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INSTRUMENTATION FOR THE DETERMINATION OF NITROGEN OXIDES CONTENT OF STATIONARY SOURCE EMISSIONS. VOLUME II

Arthur D. Snyder, et al

Monsanto Research Corporation
Dayton, Ohio

January 1972

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By

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Contract No. EHSD 71-30

Environmental Protection Agency
National Environmental Research Center
Durham, North Carolina

MONSANTO RESEARCH CORPORATION
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For

ENVIRONMENTAL PROTECTION AGENCY
NATIONAL ENVIRONMENTAL RESEARCH CENTER
DURHAM, NORTH CAROLINA

CONTRACT NO. EHSD 71-30

MONSANTO RESEARCH CORPORATION
DAYTON LABORATORY
Dayton, Ohio 45407

FOREWORD

In December of 1970, the Environmental Protection Agency contracted with Monsanto Research Corporation to conduct a laboratory and field evaluation of commercially available continuous monitors for nitrogen oxides emitted from stationary sources.

Volume I of this report (issued in October 1971) presented the results of a detailed survey of instrumentation on techniques capable of measuring NO_x emissions. The Volume I report constituted a state-of-the-art review of NO_x monitoring instrumentation including (1) commercially available units, (2) prototype and laboratory-stage instrumental methods, and (3) novel monitoring techniques based on evolving laser technology. Evaluation of these monitoring systems were based on present and projected requirements in stationary source emissions monitoring.

This survey preceded the start of laboratory and field testing of the commercially available units. This report, Volume II, details the laboratory and field evaluation studies of commercial nitrogen oxide monitors tested on this program.

ACKNOWLEDGEMENTS

Technician support on this program was furnished by Messrs. Thomas Stewart and Guthrie Wheeler and Mrs. Connie Hess. The support of Mr. Andrew Kazarinoff and Mr. George Chute of Stevenson, Jordan and Harrison, Management Consultants, Inc. is gratefully acknowledged. The cooperation of Messrs. Howard Palmer, Earl Cutter and John Nehez of the Dayton Power and Light Company in making their Tait Power Station available for the field evaluation of the nitrogen oxide monitors is particularly appreciated. Of particular note was the active participation and cooperation of the technical monitor, Dr. Fredric Jaye of the National Environmental Research Center, Research Triangle Park, North Carolina, on this program.

ABSTRACT

The performance of seven commercial monitors for applicability to the continuous determination of nitrogen oxides from stationary sources was evaluated. Based on the present and projected requirements in stationary source emissions monitoring, the ranking, utility factors and ranges of performance were first established for each of fifteen performance parameters. These desired instrument parameters formed a matrix against which the quantified performance values as measured in the laboratory and on an operating power plant flue gas composition could be compared.

The comparison of the evaluation data on each performance parameter with the desired performance matrix resulted in an estimate of overall performance of the tested nitrogen oxide monitors. This overall performance is calculated in the form of an "index of performance" for each instrument. The evaluation results indicate that the commercial monitors exhibited performance indices ranging from 0.57 to 0.78 versus a potential value of 0.99 for an instrument meeting all of the desired performance values.

It is concluded that there is a definite need for further research and development on improved continuous nitrogen oxide monitors to satisfy both the present needs, and the projected requirements when nitrogen oxide abatement processes are installed in new and existing stationary sources.

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1. INTRODUCTION

Based on an analysis of the stationary combustion source emission characteristics, instrument performance parameters were selected which continuous nitrogen oxide monitors should exhibit in order to qualify as viable monitoring devices. The instrument performance parameters were ranked according to importance and each parameter was weighted in accordance with the estimate of relative importance. Acceptable ranges of performance were then assigned to each instrument parameter; the lower limit corresponding to a highly desirable value and the upper limit corresponding to the estimated limit of acceptable operation. The performance parameter weighting and the range of acceptable performance values formed a matrix or frame reference against which the overall performance of the monitors could then be evaluated.

The instrument performance parameters quantified in laboratory and field test programs included accuracy, calibration and zero drift, interferences (sulfur dioxide, particulate, pressure and water), precision, repair requirements, repeatability, resolution, response time and lag, routine maintenance requirements, ruggedness and sensitivity.

The continuous nitrogen oxide monitors evaluated on this program included: four non-dispersive infrared instruments (Beckman 315A, Bendix UNOR-2, Intertech URAS-2, Mine Safety LIRA-200); one ultraviolet absorption instrument (duPont 461); and two electrochemical monitors (Dynasciences and EnviroMetrics). A very preliminary evaluation of Panametrics Krypton Clathrate instrument which operates on an inverse radioactive tracing concept was also included in the field evaluation phase.

Once the performance parameters were quantified, they were related to the performance parameter matrix through calculation of an overall "index of performance" for each monitor evaluated. The index of performance was designed such that perfect performance would rate an overall index of 0.99, while complete failure would be assigned a value of 0.01.

The performance parameter evaluation test results and the final performance index values are presented in this report. Conclusions concerning the present commercial "state-of-the-art" in continuous nitrogen oxide monitors for stationary sources is summarized and recommendations for further research and development are presented here and in Volume I of this report.

2. PROGRAM PLAN AND SCHEDULE

Contract No. EHSD 71-30, "Evaluation and Development of Nitrogen Oxide Monitors for Combustion Sources," was conducted in three phases:

Phase I - Evaluation of NO_x Monitors

Phase II - Testing of Existing Monitors

Phase III - Data Evaluation, Formulation of Recommended Programs and Final Reporting

A capsule summary of the program objectives, plans and schedule are presented in Figures 1-5. This summary was included as a portion of the monthly reports on the contract.

The original program included a phase effort to be initiated after the monitor test program, directed to correction of deficiencies observed in tested monitors and development of advanced monitor prototypes. This effort was deleted from the program by modification early in the contract.

OBJECTIVES AND/OR BACKGROUND

The goals of contract EHSD 71-30-are:

(1) To accurately define the current state-of-the-art in nitrogen oxides continuous monitors for stationary fossil fuel combustion sources.

(2) To evaluate the performance of commercial nitrogen oxides continuous monitors with respect to formulated instrument performance specifications.

(3) To recommend specific short- and long-range instrument development programs designed to satisfy immediate and future needs for nitrogen oxide monitors.

PROJECT DESCRIPTION AND TASKS

The project will be conducted in three phases:

Phase I - Evaluation of NO_x Monitors
Phase II - Testing of Existing Monitors
Phase III - Data Evaluation, Formulation of Recommended Programs and Final Reporting

In Phase I, Monsanto Research Corporation (MRC) with the cooperation of Stevenson, Jordan and Harrison (S,J&H), a subcontractor, will complete the following tasks:

(1) Survey nitrogen oxide monitor manufacturers and users by phone and personal interviews.

(2) Formulate instrument specifications and performance criteria.

In Phase II, MRC will evaluate the performance of commercially available nitrogen oxide monitors. The following tasks are involved:

(1) Design, procurement and installation of equipment for laboratory testing and testing in the field at the Dayton Power & Light Company Tait Station.

(2) Acquisition by purchase, rent or loan of a minimum of six commercially available nitrogen oxide monitors, and a data acquisition and handling system (digitizer/computer).

(3) Complete a laboratory test program accentuating instrument performance parameters such as accuracy, sensitivity, precision, response, resolution, drift, interferences and the effects of external humidity and temperature.

(4) Complete a short-term field test program accentuating instrument performance parameters such as accuracy, precision, response, resolution, drift, etc.

(5) Complete a long-term field test program accentuating instrument performance parameters such as the effect of environmental operating conditions, repair requirements, instrument down time, operating cost, etc.

Phase III activities include:

(1) Literature search and state-of-the-art review on advanced novel NO_x monitoring concepts.

(2) Evaluation of the instrument performance data with reference to the established performance criteria and specifications.

(3) Definition of the inadequacies in performance of the NO_x monitors.

(4) Formulate recommendations for future short-term and long-term instrument development prog[illegible]

(5) Complete and issue final report covering all effort on the contract.

OTHER MAJOR CONTRIBUTORS

Stevenson, Jordan and Harrison subcontractors on Phase I.

Figure 1. Program Plan and Objectives.

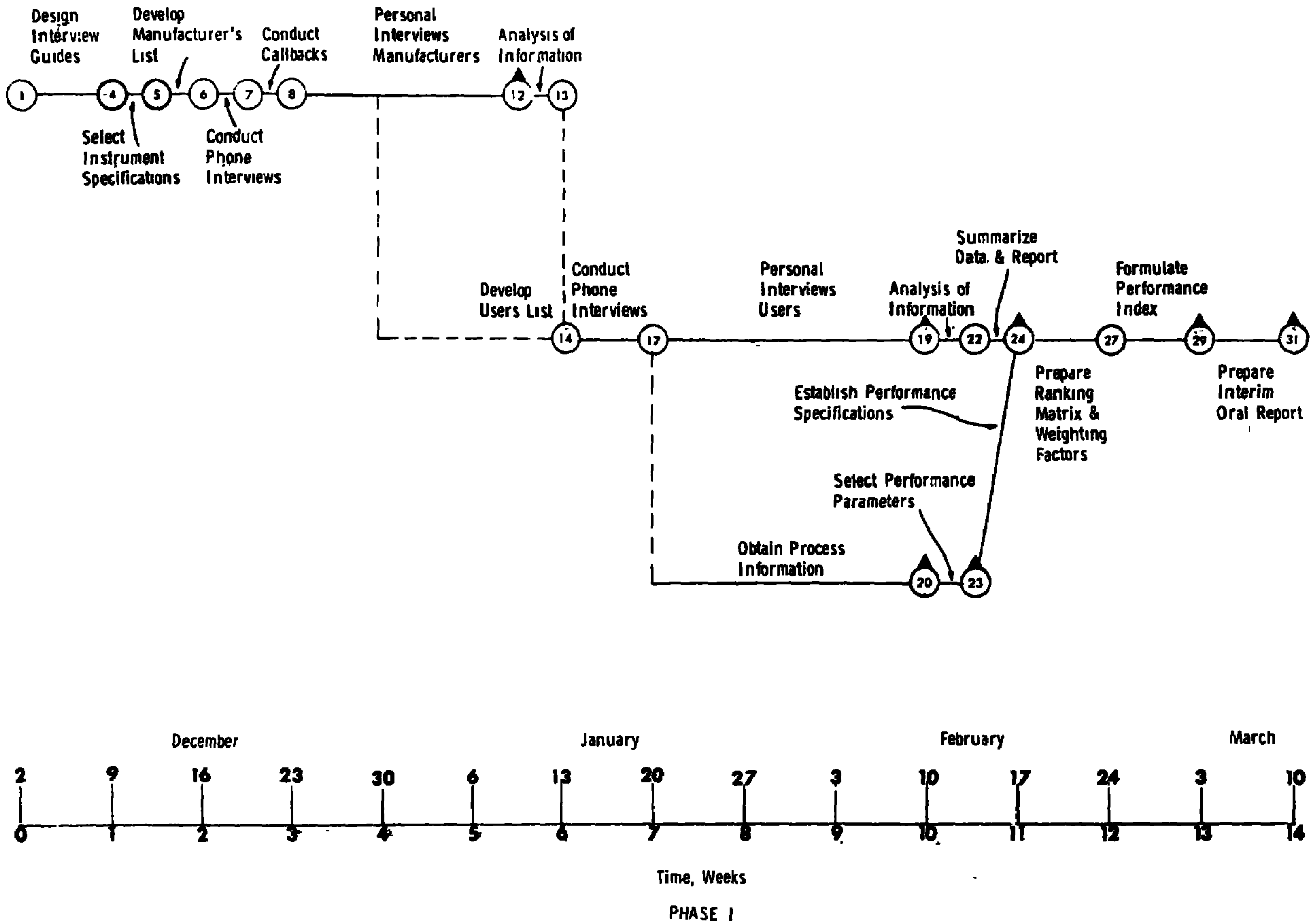

Figure 2. Program Milestone Chart - Phase I.

