the description of the entire distribution function in terms of two parameters -- the geometric mean and geometric deviation. Thus, with only twice the number of equations as the deterministic formulation would require, the entire probabilistic formulation can be handled.

With the log normality presumption the single source probabilistic models are handled easily. The multiple source modeling requires a little more consideration. In particular, if each of a number of contributing sources are individually modeled in a log normal fashion, then their summation is not log normal. Thus the approach to be taken involves the log normal modeling of the combination of sources around a midpoint equal to the sum of the means. The variances would then be (by proportionate or some other functional relationship) relegated to the contributing sources. The method of relegation will have to come out of examinations of actual data sets.

The solution technique for this problem could be handled by linear programming <u>or</u>, possibly, successive approximation dynamic programming, both will be tested to see which is best.

Once the pollution constraint equations have been set up, the operating considerations of the power system must be incorporated. On the hourly time scale the loading curves of the generation plants become quite important; these are modeled as follows. Consider, for example, the loading curve presented here:



<u>Figure 3.4.13</u>

Define $x_1^0(k)$ as plant 1 in the k^{th} interval being on or off, i.e. 1 or 0, $x_1^1(k)$ as plant 1 either operating between the midpoint and the maximum megawatt rating or not operating there, i.e. 1 or 0... Now defining $y_1^0(k)$ and $y_1^1(k)$ as the fractional operation along the first and second segments of the curve, then

Power from unit 1 at time k =

$$P_{min}x_1^0(k) + (P_{mid} - P_{min})\, y_1^0(k) + (P_{mid} - P_{min})x_1^1(k) + (P_{max} - P_{mid})y_1^1(k) \quad (3.46)$$

and the cost of operating unit 1 at time k is

$$C_1(k) = C_{min}x_1^0(k) + (C_{mid} - C_{min})y_1^0(k) + (C_{mid} - C_{min})x_1^1(k) + (C_{max} - C_{mid})y_1^1(k) \quad (3.47)$$

with the logic requirements

$$0 \leqslant y_1^i(k) \leqslant 1 \qquad i = 0,1 \quad (3.48)$$

$$x_1^i(k) = 0 \text{ or } 1 \qquad i = 0,1 \quad (3.49)$$

$$x_1^0(k) - y_1^0(k) - x_1^1(k) \geqslant 0 \quad (3.50)$$

$$x_1^1(k) - y_1^1(k) \geqslant 0 \quad (3.51)$$

to preserve the proper loading order of the cost curve (note that cost may mean economic and/or environmental costs). If this cost curve happens to break in an upward direction rather than downward (as is the case for the Penelec plants) then the second integer, $x_1^1(k)$, will not be required because the increasing incremental costs will automatically preserve the loading order. Of course, if the loading curve is linear or requires perhaps even more exact modeling, such as two or three break points, these cases are obvious extensions.

Another pertinent factor which must be included in the scope of the unit commitment strategy is the ability to relate unit startup costs to the length of previous unit down time. For the computation of these startup costs it is advantageous to define a dummy variable z(k) as follows:

$$x_1^0(k) - x_1^0(k-1) = z(k)$$

Then to represent the following startup cost curve, for example

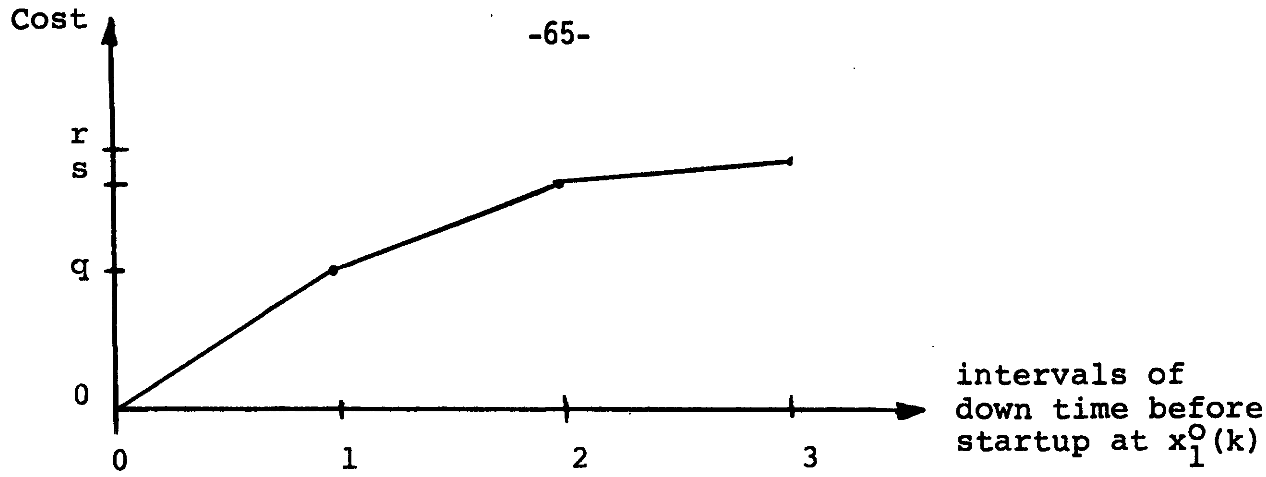


Figure 3.4.13

the cost penalty is st(k) where

$$st(k) \geq rz(k) - (s-q)x_1^o(k-2) - (r-s)z(k-2) \tag{3.52}$$

$$st(k) \geq 0 \tag{3.53}$$

(In this simulation mode all binary variables can be relaxed to allow fractional values, thus greatly increasing the speed of the simulation with little loss in accuracy.)

Some of the other features of the unit commitment strategy including modeling of:

(1) fuel switching capabilities,

(2) gas contract quotas, with penalties for misses,

(3) use of nuclear and hydro energy-use quotas,

(4) hydroelectric and pumped hydro pondage accounting,

(5) spinning reserve requirements,

(6) limited transmission loss modeling, and

(7) minimum down times and startup rate limits.

The week-by-week maintenance and production scheduling, see Figure 3.4.4 above, will also play an important role in an SCS. Climatological data can be used to help plan the 2 to 4 week long maintenance outages of facilities during times of low atmospheric dispersion potential. The minute-by-minute power system dispatch must be evaluated in light of the difference in objectives between this economic control and the environmental SCS actions. For example, the SCS could confine the operation of units to specific bands of outputs and the dispatch control would put all these on the edge of the band reflecting the most economic operation. This could have system reliability and air quality ramifications, and thus must be investigated.

3.5 Operational Program Definition

This task was identified to establish the detailed technical efforts which should be included in the actual SCS demonstration of Phase II, and in particular, tasks 6 and 7 of the original proposal. It was not possible to specify these matters before the preliminary data collection and analysis were performed and the AIRMAP system installed. Four areas of effort were undertaken: discussions with EPA, ERT operational forecasting, control demonstration stages, and model development. It was the effort in this task which led to the Phase II organization of tasks in terms of forecasting, control, modeling and analysis.

3.5.1 EPA Discussions

Discussions with the EPA were limited to the Federal EPA at the request of Penelec. Penelec would prefer approaching the Pennsylvania regulatory groups no sooner than after the mock demonstration has been tried and results of SCS operation are available.

The discussions with the EPA were intended primarily to gather information potentially affecting the demonstration project. Despite expectations, the EPA has not yet issued an approval of the promulgated regulations (Federal Register, Sept. 14, 1973) on SCS. The draft guidelines and discussions with the Office of Air Programs would indicate that no unanticipated technical requirements will be made on the project's operational SCS.

The delay in approval would seem to be related to the increasing EPA concern over the eventual fate of SO_2 in the atmosphere. Although SCS maintains ambient air quality, it can increase the total SO_2 loading in the atmosphere. The removal process is poorly understood and the products of SO_2 reactions or its synergistic effects with other pollutants may have more potential health effects than SO_2 itself. This area, which is not addressed by this project, is one of the most important areas of SCS research today, but little is being done in a quantitative manner.

In addition to gathering information, the discussions also disseminated information about the project. Discussions have been held with EPA personnel in Washington, D.C. and Research Triangle Park, N.C. including:

Dr. Robert Papetti - Ecological Processes and Effects Division, R&D, Washington, D.C.

Dr. Larry Niemeyer - Meteorology Laboratory, NERC, RTP, N.C.

Dr. Douglas Fox - Meteorology Laboratory, NERC, RTP, N.C.

Mr. Jack Thompson - Asst. Director, NERC, RTP, N.C.

Dr. Ken Caldwell - Meteorology Laboratory, NERC, RTP, N.C.

These individuals have voiced support for the thrust of the innovative modeling effort in its attempt to model explicitly the uncertainties of the air quality prediction process. It appears from our discussions that the present project's state estimation approach has been suggested by other researchers but that no one else has reached the field testing stage. On the contrary, other researchers suggesting this approach seem to be developing simulation efforts, and are not explicitly concentrating on the problem of SCS. Our discussions to date with EPA have served to establish informal contacts on both the administrative and technical levels and these contacts will be maintained through the remainder of the project.

3.5.2. ERT Operational Forecasting

The operational forecasting effort of ERT during the demonstration SCS will consist of two functions. First, ERT forecasters will prepare forecasts of the meteorological conditions at Penelec. These forecasts will be made twice daily (on two forecaster shifts) and cover the five six-hour periods immediately following the forecast. A six-hour period was chosen to reflect the limitations of forecaster accuracy and to coincide with the approximate time scale of persistent weather conditions. In situations where adverse dispersion conditions are expected additional forecasts will be made. Examples of such adverse conditions might be a morning fumigation period or a stagnating anticyclone. These forecasts will include specifications of wind speed and direction, precipitation, stability and mixing height.

Second, the ERT meteorological forecast will be combined with plant emission data to predict the regional air quality and especially any violations of standards. This air quality prediction will entail the use of ERT's air quality model and the data available from the AIRMAP monitors.

The operational forecasting will provide the prediction of a standards violation which will imitate the operation of control strategy. At that point it will be necessary to test the proposed emissions reductions to ensure that the standards are protected, and this will require a second forecast of the ERT model, using the revised emission schedule. This iteration between the control strategy codes and ERT's forecasters will be facilitated by the installation of the ERT air quality codes on the MIT computer where they can be accessed as a subroutine to the control strategy codes. A record of all forecasts will be made to allow evaluation of SCS reliability, using the methods of the report, "Analysis of the Reliability of a Supplementary Control System for SO_2 Emissions from a Point Source", which was prepared for the federal EPA by ERT.

In a parallel effort to the operational forecasting for interface with the control strategies, the forecasts of meteorology will also be provided to the innovative modeling group. This will provide a common basis for the comparison of the innovative models with the ERT operational models.

3.5.3 Control Demonstration Stages

The demonstration of the SCS will follow the course of (1) simulation, (2) "mock" control, and (3) actual control, as described previously. The evaluation will involve the cost-benefit analysis of all the possible pollution control measures, hopefully including all the inherent life-cycle costs of equipment such as scrubbers (i.e. materials, production, installation, operation, scrapping, etc.). It is intended that all the situations listed in section 3.4 will be evaluated with a firm foundation of real data from the power system under consideration. The following table shows all the possible cases which will be tabulated in the final comparative evaluation.

Pollution Control → Methods / Standards ↓	Fuel Switching (to higher and lower sulfur)	Stack Gas Temp. Modif.	Load Shifting (incl. maint. sched.)	Scrubbers (with and without bypass)	Intermit-tent use of Scrubbers
Existing, tightened & loosened 3- & 24-hr standards					
Higher & lower sulfur % standards on coal		P O S S C O M B I	I B L E N A T I O	N S	
Hypothetical standards such as 1-hr ambi-ent SO_2, sul-fur times par-tic., etc.					

Table 3.4.1

Case studies resulting in effects on air quality and total capital and operating dollar costs (with reliability effects included indirectly in costs by forcing power purchases).

The progress toward this final comparative evaluation currently stands at the stage of preparing for the advanced simulations. The simulations which have been performed up to this point, although probably adequate for the Penelec situation, would not be of general applicability. Because of the nature of the Penelec plants, baseloaded and the most efficient on the system, there is no need for strategies which involve dynamic decisions from the scheduler. That is, there will probably never be any "minimum down time" or "startup rate" problems because these plants would probably never be shut down. For this case, then, an incremental scheduler is probably sufficient, and an example of an incremental-type simulation is described later in this section.

The work on a dynamic scheduler requires the use of more sophisticated optimization techniques, which have been narrowed to two possibilities: linear programming and successive approximation dynamic programming. The optimization programs are in a stage where they are being assembled and tested separately from the rest of the control strategy, i.e. as separate subroutines.

The cruder, incremental scheduler can best be described through the presentation of a simple example that has been run through it. Unit 1 is the principal contributor to the violation that is shown to occur at grid point (10,10) at hour 14. The display shown on the next two pages shows the costs of the control strategy possibilities (stack gas temperature modification is not considered in this example.)

It is probably instructive to briefly describe what has happened in this example. Since Unit 1 was by far the major contributor to the violation, much greater proportions of other units would have had to be controlled for the same effects as small controls on Unit 1. Since costs are more or less comparable among the units, Unit 1 has the greatest "cost per pollution" leverage and is the only one controlled. Unit 1 has a higher cost increment for its top 502 MW of generation, and the replacement cost of energy is gradually more expensive on each successive hour. Thus 502 MW is scheduled in as many of the earlier time slots as is required to bring the probability of violation down to a prespecified "acceptable" level.

This example shows control only on the "incremental cost of pollution," that is, it does not assess the opportunities of shutdowns of plants (which would probably not be viable for the Penelec situation). The new optimization

```
I TO MEET STANDARDS SO THAT THE PROBABILITY OF FAILURE IS 1.00DAYS PER YEAR: I

       UNIT 1 SHOULD LOWER SO2 OUTPUT TO   83.0222 PERCENT
THIS WOULD MEAN REDUCING OUTPUT BY         305.6006MW TO       1494.3994MW

     LOAD SHIFTING:

AVERAGE POWER REDUCTION FOR THE 3 HOURS IS BEST PERFORMED AS
                      HOUR  14     502.000 MW LOAD SHIFT,AT COST OF $        7389.44
                      HOUR  15     414.802 MW LOAD SHIFT,AT COST OF $        8237.96
                      HOUR  16       0.0   MW LOAD SHIFT,AT COST OF $           0.0
THE TOTAL COST OF REPLACEMENT ENERGY =                                                   $   15627.40

     FUEL SWITCHING:

BEGINNING AT HOUR    14THE PLANT MUST SWITCH FUEL   31.3436 PERCENT OF THE NEXT 3 HOURS, OR 0.94HOURS
THE SWITCH FROM 2.40TO 1.10PERCENT SULFUR COAL WILL RESULT IN ADDITIONAL COSTS OF       $    7569.52

I TO MEET STANDARDS SO THAT THE PROBABILITY OF FAILURE IS 1.50DAYS PER YEAR: I

       UNIT 1 SHOULD LOWER SO2 OUTPUT TO   80.0889 PERCENT
THIS WOULD MEAN REDUCING OUTPUT BY         358.4004MW TO       1441.5996MW

     LOAD SHIFTING:

AVERAGE POWER REDUCTION FOR THE 3 HOURS IS BEST PERFORMED AS
                      HOUR  14     502.000 MW LOAD SHIFT,AT COST OF $        7389.44
                      HOUR  15     502.000 MW LOAD SHIFT,AT COST OF $        9969.72
                      HOUR  16      71.201 MW LOAD SHIFT,AT COST OF $        1602.74
THE TOTAL COST OF REPLACEMENT ENERGY =                                                   $   18961.89

     FUEL SWITCHING:

BEGINNNING AT HOUR   14THE PLANT MUST SWITCH FUEL  36.7590 PERCENT OF THE NEXT 3 HOURS, OR 1.10HOURS
THE SWITCH FROM 2.40TO 1.10PERCENT SULFUR COAL WILL RESULT IN ADDITIONAL COSTS OF       $    8877.34
```

Table 3.4.2

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SUPPLEMENTARY CONTROL STRATEGY

ECONOMIC OPTIMUM DISPATCH VIOLATES   3 HOUR STANDARD, AT HOUR  14
AT GRID POINT  10,  10THE MAXIMUM VIOLATION WAS PREDICTED TO BE   0.2250PPM

        I----------------------------------------------------------------------I
        I TO MEET STANDARDS SO THAT THE PROBABILITY OF FAILURE IS 0.50DAYS PER YEAR: I
        I----------------------------------------------------------------------I

          UNIT 1 SHOULD LOWER SO2 OUTPUT TO    85.9555 PERCENT
THIS WOULD MEAN REDUCING OUTPUT BY      252.9005MW TO      1547.1995MW

     LOAD SHIFTING:

AVERAGE POWER REDUCTION FOR THE 3 HOURS IS BEST PERFORMED AS
                       HOUR  14     502.600 MW LOAD SHIFT,AT COST OF $        7389.44
                       HOUR  15     256.402 MW LOAD SHIFT,AT COST OF $        5092.13
                       HOUR  16       0.0   MW LOAD SHIFT,AT COST OF $           0.0
THE TOTAL COST OF REPLACEMENT ENERGY =                                                      $   12481.57

     FUEL SWITCHING:

