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THE DESIGN AND IMPLEMENTATION OF A DEMONSTRATION
SUPPLEMENTARY CONTROL SYSTEM
SECOND PROGRESS REPORT

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August 1, 1974 - May 31, 1975

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AT (11-1) - 2428

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ABSTRACT

A Supplementary Control System (SCS) for maintaining acceptable ambient air quality has been designed. The controlled pollutant is sulfur dioxide and the SCS design includes a real-time meteorology and air quality monitoring network, periodic weather forecasting, air quality modeling and a probabilistic control strategy. Four coal burning power plants (4800 MW) in the complex terrain near Chestnut Ridge in western Pennsylvania are controlled by the design, and control actions include fuel switching, load shifting and stack gas temperature modification. The design has been implemented and is beginning its field testing period. Nine months of field data have been collected by the monitoring system and several programs have been developed to sort and analyze the data. The 24 hour standard is threatened most frequently and the background influence of Pittsburgh and Johnstown can be significant.

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1.0 Introduction

The Second Progress Report is submitted as one of the requirements of contract AT(11-1)-2428. It briefly describes the scope of investigations undertaken and the significant results obtained during the period from August 1, 1974 to May 31, 1975. During the month of August, 1974, work on this contract continued under a no-cost extension to the Period 1 S.R.S.A., and during the period from September 1, 1974, to May 31, 1975, work was supported by a renewal of the contract. The Period 2 renewal expires August 31, 1975. The work described in this report is continuing and the project final report should be completed by March, 1976.

A supplementary Control System (SCS), as an environmental control technology that takes advantage of the atmosphere as a time-varying resource, can provide both environmental and economic benefit. SCS technology can provide 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 energy supply, and consumer savings.

SCS is an evolving technology that is based on a combination of several existing technologies. Its principal components are monitoring, forecasting and control, as shown in Figure 1.

Figure 1

SCS is now operating at a chemical plant in Midland, Michigan, at electric power plants in the T.V.A., and at smelters in El Paso, Texas, and Tacoma, Washington. These systems control smaller sources than the present project, the Chestnut Ridge SCS, and do not deal with separated but interacting controlled sources (although the other SCS do control multiple-stack configurations). Terrain effects and background concentrations from uncontrolled sources are more significant in the Chestnut Ridge SCS than elsewhere. The greatest differences lie in the probabilistic real-time nature of the Chestnut Ridge SCS, which gives explicit consideration to the economics of the interconnected power system while making control decisions. The design of the Chestnut Ridge SCS is intended to provide improved reliability of air quality maintenance, improved economics and reliability of the power system, increased objectivity of SCS operation and easier regulation by state and federal agencies. These improvements are accompanied by an increase in the complexity and sophistication of the three components of SCS and their interaction.

Figure 2

Chestnut Ridge Topography

Briefly, the object of this project is to design, implement and operate an SCS for the four Chestnut Ridge power plants operated by Penelec: Keystone (1640 MW), Homer City (1200 MW), Conemaugh (1700 MW) and Seward (217 MW). The plants, monitors and general terrain are shown in Figure 2. The operation of the SCS is intended to provide field information about air quality, reliability and economics so that the following technical objectives can be satisfied:

- 1) To demonstrate that an extensive, sophisticated real time monitoring system can be operated at a level of data capture and measurement accuracy sufficient for the needs of an SCS.
- 2) To demonstrate that air quality can be forecast accurately enough and far enough in advance to be useful in an SCS.
- 3) To demonstrate that a utility suitably prepared in advance can, in fact, switch fuel, increase stack temperature and/or shift load while under an SCS so that ambient air quality standards in the vicinity are not violated.
- 4) To demonstrate that the Control Decision Logic can protect air quality standards while meeting various criteria such as cost and reliability of power system operation.
- 5) To demonstrate that in the presence of uncertainties in monitoring data, forecasts of air quality, emissions and response time, an acceptable reliability can be proven for the operation of an SCS.
- 6) To establish that a method can be developed to provide sufficient information to the appropriate regulatory agencies so they can ensure satisfactory SCS performance.
- 7) To define the steps required to transfer SCS technology to other sites and plants.

Due to contractual delays in funding, both MIT and ERT found it necessary to postpone or reduce effort on certain tasks during the period of this report. The original schedule of work anticipated the completion of SCS design by November, 1974, and a demonstration

period of approximately eight months. The actual start of the demonstration phase occurred during May, 1975, with the initiation of Mock Control. An extension is being sought to continue the demonstration through December, 1975.

The remainder of this report consists of discussions of the status and significant results of each of the project's technical task areas. Thirteen task areas have been defined for the project:

MIT	ERT
01 Contract Management	09 Project Coordination
02 Control Simulation/Design	10 Model Application/System Design
03 Control Operation	11 Forecasting and AIRMAP
04 Demonstration AQ Forecasting	12 Model Application and Evaluation
05 Innovative AQ Forecasting	13 Final Report
06 Background Modeling	
07 Data Analysis/Tabulation	
08 Documentation	

Tasks 01 and 09 are non-technical tasks involving organizational duties, preparation of monthly reports, budget management, etc., and are not discussed in the remainder of this report.

Tasks 08 and 13 concern project documentation. To date three documents have been prepared under this contract:

Ruane, M.F., Gruhl, J., Schweppe, F., Greene, B., and Egan, B., "Technical Progress Report on the Design and Implementation of a Demonstration Supplementary Control System," AEC Document No. C00-2428-1, June 10, 1974.

Ruane, M.F., Gruhl, J., Schweppe, F., Greene, B., and Egan, B., "Interim Final Report on the Design and Implementation of a Demonstration Supplementary Control System," AEC Document No. C00-2428-2, September 4, 1974.

Ruane, M.F., Gruhl, J., Schweppe, F., Egan, B.A., Fyock, D.H. and Slowik, A.A., "Supplementary Control Systems -- A Demonstration," MIT-EL-75-001-P, AEC Document No. C00-2428-3, to

to presented at IEEE Power Engineering Society Summer Meeting, San Francisco, California, July 23, 1975.

Other documentation has included the draft documentation of data management systems and models for air quality and control decision logic. At present the documentation is intended for internal use only, although Pennsylvania Electric has requested and received recent versions of the data management programs for use at their own facilities. Further discussions of tasks 08 and 13 concerning project documentation will not be included in the remainder of this report.

The Principal Investigator, Professor Fred C. Schweppe, has devoted approximately 40% of his effort to this project from August 1, 1974 to May 31, 1975. During the remaining three months of this current term, he is expected to devote approximately 14% of his effort.

In anticipation of an extension being granted through February, 1976, to allow a continuation of the demonstration period, three changes are being made in the workplan of the remaining three months in the current term. First, the general level of effort on this project is being reduced from the original levels projected for the three month period. This is primarily being accomplished by delaying some data tabulation and analysis work and by eliminating the innovative air quality modeling effort. This will result in an increased emphasis on the demonstration effort and also serves to conserve contract funds so as to minimize the added support required in the new period. Second, the month of concentrated analysis effort

originally scheduled for July will be postponed to January. This effort is intended to analyse the demonstration period data and is best done on the whole demonstration period data base. Third, and finally, the documentation period for the writing of the final report will be delayed from August to February.

The approximate total reduction of effort is 25% during the June to August period. Since some additional SCS operation is now planned in this period (originally the demonstration was to stop in July), the 25% reduction includes a greater than 25% reduction in the original tasks and some replacement with demonstration tasks. It should be emphasized that this reduction is only a delay of effort and not the elimination of effort. The one exception is discussed in task 05, Innovative AQ Forecasting.

2.0 Task Status and Significant Results

This section summarizes tasks 02 to 07 and 10 to 12. For each task, the task title and a description of the work to have been performed in the task in the periods to date are given.

2.1 Task 02 "Control Simulation/Design"

Design a Control Strategy Model incorporating air quality forecasts, power system costs and constraints, and the uncertainties involved. Test design on power system data. Incorporate ERT air quality model into Control Strategy Model to test control efficacy.

A Control Strategy Model has been designed using the mathematical structure described in the technical publication "Supplementary Control Systems - A Demonstration," by Ruane, et al. The model determines the type, timing and amount of control action required in order to reduce the probability of exceeding standards to an acceptable level. Its linear

programming formulation allows constraints on total generation and the types of control allowed, while minimizing an objective function which includes control costs, replacement power costs and reserve credits.

The Control Strategy Model requires the same meteorological inputs as the air quality forecasting model, but has a slightly different grid spacing system. The seventeen monitor locations are explicitly included. The Control Strategy Model also requires unit commitment, system lambda (replacement power costs) and reserve credit predictions.

The basic Control Strategy Model design can be applied to any power system. The design has been installed as a FORTRAN IV program on the MIT Information Processing Center IBM 370/85 system and can be used in both batch and time-sharing modes. The program has been written specifically for the Chestnut Ridge SCS and includes the Chestnut Ridge terrain and plant characteristics as part of the code. Therefore the program cannot be applied to other systems without modifications.