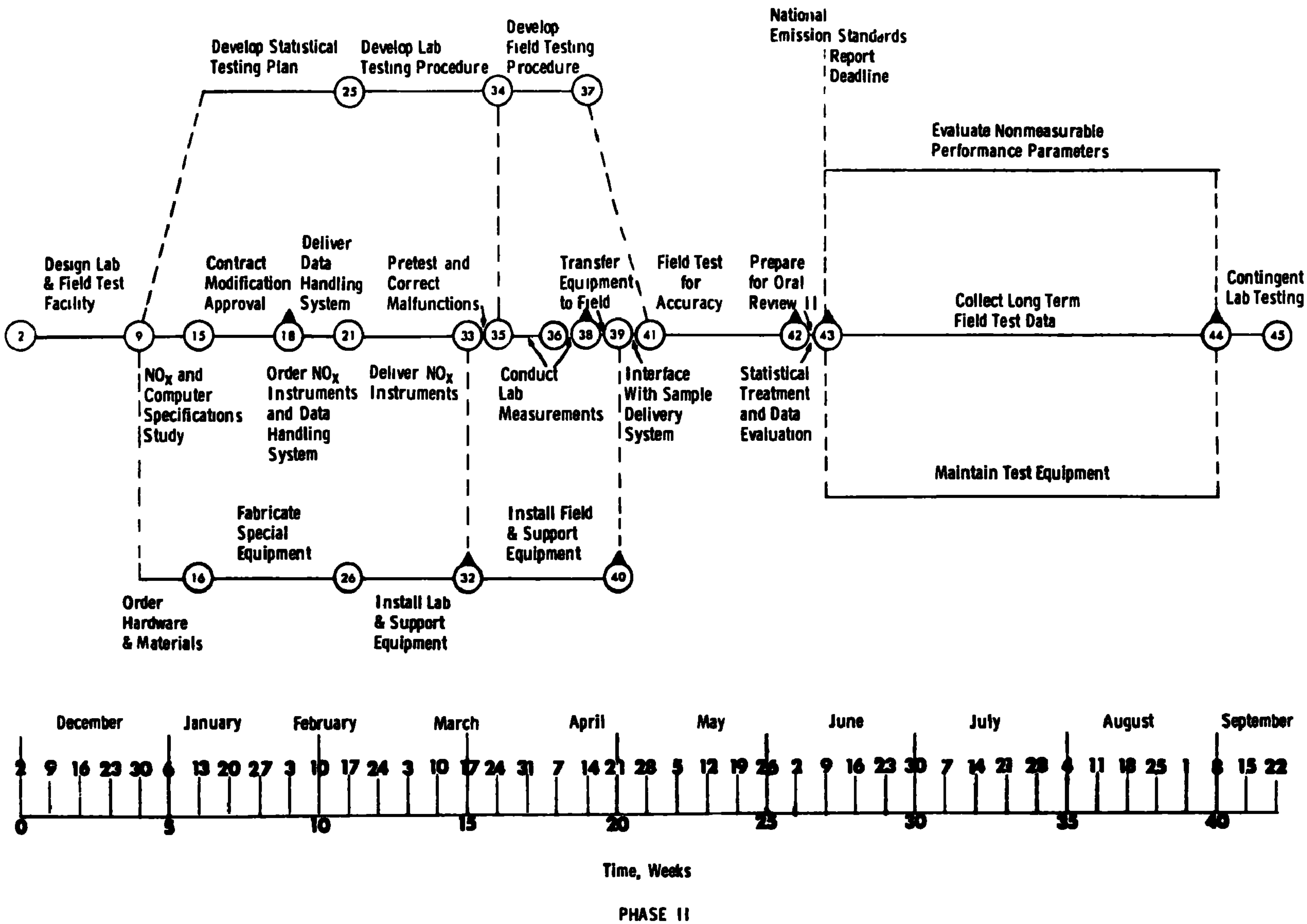

Figure 3. Program Milestone Chart - Phase II.

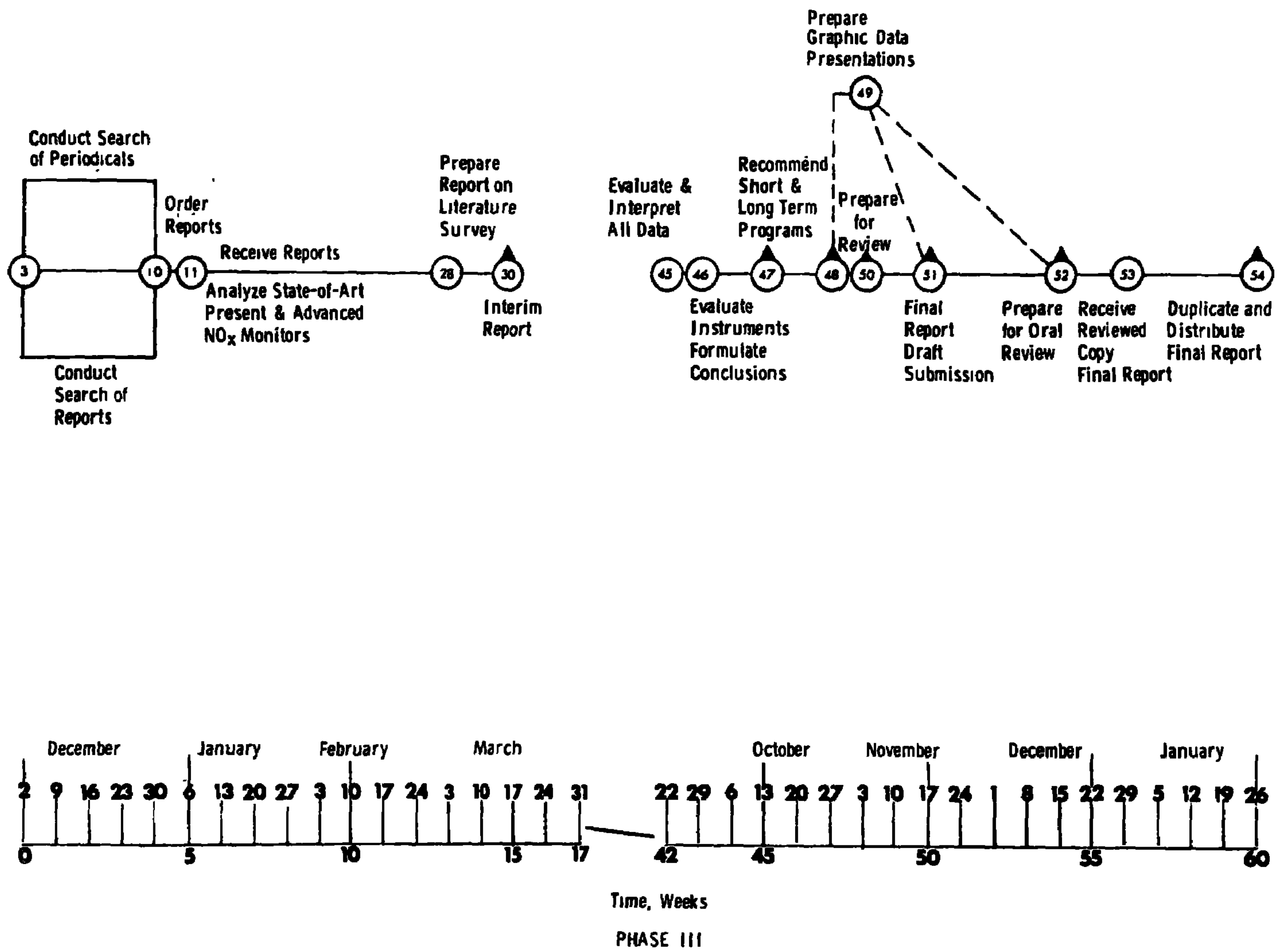

Figure 4. Program Milestone Chart - Phase III.

LEGEND

1. Initiate Phase I
2. Initiate Phase II
3. Initiate Phase III
4. Interview guides designed
5. NO_x instrument specifications selected
6. NO_x monitoring instrument manufacturers identified
7. Phone survey of instrument manufacturers completed
8. Analysis of information obtained in phone survey completed. Selection of firms to be interviewed completed
9. Laboratory and field test designs completed
10. Abstract literature search on novel NO_x monitoring concepts completed
11. Reports on NO_x monitoring concepts ordered
12. Personal interviews with NO_x instrument manufacturers completed
13. Analysis of instrument manufacturers data completed
14. NO_x monitoring instrument users list completed
15. NO_x monitoring instruments and data handling system defined for procurement
16. Hardware for laboratory and field test studies ordered
17. Phone interviews with NO_x instrument users completed
18. NO_x instruments and data handling system ordered
19. Personal interviews with NO_x instrument users completed
20. Information survey on NO_x-emitting installations completed
21. Receive data handling system
22. Analysis of NO_x instrument users data completed
23. Selection of performance parameters for the evaluation of NO_x monitors completed
24. NO_x monitor manufacturer and user information summarized and informal report completed
25. Statistical test plan completed
26. Special equipment for laboratory and field test fabricated
27. Ranking matrix and weighting factors on instrument performance parameters completed
28. State-of-the-art of advanced NO_x detection concepts defined
29. NO_x monitor performance index routine formulated
30. Report on literature survey for advanced NO_x detection concepts completed
31. Oral report I
32. Laboratory for NO_x monitor testing completed
33. NO_x monitors received
34. Laboratory testing procedures identified
35. NO_x monitors pretested and malfunctions corrected
36. Humidity and temperature parameter tests completed
37. Field testing procedures identified
38. Sensitivity, interference, and response tests completed
39. Equipment transferred to field test facility
40. Field test site and support equipment completed
41. Field test equipment interfaced with DP&L sample delivery system
42. Field test of NO_x instruments for accuracy completed
43. Statistical treatment and data evaluation completed. Oral review II
44. Long term field testing completed
45. Contingent laboratory tests completed
46. Evaluation and interpretation of all data completed
47. Instrument performance evaluated with reference to performance criteria and specifications
    Performance index calculations completed
48. Recommendations formulated for future short-term and long-term instrument development programs
49. Graphic data presentations for report, publications and oral review meeting prepared
50. Oral review III
51. Final report submitted for approval
52. Oral review IV (if necessary)
53. Final report received with recommendations for corrections
54. Final report distributed

Figure 5. Program Milestones.

3. EVALUATION OF NO_x MONITORS - PHASE I

In Phase I, Monsanto Research Corporation with the cooperation of Stevenson, Jordan and Harrison, Management Consultants, Inc., a subcontractor, completed the following tasks:

(1) Survey of nitrogen oxide monitor manufacturers and users by phone and personal interview.

(2) Formulation of instrument specifications and performance criteria.

Performance of this survey was pursuant to Bureau of the Budget clearance #158-S71010, 21 June 1971.

3.1 SURVEY OF NITROGEN OXIDE MONITOR MANUFACTURERS AND USERS

The subcontract report from Stevenson, Jordan and Harrison (S,J&H) is presented as Appendix I of this report. The portion of the survey program regarding nitrogen oxide monitor manufacturers was largely in the format of completed interview guides and was abstracted for use in Volume I of this report. A complete alphabetized list of companies contacted in this survey is presented in Table I and repeated in Appendix I.

The S,J&H approach to the survey was conducted in the following stages:

For NO_x Monitor Manufacturers

(1) All firms concerned with NO_x monitor manufacture were identified on the basis of trade literature, directories of firms, and the scientific literature.

(2) Printed material or brochures were requested describing NO_x instrumentation available from each manufacturer. Information requested included:

Specifications
Installation instructions
Sampling and pretreatment requirements
Operation and maintenance manuals including information on the electronic circuits
Other information such as customer listings, typical installations, test studies, etc.

(3) After analysis of the collected information in light of the needs of the program, manufacturers were contacted by phone to supplement the information.

Table 1

ORGANIZATIONS CONTACTED

Company	Location
Aero Chem Company	Princeton, N.J.
Aero Vac Corp	Troy, N.Y.
American Electric Power	New York, N.Y.
American Optical Corp.	Southbridge, Mass.
Atlas Electric Devices	Chicago, Ill.
Antek Instruments, Inc.	Houston, Texas
Automated Environmental Systems	Woodbury, N.Y.
Babcock & Wilcox	Barberton, Ohio
Bacharach Instrument Co.	Mountain View, Calif.
Baird Atomic, Inc.	Bedford, Mass.
Baltimore Gas & Electric	Baltimore, Md.
Barnes Engineering	Stamford, Conn.
Barringer Research	Rexdale, Ontario, Canada
Batelle Memorial Institute	Columbus, Ohio
Beckman Instruments	Fullerton, Calif.
Bendix Corp.	Ronceverte, W. Va.
Bendix Corp.	Baltimore, Md.
Bendix Corp.	Rochester, N.Y.
Bristol Div. of ACCO	Waterbury, Conn.
Bureau of Mines	Pittsburgh, Pa.
California State Air Resources	Los Angeles, Calif.
Calibrated Instruments	New York, N.Y.
Combustion Engineering, Inc.	Windsor, Conn.
Curtin Scientific Co.	Houston, Texas
Davis Instruments	Newark, N.J.
Dept. of Water & Power	Los Angeles, Calif.
Devco Engineering, Inc.	Fairfield, N.J.
Dohrmann Instruments Co.	Mountain View, Calif.
E. I. duPont de Nemours & Co.	Wilmington, Del.
Dynasciences Corp.	Chatsworth, Calif.
Dynasciences Corp.	Los Angeles, Calif.
EnviroMetrics, Inc.	Marina Del Rey, Calif.
Environment/One Corp.	Schenectady, N.Y.
Environmental Data Corp.	Monrovia, Calif.
Esso Research & Engineering	Linden, N.J.
Fisher-Porter Co.	Warminster, Pa.
Foster-Wheeler Corp.	Livingston, N.J.
Foxboro Co.	Foxboro, Mass.
GCA Corp.	Bedford, Mass.
General Electric	Schenectady, N.Y.
Gelman Instrument Co.	Ann Arbor, Mich.
Gelman Instrument Co.	Van Nuys, Calif.
Hewlett-Packard	Palo Alto, Calif.
Honeywell Industrial Div.	Fort Washington, Pa.

Company	Location
Inter-Tech	Princeton, N.J.
Ionics, Inc.	Watertown, Mass.
Jarrell-Ash	Waltham, Mass.
Jarrell-Ash	Pittsburgh, Pa.
Kaman Science Corp.	Colorado Springs, Colo.
Kem-Tech Laboratories, Inc.	Baton Rouge, La.
Leeds & Northrup Co.	North Wales, Pa.
Litton Environmental Systems	Camarillo, Calif.
Litton Industries, Inc.	Minneapolis, Minn.
Mast Development	Davenport, Iowa
Melpar	Falls Church, Va.
Mine Safety Appliances Co.	Pittsburgh, Pa.
Monsanto Research Corp.	Dayton, Ohio
National Environmental Instruments	Fall River, Mass.
Nuclear-Chicago	Des Plaines, Ill.
Pacific Electric & Gas	San Francisco, Calif.
Panametrics	Waltham, Mass.
Perkin-Elmer	Norwalk, Conn.
Philips Electronic Instruments	Mt. Vernon, N.Y.
Pollution Control Industries, Inc.	Stamford, Conn.
Pollution Monitors, Inc.	Chicago, Ill.
Precision Scientific Co.	Chicago, Ill.
Research Appliance Co.	Allison Park, Pa.
Research-Cottrell	Bound Brook, N.J.
Resource Control, Inc.	West Haven, Conn.
Riley Stoker	Worcester, Mass.
San Diego Gas & Electric	San Diego, Calif.
Scientific Gas Products, Inc.	Edison, N.J.
Scientific Industries, Inc.	Mineola, N.Y.
Scott Aviation	Lancaster, N.Y.
Southern California Edison	Los Angeles, Calif.
Technicon	Tarrytown, N.Y.
Tracor, Inc.	Austin, Texas
Tyco Labs	Waltham, Mass.
Union Carbide Corp.	White Plains, N.Y.
Universal Oil Products	Greenwich, Conn.
Walden Research Corp.	Cambridge, Mass.
Weather Measure Corp.	Sacramento, Calif.
Roy F. Weston, Inc.	West Chester, Pa.
Wilkens Anderson	Chicago, Ill.
Wilks Scientific Corp.	South Norwalk, Conn.
Zurn Industries	Erie, Pa.