BEGINNING AT HOUR   14THE PLANT MUST SWITCH FUEL  25.9282 PERCENT OF THE NEXT 3 HOURS, OR 0.78HOURS
THE SWITCH FROM 2.40TO 1.10PERCENT SULFUR COAL WILL RESULT IN ADDITIONAL COSTS OF           $    6261.70
```

Table 3.4.2

techniques now being tested for the control strategy will incorporate these dynamic capabilities, and this will make the control strategy programs transferable to any other situation.

3.5.4 Model Development

The problem of model development in the remainder of the project became a crucial area of program definition as the extent of the ERT slippages became apparent. It was decided to pursue model development both at ERT and MIT.

Had no delays occurred, Phase I would have included the complete adaptation of the ERT models to the Penelec terrain and the beginning of AQ forecasting. Instead, essentially no air quality model development occurred and the brunt of the adaptation must be performed in Phase II. This development, consisting chiefly of terrain modifications, receptor dimensionality adjustments, and control interfacing with MIT, was scheduled for the first six weeks of Phase II effort. This schedule is believed to be compatible with the original concept of the demonstration SCS since the crucial period of the demonstration is the Exercise Control period. Due to the necessity of performing control simulations and Mock Control, it would be impossible to start Exercise Control before the model development work early in Phase II. It does not require changing the operational program definition of the control tasks for the demonstration phase.

More specifically, the terrain adaptation is needed to reflect the plume transport over the ridges and hills at Penelec. The AQ forecast model to be used in Phase II is being developed by ERT for another client. That client has a source on relatively flat terrain and no provision is in the original code for the model to reflect how a plume follows the terrain. The first part of the ERT model development is the inclusion of a simple description of the plume behavior in the Penelec terrain.

The second problem concerns the potentially large number of receptors (i.e., a location, not necessarily an AIRMAP monitor, for which the AQ model predicts concentrations.) A complex terrain model may increase the number of potential receptor sites of interest. The size of the area naturally affects the potential receptors, and the Penelec region of interest is over 1200 square miles. Background concentration effects will probably be important due to the proximity of Pittsburgh, and it is desirable to have sufficient receptors upwind to aid in the prediction of background. Finally, a desire for greater accuracy of predicted concentrations will require the number of potential receptors to increase. Fortunately, at any time, only a small subset (20% for example) of the total potential receptors will be of interest. The problem is to adjust the model codes to facilitate the identification of the relevant receptors as a function of meteorological conditions.

The unmodified ERT SCS model, designed for an existing **industrial** plant, includes a form of control strategy that is unacceptable for this project, due to the large number of control options resulting from the interconnected nature of an electric power system. The final operational program definition concerns the control strategy interface between the adapted code and the MIT codes for control strategy. It was decided this had two tasks: eliminate the effects of the existing code's control decision logic without destroying the usefulness of the code and facilitate the communications between ERT and MIT in the AQ evaluation of recommended control action. It was decided to install the ERT model on the MIT machine to accomplish this.

In addition to adapting the ERT model to reflect terrain effects on plume transport, a separate modeling effort was undertaken to improve the forecast of local winds. These winds are a function of terrain and various methods exist for their prediction based on the regional geostrophic wind and topography. These methods employ numerical solutions to fluid dynamical equations to predict flow. ERT has an existing, single-layer model and is developing a multilayer model which should increase the accuracy of results by reflecting the vertical wind shear better. This development work will continue in Phase II, and the multilayer model should progress to the stage where it can provide wind flow predictions for the Penelec forecasters. The single layer model will be used in the meantime to provide wind flow data for the forecasters and the wind field matrix for the innovative modeling work.

The innovative modeling effort will continue in Phase II. It is planned that the alternate models to be explored will be chosen early in Phase II and that most of the effort will be expended on model validation. This should not be considered as a part of the operation of the SCS, since ERT models will be used for that purpose. Rather this is intended to be a parallel effort to improve the available modeling technology.

In the validation process the plants' emission data and the regular ERT meteorological forecast will be used to drive the new models. The models will forecast SO_2 concentrations in the region and these will be compared to the forecasts of ERT using the SCS operational codes. Both forecasts will then be compared to the AIRMAP field data. If validation results indicate a level of performance better than the ERT models, an attempt will be made to use the innovative models in the operational system.

4.0 COORDINATION OF PHASES I AND II

Phase I of the project was intended to prepare the groundwork for Phase II. The groundwork included establishing a project data base, developing meteorological experience, adapting the necessary air quality models to the Penelec region, developing the control strategies and preparing the structure of the innovative air quality models to be tested as part of Phase II.

While the emphasis of Phase I was on design, the emphasis of Phase II is on the implementation of the designed SCS. Phase II will include the operational forecasting of meteorology and air quality, the testing and operation of the control strategies and the analysis of the SCS performance. In a parallel effort, the innovative air quality models will be tested on the SCS field data in an attempt to improve on the operational air quality models being demonstrated. Generally the Phase II efforts are straightforward extensions of the earlier tasks, and have merely been regrouped to emphasize operation as opposed to design.

Data collection will continue as an integral part of the forecasting, control and AQ modeling efforts. Using the major data categories identified in Phase I, Phase II data collection will be concerned with maintaining the necessary operational information for SCS decision making, and for testing the performance of the SCS. Phase II data will be generated by the SCS, with the notable exceptions of National Weather Service and Penelec operating data, whereas most Phase I data was compiled from other sources.

Phase I AQ modeling will be involved in Phase II operational forecasting (ERT) and innovative air quality modeling (ERT and MIT). Developmental work on the ERT models is still needed due to delays during Phase I. The work which has been delayed involves

1) reflecting the complex terrain of Penelec in the AQ prediction model
2) choosing a grid reduction scheme to reduce the dimensionality problem caused by the number of receptors needed in the region and
3) interfacing AQ with the MIT controls.

This developmental effort should be short lived and result in an operational air quality model "tuned" to the Penelec region.

The innovative air quality modeling effort was and will continue to be a parallel effort to the operational SCS demonstration. After the model formulation begun in Phase I is completed, the models will be tested off-line to compare their prediction ability with the tuned ERT models and the field data. This effort of comparing predictions must await the operation of the ERT model, but until that time limited tests will occur using LAPPES data.

Forecast modeling in Phase I was concerned with the problem of determining the meteorological parameters needed for the use of the air quality models. This was done by preparing actual real-time forecasts. This effort is continuing into Phase II as part of the operational air quality forecasting effort. Also, a multilayer three-dimensional wind flow model has been under development to aid in predicting the complex flows in the Penelec region. This work, an improvement over ERT's present single-layer model, will continue during Phase II with any necessary wind field modeling being performed with the single layer model until the multi-layer model is satisfactory.

Control development in Phase I was concerned with establishing the relevant Penelec and PJM constraints on SCS operation, and the criteria (economic and reliability) that the utility would use to judge the acceptability of the SCS. Then these criteria and constraints were incorporated into strategies for applying control action. In Phase II the strategies will be implemented and their performance evaluated. Even though certain control actions, such as load shifting, may be very undesirable on the Penelec plants, these will still be evaluated under the utility's criteria.

Program definition is ended as a specific task after Phase I. Phase II will have its own technical decisions, such as whether to employ an artificial Exercise Control period, which will essentially define the remainder of the project. But unlike Phase I, where the initial absence of a data base and the uncertainties of SCS design made a definition of the details of SCS implementation difficult, Phase II is a well-defined program. The Phase I SCS design will be implemented and, in a parallel mode, innovative air quality models will be tested.

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A.1 METEOROLOGICAL/AIR QUALITY

This appendix lists the monthly summary of AIRMAP SO_2 air quality data at the sixteen monitoring stations. It includes concentrations equating the 24 hour standard at monitor P3 (Luciusboro) on July 14, 1974. Also included is 24 minutes of two minute average data from the entire Chestnut Ridge AIRMAP system.

The latter two tables present wind rose data for the three stations nearest to Penelec-Pittsburgh, Philipsburg and Altoona (Blair County), and mixing depth information as observed at Pittsburgh, the nearest station taking regular upper atmospheric soundings.

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

C1 West Fairfield

STATION 1 DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

DAY												HOURS (LST)													AVG
HR-BEG	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
HR-END	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.004	.001	.009	.007	.010	.008	.010	.016	.018	.009	.004	.001	.006	.999
2	.007	.009	.016	.017	.013	.012	.012	.015	.026	.028	.019	.011	.009	.012	.015	.010	.005	.002	.007	.010	.013	.008	.005	.010	.012
3	.014	.021	.027	.029	.027	.025	.032	.037	.031	.027	.020	.018	.013	.011	.009	.005	.004	.002	.002	.004	.009	.008	.007	.011	.016
4	.009	.006	.006	.006	.015	.024	.030	.029	.025	.016	.013	.008	.003	.001	.001	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999
5	.999	.999	.999	.999	.999	.999	.999	.999	.025	.029	.030	.031	.024	.013	.007	.011	.017	.010	.027	.009	.006	.005	.003	.003	.999
6	.001	.001	.001	.999	.999	.999	.002	.001	.006	.024	.023	.015	.007	.001	.999	.005	.999	.037	.051	.043	.031	.030	.028	.017	.017
7	.016	.014	.015	.005	.002	.016	.028	.010	.006	.013	.023	.181	.099	.073	.054	.033	.017	.011	.010	.013	.015	.012	.010	.011	.029
8	.006	.006	.005	.005	.005	.004	.008	.007	.012	.032	.054	.094	.108	.054	.045	.026	.016	.015	.013	.024	.034	.025	.012	.012	.026
9	.010	.009	.008	.008	.010	.009	.024	.065	.078	.105	.095	.049	.036	.032	.026	.014	.009	.010	.016	.029	.040	.048	.050	.045	.034
10	.039	.046	.056	.052	.046	.051	.052	.042	.041	.045	.040	.019	.012	.006	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.001	.001	.001	.001	.001	.001	.011	.043	.074	.052	.001	.001	.001	.001	.002	.002	.004	.001	.003	.001	.001	.001	.050	.192	.019
12	.036	.087	.145	.478	.295	.209	.151	.079	.114	.154	.035	.002	.999	.999	.021	.053	.051	.017	.009	.999	.999	.999	.999	.999	.999
13	.001	.001	.001	.001	.001	.001	.001	.001	.004	.013	.023	.016	.029	.057	.049	.013	.009	.007	.029	.051	.057	.036	.017	.011	.018
14	.006	.006	.010	.013	.032	.043	.052	.050	.038	.030	.023	.015	.009	.008	.008	.009	.008	.006	.007	.007	.006	.008	.009	.011	.017
15	.006	.001	.001	.001	.999	.999	.999	.999	.999	.001	.015	.025	.032	.037	.043	.023	.001	.001	.001	.001	.001	.001	.001	.001	.010
16	.005	.005	.005	.002	.001	.001	.005	.017	.028	.028	.094	.023	.003	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.007	.010
17	.025	.023	.013	.008	.001	.001	.001	.001	.999	.010	.007	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.002	.002	.005
18	.002	.001	.013	.003	.002	.005	.004	.004	.008	.024	.030	.020	.007	.007	.008	.008	.001	.020	.032	.045	.035	.021	.017	.021	.015
19	.024	.024	.022	.011	.015	.015	.022	.035	.045	.048	.051	.053	.029	.006	.001	.0	.0	.0	.001	.001	.001	.001	.002	.001	.017
20	.001	.001	.001	.001	.001	.001	.001	.001	.001	.077	.036	.039	.058	.060	.041	.036	.006	.0	.0	.0	.0	.0	.019	.051	.016
21	.026	.022	.023	.028	.023	.024	.015	.028	.017	.010	.055	.144	.084	.050	.026	.999	.999	.001	.001	.001	.001	.001	.007	.001	.027
22	.0	.0	.0	.0	.0	.0	.009	.034	.020	.0	.0	.0	.0	.0	.0	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003
23	.001	.001	.001	.001	.001	.006	.007	.001	.003	.003	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
24	.001	.001	.001	.001	.002	.004	.007	.009	.035	.045	.040	.045	.025	.014	.002	.001	.001	.001	.001	.001	.001	.001	.001	.005	.010
25	.002	.002	.001	.001	.001	.001	.001	.004	.007	.014	.022	.014	.007	.002	.001	.001	.001	.001	.002	.002	.003	.005	.006	.007	.004
26	.006	.006	.006	.006	.007	.008	.009	.008	.008	.009	.008	.008	.008	.006	.005	.005	.005	.001	.001	.001	.001	.001	.001	.001	.005
27	.001	.001	.001	.001	.001	.001	.001	.001	.001	.006	.011	.012	.008	.016	.097	.019	.007	.006	.008	.010	.009	.006	.005	.009	.010
28	.008	.007	.007	.007	.009	.009	.014	.030	.051	.048	.036	.024	.018	.013	.013	.013	.014	.001	.001	.001	.001	.001	.001	.001	.014
29	.001	.001	.001	.001	.001	.001	.001	.001	.004	.011	.007	.002	.001	.001	.005	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
30	.001	.001	.001	.001	.001	.001	.003	.007	.011	.009	.005	.001	.002	.001	.001	.001	.001	.001	.001	.001	.001	.003	.006	.004	.003
31	.004	.004	.003	.003	.007	.013	.013	.018	.032	.024	.011	.010	.011	.010	.025	.018	.015	.005	.005	.010	.016	.012	.013	.012	.012
	.009	.011	.013	.025	.019	.018	.018	.021	.027	.031	.028	.029	.022	.017	.017	.011	.007	.006	.009	.010	.011	.009	.010	.016	
	29.	29.	29.	28.	27.	27.	28.	28.	28.	30.	30.	31.	30.	30.	30.	29.	28.	29.	29.	28.	28.	28.	28.	28.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.016 TOTAL NO. OF VALUES = 689. MAXIMUM HOURLY VALUE = 0.478

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.327

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.116

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1.

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

C2 Laurel Ridge

STATION 3 DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY	R-BEG 00 / R-END 01	01 / 02	02 / 03	03 / 04	04 / 05	05 / 06	06 / 07	07 / 08	08 / 09	09 / 10	10 / 11	11 / 12	12 / 13	13 / 14	14 / 15	15 / 16	16 / 17	17 / 18	18 / 19	19 / 20	20 / 21	21 / 22	22 / 23	23 / 24	AVG
1	.078	.007	.001	.001	.001	.004	.009	.014	.009	.008	.006	.012	.046	.067	.049	.032	.096	.012	.068	.014	.006	.001	.001	.008	.020
2	.022	.013	.020	.020	.011	.009	.004	.011	.023	.019	.011	.010	.011	.009	.011	.009	.007	.006	.006	.012	.015	.008	.013	.014	.012
3	.016	.016	.020	.018	.024	.035	.037	.032	.028	.026	.022	.017	.015	.012	.009	.007	.006	.006	.005	.005	.009	.020	.011	.020	.017
4	.015	.009	.018	.025	.020	.029	.035	.047	.027	.017	.011	.008	.006	.002	.004	.006	.005	.001	.001	.001	.001	.001	.001	.004	.012
5	.014	.004	.005	.014	.017	.025	.026	.024	.045	.038	.021	.022	.017	.013	.009	.010	.011	.013	.027	.009	.056	.063	.024	.006	.021
6	.005	.004	.005	.024	.091	.068	.042	.042	.090	.135	.086	.029	.086	.095	.075	.069	.065	.030	.009	.013	.004	.024	.024	.006	.047
7	.008	.011	.012	.007	.006	.012	.021	.016	.012	.014	.051	.065	.050	.066	.079	.140	.148	.091	.056	.027	.022	.022	.375	.033	.056
8	.013	.016	.035	.007	.001	.001	.018	.155	.165	.119	.098	.133	.067	.134	.057	.070	.060	.015	.011	.009	.013	.020	.008	.012	.052
9	.024	.010	.006	.051	.099	.118	.120	.147	.256	.126	.097	.073	.047	.035	.029	.022	.014	.014	.019	.033	.040	.040	.032	.035	.062
10	.034	.049	.048	.042	.042	.048	.044	.040	.044	.047	.047	.032	.036	.033	.026	.008	.001	.001	.001	.001	.001	.013	.010	.030	.028
11	.033	.022	.002	.001	.001	.001	.001	.002	.005	.004	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.005	.004
12	.004	.005	.002	.001	.001	.001	.004	.009	.007	.004	.001	.001	.005	.001	.001	.001	.001	.017	.021	.009	.028	.179	.161	.088	.025
13	.045	.017	.009	.005	.035	.186	.039	.039	.039	.043	.030	.023	.027	.094	.068	.039	.020	.021	.013	.017	.022	.022	.019	.013	.037
14	.018	.031	.028	.059	.062	.052	.045	.034	.034	.030	.024	.016	.013	.010	.013	.011	.011	.006	.006	.006	.006	.009	.016	.021	.023
15	.014	.004	.001	.001	.001	.001	.001	.005	.014	.015	.024	.028	.029	.026	.034	.030	.064	.065	.010	.022	.017	.049	.031	.047	.022
16	.061	.017	.013	.017	.019	.026	.126	.075	.066	.085	.025	.032	.105	.099	.083	.081	.062	.076	.054	.025	.010	.026	.004	.004	.049
17	.004	.012	.011	.007	.007	.003	.001	.001	.001	.005	.006	.009	.007	.008	.004	.003	.008	.004	.065	.003	.003	.030	.044	.006	.008
18	.008	.008	.010	.025	.020	.007	.007	.034	.024	.021	.021	.027	.013	.012	.010	.011	.006	.022	.063	.044	.118	.031	.020	.022	.024
19	.017	.025	.024	.013	.017	.021	.041	.042	.038	.041	.046	.097	.043	.013	.004	.040	.061	.065	.112	.063	.090	.181	.060	.056	.050
20	.027	.037	.026	.011	.004	.001	.001	.001	.013	.043	.002	.002	.001	.005	.001	.001	.001	.001	.001	.001	.001	.002	.002	.001	.008
21	.001	.001	.001	.001	.001	.001	.008	.001	.015	.009	.001	.001	.001	.001	.002	.003	.004	.001	.001	.007	.001	.001	.002	.012	.003
22	.007	.053	.032	.002	.001	.001	.001	.002	.007	.006	.002	.002	.001	.001	.001	.001	.001	.001	.002	.004	.003	.002	.001	.006	.006
23	.003	.004	.004	.005	.005	.002	.007	.027	.045	.016	.011	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.006
24	.001	.014	.026	.040	.039	.016	.006	.015	.015	.030	.119	.049	.061	.059	.065	.056	.106	.019	.003	.001	.003	.014	.008	.026	.033
25	.013	.013	.010	.015	.022	.022	.021	.015	.017	.020	.025	.018	.013	.008	.006	.007	.011	.009	.006	.007	.006	.007	.008	.010	.013
26	.009	.009	.009	.010	.009	.009	.008	.009	.009	.009	.009	.008	.009	.012	.011	.011	.005	.001	.001	.001	.001	.001	.001	.001	.007
27	.002	.001	.001	.001	.002	.014	.041	.019	.022	.016	.023	.031	.034	.034	.023	.042	.074	.027	.017	.014	.013	.010	.011	.012	.020
28	.008	.011	.010	.008	.021	.045	.041	.044	.042	.040	.038	.029	.024	.019	.013	.999	.015	.054	.101	.003	.001	.001	.001	.006	.025
29	.009	.007	.006	.005	.014	.020	.025	.055	.060	.047	.027	.999	.014	.013	.008	.006	.003	.003	.012	.001	.001	.001	.001	.016	.015
30	.020	.038	.077	.058	.056	.035	.033	.037	.027	.017	.018	.012	.016	.037	.013	.009	.006	.004	.004	.009	.006	.007	.003	.024	.024
31	.022	.019	.026	.026	.026	.039	.044	.062	.247	.158	.073	.076	.102	.069	.033	.035	.026	.013	.005	.020	.019	.019	.018	.017	.049
	.018	.016	.016	.017	.022	.027	.026	.034	.047	.038	.032	.029	.030	.032	.024	.025	.029	.019	.019	.012	.017	.026	.029	.018	
	31.	31.	31.	31.	31.	31.	31.	31.	31.	31.	31.	30.	31.	31.	31.	30.	31.	31.	31.	31.	31.	31.	31.	31.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.025 TOTAL NO. OF VALUES = 742. MAXIMUM HOURLY VALUE = 0.375

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.176

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.062

NOTE : 999 - MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P5 Florence Substation

STATION 2 DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

DAY	HOURS (LST)																								AVG
HR-BEG	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
HR-END	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	.999	.999	.999	.999	.999	.999	.999	.999	.028	.007	.004	.001	.003	.008	.009	.008	.011	.012	.006	.013	.018	.010	.004	.004	.999
2	.007	.012	.013	.015	.019	.024	.019	.015	.014	.015	.010	.015	.016	.016	.015	.009	.006	.006	.006	.009	.010	.013	.011	.015	.013
3	.020	.015	.015	.018	.027	.028	.031	.031	.030	.027	.024	.025	.025	.019	.017	.017	.018	.016	.016	.011	.009	.010	.009	.007	.019
4	.016	.010	.008	.008	.016	.018	.022	.026	.029	.028	.019	.018	.010	.008	.006	.007	.004	.005	.002	.001	.027	.002	.001	.001	.012
5	.001	.001	.001	.001	.003	.001	.004	.014	.013	.024	.024	.022	.017	.013	.014	.012	.015	.015	.009	.006	.006	.004	.004	.004	.009
6	.003	.002	.002	.001	.001	.001	.001	.001	.012	.015	.015	.046	.078	.074	.100	.173	.034	.006	.011	.015	.014	.017	.008	.014	.027
7	.072	.164	.133	.124	.182	.105	.117	.091	.056	.021	.008	.011	.029	.073	.093	.095	.059	.047	.028	.028	.030	.028	.018	.015	.069
8	.019	.018	.013	.010	.009	.006	.008	.031	.028	.069	.122	.061	.040	.046	.066	.026	.024	.023	.021	.022	.022	.025	.022	.022	.032
9	.029	.024	.019	.017	.014	.016	.024	.043	.092	.076	.052	.056	.053	.040	.053	.050	.999	.999	.999	.999	.999	.999	.999	.999	.999
10	.999	.999	.999	.999	.999	.999	.999	.999	.999	.053	.054	.040	.032	.030	.014	.006	.004	.001	.001	.001	.001	.002	.001	.002	.999
11	.001	.006	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
12	.001	.042	.074	.047	.009	.006	.009	.006	.005	.003	.001	.001	.001	.001	.001	.001	.002	.007	.003	.003	.001	.002	.002	.003	.010
13	.001	.001	.001	.001	.001	.001	.001	.001	.004	.012	.017	.012	.324	.107	.077	.048	.029	.037	.038	.040	.042	.042	.038	.013	.037
14	.019	.029	.026	.031	.033	.040	.047	.046	.046	.045	.040	.034	.030	.028	.027	.025	.034	.045	.030	.027	.022	.023	.026	.010	.032
15	.007	.002	.001	.001	.001	.001	.001	.013	.033	.034	.034	.039	.038	.041	.034	.015	.041	.037	.001	.010	.007	.007	.007	.002	.017
16	.003	.006	.005	.001	.001	.004	.037	.092	.052	.045	.007	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.011
17	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003	.077	.075	.007	.006	.006	.005	.006	.006	.006	.007	.012	.024	.014	.011
18	.141	.126	.049	.026	.021	.022	.012	.009	.012	.051	.028	.039	.034	.030	.024	.030	.046	.077	.059	.053	.043	.044	.038	.010	.041
19	.021	.031	.041	.024	.022	.035	.056	.057	.034	.056	.060	.042	.013	.008	.011	.055	.055	.017	.005	.003	.003	.008	.021	.006	.029
20	.006	.005	.005	.003	.003	.002	.002	.002	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.003	.001	.001	.001	.001	.001	.001	.001	.001
22	.011	.013	.017	.039	.062	.105	.065	.064	.152	.071	.006	.003	.002	.002	.002	.014	.006	.002	.002	.016	.089	.082	.174	.045	.044
23	.000	.003	.002	.001	.004	.003	.003	.023	.033	.029	.012	.015	.010	.003	.020	.001	.001	.001	.001	.001	.001	.001	.001	.001	.007
24	.006	.021	.016	.020	.015	.008	.010	.008	.008	.010	.009	.018	.059	.049	.047	.027	.021	.004	.004	.004	.007	.006	.006	.002	.016
25	.002	.001	.001	.006	.011	.008	.085	.045	.051	.052	.040	.018	.013	.027	.099	.075	.063	.016	.008	.016	.014	.012	.014	.047	.030
26	.206	.125	.092	.035	.053	.077	.016	.027	.041	.016	.009	.008	.010	.012	.011	.012	.013	.012	.069	.023	.015	.006	.003	.003	.037
27	.005	.015	.020	.036	.009	.007	.013	.075	.063	.034	.036	.026	.023	.017	.014	.023	.058	.032	.033	.031	.034	.029	.021	.008	.026
28	.013	.010	.010	.012	.014	.026	.064	.055	.053	.050	.051	.053	.046	.999	.044	.037	.030	.004	.018	.028	.005	.001	.004	.037	.029
29	.115	.068	.038	.080	.049	.017	.007	.012	.030	.032	.038	.030	.024	.024	.016	.013	.011	.012	.001	.001	.001	.001	.001	.015	.020
30	.009	.009	.015	.015	.039	.027	.015	.019	.023	.019	.025	.013	.023	.022	.018	.014	.017	.017	.008	.012	.013	.013	.015	.008	.017
31	.009	.010	.007	.011	.009	.008	.016	.026	.046	.025	.022	.021	.015	.013	.018	.038	.028	.020	.007	.007	.020	.014	.009	.011	.017
	.026	.027	.022	.020	.022	.021	.024	.029	.034	.028	.025	.024	.034	.024	.028	.027	.021	.016	.013	.013	.015	.014	.016	.011	
	29.	29.	29.	29.	29.	29.	29.	29.	30.	31.	31.	31.	31.	30.	31.	31.	30.	30.	30.	30.	30.	30.	30.	30.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.022 TOTAL NO. OF VALUES = 718. MAXIMUM HOURLY VALUE = 0.324

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.169

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.070

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P4 Armagh

STATION 6 DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG / HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.017	.014	.009	.008	.017	.019	.022	.023	.025	.022	.023	.030	.046	.038	.039	.999
2	.036	.023	.043	.027	.030	.025	.022	.030	.029	.029	.019	.020	.025	.028	.029	.021	.018	.070	.025	.020	.031	.024	.019	.020	.028
3	.029	.022	.018	.025	.036	.041	.044	.046	.041	.040	.035	.035	.038	.032	.027	.025	.026	.027	.025	.017	.014	.016	.012	.018	.029
4	.022	.017	.015	.013	.014	.023	.036	.038	.037	.036	.026	.026	.013	.010	.008	.012	.006	.013	.008	.018	.025	.070	.087	.006	.024
5	.007	.025	.024	.023	.009	.007	.005	.007	.020	.039	.035	.033	.032	.057	.023	.019	.018	.016	.004	.009	.011	.009	.006	.004	.018
6	.001	.001	.001	.001	.001	.999	.999	.999	.029	.035	.150	.103	.073	.012	.017	.035	.002	.999	.999	.001	.001	.999	.999	.001	.999
7	.001	.001	.002	.001	.001	.001	.001	.040	.146	.136	.048	.015	.016	.028	.017	.015	.037	.141	.055	.027	.053	.056	.040	.034	.038
8	.028	.030	.023	.037	.028	.030	.037	.091	.067	.098	.139	.136	.075	.045	.104	.125	.064	.020	.018	.012	.029	.038	.033	.045	.056
9	.047	.051	.040	.042	.039	.029	.051	.043	.071	.123	.058	.058	.056	.053	.060	.076	.054	.034	.037	.049	.062	.070	.066	.064	.054
10	.070	.068	.069	.071	.062	.058	.060	.062	.057	.073	.074	.062	.044	.046	.022	.011	.002	.001	.001	.001	.001	.005	.001	.006	.039
11	.011	.011	.007	.003	.001	.001	.002	.006	.014	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003
12	.001	.001	.003	.027	.009	.011	.013	.012	.009	.007	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.002	.003	.005
13	.001	.001	.001	.003	.001	.005	.007	.065	.107	.036	.027	.011	.092	.153	.182	.163	.070	.027	.025	.022	.041	.052	.052	.043	.049
14	.037	.034	.037	.031	.040	.056	.068	.073	.064	.056	.040	.035	.026	.024	.022	.016	.021	.028	.031	.034	.026	.025	.029	.029	.037
15	.028	.014	.004	.001	.001	.001	.001	.005	.035	.044	.046	.053	.053	.058	.054	.041	.001	.001	.001	.001	.001	.001	.001	.001	.019
16	.001	.002	.002	.002	.002	.002	.002	.002	.002	.002	.001	.023	.015	.024	.016	.008	.005	.008	.006	.005	.005	.006	.004	.002	.006
17	.001	.001	.001	.001	.001	.001	.004	.016	.049	.066	.068	.063	.055	.107	.072	.019	.008	.004	.002	.007	.015	.019	.024	.025	.027
18	.020	.033	.026	.042	.046	.053	.047	.068	.019	.021	.026	.051	.048	.035	.037	.041	.062	.089	.082	.077	.062	.071	.073	.048	.049
19	.038	.031	.039	.031	.027	.036	.043	.060	.070	.071	.075	.063	.033	.010	.006	.038	.025	.005	.001	.001	.002	.001	.005	.005	.030