The Control Strategy Model includes two major functions: air quality modeling and control strategy formulation. Tabela Ia, Ib, Ic and Id are samples of the Control Strategy Model control options report form showing the two major functions. Rather than choose the single "best" control strategy, the model formulates alternate strategies based on different probabilities of violation and different control actions.

Table Ia lists the description of expected violations (lines 2.), unit commitment schedules (lines 3.), and power system costs (lines 4. and 5.). Control action costs are internal to the program. The first

SUPPLEMENTARY CONTROL SYSTEM DEMONSTRATION PROJECT

1. DATE: 4/03/75 PREDICTIONS OF SO CONCENTRATIONS AS OF 13*18*50(TIME)

PREDICTED PLACES AND PROBABILITIES OF EXCEEDING STANDARDS:

	DATE	BEGIN	STAND.	EXP.AVE	BACKGC	EST.PROB	LOCATION (UTM)	
	TIME			CONC(PPM)	(PPM)	CF VIOL	KM EAST	KM NORTH
2.	9/12	3:00	3HR.	0.510	0.120	0.5432	664.70	4457.20
2.	9/12	4:00	3HR.	0.650	0.100	0.9970	662.30	4459.00
2.	9/12	6:00	3HR.	0.470	0.080	0.3672	660.90	4455.10
2.	9/12	7:00	1HR.	0.270	0.240	0.0094	658.00	4455.80

BASED ON THE FOLLOWING ASSUMPTIONS OF PLANT OPERATING LEVELS(MW):

(MINUS SIGNS INDICATE SOURCES NOT CONTRIBUTING TO CONC. MODES)

	DATE	TIME	KEY-1	KEY-2	HMC-1	HMC-2	CCN-1	CCN-2	SEW34	SEW-5
3.	9/12	3:00	--0.	--80.	--0.	-695.	--0.	590.	--50.	--0.
3.	9/12	4:00	--0.	--87.	--0.	-695.	--0.	600.	--50.	--0.
3.	9/12	5:00	--0.	--94.	--0.	-695.	--0.	610.	--50.	--0.
3.	9/12	6:00	--0.	--94.	--0.	-695.	--0.	620.	150.	--0.
3.	9/12	7:00	--0.	100.	--0.	-695.	--0.	620.	-145.	--0.
3.	9/12	8:00	--0.	-100.	--0.	700.	--0.	-620.	-145.	--0.

ASSUMING (IN MILLS/KWHR OR \$/MWHR):

4.	SYSTEM LAMBDA	21.	AT 3:00;	22.	AT 4:00;	24.	AT 5:00;	25.	AT 6:00;
4.	SYSTEM LAMBDA	25.	AT 7:00;	27.	AT 8:00;				
5.	RESERVE CREDIT	3.	AT 3:00;	3.	AT 4:00;	3.	AT 5:00;	3.	AT 6:00;
5.	RESERVE CREDIT	3.	AT 7:00;	3.	AT 8:00;				

1. STRATEGIES 1 AIMING AT PROBABILITY OF VIOLATION OF 10.50001

L=LOAD SHIFTING, F=FUEL SWITCHING, S=STACK GAS TEMP MODIF

CONTROL TYPE	PLANT	% OF FULL CONTROL	HR.	INITIALS: MAX AVE CONC	STAND.	EST PROB OF VIOL.	CONTROL COST
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6. ESTIMATED LEAST COST COMBINATION:

S	CCN-2	100%	4:00		0.490	3HR.	0.4546	
S	CCN-2	100%	5:00		0.500	3HR.	0.5000	
S	CCN-2	100%	6:00		0.464	3HR.	0.3427	
L	SEW34	99%	4:00		0.270	1HR.	0.0094	\$ 1540.
F	SEW34	1%	4:00					
S	SEW34	1%	4:00					
L	SEW34	100%	5:00					

7. (L) LOAD SHIFTING ONLY:

L	CCN-2	21%	4:00		0.480	3HR.	0.4114	
L	SEW34	100%	4:00		0.500	3HR.	0.5000	
L	SEW34	100%	5:00		0.470	3HR.	0.3672	
					0.270	1HR.	0.0094	\$ 3140.

Table 1a

8. (F) FUEL SWITCHING ONLY:

F	CCN-2	91%	5:00		0.430	3HR.	0.2041	
F	SEW34	100%	4:00		0.500	3HR.	0.5000	
F	SEW34	100%	5:00		0.470	3HR.	0.3672	
					0.270	1HR.	0.0094	\$ 1840.

9. (S) STACK GAS TEMP MODIFICATION ONLY:

S	CCN-2	100%	4:00		0.490	3HR.	0.4546	
S	CCN-2	100%	5:00		0.611	3HR.	0.9827	
S	CCN-2	100%	6:00		0.464	3HR.	0.3427	
S	SEW34	100%	4:00		0.270	1HR.	0.0094	\$ 400.
S	SEW34	100%	5:00					

1. STRATEGIES 1 AIMING AT PROBABILITY OF VIOLATION OF 10.20001
L=LOAD SHIFTING, F=FUEL SWITCHING, S=STACK GAS TEMP MODIF

CONTROL TYPE	PLANT	% OF FULL CONTROL	HR.	INITIALS: MAX AVE CONC	STAND.	EST PROB OF VIOL.	CONTROL COST
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6. ESTIMATED LEAST COST COMBINATION:

S	CCN-2	100%	4:00		0.429	3HR.	0.2000	
F	CCN-2	79%	5:00		0.461	3HR.	0.2000	
S	CCN-2	21%	5:00		0.429	3HR.	0.2000	
F	CCN-2	34%	6:00		0.270	1HR.	0.0094	\$ 2610.
S	CCN-2	66%	6:00					
F	SEW34	100%	4:00					
S	SEW34	100%	4:00					
F	SEW34	100%	5:00					
S	SEW34	100%	5:00					
F	SEW34	22%	6:00					
S	SEW34	78%	6:00					

7. (L) LOAD SHIFTING ONLY:

L	CCN-2	58%	4:00		0.429	3HR.	0.2000	
L	SEW34	75%	4:00		0.461	3HR.	0.2000	
L	SEW34	100%	5:00		0.429	3HR.	0.2000	
L	SEW34	34%	6:00		0.270	1HR.	0.0094	\$ 7060.

8. (F) FUEL SWITCHING ONLY:

F	CCN-2	93%	5:00		0.429	3HR.	0.2000	
F	CCN-2	46%	6:00		0.461	3HR.	0.2000	
F	SEW34	100%	4:00		0.429	3HR.	0.2000	
F	SEW34	100%	5:00		0.270	1HR.	0.0094	\$ 2750.
F	SEW34	28%	6:00					

9. (S) STACK GAS TEMP MODIFICATION ONLY:

S	CCN-2	100%	3:00		0.483	3HR.	0.4234	
S	CCN-2	100%	4:00		0.611	3HR.	0.9827	
S	CCN-2	100%	5:00		0.443	3HR.	0.2522	
S	CCN-2	100%	6:00		0.270	1HR.	0.0094	\$ 820.
S	SEW34	100%	4:00					
S	SEW34	100%	5:00					
S	CCN-2	100%	7:00					
S	HMC-2	100%	8:00					
S	SEW34	100%	6:00					

SUBSTRATEGIES 1 AIMING AT PROBABILITY OF VIOLATION OF 10.10001
 L=LOAD SHIFTING, F=FUEL SWITCHING, S=STACK GAS TEMP MODIF

CONTROL TYPE	PLANT	% OF FULL CONTROL	HR.	TOTALS: MAX AVE CONC	STAND.	EST PROB OF VIOL.	CONTROL COST
6. ESTIMATED LEAST COST COMBINATION:							
F	CCN-2	23%	4:00	0.396	3HR.	0.1000	
S	CCN-2	77%	4:00	0.443	3HR.	0.1000	
F	CCN-2	100%	5:00	0.396	3HR.	0.1000	
F	CCN-2	14%	6:00	0.270	1HR.	0.0094	\$ 3410.
S	CCN-2	86%	6:00				
F	SEW34	100%	4:00				
S	SEW34	100%	4:00				
F	SEW34	100%	5:00				
S	SEW34	100%	5:00				
F	SEW34	88%	6:00				
S	SEW34	12%	6:00				
7. (L) LOAD SHIFTING ONLY:							
L	CCN-2	82%	4:00	0.396	3HR.	0.1000	
L	SEW34	47%	4:00	0.443	3HR.	0.1000	
L	SEW34	100%	5:00	0.396	3HR.	0.1000	
L	SEW34	62%	6:00	0.270	1HR.	0.0094	\$ 9630.
8. (F) FUEL SWITCHING ONLY:							
F	CCN-2	33%	4:00	0.396	3HR.	0.1000	
F	CCN-2	100%	5:00	0.443	3HR.	0.1000	
F	CCN-2	29%	6:00	0.396	3HR.	0.1000	
F	SEW34	100%	4:00	0.270	1HR.	0.0094	\$ 3510.
F	SEW34	100%	5:00				
F	SEW34	87%	6:00				
9. (S) STACK GAS TEMP MODIFICATION ONLY:							
S	CCN-2	100%	3:00	0.483	3HR.	0.4234	
S	CCN-2	100%	4:00	0.611	3HR.	0.9827	
S	CCN-2	100%	5:00	0.443	3HR.	0.2522	
S	CCN-2	100%	6:00	0.270	1HR.	0.0094	\$ 820.
S	SEW34	100%	4:00				
S	SEW34	100%	5:00				
S	CCN-2	100%	7:00				
S	HMC-2	100%	8:00				
S	SEW34	100%	6:00				