(4) Personal interviews with selected manufacturers of NO_x instruments were conducted in the field using the Interview Guide for Manufacturers of Nitrogen Oxide Monitors form presented in Appendix I.

These manufacturers were selected on the basis of instrument technology, technological competence, commercial prominence, and other factors. These personal interviews provided information not readily obtainable by other techniques, such as information on research and development conducted by the manufacturer on improvement of existing instruments and on new instrument concepts, the identification of customers, significant installations of the manufacturer's instrumentation, technical information on operational characteristics, and the like.

For NO_x Monitor Users

(1) Locations employing NO_x instrumentation were identified from manufacturer's customer lists, and a phone survey of organizations such as power generating plants, engineering construction firms, pollution control manufacturers and consultants, etc.

(2) Information regarding existing NO_x monitoring installations was obtained by phone and mail in order to select NO_x monitor users to be included in a more detailed personal interview.

(3) Direct interviews were conducted in the field using the "Interview Guide for Users of Nitrogen Oxide Monitors" form presented in Appendix I.

The users experience with continuous nitrogen oxide monitor systems was found to be extremely limited compared to the installations for SO_2 monitoring. A number of utilities merely made facilities available to research organizations for experimental studies but did not actively participate in the testing or evaluation of the nitrogen oxide monitors. A summary of the user experience in NO_x monitors is included in Appendix I.

3.2 FORMULATION OF INSTRUMENT SPECIFICATIONS AND PERFORMANCE CRITERIA

Employing the results of the nitrogen oxide monitor manufacturer and user survey as input, instrument specifications and performance criteria were formulated. A panel of nine scientists and engineers was formed in order to:

- Establish NO_x monitor performance parameters
- Rank the selected parameters in order of importance
- Quantify acceptable parameter ranges

Five personnel from the Monsanto Research Corporation staff, two from Stevenson, Jordan and Harrison, and a representative of Dayton Power and Light Company attended the meeting in addition to Dr. Fredric Jaye the contract monitor.

The S,J&H attendees presented an NO_x monitor users consensus of the performance of three types of instruments in use at the nine locations interviewed to the date of the meeting.

It must be cautioned that (1) this information was derived from a small sample of NO_x monitor users, and (2) that the estimates include the user's bias due to sample pretreatment problems.

The meeting attendees selected 18 performance parameters for ranking. A list of the parameters was prepared as shown in Table 2 and each person ranked the order of importance of each parameter. In Table 3 the individual rankings of each attendee are listed. The first column entered in Table 3 is a ranking selection indicative of a typical control agency viewpoint, while the following nine columns are the individual selections of the nine attendees.

Finally, a consensus of the group was obtained as a result of further discussion. The final rankings are shown in Table 4 along with weighting factors (Q) derived by linear transformation of all parameters in a range from 1.0 to 0.5. (Q) is defined as

$$Q = (-0.03571)(\text{Performance Parameter Rank}) + 1.03571$$

Included in the last column of Table 4 are the quantified ranges of the performance parameters deemed acceptable by the group.

In the process of the discussion it was decided that the parameters auto calibration, self-zero and size and weight be omitted from the performance parameters due to eiter redundance or a lack of importance by consensus view.

The panel members represented a variety of technical disciplines including analytical and physical chemistry, physics, chemical and mechanical engineering, computer science and systems analysis. All panel members had been involved in the contract study for three months, and therefore had formulated a clear picture of the end-use application of the nitrogen oxide monitor.

The information in Table 4 represents the frame of reference against which the evaluation of alternate monitoring techniques could be conducted for applicability to continuous monitoring of stationary combustion sources.

Table 2

QUESTIONNAIRE FOR RANKING PERFORMANCE PARAMETERS OF A CONTINUOUS NO_x MONITOR OF STACK GASES

How Important are the Following Performance Parameters?

Rank in Decreasing Order:

1 - For the most important/desirable feature
2 - The next most important/desirable feature, etc.

_____ Ruggedness

_____ Response time and lag

_____ Size and weight

_____ Auto calibration

_____ Precision

_____ Accuracy (NO, NO_x)

_____ Self-Zero

_____ Repeatability

_____ Zero drift

_____ Routine operating maintenance

_____ Sensitivity

_____ H_2O interference

_____ SO_2 interference

_____ Particulate interference

_____ Temperature interference

_____ Calibration drift

_____ Repair (mean time to failure, time to repair, repair skills)

_____ Resolution

_____

Table 3

RANKING OF PERFORMANCE PARAMETERS BY THE ATTENDEES

Performance Parameter	A*	1	2	3	4	5	6	7	8	9
Ruggedness	15	14	7	16	1	15	10	6	9	15
Response Time & Lag	14	8	8	3	14	5	17	18	17	12
Size & Weight	16	18	15	18	18	16	18	17	18	18
Auto Calibration	11	3	12	8	15	14	16	9	12	14
Precision	2	16	16	4	16	18	7	10	14	4
Accuracy (NO, NO_x)	1	1	13	1	4	1	1	1	4	1
Self-Zero	12	4	11	14	17	13	15	11	11	13
Repeatability	4	2	5	5	5	2	6	13	13	3
Zero Drift	13	15	10	6	8	8	11	15	8	11
Routine Operating Maint.	17	6	9	17	6	7	9	8	1	16
Sensitivity	7	5	17	13	3	17	14	12	15	2
H_2O Interference	5	10	1	9	11	4	3	3	2	7
SO_2 Interference	6	11	4	10	13	3	2	4	3	8
Particulate Interference	8	9	3	11	7	11	4	2	6	6
Temperature Interference	9	17	2	12	10	10	5	6	5	9
Calibration Drift	10	12	14	7	2	9	12	14	7	10
Repair (mean time to failure, time to repair, repair skills)	18	7	6	15	9	6	8	7	10	17
Resolution	3	13	18	2	12	12	13	16	16	5

A* - Ranking indicative of a typical control agency viewpoint.

Table 4

RANKING, UTILITY FACTORS, AND RANGES OF THE PERFORMANCE PARAMETERS

Rank	Performance Parameter	Q	Range	
1	Accuracy	1.00	±2%	>10%
2	Repeatability	.964	±2%	>5%
3	H_2O (gas)(<14%)	.929	0	>5%
4	SO_2 (<3000 ppm)	.893	0	>5%
5	Particulate (<20 grains/ft^3)	.857	0	>5%
6	Zero-Drift	.821	0	>5%/24 hours
7	Calibration Drift	.786	0	>5%/24 hours
8	Routine Maintenance	.75	1	>4 man-hours/week
9	Ruggedness (electro-mechanical)	.714	.95	.01
10	Temperature & Pressure (±10% & ±2%)	.679	0	>5%
11	Repair	.643	0	>5 incidents/year
12	Resolution (10% full scale change)	.607	1%	>5%
13	Precision	.571	1%	>5%
14	Sensitivity	.536	minimum input above noise	
15	Response Time & Lag	.50	5 sec	>3 min.

4. PHASE II - LABORATORY AND FIELD EVALUATION STUDIES

4.1 SELECTION OF NITROGEN OXIDE MONITORS FOR TEST

The survey of nitrogen oxide monitor manufacturers and users uncovered a number of advanced techniques that were either in the early commercial stage or the advanced development prototype stage. These techniques, which are described in the Volume I report, are listed as follows:

Chemiluminescent Emission - Monsanto Research Corporation
Aerochem Research Laboratories, Inc.

Correlation Spectroscopy - Barringer Research, Ltd.
Combustion Engineering Associates

Inverse Radioactive Tracing - Panametrics, Inc.

Selective Photoionization - Walden Research Corporation

On-Stack Absorption - Environmental Data Corporation

Efforts to obtain prototypes of these monitors for the evaluation test program were unsuccessful, since the monitors could not be made available for delivery in time for the 17 March 1971 test program initiation date.

The evaluation program was therefore restricted to studies on commercially available monitors or prototypes that could be assembled and pretested on the limited time scale. Seven instruments were procured by purchase or loan from instrument manufacturers or by loan from the contracting officer or Monsanto Research Corporation. The instruments selected for test are listed as follows by detection concept:

Nondispersive Infrared -

1. Intertech Corporation, Uras-2 with interchangeable components to adapt for NO analysis

2. Mine Safety Appliances Company, LIRA 200

3. Beckman Instruments, Inc., Model 315 Infrared Analyzer

4. The Bendix Corporation, UNOR 2

Nondispersive Visible and Ultraviolet -

5. duPont Company, Model 461 Photometric Analyzer

Electrochemical -

6. Dynasciences Corporation, Instrument Systems Division, Model NX-130 Air Pollution Monitor

7. EnviroMetrics, Inc., Series NS-200A with types 64H2 and 76H2 sensors.

Of these, the duPont instrument is not a truly continuous monitor, but functions on a 5 to 10 minute cycle to give NO_2 and NO_x readings. The nondispersive infrared monitors measure NO only, while the electrochemical monitors are designed to measure NO_x ($NO + NO_2$). The operational principles and reported performance characteristics of these monitors are presented in detail in Volume I of this report.

In addition to these nitrogen oxide monitors, a Digital Equipment Corp. PDP-12A computer with memory extension control and real time clock was obtained to facilitate acquisition of data from the instruments during the evaluation program.

4.2 NO_x MONITOR EVALUATION TEST FACILITIES

Very early in this study it became apparent to both Monsanto Research Corporation (MRC) and the National Air Pollution Control Association (NAPCA), now the Environmental Protection Agency (EPA), that two instrument test facilities would be required to obtain the necessary instrument performance data as listed in Table 4. Some parameters such as calibration drift, interferences, response time, and response lag, could be measured most easily under the closely controlled conditions that could be obtained in a laboratory facility. By contrast, parameters such as maintenance requirements, susceptibility to operational damage, and attention factors would be best defined under actual field operation. Thus, MRC prepared two test facilities for the NO_x Monitoring Instrument Evaluation Study.

The laboratory facilities were located in a controlled environment laboratory located at the MRC Dayton Laboratory. This laboratory had the necessary temperature and humidity controls to maintain any given environmental condition between 50°F to 90°F at relative humidities between 40% and 60%. The limitation on relative humidity (60%) was based on the size of the steam line feeding water vapor into the room. At lower temperatures (about 70°F) humidities up to 90% could be obtained.

The field test facilities were located on the roof of the Dayton Power and Light Tait Station. The proximity of the Tait Station to the MRC laboratory (~1 mile) facilitated movement of equipment and instruments from one location to the other.

4.2.1 Laboratory Test Facilities

The primary objective of the laboratory test facility design was to provide a system which would permit the evaluation of the following instrument parameters:

1. Accuracy
2. Calibration Drift
3. Precision
4. Sensitivity
5. Response Lag
6. Response Time
7. Reliability
8. Susceptibility to Environmental Changes

A secondary objective of this study was to interface the instrument output with the PDP-12 computer to obtain real-time data acquisition. A final objective was to provide some degree of automation by utilizing the PDP-12 computer to alter feed concentrations on a predetermined time cycle.

To meet these objectives the following criteria had to be met:

1. The facility must be capable of preparing a synthetic flue gas having a known, and variable composition.

2. The system shall be able to deliver a sample of this synthetic gas mixture to all instruments simultaneously.

3. The system should be able to operate continuously for extended periods without attention.

4. The system should provide for automatic "step" changes in NO concentrations in the synthetic gas mixtures.

5. The system should be designed to minimize specie reactions enroute to the instruments.

6. All effluent streams should be vented for personnel safety.

Approach to Test Design

A synthetic gas mixture would be prepared by separately metering the following compounds:

Compound	Chemical Symbol	Approximate Typical Vol %
1. Nitrogen	N_2	75.10
2. Carbon dioxide	CO_2	14.00
3. Oxygen	O_2	3.00
4. Nitric oxide	NO	0.05
5. Nitrogen dioxide	NO_2	0.05 (max.)
6. Sulfur dioxide	SO_2	0.30
7. Water	H_2O	7.50

Since a minimum of six continuous monitors were to be tested, and since each instrument typically uses about 2 scfh of sample, the quantity of synthetic gas to be used was at least 12 scfh. To allow for additional instruments and grab samples, plus a 50% safety margin, the flow rates of the gases would be set to deliver about 30-40 scfh of synthetic gas mixture. This large flow requirement precluded the possibility of using bottled gas mixtures for "routine operation."

Once the compounds were properly metered, precautions would be taken to prevent their degradation either by condensation or by reaction with other species. This would be accomplished by keeping potentially reactive species separate until they reached a mixing chamber just prior to a distribution manifold. Furthermore, all lines would be heated to about 300°F to prevent condensation.

The distribution system would consist of a primary distribution manifold, separate flow indicators for each instrument, manometers for each instrument and a back pressure control valve and manometer. The back pressure control valve and manometer as well as the flow indicators were necessary because some instruments were thought to be sensitive to either or both sample flow rate and sample pressure.