20	.004	.005	.005	.003	.003	.002	.003	.004	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
22	.001	.001	.001	.001	.001	.001	.001	.003	.011	.014	.011	.007	.026	.039	.011	.004	.004	.005	.011	.014	.017	.009	.008	.006	.009
23	.006	.006	.012	.012	.010	.008	.008	.010	.013	.028	.038	.023	.015	.007	.005	.011	.055	.011	.043	.016	.020	.006	.001	.005	.015
24	.006	.002	.010	.029	.025	.015	.009	.008	.039	.012	.009	.008	.009	.034	.062	.045	.060	.035	.005	.004	.010	.009	.006	.004	.016
25	.001	.005	.001	.001	.001	.001	.000	.017	.035	.049	.050	.228	.119	.036	.037	.019	.014	.012	.008	.013	.024	.024	.020	.019	.032
26	.016	.022	.028	.055	.034	.037	.055	.027	.019	.018	.015	.014	.015	.037	.027	.020	.019	.009	.003	.001	.001	.002	.001	.001	.016
27	.001	.001	.002	.007	.006	.010	.006	.022	.057	.080	.040	.030	.017	.010	.006	.006	.035	.009	.006	.025	.031	.024	.023	.024	.019
28	.030	.024	.011	.015	.016	.012	.022	.039	.059	.061	.054	.048	.041	.027	.023	.034	.027	.006	.005	.023	.029	.011	.007	.002	.026
29	.003	.001	.004	.005	.007	.012	.006	.033	.048	.037	.999	.029	.029	.034	.015	.012	.011	.006	.043	.014	.001	.002	.008	.001	.016
30	.051	.044	.025	.024	.020	.015	.018	.025	.027	.021	.019	.015	.019	.020	.017	.014	.016	.017	.012	.010	.013	.014	.018	.022	.021
31	.041	.021	.019	.016	.014	.020	.021	.027	.040	.025	.040	.031	.020	.017	.018	.040	.031	.028	.013	.010	.010	.012	.017	.020	.023
	.018	.016	.016	.018	.016	.018	.019	.030	.039	.041	.040	.040	.033	.032	.030	.029	.023	.022	.017	.015	.018	.021	.020	.016	
	30.	30.	30.	30.	30.	29.	29.	29.	30.	31.	30.	31.	31.	31.	31.	31.	31.	30.	30.	31.	31.	30.	30.	31.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.025 TOTAL NO. OF VALUES = 727. MAXIMUM HOURLY VALUE = 0.228

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.166

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.065

NOTE : 999 - MISSING VALUE INDICATOR

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TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

S1 Gas Center

STATION 7 DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.010	.019	.021	.025	.022	.023	.019	.020	.023	.029	.036	.999
2	.036	.061	.042	.037	.027	.026	.030	.093	.340	.211	.030	.075	.082	.035	.045	.027	.038	.016	.016	.021	.024	.026	.214	.999	.067
3	.051	.053	.068	.053	.069	.049	.115	.082	.043	.038	.053	.030	.031	.026	.023	.026	.020	.021	.019	.017	.034	.095	.072	.090	.048
4	.031	.118	.120	.099	.062	.060	.044	.131	.136	.043	.039	.061	.046	.030	.021	.034	.016	.999	.999	.999	.013	.012	.004	.006	.055
5	.028	.042	.023	.012	.003	.019	.050	.057	.029	.032	.051	.042	.052	.051	.042	.024	.031	.024	.019	.012	.011	.010	.014	.999	.029
6	.010	.007	.006	.003	.001	.001	.001	.001	.007	.022	.050	.057	.027	.022	.022	.032	.017	.006	.003	.004	.004	.001	.001	.004	.013
7	.001	.001	.001	.001	.001	.001	.001	.017	.375	.252	.097	.031	.023	.024	.032	.033	.033	.065	.068	.043	.050	.039	.028	.999	.053
8	.030	.019	.042	.028	.021	.016	.092	.068	.410	.267	.136	.090	.057	.049	.056	.071	.039	.039	.036	.028	.025	.029	.065	.059	.075
9	.043	.028	.027	.047	.045	.036	.150	.232	.218	.159	.074	.046	.043	.044	.045	.064	.054	.042	.039	.040	.049	.071	.098	.115	.076
10	.106	.096	.089	.096	.158	.075	.064	.082	.057	.050	.048	.049	.035	.029	.026	.049	.043	.065	.046	.037	.999	.999	.999	.999	.065
11	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.006	.005	.003	.004	.003	.001	.001	.001	.001	.001	.001	.001	.001	.999
12	.001	.001	.001	.001	.001	.001	.005	.006	.007	.007	.007	.008	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
13	.008	.008	.005	.004	.001	.001	.001	.009	.135	.208	.054	.029	.023	.059	.068	.069	.040	.030	.030	.020	.023	.026	.062	.075	.041
14	.107	.123	.127	.177	.176	.247	.260	.196	.153	.114	.069	.075	.039	.032	.039	.077	.045	.048	.037	.039	.030	.051	.046	.999	.101
15	.024	.021	.014	.009	.035	.061	.063	.113	.145	.061	.061	.041	.038	.034	.038	.033	.022	.023	.016	.012	.006	.004	.002	.005	.038
16	.005	.006	.007	.006	.007	.008	.010	.035	.110	.038	.012	.008	.010	.014	.008	.008	.007	.007	.008	.003	.001	.001	.001	.001	.013
17	.001	.001	.001	.001	.001	.001	.001	.006	.011	.012	.016	.015	.011	.020	.046	.040	.033	.012	.007	.003	.001	.003	.004	.006	.011
18	.010	.023	.017	.022	.037	.040	.042	.041	.077	.079	.057	.040	.999	.999	.999	.999	.999	.058	.046	.035	.029	.043	.041	.090	.044
19	.071	.090	.058	.044	.027	.033	.029	.035	.042	.039	.043	.042	.030	.018	.013	.024	.014	.009	.005	.003	.002	.0	.001	.005	.028
20	.002	.001	.001	.001	.001	.001	.001	.001	.002	.002	.001	.002	.003	.002	.002	.001	.002	.001	.001	.001	.001	.001	.001	.001	.001
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.003	.003	.004	.004	.004	.005	.006	.007	.006	.007	.005	.003	.002	.004	.003
22	.001	.003	.001	.001	.002	.001	.004	.007	.013	.017	.012	.008	.008	.007	.009	.006	.008	.009	.007	.010	.016	.011	.010	.009	.008
23	.009	.012	.013	.014	.011	.009	.010	.012	.005	.021	.020	.017	.017	.009	.008	.007	.006	.007	.005	.004	.003	.001	.001	.001	.009
24	.001	.001	.004	.015	.016	.013	.009	.009	.008	.011	.012	.012	.011	.019	.034	.031	.033	.033	.011	.005	.004	.006	.003	.002	.013
25	.001	.001	.001	.001	.001	.001	.003	.006	.012	.021	.031	.041	.031	.024	.015	.015	.016	.015	.013	.015	.021	.023	.030	.027	.015
26	.022	.024	.032	.027	.024	.024	.022	.021	.022	.018	.016	.015	.013	.027	.030	.021	.017	.013	.011	.008	.007	.006	.002	.004	.018
27	.005	.003	.002	.002	.001	.004	.006	.011	.016	.023	.033	.025	.024	.022	.020	.018	.036	.031	.022	.017	.017	.013	.011	.012	.016
28	.011	.016	.011	.010	.013	.014	.016	.021	.135	.155	.169	.116	.082	.082	.071	.040	.032	.014	.007	.025	.006	.006	.003	.004	.044
29	.003	.001	.001	.002	.007	.007	.007	.011	.021	.017	.037	.032	.033	.047	.079	.039	.019	.013	.999	.999	.999	.999	.999	.999	.021
30	.012	.017	.023	.016	.015	.045	.053	.036	.040	.062	.026	.018	.013	.015	.011	.008	.010	.010	.008	.006	.009	.007	.011	.016	.020
31	.011	.010	.010	.009	.024	.125	.125	.153	.187	.079	.022	.020	.015	.012	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
	.022	.027	.026	.025	.027	.032	.043	.052	.095	.071	.043	.035	.029	.027	.030	.050	.024	.023	.019	.016	.015	.019	.028	.025	
	29.	29.	29.	29.	29.	29.	29.	29.	29.	29.	29.	30.	28.	29.	28.	28.	28.	28.	27.	27.	27.	27.	27.	23.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.033 TOTAL NO. OF VALUES = 676. MAXIMUM HOURLY VALUE = 0.410

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.271

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.101

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P3 Luciusboro

STATION A DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.001	.001	.001	.001	.001	.001	.001	.999	.046	.038	.036	.028	.032	.083	.069	.049	.086	.047	.042	.046	.068	.037	.027	.001	.032
2	.008	.032	.036	.045	.041	.038	.037	.044	.036	.063	.054	.057	.053	.048	.045	.023	.016	.011	.007	.014	.031	.065	.055	.062	.038
3	.064	.054	.058	.060	.062	.066	.082	.076	.066	.057	.059	.077	.088	.070	.048	.047	.049	.059	.056	.030	.023	.017	.070	.123	.061
4	.101	.086	.061	.066	.046	.045	.067	.093	.069	.060	.037	.047	.029	.009	.010	.024	.014	.016	.999	.999	.039	.002	.999	.999	.046
5	.999	.999	.999	.999	.003	.022	.043	.064	.073	.056	.048	.039	.039	.039	.034	.024	.025	.009	.008	.010	.004	.004	.999	.999	.030
6	.999	.999	.999	.999	.999	.999	.999	.001	.005	.145	.113	.079	.020	.081	.137	.038	.001	.001	.004	.003	.009	.010	.002	.001	.999
7	.999	.006	.125	.051	.051	.044	.073	.136	.090	.030	.019	.008	.008	.017	.067	.234	.272	.121	.056	.062	.059	.046	.042	.053	.073
8	.038	.035	.041	.014	.023	.025	.031	.030	.299	.305	.321	.291	.173	.227	.130	.147	.099	.051	.040	.036	.036	.064	.096	.075	.109
9	.083	.066	.111	.077	.100	.107	.151	.193	.300	.210	.125	.114	.099	.097	.106	.115	.101	.064	.055	.074	.106	.099	.101	.093	.114
10	.098	.129	.150	.136	.124	.127	.132	.110	.112	.110	.115	.113	.095	.078	.016	.005	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.016	.003	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.999	.002
12	.999	.999	.999	.999	.999	.999	.999	.999	.004	.005	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.005	.027	.012	.999
13	.004	.999	.999	.999	.999	.999	.999	.004	.021	.031	.032	.149	.213	.378	.336	.181	.135	.083	.076	.045	.055	.090	.090	.048	.109
14	.057	.104	.140	.187	.190	.175	.162	.130	.125	.114	.099	.072	.064	.050	.046	.040	.058	.079	.056	.051	.037	.034	.034	.035	.069
15	.003	.001	.001	.999	.999	.999	.999	.999	.999	.015	.040	.065	.075	.113	.089	.011	.003	.015	.003	.012	.012	.009	.011	.006	.027
16	.001	.001	.001	.001	.001	.001	.002	.019	.069	.029	.008	.023	.064	.052	.043	.046	.043	.047	.015	.010	.007	.005	.001	.001	.020
17	.001	.001	.001	.001	.006	.010	.023	.039	.055	.054	.032	.180	.122	.016	.006	.002	.001	.001	.005	.002	.011	.008	.047	.029	.027
18	.036	.084	.068	.041	.029	.032	.021	.033	.062	.041	.038	.054	.091	.091	.064	.058	.141	.169	.303	.145	.087	.096	.091	.055	.060
19	.049	.055	.078	.049	.056	.052	.066	.095	.093	.106	.125	.140	.043	.001	.999	.053	.046	.001	.999	.999	.999	.001	.002	.999	.060
20	.002	.002	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
21	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
22	.999	.999	.999	.008	.056	.030	.040	.029	.064	.217	.169	.011	.006	.002	.017	.026	.022	.007	.011	.049	.051	.045	.032	.061	.045
23	.164	.072	.007	.047	.008	.001	.001	.005	.022	.013	.034	.020	.012	.054	.042	.017	.999	.999	.999	.999	.999	.999	.999	.999	.999
24	.999	.008	.027	.025	.020	.006	.001	.002	.006	.013	.012	.013	.029	.050	.056	.044	.063	.069	.005	.002	.002	.007	.004	.002	.020
25	.999	.999	.013	.020	.024	.040	.175	.183	.046	.089	.165	.093	.029	.018	.087	.160	.122	.033	.015	.011	.018	.019	.022	.048	.065
26	.056	.049	.055	.042	.063	.044	.028	.051	.193	.131	.038	.002	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
27	.999	.999	.999	.999	.999	.999	.006	.030	.038	.053	.046	.017	.007	.001	.002	.138	.101	.040	.035	.051	.044	.049	.043	.035	.042
28	.027	.021	.019	.020	.018	.029	.069	.139	.171	.127	.102	.077	.074	.054	.033	.033	.011	.012	.024	.080	.020	.027	.011	.013	.050
29	.018	.010	.007	.008	.023	.012	.001	.007	.072	.085	.083	.073	.057	.068	.060	.024	.029	.004	.999	.999	.999	.999	.999	.999	.036
30	.999	.032	.037	.069	.061	.055	.051	.048	.063	.046	.060	.042	.041	.021	.030	.030	.031	.999	.025	.026	.028	.028	.027	.006	.039
31	.006	.006	.007	.007	.007	.006	.006	.006	.073	.035	.106	.047	.090	.079	.022	.027	.020	.024	.015	.006	.013	.018	.017	.008	.027
	.040	.037	.045	.042	.042	.040	.051	.060	.082	.079	.073	.067	.057	.064	.059	.057	.057	.039	.037	.033	.032	.031	.037	.037	
	21.	23.	23.	23.	24.	24.	25.	26.	28.	29.	29.	29.	29.	28.	27.	28.	26.	25.	23.	23.	24.	25.	23.	21.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.051 TOTAL NO. OF VALUES = 606. MAXIMUM HOURLY VALUE = 0.378

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.309

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P3 Luciusboro

PEAK VALUE ANALYSIS FOR STATION A JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

THE FOLLOWING 24-HOUR VALUES EXCEED 0.140

DAY	HOUR	VALUE
14	10	0.140

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

H3 Lewisville

STATION B DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.005	.004	.004	.005	.005	.005	.005	.007	.025	.020	.017	.015	.015	.015	.015	.015	.015	.015	.015	.015	.016	.020	.018	.005	.012
2	.001	.001	.001	.006	.015	.018	.022	.025	.026	.019	.015	.003	.001	.001	.002	.003	.003	.002	.001	.003	.007	.012	.026	.010	.009
3	.007	.010	.017	.015	.017	.020	.022	.029	.031	.033	.040	.024	.013	.012	.009	.006	.010	.022	.028	.013	.006	.007	.006	.006	.017
4	.008	.017	.024	.016	.025	.016	.018	.019	.022	.020	.007	.003	.002	.001	.001	.002	.005	.005	.001	.001	.001	.001	.001	.004	.009
5	.006	.002	.001	.003	.009	.014	.017	.026	.045	.045	.029	.018	.019	.016	.012	.009	.008	.001	.001	.001	.001	.001	.001	.001	.012
6	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.039	.093	.045	.025	.008	.002	.001	.001	.001	.001	.002	.999
7	.001	.001	.001	.001	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.999
8	.001	.001	.002	.002	.001	.002	.001	.001	.001	.001	.014	.014	.014	.014	.014	.003	.002	.002	.003	.002	.002	.003	.004	.007	.005
9	.005	.005	.005	.005	.005	.005	.005	.006	.007	.008	.008	.007	.006	.007	.006	.006	.006	.005	.004	.005	.005	.005	.005	.006	.006
10	.004	.004	.004	.005	.005	.005	.005	.005	.005	.005	.004	.005	.004	.002	.001	.001	.008	.001	.001	.001	.001	.001	.001	.001	.003
11	.001	.001	.001	.003	.002	.003	.001	.001	.004	.012	.012	.011	.011	.011	.013	.016	.014	.022	.012	.013	.012	.012	.014	.015	.009
12	.013	.011	.010	.011	.012	.011	.010	.010	.012	.009	.008	.006	.030	.061	.055	.075	.042	.008	.005	.004	.008	.013	.011	.009	.018
13	.009	.010	.002	.999	.999	.999	.999	.999	.011	.017	.032	.067	.053	.055	.056	.058	.076	.058	.043	.039	.043	.063	.068	.029	.042
14	.038	.033	.034	.033	.029	.026	.065	.079	.080	.090	.088	.076	.062	.066	.066	.082	.086	.112	.141	.138	.076	.049	.040	.010	.067
15	.005	.003	.001	.999	.001	.001	.999	.001	.999	.048	.039	.064	.083	.071	.029	.009	.011	.008	.007	.009	.004	.004	.008	.009	.020
16	.007	.007	.015	.010	.003	.001	.005	.014	.001	.005	.005	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.007	.004
17	.006	.007	.013	.010	.013	.016	.026	.070	.023	.015	.020	.017	.013	.012	.012	.012	.011	.010	.010	.008	.008	.006	.010	.019	.015
18	.035	.069	.040	.021	.017	.015	.018	.028	.048	.031	.036	.045	.047	.066	.106	.159	.130	.073	.057	.057	.051	.052	.059	.021	.053
19	.030	.052	.063	.041	.038	.041	.036	.087	.111	.109	.084	.030	.013	.999	.999	.999	.999	.999	.999	.006	.999	.007	.012	.011	.999
20	.008	.010	.019	.019	.024	.033	.025	.030	.016	.076	.016	.026	.069	.063	.103	.060	.041	.013	.010	.999	.999	.999	.999	.003	.034
21	.999	.999	.999	.999	.999	.999	.999	.999	.134	.113	.999	.999	.019	.010	.017	.067	.058	.033	.001	.999	.999	.999	.999	.001	.999
22	.005	.023	.023	.047	.073	.041	.033	.045	.022	.015	.019	.015	.015	.016	.013	.007	.010	.009	.009	.009	.006	.015	.009	.008	.020
23	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
24	.022	.017	.015	.017	.015	.015	.019	.016	.090	.025	.067	.035	.021	.018	.013	.013	.009	.015	.013	.015	.012	.015	.014	.015	.022
25	.014	.016	.017	.015	.011	.017	.019	.022	.025	.020	.038	.044	.038	.035	.032	.027	.023	.023	.026	.030	.029	.020	.015	.018	.024
26	.017	.015	.020	.020	.020	.019	.017	.999	.075	.015	.015	.018	.026	.028	.038	.040	.065	.068	.058	.050	.023	.999	.999	.020	.032
27	.019	.017	.019	.028	.045	.026	.041	.037	.028	.034	.056	.049	.044	.043	.043	.060	.072	.051	.036	.029	.039	.037	.034	.036	.039
28	.043	.039	.040	.034	.038	.040	.052	.086	.096	.102	.101	.091	.069	.063	.061	.053	.024	.017	.014	.013	.010	.009	.008	.011	.046
29	.012	.011	.014	.014	.012	.007	.012	.026	.046	.067	.085	.082	.077	.079	.063	.066	.047	.999	.999	.999	.999	.999	.999	.009	.040
30	.012	.020	.038	.047	.035	.030	.035	.047	.072	.054	.114	.054	.025	.024	.032	.026	.035	.029	.021	.017	.018	.021	.011	.013	.035
31	.010	.011	.011	.015	.017	.015	.026	.052	.072	.075	.050	.025	.017	.034	.048	.041	.029	.029	.025	.017	.019	.021	.018	.013	.029
	.012	.014	.016	.017	.018	.016	.022	.031	.042	.039	.038	.031	.028	.031	.034	.035	.031	.024	.020	.019	.016	.016	.016	.011	
	28.	28.	28.	26.	27.	27.	25.	25.	27.	28.	27.	27.	29.	28.	28.	28.	28.	27.	27.	26.	25.	25.	25.	30.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.024 TOTAL NO. OF VALUES = 649. MAXIMUM HOURLY VALUE = 0.159

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.132

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.069

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

This data is questionable until 7/24.

PENELEC - CHESTNUT RIDGE

H4 Rustic Lodge

STATION C DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

DAY	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	AVG
HR-BEG / HR-END	00 / 01	01 / 02	02 / 03	03 / 04	04 / 05	05 / 06	06 / 07	07 / 08	08 / 09	09 / 10	10 / 11	11 / 12	12 / 13	13 / 14	14 / 15	15 / 16	16 / 17	17 / 18	18 / 19	19 / 20	20 / 21	21 / 22	22 / 23	23 / 24	
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.001	.999	.003	.999	.999	.999	.999	.999	.999
2	.001	.001	.001	.001	.001	.001	.003	.999	.999	.035	.035	.028	.020	.020	.022	.026	.027	.018	.014	.015	.019	.025	.021	.017	.016
3	.028	.025	.025	.019	.020	.031	.032	.035	.999	.043	.044	.038	.027	.024	.033	.032	.042	.052	.060	.043	.020	.006	.001	.001	.030
4	.999	.999	.001	.001	.999	.999	.008	.021	.024	.023	.015	.010	.019	.005	.013	.014	.025	.025	.007	.999	.999	.999	.999	.003	.999
5	.999	.999	.999	.999	.005	.010	.020	.032	.041	.040	.035	.024	.016	.021	.021	.011	.003	.999	.999	.999	.999	.999	.999	.999	.999
6	.999	.999	.999	.999	.999	.999	.999	.999	.999	.026	.112	.134	.067	.005	.002	.003	.002	.004	.003	.001	.001	.001	.001	.001	.999
7	.999	.999	.999	.999	.999	.999	.032	[illegible]	.055	.039	.011	.009	.011	.039	.073	.072	.055	.052	.051	.025	.007	.001	.001	.999	.999
8	.999	.999	.999	.999	.999	.999	.999	.004	.037	.048	.049	.060	.020	.017	.065	.035	.008	.008	.002	.999	.999	.999	.999	.999	.999
9	.999	.999	.999	.999	.999	.999	.999	.034	.035	.063	.043	.038	.032	.029	.030	.035	.041	.039	.020	.009	.029	.022	.015	.999	.999
10	.999	.009	.017	.033	.029	.022	.039	.039	.032	.043	.043	.032	.024	.009	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.003	.999	.999	.999	.999	.999	.999	.999	.001	.001	.001	.001	.001	.001	.001	.002	.003	.003	.005	.005	.005	.005	.004	.002	.999
12	.999	.999	.999	.999	.999	.999	.003	.009	.008	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
13	.001	.001	.001	.001	.001	.001	.001	.001	.002	.002	.005	.017	.123	.046	.090	.055	.022	.016	.017	.011	.004	.001	.001	.001	.018
14	.001	.001	.001	.001	.001	.001	.012	.050	.034	.035	.050	.044	.037	.032	.033	.031	.035	.042	.056	.068	.038	.025	.019	.033	.030
15	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.020	.029	.031	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
16	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.004	.010	.007	.008	.006	.006	.008	.004	.001	.001	.001	.001	.001	.001	.999
17	.001	.001	.001	.001	.001	.001	.001	.008	.024	.016	.057	.091	.063	.130	.094	.008	.005	.002	.001	.001	.001	.001	.001	.001	.021
18	.001	.006	.024	.013	.006	.001	.004	.011	.025	.021	.017	.029	.026	.038	.054	.080	.067	.041	.029	.023	.019	.031	.028	.020	.026
19	.009	.021	.032	.037	.028	.029	.025	.037	.057	.062	.052	.022	.038	.039	.016	.999	.999	.999	.999	.999	.999	.999	.999	.001	.999
20	.001	.001	.999	.999	.999	.999	.999	.001	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
21	.001	.001	.001	.001	.001	.001	.001	.099	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
22	.999	.999	.999	.999	.999	.999	.999	.016	.125	.140	.100	.036	.134	.104	.092	.060	.016	.010	.001	.008	.014	.019	.038	.062	.999
23	.045	.999	.999	.999	.999	.999	.999	.999	.013	.002	.015	.020	.011	.007	.002	.003	.001	.004	.001	.999	.999	.999	.999	.004	.999
24	.005	.006	.005	.013	.004	.001	.001	.001	.006	.011	.015	.020	.025	.037	.016	.056	.109	.050	.013	.010	.008	.008	.008	.006	.018
25	.001	.001	.001	.001	.001	.011	.025	.052	.094	.066	.069	.110	.142	.110	.082	.042	.036	.999	.029	.015	.007	.007	.012	.015	.040
26	.018	.017	.023	.026	.023	.014	.015	.030	.041	.032	.039	.049	.023	.019	.023	.026	.035	.044	.041	.015	.007	.004	.002	.002	.024
27	.001	.001	.001	.001	.001	.001	.004	.016	.029	.035	.041	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
28	.999	.999	.999	.999	.999	.999	.999	.041	.064	.062	.060	.062	.046	.035	.034	.035	.010	.006	.001	.001	.999	.999	.999	.001	.999
29	.001	.001	.001	.001	.001	.001	.001	.016	.037	.055	.055	.060	.048	.048	.039	.046	.034	.007	.005	.001	.001	.001	.001	.001	.019
30	.004	.020	.046	.053	.041	.053	.029	.039	.048	.039	.031	.066	.024	.020	.018	.013	.015	.026	.017	.009	.006	.005	.009	.003	.026
31	.001	.001	.001	.001	.001	.001	.003	.038	.043	.026	.015	.005	.002	.005	.018	.032	.027	.023	.024	.019	.011	.007	.004	.001	.013
	.999	.999	.999	.999	.999	.999	.012	.029	.033	.037	.037	.038	.038	.033	.036	.029	.025	.022	.017	.014	.999	.999	.999	.009	
	18.	17.	17.	17.	17.	17.	20.	24.	24.	27.	27.	27.	27.	27.	25.	25.	25.	22.	24.	20.	19.	19.	19.	21.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.023 TOTAL NO. OF VALUES = 525. MAXIMUM HOURLY VALUE = 0.142

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.122

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.070

NOTE : 999 = MISSING VALUE INDICATOR

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TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P2 Penn Run

STATION D DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY / HR-BEG / HR-END	00 / 01	01 / 02	02 / 03	03 / 04	04 / 05	05 / 06	06 / 07	07 / 08	08 / 09	09 / 10	10 / 11	11 / 12	12 / 13	13 / 14	14 / 15	15 / 16	16 / 17	17 / 18	18 / 19	19 / 20	20 / 21	21 / 22	22 / 23	23 / 24	AVG
1	.999	.999	.999	.999	.999	.999	.999	.999	.097	.133	.058	.009	.005	.002	.014	.005	.001	.001	.004	.010	.017	.026	.003	.001	.999
2	.006	.014	.040	.049	.035	.033	.025	.026	.031	.046	.045	.033	.038	.007	.008	.005	.010	.006	.002	.004	.004	.017	.024	.024	.022
3	.023	.026	.024	.027	.030	.029	.053	.040	.032	.031	.054	.035	.025	.019	.024	.025	.022	.031	.036	.029	.017	.010	.008	.019	.026
4	.032	.035	.029	.023	.026	.022	.025	.031	.031	.026	.017	.011	.018	.011	.009	.015	.015	.014	.005	.001	.010	.043	.007	.001	.019
5	.001	.001	.002	.006	.009	.017	.022	.034	.049	.035	.027	.027	.038	.048	.033	.055	.012	.007	.007	.005	.001	.001	.001	.001	.018
6	.999	.999	.999	.999	.999	.999	.999	.001	.001	.027	.023	.037	.031	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.005	.999
7	.001	.001	.004	.006	.007	.020	.059	.070	.052	.019	.015	.014	.013	.011	.010	.010	.028	.038	.054	.050	.047	.030	.026	.015	.024
8	.016	.016	.014	.017	.013	.015	.015	.030	.041	.053	.043	.039	.048	.025	.052	.053	.028	.013	.019	.024	.016	.014	.013	.021	.026
9	.018	.022	.023	.031	.036	.043	.060	.063	.099	.047	.007	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
10	.999	.999	.999	.999	.999	.999	.999	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.999	.999	.999	.999	.999	.999	.999	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.999
12	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
13	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
14	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
15	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
16	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
17	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
18	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
19	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.003	.003	.003	.003	.003	.003	.003	.003	.999	.002
20	.999	.999	.999	.999	.999	.999	.999	.999	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.003	.001	.999
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
22	.999	.999	.999	.999	.999	.999	.999	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.002	.999
23	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.002	.999	.002
24	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.005	.001	.999
25	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
26	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
27	.001	.001	.001	.001	.001	.001	.001	.001	.999	.999	.999	.999	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
28	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
29	.001	.001	.001	.001	.001	.001	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.999
30	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
31	.001	.001	.001	.001	.001	.001	.001	.001	.035	.037	.029	.023	.010	.001	.007	.024	.025	.014	.018	.012	.014	.019	.022	.016	.013
	.005	.006	.007	.008	.008	.008	.011	.012	.018	.018	.012	.010	.009	.006	.007	.008	.006	.006	.007	.006	.006	.007	.005	.005	
	23.	23.	23.	23.	23.	23.	23.	27.	27.	26.	27.	26.	27.	27.	27.	27.	27.	27.	27.	27.	27.	27.	27.	26.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.008 TOTAL NO. OF VALUES = 517. MAXIMUM HOURLY VALUE = 0.133

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.096

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.040

NOTE : 999 - MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

H1 Brush Valley

STATION E DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

DAY	HOURS (LST)																								AVG
HR-BEG	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
HR-END	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.022	.074	.056	.004	.009	.023	.011	.999	.024	.027	.026	.036	.031	.018	.013	.999
2	.010	.016	.029	.025	.027	.028	.027	.032	.061	.039	.040	.035	.044	.038	.037	.047	.024	.016	.015	.014	.017	.031	.033	.029	.030
3	.037	.036	.043	.057	.055	.048	.055	.089	.094	.066	.052	.068	.042	.062	.070	.049	.090	.073	.063	.038	.020	.015	.018	.010	.052
4	.055	.049	.035	.040	.036	.033	.040	.068	.071	.056	.029	.026	.030	.022	.019	.026	.032	.020	.999	.999	.999	.068	.028	.999	.036
5	.999	.999	.999	.999	.999	.025	.042	.061	.055	.042	.092	.091	.026	.015	.014	.006	.017	.014	.014	.007	.008	.999	.999	.999	.999
6	.999	.999	.999	.999	.999	.999	.999	.999	.001	.044	.068	.064	.085	.016	.014	.999	.999	.999	.999	.999	.999	.999	.999	.001	.999
7	.001	.003	.019	.012	.033	.092	.051	.075	.064	.053	.022	.024	.016	.018	.019	.047	.083	.068	.064	.079	.068	.055	.045	.040	.043
8	.040	.042	.038	.039	.026	.027	.028	.022	.026	.072	.064	.049	.056	.038	.036	.064	.058	.031	.020	.016	.024	.016	.017	.040	.037
9	.047	.056	.064	.067	.061	.064	.061	.083	.133	.107	.066	.058	.060	.052	.071	.120	.107	.062	.044	.049	.072	.076	.075	.065	.072
10	.070	.050	.093	.091	.085	.092	.069	.099	.088	.072	.066	.071	.043	.014	.012	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.003	.008	.006	.005	.004	.004	.004	.004	.005	.006	.019	.027	.019	.002	.999
12	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.002	.004	.005	.005	.003	.002	.001	.001	.001	.009	.029	.016	.016	.002	.999
13	.999	.999	.999	.999	.999	.999	.999	.999	.999	.006	.013	.999	.999	.064	.049	.080	.034	.028	.012	.021	.025	.052	.052	.041	.999
14	.038	.049	.067	.082	.094	.080	.066	.121	.157	.164	.155	.163	.157	.187	.159	.066	.088	.099	.124	.096	.037	.023	.030	.008	.096
15	.001	.004	.999	.999	.999	.001	.058	.097	.100	.100	.092	.063	.046	.045	.047	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
16	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.001	.001	.001	.003	.003	.001	.001	.001	.001	.001	.001	.999
17	.001	.001	.001	.001	.007	.005	.001	.001	.035	.047	.090	.136	.119	.066	.018	.005	.057	.052	.011	.007	.001	.017	.022	.011	.032
18	.011	.017	.063	.040	.051	.035	.031	.017	.032	.024	.186	.116	.045	.061	.087	.107	.099	.070	.039	.030	.027	.042	.036	.032	.054
19	.036	.032	.054	.043	.036	.077	.066	.121	.098	.078	.074	.049	.022	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.999
20	.001	.999	.999	.999	.999	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
21	.999	.999	.999	.999	.999	.999	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
22	.999	.999	.999	.999	.001	.004	.001	.010	.011	.011	.025	.040	.024	.032	.040	.039	.024	.015	.014	.011	.010	.013	.011	.006	.017
23	.005	.006	.016	.015	.013	.011	.011	.011	.010	.008	.006	.005	.002	.010	.007	.009	.018	.025	.019	.009	.003	.001	.001	.007	.010
24	.011	.016	.010	.015	.012	.009	.008	.008	.009	.011	.009	.012	.011	.014	.021	.013	.027	.040	.023	.011	.008	.007	.007	.002	.013
25	.001	.001	.001	.001	.001	.001	.005	.027	.027	.028	.034	.061	.043	.029	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