Table Ic

STRATEGIES 1 AIMING AT PROBABILITY OF VIOLATION OF 10.00301

L=LOAD SHIFTING, F=FUEL SWITCHING, S=STACK GAS TEMP MODIF

CONTROL TYPE	PLANT	% OF FULL CONTRCL	HR.	ICIALS: MAX AVE CONC	STAND.	EST. PROB. OF VIOL.	CONTROL COST
6. ESTIMATED LEAST COST COMBINATION:							
F	CCN-2	44%	3:00	0.303	3HR.	0.0030	
S	CCN-2	56%	3:00	0.385	3HR.	0.0030	
F	CCN-2	100%	4:00	0.303	3HR.	0.0030	
S	CCN-2	100%	4:00	0.243	1HR.	0.0030	\$ 8450.
F	CCN-2	100%	5:00				
S	CCN-2	100%	5:00				
F	CCN-2	47%	6:00				
S	CCN-2	53%	6:00				
S	SEW34	100%	4:00				
F	SEW34	100%	5:00				
F	HMC-2	82%	8:00				
S	HMC-2	18%	8:00				
F	SEW34	100%	6:00				
S	SEW34	100%	6:00				
L	KEY-2	73%	7:00				
F	KEY-2	27%	7:00				
S	KEY-2	27%	7:00				
7. (L) LOAD SHIFTING ONLY:							
L	CCN-2	100%	4:00	0.303	3HR.	0.0030	
L	CCN-2	45%	5:00	0.385	3HR.	0.0030	
L	SEW34	83%	5:00	0.303	3HR.	0.0030	
L	HMC-2	34%	8:00	0.243	1HR.	0.0030	\$ 22810.
L	SEW34	100%	6:00				
L	KEY-2	89%	7:00				
8. (F) FUEL SWITCHING ONLY:							
F	CCN-2	65%	3:00	0.303	3HR.	0.0030	
F	CCN-2	100%	4:00	0.385	3HR.	0.0030	
F	CCN-2	100%	5:00	0.303	3HR.	0.0030	
F	CCN-2	68%	6:00	0.252	1HR.	0.0046	\$ 7420.
F	SEW34	100%	5:00				
F	HMC-2	80%	8:00				
F	SEW34	100%	6:00				
F	KEY-2	100%	7:00				
9. (S) STACK GAS TEMP MODIFICATION ONLY:							
S	CCN-2	100%	3:00	0.483	3HR.	0.4234	
S	CCN-2	100%	4:00	0.611	3HR.	0.9827	
S	CCN-2	100%	5:00	0.443	3HR.	0.2522	
S	CCN-2	100%	6:00	0.268	1HR.	0.0087	\$ 840.
S	SEW34	100%	4:00				
S	SEW34	100%	5:00				
S	CCN-2	100%	7:00				
S	HMC-2	100%	8:00				
S	SEW34	100%	6:00				
S	KEY-2	100%	7:00				

probability of violation level is 0.5. For that probability constraint the Control Strategy Model determines the least cost strategy, which may use a combination of several control actions simultaneously. Single control action strategies are then determined for the same probability constraint. For each strategy the cost of control, the maximum average concentration expected with control and the probability of violation are listed. For some control actions no feasible strategy exists which will protect standards. The above process is repeated for several levels of probability in the rest of Table I.

It is anticipated that only minor adjustments will be required in the Control Strategy Model during the remainder of this project.

2.2 Task 03 "Control Operation"

Daily operation of control related activities in support of Control Strategy Model, including communication and computer facilities used during the demonstration period. Preparation of control procedures for the operational demonstration period.

The bulk of the work associated with this task remains to be done during the operational period of the demonstration. The Control Strategy Model, which has been installed on the MIT computer facility in a time-sharing mode, is available to the ERT forecasters through a remote teletype terminal. The time-sharing system is down daily from six to eight a.m. for maintenance but this is not expected to cause serious difficulties since violations will be forecast and control strategies determined on a 30-hr look-ahead basis, and the down-time of the facility can be avoided. The alternatives to the two hour down-time are to invest in a round-the-clock computer terminal or to try to install the control model on the ERT computer. Both would be prohibitively expensive.

When the forecasters expect a violation the control model is used to produce a control options report as described in section 2.1. If significant changes in power system data have occurred since the forecast data was prepared, the forecasters can run the Control Strategy Model a second time.

The power plants will then implement the chosen controls and report back to ERT and MIT the actions taken. The element of choice involved stems from the development of different control options with different costs and reliabilities and from the responsibility of the plant dispatchers and operations to determine what controls, if any, will be implemented. There is no enforcement power involved which could require control compliance.

2.3 Task 04 "Demonstration Air Quality Forecasting"

Provide assistance to ERT in the adaptation of the air quality model to the Chestnut Ridge region. Coordinate forecasting procedures to facilitate later analysis tasks requiring air quality forecasting information.

This task has been supportive of the ERT effort of model adaptation for operational air quality forecasting. Because the full air quality model was considered to be too slow and cumbersome for direct incorporation into the MIT Control Strategy Model structure, a less detailed but faster version was installed at MIT. The faster version at MIT has been used for testing modeling assumptions without permanently altering the code at ERT. This cooperation also is being used to develop statistics for the analysis of air quality forecasting accuracy, since direct interface with the master data file is possible at MIT, making it straightforward to compare forecasts and observations.

As satisfactory modeling assumptions have been developed, they have been incorporated in the air quality model.

The operation of air quality forecasting within the MIT Control Strategy Model also serves as a check on the operational forecasts whenever violations are predicted. No control action would be undertaken unless violations were forecast with both versions of the air quality model.

Under this task MIT has also helped define the forecasting procedures to be used in the operational period so as to make control strategy determination and the final analysis tasks simpler. For example, the forecasters normally predict air quality based on the daily projected plant unit commitment schedule. If a violation is forecast, the control version is run for comparison and to determine the controls required. At that point the plant operators are contacted to check that the plants actually followed the planned unit commitment schedule. This procedure minimizes communication needs, the possibility of "false alarms" being given, and the number of air quality forecasts required under normal operation.

2.4 Task 05 "Innovative Air Quality Forecasting"

Design steady state dispersion models based on previous dynamic state estimation for air quality. Include terrain, probabilistic wind and stability fields and emissions. Incorporate model in general purpose estimator GPSIE and test using Chestnut Ridge data. Compare with plume models being used.

This task is no longer being pursued for two reasons. First, background concentration analysis and modeling became significant needs after early AIRMAP data was collected. It was decided that the effort originally planned for Innovative Air Quality Forecasting would provide more support to the demonstration's success if it were redirected to background problems. Second, the task ran into several technical problems which indicated that a larger effort than anticipated would be

required in order to obtain the intended results. The technical approach and problems will now be discussed.

Earlier work at MIT had indicated that state estimation techniques could be used to forecast the dynamic dispersion of atmospheric pollutants, using a prognostic equation statement of conservation of mass:

$$\frac{\partial C}{\partial t} = -\underline{V} \cdot \nabla C + \nabla \cdot \underline{K} \nabla C + \underline{Q}$$

Equation 1

Our approach was to assume this equation reached steady state ($\frac{\partial C}{\partial t} = 0$) to yield the static advection diffusion equation:

$$0 = -\underline{V} \cdot \nabla C + \nabla \cdot \underline{K} \nabla C + \underline{Q}$$

Equation 2

This would provide a measure of average concentrations over a time period as determined by the averaging period of the meteorological inputs used to determine the value of $\underline{V}$ and $\underline{K}$, and the emissions $\underline{Q}$. Our approach was to follow five steps:

- 1) develop a model incorporating meteorological and emissions data into Eq. 2.
- 2) test the model against the Gaussian plume model.
- 3) incorporate the model into GPSIE, a general purpose state estimator.
- 4) process AIRMAP data with GPSIE in an offline mode.
- 5) apply the model operationally to the Chestnut Ridge system.

Only steps 1 and 2 were attempted, as good agreement with Gaussian behavior was not obtained with our models. The difficulties arose in an attempt to represent Eq. 2 by finite difference techniques. This was desirable in order to solve Eq. 2 for the large region at Chestnut Ridge [roughly 2000 km²] with a reasonable level of detail. Finite difference would allow Eq. 2 to be readily expressed in the form:

$$\underline{A} \underline{C} = \underline{b}$$

Equation 3

which can be solved with sparse matrix techniques. Realizing that dimensionality would be a problem, it was decided to develop and test the finite difference model using only one sector around the Homer City plant. A test day was identified in the LAPPES study having good field observations and fairly high concentrations. A 1 km² grid was defined, with representative terrain in a 15°, 25 km radius sector. The grid was five layers deep and had 714 cells after terrain was represented. Wind

and diffusion constant fields were defined, along with emissions, as model inputs. Outputs were the concentration in each cell.