Schematic Layout of Laboratory Apparatus

Figure 6, Drawing No. B-007-010-ILO-0, is a schematic layout of the laboratory facilities used for the NO_x instrument studies. As discussed previously, the synthetic flue gas mixture was obtained by metering known quantities of high purity N_2, H_2O, CO_2, O_2, SO_2, NO and NO_2 into a mixing chamber. All flow rates were controlled by means of fine metering needle control valves and suitably sized rotameters provided visual indication of the individual flow rates. Flow regulators in the nitrogen and nitric oxide flow systems provided an extra margin of control for these

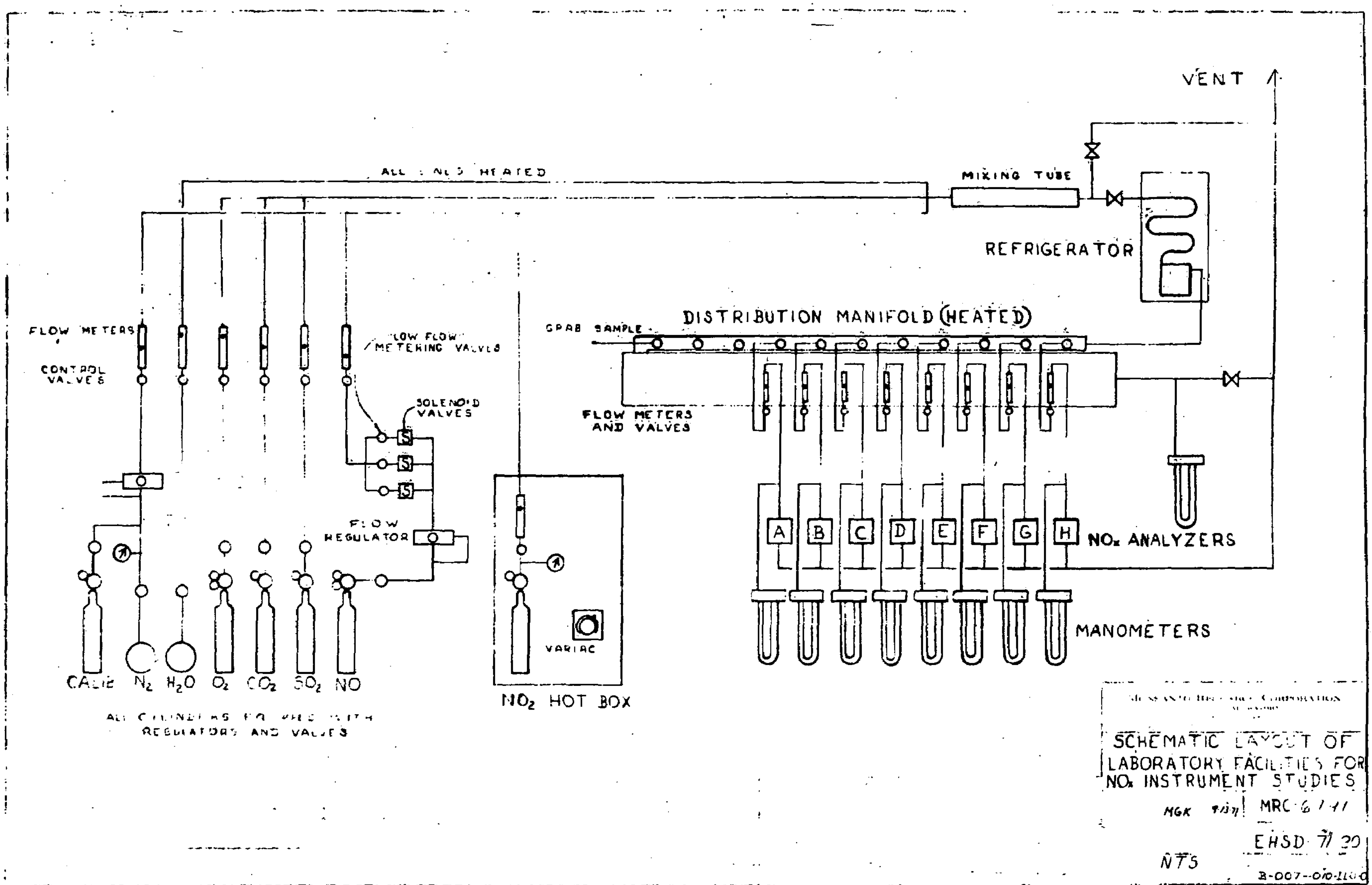

Figure 6. Schematic Layout of Laboratory Facilities for NO_x Instrument Studies.

gases. This was necessary for the following reasons: (1) the nitrogen flow rate was the highest of all flows and any slight change in the nitrogen flow rate would affect the composition of all gases significantly, (2) the flow of nitric oxide was the most critical of all flows since it was the compound of interest in this study.

Three solenoid valves, coupled with three preset "low flow" metering valves, were arranged in parallel in the NO feed system. The flow of NO would begin whenever one of the solenoid valves (normally closed) was actuated by a signal from the PDP-12 computer. Thus, three different concentrations of NO (in addition to zero) could be obtained at any time by means of a predetermined time cycle programmed into the computer.

With the exception of NO_2 and water, all the gases mixed in the feed systems were obtained from high pressure gas cylinders. For this study, the water was metered as a liquid and vaporized downstream of the rotameter. NO_2 was obtained in liquid NO_2 cylinders which exhibit very low vapor pressure at room temperatures. Thus a hot box was provided for NO_2. The hot box was electrically heated to 125°F. At that temperature, the vapor pressure of NO_2 is sufficiently high to facilitate flow control and metering as a gas.

All lines downstream of the rotameters were heat traced and insulated. The lines were maintained at about 300°F. To minimize the chance of chemical reaction between species enroute to the mixing tube, separate lines were used for gases which were known to be reactive. The mixing tube was a 2-inch diameter pipe, 2-feet long, packed with 1/4-inch Interlok Saddles. All indications were that the mixing tube performed satisfactorily.

Following the mixing tube, the gases were led through a refrigerator to remove water vapor. All of the NDIR instruments were very sensitive to water vapor and its removal from the gas stream was mandatory. Except during the H_2O interference testing, water was not fed to the system.

The refrigerator, which was supplied by Intertech, was maintained at about 1.0°C, which corresponds to an equilibrium water vapor pressure of about 5.0 mm Hg (∿0.8 Vol %).

The gases, after leaving the refrigerator, entered the distribution manifold which consisted of a 2-inch square primary distribution duct and an 8-inch square exit duct. The 2-inch square duct received the sample from the refrigerator and distributed samples of this gas to each instrument simultaneously through the appropriate valves and rotameters.

Extra ports were provided in the manifold for grab samples and any additional instruments which might be obtained at a later date. The excess gas leaving the 2-inch square duct traveled to the end of the manifold where it entered the 8-inch square duct. This duct was originally designed for the purpose of testing an "across the stack" monitor. The 8-inch duct was 10-feet long and had a removable plate on both ends. It was anticipated that the monitor and its receiver would be mounted on these plates. However, no such monitor was obtained during this contract so its ability to simulate a 10-foot diameter stack was never tested. The gas leaving the 8-inch duct passed through a suitable pressure control valve before venting to the outside. A water filled manometer was used to measure the back pressure on the distribution manifold.

Figure 7, Drawing No. B-007-012 -SkLO-0, is an exploded view of the 8-inch duct; and Figure 8, drawing No. B-007-011-MLL-0, is a detailed design drawing of the 2-inch and 8-inch ducts. The entire assembled manifold system was electrically heated by two 800-watt beaded heating coils and insulated with 1 inch (or more) of a low thermal conductivity (<0.8) insulating block. There were fifteen holes drilled and tapped for 1/4-inch pipe threads in the 2-inch duct. Twelve holes were provided in the front face and constitute the required sample tap openings. Three holes were provided on top of the 2-inch duct and these were used for thermocouples. Figure 9 shows the distribution manifold and several instruments as they were installed in the laboratory test facility. Other photographs of the laboratory test facility are shown in Figures 10 and 11.

4.2.2 Field Test Facilities

When this program was initiated, the primary objective of the field test facility was to provide a system which would permit the evaluation of the following instrument parameters <u>using untreated flue gas</u>:

1. Accuracy
2. Susceptibility to environmental changes
3. Sample loss and metering instability
4. Vibrational susceptibility
5. Reliability
6. Maintenance requirements
7. Susceptibility to operational damage
8. Attention factors

The above parameters were to be measured over extended periods to define the long term effects of actual field operation on the instruments. To meet this objective the following criteria had to be met:

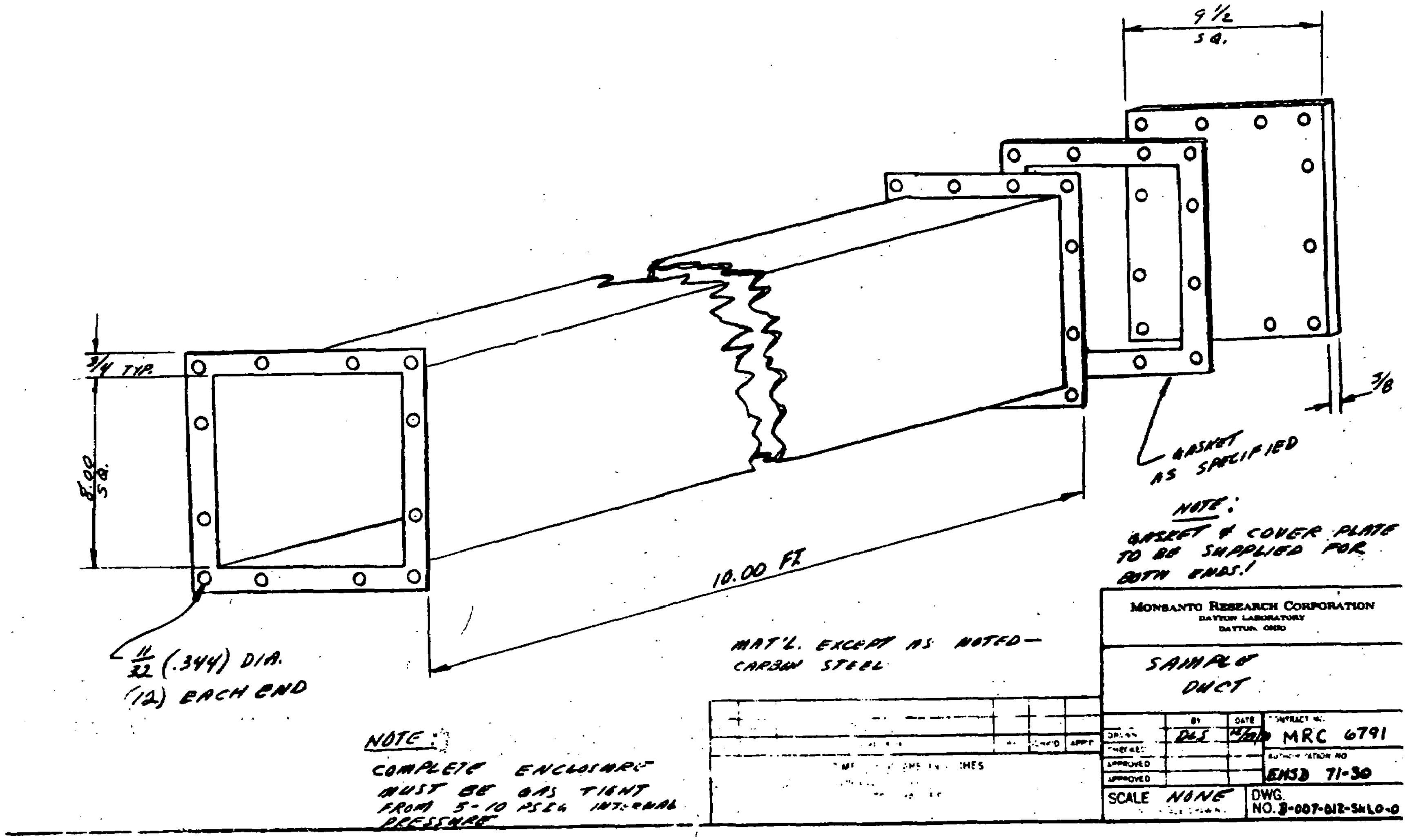

Figure 7. Sample Duct.