26	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.026	.024	.019	.029	.030	.027	.011	.004	.999	.999	.999	.005	.999
27	.003	.003	.005	.010	.015	.019	.023	.022	.999	.999	.999	.999	.999	.999	.006	.006	.015	.040	.036	.026	.027	.027	.029	.020	.019
28	.026	.026	.027	.027	.024	.024	.028	.038	.086	.182	.140	.072	.045	.053	.042	.035	.028	.016	.013	.011	.005	.009	.011	.020	.041
29	.018	.031	.040	.051	.044	.024	.020	.017	.022	.037	.038	.052	.042	.038	.045	.039	.041	.024	.009	.021	.003	.001	.002	.008	.027
30	.010	.012	.012	.053	.102	.074	.034	.033	.052	.070	.053	.052	.032	.019	.017	.019	.026	.035	.024	.015	.018	.018	.015	.010	.034
31	.009	.010	.013	.015	.031	.030	.028	.083	.088	.040	.024	.016	.006	.005	.013	.028	.036	.034	.025	.020	.016	.020	.015	.012	.026
	.021	.025	.999	.999	.038	.035	.034	.052	.062	.057	.058	.056	.037	.035	.033	.036	.041	.034	.027	.023	.022	.025	.023	.017	
	21.	20.	19.	19.	20.	23.	24.	22.	22.	24.	26.	25.	27.	27.	27.	24.	23.	24.	23.	23.	22.	22.	22.	24.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.036 TOTAL NO. OF VALUES = 553. MAXIMUM HOURLY VALUE = 0.187

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.174

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.101

NOTE : 999 - MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P1 Liggett

STATION F DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.999	.999	.999	.999	.999	.999	.999	.999	.012	.010	.008	.007	.030	.013	.009	.006	.007	.017	.010	.009	.018	.008	.002	.008	.999
2	.009	.015	.029	.036	.027	.020	.016	.032	.025	.999	.013	.012	.009	.006	.007	.005	.005	.005	.005	.007	.009	.016	.013	.016	.015
3	.022	.019	.020	.022	.023	.023	.027	.028	.024	.022	.022	.029	.047	.024	.013	.011	.012	.018	.014	.008	.007	.007	.020	.026	.020
4	.032	.026	.021	.021	.017	.017	.021	.030	.025	.020	.013	.013	.009	.008	.005	.006	.005	.005	.001	.001	.036	.007	.001	.004	.014
5	.001	.002	.002	.007	.009	.014	.018	.024	.027	.022	.018	.016	.017	.017	.014	.010	.012	.005	.005	.005	.006	.005	.004	.004	.011
6	.002	.001	.001	.001	.001	.001	.001	.001	.002	.008	.015	.008	.008	.046	.029	.002	.002	.002	.004	.005	.005	.005	.005	.005	.007
7	.004	.012	.007	.047	.057	.051	.042	.026	.026	.018	.008	.009	.009	.009	.026	.057	.120	.051	.018	.021	.015	.013	.014	.019	.032
8	.015	.012	.012	.011	.009	.009	.014	.043	.064	.078	.076	.049	.106	.037	.010	.007	.008	.006	.008	.008	.008	.018	.025	.019	.027
9	.020	.022	.027	.034	.055	.053	.065	.090	.127	.146	.125	.072	.079	.050	.037	.032	.029	.018	.013	.019	.032	.031	.033	.032	.052
10	.031	.037	.042	.044	.044	.051	.050	.040	.041	.042	.062	.067	.058	.031	.020	.006	.002	.001	.001	.005	.005	.006	.005	.006	.029
11	.009	.009	.004	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003	.002	.001	.001	.002
12	.001	.001	.001	.001	.001	.001	.001	.002	.004	.004	.002	.002	.002	.002	.002	.002	.002	.002	.001	.003	.003	.004	.010	.006	.002
13	.005	.005	.004	.003	.002	.002	.003	.004	.010	.015	.017	.025	.051	.117	.050	.018	.014	.005	.006	.012	.016	.031	.029	.017	.015
14	.018	.033	.051	.059	.061	.058	.055	.049	.046	.041	.034	.024	.021	.012	.010	.009	.012	.018	.026	.019	.012	.010	.013	.022	.030
15	.001	.004	.001	.001	.001	.001	.001	.006	.012	.012	.016	.024	.029	.036	.035	.021	.012	.011	.015	.006	.004	.002	.007	.005	.011
16	.007	.006	.006	.005	.005	.005	.005	.007	.014	.008	.005	.005	.014	.008	.007	.006	.006	.008	.004	.003	.005	.003	.001	.002	.006
17	.001	.001	.001	.001	.005	.005	.010	.016	.022	.020	.036	.053	.056	.012	.005	.004	.009	.015	.007	.005	.009	.010	.013	.010	.014
18	.018	.053	.025	.014	.012	.011	.010	.016	.020	.014	.012	.016	.021	.020	.014	.012	.040	.043	.023	.024	.021	.053	.050	.020	.022
19	.019	.019	.028	.019	.020	.018	.050	.057	.036	.043	.048	.024	.006	.014	.010	.031	.007	.005	.005	.003	.001	.002	.003	.004	.018
20	.006	.005	.004	.005	.004	.002	.003	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
22	.001	.001	.001	.005	.017	.010	.011	.006	.013	.055	.069	.007	.002	.003	.010	.007	.007	.003	.003	.041	.056	.021	.023	.020	.016
23	.034	.082	.019	.024	.007	.005	.005	.008	.009	.007	.015	.012	.006	.015	.019	.010	.002	.001	.001	.001	.001	.001	.002	.005	.012
24	.006	.009	.012	.010	.010	.007	.006	.006	.006	.008	.008	.006	.010	.019	.021	.019	.013	.014	.002	.001	.001	.004	.003	.004	.009
25	.003	.003	.003	.009	.010	.018	.052	.021	.018	.034	.039	.042	.028	.014	.032	.057	.036	.013	.007	.005	.007	.007	.007	.009	.020
26	.013	.011	.008	.010	.011	.012	.014	.014	.038	.049	.030	.008	.006	.007	.006	.005	.005	.006	.003	.001	.001	.006	.006	.004	.011
27	.004	.007	.006	.004	.004	.006	.009	.016	.018	.021	.019	.008	.999	.009	.006	.054	.012	.021	.016	.017	.012	.014	.015	.015	.014
28	.012	.011	.012	.013	.014	.018	.031	.093	.095	.082	.048	.032	.028	.020	.015	.014	.008	.001	.019	.043	.028	.021	.014	.028	.029
29	.017	.023	.017	.019	.016	.015	.012	.033	.070	.073	.060	.034	.021	.019	.019	.006	.008	.003	.999	.999	.999	.999	.999	.999	.026
30	.006	.001	.012	.037	.035	.024	.022	.024	.030	.020	.047	.056	.061	.059	.026	.009	.999	.999	.999	.999	.999	.999	.999	.007	.999
31	.011	.015	.020	.036	.053	.059	.059	.091	.106	.191	.036	.022	.009	.011	.046	.038	.024	.028	.022	.016	.012	.024	.021	.013	.040
	.011	.015	.016	.017	.018	.017	.020	.026	.030	.036	.029	.022	.024	.021	.016	.015	.014	.011	.008	.010	.012	.011	.011	.011	
	30.	30.	30.	30.	30.	30.	30.	30.	31.	30.	31.	31.	30.	31.	31.	31.	30.	30.	29.	29.	29.	29.	29.	30.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.018 TOTAL NO. OF VALUES = 721. MAXIMUM HOURLY VALUE = 0.191

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.133

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.054

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

H2 Penn View

STATION G DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.001	.001	.001	.007	.014	.010	.021	.029	.023	.019	.017	.007	.006	.009	.016	.014	.021	.017	.017	.032	.018	.003	.007	.012	.015
2	.033	.034	.053	.065	.047	.029	.054	.049	.037	.031	.025	.032	.031	.032	.029	.008	.007	.009	.010	.012	.038	.045	.040	.056	.034
3	.042	.037	.038	.038	.040	.046	.054	.048	.042	.034	.034	.041	.036	.031	.029	.030	.030	.029	.023	.016	.010	.015	.077	.045	.036
4	.052	.056	.040	.038	.029	.037	.055	.048	.049	.039	.036	.032	.020	.009	.016	.016	.012	.013	.999	.999	.999	.999	.999	.999	.033
5	.999	.999	.999	.999	.999	.999	.999	.041	.044	.044	.041	.030	.024	.021	.021	.009	.025	.023	.016	.010	.010	.016	.003	.001	.999
6	.001	.001	.001	.001	.001	.192	.052	.009	.014	.023	.022	.012	.012	.083	.012	.073	.108	.023	.033	.033	.033	.039	.048	.026	.035
7	.038	.036	.026	.016	.028	.041	.050	.062	.045	.023	.019	.017	.045	.073	.051	.054	.049	.049	.040	.036	.038	.033	.034	.032	.039
8	.032	.033	.032	.033	.051	.063	.069	.381	.293	.156	.115	.087	.080	.068	.057	.043	.049	.047	.041	.046	.061	.070	.056	.085	.066
9	.065	.063	.096	.156	.125	.142	.156	.192	.191	.118	.102	.112	.081	.075	.099	.094	.057	.047	.054	.089	.090	.083	.062	.066	.101
10	.075	.088	.088	.086	.090	.069	.077	.090	.085	.074	.082	.063	.044	.035	.015	.999	.999	.999	.005	.006	.007	.009	.011	.021	.054
11	.020	.017	.010	.005	.001	.001	.001	.001	.001	.001	.001	.026	.017	.023	.016	.043	.023	.030	.003	.002	.004	.003	.001	.001	.011
12	.001	.013	.024	.029	.005	.001	.001	.008	.036	.001	.001	.001	.038	.076	.127	.095	.067	.031	.006	.001	.001	.001	.001	.004	.022
13	.002	.001	.001	.001	.004	.007	.009	.020	.020	.018	.019	.083	.080	.072	.039	.039	.047	.047	.064	.068	.068	.051	.050	.037	.035
14	.052	.110	.102	.128	.118	.111	.102	.080	.077	.067	.062	.049	.048	.043	.042	.040	.060	.062	.051	.041	.037	.036	.045	.022	.060
15	.003	.001	.001	.001	.001	.001	.001	.020	.044	.039	.037	.999	.999	.999	.999	.999	.999	.999	.001	.004	.007	.004	.001	.004	.999
16	.008	.008	.008	.008	.008	.008	.010	.007	.016	.030	.045	.029	.002	.025	.025	.019	.032	.017	.002	.001	.001	.001	.001	.004	.013
17	.003	.004	.010	.031	.067	.119	.034	.018	.016	.008	.013	.011	.009	.008	.008	.008	.009	.008	.008	.008	.008	.035	.217	.068	.031
18	.110	.025	.017	.011	.010	.007	.021	.045	.037	.024	.026	.060	.049	.046	.037	.057	.095	.114	.064	.088	.071	.040	.034	.035	.048
19	.033	.038	.046	.032	.033	.056	.067	.061	.055	.057	.071	.051	.017	.001	.001	.999	.999	.001	.006	.004	.001	.002	.005	.009	.029
20	.009	.009	.009	.008	.006	.005	.006	.007	.010	.111	.091	.083	.099	.068	.117	.059	.006	.003	.001	.001	.001	.001	.001	.001	.030
21	.001	.001	.001	.001	.001	.001	.001	.009	.023	.041	.001	.001	.001	.001	.006	.008	.028	.014	.008	.006	.001	.001	.001	.022	.007
22	.049	.066	.046	.010	.006	.006	.009	.010	.008	.007	.004	.003	.004	.005	.005	.004	.003	.005	.005	.005	.004	.005	.006	.006	.012
23	.008	.008	.009	.008	.007	.007	.012	.015	.016	.028	.015	.006	.005	.005	.004	.003	.002	.003	.001	.001	.006	.014	.010	.008	.008
24	.019	.021	.022	.021	.019	.015	.014	.012	.026	.037	.057	.045	.032	.020	.006	.007	.011	.003	.001	.007	.010	.019	.010	.011	.019
25	.011	.017	.112	.059	.034	.031	.023	.021	.032	.055	.052	.034	.021	.021	.016	.021	.020	.040	.036	.017	.015	.015	.016	.015	.031
26	.015	.015	.016	.017	.017	.016	.017	.017	.015	.014	.015	.016	.018	.022	.024	.021	.026	.029	.013	.006	.004	.003	.002	.006	.015
27	.006	.005	.006	.014	.013	.012	.013	.015	.022	.034	.033	.028	.032	.030	.035	.073	.063	.054	.060	.056	.059	.053	.045	.040	.033
28	.056	.051	.046	.050	.073	.075	.079	.117	.106	.086	.091	.093	.084	.080	.064	.058	.032	.009	.007	.004	.004	.004	.006	.013	.054
29	.014	.017	.012	.014	.033	.052	.064	.088	.094	.073	.056	.057	.053	.054	.040	.023	.024	.013	.999	.999	.999	.999	.999	.999	.043
30	.029	.063	.063	.047	.041	.039	.037	.034	.037	.017	.028	.004	.023	.012	.009	.003	.999	.016	.006	.016	.015	.012	.004	.012	.025
31	.015	.016	.026	.035	.045	.049	.056	.062	.049	.040	.024	.024	.018	.019	.025	.035	.029	.012	.006	.012	.024	.020	.018	.011	.028
	.027	.028	.032	.032	.033	.042	.039	.052	.049	.044	.040	.038	.034	.036	.033	.034	.035	.026	.021	.022	.022	.022	.028	.023	
	30.	30.	30.	30.	30.	30.	30.	31.	31.	31.	31.	30.	30.	30.	30.	28.	27.	29.	29.	29.	29.	29.	29.	29.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.033 TOTAL NO. OF VALUES = 712. MAXIMUM HOURLY VALUE = 0.381

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.287

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.105

NOTE : 999 - MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

K1 Creekside

STATION L DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

DAY / HOURS (LST) HR-BEG / HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.999	.052	.011	.033	.009	.999	.999	.999	.999	.030	.020	.017	.016	.003	.005	.999	.999	.999	.999	.002	.999	.999	.002	.999	.999
2	.999	.003	.011	.001	.018	.033	.030	.031	.029	.016	.008	.013	.017	.019	.015	.016	.020	.019	.008	.004	.001	.004	.005	.004	.014
3	.006	.008	.013	.026	.028	.035	.045	.051	.051	.089	.070	.120	.091	.084	.024	.016	.009	.008	.017	.035	.033	.015	.007	.003	.037
4	.001	.004	.016	.025	.035	.039	.036	.040	.046	.033	.019	.016	.014	.005	.001	.008	.018	.022	.016	.023	.016	.001	.001	.009	.016
5	.004	.006	.006	.006	.012	.024	.032	.035	.033	.037	.045	.054	.046	.059	.075	.028	.007	.008	.006	.001	.001	.001	.001	.001	.022
6	.001	.001	.001	.001	.001	.001	.001	.002	.003	.004	.003	.002	.001	.004	.003	.006	.006	.005	.004	.005	.003	.001	.001	.001	.003
7	.001	.001	.001	.001	.001	.001	.001	.025	.044	.021	.006	.013	.010	.013	.022	.127	.136	.076	.028	.025	.025	.024	.021	.020	.027
8	.016	.005	.009	.009	.007	.012	.006	.011	.030	.024	.025	.040	.052	.047	.044	.040	.039	.040	.032	.029	.025	.022	.018	.020	.025
9	.023	.031	.036	.043	.045	.037	.051	.059	.091	.089	.093	.058	.057	.087	.096	.050	.042	.059	.057	.041	.039	.042	.044	.051	.055
10	.064	.065	.060	.069	.067	.064	.059	.062	.062	.056	.142	.065	.074	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.999	.999	.999	.999	.999	.999	.999	.999	.999	.003	.002	.001	.001	.001	.002	.003	.003	.004	.005	.005	.004	.003	.005	.006	.999
12	.003	.001	.001	.001	.001	.001	.001	.006	.007	.004	.001	.001	.001	.001	.001	.001	.001	.001	.002	.001	.001	.001	.004	.006	.002
13	.006	.003	.003	.002	.001	.001	.001	.002	.005	.008	.010	.005	.004	.010	.002	.007	.014	.009	.011	.014	.013	.013	.024	.042	.009
14	.066	.102	.092	.071	.073	.062	.067	.077	.080	.093	.104	.115	.119	.060	.044	.026	.020	.019	.027	.041	.084	.080	.067	.010	.067
15	.001	.001	.001	.001	.001	.001	.001	.001	.004	.020	.074	.041	.036	.031	.013	.001	.001	.001	.002	.001	.001	.001	.003	.002	.010
16	.008	.005	.003	.001	.001	.001	.001	.001	.001	.001	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.005	.002
17	.001	.001	.001	.001	.001	.001	.004	.006	.014	.015	.016	.157	.169	.121	.020	.005	.004	.003	.001	.001	.002	.003	.003	.004	.023
18	.007	.021	.031	.031	.024	.026	.016	.014	.014	.014	.049	.035	.038	.026	.017	.027	.026	.030	.033	.019	.014	.017	.027	.023	.024
19	.052	.045	.043	.053	.046	.041	.049	.067	.065	.047	.032	.017	.007	.002	.001	.003	.006	.002	.004	.009	.009	.003	.007	.007	.026
20	.006	.001	.001	.001	.001	.003	.006	.006	.004	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
22	.001	.001	.001	.001	.001	.001	.001	.001	.004	.116	.119	.095	.040	.028	.004	.019	.001	.001	.001	.001	.008	.043	.024	.010	.022
23	.023	.024	.007	.007	.007	.006	.006	.005	.006	.007	.005	.002	.003	.005	.005	.001	.001	.001	.001	.001	.001	.001	.001	.003	.005
24	.004	.004	.004	.005	.004	.001	.002	.005	.007	.007	.007	.006	.005	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003
25	.001	.001	.001	.001	.001	.001	.001	.005	.019	.034	.036	.054	.072	.057	.020	.019	.016	.023	.022	.010	.007	.006	.006	.008	.018
26	.007	.008	.006	.010	.013	.014	.014	.015	.027	.044	.039	.021	.012	.013	.020	.059	.059	.040	.022	.019	.007	.005	.007	.007	.020
27	.008	.008	.008	.008	.008	.013	.017	.021	.021	.028	.030	.019	.013	.008	.006	.023	.073	.015	.007	.007	.008	.009	.008	.015	.016
28	.018	.018	.016	.017	.029	.034	.035	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
29	.999	.999	.032	.029	.023	.018	.017	.022	.029	.046	.044	.031	.026	.019	.014	.011	.009	.013	.011	.003	.003	.007	.007	.020	.020
30	.021	.020	.035	.046	.042	.043	.057	.071	.076	.091	.096	.246	.103	.047	.076	.056	.035	.018	.020	.014	.014	.021	.021	.014	.053
31	.010	.014	.022	.029	.035	.045	.052	.059	.046	.029	.016	.011	.006	.006	.999	.025	.046	.025	.015	.015	.014	.018	.016	.022	.025
	.013	.015	.016	.018	.018	.019	.021	.025	.029	.034	.037	.043	.035	.026	.019	.021	.021	.016	.013	.011	.012	.012	.012	.011	
	27.	29.	30.	30.	30.	29.	29.	28.	28.	30.	30.	30.	30.	29.	28.	28.	28.	28.	28.	29.	28.	28.	29.	28.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.021 TOTAL NO. OF VALUES = 691. MAXIMUM HOURLY VALUE = 0.246

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.149

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.072

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

K3 Girty

STATION M DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
2	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.013	.012	.007	.005	.005	.005	.009	.999
3	.015	.030	.035	.037	.037	.039	.050	.055	.054	.044	.033	.028	.029	.027	.027	.024	.019	.023	.031	.026	.022	.046	.021	.012	.032
4	.011	.011	.010	.032	.052	.066	.060	.047	[illegible]	.042	.037	.035	.036	.012	.006	.006	.008	.010	.009	.006	.003	.001	.001	.002	.023
5	.001	.001	.003	.012	.017	.015	.024	.022	.021	.027	.036	.035	.033	.031	.017	.012	.005	.005	.004	.001	.001	.001	.001	.001	.014
6	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.004	.001	.001	.010	.011	.008	.006	.005	.003
7	.002	.001	.001	.001	.001	.001	.001	.001	.013	.010	.016	.025	.038	.033	.030	.027	.023	.023	.021	.018	.016	.012	.011	.010	.014
8	.008	.006	.008	.008	.006	.005	.007	.013	.040	.052	.027	.024	.031	.024	.025	.026	.021	.014	.012	.010	.008	.009	.010	.020	.017
9	.017	.013	.027	.028	.017	.017	.045	.074	.098	.078	.056	.039	.030	.030	.029	.029	.027	.046	.041	.025	.021	.027	.056	.042	.037
10	.050	.060	.057	.053	.049	.042	.056	.033	.033	.050	.040	.036	.017	.001	.001	.001	.001	.005	.012	.015	.012	.007	.005	.004	.026
11	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.007	.007	.006	.004	.004	.003	.001	.001	.001	.002	.002	.002	.002
12	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
13	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.008	.016	.015	.017	.017	.017	.015	.013	.011	.023	.040	.009
14	.038	.041	.043	.044	.048	.047	.041	.062	.063	.063	.057	.056	.060	.047	.032	.030	.033	.029	.019	.022	.038	.060	.033	.001	.042
15	.001	.001	.001	.003	.001	.001	.015	.034	.033	.031	.026	.027	.032	.013	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.010
16	.001	.001	.001	.001	.001	.001	.001	.004	.012	.005	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
17	.001	.001	.001	.001	.001	.001	.001	.001	.017	.008	.007	.008	.006	.003	.002	.002	.003	.001	.001	.001	.001	.001	.001	.001	.003
18	.001	.010	.013	.007	.003	.003	.005	.009	.021	.032	.057	.047	.030	.031	.025	.025	.029	.020	.021	.009	.012	.018	.033	.034	.021
19	.037	.033	.034	.035	.047	.045	.047	.051	.048	.042	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.001	.018
20	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.999	.999	.999	.999	.001
21	.999	.999	.999	.999	.999	.999	.999	.001	.026	.063	.001	.001	.001	.004	.061	.054	.051	.051	.001	.001	.001	.001	.001	.001	.999
22	.001	.001	.001	.001	.001	.999	.001	.001	.003	.001	.001	.001	.001	.001	.001	.001	.001	.002	.003	.005	.001	.001	.001	.001	.001
23	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002	.005	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
24	.001	.003	.004	.001	.003	.005	.001	.002	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
25	.001	.001	.001	.001	.001	.001	.001	.001	.001	.005	.015	.024	.022	.016	.011	.009	.009	.008	.010	.016	.018	.012	.008	.008	.008
26	.007	.004	.001	.001	.001	.001	.002	.007	.011	.007	.011	.020	.032	.026	.036	.039	.031	.024	.023	.019	.016	.016	.008	.005	.014
27	.005	.001	.001	.001	.001	.001	.001	.002	.010	.015	.024	.024	.014	.014	.015	.011	.010	.010	.009	.014	.018	.027	.039	.019	.012
28	.032	.025	.028	.071	.056	.029	.033	.061	.098	.100	.078	.060	.058	.050	.033	.020	.001	.001	.001	.001	.001	.001	.001	.001	.035
29	.001	.001	.001	.001	.001	.001	.009	.014	.025	.043	.030	.030	.016	.011	.009	.007	.007	.001	.001	.001	.009	.012	.026	.024	.012
30	.025	.024	.033	.042	.045	.054	.058	.060	.066	.055	.042	.049	.018	.023	.021	.009	.009	.017	.018	.006	.006	.025	.039	.034	.032
31	.033	.031	.035	.038	.037	.037	.041	.040	.032	.022	.011	.005	.001	.005	.012	.020	.999	.019	.013	.008	.010	.020	.029	.086	.025
	.011	.011	.013	.015	.015	.016	.017	.021	.027	.028	.021	.020	.018	.015	.015	.013	.011	.012	.010	.008	.009	.011	.012	.013	
	28.	28.	28.	28.	28.	27.	26.	29.	29.	29.	29.	29.	29.	29.	29.	29.	28.	30.	30.	30.	29.	29.	29.	29.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.015 TOTAL NO. OF VALUES = 590. MAXIMUM HOURLY VALUE = 0.100

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.092

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.045

NOTE : 999 = MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

P6 Keystone Dam

STATION N DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.999	.999	.999	.999	.999	.999	.999	.999	.999	.057	.039	.013	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
2	.999	.999	.999	.999	.999	.999	.999	.999	.999	.049	.030	.058	.037	.038	.027	.013	.015	.021	.008	.001	.001	.005	.004	.004	.999
3	.012	.022	.025	.028	.029	.028	.039	.054	.057	.056	.042	.031	.027	.016	.010	.007	.005	.006	.015	.018	.035	.034	.015	.009	.026
4	.007	.006	.010	.025	.036	.037	.035	.038	.045	.038	.027	.074	.104	.043	.021	.050	.034	.035	.008	.999	.999	.999	.999	.002	.034
5	.001	.999	.999	.001	.008	.017	.023	.025	.029	.027	.030	.029	.039	.035	.030	.020	.004	.006	.005	.001	.001	.001	.001	.001	.015
6	.001	.0	.0	.0	.0	.0	.0	.0	.0	.005	.017	.010	.001	.001	.001	.001	.001	.001	.001	.001	.0	.0	.0	.0	.002
7	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
8	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.999
9	.001	.001	.001	.001	.001	.001	.001	.003	.005	.005	.006	.005	.003	.002	.001	.002	.001	.006	.006	.005	.003	.003	.004	.006	.003
10	.009	.009	.009	.009	.009	.009	.009	.008	.005	.001	.001	.001	.001	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.001	.001	.001	.001	.001	.001	.001	.001	.001	.999	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
12	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
13	.001	.001	.001	.001	.001	.001	.001	.001	.999	.999	.999	.999	.999	.999	.009	.009	.009	.009	.009	.009	.009	.009	.009	.009	.005
14	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003	.005	.004	.005	.001	.001	.001	.001	.001	.001	.002	.004	.003	.003	.002
15	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
16	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
17	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
18	.001	.001	.001	.001	.001	.001	.001	.001	.003	.005	.005	.003	.004	.003	.003	.003	.001	.001	.001	.002	.003	.006	.006	.005	.003
19	.003	.003	.004	.005	.006	.007	.007	.003	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
20	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
22	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
23	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
24	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
25	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
26	.003	.002	.003	.004	.004	.004	.004	.004	.005	.004	.004	.003	.002	.002	.004	.005	.005	.005	.004	.004	.003	.001	.001	.001	.003
27	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.003	.004	.005	.005	.005	.006	.006	.002
28	.006	.005	.005	.004	.006	.007	.006	.006	.007	.008	.060	.174	.052	.029	.010	.008	.001	.001	.001	.001	.001	.001	.001	.001	.017
29	.006	.003	.003	.003	.003	.003	.003	.003	.003	.003	.005	.005	.004	.005	.003	.003	.003	.001	.001	.001	.001	.001	.001	.001	.003
30	.001	.001	.001	.001	.001	.001	.001	.002	.002	.005	.005	.006	.006	.006	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.002
31	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.009	.024	.023	.022	.019	.016	.010	.009	.010	.012	.007
	.002	.003	.003	.003	.004	.005	.005	.006	.007	.010	.010	.014	.010	.007	.005	.006	.004	.005	.003	.003	.003	.003	.003	.003	
	28.	27.	27.	28.	28.	28.	28.	28.	27.	28.	29.	30.	29.	28.	28.	28.	28.	28.	28.	27.	27.	27.	27.	28.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.005 TOTAL NO. OF VALUES = 669. MAXIMUM HOURLY VALUE = 0.174

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.095

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.036

NOTE : 999 - MISSING VALUE INDICATOR

TABLE A.1.1

ENVIRONMENTAL RESEARCH & TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173

PENELEC - CHESTNUT RIDGE

K2 Parkwood

STATION 0 DATA FOR JULY 1974 SULFUR DIOXIDE CONCENTRATION (PPM)

HOURS (LST)

DAY HR-BEG / HR-END	00 01	01 02	02 03	03 04	04 05	05 06	06 07	07 08	08 09	09 10	10 11	11 12	12 13	13 14	14 15	15 16	16 17	17 18	18 19	19 20	20 21	21 22	22 23	23 24	AVG
1	.001	.001	.001	.006	.006	.005	.002	.005	.009	.023	.018	.011	.016	.013	.019	.009	.012	.011	.016	.019	.017	.025	.020	.014	.012
2	.014	.020	.018	.022	.037	.039	.034	.036	.030	.023	.016	.020	.020	.019	.020	.024	.030	.021	.015	.013	.022	.020	.026	.027	.024
3	.016	.015	.021	.026	.029	.030	.034	.036	.032	.039	.042	.034	.028	.025	.019	.016	.023	.026	.048	.053	.030	.020	.015	.013	.026
4	.015	.033	.041	.039	.041	.033	.028	.026	.034	.027	.019	.016	.019	.011	.014	.021	.029	.029	.020	.018	.008	.006	.005	.006	.022
5	.011	.010	.008	.009	.016	.026	.027	.023	.019	.028	.034	.025	.024	.022	.026	.019	.014	.010	.009	.008	.007	.007	.006	.006	.016
6	.005	.004	.001	.001	.001	.001	.004	.002	.005	.033	.121	.023	.016	.020	.010	.008	.006	.006	.008	.008	.011	.020	.021	.023	.015
7	.014	.039	.071	.098	.095	.074	.040	.033	.019	.009	.007	.015	.015	.019	.026	.022	.021	.045	.037	.020	.014	.010	.011	.021	.032
8	.026	.022	.027	.026	.029	.036	.050	.024	.038	.043	.047	.061	.027	.051	.069	.046	.017	.019	.020	.015	.011	.012	.013	.045	.033
9	.054	.065	.079	.073	.059	.066	.066	.062	.076	.076	.058	.051	.042	.040	.037	.035	.035	.045	.053	.028	.041	.047	.048	.054	.053
10	.059	.057	.061	.060	.059	.057	.056	.047	.042	.051	.054	.043	.037	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999	.999
11	.999	.004	.999	.999	.999	.999	.999	.999	.001	.001	.001	.001	.001	.001	.001	.001	.001	.005	.007	.006	.006	.006	.008	.007	.999
12	.005	.005	.006	.005	.001	.001	.002	.011	.011	.008	.005	.002	.002	.001	.001	.002	.001	.001	.004	.002	.004	.005	.007	.010	.004
13	.007	.004	.010	.009	.010	.006	.007	.010	.010	.012	.033	.075	.260	.154	.138	.126	.037	.018	.021	.022	.016	.018	.064	.097	.046
14	.134	.105	.080	.083	.072	.075	.086	.082	.076	.068	.067	.067	.062	.056	.049	.034	.028	.045	.068	.086	.102	.055	.046	.013	.068
15	.020	.003	.002	.002	.001	.001	.004	.013	.023	.025	.030	.041	.050	.053	.039	.007	.001	.005	.006	.018	.012	.014	.007	.007	.017
16	.017	.019	.010	.007	.015	.021	.015	.010	.008	.008	.008	.030	.017	.017	.017	.017	.015	.013	.010	.008	.006	.005	.002	.008	.013
17	.008	.007	.008	.032	.039	.025	.018	.035	.049	.035	.048	.175	.189	.082	.010	.006	.005	.004	.002	.001	.001	.001	.001	.015	.033
18	.028	.056	.055	.030	.024	.023	.021	.022	.028	.025	.026	.040	.049	.046	.041	.065	.043	.027	.032	.022	.021	.042	.060	.041	.036
19	.045	.060	.051	.066	.048	.050	.062	.057	.070	.062	.079	.106	.011	.002	.001	.001	.008	.008	.005	.001	.001	.007	.006	.009	.035
20	.014	.012	.008	.007	.007	.014	.017	.012	.009	.007	.005	.006	.004	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.006
21	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001	.001
22	.001	.001	.001	.001	.016	.006	.002	.067	.136	.184	.191	.112	.036	.010	.032	.019	.001	.001	.001	.004	.008	.038	.081	.070	.047
23	.039	.016	.015	.005	.001	.006	.009	.008	.009	.012	.011	.020	.014	.007	.004	.001	.001	.001	.001	.999	.001	.001	.001	.009	.006
24	.013	.013	.015	.014	.012	.009	.008	.011	.015	.017	.016	.015	.016	.014	.008	.013	.030	.031	.006	.004	.003	.005	.005	.010	.013
25	.008	.008	.008	.008	.008	.027	.044	.035	.037	.041	.045	.088	.089	.037	.072	.048	.038	.035	.042	.017	.014	.018	.017	.019	.033
26	.020	.026	.034	.039	.050	.061	.034	.029	.039	.044	.040	.017	.019	.021	.023	.020	.029	.038	.040	.029	.011	.014	.017	.021	.030
27	.019	.018	.018	.035	.034	.038	.022	.047	.042	.045	.038	.024	.017	.014	.008	.050	.104	.026	.015	.009	.008	.011	.033	.044	.030
28	.033	.030	.030	.043	.045	.055	.063	.065	.067	.068	.051	.045	.034	.026	.019	.018	.004	.001	.003	.001	.004	.015	.011	.011	.031
29	.012	.019	.024	.026	.021	.020	.030	.041	.042	.050	.046	.050	.031	.033	.021	.015	.008	.003	.003	.001	.001	.001	.005	.036	.022
30	.020	.013	.025	.036	.036	.033	.037	.049	.059	.061	.044	.081	.031	.031	.031	.022	.016	.029	.022	.021	.032	.037	.030	.017	.034
31	.017	.036	.038	.052	.065	.063	.052	.055	.069	.039	.042	.022	.012	.010	.023	.031	.040	.033	.032	.036	.052	.035	.056	.055	.039
	.023	.023	.026	.029	.029	.032	.030	.032	.036	.038	.040	.043	.038	.029	.027	.023	.020	.018	.018	.016	.016	.017	.020	.025	
	30.	31.	30.	30.	30.	30.	30.	30.	31.	31.	31.	31.	31.	30.	30.	30.	30.	30.	30.	29.	30.	30.	30.	30.	

ABOVE TWO ROWS ARE TOTAL HOURLY AVERAGES AND TOTAL OBSERVATIONS/HOUR, RESPECTIVELY

TOTAL AVERAGE = 0.027 TOTAL NO. OF VALUES = 725. MAXIMUM HOURLY VALUE = 0.260

NO 3-HOUR RUNNING VALUES EXCEED 0.500 ,MAXIMUM 3-HOUR RUNNING AVERAGE IS 0.184

NO 24-HOUR RUNNING VALUES EXCEED 0.140 ,MAXIMUM 24-HOUR RUNNING AVERAGE IS 0.082

NOTE : 999 - MISSING VALUE INDICATOR

TABLE A.1.2

TWO MINUTE TELETYPE DATA

PENELEC - AUG. 18, 1974

09:28 EST