The inputs to the finite difference model were assigned values corresponding to the assumptions of the Gaussian plume and the outputs of the two models were compared. For this data, the Gaussian plume was an analytic solution of Eq. 2.

General qualitative agreement was good. A Gaussian crosswind decay was observed in the finite difference model, concentrations varied correctly in the downwind direction (rise, peak, slow decay with distance downwind) and as wind speed, stability, or emissions

were varied, the correct qualitative behavior occurred.

However, closer numerical comparison showed errors with spatial periodicity which could result in the propagation of negative concentrations through the finite difference grid. The error existed throughout the grid but was more apparent away from the centerline since the error varied more slowly than the true concentrations and was an order of magnitude or more smaller than the peaks. On the centerline the error was observed as a ripple on the otherwise smooth decaying distribution while on the tails of the Gaussian crosswind distribution the error drove predictions negative. This is both physically and numerically unacceptable, and several attempts were made to eliminate the error.

Since the error arose principally from the finite difference approximation error in the gradient terms, different differencing techniques were tried, including both backward and centered differences. Since the highest order error is a pseudo-diffusive phenomenon, a pseudo-diffusion constant K' was used to replace K in Eq. 2. The pseudo-diffusive coefficient is chosen so that the sum of K' and the analytically identified pseudo-diffusive errors in the gradient approximation equals the desired coefficient K . This approach was tried to avoid the boundary condition problem at the downwind boundary, caused by a systematic application of centered differences.

As these problems arose the 714 cell grid was abandoned for a simpler, flat-earth 100 cell grid ($5 \times 5 \times 4$) which was chosen as the smallest three-dimensional grid which could exhibit all of the symmetry

and error patterns desired. With this grid the sensitivity of the errors to grid spacing was tested. It was found that the error could not be eliminated by using any reasonable assumptions on grid size. Going to a 250m x 250m grid would raise the number of cells needed for all of the Chestnut Ridge region to over 50,000. A 50,000 by 50,000 matrix, even with the less than 1% fill-in seen with the finite difference formulation, is beyond the storage capacity of most computers and certainly is not practical for an SCS real-time operation.

At this point it was decided that two options existed: use a higher order difference scheme or moment reconstruction techniques to solve Eq. 2; or use a different dispersion model altogether. Since both efforts would have required essentially starting over completely and since background modeling had increased in importance, it was decided to halt this task during this project.

None of our results indicate that the basic idea of applying state estimation to air quality forecasting is unsound. They do indicate that numerical modeling problems are a major obstacle to such an approach and must receive more attention.

2.5 Task 06 "Background Modeling"

Analyze monitor data to establish significance of background concentrations. Identify meteorological conditions and monitors which require background models. Develop a predictive model for significant background cases.

An interim background model is being used for operational forecasts while further analyses of the background conditions continue. Initially it was believed that with nearly 50 Km separation from Pittsburgh there would be no significant background influence. A second reason for believing that to be the case was that the total hourly maximum

emissions of the Chestnut Ridge power plants is several times the emissions of Allegheny County.

AIRMAP data however has indicated that on certain days there is a region wide increase in concentrations. The rise in concentrations often occurs first at the higher elevation monitors, leading us to believe that a distant source is producing an elevated plume which down-washes as solar insolation causes the unstable layer to mix upwards during the day.

A second phenomenon is observed concerning the wind sector averaged concentrations at certain monitors. The sector averages indicate a strong influence in sectors for which no power plant influence is expected, leading to the conclusion that background is significant.

These issues are important because the pattern of high background concentrations seems to be persistent enough to affect the 24 hour averages at some monitors and threaten violations. The plants themselves, especially with their tall stacks, appear to influence monitors sporadically as the narrowness of the plume and natural variability of the wind combine to "sweep" the plume over any given monitor so as to produce only a few hours of high concentrations. The greatest threat to standards would then appear to occur when a period of high background coincides with a plume persisting at one location for several hours. If the location has a monitor, AIRMAP will record the violation or near-violation. But since we know that a plume of a certain strength is touching down someplace during a period of high background, we can also forecast unobserved violations. One key to such a forecast is to

accurately predict the background.

The present model has three point sources whose total emission rate equals that of Allegheny County. The sources are located to the north, west and south of Pittsburgh near known large point sources. The patterns of background behavior are being studied to answer three questions.

First, what stations exhibit background influences strong enough to necessitate inclusion in forecasting? Some monitors, because of location and terrain, are more likely to see background contributions that are high.

Second, what meteorological and other data accompany these high background contributions? We already know the directional influence of winds from Pittsburgh and Johnstown. Other factors will improve the forecasting accuracy of future background conditions.

Third, how do the meteorological and other data and observed concentrations elsewhere on AIRMAP relate to the magnitude of the background concentrations? The answers to these questions will allow us to predict when background is high, which stations are affected and what the concentrations will be. The present point sources are a reasonable, conservative attempt to include these effects, but could be improved.

2.6 Task 07 "Data Tabulation and Analysis"

Maintain master data file of all project data. Develop tools to manipulate and analyze data. Perform analysis of plant forced outage effects on air quality; analyze SCS effectiveness, cost and reliability.

A master data file is being maintained at MIT on both disk and cards. The file has entries for all AIRMAP SO₂ data, observed meteorological data at the AIRMAP tower and local airports, and plant operating levels. There are presently 46 variables arranged in chronological data records. All data in the master file is historical. Forecast meteorological information has also been prepared, but is separate from the master

data files and is to be used for analyzing the effectiveness of the meteorological forecasting efforts. There is a six week lag between the collection of one month of AIRMAP data and its entry into the master data file.

Data management programs have been developed to perform several functions. The AIRMAP system has a report generator which tabulates each month's data and identifies violations of three and 24 hour standards. Tabulations are also prepared for all AIRMAP tower data. MIT has developed data tabulation programs for the other variables, as well as programs to load and edit the entire master data file. There is a series of standard analysis packages available for studying the data including statistical packages, plotting routines and histogram routines. In addition a report generator has been developed to list the data of interest. These analysis tools interface with the data file through a data retrieval program called SORT. SORT separates subsets of data from the master data file on the basis of upper and lower bound-type constraints which can be set for any of the 46 variables, groups of variables or functions of variables. For example, SORT would be able to retrieve the subset consisting of SO₂ concentrations at the five monitors nearest to Keystone, wind speeds and directions at the airports and tower and rainfall, whenever the data occurred between 8 a.m. and 10 a.m. and the sum of the solar insolation in that period exceeded a specified number.

The analysis of plant forced outage rates was started because of the relative scarcity of observed violations at the AIRMAP monitors. By examining the air quality at different levels of plant output and main-

taining similar background concentrations and meteorology, it is hoped to establish that changes in plant output (which might have occurred because of control actions instead of a forced outage) result in improvements in air quality. Our results to date have been inconclusive due to the difficulty in assigning credible background values and the "noisiness", or predominance of random low concentrations. The "noise" makes statistical analysis over the complete data set of little use when forced outage analysis is desired. For example, attempts to establish relationships between plant outputs and concentrations, as a function of mixing depth or wind speed were inconclusive. The problem is that most of the time the monitor does not see a plant plume impact and instead registers a background concentration which is generally less than .03 ppm.

The solution involves analyzing only higher concentration values where there is some confidence that the values are plant-influenced. This implies a smaller data set of useable information, but does give better insight into the forced outage effects. Hourly values above .1 ppm, which is 20% of the 3 hr standard make up less than 5% of the total data set.

On most analysis tasks effort has been directed at identifying procedures which can be used on the entire data base when it is available. We will have approximately nine months of "base-line" data to establish plant behavior before SCS implementation. No SCS effectiveness, cost or reliability analysis has been performed yet.

2.7 Task 10 "Air Quality Model Development and Implementation"

Modification and tuning of the ERT model for improved predictive ability and efficiency in the Chestnut Ridge application, including incorporation of interactions of plumes and topography,

changes of source characteristics with generating loads; selection of receptors at points of expected maximum impact; assistance to MIT in implementing the model as part of the control strategy program. Application of single-layer wind field model to Chestnut Ridge terrain.

Locations of 362 receptors, 17 of which are monitors, were selected with the aid of USGS topographic maps and incorporated into the data file of the model.

Terrain has been represented by lifting the centerline of the plume over hills and ridges with the closeness of approach defined as a function of stability on the basis of the results of numerical simulations and previous wind-tunnel studies.

Characteristics of the Penelec sources (heat emissions in stack effluent, SO_2 output, flue gas volume) were made to change according to the generating loads projected by the daily Penelec unit commitment schedule.

The model has been operating routinely in forecast mode twice a day since 9 April 1975 and an equivalent model has been implemented in the MIT Control Strategy Model.

The single-layer wind field model was run for the Chestnut Ridge terrain. The neglect of friction and stability factors led to unrealistically small changes in flow patterns and further use of the wind field model was dropped.