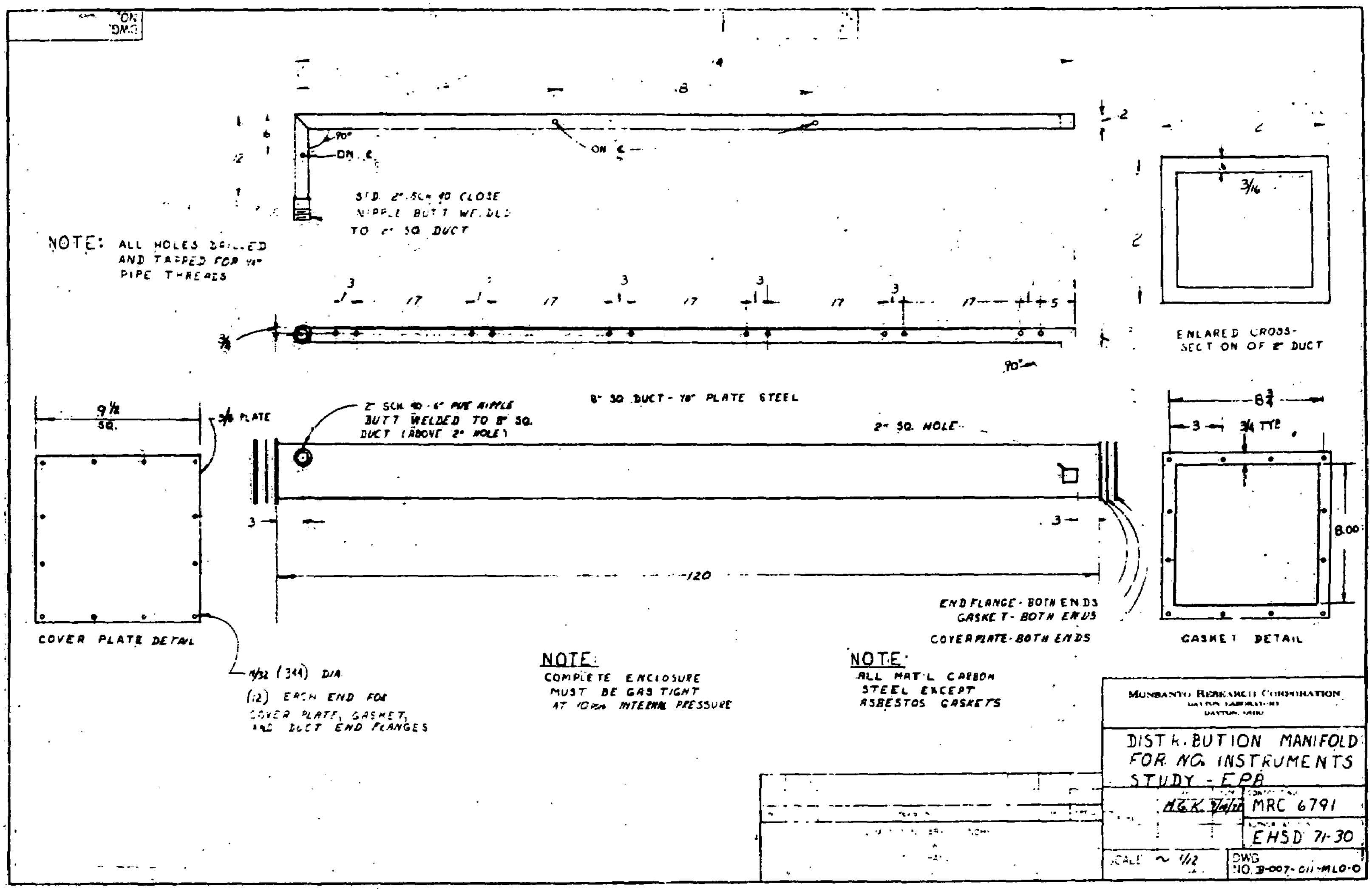

Figure 8. Distribution Manifold

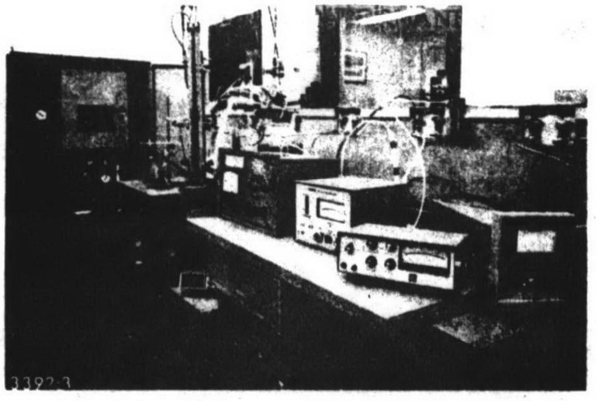

Figure 9. NO_x Laboratory Test Facility

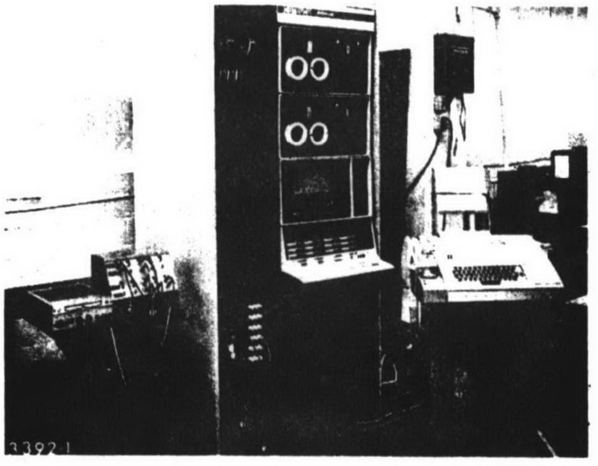

Figure 10. PDP-12A Digital Computer System

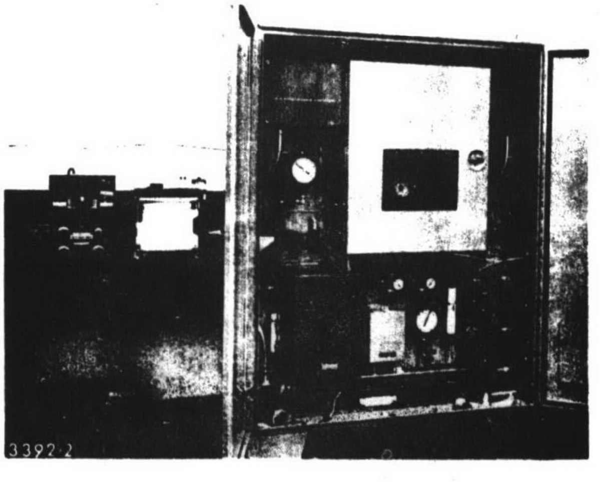

Figure 11. DuPont 461 NO_2/NO_x Analyzer

1. The system must be able to take a representative sample from the power plant duct work.

2. It must deliver the sample to the distribution manifold in an essentially unaltered form.

3. The instruments should be protected from the weather in a suitable enclosure.

4. The enclosure should be sufficiently large to permit easy access and mobility for personnel.

5. The shed should be insulated, lighted, and air conditioned.

Approach to Test Design

As the initial objective was stated, the field test facility was to deliver a "representative sample," "essentially unaltered," to every instrument. The sample delivered to each instrument would therefore contain appreciable quantities of fly ash and water vapor. Originally, the expectation was that each instrument manufacturer would provide his own sample pretreatment system. Only after much of the field test facility was installed, was it realized that the instrument manufacturers were not prepared to deliver sample pretreatment systems. Thus, it was necessary to "patch-on" a sample pretreatment system to the delivery system. The sample pretreatment systems that were tried are discussed later.

To meet the original objective, an excess of sample would be withdrawn from a convenient location in the flue gas duct work. This large sample would be transported from its point of origin to a conveniently located shed through an electrically heated and insulated 2-inch diameter Sch 40 pipe. A portion of this sample would be fed to the distribution manifold used in the laboratory tests; the remainder would be vented. Furthermore, by taking a large sample, the problem of maintaining sample gas temperature above 300°C was simplified.

The distribution system used in the laboratory studies was brought intact to the field test facility with the exception that the manometers measuring the pressure drop through the individual instruments were removed.

Schematic Layout of Field Test Facilities

Figure 12, Drawing No. A-007-008-IPO-0, is a schematic layout of the field test facilities as it existed at the end of the contract. In its original configuration there was no cyclone, H_2SO_4 scrubber, fiberglass filter or gas pump. A 1-inch diameter 316 stainless steel probe about 5 feet long was used to obtain

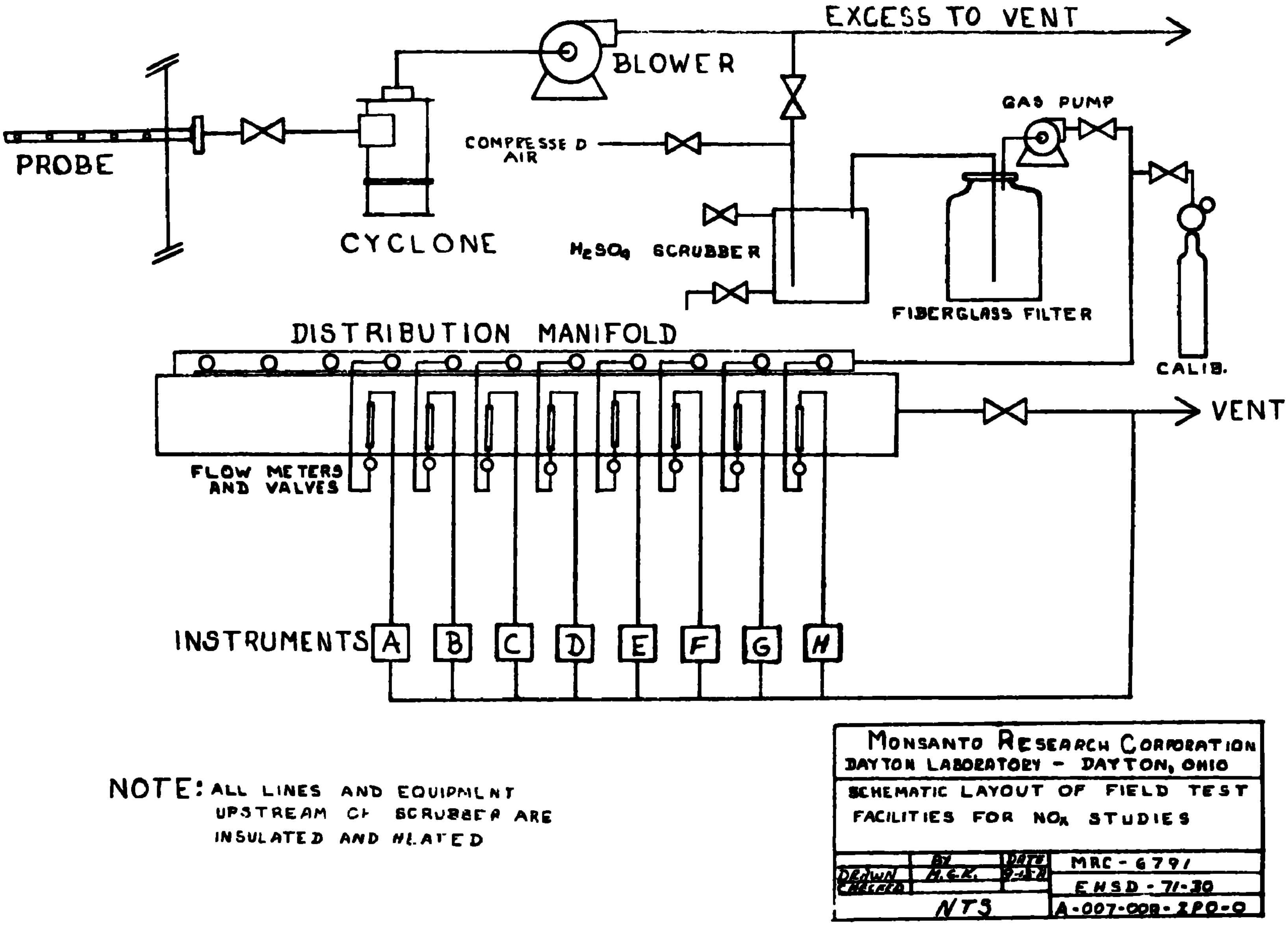

Figure 12. Schematic Layout of Field Test Facilities for NO_x Studies.

a sample from the duct work. The probe contained seven 1/2-inch diameter holes through which the sample entered. A high pressure blower delivered the sample (about 100 cfm) to a "TEE" located outside the instrument shed. A small sub-sample was withdrawn at this point and led to the distribution manifold; the remainder of the sample being vented.

Figure 13, Drawing No. A-011-007-APO-0, shows the top, front, and side views of the delivery line and blower installation. Samples could be drawn from either of two places atop the elevator shaft. These two places corresponded to the duct work leading to the I.D. fans from boilers No. 4 and 5 at the Tait Station. Thus, if either boiler was down, a sample could be obtained from the other. The two sample lines joined before entering the high pressure blower, also located atop the elevator shaft. The blower was capable of delivering 100 cfm of 300°F gas at an increase of 22-inches W.G. Since the sample points were at a negative 15-inch W.G., the effective pressure of the gas downstream of the blower was 7-inches W.G. The 2-inch diameter Sch 40 carbon steel delivery line carried the sample from the blower down to the Tait Station roof, about 32 feet below. All sections of the delivery line and blower were heated and insulated. The entire system was weatherproofed.

To suitably house the instruments, a 10-ft x 14-ft prefabricated steel shed was purchased and installed on the roof. Figure 14 is a picture of the power plant NO_x test facility showing the blower, delivery line and the exterior of the shed with a 23,000 Btu air conditioner installed in one of the doors.

Facilities included within the shed were: (1) six 40W fluorescent lights, (2) 1-inch styrofoam insulation on all walls, (3) 3/4-inch plywood flooring, (4) two 30-amp 230-volt circuits for the air conditioner and computer, (5) six 30-amp 110-volt circuits for the instruments and other accessories, (6) a telephone, and (7) three steel work benches. Figures 15 and 16 show the field test facility interior.

Sample Pretreatment Design

As mentioned earlier, the need to include a sample pretreatment system was revealed after much of the field test facilities had been installed. Therefore, the sample pretreatment system was not an integrally engineered section of the test facility, and was, in fact, an add-on system.