```
                        parameter code
                        |
                        |         parameter value
                        |        /
                        v       v
Parameter identifier:  N2H  XXXX  XX <-- monitor status code
                       ^^
                       | station code, 2 is Florence Substation
                       |
                       Network code, N is Chestnut Ridge
```

999 indicates missing data

Note that the tower data at station G is mostly nonsense on this printout. The tower was still not functioning properly at the time.

Current Parameter Code Listing

Code	Format				
0	NN.N	Particulates*	J	±NN	Vert. Wind Comp. (Bivane)
1	NNN.	Wind Speed (miles)	K	NNN.	Horiz. Wind Comp. (Bivane)
2	NNN.	Wind Direction (degrees)	L	NN.N	Hydrocarbon Concentration (PPM)
3	NNN.	Temperature (degrees F)	M	N.NN	Methane Concentration
4	NN.N	Carbon Monoxide Concen.(PPM)	N	NNN.	Voltage Test**
5	N.NN	Hydrocarbn Concen.- meth. (PPM)	P	.NNN	Nitro. Oxide Concen. (PPM) NO
6	.NNN	Oxides of Nitrgn. (PPM) NO_x	Q	NNN.	Wind Speed (Knots)
7	.NNN	Sul. Diox. Concen.(PPM) L & N	R		Remote Readout**
8	NN.N	Temp. Difference (degrees F)	S	N.NN	Rain (inches)
9	NNN.	Dewpoint (degrees F)	T	NNN.	Coefficient of Haze (degrees)
A	NNN.	Stability Classification	U	N.NN	Sunlight Intensity(cal/cm^2)
B	NNN.	Wind Range (degrees)	V	NNN.	Visibility (tens of meters)
C	NNN.	Nitrgn. Diox. Concen.(PPM)NO_2	W	NNN.	Megawatts
D	NNN.	Cloud Ceiling (100 feet)	X	N.NN	Generalized Control/Monitor**
E	NN.N	Cloud Cover (0.0 to 1.0)	Y		
F	NNN.	Solar Altitude	Z	NNN.	Air Mass
G	.NNN	Ozone Concen (PPM)			
H	.NNN	Sul. Diox. Concen.(PPM)Meloy			
I					

** Primarily used by the NOVA programs, and not by statistical programs.

TABLE A.1.2

09:28	NON:	9.99	20	N1H:	.019	04	N2H:	.029	04	N3H:	.161	04	N6H:	.999	20
	N7H:	.033	04	N8H:	.990	07	NAH:	.058	04	NBH:	.038	04	NCH:	.042	04
	NDH:	.038	04	NEH:	.174	04	NFH:	.137	04	NGH:	.000	05	NLH:	.051	04
	NMH:	.078	04	NNH:	.035	02	NOH:	.091	04	N3C:	.047	04	N36:	.100	04
	N7C:	.013	04	N76:	.034	04	N8C:	.999	20	N86:	.999	20	NFC:	.037	04
	NF6:	.065	04	NGC:	.010	04	NG6:	.253	04	NOC:	.015	04	NO6:	.089	04
	NG2:	55.	04	NG1:	49.	04	NT2:	179.	04	NT1:	9.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.040	04	N1T:	91.9	04	N2T:	100.0	04
	N3T:	97.4	04	N6T:	99.9	20	N7T:	93.9	04	N8T:	99.9	20	NAT:	97.6	04
	NBT:	99.9	20	NCT:	93.1	04	NDT:	.0	04	NET:	95.3	04	NFT:	100.0	04
	NGT:	98.8	04	NLT:	97.2	04	NMT:	92.5	04	NNT:	100.0	04	NOT:	97.0	04
	N1X:	74.	04	N2X:	74.	04	N3X:	84.	04	N6X:	999.	20	N7X:	80.	06
	N8X:	999.	20	NAX:	73.	04	NBX:	109.	04	NCX:	77.	04	NDX:	71.	06
	NEX:	77.	04	NFX:	76.	04	NLX:	77.	04	NMX:	79.	04	NNX:	76.	04
	NOX:	78.	04	NG9:	42.	04	NGU:	9.99	20	NTJ:	46.8	04	NTK:	238.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

09:30	NON:	9.97	07	N1H:	.023	04	N2H:	.028	04	N3H:	.168	04	N6H:	.999	20
	N7H:	.999	20	N8H:	.853	07	NAH:	.056	04	NBH:	.038	04	NCH:	.052	04
	NDH:	.034	04	NEH:	.166	04	NFH:	.172	04	NGH:	.000	05	NLH:	.053	04
	NMH:	.073	04	NNH:	.035	02	NOH:	.067	04	N3C:	.055	04	N36:	.102	04
	N7C:	.012	04	N76:	.034	04	N8C:	.999	20	N86:	.999	20	NFC:	.999	20
	NF6:	.079	04	NGC:	.000	04	NG6:	.258	04	NOC:	.015	04	NO6:	.089	04
	NG2:	55.	04	NG1:	49.	04	NT2:	179.	04	NT1:	9.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.038	04	N1T:	92.1	04	N2T:	100.0	04
	N3T:	98.0	04	N6T:	99.9	20	N7T:	93.9	04	N8T:	99.9	20	NAT:	97.6	04
	NBT:	99.9	20	NCT:	93.1	04	NDT:	.0	04	NET:	95.1	04	NFT:	100.0	04
	NGT:	98.8	04	NLT:	97.0	04	NMT:	92.5	04	NNT:	100.0	04	NOT:	96.8	04
	N1X:	75.	04	N2X:	73.	04	N3X:	85.	04	N6X:	999.	20	N7X:	79.	06
	N8X:	999.	20	NAX:	74.	04	NBX:	122.	00	NCX:	77.	04	NDX:	71.	06
	NEX:	76.	04	NFX:	77.	04	NLX:	77.	04	NMX:	78.	04	NNX:	76.	04
	NOX:	78.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	48.7	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

09:32	NON:	9.99	20	N1H:	.022	04	N2H:	.026	04	N3H:	.200	04	N6H:	.999	20
	N7H:	.035	04	N8H:	.999	20	NAH:	.052	04	NBH:	.035	04	NCH:	.061	04
	NDH:	.041	04	NEH:	.148	04	NFH:	.155	04	NGH:	.000	05	NLH:	.049	04
	NMH:	.076	04	NNH:	.035	02	NOH:	.063	04	N3C:	.044	04	N36:	.104	04
	N7C:	.012	04	N76:	.034	04	N8C:	.999	20	N86:	.999	20	NFC:	.037	04
	NF6:	.072	04	NGC:	.004	04	NG6:	.266	04	NOC:	.016	04	NO6:	.088	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	10.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.039	04	N1T:	91.9	04	N2T:	100.0	04
	N3T:	97.4	04	N6T:	99.9	20	N7T:	93.9	04	N8T:	99.9	20	NAT:	97.6	04
	NBT:	99.9	20	NCT:	92.9	04	NDT:	.0	04	NET:	95.3	04	NFT:	100.0	04
	NGT:	98.6	04	NLT:	97.0	04	NMT:	91.9	04	NNT:	100.0	04	NOT:	97.0	04
	N1X:	75.	04	N2X:	74.	04	N3X:	83.	04	N6X:	999.	20	N7X:	80.	06
	N8X:	999.	20	NAX:	74.	04	NBX:	999.	20	NCX:	78.	04	NDX:	72.	06
	NEX:	79.	04	NFX:	78.	04	NLX:	78.	04	NMX:	80.	04	NNX:	74.	04
	NOX:	79.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	47.3	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

TABLE A.1.2

09:34	NON:	9.99	20	N1H:	.023	04	N2H:	.028	04	N3H:	.217	04	N6H:	.999	20
	N7H:	.035	04	N8H:	.999	20	NAH:	.072	04	NBH:	.038	04	NCH:	.047	04
	NDH:	.039	04	NEH:	.129	04	NFH:	.219	04	NGH:	.000	05	NLH:	.051	04
	NMH:	.072	04	NNH:	.035	02	NOH:	.049	04	N3C:	.097	04	N36:	.165	04
	N7C:	.013	04	N76:	.033	04	N8C:	.999	20	N86:	.999	20	NFC:	.045	04
	NF6:	.092	04	NGC:	.005	04	NG6:	.271	04	NOC:	.013	04	NO6:	.087	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	10.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.039	04	N1T:	92.1	04	N2T:	100.0	04
	N3T:	97.4	04	N6T:	99.9	20	N7T:	93.9	04	N8T:	99.9	20	NAT:	97.6	04
	NBT:	99.9	20	NCT:	92.9	04	NDT:	.0	04	NET:	95.3	04	NFT:	100.0	04
	NGT:	98.6	04	NLT:	97.0	04	NMT:	90.8	04	NNT:	100.0	04	NOT:	96.0	04
	N1X:	75.	04	N2X:	75.	04	N3X:	85.	04	N6X:	999.	20	N7X:	82.	06
	N8X:	999.	20	NAX:	73.	04	NBX:	109.	04	NCX:	76.	04	NDX:	72.	06
	NEX:	80.	04	NFX:	78.	04	NLX:	78.	04	NMX:	82.	04	NNX:	76.	04
	NOX:	79.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	49.6	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

09:36	NON:	9.99	20	N1H:	.020	04	N2H:	.027	04	N3H:	.175	04	N6H:	.999	20
	N7H:	.033	04	N8H:	.999	20	NAH:	.061	04	NBH:	.999	20	NCH:	.045	04
	NDH:	.038	04	NEH:	.123	04	NFH:	.259	04	NGH:	.000	05	NLH:	.057	04
	NMH:	.073	04	NNH:	.035	02	NOH:	.057	04	N3C:	.066	04	N36:	.123	04
	N7C:	.011	04	N76:	.032	04	N8C:	.999	20	N86:	.999	20	NFC:	.083	04
	NF6:	.135	04	NGC:	.016	04	NG6:	.288	04	NOC:	.012	04	NO6:	.085	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	9.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.041	04	N1T:	91.7	04	N2T:	100.0	04
	N3T:	97.8	04	N6T:	99.9	20	N7T:	93.9	04	N8T:	99.9	20	NAT:	97.6	04
	NBT:	99.9	20	NCT:	92.9	04	NDT:	.0	04	NET:	95.1	04	NFT:	100.0	04
	NGT:	98.6	04	NLT:	96.8	04	NMT:	91.7	04	NNT:	100.0	04	NOT:	96.6	04
	N1X:	74.	04	N2X:	75.	04	N3X:	83.	04	N6X:	999.	20	N7X:	81.	06
	N8X:	999.	20	NAX:	73.	04	NBX:	999.	20	NCX:	75.	04	NDX:	73.	06
	NEX:	80.	04	NFX:	76.	04	NLX:	78.	04	NMX:	80.	04	NNX:	77.	04
	NOX:	78.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	48.5	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

09:38	NON:	9.99	20	N1H:	.999	20	N2H:	.028	04	N3H:	.134	04	N6H:	.999	20
	N7H:	.033	04	N8H:	.999	20	NAH:	.065	04	NBH:	.999	20	NCH:	.046	04
	NDH:	.038	04	NEH:	.112	04	NFH:	.211	04	NGH:	.000	05	NLH:	.057	04
	NMH:	.071	04	NNH:	.035	02	NOH:	.054	04	N3C:	.038	04	N36:	.089	04
	N7C:	.012	04	N76:	.032	04	N8C:	.999	20	N86:	.999	20	NFC:	.042	04
	NF6:	.090	04	NGC:	.013	04	NG6:	.300	04	NOC:	.014	04	NO6:	.088	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	9.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.040	04	N1T:	91.7	04	N2T:	99.9	20
	N3T:	97.4	04	N6T:	99.9	20	N7T:	93.7	04	N8T:	99.9	20	NAT:	97.6	04
	NBT:	100.0	00	NCT:	92.9	04	NDT:	.0	04	NET:	95.3	04	NFT:	100.0	04
	NGT:	98.6	04	NLT:	97.0	04	NMT:	91.2	04	NNT:	100.0	04	NOT:	96.6	04
	N1X:	74.	04	N2X:	76.	04	N3X:	85.	04	N6X:	999.	20	N7X:	81.	06
	N8X:	999.	20	NAX:	70.	04	NBX:	999.	20	NCX:	76.	04	NDX:	73.	06
	NEX:	78.	04	NFX:	77.	04	NLX:	79.	04	NMX:	81.	04	NNX:	76.	04
	NOX:	78.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	52.5	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

TABLE A.1.2

09:40	NON: 9.99 20	N1H: .023 04	N2H: .999 20	N3H: .110 04	N6H: .999 20
	N7H: .035 04	N8H: .999 20	NAH: .053 04	NBH: .999 20	NCH: .038 04
	NDH: .036 04	NEH: .105 04	NFH: .178 04	NGH: .000 05	NLH: .052 04
	NMH: .078 04	NNH: .039 04	NOH: .090 04	N3C: .050 04	N36: .087 04
	N7C: .012 04	N76: .033 04	N8C: .999 20	N86: .999 20	NFC: .041 04
	NF6: .079 04	NGC: .000 04	NG6: .300 04	NOC: .022 04	NO6: .096 04
	NG2: 68. 04	NG1: 49. 04	NT2: 179. 04	NT1: 9. 04	NG3: 121. 04
	NS8: -3.4 04	NT8: 8.9 04	NGS: .038 04	N1T: 91.6 04	N2T: 99.9 20
	N3T: 97.8 04	N6T: 99.9 20	N7T: 93.7 04	N8T: 99.9 20	NAT: 97.4 04
	NBT: 99.9 20	NCT: 92.7 04	NDT: .0 04	NET: 95.3 04	NFT: 100.0 04
	NGT: 98.4 04	NLT: 97.0 04	NMT: 91.2 04	NNT: 100.0 04	NOT: 96.4 04
	N1X: 75. 04	N2X: 76. 04	N3X: 85. 04	N6X: 999. 20	N7X: 80. 06
	N8X: 999. 20	NAX: 71. 04	NBX: 999. 20	NCX: 76. 04	NDX: 74. 06
	NEX: 77. 04	NFX: 77. 04	NLX: 79. 04	NMX: 82. 04	NNX: 76. 04
	NOX: 79 04	NG9: 42. 04	NGU: 1.99 04	NTJ: 50.6 04	NTK: 240. 04
	NHR: 9.99 04	N4R: 9.99 20	NKR: 9.99 20		
09:42	NON: 9.99 20	N1H: .023 04	N2H: .999 20	N3H: .109 04	N6H: .999 20
	N7H: .034 04	N8H: .999 20	NAH: .062 04	NBH: .999 20	NCH: .035 04
	NDH: .034 04	NEH: .112 04	NFH: .132 04	NGH: .000 05	NLH: .043 04
	NMH: .076 04	NNH: .039 04	NOH: .100 04	N3C: .037 04	N36: .080 04
	N7C: .013 04	N76: .035 04	N8C: .999 20	N86: .999 20	NFC: .036 04
	NF6: .062 04	NGC: .005 04	NG6: .305 04	NOC: .021 04	NO6: .097 04
	NG2: 68. 04	NG1: 49. 04	NT2: 179. 04	NT1: 9. 04	NG3: 121. 04
	NS8: -3.4 04	NT8: 8.9 04	NGS: .038 04	N1T: 91.7 04	N2T: 99.9 20
	N3T: 97.4 04	N6T: 99.9 20	N7T: 93.5 04	N8T: 99.9 20	NAT: 99.8 04
	NBT: 99.9 20	NCT: 92.9 04	NDT: .0 04	NET: 95.3 04	NFT: 100.0 04
	NGT: 98.4 04	NLT: 96.8 04	NMT: 91.2 04	NNT: 100.0 04	NOT: 96.6 04
	N1X: 75. 04	N2X: 73. 04	N3X: 84. 04	N6X: 999. 20	N7X: 80. 06
	N8X: 121. 07	NAX: 73. 04	NBX: 999. 20	NCX: 77. 04	NDX: 74. 06
	NEX: 77. 04	NFX: 78. 04	NLX: 79. 04	NMX: 79. 04	NNX: 74. 04
	NOX: 79. 04	NG9: 42. 04	NGU: 1.99 04	NTJ: 50.6 04	NTK: 236. 04
	NHR: 9.99 04	N4R: 9.99 20	NKR: 9.99 20		
09:44	NON: 9.99 20	N1H: .020 04	N2H: .026 04	N3H: .121 04	N6H: .999 20
	N7H: .035 04	N8H: .999 20	NAH: .115 04	NBH: .999 20	NCH: .063 04
	NDH: .031 04	NEH: .113 04	NFH: .146 04	NGH: .000 05	NLH: .041 04
	NMH: .077 04	NNH: .038 04	NOH: .116 04	N3C: .044 04	N36: .083 04
	N7C: .013 04	N76: .035 04	N8C: .999 20	N86: .999 20	NFC: .026 04
	NF6: .059 04	NGC: .000 04	NG6: .291 04	NOC: .025 04	NO6: .100 04
	NG2: 68. 04	NG1: 49. 04	NT2: 179. 04	NT1: 9. 04	NG3: 121. 04
	NS8: -3.4 04	NT8: 8.9 04	NGS: .039 04	N1T: 91.4 04	N2T: 100.0 04
	N3T: 97.4 04	N6T: 99.9 20	N7T: 93.5 04	N8T: 99.9 20	NAT: 99.8 04
	NBT: 99.9 20	NCT: 92.7 04	NDT: .0 04	NET: 95.3 04	NFT: 100.0 04
	NGT: 98.2 04	NLT: 96.6 04	NMT: 90.0 04	NNT: 100.0 04	NOT: 96.6 04
	N1X: 76. 04	N2X: 74. 04	N3X: 84. 04	N6X: 999. 20	N7X: 82. 06
	N8X: 999. 20	NAX: 73. 04	NBX: 999. 20	NCX: 78. 04	NDX: 73. 06
	NEX: 79. 04	NFX: 77. 04	NLX: 77. 04	NMX: 78. 04	NNX: 75. 04
	NOX: 78. 04	NG9: 42 04	NGU: 1.99 04	NTJ: 47.1 04	NTK: 236. 04
	NHR: 9.99 04	N4R: 9.99 20	NKR: 9.99 20		

TABLE A.1.2

09:46	NON:	9.99	20	N1H:	.021	04	N2H:	.026	04	N3H:	.129	04	N6H:	.999	20
	N7H:	.035	04	N8H:	.999	20	NAH:	.080	04	NBH:	.999	20	NCH:	.049	04
	NDH:	.038	04	NEH:	.120	04	NFH:	.119	04	NGH:	.000	05	NLH:	.045	04
	NMH:	.079	04	NNH:	.039	04	NOH:	.105	04	N3C:	.049	04	N36:	.088	04
	N7C:	.012	04	N76:	.035	04	N8C:	.999	20	N86:	.999	20	NFC:	.036	04
	NF6:	.065	04	NGC:	.009	04	NG6:	.295	04	NOC:	.020	04	NO6:	.099	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	10.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.040	04	N1T:	95.7	04	N2T:	100.0	04
	N3T:	97.8	04	N6T:	100.0	07	N7T:	95.7	04	N8T:	99.9	20	NAT:	99.6	04
	NBT:	100.0	00	NCT:	98.4	04	NDT:	.0	04	NET:	95.3	04	NFT:	100.0	04
	NGT:	97.4	04	NLT:	98.4	04	NMT:	90.6	04	NNT:	100.0	04	NOT:	96.4	04
	N1X:	74.	04	N2X:	75.	04	N3X:	83.	04	N6X:	999.	20	N7X:	80.	06
	N8X:	999.	20	NAX:	74.	04	NBX:	999.	20	NCX:	77.	04	NDX:	71.	06
	NEX:	80.	04	NFX:	76.	04	NLX:	77.	04	NMX:	80.	04	NNX:	77.	04
	NOX:	78.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	48.7	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

09:48	NON:	9.99	20	N1H:	.021	04	N2H:	.026	04	N3H:	.150	04	N6H:	.999	20
	N7H:	.035	04	N8H:	.999	20	NAH:	.065	04	NBH:	.999	20	NCH:	.040	04
	NDH:	.053	04	NEH:	.113	04	NFH:	.121	04	NGH:	.000	05	NLH:	.051	04
	NMH:	.077	04	NNH:	.040	04	NOH:	.111	04	N3C:	.045	04	N36:	.091	04
	N7C:	.013	04	N76:	.034	04	N8C:	.999	20	N86:	.999	20	NFC:	.034	04
	NF6:	.061	04	NGC:	.003	04	NG6:	.285	04	NOC:	.021	04	NO6:	.098	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	10.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.039	04	N1T:	93.3	04	N2T:	99.6	04
	N3T:	98.0	04	N6T:	99.9	20	N7T:	95.7	04	N8T:	99.9	20	NAT:	99.6	04
	NBT:	99.9	20	NCT:	98.2	04	NDT:	.0	04	NET:	95.8	04	NFT:	100.0	04
	NGT:	97.4	04	NLT:	97.8	04	NMT:	90.4	04	NNT:	100.0	04	NOT:	98.6	04
	N1X:	74.	04	N2X:	75.	04	N3X:	85.	04	N6X:	999.	20	N7X:	80.	06
	N8X:	999.	20	NAX:	74.	04	NBX:	999.	20	NCX:	75.	04	NDX:	71.	06
	NEX:	80.	04	NFX:	77.	04	NLX:	77.	04	NMX:	82.	04	NNX:	77.	04
	NOX:	79.	04	NG9:	42.	04	NGU:	1.99	04	NTJ:	48.7	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

09:50	NON:	9.99	20	N1H:	.019	04	N2H:	.026	04	N3H:	.119	04	N6H:	.999	20
	N7H:	.033	04	N8H:	.999	20	NAH:	.080	04	NBH:	.999	20	NCH:	.054	04
	NDH:	.053	04	NEH:	.104	04	NFH:	.176	04	NGH:	.000	05	NLH:	.053	04
	NMH:	.079	04	NNH:	.042	04	NOH:	.104	04	N3C:	.046	04	N36:	.087	04
	N7C:	.012	04	N76:	.033	04	N8C:	.999	20	N86:	.999	20	NFC:	.049	04
	NF6:	.081	04	NGC:	.004	04	NG6:	.285	04	NOC:	.020	04	NO6:	.097	04
	NG2:	68.	04	NG1:	49.	04	NT2:	179.	04	NT1:	9.	04	NG3:	121.	04
	NS8:	-3.4	04	NT8:	8.9	04	NGS:	.038	04	N1T:	93.3	04	N2T:	98.4	04
	N3T:	97.2	04	N6T:	99.9	20	N7T:	95.7	04	N8T:	99.9	20	NAT:	99.6	04
	NBT:	97.4	04	NCT:	98.4	04	NDT:	.0	04	NET:	96.0	04	NFT:	100.0	04
	NGT:	97.4	04	NLT:	97.8	04	NMT:	90.8	04	NNT:	100.0	04	NOT:	98.6	04
	N1X:	74.	04	N2X:	76.	04	N3X:	83.	04	N6X:	999.	20	N7X:	81.	06
	N8X:	999.	20	NAX:	71.	04	NBX:	999.	20	NCX:	75.	04	NDX:	72.	06
	NEX:	77.	04	NFX:	78.	04	NLX:	78.	04	NMX:	80.	04	NNX:	76.	04
	NOX:	79.	04	NG9:	41.	04	NGU:	1.99	04	NTJ:	49.6	04	NTK:	236.	04
	NHR:	9.99	04	N4R:	9.99	20	NKR:	9.99	20						

TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON. MASSACHUSETTS 02173
PHILIPSBURG. PA.. WINTER WINDROSE 1950-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

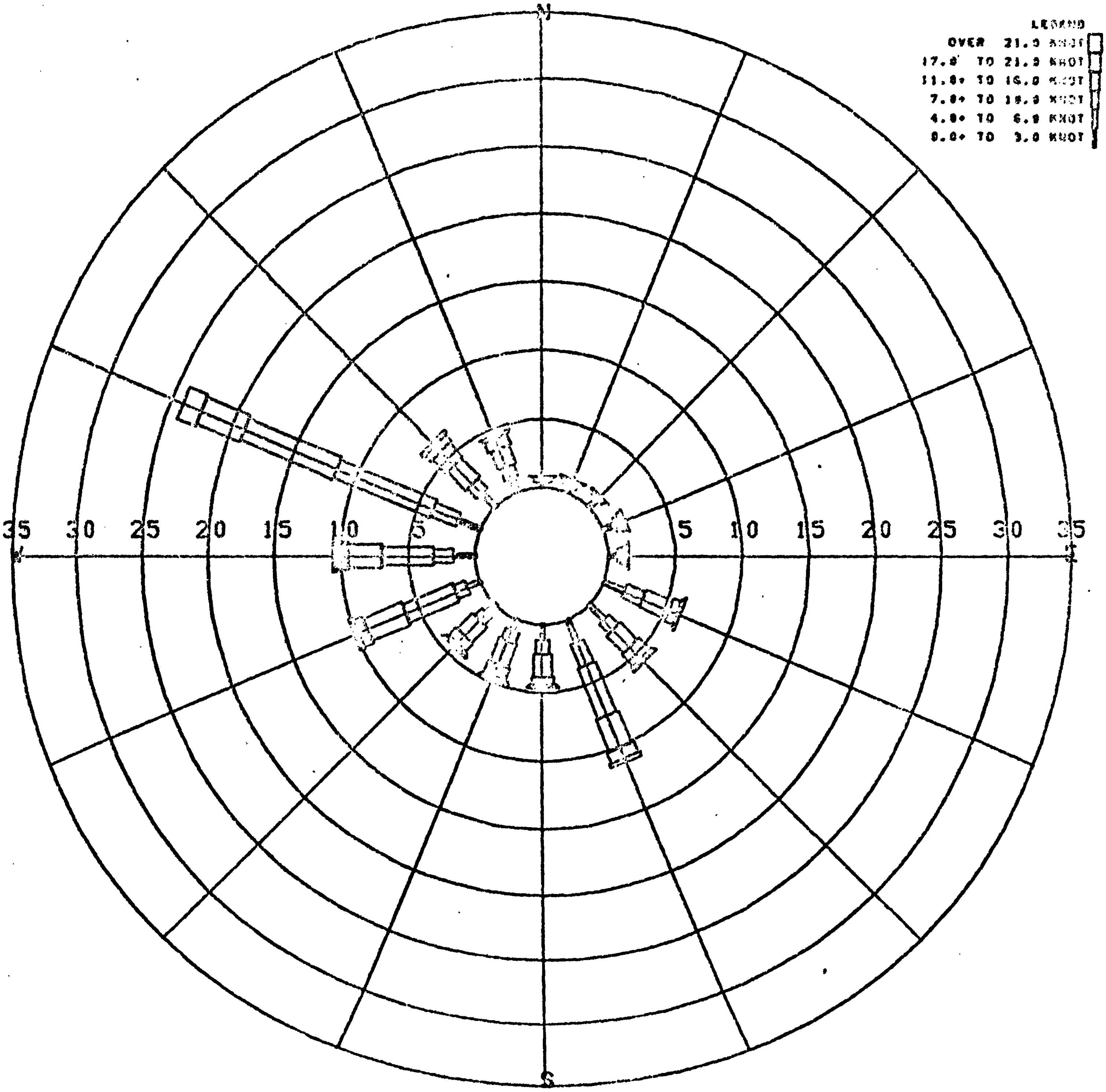


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PHILIPSBURG, PA., SPRING WINDROSE 1950-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

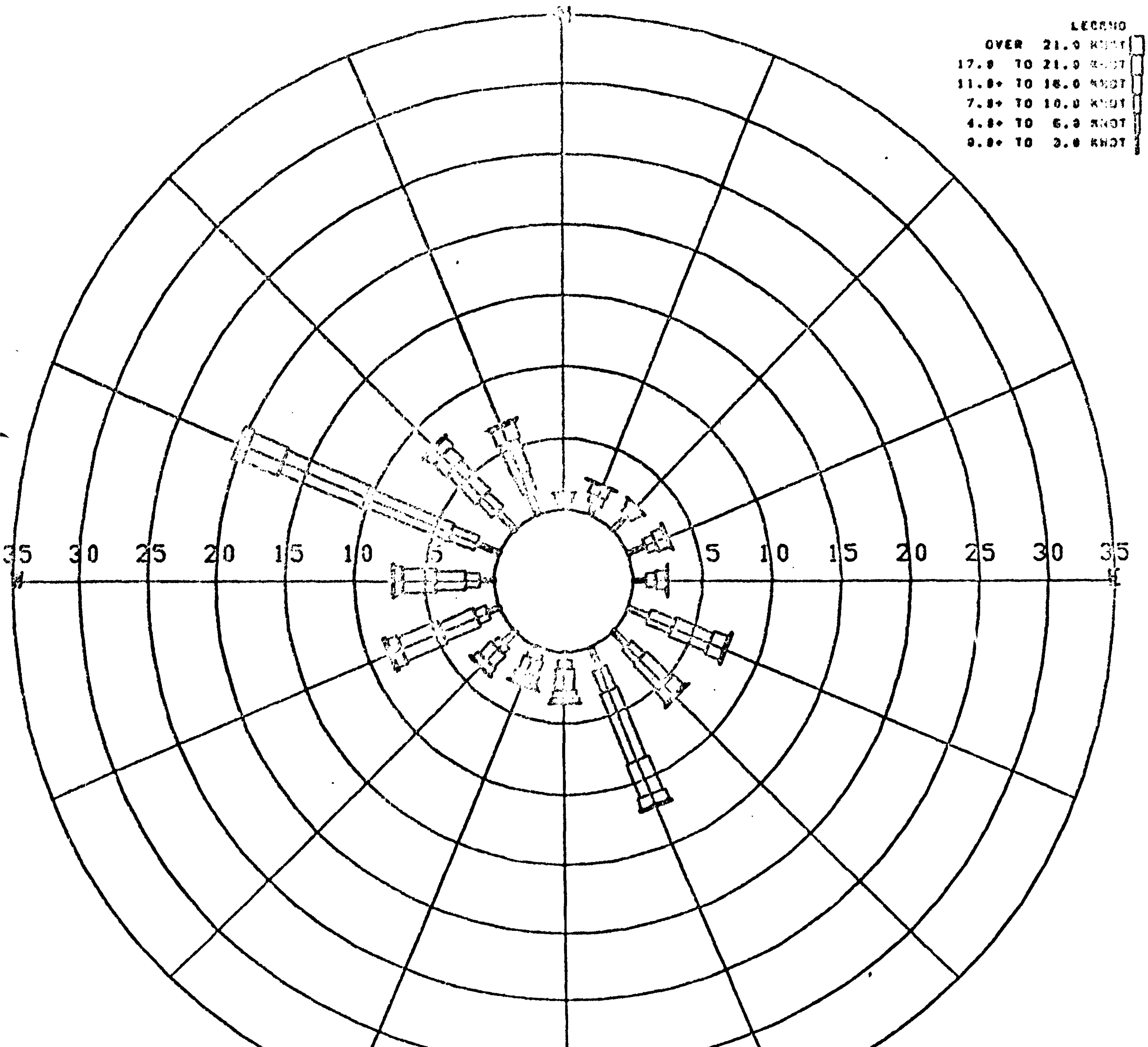


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PHILIPSBURG, PA., SUMMER WINDROSE 1950-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

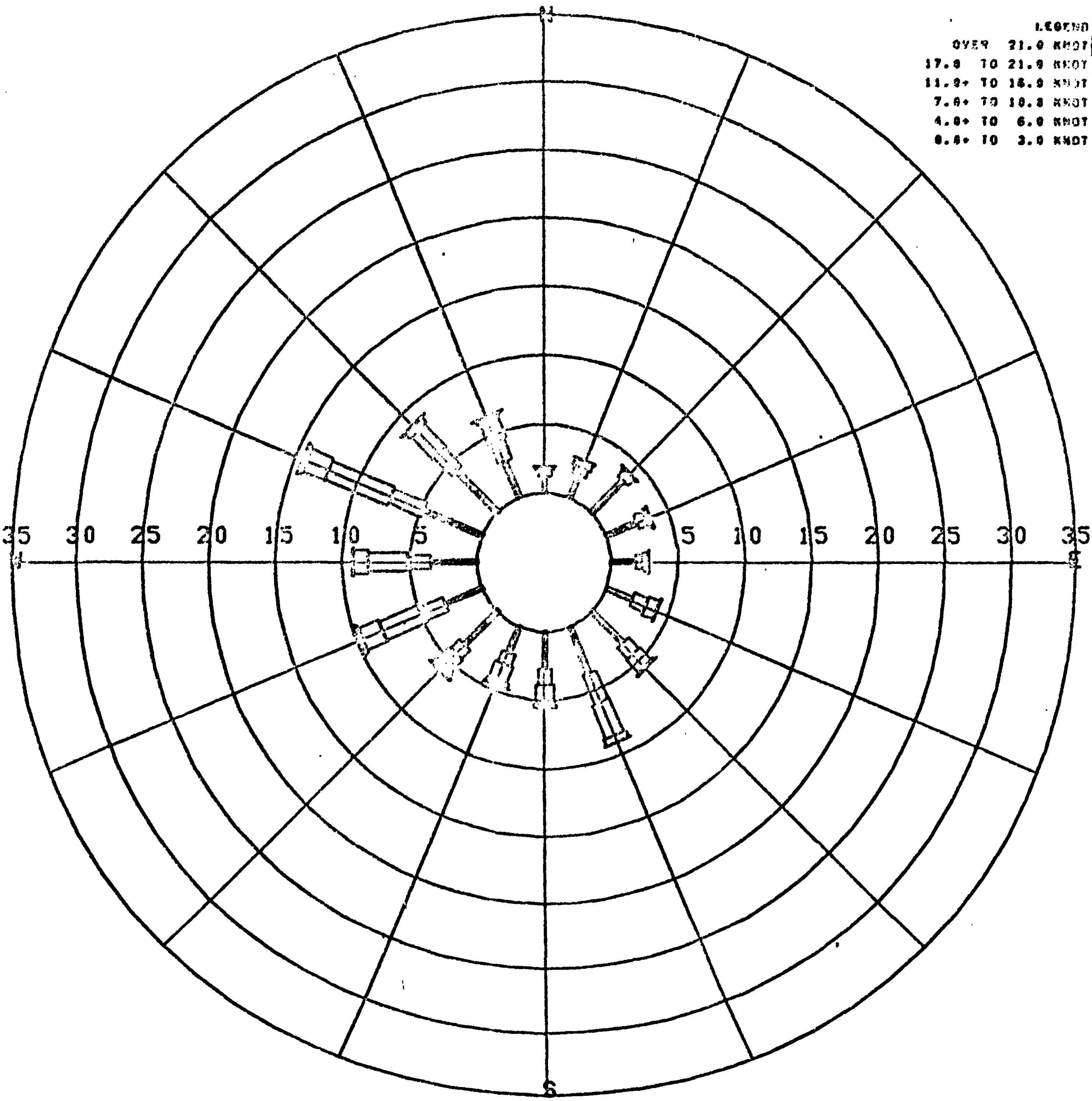


TABLE A.1.3

E VIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON. MASSACHUSETTS 02173
ILIPSBURG. PA., AUTUMN WINDROSE 1950-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT***

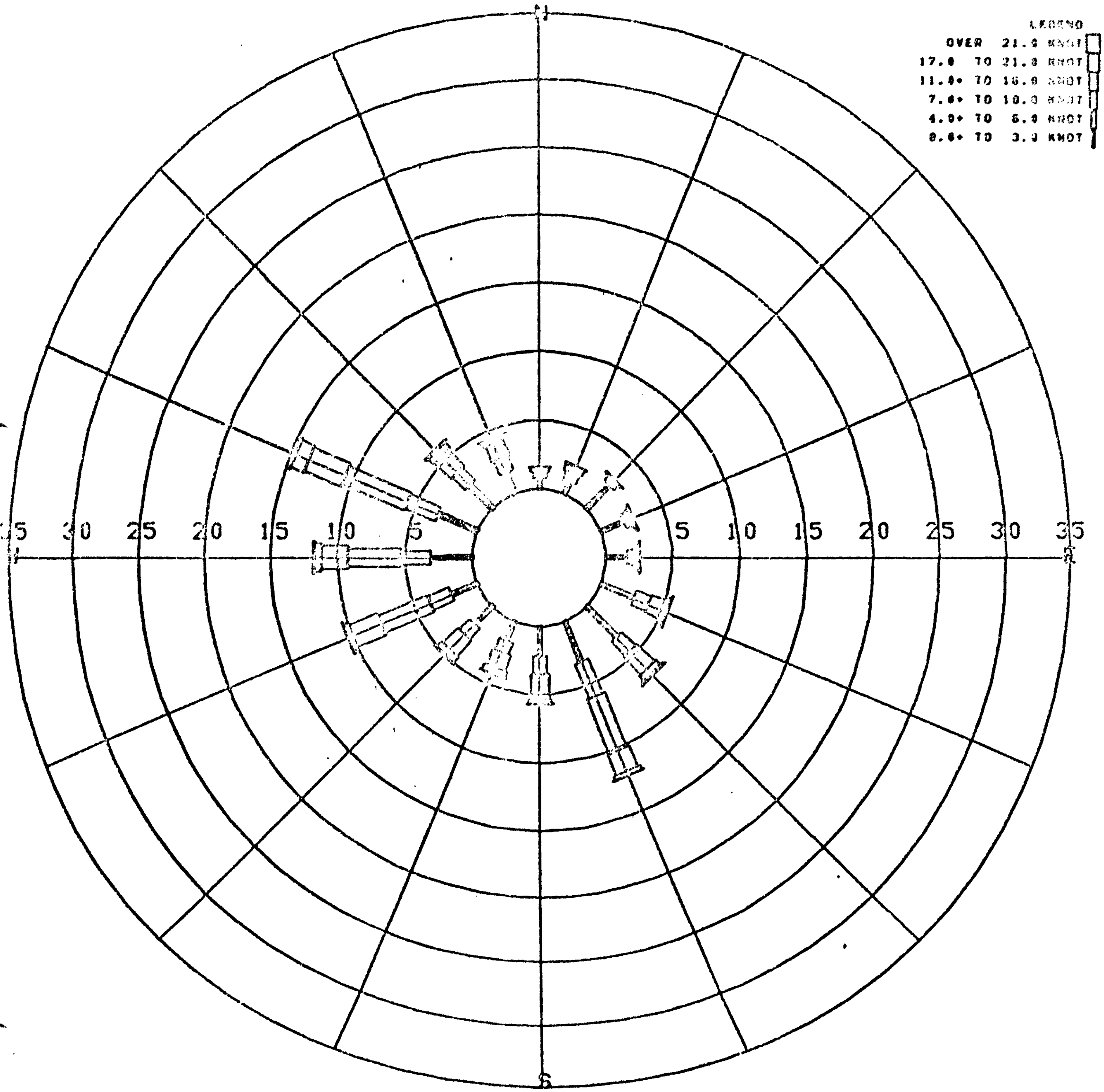


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PHILIPSBURG, PA., ANNUAL WINDROSE 1950-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

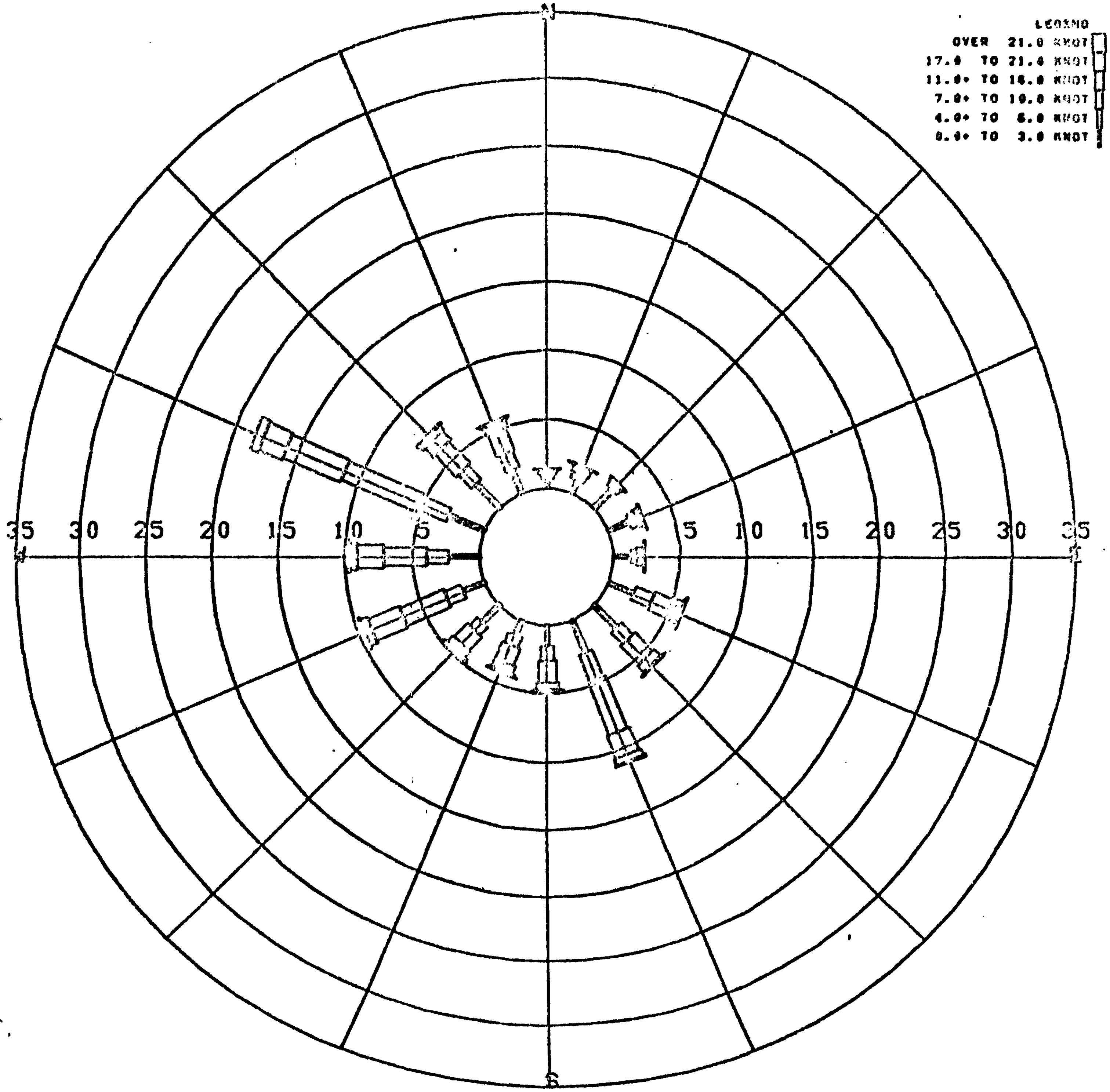


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
ALTOONA, PA., WINTER WINDROSE 1949-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT*

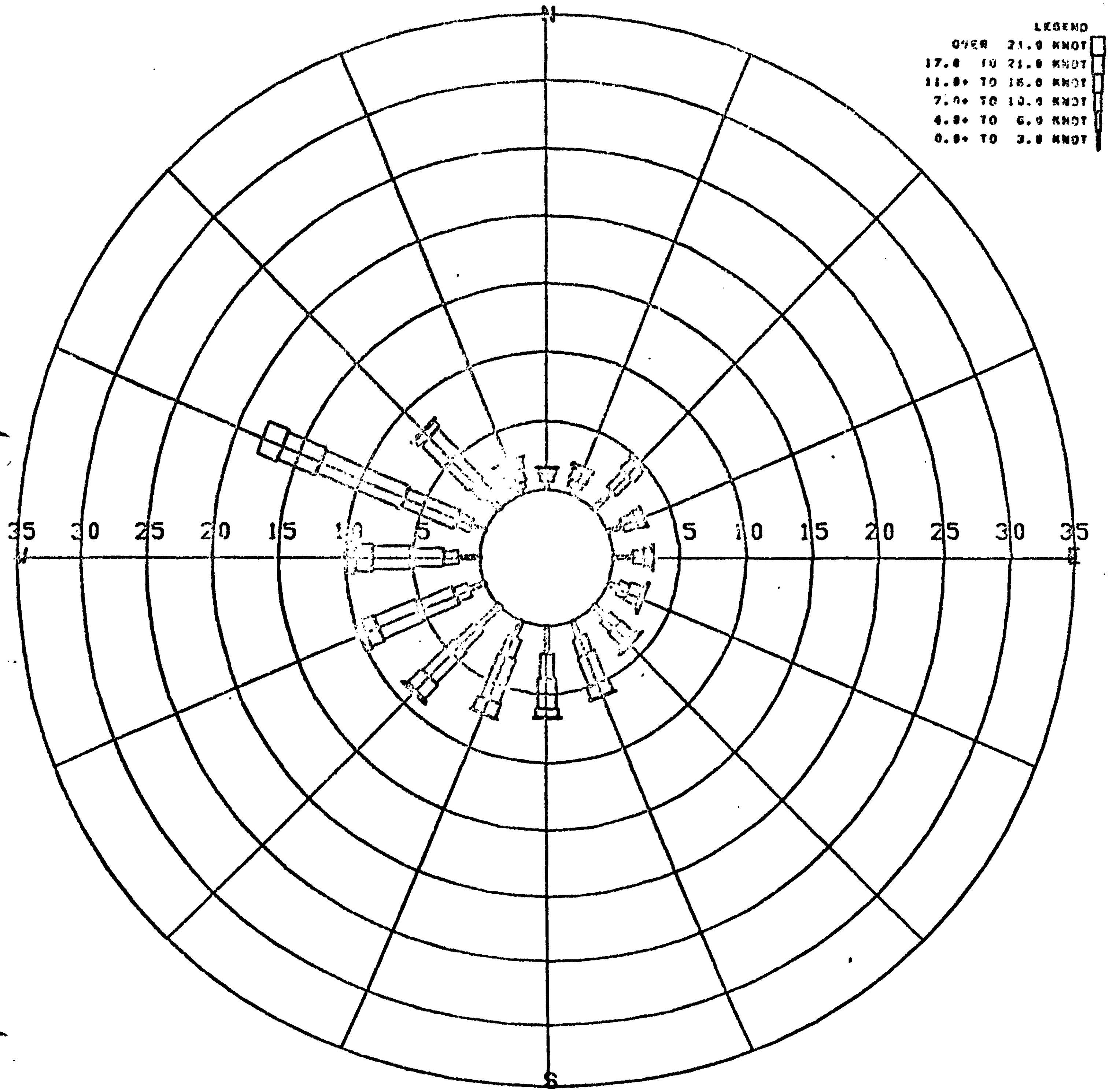


TABLE A.1.3

E VIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON. MASSACHUSETTS 02173
/ TOONA, PA.. SPRING WINDROSE 1949-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT*

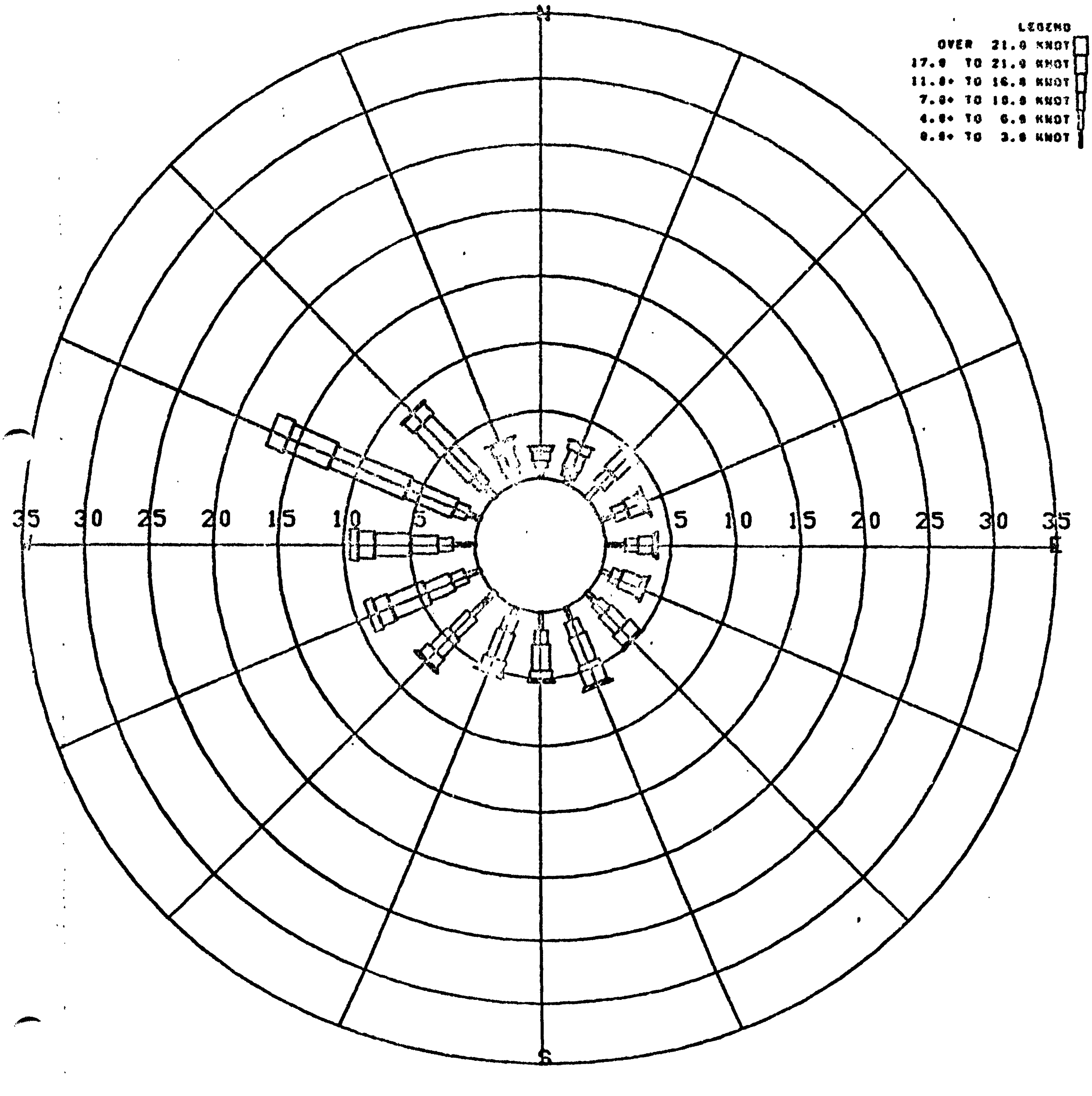


TABLE A.1.3

NVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON. MASSACHUSETTS 02173
LTOONA. PA., SUMMER WINDROSE 1949-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

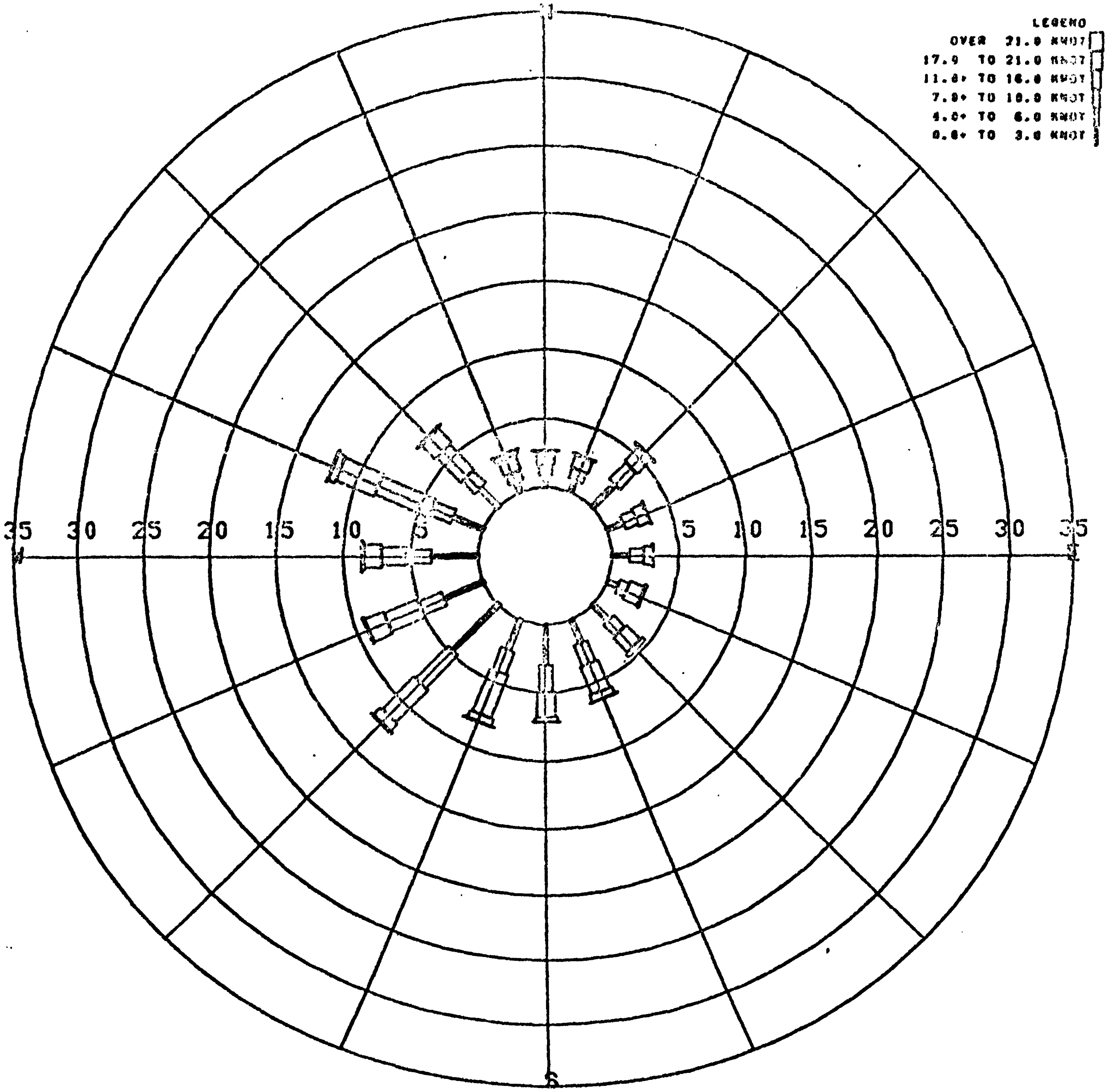


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
ALTOONA, PA., AUTUMN WINDROSE 1949-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

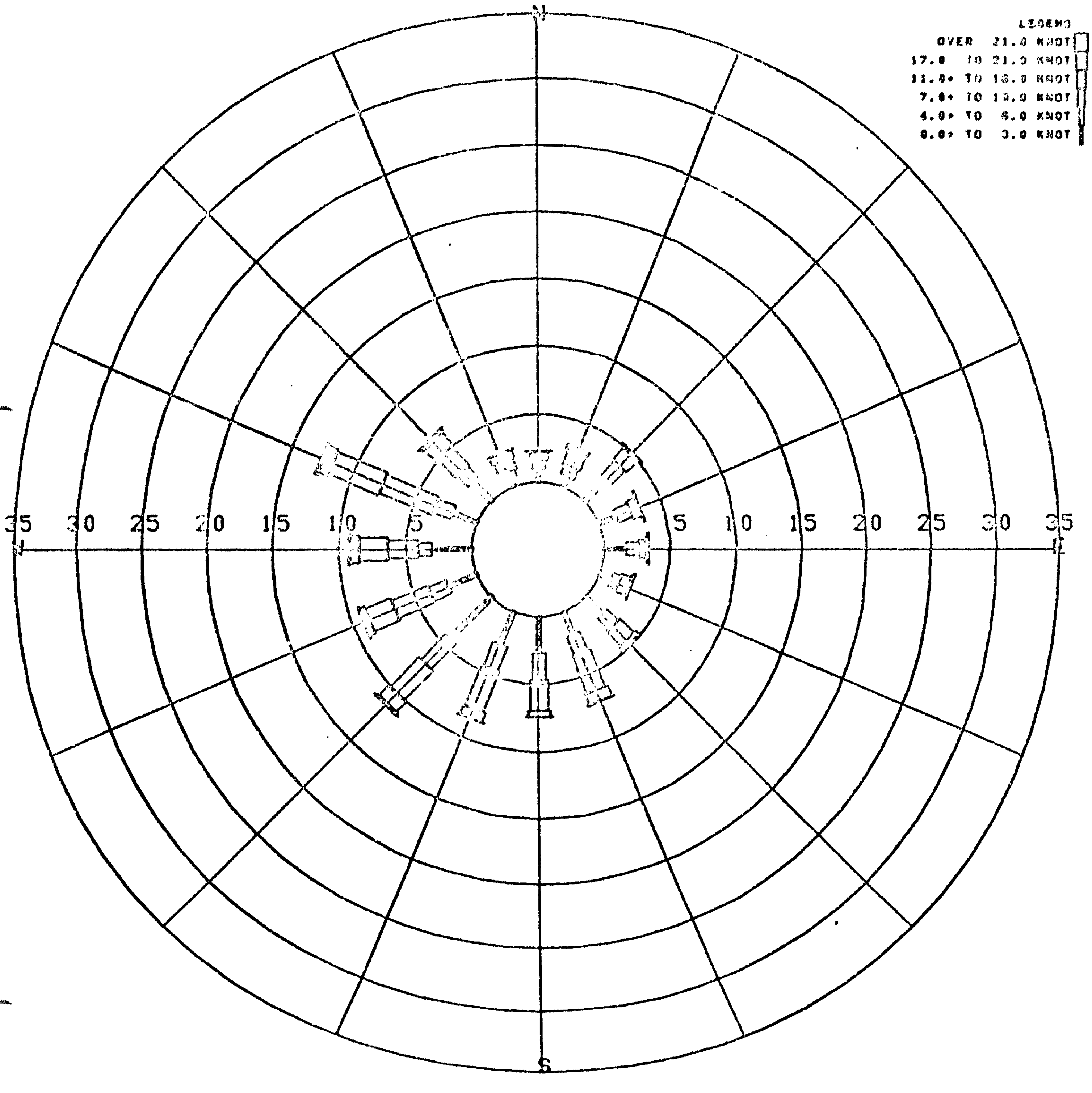
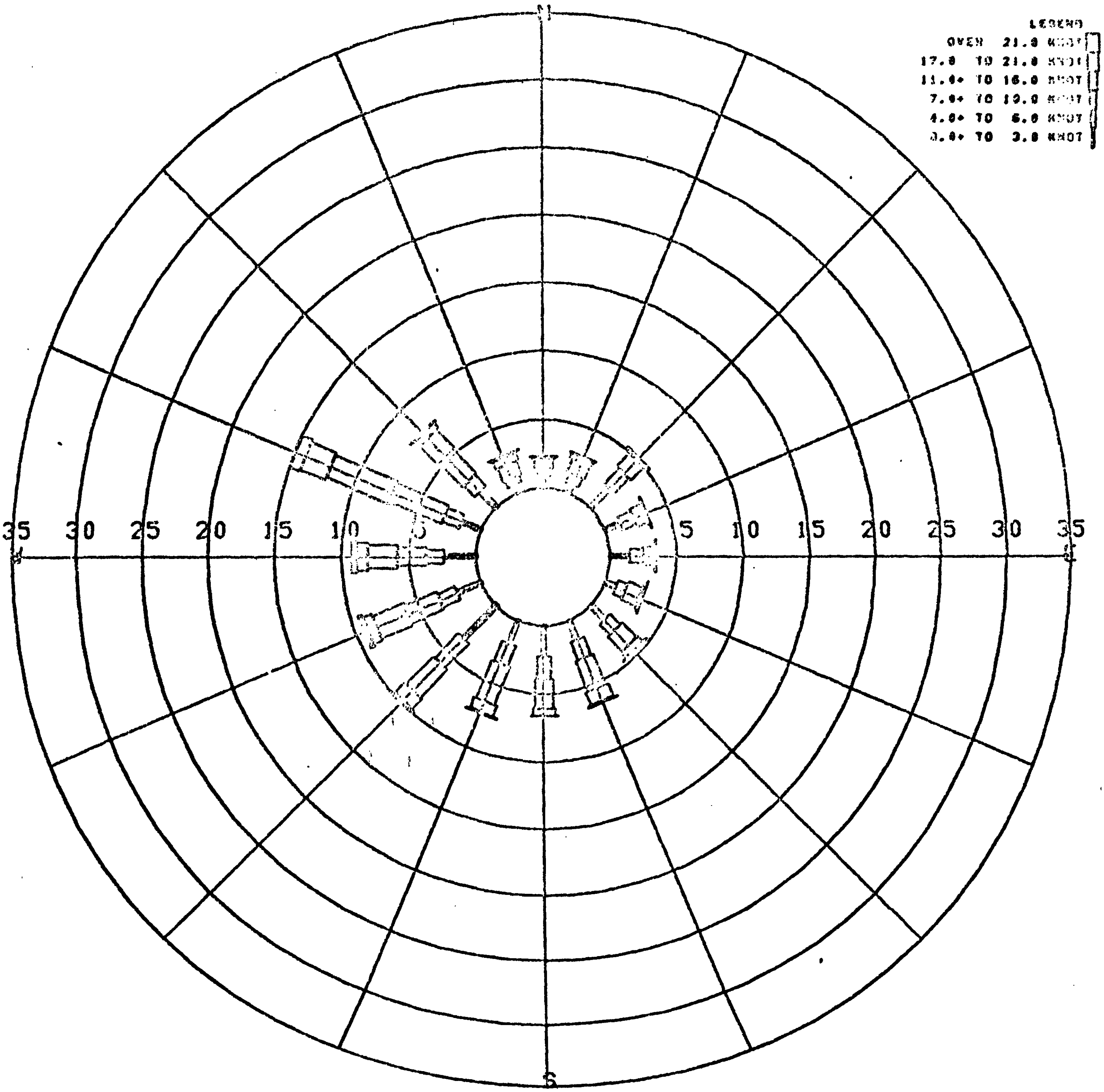


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
ALTOONA, PA., ANNUAL WINDROSE 1949-54
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT



ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PITTSBURGH, PA., ANNUAL STAR WINDROSE 1965-69
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

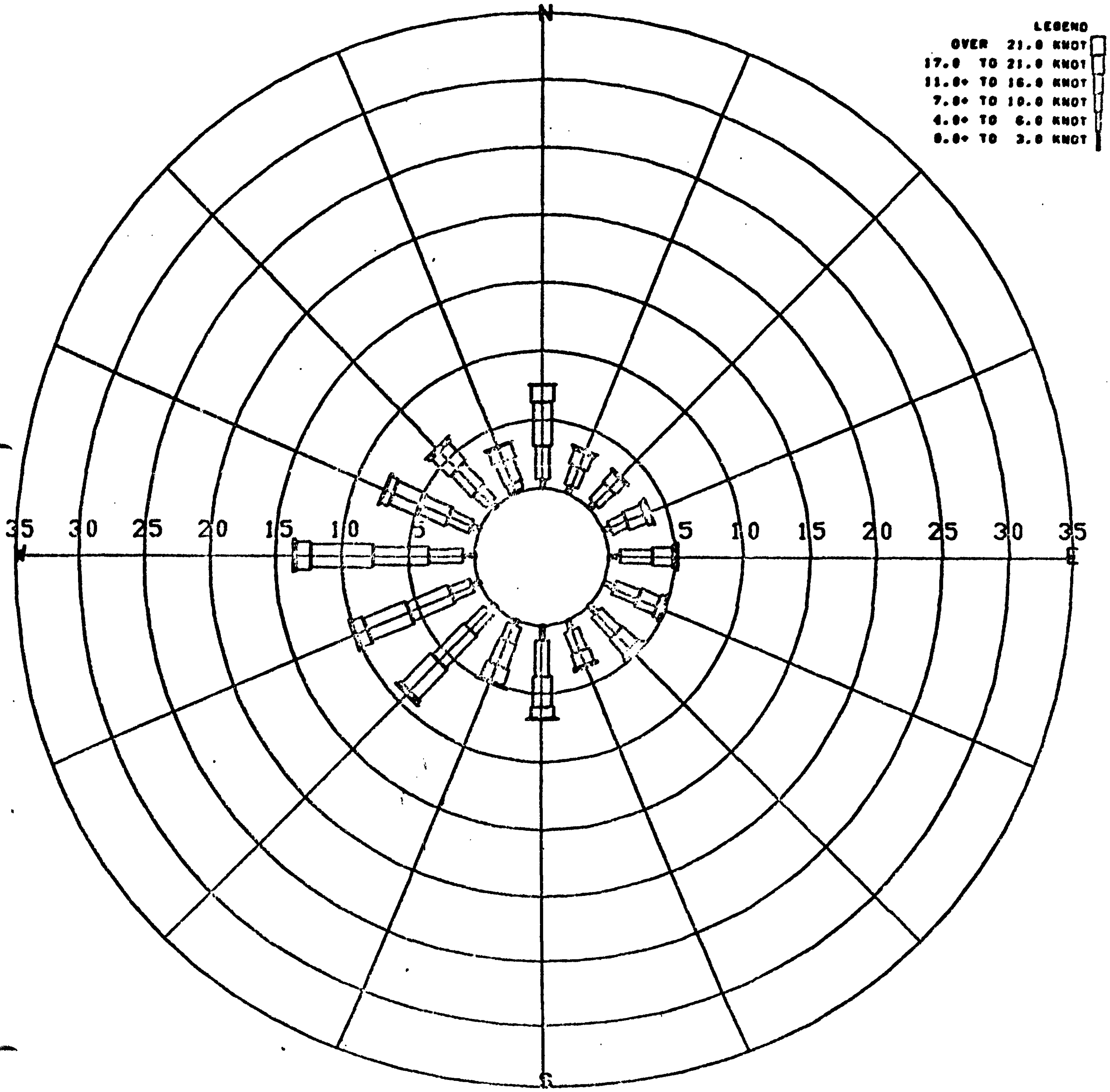


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PITTSBURGH, PA., WINTER STAR WINDROSE 1965-69
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

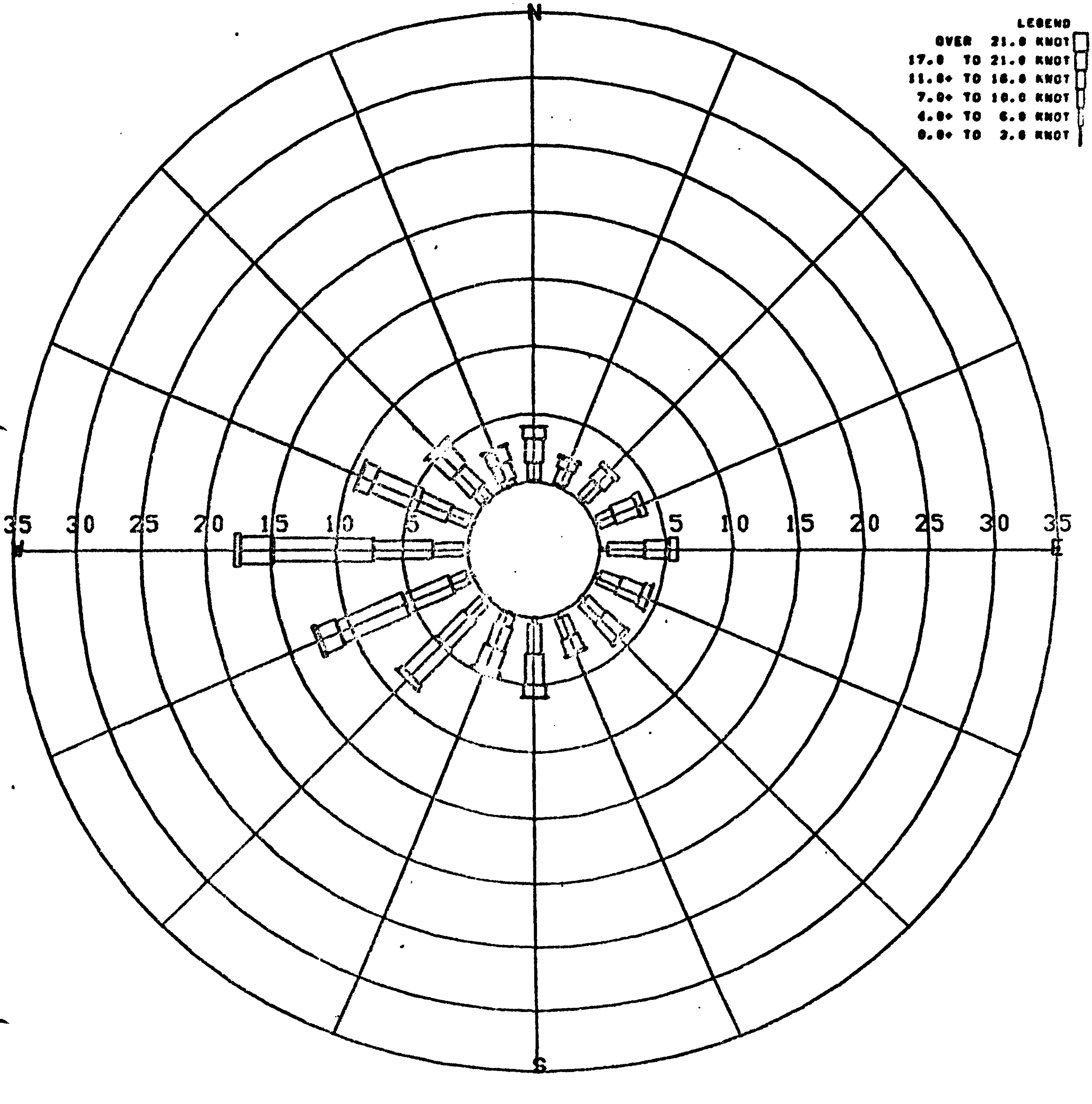


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PITTSBURGH, PA., SPRING STAR WINDROSE 1965-69