2.8 Task 11 "Operational Air Quality and Meteorological Forecasting"

Routine forecasting of meteorological variables for input to SO_2 forecast model runs; routine forecasting of surface wind observations at National Weather Service stations at Altoona, Blairsville, Johnstown, and Allegheny Airport; forecasting of mixing depth as indicated by radiosonde observations at Pittsburgh Airport; verification of all meteorological forecasts. Provision of listings and punched cards of verified SO_2 and meteorological data from the Chestnut Ridge AIRMAP network. Additionally, during the control demonstration period, running the MIT control strategy model from the AIRMAP operations center.

Forecasts of meteorological variables began on a seven-day-per-week basis. Initially forecasts were prepared over each day at approximately midnight for the succeeding five 6-hr periods. All forecasts were verified.

On 9 December 1974 forecasting began twice daily operation with each forecast prepared for the succeeding five 6-hr periods. Forecasts were made at 11 a.m. and 9 p.m. All forecasts were verified.

On 9 April 1975 forecasting was changed to provide forecasts for the succeeding 10 3-hr periods. This shortening of the period was made in order that both the forecasts and the verifications would be more meaningful. Quite different meteorological conditions typically occur within 6-hr periods, whereas a 3-hr period may be more realistically approximated by one set of values of the meteorological variables. All forecasts have been verified. Forecasting is continuing on this basis using the forms shown in Table II and Table III.

Forecasts are made at shortly before noon and midnight. Forecasts are made of the following variables:

1. Turner-Pasquill stability (A through E, or 1 through 5, only),
2. Air-mass stability (an AIRMAP stability estimated based on air mass characteristics)
3. Wind speed in knots, and direction in tens of degrees at the NWS surface stations at Altoona, Johnstown, Blairsville, and Allegheny County Airport
4. Wind speed (class 1 through 6) and direction (sector 1 through 16) at the top of the Penn View tower (part of the AIRMAP network), ΔT between the 299-ft and 33-ft levels of the tower ($^{\circ}F$), and precipitation (inches as recorded at the tower).

AQFOR-- FORECAST DATA CODING FORM

recast date,

1 5
7 5 1 0 4

Hour,

6 7
1 2

F/O

8
F

Forecast (F) or
Observed (O) conditions:

Forecast
period

Hour

WD:

U:

DMX:

S:

ΔT

PRECIP

T + 3

15

9

8 4

3

1 5

14
2

-3.0

0

T + 6

18

15

8 5

3

1 3

20
4

-2.4

0

T + 9

21

21

0 8

3

0 9

26
4

-1.0

0

T + 12

00

27

0 8

4

0 7

32
4

-.5

TRACE

T + 19

03

33

0 8

4

0 6

38
5

0.0

.02

T + 18

06

39

0 7

4

0 8

44
5

0.4

.05

T + 21

09

45

0 6

4

1 1

50
5

0.0

.05

T + 24

12

51

0 5

4

1 4

56
5

-0.4

.05

T + 27

15

57

0 4

5

1 2

62
5

-0.5

.03

T + 30

18

63

0 3

5

0 9

68
5

0.0

TRACE

Notes:

PRECIP: In inches at Sta NGS

DMX: Mixing depth, hundreds of meters.

S: Stability class, 1 to 5.

WD: Wind direction class, 1 to 16

U: Wind speed class, 1 to 6

ΔT : Degrees F Top to Bottom of Tower

Comments:

Forecaster Initials: WA

Date: 4/14/75

Time: 1300

Table II

CHESTNUT RIDGE FORECAST AND VERIFICATION FORM

FORECAST DATE: 4/14/75 FORECASTER: WA DATE: 4/14/75 TIME: 1200

FORECAST PERIOD	HOUR	AGC		AGC		BSI		BSI		A00		A00		JST		JST	
		WD	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD	WS	WD	WS
		FORECAST		VERIFICATION		FORECAST		VERIFICATION		FORECAST		VERIFICATION		FORECAST		VERIFICATION	
T+3	15	15	08	99		15	10	99		18	08	18	09	15	08	18	11
T+6	18	16	10	M		15	12	M		16	08	16	10	15	10	16	07
T+9	21	16	10	1304		15	10	M		00	00	2005		14	08	16	16
T+12	00	16	08	1806		14	10	M		00	00	1604		14	08	M	
T+15	03	15	05	1805		14	08	M		17	08	1305		14	06	M	
T+18	06	12	05	1204		12	10	1308		16	05	0908		12	08	1304	
T+21	09	08	08	99		10	10	1204		10	10	0905		10	08	1305	
T+24	12	04	10	3112		09	12	2912		06	00	99		09	10	M	
T+27	15	36	10	3112		03	15	3010		03	12	0105		05	12	3105	
T+30	18	36	10	3011		02	15	2816		03	12	99		02	15	3108	

VERIFYING METEOROLOGIST(S): _____ DATE: _____ TIME: _____

WD: Wind Direction in tens of degrees

WS: Wind Speed in knots

All entries in ink, please.

5. Mixing depth in hundreds of meters as given by the routine radiosondes at the Pittsburgh Airport reported on NWS Service C.

The Chestnut Ridge AIRMAP network has had the data-capture rate reported on the enclosed chart (Table IV).

Since starting of the monitoring system at Chestnut Ridge, 23 violations of the 3-hr SO_2 standard 0.50 ppm and 159 violations of the 24-hr SO_2 standard have been observed by the monitors.

Routine runs of the SO_2 forecast model have been made by the AIRMAP forecasters twice each day since 9 April 1975. These runs use the unit commitment schedule obtained each morning from Penelec. The SO_2 concentrations are forecast for each of the 3-hr periods for which the meteorological forecasts are made. Model values of concentrations are produced for each of the 17 monitors and for each of 345 other points. The ten 3-hr averages as well as the three 24-hr averages that may be made from the 3-hr forecasts are listed by the program. (See Appendix).

The annual SO_2 standard of 0.03 ppm appears to be in jeopardy at several Chestnut Ridge monitors. Preliminary analysis of the data indicates that this is attributable both to the Chestnut Ridge generating stations and to "background" sources.

A complete set of validated AIRMAP data is available for the September to March period. It is regularly updated as each month of data is completed from the strip charts for those periods for which this becomes necessary because of failure of the telemetry system.

2.9 Task 12 "Model Application and Evaluation"

Continuing assessment of SCS effectiveness, including model validation, performance statistics of meteorological forecasts, and the impact of terrain. Analysis of AIRMAP data in support of Tasks 06 and 07.

Table IV

ERT DATA CAPTURE RATES (%)

DATA	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR
<u>SO₂</u>									
1	92.61	95.70	99.31	93.23	99.86	97.85	89.52	99.85	82.86
2	96.77	96.10	95.83	84.95	100	100	81.05	92.71	94.76
3	99.73	87.23	80.42	96.10	99.72	98.52	99.87	99.55	100
6	97.71	92.20	89.58	98.79	88.47	87.23	95.83	67.41	98.92
7	90.86	86.83	100	89.38	98.47	90.86	94.49	96.28	89.11
8	—	—	—	—	—	—	94.22	93.01	99.60
A	81.45	97.04	98.75	99.87	99.58	86.16	98.12	97.62	92.88
B	87.23	91.40	87.36	83.20	84.58	81.45	90.05	95.98	85.22
C	70.56	95.30	85.97	100	99.58	90.86	96.64	100	99.19
D	82.93	97.58	98.89	100	99.58	77.28	89.25	96.58	96.37
E	74.33	97.18	98.75	100	97.50	88.84	93.68	99.70	86.83
F	96.91	91.67	97.36	99.73	97.64	83.06	92.74	96.88	93.41
G	95.70	72.98	44.86	21.24	99.31	93.95	95.03	97.32	97.45
L	92.88	97.58	90.69	83.60	99.44	94.49	98.66	100	93.28
M	79.30	83.87	88.19	100	97.50	86.42	79.30	98.21	100
N	89.92	91.13	95.97	100	99.86	92.47	99.73	100	97.04
O	<u>97.45</u>	<u>97.98</u>	<u>99.58</u>	<u>96.24</u>	<u>99.72</u>	<u>99.73</u>	<u>99.33</u>	<u>94.35</u>	<u>92.34</u>
Total SO ₂	89.15	91.98	90.72	90.39	97.58	90.57	93.38	95.61	94.08
<u>MET</u>									
Ground Speed	—	94.79	100	100	96.25	78.90	97.98	77.23	97.04
300' Speed	—	100	100	100	100	78.76	22.04	59.82	54.70
Ground Dir.	—	97.40	100	99.87	99.31	88.58	100	80.80	97.45
300' Dir.	—	97.40	100	100	100	96.10	100	100	97.58
Ground Temp.	—	94.79	100	99.87	100	97.45	100	100	84.54
150' ΔT	—	94.79	97.64	100	100	97.45	100	100	85.08
300' ΔT	—	94.79	97.64	100	100	97.45	100	100	84.54
Dew Pt	—	—	81.53	100	99.86	97.45	100	100	84.95
Rain	—	—	99.31	100	100	97.45	100	100	100
Solar Insol.	—	<u>100</u>	<u>100</u>	<u>100</u>	<u>100</u>	<u>97.45</u>	<u>100</u>	<u>100</u>	<u>85.08</u>
Total Met.	—	96.74	97.61	99.97	99.54	92.70	92.00	91.79	87.10

Comparison of the AQ model with monitor data has raised two problems that are now being corrected. First, the model overpredicts concentrations on the tops of ridges. Second, the model's 22 1/2 degree sector width just misses some monitors in certain wind sectors and consequently overemphasizes the effect of wind direction.