The first sample pretreatment system consisted of a combination of dust filter and refrigerator. A "home-made" dust filter was made by modifying a high efficiency air pure dust filter, type 7C-33-G, as shown in Figure 17, Drawing No. A-007-010-SKPO-1. This was installed downstream of the sub-sample valve and was

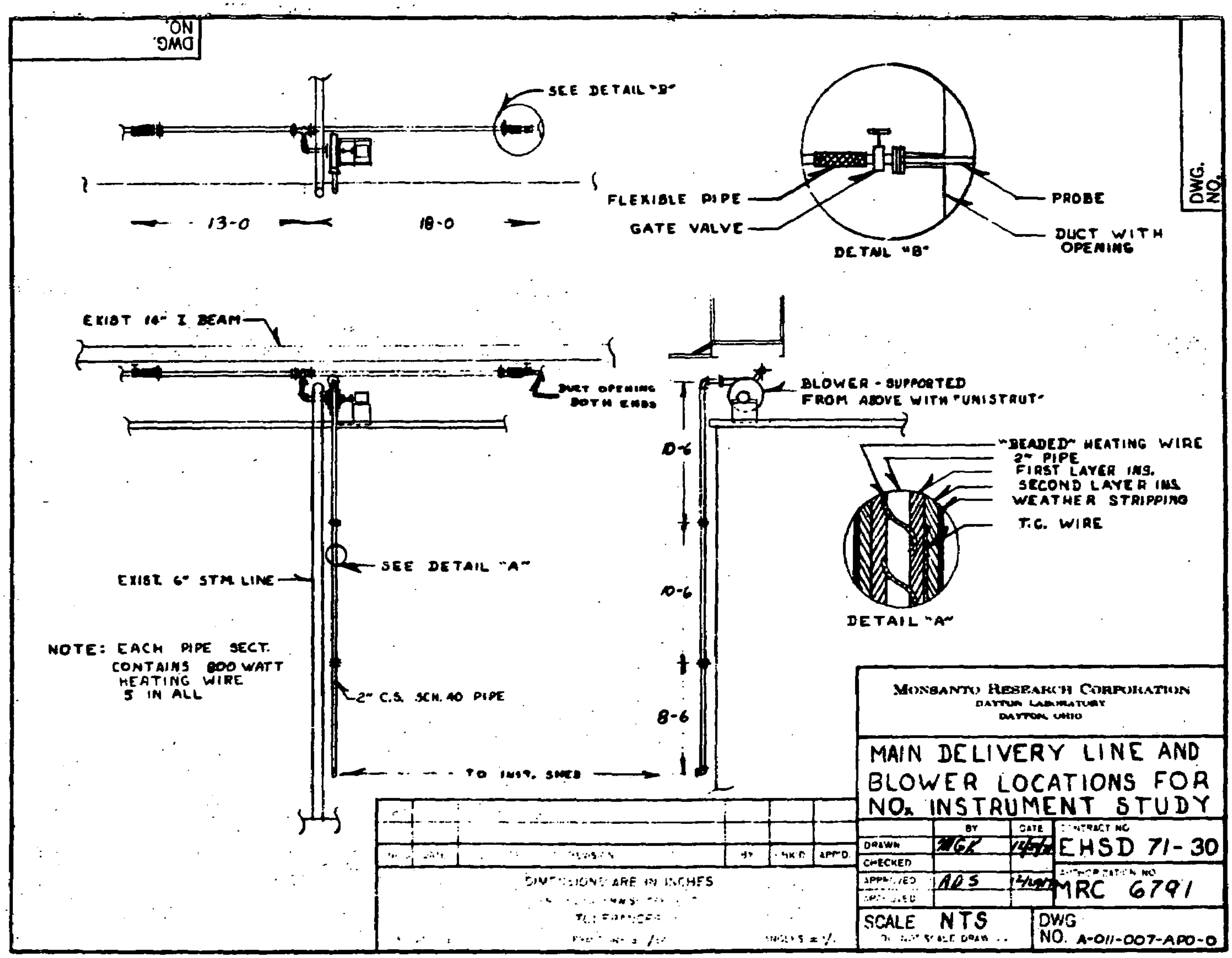

Figure 13. Main Delivery Line and Blower Locations for NO_x Instrument Study.

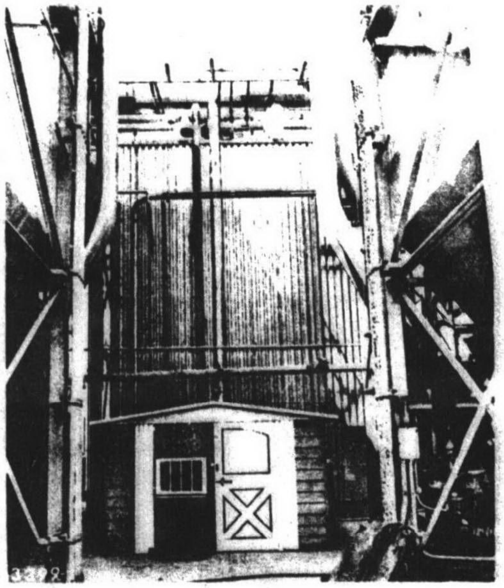

Figure 14. Power Plant NO_x Test Facility.

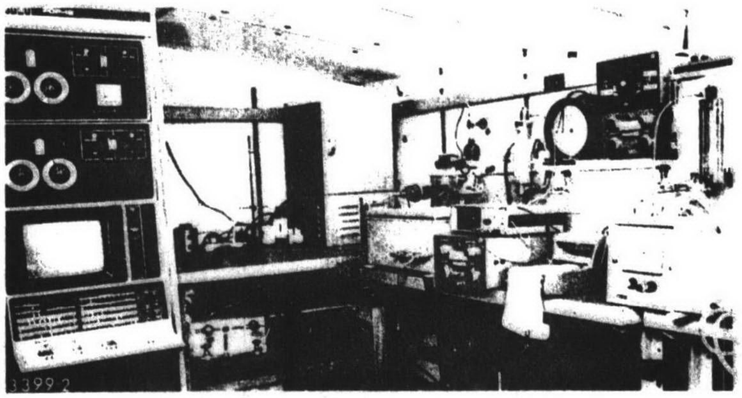

Figure 15. Field Test Facility Interior Showing Digital Computer and Instruments

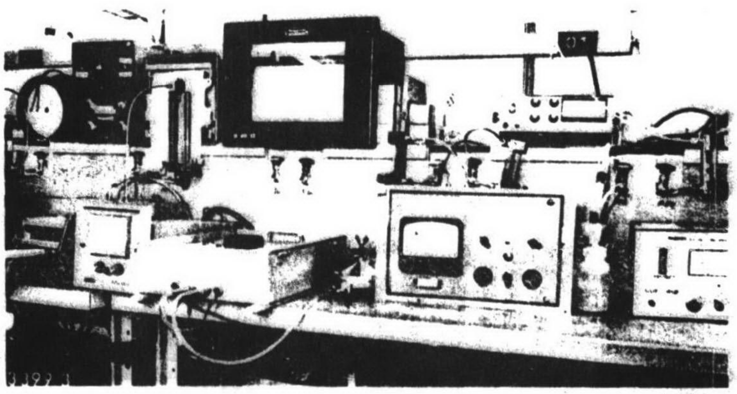

Figure 16. Field Test Facility Interior Showing NO_x Instruments

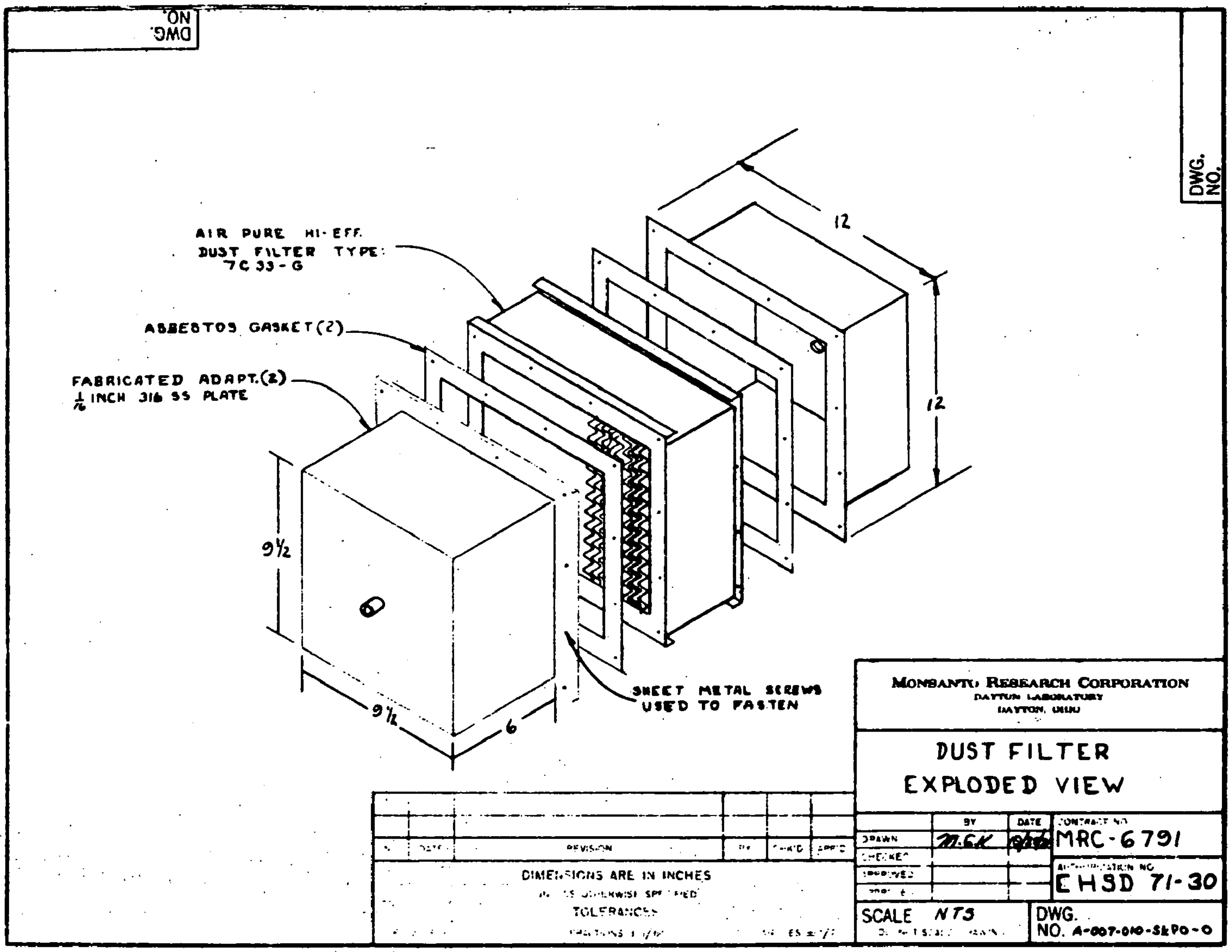

Figure 17. Dust Filter - Exploded View.

followed by the Intertech refrigerator used in the laboratory. With the increased pressure drop caused by these two pieces of equipment, the gas would not flow with sufficient volume to supply all the instruments. Thus, a booster gas pump was added to increase the flow.

This system quickly failed for the following two reasons: (1) the filter became clogged with a pasty material which we believed to be a combination of fly ash and sulfuric acid, and (2) enough moisture passed through the refrigerator even at 1°C to cause severe deviations in the NDIR instrument readings. Reversing the dust filter and the refrigerator was not considered on the basis that the condensing water would have trapped the fly ash, causing pluggage of the gas cooling coil.

Our next pretreatment system consisted of a 10-gallon sulfuric acid scrubber. We believed that the fly ash and water vapor would be removed in the sulfuric acid simultaneously. This system worked for a few days until the lines downstream of the acid scrubber plugged with fly ash.

Our third attempt to properly condition the sample resulted in the installation of a cyclone prior to the blower. The cyclone was made from a 55-gallon drum modified as follows:

1. A 7-inch diameter hole was cut into the top.

2. An adaptor from the 7-inch opening to a 2-inch diameter pipe was welded to the top.

3. A 7-inch square tangential entry port (with suitable adaptor) was welded into the side about 8 inches below the top.

4. The bottom was cut off and a removable bottom section was flanged to the bottom. This provided a method for removing fly ash without dismounting the cyclone.

To provide additional dust filtering capacity to the system, a "home-made" fiberglass filter was placed immediately after the acid scrubber. This system performed satisfactorily for several months. Unfortunately, handling sulfuric acid in any sizable quantity becomes dangerous and cumbersome and we recognize the need to find an improved pretreatment system.

4.3 LABORATORY EVALUATION TEST PROGRAM

In the laboratory testing phase, six continuous nitrogen oxide monitors were interfaced with a Digital Corp. PDP-12A computer for real-time data acquisition. The signals from each instrument were amplified so that a value of one millivolt at the computer corresponded to one part per million of nitric oxide in nitrogen gas diluent. The seventh monitor (DuPont 461 NO_2/NO_x ultraviolet analyzer) involved a time sequenced analysis which was not interfaced directly with the other instruments. This instrument was set to give a value of NO_x concentration on a ten-minute cycle and was employed as a reference instrument during the evaluation program.

In order to facilitate final data evaluation, a true value of NO_x concentration was required against which the continuous monitor readings could be compared. The primary standard selected to furnish this value was the phenol/disulfonic acid (PDS) analysis method. Sufficient PDS data were obtained in the laboratory and field tests to correlate the PDS analysis results with the DuPont 461 strip chart record. This record was then corrected by a factor (PDS/DuPont 461) and used as the true value for NO_x concentration. The choice of the DuPont 461 instrument as a reference was somewhat arbitrary and based on the following considerations:

a. The choice of some instrument which gave quasi-continuous readings was preferred to give real time comparisons which would not have been possible with the lengthy PDS analysis procedure.

b. The analysis of the number of PDS samples required would have resulted in an inordinate investment in equipment and time.

c. The correlations between the PDS analysis results and all the instruments was examined and the DuPont 461 analyzer was found to exhibit the most consistent relationship in the lab phases.

d. The DuPont 461 analyzer was the only unit equipped with automatic zero correction circuitry and exhibited a narrower reading to reading deviation than the other instruments.