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

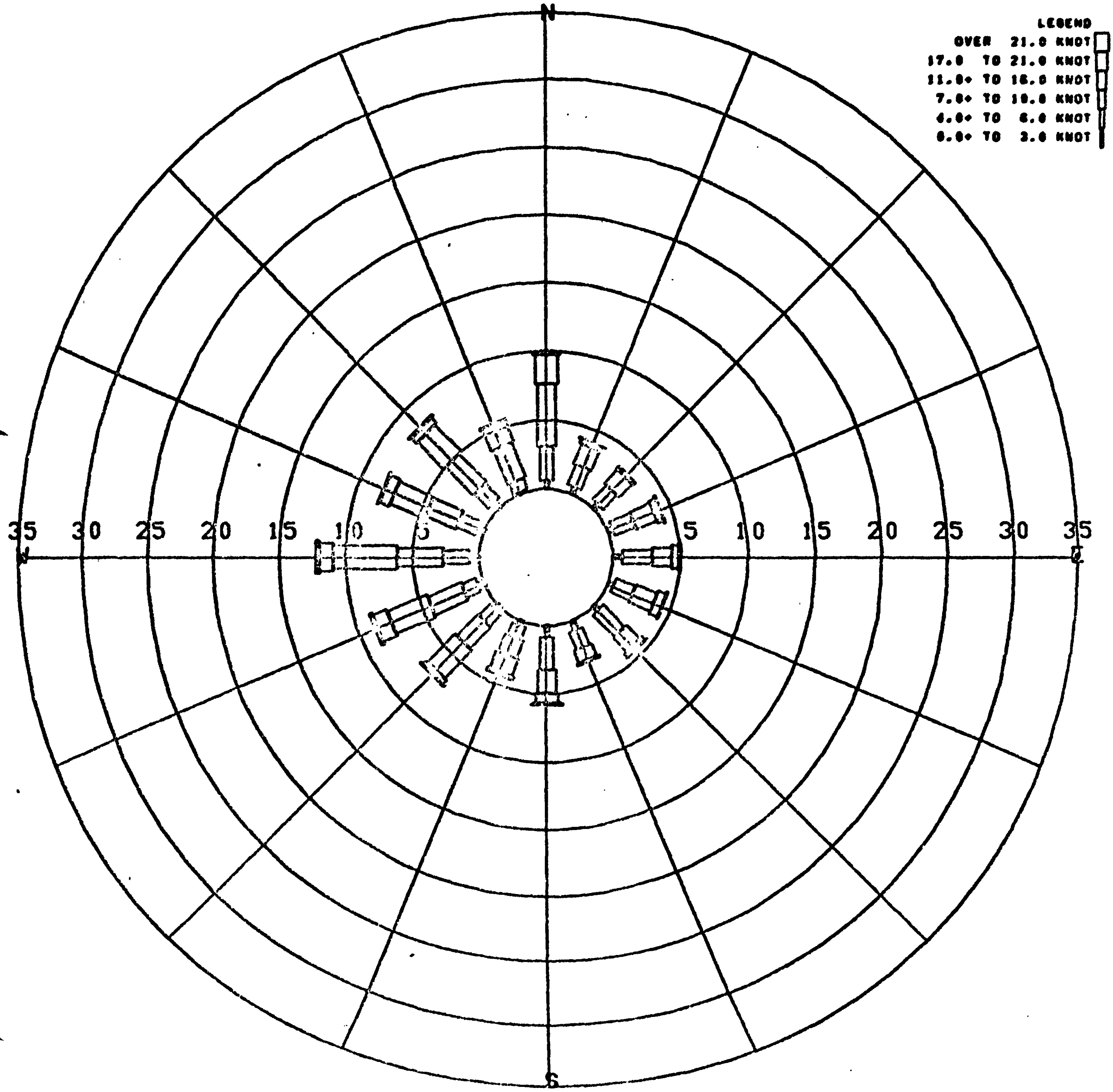


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PITTSBURGH, PA., SUMMER STAR WINDROSE 1965-69
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

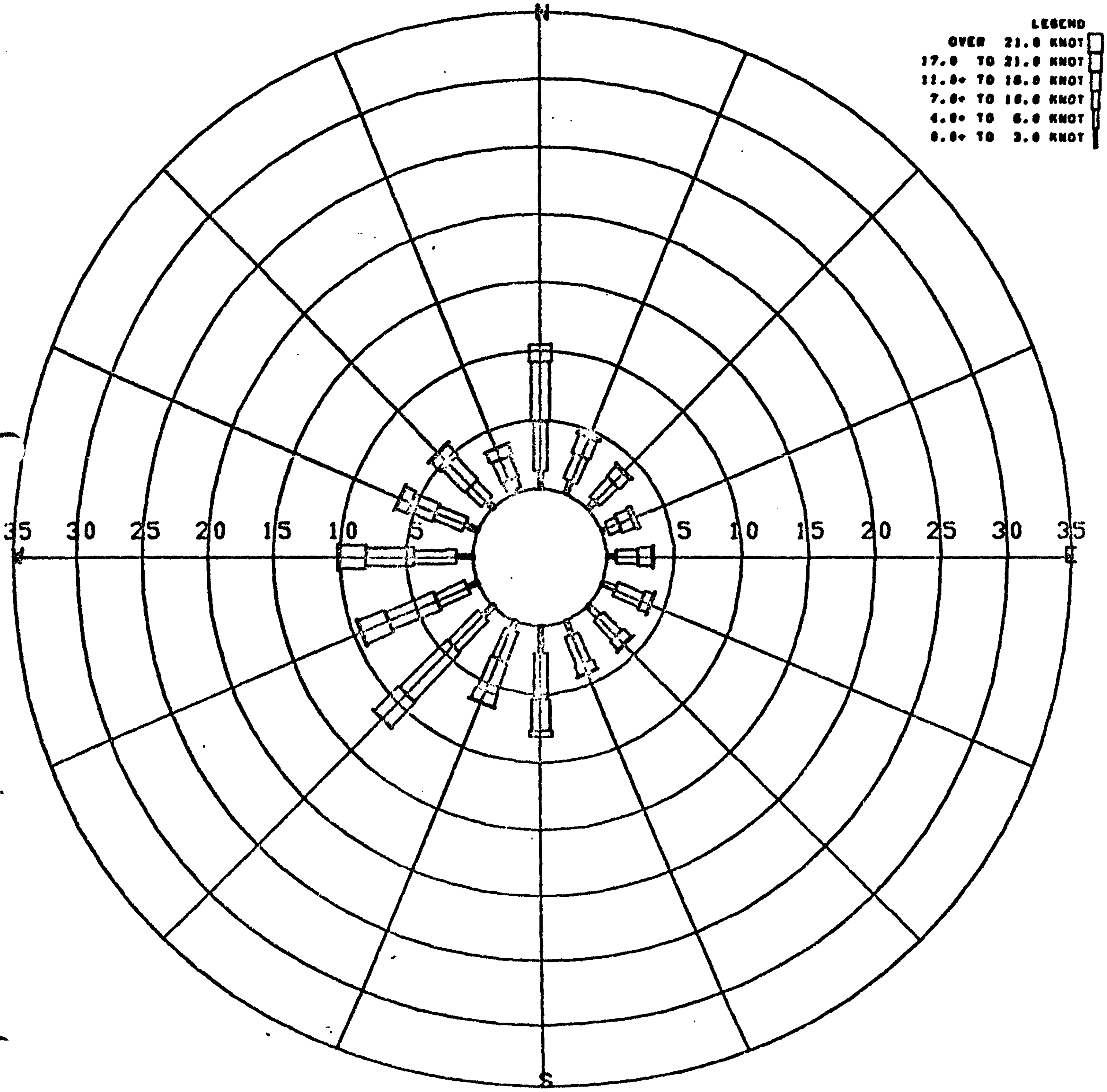


TABLE A.1.3

ENVIRONMENTAL RESEARCH + TECHNOLOGY LEXINGTON, MASSACHUSETTS 02173
PITTSBURGH, PA., AUTUMN STAR WINDROSE 1965-69
GRID VALUES REPRESENT WIND DISTRIBUTION IN PERCENT

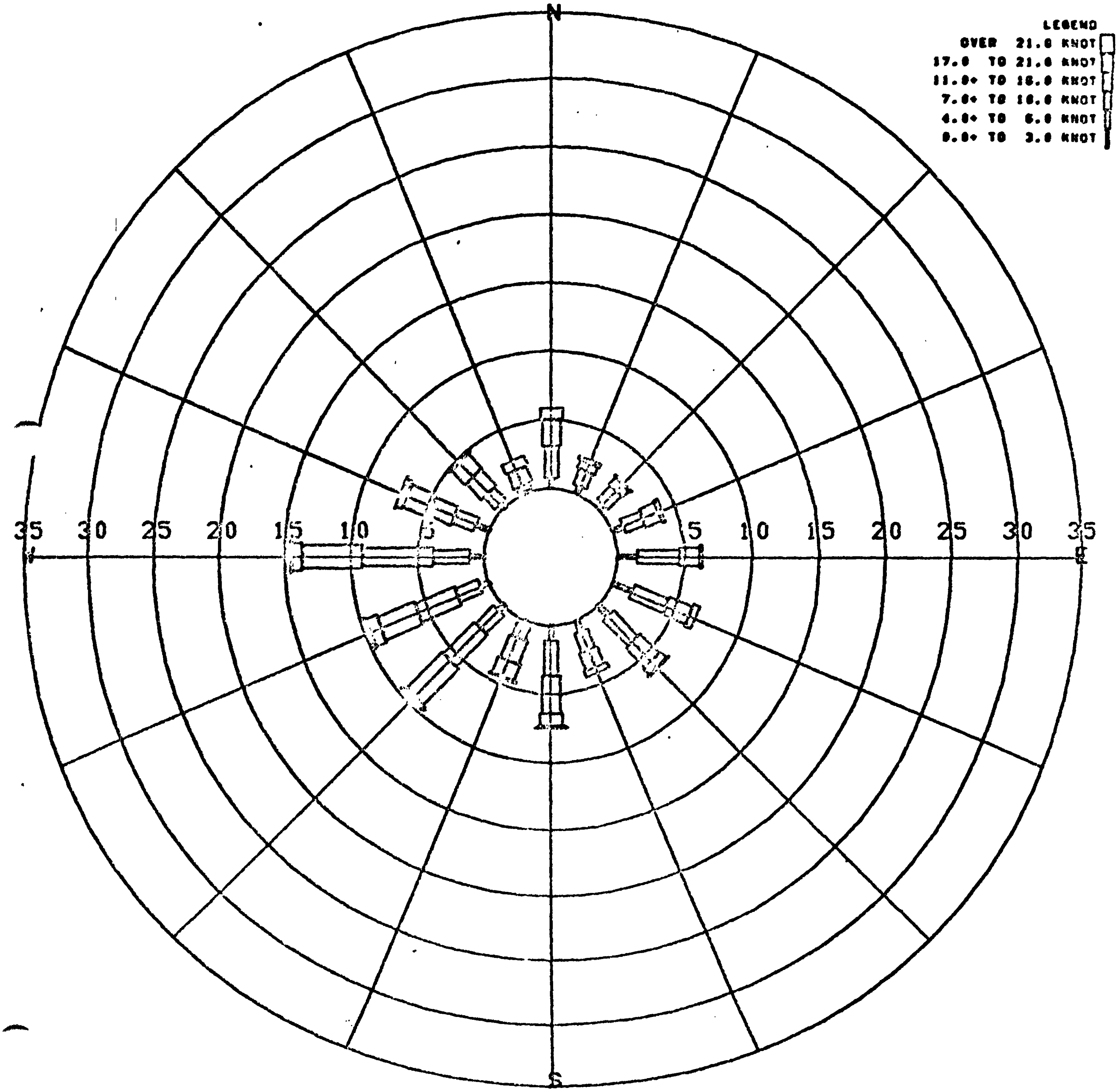


TABLE A.1.3

TABLE A.1.4

Pittsburgh
Mixing Depth Data*

	Annual	Winter	Spring	Summer	Autumn
Mixing Layer Depth (Mornings)	540 m	660 m	595 m	395 m	510 m
Mixing Layer Depth (Afternoons)	1550 m	1000 m	1900 m	1900 m	1400 m
Average Wind Speed Through Mixing Layer (Mornings)	5.1m/s	6.5m/s	5.9m/s	3.5m/s	4.5m/s
Average Wind Speed Through Mixing Layer (Afternoons)	7.1m/s	8.0m/s	8.4m/s	5.6m/s	6.3m/s

Two Day Duration Episodes(5 year data)

Mixing Height m	Wind Speed m/s	Episodes	Episode Days	Season
500	2	0	0	-
500	4	1	3	w
500	6	1	3	w
1000	2	0	0	-
1000	4	6	16	w
1000	6	10	29	w
1500	2	0	0	-
1500	4	16	39	a
1500	6	36	98	a
2000	2	1	2	su
2000	4	32	77	a
2000	6	81	225	a

Five Day Duration Episodes(5 year data)

Mixing Height m	Wind Speed m/s	Episodes	Epispode Days	Season
500	4	0	0	-
500	6	0	0	-
1000	4	0	0	-
1000	6	1	5	w
1500	4	0	0	-
1500	6	2	11	
2000	4	0	0	-
2000	6	5	31	a

*Source: [Holzworth, (1)]

A.2 Chestnut Ridge AIRMAP Network

The Chestnut Ridge AIRMAP network consists of three major components:

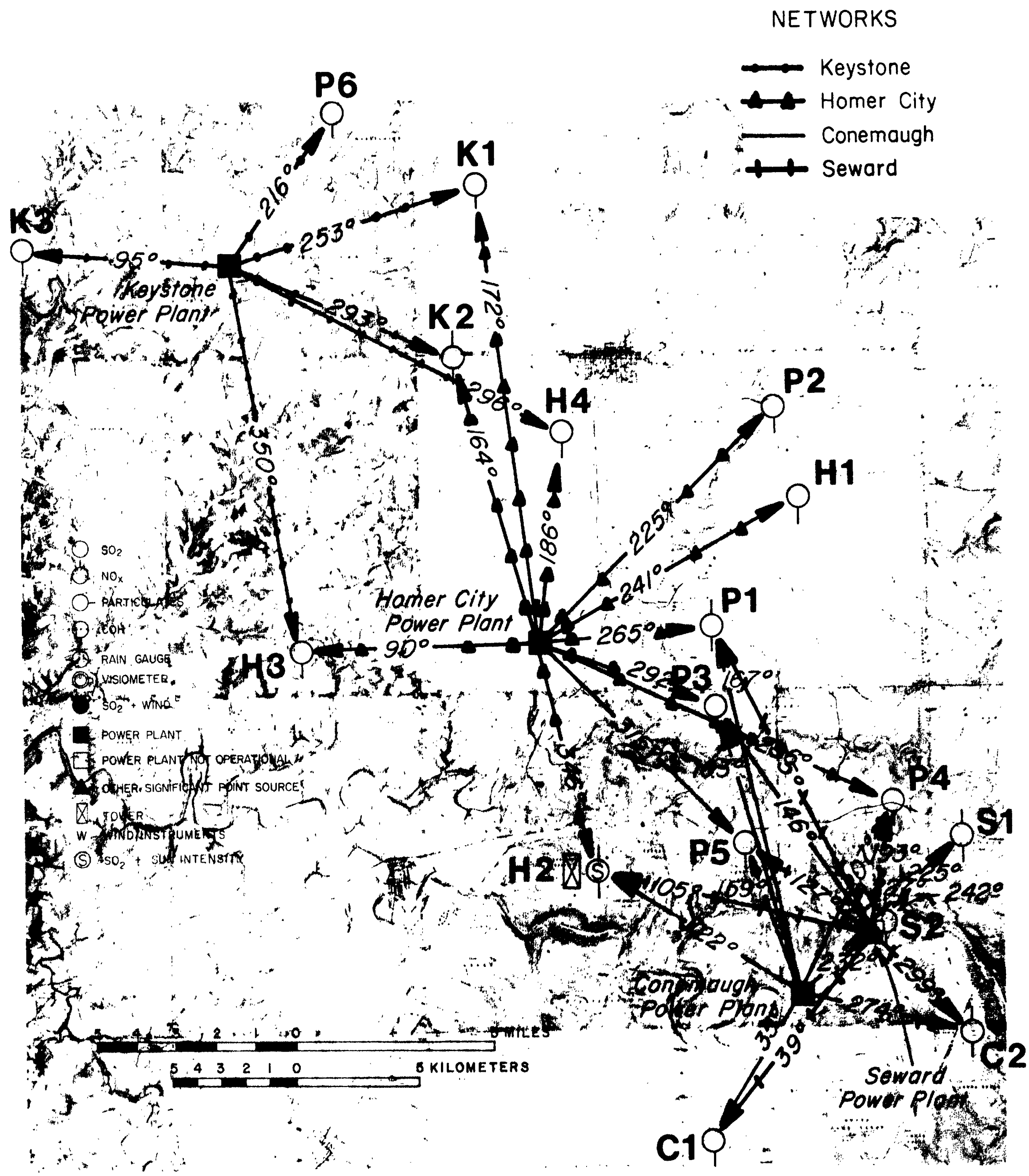
1) Sensors and station facilities
2) Telecommunication system
3) Central facility computers and meteorological data acquisition equipment.

A.2.1 Sensors and Station Facilities

For SO_2 measurements, the AIRMAP system uses the Meloy flame photometric total sulfur sensor with automatic calibration, thermoelectric cooling, and hydrogen shut-off options. These sensors have been modified by ERT so that initiation of the calibration cycle, sensing of flameouts, and reignition of the hydrogen flame are all performed remotely by the central computer. For NO/NO_2 the Thermo-Electron chemiluminescent sensor is used. For wind speed, wind direction, temperature, and temperature differential, CLIMET sensors are used.

The sulfur and nitrogen sensors, together with the meteorological amplifiers and telemetry electronics, are operated in air conditioned, temperature-controlled enclosures. These enclosures are maintained near 68°F throughout the year.

The complete Chestnut Ridge network comprises sixteen sites, as is shown in Figure A.2.1. Each is equipped with a Meloy sulfur analyzer and a coefficient-of-haze (COH) analyzer. Six of the sites have Thermo-Electron chemiluminescent sensors for NO/NO_x. The 300-foot meteorological tower at the Penn View site on the crest of Chestnut Ridge is instrumented as follows: at the 33-foot level, wind speed wind direction, and temperature; at the 150-foot level, temperature difference from the 33-foot level; and



Station Designation

Old Penelec	ERT	Penelec	Name	Old Penelec	ERT	Penelec	Name
C1	1	C1	West Fairfield	H5	D	P2	Penn Run
C3	2	P5	Florence Substation	H6	E	H1	Brush Valley
C2	3	C2	Laurel Ridge	H7	F	P1	Liggett
S3	6	P4	Armagh	H2/T2	G	H2	Penn View
S1	7	S1	Gas Center	K1	L	K1	Creekside
H1	A	P3	Luciusboro	K3	M	K3	Girdy
H3	B	H3	Lewisville	K4	N	P6	Keystone Dam
H4	C	H4	Rustic Lodge	K2	O	K2	Parkwood

a bivane. The processing of the output from the bivane requires a major revision of the AIRMAP program, which has not yet been implemented.

Ten of the sixteen SO_2 monitoring stations of the Chestnut Ridge AIRMAP network have been operating in the real-time mode since 1 June 1974. Three stations came on line shortly thereafter in June. The remaining three came on in July. The seventeenth planned SO_2 monitor, originally intended for location in Seward, Pennsylvania, was dropped from the system because of Penelec's difficulty in finding a site. Siting difficulties also caused the second meteorological tower to be eliminated. Because of the union construction problems mentioned in Section 2.0.1 above, the meteorological tower at the Penn View site was not brought on line and calibrated until August 16. Consequently no hourly averaged meteorological data has been available as model input, nor has the low-level thermal stratification been measured.

A.2.2 AIRMAP Telecommunications Systems

The AIRMAP telecommunications system permits the computer at ERT AIRMAP Central to acquire data and status information from each of the air quality analyzers and meteorological instruments and to initiate control functions at remote locations. In addition, it provides for remote printing of system-generated information obtained from the acquired data. The link between AIRMAP Central in Lexington, Mass. and the instrument sites consists of a set of telephone lines and transponders which convert digital circuit logic levels to other tones for transmission and back to logic voltage levels upon reception.

The telephone lines used are unconditioned voice grade, private line data channels. They have sufficient noise immunity so that data loss from cross-talk and random noise from the transmission lines has been negligible. Total costs, including central station termination charges, also favor using these lines. Attenuation due to line length is highly compensated by the Bell System, and loading effects are also compensated so that a large number of terminals can be connected to a single computer data port (limited by noise). The current system uses shared telephone circuits in that ten or more remote instrument sites can be connected to a single telephone line.

Telemetry equipment for the AIRMAP System was designed jointly at ERT and the Massachusetts Institute of Technology (MIT). Each site has one transponder. Up to 16 separate voltage-producing devices (instruments) can be connected to this interface. The central computer sends out a coded binary word to which only one transponder responds. Part of that binary word also designates one of the 16 input channels to the transponder. The transponder responds by opening the channel to the desired device and for some designated period of time, the signal from that device is sampled by the AIRMAP Central computer.

The transponder logic is very general and is used without modification to control and transmit all output to remote teletypes. These teletypewriter outputs can be transmitted on the same dedicated lines as the sensors.

Another important feature of the transponders is that they also transmit the setting of three sense switches that indicate to the AIRMAP Central computer exactly what state the analyzer is in, be it normal, calibrate test, etc. This allows erroneous values to be excluded from the statistics.

Because of the real-time control features of the ERT telemetry system, the field operation and maintenance personnel have the following increased capabilities:

1) Ability to evaluate current status of analyzers without visiting each site (thus, enabling maintenance personnel to visit stations that have malfunctioning sensors as fast as possible)
2) Ability to spot instrument malfunctions that occur after a site has been visited during a given work day
3) Ability to activate a dynamic calibration cycle at any time
4) Ability through computer control to automatically reignite flameouts on any Meloy instrument within the 1-minute interrogation cycle.

In addition, the implementation of an automatic rezero capability in the real-time system tends to restrict zero baseline drifts to an absolute minimum. All of these features of the ERT telemetry system reduce the amount of unnecessary lost data and thus increase the total data capture rate.

A.2.3. AIRMAP Central: Computers and Meteorological Data Acquisition Equipment

The heart of AIRMAP Central consists of two identically configured 32K-word memory Data General computers. The reasons for two such units are: (1) complete redundancy can be provided if one unit should fail for any reason, (2) programming and off-line data processing can be accomplished with the computer that is not gathering data and (3) the second computer is available for running the ERT air quality prediction models.

Both computers operate from a real-time operating system, meaning that they can conduct many tasks simultaneously, greatly increasing the efficiency of both machines. First priority is the data interrogation routine. Second priority is processing of the data as it comes in to analyze and calibrate the raw data and compute short-, intermediate-, and long-term averages and other statistics. The third level of priority is to transmit digested data to remote readout sites. After these three tasks have been satisfied, up to 13 other levels of priority can be specified. Reliability of the ERT real-time AIRMAP system is demonstrated by the fact that real-time data capture averaged 91.5% for the year 1973 for all sensors in the operational networks.

Weather data are continuously supplied to AIRMAP Central by means of a Service "A" weather teletype, which transmits weather observations at least once each hour from more than 200 cities in the United States; a Western Union Service "C" teletype, which sends upper air observations and forecasts; and a national weather facsimile machine, which produces copies of the latest surface and upper air charts and forecast maps. These weather data are used for the analysis of air quality as a function of meteorological conditions and as input to the predictions of air quality.

A.3 CONTROL

This Appendix contains general samples of the data relevant to the control strategy. In all cases the material here is backed up in depth by more precise information. The information contained here is given only as an indication of the magnitudes of the important parameters.

Overall System

Table A.3.1 on the next three pages shows the sizes, types and capacities of all the units involved in GPU (the service corporation which owns Penelec). The following two pages show the locations of these plants on a map of the GPU system. This information is important because the operation of the GPU system is coordinated at the power pool level (Pennsylvania-Jersey-Maryland) and so all of these plants, and the others in PJM as well, are available for picking up the load shifted from the facilities concerned. The four plants specifically included in this project comprise the largest complex of coal-burning power stations in the United States. The ownership of these generating stations, along with some general characteristics are listed below in Table A.3.2.

TABLE A.3.1

GPU SERVICE CORPORATION
System Capacity
As of June 1, 1974

Station (Coal, Gas or Oil Fired)

Station	Unit	Net Capability (Mw) Summer	Net Capability (Mw) Winter
Shawville	1	116	121
	2	123	128
	3	172	178
	4	172	178
		583	605
Homer City	1	300	300
	2	300	300
		600	600
Front Street	1-2-3-5	90	82
	4	28	28
		118	110
Seward	3-4	79	81
	5	136	137
		215	218
Warren	1	40	40
	2	40	40
		80	80
Saxton	2-3	34	35
Williamsburg	5	30	31
Portland	1	158	156
	2	246	246
		404	402
Crawford	1-2-3-4	111	113
Titus	1	78	80
	2	78	80
	3	78	80
		234	240
Eyler	5-6-7	51	54

Station (Coal, Gas or Oil Fired)

Station	Unit	Net Capability (Mw) Summer	Net Capability (Mw) Winter
Gilbert	1-2	45	46
	3	72	73
		117	119
Werner	1	15	17
	3	15	17
	4	58	60
		88	94
Sayreville	1-2-3	84	90
	4	122	126
	5	123	127
		329	343
Keystone	1	137	137
	2	136	136
		273	273
Conemaugh	1	140	140
	2	140	140
		280	280
Total Coal, Gas or Oil Fired		3547	3597

Station (Nuclear)

Station	Unit	Summer	Winter
Oyster Creek	1	620	650

TABLE A.3.1

Station (Combustion Turbine)	Unit	Net Capability (Mw) Summer	Winter
Blossburg	1	20	27
Wayne		54	73
Warren		55	73
Hunterstown	1	21	27
	2	21	27
	3	21	27
		63	81
Portland	3	15	19
	4	21	27
		36	46
Titus	4	15	19
	5	16	20
		31	39
Orrtanna	1	21	27
Hamilton	1	21	27
Shawnee	1	21	27
Tolna	1	21	27
	2	21	27
		42	54
Mountain	1	21	27
	2	21	27
		42	54
Riegel	C-1	22	28
Gilbert	C-1	25	32
	C-2	25	32
	C-3	25	32
	C-4	25	32
	4	56	72
	5	56	72
	6	56	72
	7	56	72
		324	416

Station (Combustion Turbine)	Unit	Net Capability (Mw) Summer	Winter
Glen Gardner	A-1	21	27
	A-2	21	27
	A-3	21	27
	A-4	21	27
	B-5	21	27
	B-6	21	27
	B-7	21	27
	B-8	21	27
		168	216
Sayreville	C-1	53	73
	C-2	53	73
	C-3	53	73
	C-4	53	73
		212	292
Werner	C-1	53	73
	C-2	53	73
	C-3	53	73
	C-4	53	73
		212	292
Total Combustion Turbines		1344	1772

TABLE A.3.1

Station (Diesel)

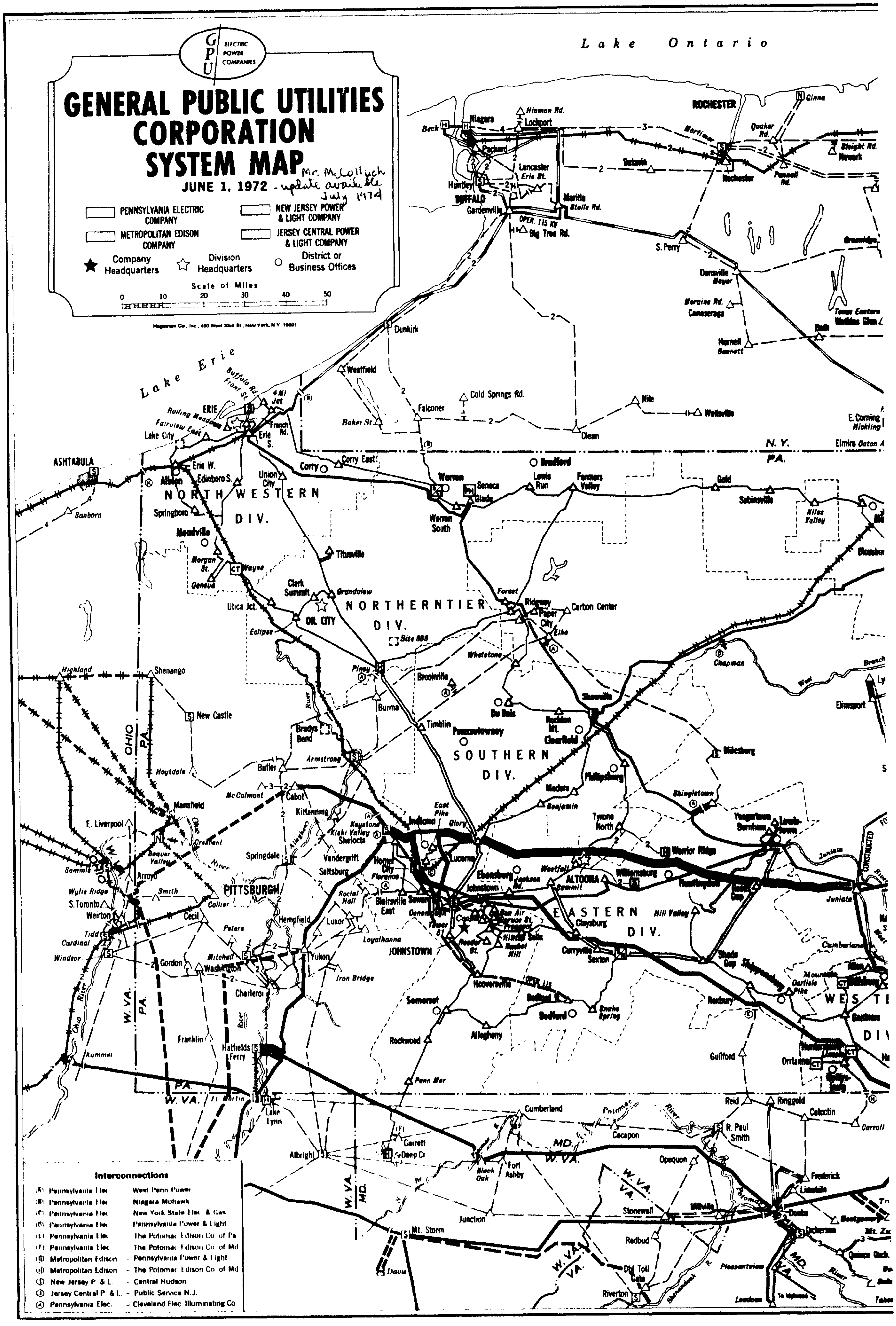
Station	Unit	Net Capability (Mw) Summer	Winter
Shawville	5	2	2
		2	2
	7	2	2
		6	6
Homer City	4	1	1
	5	1	1
	6	1	1
		3	3
Benton	1	2	2
	2	2	2
		4	4
Keystone	3-4-5-6	2	2
Conemaugh	A-B-C-D	2	2
Total Diesel		17	17

Station (Hydro - Conventional or P.S.)

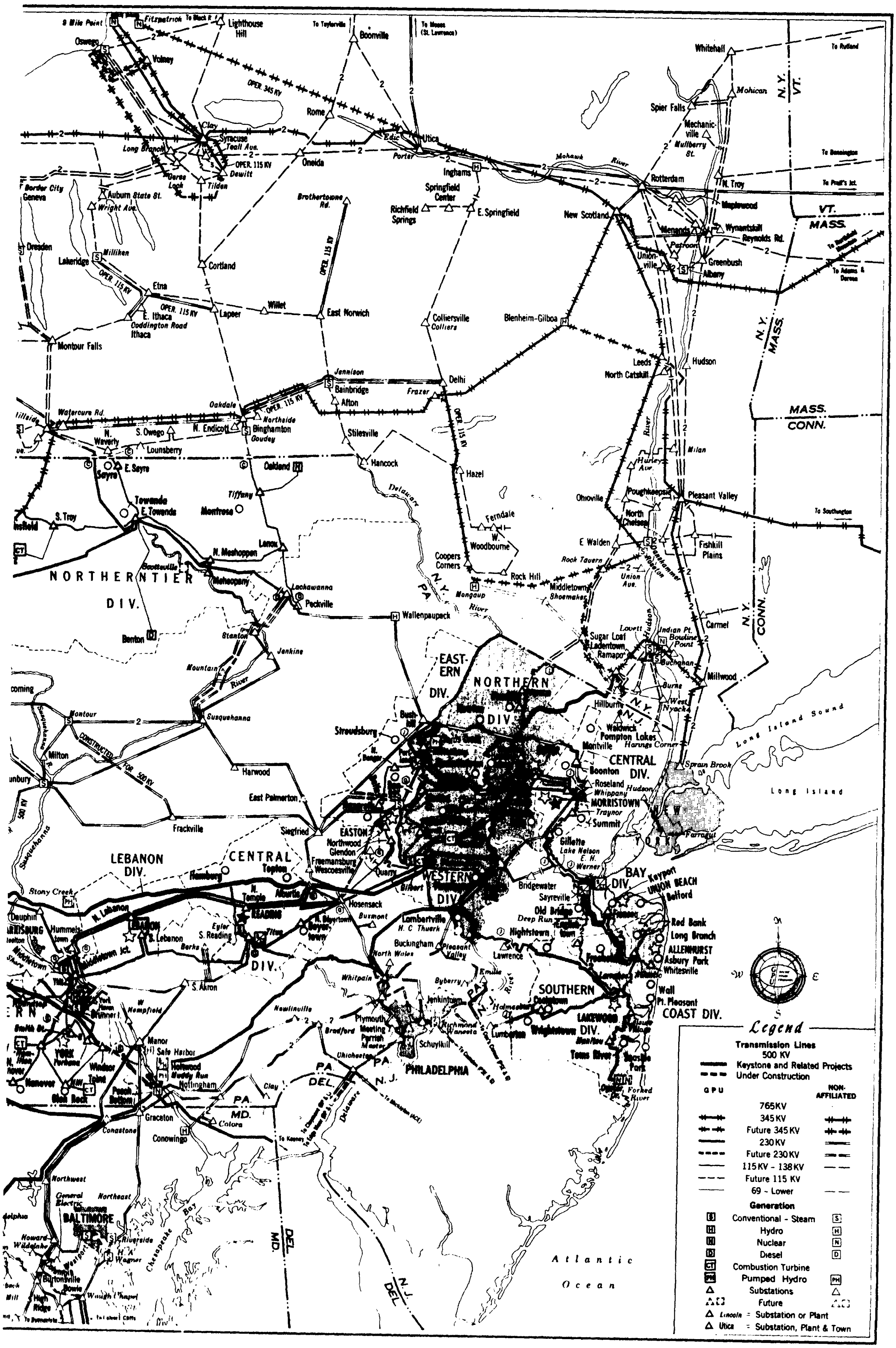
Station	Unit	Net Capability (Mw) Summer	Winter
Yards Creek	1	55	55
	2	55	55
	3	55	55
		165	165
Seneca	1)		
	2)	76	76
	3)		
		76	76
Piney	1	9	9
	2	9	9
	3	9	10
		27	28
Deep Creek	1	9	10
	2	9	9
		18	19
York Haven	20 Units	10	14
Total Hydro - Conventional & P.S.		296	302
Total GPU System		5824	6338
PP&L Purchase - 6/1/74		190	0
		6014	6338

PN	1923	1988
ME	1559	1460
JC	2532	2890

EDJ
6/1/74



GPU ELECTRIC POWER COMPANIES
GENERAL PUBLIC UTILITIES CORPORATION SYSTEM MAP
JUNE 1, 1972
Mr. McCollugh - update available July 1974
PENNSYLVANIA ELECTRIC COMPANY
NEW JERSEY POWER & LIGHT COMPANY
METROPOLITAN EDISON COMPANY
JERSEY CENTRAL POWER & LIGHT COMPANY
Company Headquarters
Division Headquarters
District or Business Offices
Scale of Miles
0 10 20 30 40 50
Lake Ontario
Lake Erie
NORTH WESTERN DIV.
NORTHERNTIER DIV.
SOUTHERN DIV.
EASTERN DIV.
N.Y.
PA.
OHIO
W. VA.
MD.
VA.
ROCHESTER
BUFFALO
ERIE
ASHTABULA
OIL CITY
PITTSBURGH
ALTOONA
JOHNSTOWN
Dunkirk
Olean
Warren
Meadville
Titusville
Indiana
Cumberland
Frederick
Interconnections
(A) Pennsylvania Elec - West Penn Power
(B) Pennsylvania Elec - Niagara Mohawk
(C) Pennsylvania Elec - New York State Elec & Gas
(D) Pennsylvania Elec - Pennsylvania Power & Light
(E) Pennsylvania Elec - The Potomac Edison Co of Pa
(F) Pennsylvania Elec - The Potomac Edison Co of Md
(G) Metropolitan Edison - Pennsylvania Power & Light
(H) Metropolitan Edison - The Potomac Edison Co of Md
(I) New Jersey P & L. - Central Hudson
(J) Jersey Central P & L. - Public Service N.J.
(K) Pennsylvania Elec. - Cleveland Elec Illuminating Co



NORTHERN TIER
DIV.
EASTERN DIV.
NORTHERN DIV.
CENTRAL DIV.
LEBANON DIV.
CENTRAL DIV.
WESTERN DIV.
SOUTHERN DIV.
BAY DIV.
COAST DIV.
LAKEWOOD DIV.
N.Y.
VT.
MASS.
CONN.
PA.
N.J.
DEL.
MD.
Oswego
Syracuse
Utica
Rome
Oneida
Cortland
Ithaca
Binghamton
Delhi
Rotterdam
New Scotland
Albany
Hudson
Leeds
Pleasant Valley
Poughkeepsie
Blenheim-Gilboa
Wallenpaupack
Stroudsburg
Easton
Morristown
Reading
Lebanon
York
Baltimore
PHILADELPHIA
Long Island
Long Island Sound
Atlantic Ocean
Chesapeake Bay
Delaware
Legend
Transmission Lines
500 KV
Keystone and Related Projects
Under Construction
GPU
NON-AFFILIATED
765KV
345 KV
Future 345 KV
230 KV
Future 230 KV
115 KV - 138 KV
Future 115 KV
69 - Lower
Generation
Conventional - Steam
Hydro
Nuclear
Diesel
Combustion Turbine
Pumped Hydro
Substations
Future
Lincoln = Substation or Plant
Utica = Substation, Plant & Town

TABLE A.3.2

PLANT CAPACITIES AND ENTITLEMENTS
(1973 ELECTRICAL WORLD-DIRECTORY OF ELECTRIC UTILITIES)

KEYSTONE - Shelocta, Pa.			
PSE&G		24.7%	427,565 Kw
BG&E		19.9	344,000
PECO		19.9	344,000
JCP&L		15.8	273,000
PP&L		13.4	231,000
DELMARVA		3.7	64,306
ACEC		2.6	44,460
PLANT TOTAL CAPACITY			1,728,331
Unit 1	9698 Btu/kwh	900,000 KW)	) NOMINAL (LAPPES)
Unit 2	9864 "	900,000 KW)	
CONEMAUGH - Huff, Pa. (On Conemaugh River)			
PSE&G			421,200 Kw
PECO			352,000
METED			308,000
PP&L			213,000
BG&E			180,000
PEPCO			166,100
ACEC			64,482
DELMARVA			62,630
PLANT TOTAL CAPACITY			1,767,612
Unit 1	9698 Btu/kwh	900,000)	) NOMINAL (LAPPES)
Unit 2	9864 "	900,000)	
HOMER CITY- Homer City, Pa.			
PENELEC		50%	659,700 KW
NYSE&G CORP.		50	659,700
PLANT TOTAL CAPACITY			1,319,400
Unit 1	10,251 Btu/kwh	640,000 KW)	) NOMINAL (LAPPES)
Unit 2	10,112 "	640,000 KW)	
SEWARD - Seward, Pa.			
PENELEC		100%	222,000 KW
PLANT TOTAL CAPACITY			222,000
Units 2-3-4	-	85,000 KW	
Unit 5	9993 Btu/kwh	137,000 KW	

ACEC - Atlantic City Electric Co. - NJ
BG&E - Baltimore Gas & Electric - Ma
DELMARVA - Delaware-Maryland-Virginia Power Co. - Del.
JCP&L - Jersey Central Power & Light - NJ
METED - Metropolitan Edison - Pa.
NYSE&G Corp. - N.Y. State Electricity & Gas Corp.
PECO - Philadelphia Electric Co. - Pa.
PENELEC - Pennsylvania Electric Co. - Pa.
PEPCO - Pittsburgh Electric Power Co. -Pa.
PP&L - Pennsylvania Power & Light - Pa.
PSE&G - Public Service Electric and Gas - NJ