Preliminary examination of the monitor records shows that something akin to fumigation occasionally occurs at certain stations. During these situations, which most often take place when the wind has a southerly component at Penn View, the model underpredicts. Case study analyses of these situations are being undertaken to see if they appear to be susceptible to prediction.

Work is now underway on the analysis of model performance to establish its ability to forecast violations or near-violations of standards.

APPENDIX

Typical ERT

Air Quality Model Output

SCHEDULE

(UNIT 5)

YR-DAY-HR	OPERATION	
74- 1- 0	BOILER PITN SET TO USE DUMY WITH A LOAD OF	1700.
74- 1- 0	BOILER PITS SET TO USE DUMY WITH A LOAD OF	2000.
74- 1- 0	BOILER PITW SET TO USE DUMY WITH A LOAD OF	2000.
75-129-12	BOILER SEWS SET TO USE COAL WITH A LOAD OF	137.
75-160- 6	BOILER HCU1 SET TO USE COL2 WITH A LOAD OF	550.
75-160- 6	BOILER CON2 SET TO USE COAL WITH A LOAD OF	770.
75-160- 6	BOILER COM1 SET TO USE COAL WITH A LOAD OF	770.
75-161- 6	BOILER KEY1 SET TO USE COL3 WITH A LOAD OF	805.
75-161- 6	BOILER KEY2 SET TO USE COL3 WITH A LOAD OF	810.
75-161-12	BOILER HCU2 SET TO USE COL2 WITH A LOAD OF	500.
75-162- 6	BOILER S3&4 SET TO USE COAL WITH A LOAD OF	60.
75-162-18	BOILER KEY1 SET TO USE COL3 WITH A LOAD OF	780.
75-162-18	BOILER KEY2 SET TO USE COL3 WITH A LOAD OF	780.
75-162-24	BOILER HCU1 SET TO USE COL2 WITH A LOAD OF	400.
75-163- 6	BOILER KEY1 SET TO USE COL3 WITH A LOAD OF	805.
75-163- 6	BOILER KEY2 SET TO USE COL3 WITH A LOAD OF	810.
75-163- 6	BOILER HCU1 SET TO USE COL2 WITH A LOAD OF	550.

03 1129

ERT AIR QUALITY FORECAST PROGRAM

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FORECAST

(UNIT 5)

FORECAST	YR-DAY-HR	WD	U	DMX	S RAIN	VAR
	75 162 24					
		11	6	5	4	0
		11	6	5	4	0
		11	6	9	4	0
		12	5	14	4	0
		12	5	10	4	0
		12	5	15	4	0
		12	5	10	4	0
		12	5	10	4	0
		12	5	5	4	0
		12	5	5	4	0

6-11-2400

 * PERIOD 1 *

SOURCE DESCRIPTIONS:

NO.	X-COORD1 (SCALE U)	Y-COORD (SCALE U)	BASE HT. (M)	HEIGHT (M)	DIAM. (M)	EXIT VEL (M/S)	HEAT OUT (CAL/S)	SO2 OUT (G/S)
MODE = 0								
1	593.00	4461.00	305.	76.2	15.24	0.01	5.09E 3	2.02E 3
2	581.00	4477.00	274.	76.2	15.24	0.01	5.09E 3	2.02E 3
3	595.00	4483.00	274.	76.2	15.24	0.01	4.33E 3	1.72E 3
4	666.80	4474.70	331.	69.7	2.29	34.02	6.45E 6	3.10E 2
5	666.80	4474.70	331.	70.7	2.95	37.63	5.85E 6	6.01E 2
6	652.73	4486.19	372.	242.6	8.84	9.39	1.45E 7	3.62E 3
7	652.73	4486.19	372.	242.6	8.84	11.73	1.81E 7	4.52E 3
8	664.25	4472.00	329.	304.8	8.23	22.04	3.15E 7	3.24E 3
9	664.25	4472.00	329.	304.8	8.23	22.04	3.15E 7	3.24E 3
10	640.10	4502.20	311.	242.9	8.84	20.30	3.12E 7	2.01E 3
11	640.10	4502.20	311.	242.9	8.84	20.30	3.12E 7	2.01E 3
CYCLE COUNT =		182.						

*****XRF HFR 80-ETTT FORECAST PROGRAM***** CERSTON 1.1 (790507) ***** PAGE 9

SOURCE DESCRIPTIONS:

NO.	X-COORD1 (SCALE U)	Y-COORD (SCALE U)	BASE HT. (M)	HEIGHT (M)	DIAM. (M)	EXIT VEL (M/S)	HEAT OUT (CAL/S)	SO2 OUT (G/S)
MODE = 0								
1	593.00	4461.00	305.	76.2	15.24	0.01	5.09E 3	2.02E 3
2	581.00	4477.00	274.	76.2	15.24	0.01	5.09E 3	2.02E 3
3	595.00	4483.00	274.	76.2	15.24	0.01	4.33E 3	1.72E 3
4	666.80	4474.70	331.	68.7	2.29	34.02	6.45E 6	3.10E 2
5	656.80	4474.70	331.	70.7	2.95	37.63	5.85E 6	6.01E 2
6	652.73	4486.19	372.	242.6	8.84	12.91	1.99E 7	4.98E 3
7	652.73	4486.19	372.	242.6	8.84	11.73	1.81E 7	4.52E 3
8	664.25	4472.00	329.	304.8	8.23	22.04	3.15E 7	3.24E 3
9	664.25	4472.00	329.	304.8	8.23	22.04	3.15E 7	3.24E 3
10	640.10	4502.20	311.	242.9	8.84	20.95	3.22E 7	2.07E 3
11	640.10	4502.20	311.	242.9	8.84	21.08	3.24E 7	2.09E 3
CYCLE COUNT =	182.							
CYCLE COUNT =	182.							
CYCLE COUNT =	424.							
CYCLE COUNT =	424.							
CYCLE COUNT =	424.							
CYCLE COUNT =	424.							
CYCLE COUNT =	424.							
CYCLE COUNT =	386.							
CYCLE COUNT =	386.							

MAXIMUM CONCENTRATIONS OVER ALL RECEPTORS (3-HOUR AVG)

PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD	PERIOD
1	2	3	4	5	6	7	8	9	10		
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

MINIMUM OPERATIONS PERMISSIBLE FOR EACH PERIOD:

MODE:
0,
0,
0,
0,
0,
0,
0,
0,
0,
0,
0,
0,

99999

(UNIT 5)

(UNIT 5)

RECEIVED
FROM TO

FROM TO

1	8	0.000	0.002	0.000	0.001	0.047	0.035	0.002	0.002
9	16	0.005	0.033	0.055	0.002	0.002	0.020	0.005	0.017
17	24	0.005	0.000	0.002	0.002	0.002	0.001	0.001	0.029
25	32	0.001	0.001	0.001	0.035	0.000	0.000	0.008	0.053
33	40	0.067	0.061	0.046	0.044	0.053	0.031	0.001	0.027
41	48	0.021	0.000	0.000	0.002	0.079	0.014	0.033	0.060
49	56	0.044	0.053	0.048	0.039	0.026	0.000	0.000	0.002
57	64	0.020	0.000	0.000	0.050	0.000	0.000	0.000	0.000
65	72	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
73	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
81	88	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	96	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
97	104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
105	112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113	120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
121	128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129	136	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137	144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
145	152	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
153	160	0.000	0.000	0.000	0.000	0.000	0.002	0.002	0.000
161	168	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.000
169	176	0.000	0.002	0.002	0.002	0.002	0.000	0.000	0.002
177	184	0.002	0.002	0.000	0.000	0.002	0.002	0.002	0.002
185	192	0.001	0.001	0.001	0.002	0.002	0.003	0.005	0.004
193	200	0.016	0.002	0.009	0.045	0.041	0.031	0.028	0.002
201	208	0.006	0.078	0.075	0.056	0.032	0.002	0.002	0.002
209	216	0.002	0.001	0.001	0.001	0.002	0.002	0.002	0.006
217	224	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
225	232	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.002
233	240	0.002	0.002	0.002	0.000	0.000	0.002	0.002	0.002
241	248	0.002	0.002	0.003	0.006	0.002	0.002	0.002	0.002
249	256	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002
257	264	0.002	0.004	0.002	0.002	0.002	0.005	0.002	0.002
265	272	0.003	0.005	0.002	0.002	0.003	0.005	0.005	0.003
273	280	0.006	0.005	0.005	0.005	0.005	0.004	0.005	0.005
281	288	0.013	0.022	0.017	0.014	0.005	0.006	0.014	0.025
289	296	0.022	0.017	0.005	0.005	0.005	0.005	0.005	0.004
297	304	0.006	0.005	0.005	0.005	0.005	0.006	0.006	0.005
305	312	0.005	0.006	0.006	0.006	0.006	0.006	0.006	0.006
313	320	0.006	0.006	0.006	0.000	0.006	0.003	0.003	0.006
321	328	0.006	0.006	0.007	0.008	0.005	0.006		