The data comparing the PDS method with the DuPont 461 readings are presented in Table 5 where W refers to the PDS value and I refers to the 461 reading. Duplicates are shown where available followed by the average. Those readings marked with an asterisk were of questionable validity and were deleted from

Table 5

RESULTS OF WET CHEMICAL vs. DUPONT 461 ANALYSES

Run No.		Span Level 30% W	30% I	90% W	90% I	60% W	60% I
3		122.5	95	353.7	340	250.2	225
		95.1	99	407.5	345	150.8*	228
	Avg	108.8	97	380.6	342.5	250.2	226.5
4		84.9	95	366.7	315	267	230
		141.6	95	358.8	325	248.2	240
	Avg	113.3	95	362.7	320	257.6	235
5		100.9	90	390	305	287.1	220
		35.7*	-	263.3	310	235.4	223
	Avg	100.9	90	326.7	307.5	261.3	221.5
6		135.8	90	435.8	410	265.9	245
		67.7	-	426.7	-	275.9	-
	Avg	101.8	90	431.3	410	270.9	245
7		127	105	478.7	425	283.4	250
		96	-	163.9*	-	200.8*	-
	Avg	111.5	105	478.7	425	283.4	250
8		114.7	97	460.55	395	285.1	225
		114.3	-	-	-	281.4	-
	Avg	114.5	97	460.55	395	283.3	225
9		100.4	95	480.4	408	274.2	225
		65.9	96	462.7	410	276.3	228
	Avg	83.2	95.5	471.6	409	275.3	226.5

the averaging calculation. The data in Table 6a were generated by fixing the span level and calculating the correction factors F_i for each run

$$\frac{\text{Avg } W_i}{\text{Avg } I_i} = F_i \qquad \text{runs } i = 3, 4, \ldots, 9$$

then inputting them into a short statistical analysis program. The mean correction factors $\bar{F}^j$ (where j = 30, 90, 60% span) were then input into the same program to yield the overall correction factor $\bar{F}$, which along with other statistics is presented in Table 6b.

The selection of the DuPont 461 for this role was purely to facilitate the handling and analysis of the data and does not imply that it is a "secondary standard." In fact the consistent relationship derived from the comparison with the PDS analyses indicated that the unit reads some 12% low.

The major portion of the laboratory evaluation was directed toward testing of calibration drift, zero drift, accuracy and repeatability during nine, 17.5-hour tests at preset conditions of temperature and humidity. The PDP-12A computer was programmed to operate three solenoid valves in an automatic manner, thereby sequencing the nitric oxide concentration in nitrogen between zero, 150, 300 and 450 ppm (zero, 30, 60 and 90% of span).

The laboratory phase of instruments testing followed the basic sequence shown in Figure 18.

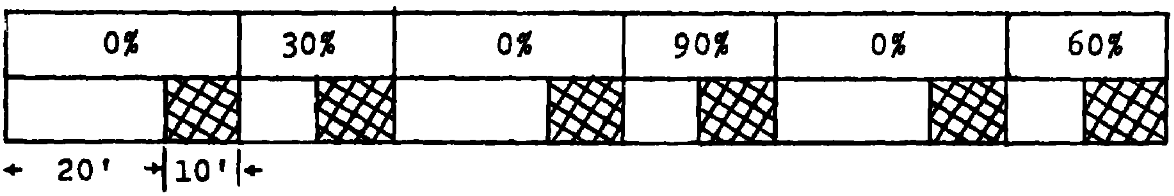

Figure 18. Time Sequence for One Test Replicate

One replicate consists of 30 minutes zero gas, 20 minutes 30% span gas, 30 minutes zero gas, 20 minutes 90% span gas, 30 minutes zero gas, 20 minutes 60% span gas. (Cross-hatched areas show when the computer was taking readings.) All 10-minute sampling periods were conducted as follows: the computer measured each instrument's output every 20 seconds for 200 seconds (3 min 20 sec). It then computed averages and variances for all instruments and stored these data on magnetic tape. Seven replicates comprised a complete experiment at one level of temperature and humidity.

Table 6a

RESULTS OF CORRECTION FACTOR CALCULATIONS FOR INDIVIDUAL SPANS

	Span Level		
	30%	90%	60%
Sample Size	7	7	7
Maximum	1.19263	1.16595	1.25911
Minimum	0.871204	1.05195	1.09617
Range	0.321427	0.113998	0.162941
Mean ($\bar{F}_j$)	1.09715	1.11483	1.15634
Variance	0.0117785	0.00188891	0.00399583
Standard Deviation	0.108529	0.0434616	0.0632126
Mean Deviation	0.0746239	0.0341414	0.0529237
Median	1.12165	1.12635	1.1336

Table 6b

RESULTS OF OVERALL CORRECTION FACTOR CALCULATION

Sample Size	3
Maximum	1.16
Minimum	1.1
Range	0.0599999
Mean ($\bar{\bar{F}}$)	1.12667
Variance	$9.33331E^{-4}$
Standard Deviation	0.0305505
Mean Deviation	0.0222222
Median	1.12

A summary of the data sheets is presented in Table 7. This summary contains the following information:

(a) Heading; gives the run number and describes the environmetal conditions for that run.

(b) In the left margin, reading from top to bottom, we have the instrument code*, replicate number and span level (%), respectively.

(c) Column 1, labeled AVG, is the grand mean of the three, ten-point, span-level averages (ppm NO_x) reported in the basic data output from the PDP-12.

(d) Column 2, labeled SD, is the standard deviation of the span-level, grand mean.

(e) Column 3, labeled ZERO, is the grand mean of the three, ten-point, zero-level averages, reported in the basic data output.

(f) Column 4, labeled SD, is the standard deviation of the zero-level, grand mean.

(g) Column 5, labeled 1-3, is the result of subtracting column three from column one, thus giving a value corrected for zero-drift.

(h) Column 6, labeled TV, gives the true value (DuPont 461 x 1.12), or actual concentration of nitric oxide, that the instruments were seeing.

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*The letter coded instruments are defined as:

A - Beckman Model 315A Infrared Analyzer

B - Mine Safety Appliance - LIRA Model 200 Infrared Analyzer

C - Dynasciences Corp. - NX 130 Electrochemical Transducer

D - EnviroMetrics, Inc. - Electrochemical Faristor™ Series NS-200A

E - Intertech Corporation - Uras-2 Infrared Analyzer

F - Bendix Corp. - UNOR-2 Infrared Analyzer

Table 7

SUMMARY OF LABORATORY TESTS OF NITROGEN OXIDE INSTRUMENTS
(Temperature and Humidity Variation)

RUN 1   70 DEG F   50 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	151.4	0.36	-2.9	0.35	154.3	161.5	-4.44	-6.28
	1	90	438.7	1.00	-2.7	0.40	441.4	501.7	-12.01	-12.56
		60	324.5	1.25	-3.2	0.56	327.8	344.6	-4.87	-5.82
		30	148.5	0.89	-3.0	0.73	151.0	0.0	******	******
	2	90	440.1	1.25	-2.9	0.60	443.1	0.0	******	******
		60	321.7	1.73	-3.9	0.34	325.6	0.0	******	******
		30	149.7	0.71	-4.0	0.17	153.3	0.0	******	******
	3	90	437.3	1.06	-3.7	0.49	441.0	0.0	******	******
		60	320.0	0.79	-3.5	0.58	323.6	0.0	******	******
		30	149.5	0.69	-3.6	0.50	153.1	0.0	******	******
A	4	90	441.4	1.64	-3.2	0.05	444.7	0.0	******	******
		60	319.8	1.35	-3.2	0.86	323.1	0.0	******	******
		30	151.1	0.66	-3.2	0.32	154.3	0.0	******	******
	5	90	440.4	1.66	-2.5	0.60	442.9	0.0	******	******
		60	318.5	0.94	-3.0	0.11	321.5	0.0	******	******
		30	150.7	0.46	-2.8	0.32	153.5	0.0	******	******
	6	90	442.8	1.54	-2.3	0.61	445.2	0.0	******	******
		60	317.5	0.55	-2.7	0.66	320.2	0.0	******	******
		30	151.1	0.64	-3.2	0.11	154.3	0.0	******	******
	7	90	442.9	1.49	-3.4	0.60	446.3	0.0	******	******
		60	314.7	1.85	-3.4	0.45	318.0	0.0	******	******
		30	157.5	0.53	16.2	0.26	141.2	161.5	-12.55	-2.5
	1	90	444.9	0.99	17.9	0.47	426.9	501.7	-14.89	-11.3
		60	327.3	0.88	16.5	0.79	310.8	344.6	-9.81	-5.0
		30	156.4	0.35	16.5	0.34	139.9	0.0	******	*****
	2	90	446.2	1.20	16.6	0.11	429.5	0.0	******	*****
		60	324.4	1.22	15.9	0.51	308.5	0.0	******	*****
		30	156.1	0.30	15.6	0.45	140.5	0.0	******	*****
	3	90	443.3	0.97	15.6	0.06	427.6	0.0	******	*****
		60	322.0	1.52	15.7	0.30	306.2	0.0	******	*****
		30	156.5	0.32	16.0	0.49	140.4	0.0	******	*****
B	4	90	442.4	1.11	15.9	0.45	426.4	0.0	******	*****
		60	318.0	1.17	14.0	0.30	303.9	0.0	******	****
		30	153.4	0.56	12.7	1.75	140.6	0.0	******	****
	5	90	439.7	0.83	13.1	0.96	426.5	0.0	******	*****
		60	314.9	2.51	13.6	0.86	301.2	0.0	******	*****
		30	152.3	1.39	12.9	0.45	139.3	0.0	******	*****
	6	90	442.1	1.46	12.6	0.98	429.5	0.0	******	*****
		60	311.4	1.93	11.3	0.45	300.0	0.0	******	*****
		30	149.9	1.47	9.7	0.23	140.1	0.0	******	*****
	7	90	437.3	1.92	9.2	0.83	428.1	0.0	******	*****
		60	305.8	1.55	9.5	0.41	296.3	0.0	******	******
		30	156.2	0.90	12.6	1.25	143.6	161.5	-11.09	-3.29
	1	90	452.8	1.34	12.9	0.43	439.9	501.7	-12.31	-9.74
		60	331.8	0.96	12.5	1.15	319.3	344.6	-7.33	-3.69
		30	157.3	1.22	11.3	0.55	146.0	0.0	******	******
	2	90	460.2	2.17	13.2	0.23	446.9	0.0	******	******
		60	336.0	0.66	14.5	0.30	321.6	0.0	******	******
		30	162.3	0.61	15.9	0.25	146.3	0.0	******	******
	[illegible]	90	465.7	1.66	18.8	0.77	446.9	0.0	******	******
		60	341.9	1.67	20.4	0.65	321.4	0.0	******	******
		30	169.8	0.73	23.7	0.66	146.1	0.0	******	******
C	[illegible]	90	475.1	2.51	25.4	0.21	450.6	0.0	******	******
		60	343.7	1.42	24.2	0.75	319.7	0.0	******	******
		30	172.5	0.46	26.5	1.53	146.0	0.0	******	******
	[illegible]	90	479.7	2.09	27.7	0.81	452.0	0.0	******	******
		60	349.6	0.85	[illegible]	0.93	318.0	0.0	******	******
		30	181.2	0.84	[illegible]	0.11	149.0	0.0	******	******
	[illegible]	90	486.5	1.64	34.0	0.91	454.4	0.0	******	******
		60	[illegible]	1.65	34.8	0.64	315.8	0.0	******	******
		[illegible]	[illegible]	[illegible]	34.1	0.25	147.7	0.0	******	******
	[illegible]	[illegible]	484.3	[illegible]	32.3	0.46	452.0	0.0	******	******
		[illegible]	[illegible]	[illegible]	[illegible]	0.46	313.6	0.0	******	******