Fuel Characteristics and Processing

A previous study (LAPPES) shows some typical data on the variations of the coal characteristics from a given plant. These variations are still evident in the operation of the plants.

Keystone Station March 1968 Series	
Moisture (%)	3.20
Volatile Matter (%)	29.94
Fixed Carbon (%)	48.08
Ash (%)	16.66
Sulfur (%)	2.12
Btu per Pound	12,093
Calories per Gram	6,718

Keystone Station May 1968 Series	
Moisture (%)	3.32
Volatile Matter (%)	30.19
Fixed Carbon (%)	47.81
Ash (%)	16.48
Sulfur (%)	2.20
Btu per Pound	12,053
Calories per Gram	6,695

Keystone Station July 1968 Series	
Moisture (%)	3.83
Volatile Matter (%)	29.65
Fixed Carbon (%)	48.67
Ash (%)	15.67
Sulfur (%)	2.18
Btu per Pound	12,081
Calories per Gram	6,711

Keystone Station October 1968 Series	
Moisture	3.72
Volatile Matter (%)	29.27
Fixed Carbon (%)	47.36
Ash (%)	17.29
Sulfur (%)	2.36
Btu per Pound	11,847
Calories per Gram	6,581

The variation of the sulfur percent, which is generally normalized to account for variation in Btu per pound, is not a gradual change. In fact, the percent sulfur can vary by a factor of three from one lump of coal to the next. Since utilities must stay below standards by the amount of uncertainty they have in their measurements, there are millions of dollars lost. Nuclear metering methods are underway to eventually yield a continuous readout of the sulfur content of the incoming coals.

There is also significant variation in coal characteristics from one plant to the next at the same point in time.

TABLE A.3.3

APRIL 1974

STATION	TONS	Weighted Average BTU	MOISTURE	ASH	SULFUR
KEYSTONE	393,981	11,902	2.81	18.95	2.16
CONEMAUGH	252,598	11,426	5.23	18.49	2.29
HOMER CITY	158,951	11,762	3.92	19.30	2.29
SHAWVILLE	170,437	12,233	5.78	14.27	2.55
SEWARD	45,087	12,349	3.28	16.51	2.77
FRONT ST.	36,919	12,185	4.78	13.61	2.58
WARREN	23,998	11,638	7.25	13.65	2.06
WMBG	5,797	12,122	7.20	13.14	2.71
SAXTON	11,727	12,925	3.93	12.75	1.63

This type of information is kept for each plant and each coal shipper (sometimes as many as six) to each plant. This data is collected to check the contracted levels of sulfur, and is readily available on a daily and monthly basis.

To effect fuel switching at any plant, a utility could maintain a clean coal stockpile, using either specially bought and trucked coal or maintaining a coal-cleaning plant at one point and shipping around that cleaned coal. The clean piles presently (Aug. 26, 1974) available include:

Homer City	34,242 tons	1.94%S	3.4 day supply
Keystone	45,673 tons	1.39%	3.0 day supply
Connemaugh	50,078 tons	.92%	3.3 day supply
Seward	(gone)	-	-

Once a fuel switch decision is made the clean coal would begin to be dumped into the bunkers. The amount of coal already in storage in the plant's bunker would have to be burned first, with some blending being inevitable. The total storage of the bunkers, and thus the maximum time for a fuel switch, is 8 to 9 hours at all the plants except 1 day at Seward. The bunkers might be as little as half full, with 1/2 to 3/4 as the general operating range.

The cleanest coal, about .8% sulfur, is termed metallurgical coal because it is necessary for steel-making processes. Although this metallurgical coal is an extremely valuable, strategic and costly resource, some is currently bought by utilities to blend in with coals which the automatic cutter or grab samples determine are above standard (i.e. will yield more than 4 lbs. SO_2 per million Btu heat input or about 2.4% sulfur on 12,000 Btu coal.)

The costs of coal are elusive numbers due to the blending of different sources and the long-term and utility-owned supplies. Crude estimates yield costs in the range of

3 to 6% sulfur	$15 to $20 per ton
2 to 3	18 to 25
1 to 2	25 to 30
.7 to 1 (western)	30 to 35
Solvent refined coal (future)	45 to 50

with transportation costs of about $2.50 (for local) to $10 (for western) per ton included.

Two people can implement the dynamics of the fuel switch, and can generally be drawn from the on-site operating personnel with an outside possibility of overtime charges.

There are two means by which sulfur is held in coal: pyritic and organic. The pyritic sulfur is in a form of rock which is freeable through existing "coal cleaning" processes. Since the pyrite is heavier than coal, the raw coal can be crushed and separated in a bath of material with specific gravity between that of coal and pyrite. The cleaning cost can be as little as $2.40 per ton (10¢/million Btu) for 1.4% sulfur coal. Western coal has no pyritic sulfur and contains all of its .8% sulfur in organic form. This .8% is about standard for the organic sulfur content of coal, and this can be removed only through solvent refining (at about $45 per ton delivered price some time in the future, when the existing technology is applied). All forms of coal cleaning result in a loss of a certain percent of the Btu content of the coal (generally between 4% and 12%).

Power Plant Models

To present a general overview of the types and magnitudes of the data that is available, information of the Conemaugh station will be presented.

Unit 1	9698 Btu/kwh	900MW
Unit 2	9864 "	900MW
Coal consumption	590 metric tons per hour	
Cooling towers	2 natural draft, 113 meters tall	

The specific loading curve for either Unit 1 or 2 can be modeled as:

TABLE A.3.4

Gross Block MW	λ heat rate Btu/net kwh	Cost Factor	λ cost Bus Bar Basis $/net MWh
400	7325		5.22
600	7500	↑	5.35
860	8023	0.713	5.72
1000	8472	↓	6.04
Start Cost	4,200 x 10^{16}	2.282	
Spin Cost	610 x 10^6	0.713	

where the cost factor = (fuel cost + incremental maintenance) times penalty factor = (.575 + .062)(1.120) = 0.713 and on start cost = (2.220 + .062)(1.000) = 2.282. This data is also available in tabulated form:

TABLE A.3.5

EXCERPTS FROM CONEMAUGH GENERATION STATION

BASIC HEAT INPUT DATA

Gross MW	Boiler Input 10^6 Btu/hr	Gross MW	Boiler Input 10^6 Btu/hr	Gross MW	Boiler Input 10^6 Btu/hr	Gross MW	Boiler Input 10^6 Btu/hr
0	610	40	896	80	1182	120	1463
1	617	41	903	81	1189	121	1475
2	624	42	910	82	1196	122	1482
3	631	43	917	83	1203	123	1489
4	639	44	925	84	1211	124	1497
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
35	860	75	1146	115	1432	155	1718
36	867	76	1153	116	1439	156	1725
37	875	77	1161	117	1447	157	1733
38	882	78	1168	118	1454	158	1740
39	889	79	1175	119	1461	159	1747
.	.	.	.	.	.	.	.

The startup-shutdown rate is 6MW/minute, or 5MW/minute without changing the normal ramp control procedure. The control procedures are the same as those described for Keystone in the American Power Conference Proceedings of 1964.

Abatement Equipment

The cooling towers on, for instance, the Connemaugh plant handle about 21.2 x 10^5 liters of water per minute. They cool the water from about 48°C to 32°C and consume between 34,000 and 49,000 liters per minute (evaporation loss).

The particulate precipitators normally have a net efficiency of between 98.2% and 99.9%. This precipitator efficiency, however, is closely related to the sulfur content of the emissions. In particular, the precipitators work better with more sulfur present. If the sulfur content is significantly lower, either from the use of clean fuel or a scrubber system (if it is used before the precipitators), the efficiency could drop to 83%! There is test data available from which the curve of "sulfur percent in fuel" versus "precipitator efficiency" could be drawn. Preliminarily it would seem to look like this:

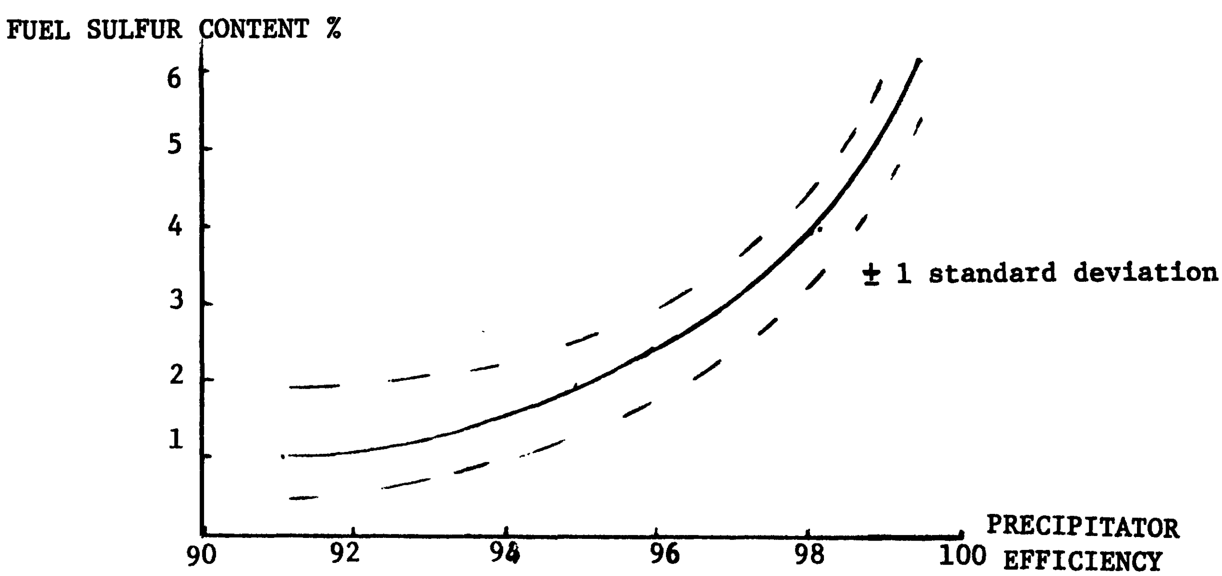


FIGURE A.3.2

The curve of ash versus dust loading for the precipitators on this system is

$$\text{Ash } (7\%) - 3.4(\pm 1.5) = 2.72 \text{ loading (GR/SCF)}.$$

There are several problems with scrubber systems, not the least of which is the unavailability of good data. Reliability is a key factor with good performance in the 70% to 80% availability range and bad from 30% to 40%. Sulfur removal efficiencies vary around 80%, being generally in the 60% to 90% range. The temperature of the emissions can drop from about 300°F to about 120°F to 160°F with a scrubber. This can significantly add to groundlevel concentrations at times. Costs are about $50 to $60 per kw, 2 to 4 mills/kwh. The scrubber system for the 650MW Homer City Unit 3, when it is chosen by Penelec this summer, will be the scrubber system used in the simulation comparative evaluations.

Power Plant Emissions

There is a procedure by which the temperature of the stack gas can be changed appreciably. By the use of baffles, portions of the exhaust (15% or more) can be made to bypass the air preheaters. This bypassed exhaust, then at about 700°F, will mix with the exhaust coming out of the air preheater (at about 300°F).

The loss in plant efficiency of this process is about 1% per 40°F increase on exiting gas temperature. To operate and to keep in reliable operating condition, such facilities would require about $10,000 per year in labor, equipment and parts.

The efficiency of the precipitators with respect to exiting gas temperature is nearly the same at 300°F and 550°F. However, in between those temperatures there is a significant drop in efficiency. There might be an increase in the maintenance cost on precipitators if these control actions are taken frequently.

The process of temperature modification requires the mobilization of 3 men, and the maximum effect could be reached at about one hour from the initiation of the order.

Keystone is a "go-no go" operation with ΔT_{max} not much higher than 50°F

Homer City has variable controls with a T_{max} from 550°F to possibly 600°F. After 1976 T_{max} will be about 400°F due to the addition of other equipment.

Conemaugh is like Homer City except that there are additional problems when the coal is wet in which case the T_{max} cannot go much higher than 350°F.

Seward has only the typical 15% bypass capability with $\Delta T_{max} \approx 50°F$.

Some of the other emission parameters can be calculated by methods presented in the LAPPES study, for example,

The stack gas exit velocity in ft per sec is calculated hourly from the following equation:

$$V = \frac{Tc}{3600\ A_s} \quad H_2O\left(\frac{359}{18}\right) + CO_2\left(\frac{359}{44}\right) + N_2\left(\frac{359}{28}\right) + SO_2\left(\frac{359}{64}\right) + A_e\left(\frac{359}{29}\right) \quad \frac{t_s + 460}{t_a + 460} \qquad \text{(A.3.1)}$$

where

T_c = hourly coal consumption in lbs per hr per unit.

A_s = stack area = 581.42 sq ft for Keystone.

t_s = hourly gas temperature leaving stack in °F.

t_a = hourly ambient temperature in °F.

460 = conversion to Rankine temperature scale.

3600 = sec per hr.

H_2O, CO_2, N_2 and SO_2 = series average in lbs per lb of coal as products of combustion.

A_e = series average excess air in lbs per lb of coal required for combustion.

Denominators in parentheses are molecular weights of respective gaseous constituents in whole grams per mole.

359 = conversion factor to British units calculated as follows:

$$\frac{22.414 \text{ liters/mole}}{28.317 \text{ liters ft}^3} \times 453.9 \text{ grams/lb} = 359 \frac{\text{grams ft}^3}{\text{lb mole}}$$

SO_2 emission from each unit in tons per hr is calculated hourly be means of this formula: (A.3.2)

$$SO_2 = \frac{T_c \times \% S \times 2}{2000}$$

where

T_c = hourly coal consumption in lbs per hr per unit.

% S = series average percent sulfur in fuel.

2 = parts sulfur per parts oxygen in SO_2.

2000 = lbs per ton.

The parameter, stack heat emission in Btu per sec, is computed from the following equation:

(A.3.3)

$$Q_h = \frac{T_c}{3600} \times \% DG \times HV \times \frac{(t_s - t_a)}{(t_g - t_a)}$$

where

T_c = hourly coal consumption in lbs per hr per unit.

% DG = hourly percent dry gas loss.

HV - series average heat value of fuel in Btu per lb.

t_s = hourly gas temperature leaving stack in °F.

t_g = hourly gas temperature leaving air heaters in °F.

t_a = hourly ambient temperature in °F.

Dispatch and Unit Commitment Schedulers

These schedulers are at the PJM interconnection headquarters. The system incremental costs are predicted 6 hours in advance and many of the scheduling decisions are made manually from lookup tables. For example, as the load demands come in there is a daily routine for those plants which should come on or go off. These are generally the next cheapest facilities, as shown on a lookup table (Table A.3.6). The economic dispatcher works within the plan given it by the unit commitment scheduler. The transmission losses are accounted for with predetermined "penalty factors" which are a measure of the distance to the load centers at any given time of day.

An automated unit commitment scheme which is being set up is shown in the block diagram, figure A.3.3.

For some simulations the most effective form of the "thermal files" is the "cost duration data" which is available monthly (Table A.3.7).

Maintenance Scheduling

Maintenance scheduling information on the four plants and the rest of the Penelec system is collected and tentatively scheduled by Penelec persons. Their criteria are:

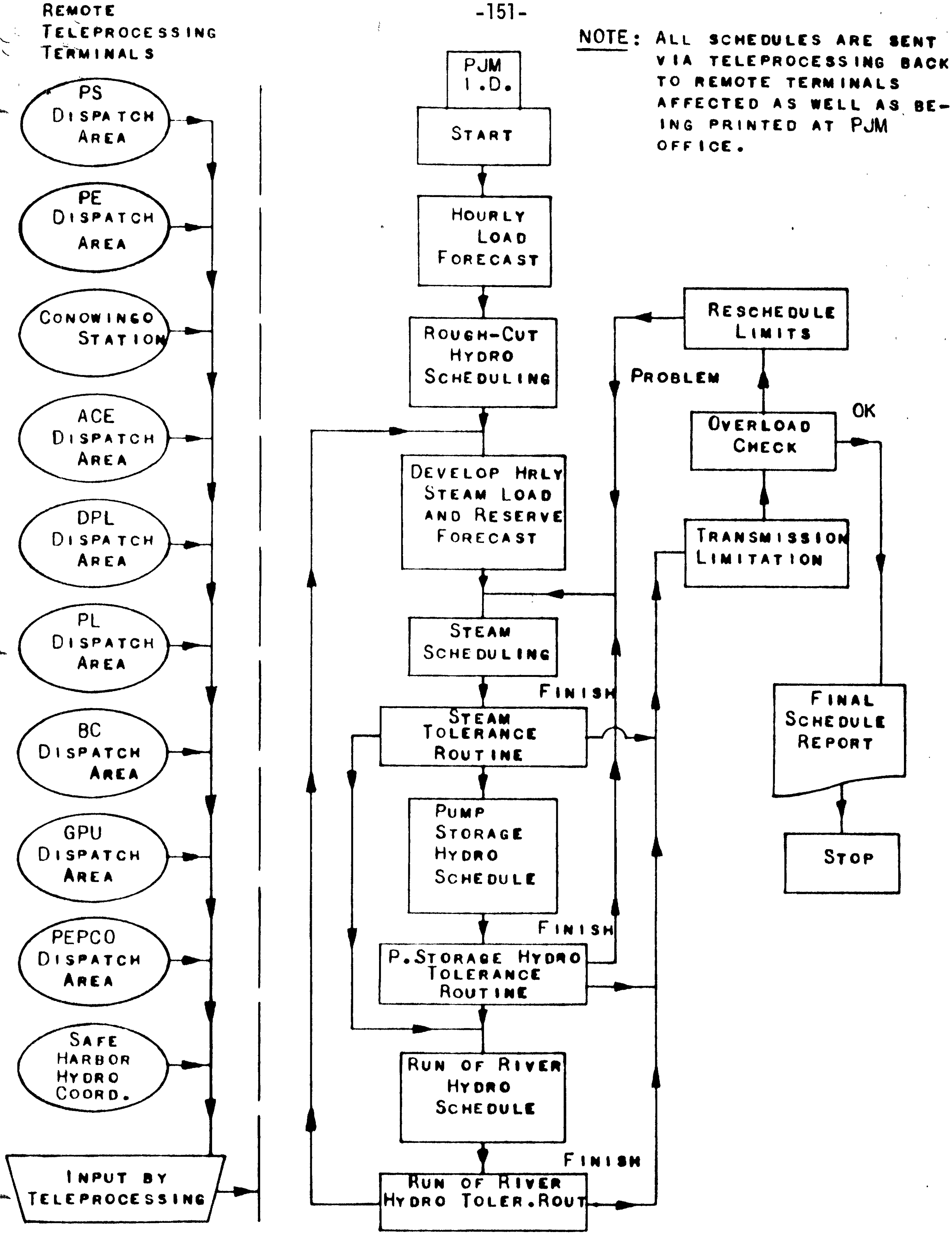
1. None (or very rarely, when equipment availability forces it) of the PJM plants are scheduled out from June 1 to September 15.
2. Because Penelec is winter peaking (vs. PJM which has a summer peak) and because parts movement and support services are impossible over holidays, maintenance is avoided as much as possible during the September 15 to January 1 period.

3. They schedule boiler maintenance every twelve months, -4 to +0 months from the plant supervisor's point of view and -1 to +6 months from the system supervisor's point of view. Long extensions are sometimes justified to skip the summer period (Shawville is scheduled for 15 months of operation, through 1975, for this purpose).
4. Turbine inspection is every 5 years +0, -1 year. Extensions are possible if equipment is unavailable (6 years on Shawville now).
5. Due to crew availability constraints, Penelec units should have minimum overlapping (although they have had as many as 3 out at one time).
6. Duration is (3,4,4,4) weeks and (6,8,8,8) weeks on (Seward, Keystone, Conemaugh, Homer City) for Boiler and Turbine sessions respectively.

The maintenance schedule now in force is given in Table A.3.8.

TABLE A.3.6 DISPATCH LEVELS VS. INCREMENTAL COST (λ) (FOR MOST EFFICIENT UNITS ONLY)

λ	SHAWVILLE 3 or 4	3 & 4	1 or 2	1 & 2	FRONT STREET #4	#5	2, 3 & 5	5 & 2 or 3	1, 2, 3 & 5	1, 2 & 3	5, 1 & 2 or 3	1 & 3	WILLIAMSBURG #5	HOMER CITY 1 or 2
Mn.	100	200	60	120	8	13	15	13	18	13	15	10	5	160
.1														210
.2													6	305 (5.5)
.6	135	270	100	200									8	350
.8	165	330	120	240										
.9	182	364											10	
.0			130	260									12 (6.1)	
.2			138	276									14 (6.3)	
.4													16	
.5			140	280									18 (6.6)	
.7			145	290									20 (6.8)	
.0													24	
.1	192	384											30 (7.3)	
.4	195	390							25 (8.9)					
.1											20		32 (9.4)	
.5	198	396											35 (9.6)	
.3											30			
.9								25				15 (10.0)		
0.1												20		
0.2							45			20				
0.3						20			70					
0.4								35				25		
0.5											40			
0.6						45		40						
0.8								50	75		45			
0.9	200	400								30		28		
1.0									90		70			
1.1							55							
1.2								55						
1.3										35				
1.4						50								
1.6											80			
1.7									97			30		



MASTER SCHEDULE PROGRAM

FIGURE A.3.3

TABLE A.3.7

PJM SYSTF

COST DURATION DATA

NTHLY REPORT APRIL 1974

	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH
PRIL	2	46.2	3	42.9	6	42.2	7	42.0	30	41.4	31	41.3	32	41.1
	33	40.9	34	40.7	36	40.4	37	39.7	38	39.0	40	38.6	41	38.3
	42	38.1	44	37.4	45	37.3	46	37.1	47	37.0	49	36.9	60	36.8
	64	36.3	67	36.1	68	35.9	76	35.8	78	35.7	87	35.5	89	35.4
	91	35.3	94	35.2	97	35.1	103	35.0	104	34.9	106	34.7	116	34.5
	118	34.4	119	34.3	121	34.2	122	34.1	126	34.0	127	33.9	130	33.8
	136	33.7	140	33.5	144	33.4	148	33.3	153	33.1	174	33.0	178	32.9
	183	32.8	186	32.7	192	32.5	198	32.4	203	32.3	206	32.2	209	32.1
	219	32.0	223	31.9	226	31.8	229	31.7	230	31.6	232	31.5	233	31.4
	238	31.3	240	31.2	241	31.1	242	31.0	246	30.9	250	30.8	251	30.7
	253	30.6	255	30.5	257	30.3	260	30.1	265	30.0	266	29.8	268	29.7
	270	29.6	272	29.5	274	29.4	275	29.3	278	29.1	281	28.9	285	28.8
	283	28.7	290	28.6	298	28.5	301	28.4	303	28.2	304	28.1	308	28.0
	314	27.9	319	27.8	320	27.7	326	27.6	332	27.5	335	27.4	341	27.3
	342	27.2	348	27.1	351	27.0	353	26.9	357	26.8	358	26.7	362	26.6
	364	26.5	367	26.4	368	26.3	370	26.2	375	26.1	379	26.0	381	25.9
	385	25.8	386	25.7	389	25.6	390	25.5	392	25.4	395	25.3	397	25.2
	399	25.1	400	25.0	403	24.9	408	24.8	411	24.7	413	24.6	419	24.5
	421	24.4	422	24.3	426	24.2	430	24.1	436	24.0	443	23.9	444	23.8