Q	24-HR AVERAGE FOR PERIODS	2 TO	9
1	100	100	100
2	100	100	100
3	100	100	100
4	100	100	100
5	100	100	100
6	100	100	100
7	100	100	100
8	100	100	100
9	100	100	100
10	100	100	100
11	100	100	100
12	100	100	100
13	100	100	100
14	100	100	100
15	100	100	100
16	100	100	100
17	100	100	100
18	100	100	100
19	100	100	100
20	100	100	100
21	100	100	100
22	100	100	100
23	100	100	100
24	100	100	100
25	100	100	100
26	100	100	100
27	100	100	100
28	100	100	100
29	100	100	100
30	100	100	100
31	100	100	100
32	100	100	100
33	100	100	100
34	100	100	100
35	100	100	100
36	100	100	100
37	100	100	100
38	100	100	100
39	100	100	100
40	100	100	100
41	100	100	100
42	100	100	100
43	100	100	100
44	100	100	100
45	100	100	100
46	100	100	100
47	100	100	100
48	100	100	100
49	100	100	100
50	100	100	100
51	100	100	100
52	100	100	100
53	100	100	100
54	100	100	100
55	100	100	100
56	100	100	100
57	100	100	100
58	100	100	100
59	100	100	100
60	100	100	100
61	100	100	100
62	100	100	100
63	100	100	100
64	100	100	100
65	100	100	100
66	100	100	100
67	100	100	100
68	100	100	100
69	100	100	100
70	100	100	100
71	100	100	100
72	100	100	100
73	100	100	100
74	100	100	100
75	100	100	100
76	100	100	100
77	100	100	100
78	100	100	100
79	100	100	100
80	100	100	100
81	100	100	100
82	100	100	100
83	100	100	100
84	100	100	100
85	100	100	100
86	100	100	100
87	100	100	100
88	100	100	100
89	100	100	100
90	100	100	100
91	100	100	100
92	100	100	100
93	100	100	100
94	100	100	100
95	100	100	100
96	100	100	100

1	8	0.000	0.002	0.000	0.002	0.031	0.038	0.002	0.003
9	16	0.007	0.026	0.072	0.002	0.003	0.028	0.008	0.014
17	24	0.007	0.000	0.002	0.002	0.002	0.002	0.002	0.019
25	32	0.002	0.002	0.002	0.049	0.000	0.000	0.006	0.036
33	40	0.045	0.055	0.030	0.029	0.053	0.021	0.002	0.017
41	48	0.014	0.000	0.000	0.002	0.093	0.014	0.033	0.065
49	56	0.044	0.056	0.051	0.042	0.028	0.000	0.000	0.002
57	64	0.020	0.000	0.000	0.050	0.000	0.000	0.000	0.000
65	72	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
73	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
81	88	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
89	96	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
97	104	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
105	112	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
113	120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
121	128	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
129	136	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
137	144	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
145	152	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
153	160	0.000	0.000	0.000	0.000	0.000	0.003	0.003	0.000
161	168	0.000	0.000	0.000	0.002	0.002	0.003	0.003	0.000
169	176	0.000	0.002	0.002	0.002	0.002	0.000	0.000	0.002
177	184	0.002	0.002	0.000	0.000	0.002	0.002	0.002	0.002
185	192	0.002	0.002	0.002	0.003	0.002	0.005	0.007	0.006
193	200	0.023	0.003	0.007	0.031	0.029	0.022	0.021	0.003
201	208	0.009	0.101	0.099	0.075	0.045	0.003	0.002	0.002
209	216	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.007
217	224	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
225	232	0.003	0.003	0.003	0.003	0.000	0.000	0.000	0.003
233	240	0.003	0.003	0.003	0.000	0.000	0.003	0.003	0.003
241	248	0.003	0.003	0.004	0.006	0.003	0.003	0.003	0.004
249	256	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003
257	264	0.003	0.006	0.003	0.003	0.003	0.003	0.003	0.003
265	272	0.005	0.007	0.003	0.003	0.005	0.007	0.006	0.005
273	280	0.006	0.006	0.006	0.006	0.006	0.004	0.006	0.006
281	288	0.011	0.016	0.013	0.011	0.006	0.007	0.019	0.035
289	296	0.030	0.022	0.006	0.006	0.006	0.006	0.006	0.006
297	304	0.006	0.006	0.006	0.007	0.006	0.006	0.006	0.006
305	312	0.007	0.006	0.006	0.006	0.008	0.006	0.007	0.007
313	320	0.009	0.006	0.007	0.000	0.008	0.004	0.004	0.006
321	328	0.007	0.007	0.008	0.010	0.005	0.006		

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ERT AIR QUALITY FORECAST PROGRAM

VERSION 1.1 (750507)

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PRMODE

(UNIT 5)

CONCENTRATIONS FOR MODE NUMBER: 0 (3-HOUR AVG)

IRCP #	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6	PERIOD 7	PERIOD 8	PERIOD 9	PERIOD 10
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.005
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.005	0.005
5	0.130	0.135	0.093	0.002	0.002	0.002	0.002	0.004	0.005	0.005
6	0.010	0.010	0.010	0.045	0.045	0.045	0.045	0.045	0.045	0.045
7	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.005
8	0.000	0.000	0.000	0.003	0.003	0.003	0.003	0.005	0.008	0.008
9	0.000	0.000	0.000	0.005	0.005	0.005	0.007	0.012	0.019	0.019
10	0.079	0.092	0.062	0.006	0.005	0.005	0.006	0.010	0.017	0.017
11	0.000	0.000	0.000	0.087	0.086	0.086	0.087	0.089	0.145	0.145
12	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.005
13	0.000	0.000	0.000	0.003	0.002	0.002	0.003	0.004	0.007	0.007
14	0.005	0.005	0.002	0.030	0.029	0.029	0.030	0.033	0.064	0.064
15	0.006	0.006	0.003	0.007	0.006	0.006	0.007	0.011	0.018	0.018

33	0.184	0.184	0.157	0.002	0.002	0.002	0.002	0.004	0.006	0.006	
34	0.098	0.098	0.051	0.048	0.047	0.048	0.048	0.049	0.052	0.052	
35	0.133	0.133	0.090	0.002	0.002	0.002	0.002	0.004	0.006	0.006	
36	0.128	0.128	0.084	0.002	0.002	0.002	0.002	0.004	0.006	0.006	
37	0.000	0.000	0.000	0.084	0.084	0.084	0.085	0.088	0.039	0.039	
38	0.092	0.092	0.057	0.002	0.002	0.002	0.002	0.003	0.006	0.006	
39	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.003	0.006	0.006	
40	0.079	0.079	0.045	0.002	0.001	0.002	0.002	0.003	0.005	0.005	
41	0.061	0.061	0.033	0.002	0.001	0.002	0.002	0.003	0.005	0.005	
42	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
43	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
44	0.000	0.000	0.000	0.003	0.003	0.003	0.003	0.003	0.000	0.000	
45	0.000	0.000	0.000	0.127	0.127	0.127	0.127	0.127	0.115	0.115	
46	0.000	0.000	0.000	0.022	0.022	0.022	0.022	0.022	0.000	0.000	
47	0.000	0.000	0.000	0.052	0.052	0.052	0.052	0.053	0.000	0.000	
48	0.000	0.000	0.000	0.095	0.095	0.095	0.095	0.097	0.042	0.042	
49	0.000	0.000	0.000	0.069	0.069	0.069	0.069	0.074	0.000	0.000	

[illegible]

[illegible]

[illegible]

I135	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I136	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I137	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I138	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I139	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I140	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I141	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I142	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I143	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I144	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I145	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I146	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I147	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I148	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I149	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I150	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I
I151	I	0.000	I	0.000	I	0.000	I	0.000	I	0.000	I

[illegible]

I169	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I170	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I171	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I172	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I173	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I174	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I175	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I176	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I177	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I178	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.005	0.006	0.006
I179	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I180	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I181	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.005	0.006	0.006
I182	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.005	0.006	0.006
I183	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.005	0.006	0.006
I184	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.005	0.006	0.006
I185	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.005	0.006	0.006

I186	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.006	0.006
I187	0.000	0.000	0.000	0.002	0.002	0.002	0.002	0.004	0.006	0.006
I188	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.006	0.006
I189	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.006	0.006
I190	0.000	0.000	0.000	0.004	0.004	0.004	0.005	0.007	0.013	0.013
I191	0.000	0.000	0.000	0.005	0.005	0.006	0.007	0.011	0.019	0.019
I192	0.000	0.000	0.000	0.006	0.005	0.005	0.006	0.010	0.017	0.017
I193	0.000	0.000	0.000	0.023	0.022	0.023	0.024	0.032	0.056	0.056
I194	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.006	0.006
I195	0.021	0.019	0.019	0.002	0.002	0.002	0.003	0.004	0.006	0.006
I196	0.113	0.123	0.105	0.002	0.002	0.002	0.002	0.004	0.006	0.006
I197	0.104	0.121	0.081	0.004	0.003	0.003	0.005	0.007	0.011	0.011
I198	0.078	0.091	0.055	0.004	0.003	0.003	0.004	0.006	0.011	0.011
I199	0.068	0.079	0.045	0.005	0.004	0.005	0.006	0.009	0.016	0.016
I200	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.006	0.006
I201	0.000	0.000	0.000	0.010	0.009	0.010	0.011	0.012	0.014	0.014
I202	0.000	0.000	0.000	0.126	0.125	0.126	0.126	0.127	0.178	0.178

I203	I	0.000	I	0.000	I	0.000	I	0.121	I	0.121	I	0.121	I	0.121	I	0.123	I	0.187	I	0.187	I
I204	I	0.000	I	0.000	I	0.000	I	0.088	I	0.087	I	0.088	I	0.089	I	0.094	I	0.156	I	0.156	I
I205	I	0.000	I	0.000	I	0.000	I	0.049	I	0.049	I	0.049	I	0.050	I	0.059	I	0.104	I	0.104	I
I206	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I207	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I208	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I209	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.002	I	0.004	I	0.006	I	0.006	I
I210	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.002	I	0.003	I	0.006	I	0.006	I
I211	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.002	I	0.003	I	0.005	I	0.005	I
I212	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.002	I	0.003	I	0.006	I	0.006	I
I213	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I214	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I215	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I216	I	0.006	I	0.006	I	0.003	I	0.006	I	0.006	I	0.006	I	0.006	I	0.009	I	0.015	I	0.015	I
I217	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.007	I	0.007	I
I218	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I
I219	I	0.000	I	0.000	I	0.000	I	0.002	I	0.002	I	0.002	I	0.003	I	0.004	I	0.006	I	0.006	I

[illegible]

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ERT AIR QUALITY FORECAST PROGRAM

VERSION 1.1 (750507)

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1254	0.000	0.000	0.000	0.003	0.003	0.003	0.004	0.005	0.008	0.008
1255	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.007	0.007
1256	0.000	0.000	0.000	0.003	0.002	0.002	0.003	0.004	0.007	0.007

CONCENTRATIONS FOR MODE NUMBER: 0 (3-HOUR AVG)

IRCP #	PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4	PERIOD 5	PERIOD 6	PERIOD 7	PERIOD 8	PERIOD 9	PERIOD 10
1257	0.000	0.000	0.000	0.003	0.002	0.002	0.003	0.004	0.007	0.007
1258	0.000	0.000	0.000	0.005	0.005	0.005	0.006	0.009	0.015	0.015
1259	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.007	0.007
1260	0.000	0.000	0.000	0.003	0.002	0.002	0.003	0.00	0.007	0.007
1261	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.007	0.007
1262	0.000	0.000	0.000	0.007	0.007	0.007	0.008	0.013	0.022	0.022
1263	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.007	0.007
1264	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.007	0.007
1265	0.000	0.000	0.000	0.005	0.004	0.004	0.005	0.008	0.014	0.014
1266	0.000	0.000	0.000	0.007	0.006	0.006	0.008	0.012	0.020	0.020
1267	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.006	0.006
1268	0.000	0.000	0.000	0.002	0.002	0.002	0.003	0.004	0.006	0.006

1269	0.000	0.000	0.000	0.005	0.004	0.004	0.005	0.008	0.013	0.013
1270	0.000	0.000	0.000	0.005	0.005	0.006	0.007	0.012	0.019	0.019
1271	0.005	0.005	0.003	0.004	0.004	0.004	0.005	0.007	0.013	0.013
1272	0.000	0.000	0.000	0.004	0.004	0.004	0.005	0.007	0.013	0.013
1273	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.009	0.015	0.015
1274	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.009	0.015	0.015
1275	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014
1276	0.005	0.005	0.003	0.005	0.004	0.004	0.005	0.008	0.013	0.013
1277	0.004	0.004	0.002	0.004	0.004	0.004	0.005	0.007	0.013	0.013
1278	0.003	0.003	0.005	0.002	0.002	0.002	0.002	0.004	0.006	0.006
1279	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.015	0.015
1280	0.006	0.006	0.004	0.005	0.005	0.005	0.006	0.008	0.014	0.014
1281	0.027	0.027	0.022	0.005	0.004	0.005	0.006	0.008	0.014	0.014
1282	0.054	0.056	0.037	0.005	0.004	0.004	0.005	0.007	0.013	0.013
1283	0.043	0.045	0.026	0.004	0.004	0.004	0.005	0.007	0.012	0.012
1284	0.034	0.035	0.020	0.004	0.003	0.004	0.005	0.006	0.011	0.011
1285	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014

1286	0.005	0.005	0.003	0.006	0.006	0.006	0.007	0.010	0.017	0.017
1287	0.005	0.005	0.003	0.020	0.019	0.019	0.020	0.023	0.045	0.045
1288	0.005	0.005	0.003	0.038	0.037	0.037	0.038	0.041	0.081	0.081
1289	0.004	0.004	0.002	0.032	0.031	0.031	0.032	0.037	0.068	0.068
1290	0.004	0.004	0.002	0.023	0.022	0.023	0.024	0.029	0.051	0.051
1291	0.005	0.005	0.003	0.005	0.005	0.005	0.005	0.008	0.014	0.014
1292	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014
1293	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014
1294	0.005	0.005	0.003	0.005	0.004	0.004	0.005	0.007	0.013	0.013
1295	0.000	0.000	0.000	0.006	0.006	0.006	0.007	0.011	0.019	0.019
1296	0.000	0.000	0.000	0.006	0.005	0.005	0.006	0.010	0. 17	0.017
1297	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.009	0.015	0.015
1298	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.015	0.015
1299	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014
1300	0.000	0.000	0.000	0.007	0.006	0.006	0.008	0.012	0.020	0.020
1301	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014
1302	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.009	0.015	0.015

I303	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.009	0.015	0.015
I304	0.005	0.005	0.003	0.005	0.005	0.005	0.006	0.008	0.014	0.014
I305	0.000	0.000	0.000	0.007	0.006	0.006	0.008	0.013	0.021	0.021
I306	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I307	0.005	0.006	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I308	0.005	0.006	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I309	0.000	0.000	0.000	0.008	0.007	0.007	0.009	0.014	0.022	0.022
I310	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I311	0.005	0.006	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I312	0.005	0.006	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I313	0.000	0.000	0.000	0.009	0.008	0.008	0.009	0.015	0.024	0.024
I314	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
I315	0.005	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
I316	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
I317	0.005	0.006	0.003	0.006	0.006	0.006	0.007	0.010	0.017	0.017
I318	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.006	0.009	0.009
I319	0.000	0.000	0.000	0.004	0.004	0.004	0.004	0.006	0.009	0.009

1320	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
1321	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
1322	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
1323	0.006	0.006	0.004	0.007	0.007	0.007	0.007	0.011	0.018	0.018
1324	0.007	0.007	0.004	0.009	0.008	0.008	0.009	0.013	0.021	0.021
1325	0.007	0.007	0.004	0.004	0.004	0.004	0.004	0.006	0.009	0.009
1326	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
1327	0.005	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
1328	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
1329	0.006	0.006	0.003	0.007	0.007	0.007	0.007	0.011	0.018	0.018
1330	0.006	0.006	0.004	0.009	0.009	0.009	0.009	0.013	0.021	0.021
1331	0.007	0.007	0.004	0.012	0.012	0.012	0.012	0.014	0.023	0.023
1332	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015
1333	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
1334	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016
1335	0.006	0.006	0.003	0.007	0.006	0.006	0.007	0.011	0.018	0.018
1336	0.006	0.006	0.004	0.008	0.008	0.008	0.009	0.012	0.020	0.020

I337	0.009	0.009	0.005	0.004	0.004	0.004	0.004	0.006	0.009	0.009	
I338	0.005	0.005	0.003	0.006	0.005	0.006	0.006	0.009	0.015	0.015	
I339	0.006	0.006	0.003	0.006	0.005	0.006	0.006	0.009	0.016	0.016	
I340	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016	
I341	0.006	0.006	0.003	0.006	0.006	0.006	0.007	0.011	0.017	0.017	
I342	0.019	0.019	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
I343	0.014	0.014	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
I344	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
I345	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015	
I346	0.006	0.006	0.003	0.006	0.006	0.006	0.006	0.009	0.016	0.016	
I347	0.012	0.012	0.006	0.003	0.002	0.003	0.003	0.005	0.007	0.007	
I348	0.018	0.018	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
I349	0.012	0.012	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
I350	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015	
I351	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015	
I352	0.005	0.005	0.003	0.006	0.005	0.005	0.006	0.009	0.015	0.015	
I353	0.011	0.011	0.006	0.003	0.002	0.002	0.003	0.004	0.007	0.007	