	447	23.7	452	23.6	460	23.5	462	23.4	467	23.3	472	23.2	475	23.1
	477	23.0	479	22.9	482	22.8	485	22.7	489	22.6	504	22.5	508	22.4
	516	22.3	521	22.2	528	22.1	546	22.0	555	21.9	559	21.8	563	21.7
	565	21.6	566	21.5	572	21.4	577	21.3	579	21.2	585	21.1	592	21.0
	593	20.9	595	20.8	599	20.7	603	20.6	612	20.5	618	20.4	622	20.3
	623	20.2	626	20.1	627	20.0	630	19.9	635	19.8	637	19.6	643	19.5
	646	19.4	648	19.3	651	19.1	654	19.0	657	18.9	659	18.8	661	18.7

TABLE A.3.7

PJM SYSTEM

COST DURATION DATA

MONTHLY REPORT

APRIL 1974

HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH	HRS	MILL/KWH
662	18.4	664	18.2	666	18.1	667	18.0	668	17.9	669	17.8	670	17.7
671	17.6	673	17.5	674	17.2	675	17.1	676	17.0	678	16.9	679	16.8
681	16.7	682	16.6	683	16.5	684	16.2	686	16.0	687	15.6	689	15.4
690	15.0	691	14.9	692	14.6	693	14.4	694	14.2	696	14.1	697	13.7
698	13.6	700	13.5	701	13.4	704	13.3	705	13.1	706	13.0	707	12.9
708	12.7	709	12.5	710	12.4	711	12.3	715	12.1	716	11.9	717	11.6
718	11.0	719	10.8	720	10.5								

AVERAGE MONTHLY COST 27.1

Revised 5-24-72

1973

DATE	KEY-STONE	CONE-MAUGH	HOMER CITY	SEWARD	SHAW-VILLE	SENECA
Jan. 1						
8		1				
15		1				
22		1				
29		1				
Feb. 5						
12	1					
19	1					
26	1				1	
Mar. 5	1				1	
12				3(1)	1	
19				3	2	
26				3	3	
Apr. 2				3	3	
9				3	3	
16				3	3	
23	2					1
30	2					1
May 7	2				4	2
14	2				4	2
21					4	3
28						
June 4						
11						
18						
25						
July 2						
9						
16						
23						
30						
Aug. 6						
13						
20						
27						
Sept. 3						
10						
17			2(4)			
24			2			
Oct. 1			2			
8			2			
15			2			
22			2			
29			2	5		
Nov. 5			2	5		
12			2	5		
19			2			
26						
Dec. 3						
10						
17						
24						
31						

1974

DATE	KEY-STONE	CONE-MAUGH	HOMER CITY	SEWARD	SHAW-VILLE	SENECA
Jan. 7						
14						
21						
28						
Feb. 4						
11						
18				14		
25		2	1(7,4)	14		
Mar. 4		2	1	14	2	
11	1(4)	2	1	12	2	
18	1	2	1	12	2	
25	1		1	12		
Apr. 1	1		1			
8	1		1			
15	1		1			
22	1		1			1
29	1		1			1
May 6	1		1			2
13	1		1		3(8)	2
20	1(5)		1		3	3
27	1		1		3	
June 3	1		1		3	
10	1		1		3	
17	1		1			
24			1			
July 1						
8						
15						
22						
29						
Aug. 5						
12						
19						
26						
Sept. 2	2(4)					
9	2					
16	2			5	4	
23	2			5	4	
30	2			5	4	
Oct. 7	2	1		5		
14	2	1				
21	2	1				
28	2	1				
Nov. 4	2					
11	2					
18	2					
25	2					
Dec. 2						
9						
16						
23						
30						

1975

DATE	KEY-STONE	CONE-MAUGH	HOMER CITY	SEWARD	SHAW-VILLE	SENECA
Jan. 6						
13					2(1)	
20					2	
27					2	
Feb. 3					2	
10					2	
17			2(7)		2	
24			2			
Mar. 3			2			
10			2			
17			2			
24			2			
31						
Apr. 7						
14		2				
21		2				1
28		2				1
May 5		2				2
12					3	2
19					3	3
26					3	
June 2						
9						
16						
23						
30						
July 7						
14						
21						
28						
Aug. 4						
11						
18						
25						
Sept. 1				4(9)		
8				4		
15	1			4	4	
22	1			4	4	
29	1			4-5	4	
Oct. 6	1			4-5		
13				4-5	1(1)	
20			1	4	1	
27			1	4	1	
Nov. 3			1	4	1	
10			1	4	1	
17				4	1	
24				4		
Dec. 1				4		
8				4		
15				4		
22				4		
29				4		

1976

DATE	KEY-STONE	CONE-MAUGH	HOMER CITY	SEWARD	SHAW-VILLE	SENECA
Jan. 5		1		4		
12		1		4	3(1)	
19		1		4	3	
26		1		4	3	
Feb. 2				4	3	
9	2			4	3	
16	2				3	
23	2					
Mar. 1	2					
8				12		
15				12		
22				12		
29						
Apr. 5						
12						
19			2			
26			2			1
May 3			2			1
10			2	14	2	2
17				14	2	2
24				14	2	3
31						
June 7						
14						
21						
28						
July 5						
12						
19						
26						
Aug. 2						
9						
16						
23						
30						
Sept. 6						
13		2(2)				
20		2				
27		2				
Oct. 4		2			4	
11		2			4	
18		2			4	
25			1			
Nov. 1	1		1	5		
8	1		1	5		
15	1		1	5		
22	1				1	
29					1	
Dec. 6					1	
13						
20						
27						

(1) Internal Inspection
(2) Internal Inspection of HP or LP Turbine-Generator Only
(3) Rewind Generator
(4) Repair Nozzle Block
(5) Economizer and Panel Tube
(6) Vibration Problems and Internal Inspection
(7) Economizer
(8) Superheater
(9) Replace Turbine Shell

TABLE A.3.8
PENELEC MAINTENANCE SCHEDULE

A.4 State Estimation LAPPES Test

The LAPPES data presented in this section represents the input data to be used for a test of the state estimation, static advection-diffusion model. It was decided to use LAPPES data for the following reasons: 1) it is publically available, validated data; 2) LAPPES included pilot balloon ascents which can be used to determine upper level wind characteristics for the grid of states (concentrations); 3) the LAPPES data could be sorted to find a day with good data capture and minimal terrain effects; 4) the model test could be prepared without waiting for an ERT data base to be established; 5) the LAPPES sensors are more dense with respect to a single plant than the Penelec system and can therefore provide more data in a short time period.

The LAPPES day chosen for the initial tests is May 1, 1970. (LAPPES Vol. 3). A Homer City study day was chosen to partly avoid the more complex terrain at Connemaugh and Seward, and partly because Penelec's interest in SCS is greatest at Homer City where SCS is considered to be a control measure which may help Homer City avoid violating standards between July, 1975 and the installation of flue gas cleaning equipment in 1976.

May 1, 1970 had good ground level coverage by the bubblers and the Jimmy Stewart Airport station saw the plume during a wind shift. The prevailing wind kept this plume in a sector between 10° and 40° and avoided the complications of plume travel over Chestnut Ridge or subsidence of winds as they come off the ridge.

GRID LAYOUT MAY 1, 1970 HOMER CITY UNITS

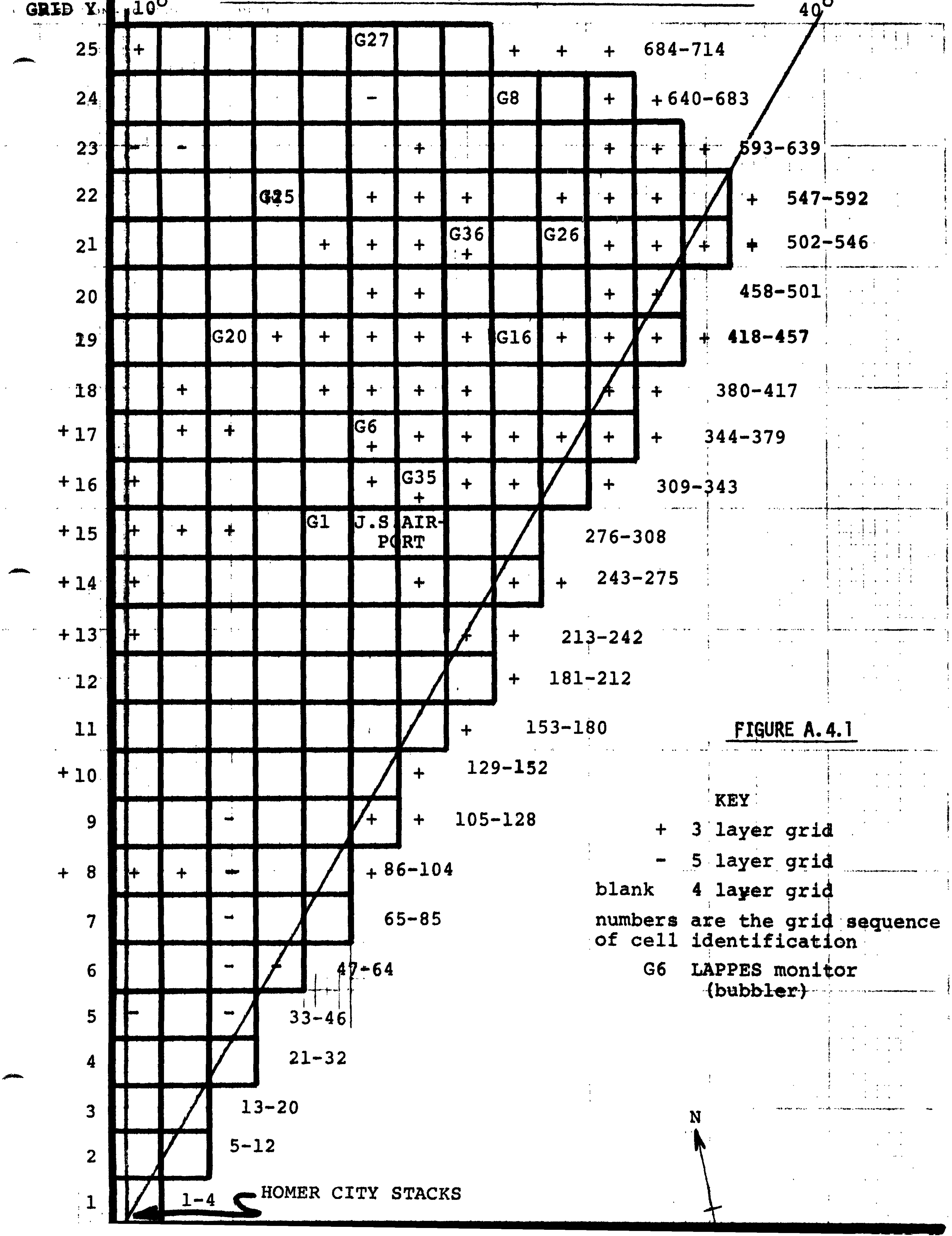
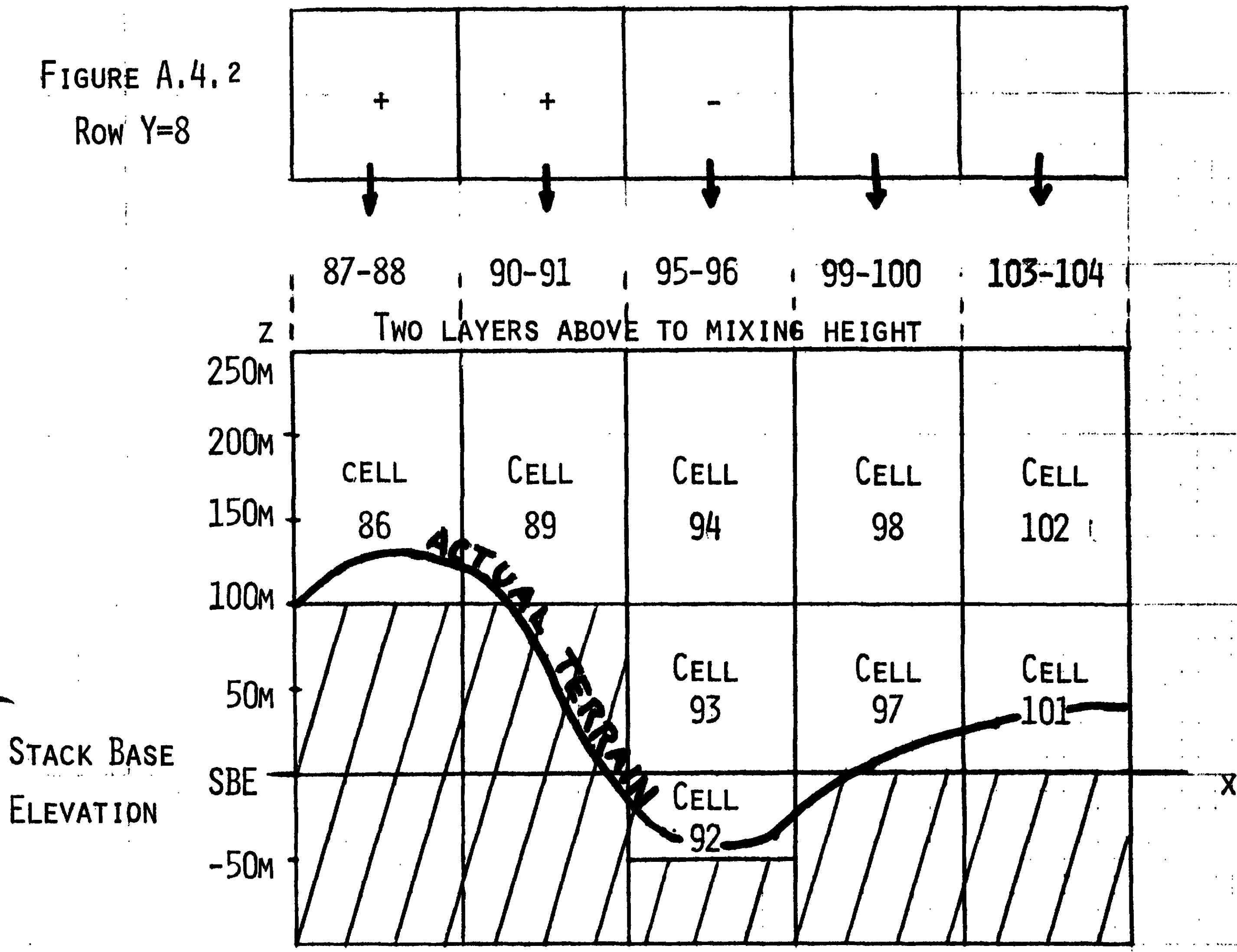


FIGURE A.4.1



CRITERION FOR RAISING OR LOWERING CELL BASE TO NEXT LAYER:
HIGHEST ELEVATION IN CELL ENTERS NEXT LAYER

FIGURE A.4.2

TABLE A.4.1

LAYER NAME	LAYER THICKNESS	LAYER ALTITUDE
BELOW SBE	50M	1000-1200 FT
SBE	100M	1200-1500 FT
2	150M	1500-2000 FT
3	250M	2000-2800 FT
4	L - 500M	2800- L FT

The first problem in establishing a test of the state estimation techniques is the assignment of states, i.e. the creation of a grid system in the region of interest near Homer City. The grid assignment reflects a standard approach to considering topography and mixing layer height, both of which appear as boundary conditions in the model. The horizontal grid spacing of 1 Km was chosen as a tradeoff between increasing complexity and storage costs during computer operation, and decreasing detail of representation. There are 191 ground level cells and 714 cells alltogether, covering the 25 Km radiais sector between 10° and 30° as shown in figure A.4.1. The vertical number of cells vary as shown in figure A.4.2 and table A.4.1.

Bubbler locations are shown in the grid and the raw bubbler average data is shown in Table A.4.2. Since state estimation assumes simultaneous observations occur the raw data must be "cleaned up" as in table A.4.3 A step function average was assumed during the observation period of the raw data.

Wind and concentration data from Jimmy Stewart Airport are shown in table A.4.4. The same step function assumption is made for the concentration averages to transform them to the .5 hr averaging period of the bubblers, as is shown in the last column of table A.4.3.

Wind data at Jimmy Stewart Airport is a true hourly average observation taken from strip chart recorders. The same step function assumption is applied to the data at the station to provide .5 hr averages. Pilot ballon ascents were made on the half hour at the Homer City plant as shown in table table A.4.5. Table A.4.6 shows radiosonde data which was used to

TABLE A.4.2

Raw Bubbler Data

Homer City Plume 1 May 1970

G-1 45 SBE GMQ 026/14.9		G-6 80 SBE AMQ 027/17.3		G-20 15 SBE DMQ 017/18.4		G-25 50 SBE BMQ 019/21.4		G-27 -25 SBE DMQ 021/24.7		G-8 -20 SBE DMQ 029/24.7		G-26 15 SBE DMQ 034/22.5		G-36 50 SBE DMQ 028/21.9		G-16 -5 SBE CMQ 035/20.3		G-35 55 SBE DMQ 034/16.5	
EST	pphm	EST	pphm	EST	pphm	EST	pphm	EST	pphm	EST	pphm	EST	pphm	EST	pphm	EST	pphm	EST	pphm
0751-21	0	0817-47	1	0828-58	1	0836-06	1	0847-17	1	0857-27	2	0908-38	2	0923-53	3	0931-01	4	0946-16	1
0821-51	3	0847-17	3	0858-28	0	0906-36	0	0917-47	2	0927-57	2	0938-08	1	0953-23	0	1001-31	1	1016-46	5
0851-21	3	0917-47	3	0928-58	0	0936-05	0	0947-17	0	0957-27	1	1008-38	0	1023-53	0	1031-01	4	1046-16	5
0921-51	0	0947-17	0	0958-28	0	1006-36	4	1017-47	0	1027-57	0	1038-08	0	1053-23	0	1101-31	4	1116-46	2
0951-21	0	1017-47	0	1028-58	0	1036-06	0	1047-17	0	1057-27	0	1108-38	2	1123-53	1	1131-01	4	1146-16	2
1021-51	0	1047-17	1	1058-28	0	1106-36	0	1117-47	0	1127-57	0	1138-08	4	1153-23	0	1201-31	0	1216-46	0

TABLE A4.3

Homer City Plume
Adjusted Bubbler Data

EST	G-1	G-6	G-20	G-25	G-27	G-8	G-26	G-36	G-16	G-35	JSA
0800-30	1	-	-	-	-	-	-	-	-	-	1
0830-00	3	2	1	1							1
0900-30	2	3	0	0	1	2	2				5
0930-00	0	2	0	0	0	2	1	2	4	3	5
1000-30	0	0	0	3	0	1	0	1	1	5	0
1030-00		1	0	1	0	0	0	0	4	5	0
1100-30		1	0	0	0	0	2	0	4	4	4
1130-00					0	0	4	1	4	2	4
1200-30								0	0	1	-

TABLE A.4.4

JIMMY STEWART AIRPORT DATA

1 May 1970

Time, EST	Dir, deg	Speed, mps	Temp, °C	RH, %	P, cm	SO_2, pphm Avg	SO_2, pphm Peak	Ly/min
0100	156	4.4	21.1	61		1	1	
0200	149	4.5	20.0	61		1	1	
0300	144	5.6	19.4	63		0	0	
0400	142	5.1	18.8	63		0	1	
0500	142	4.7	18.3	67		0	0	
0600	142	4.2	17.7	68		0	1	
0700	141	4.3	18.8	67		0	1	0.20
0800	160	4.2	21.1	58	0.08	1	1	0.45
0900	184	5.0	22.7	53	0.03	1	2	0.54
1000	209	6.1	24.4	50		5	11	0.74
1100	203	6.7	24.9	47		0	0	0.67
1200	204	6.5	26.1	48		4	8	1.03
1300	228	6.7	28.3	46		-	-	0.85
1400	214	6.6	28.3	46		-	-	0.85
1500	213	5.9	28.3	46		-	-	0.75
1600	222	7.0	28.8	45		-	-	0.56
1700	206	5.9	27.7	45		-	-	0.48
1800	209	5.8	26.6	47		0	1	0.18
1900	187	4.7	25.5	50		2	3	0.09
2000	214	3.6	22.2	59		1	2	
2100	192	2.1	21.1	63		2	4	
2200	155	2.6	21.1	55		2	3	
2300	150	3.0	20.5	59		1	1	
2400	175	1.3	20.0	64		2	2	
Day	186	4.2			0.11	1	11	443

TABLE A.4.5 - PILOT BALLOON DATA

Ascn H-3 1 May 70 0700 EST Double		Ascn H-4 1 May 70 0730 EST Single		Ascn H-5 1 May 70 0800 EST Combined		Ascn H-6 1 May 70 0830 EST Double		Ascn H-7 1 May 70 0900 EST Single		Ascn H-8 1 May 70 0930 EST Double		Ascn H-9 1 May 70 1000 EST Single		Ascn H-10 1 May 70 1030 EST Single		
D,deg	S,mps	D,deg	S,mps	D,deg	S,mps	D,deg	S,mps	D,deg	S,mps	D,deg	S,mps	D,deg	S,mps	D,deg	S,mps	Z, m
	0.0		0.0	310.0	6.2	225.0	1.7	265.0	1.3	235.0	3.5	235.0	10.2	235.0	7.1	Sfc
161.0	3.0	128.9	0.3	199.4	6.5	195.5	4.7	131.5	0.3	231.1	7.2	141.7	1.7	135.6	1.0	50
183.1	4.0	141.3	2.4	203.2	7.4	199.2	6.3	143.2	2.3	226.3	8.3	172.1	12.1	159.6	7.5	100
193.2	5.6	200.3	4.2	203.4	8.1	201.3	7.4	216.1	3.7	223.5	8.7	202.9	17.4	193.9	11.4	150
197.3	7.2	189.2	6.0	202.0	8.7	203.2	7.6	186.1	6.6	222.2	8.1	208.5	18.0	199.1	12.9	200
198.5	8.7	190.2	8.5	198.9	8.9	207.3	7.2	202.5	6.1	219.2	7.9	222.0	16.9	203.9	13.3	250
198.8	10.0	192.3	10.4	202.0	9.9	211.3	7.1	222.0	6.2	214.1	8.2	229.1	18.4	207.5	14.0	300
198.4	11.0	196.5	10.6	204.2	10.5	214.5	8.7	230.2	7.0	213.5	9.3	220.1	24.5	208.8	15.6	350
201.3	12.1	200.2	11.2	204.3	10.9	213.5	10.6	223.2	8.7	215.2	10.8	217.6	29.7	211.3	16.1	400
207.2	13.4	204.3	12.0	205.1	11.5	209.9	12.5	216.2	10.9	216.4	12.0	217.2	31.6	214.4	16.0	450
210.8	13.5	210.9	13.5	209.8	10.7	215.3	12.4	216.2	13.2	217.3	13.0	219.4	22.1	217.6	14.7	500
214.1	14.5	214.9	14.7	218.5	11.4	219.8	12.9	218.6	13.0	217.7	14.2	220.4	17.9	223.3	11.7	550
216.0	16.7	218.2	15.8	198.2	14.5	218.8	15.3	222.3	12.4	217.3	16.2	219.7	16.1	230.6	8.9	600
215.1	20.3	223.1	17.0	173.3	24.6	221.0	16.1	224.0	14.1	219.0	15.5	216.9	13.9	224.4	9.6	650
223.1	18.1	226.2	18.0	211.3	17.0	224.8	17.1	228.6	14.3	222.4	13.7	219.4	12.9	220.7	10.5	700
241.2	14.1	229.3	18.7	233.3	16.6	228.5	18.9	234.3	14.1	223.0	14.9	223.5	11.9	219.7	11.8	750
239.3	17.1	233.4	19.0	238.7	16.0	235.1	16.8	239.4	13.8	225.1	15.9	225.9	9.7	221.7	14.2	800
243.2	17.3	235.6	19.5	241.3	15.2	240.1	15.6	240.0	14.3	227.7	15.9	234.1	6.3	219.9	16.5	850
252.5	15.6	238.4	19.4	245.6	15.6			241.0	14.2	231.0	15.3	236.3	6.8	218.6	15.4	900
250.6	16.2	242.2	18.7	249.3	15.3			243.0	13.6	231.5	16.4	230.4	11.1	218.1	11.2	950
		246.9	17.5	252.2	14.4			243.2	12.4	233.4	16.2	226.7	15.9	225.2	8.2	1000
		250.1	16.5	251.1	13.9			242.0	12.1	237.3	13.9	226.9	16.2	231.7	6.4	1050
		253.4	15.6	248.2	14.5			240.4	11.8	242.1	11.5	227.1	16.2	230.9	6.7	1100
		258.4	14.7	246.8	15.0			239.5	11.1	240.0	12.2	225.0	20.3	222.1	10.5	1150
		258.5	14.3	247.6	15.0			237.8	11.9	238.1	12.8	228.7	15.3	227.0	10.0	1200
		256.7	13.8	251.3	13.8			239.0	12.0	236.6	13.3	234.5	13.6	228.0	12.6	1250
		253.1	13.3	248.7	14.2			243.2	11.5	239.6	10.6	238.1	16.1	226.5	18.7	1300
		248.2	14.4	245.7	15.0			245.7	11.8	249.0	4.9	241.3	19.0	231.2	24.6	1350
		245.9	13.5					246.6	11.9			244.5	18.3	232.7	28.1	1400
		244.7	12.3					246.8	12.0			247.5	16.8	233.1	29.8	1450

TABLE A.4.6

RADIOSONDE DATA

Ascn 243 1 May 1970 0503 EST

P,mb	Z, m	T,°C	Td,°C	H, m	D,deg	S,mps
1000	165					
970	428	19.1	13.1	Sfc	240	4.0
953	580	21.5	10.4	150	185	9.0
950	608	21.3	9.9	300	204	11.3
905	1026	18.4	6.6			
900	1073	18.6	7.1	500	195	7.2
884	1228	19.5	9.7	1000	226	15.4
850	1564	17.3	7.9	1500	236	16.2
819	1881	15.2	6.2	2000	230	10.0
800	2079	13.5	7.1	2500	207	12.3
777	2325	11.5	7.2	3000	208	14.6
750	2620	9.6	1.0			
733	2810	8.4	- 3.7			
700	3189	5.3	- 3.0			

Ascn 244 1 May 1970 1216 EST

P,mb	Z, m	T,°C	Td,°C	H, m	D,deg	S,mps
1000	154					
970	428	28.0	15.7	Sfc	250	7.6
950	612	26.0	12.8	150	250	6.9
922	874	23.5	9.1	300	234	8.8
900	1084	21.4	8.3			
855	1526	17.1	6.6	500	255	6.7
850	1576	16.6	6.4	1000	231	11.2
819	1891	13.1	6.2	1500	227	10.1
800	2088	12.2	6.9	2000	234	12.4
781	2290	11.3	7.2	2500	228	13.7
765	2462	9.4	3.4			
750	2627	8.1	2.1			
700	3193	4.5	- 1.0			

TABLE A.4.7

EST	SBE*		2		3		4		L
	D,deg,	S,mps	D,deg,	S,mps	D,deg,	S,mps	D,deg,	S,mps	m
0700-30	172	3.5	196	7.2	203	12.0	-	-	450
0730-00	135	1.4	193	6.2	201	11.5	-	-	500
0800-30	238	6.7	201	8.6	205	10.7	218	11.4	550
0830-00	207	4.2	204	7.4	213	10.3	219	14.1	600
0900-30	180	1.3	202	5.5	221	9.2	222	13.2	650
0930-00	231	6.3	222	8.2	215	10.7	219	14.9	700
1000-30	183	8.0	211	17.4	221	25.3	220	14.5	750
1030-00	177	5.2	199	12.5	212	15.3	223	11.1	800
1100-30	-	-	-	-	-	-	-	-	850
1130-00	-	-	-	-	-	-	-	-	900
1200-30	250	7.6	250	6.9	245	7.6	242	9.0	950
1230-00	-	-	-	-	-	-	-	-	1000

*Below SBE layer assumed to be identical to SBE layer.

establish the height of the mixing layer (L) at 500 EST (400 m) and 1230 EST (1100 m, calculated graphically from the 0500 sounding using the 1230 surface temperature). It is assumed that L grows linearly with time between these data points. The value of L under this assumption is then used to determine the grid size in the top layer. With a knowledge of pilot balloon behavior and all the grid sizes the wind behavior in each grid layer can be approximated by averaging the wind data through the depth of the layer and assuming it is representative of the next .5hr. These calculated mixing heights and grid layer wind speeds are shown in Table A.4.7. For a wind of V mps from Θ°. and a cartesian grid with + x at ϕ°, the components are given by:

$$u = V_x = - V \cos (\Theta - \phi)$$
$$v = V = V \sin (\Theta - \phi) \qquad (A.4.1)$$

Table A.4.8 presents the unit data at Homer City. The step function assumption also applies to this date yielding the.5hr average concentration and plume rise shown in Table A.4.9 (Briggs, 1965). Based on these plume rise figures, it is assumed that the plume is trapped in the upper grid cell layer when it reaches its equilibrium position.

TABLE A.4.8

Homer City Emission Data

Homer City Unit 1 1 May 1970

Time, EST	Load, mw	T, °C	DT, °C	Vel, mps	SO_2, g/sec	Cal/sec x 10^6
0400						
0500	470	150	128	17.1	2099	17.9
0600	468	150	128	17.1	2090	17.9
0700	465	149	127	16.9	2077	17.6
0800	470	150	127	17.1	2099	17.8
0900	476	150	127	17.4	2126	18.0
1000	483	151	127	17.6	2157	18.3
1100	484	151	127	17.7	2162	18.3
1200	484	151	126	17.7	2161	18.2
1300	484	151	126	17.7	2161	18.2
1400						
1500						
1600						
1700						

Homer City Unit 2 1 May 1970

Time, EST	Load, mw	T, °C	DT, °C	Vel, mps	SO_2, g/sec	Cal/sec x 10^6
0400						
0500	314	132	110	11.7	1492	10.9
0600	315	132	111	11.7	1497	11.0
0700	385	141	119	14.6	1830	14.5
0800	435	146	123	16.7	2067	17.0
0900	438	146	123	16.8	2081	17.0
1000	460	148	124	17.7	2186	18.0
1100	454	148	124	17.5	2157	17.8
1200	442	146	121	17.0	2100	16.9
1300	443	147	122	17.1	2105	17.1
1400						
1500						
1600						
1700						

TABLE A.4.9

Homer City Adjusted Emission Data

	SO_2 Unit 1	Δh	SO_2 Unit 2	Δh
0800-30	2126	896	2081	847
0830-00	2126	854	2081	806
0900-30	2157	1057	2186	1040
0930-00	2157	917	2186	902
1000-30	2162	1503	2157	1463
1030-00	2162	1026	2157	999
1100-30	2161	967	2100	898
1130-00	2161	967	2100	898
1200-30	2161	1593	2105	1498
1230-00	2161	1593	2105	1498