RUN 1   70 DEG F   50 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	132.2	0.64	-9.6	0.15	141.9	161.5	-12.16	-18.12
	[illegible]	90	444.8	1.60	-10.5	0.58	455.4	501.7	-9.22	-11.32
		60	313.8	2.83	-12.2	0.36	326.0	344.6	-5.38	-8.92
		30	128.4	0.68	-13.1	0.10	141.6	0.0	******	******
	2	90	444.3	2.07	-13.2	0.37	457.5	0.0	******	******
		60	311.4	1.02	-13.3	0.11	324.7	0.0	******	******
		30	128.8	0.29	-13.5	0.20	142.4	0.0	******	******
	3	90	443.1	1.32	-12.9	0.45	456.0	0.0	******	******
		60	308.0	1.99	-13.3	0.40	321.4	0.0	******	******
		30	129.1	0.24	-13.5	0.20	142.7	0.0	******	******
D	4	90	444.7	2.12	-13.6	0.50	458.3	0.0	******	******
		60	304.2	0.98	-13.8	0.78	318.0	0.0	******	******
		30	128.5	0.29	-13.7	0.37	142.2	0.0	******	******
	5	90	441.5	1.89	-14.2	0.28	455.7	0.0	******	******
		60	304.2	1.08	-14.0	0.30	318.2	0.0	******	******
		30	129.0	0.48	-13.7	0.36	142.7	0.0	******	******
	6	90	443.2	2.09	-13.8	0.32	457.0	0.0	******	******
		60	300.2	1.39	-13.4	0.11	313.7	0.0	******	******
		30	130.3	0.78	-12.8	0.36	143.2	0.0	******	******
	7	90	435.7	2.01	-11.7	0.17	447.4	0.0	******	******
		60	297.3	0.93	-9.9	0.32	307.2	0.0	******	******
		30	0.0	0.00	0.0	0.00	0.0	161.5	******	******
	1	90	0.7	0.17	-0.0	0.05	0.8	501.7	-99.83	-99.84
		60	0.0	0.09	-0.0	0.05	0.1	344.6	-99.96	-99.97
		30	0.0	0.00	-0.0	0.05	0.0	0.0	******	******
	2	90	0.8	0.11	-0.0	0.05	0.8	0.0	******	******
		60	0.0	0.09	-0.0	0.05	0.1	0.0	******	******
		30	0.0	0.00	0.0	0.00	0.0	0.0	******	******
	3	90	0.8	0.05	-0.0	0.05	0.8	0.0	******	******
		60	0.1	0.11	-0.0	0.05	0.1	0.0	******	******
		30	0.0	0.00	-0.0	0.05	0.0	0.0	******	******
E	4	90	0.8	0.05	-0.0	0.11	0.9	0.0	******	******
		60	0.0	0.05	-0.0	0.05	0.0	0.0	******	******
		30	0.0	0.00	-0.0	0.05	0.0	0.0	******	******
	5	90	0.7	0.15	0.0	0.00	0.7	0.0	******	******
		60	0.0	0.05	-0.0	0.05	0.0	0.0	******	******
		30	0.0	0.00	-0.0	0.05	0.0	0.0	******	******
	6	90	0.6	0.26	-0.0	0.05	0.6	0.0	******	******
		60	0.0	0.05	-0.0	0.05	0.1	0.0	******	******
		30	0.0	0.00	-0.0	0.05	0.0	0.0	******	******
	7	90	0.6	0.30	-0.0	0.05	0.6	0.0	******	******
		60	0.0	0.05	-0.0	0.05	0.0	0.0	******	******
		30	117.2	0.40	-5.6	0.05	122.8	161.5	-23.96	-27.45
	1	90	432.0	1.38	-5.4	0.10	437.5	501.7	-12.78	-13.87
		60	303.6	1.06	-5.6	0.47	309.2	344.6	-10.26	-11.90
		30	116.1	0.49	-5.4	0.26	121.5	0.0	******	******
	2	90	434.6	1.49	-5.3	0.10	439.9	0.0	******	******
		60	301.1	1.41	-5.3	0.17	306.5	0.0	******	******
		30	116.3	0.54	-5.3	0.15	121.6	0.0	******	******
	3	90	431.9	1.33	-5.6	0.32	437.5	0.0	******	******
		60	302.7	1.03	-5.3	0.05	308.0	0.0	******	******
		30	119.1	0.45	-4.9	0.37	123.1	0.0	******	******
[illegible]	[illegible]	90	439.9	1.59	-5.0	0.26	445.0	0.0	******	******
		60	300.8	1.61	-5.0	0.32	305.9	0.0	******	******
		30	119.0	0.56	-4.8	0.35	123.9	0.0	******	******
	5	90	439.7	0.93	-4.6	0.32	444.3	0.0	******	******
		60	300.2	0.89	-4.8	0.11	305.1	0.0	******	******
		30	118.9	0.91	-4.6	0.26	123.6	0.0	******	******
	6	90	440.9	1.79	-4.9	0.55	445.7	0.0	******	******
		60	297.2	0.79	-4.8	0.11	302.0	0.0	******	******
		30	119.7	0.87	-5.3	0.47	125.0	0.0	******	******
	7	90	442.2	1.24	-4.8	0.35	447.0	0.0	******	******
		60	295.2	0.83	-5.1	0.30	300.4	0.0	******	******

Table 7 - (Cont'd)

RUN 2 — 70 DEG F — 60 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	149.8	0.55	-8.0	0.37	157.8	170.6	-7.49	-12.20
	1	90	435.2	1.12	-4.0	0.80	439.3	514.1	-14.54	-15.34
		60	311.8	1.08	-5.3	1.00	317.1	339.0	-6.44	-8.00
		30	149.9	0.33	-5.6	0.75	155.5	0.0	******	******
	2	90	429.8	0.91	-5.8	0.52	435.7	0.0	******	******
		60	309.4	1.30	-5.3	0.47	314.7	0.0	******	******
		30	148.3	0.55	-4.1	0.52	152.4	0.0	******	******
	3	90	427.9	1.08	-5.1	0.52	433.0	0.0	******	******
		60	306.3	0.80	-5.7	0.55	312.1	0.0	******	******
		30	148.1	0.92	-5.0	0.80	153.2	0.0	******	******
A	4	90	437.1	0.93	-7.3	0.26	444.5	0.0	******	******
		60	303.5	0.72	-8.1	0.45	311.7	0.0	******	******
		30	146.2	1.13	-7.8	0.43	154.0	0.0	******	******
	5	90	423.1	0.91	-8.5	0.56	431.6	0.0	******	******
		60	302.1	0.87	-7.2	0.40	309.4	0.0	******	******
		30	146.1	0.42	-8.6	0.25	154.8	0.0	******	******
	6	90	426.0	1.16	-8.7	0.80	434.8	0.0	******	******
		60	300.0	1.19	-8.1	0.50	308.0	0.0	******	******
		30	147.6	0.52	-6.9	0.55	154.6	0.0	******	******
	7	90	423.8	1.05	-7.7	0.30	431.6	0.0	******	******
		60	302.3	0.60	-7.7	0.47	310.0	0.0	******	******
		30	159.6	1.08	16.0	0.50	143.6	170.6	-15.78	-6.40
	1	90	438.0	1.35	18.5	0.45	419.4	514.1	-18.41	-14.80
		60	313.1	0.65	17.8	0.36	295.2	339.0	-12.90	-7.62
		30	157.3	0.62	16.5	0.35	140.7	0.0	******	******
	2	90	433.2	1.07	15.7	0.98	417.5	0.0	******	******
		60	309.9	1.88	15.6	0.76	294.2	0.0	******	******
		30	155.7	0.44	15.6	0.32	140.0	0.0	******	******
	3	90	434.9	0.87	15.6	0.25	419.2	0.0	******	******
		60	308.7	0.90	14.9	1.05	293.7	0.0	******	******
		30	154.8	0.69	14.6	0.36	140.1	0.0	******	******
B	4	90	444.5	0.97	14.1	1.41	430.4	0.0	******	******
		60	307.0	1.82	13.7	0.63	293.2	0.0	******	******
		30	154.4	0.82	13.1	0.40	141.2	0.0	******	******
	5	90	429.2	1.14	13.5	0.65	415.7	0.0	******	******
		60	303.7	1.20	13.3	0.15	290.4	0.0	******	******
		30	152.8	0.40	13.2	0.68	139.6	0.0	******	******
	6	90	431.5	1.28	12.4	0.20	419.1	0.0	******	******
		60	301.5	1.13	10.9	0.66	290.5	0.0	******	******
		30	152.6	0.89	12.2	1.00	140.4	0.0	******	******
	7	90	425.8	0.84	11.3	0.72	414.4	0.0	******	******
		60	301.3	0.72	10.7	0.39	290.5	0.0	******	******
		30	170.4	1.07	17.9	0.90	152.5	170.6	-10.62	-0.09
	1	90	465.8	1.63	22.7	0.52	443.0	514.1	-13.83	-9.39
		60	338.0	1.11	25.7	0.75	312.2	339.0	-7.84	-0.28
		30	172.8	0.55	24.9	0.15	147.9	0.0	******	******
	2	90	466.0	1.00	26.5	0.83	439.5	0.0	******	******
		60	337.1	1.90	28.7	1.00	308.3	0.0	******	******
		30	181.5	0.74	31.7	0.26	149.8	0.0	******	******
	3	90	485.8	1.32	40.7	1.05	445.0	0.0	******	******
		60	355.3	1.02	45.2	1.64	310.0	0.0	******	******
		30	196.7	0.49	49.9	0.21	146.8	0.0	******	******
C	4	90	499.0	0.99	50.6	0.55	448.3	0.0	******	******
		60	364.5	0.84	54.5	0.80	309.9	0.0	******	******
		30	205.5	0.82	55.9	0.56	149.5	0.0	******	******
	5	90	495.7	0.98	57.6	0.21	441.0	0.0	******	******
		60	369.9	0.75	61.1	0.70	308.7	0.0	******	******
		30	212.7	0.96	62.8	0.11	149.8	0.0	******	******
	6	90	499.0	0.99	63.6	0.11	435.3	0.0	******	******
		60	374.1	1.78	66.7	1.07	307.3	0.0	******	******
		30	216.9	0.55	67.8	0.73	149.1	0.0	******	******
	7	90	499.0	0.49	67.6	0.37	431.3	0.0	******	******
		60	379.0	[illegible]	67.1	0.20	311.8	0.0	******	******
		30	131.0	0.30	-12.6	0.23	143.7	170.6	-15.78	-23.18
	1	90	433.9	1.33	-11.2	0.15	445.2	514.1	-13.40	-15.58
		60	299.0	0.57	-10.6	0.51	309.7	339.0	-8.63	-11.78
		30	131.2	0.24	-10.5	0.36	141.7	0.0	******	******
	2	90	429.3	0.88	-12.5	0.15	441.8	0.0	******	******
		60	294.2	0.62	-9.6	0.66	303.8	0.0	******	******
		30	130.7	0.38	-9.5	0.17	140.2	0.0	******	******
	3	90	434.1	0.94	-7.6	0.10	441.8	0.0	******	******
		60	300.1	0.57	-6.0	0.50	306.2	0.0	******	******
		30	137.6	0.43	-3.0	0.86	140.6	0.0	******	******
D	4	90	436.9	1.14	-4.6	0.45	441.6	0.0	******	******
		60	297.8	0.78	-5.6	0.45	303.4	0.0	******	******
		30	134.7	0.25	-7.0	0.65	141.7	0.0	******	******
	5	90	431.6	0.85	-7.1	0.40	438.7	0.0	******	******
		60	294.9	0.59	-7.4	0.36	302.4	0.0	******	******
		30	134.5	0.43	-7.7	0.05	142.2	0.0	******	******
	6	90	435.3	1.69	-8.1	0.20	443.5	0.0	******	******
		60	293.7	0.56	-8.3	0.60	302.1	0.0	******	******
		30	134.2	0.34	-7.8	0.26	142.1	0.0	******	******
	7	90	430.7	0.98	-7.6	0.15	438.3	0.0	******	******
		60	294.9	0.95	-7.7	0.05	302.6	0.0	******	******
		30	0.0	0.00	0.0	0.00	0.0	170.6	******	******
	1	90	0.7	0.10	-0.0	0.05	0.8	514.1	-99.83	-99.84
		60	305.6	0.84	-0.0	0.05	305.7	339.0	-9.82	-9.83
		30	132.2	0.38	-7.8	0.00	140.0	0.0	******	******
	2	90	302.6	5.80	-6.7	1.28	309.4	0.0	******	******
		60	296.5	1.45	-4.5	0.55	301.0	0.0	******	******
		30	128.2	0.41	-6.4	0.60	134.7	0.0	******	******
	3	90	346.5	1.23	-6.9	0.60	353.5	0.0	******	******
		60	289.3	0.57	-6.4	0.20	295.7	0.0	******	******
		30	128.4	0.33	-5.9	0.30	134.4	0.0	******	******
E	4	90	327.9	0.74	-6.1	0.25	334.0	0.0	******	******
		60	291.4	0.99	-6.0	0.26	297.5	0.0	******	******
		30	131.1	0.24	-4.8	0.25	136.0	0.0	******	******
	5	90	362.6	1.57	-4.7	0.35	367.4	0.0	******	******
		60	289.7	1.12	-4.1	0.36	293.9	0.0	******	******
		30	131.3	0.30	-3.9	0.00	135.2	0.0	******	******
	6	90	354.2	4.93	-3.4	0.17	357.6	0.0	******	******
		60	287.6	0.79	-3.7	0.10	291.4	0.0	******	******
		30	131.0	0.34	-3.9	0.11	134.9	0.0	******	******
	7	90	373.0	5.88	-4.4	0.35	377.4	0.0	******	******
		60	288.3	1.00	-5.6	0.30	293.9	0.0	******	******
		30	120.4	0.27	-6.1	0.40	126.6	170.6	-25.74	-29.37
	1	90	430.0	0.79	-5.0	0.51	435.0	514.1	-15.37	-16.36
		60	292.4	0.66	-5.2	0.30	297.6	339.0	-12.19	-13.73
		30	119.7	0.35	-5.1	0.15	124.9	0.0	******	******
	2	90	427.3	0.80	-5.1	0.15	432.4	0.0	******	******
		60	292.2	1.17	-5.3	0.05	297.5	0.0	******	******
		30	117.3	0.58	-4.9	0.20	122.2	0.0	******	******
	3	90	424.4	0.81	-5.3	0.15	429.7	0.0	******	******
		60	284.8	0.92	-5.3	0.25	290.1	0.0	******	******
		30	118.1	0.29	-5.2	0.15	123.3	0.0	******	******
F	4	90	442.4	1.03	-5.1	0.20	447.6	0.0	******	******
		60	290.3	0.74	-4.9	0.20	295.2	0.0	******	******
		30	119.8	0.30	-5.3	0.10	125.2	0.0	******	******
	5	90	427.6	1.12	-5.0	0.40	432.6	0.0	******	******
		60	287.8	1.10	-5.0	0.28	292.9	0.0	******	******
		30	120.2	0.22	-5.4	0.20	125.6	0.0	******	******
	6	90	432.1	1.16	-5.3	0.00	437.4	0.0	******	******
		60	287.0	1.02	-5.4	0.28	292.4	0.0	******	******
		30	120.3	0.53	-5.3	0.10	125.6	0.0	******	******
	7	90	428.1	1.10	-5.0	0.26	433.1	0.0	******	******
		60	288.2	1.11	-5.1	0.11	293.3	0.0	******	******

Table 7 - (Cont'd)

			RUN 3		50 DEG F		50 PCNT HUMIDITY							RUN 3		50 DEG F		50 PCNT HUMIDITY			
INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2	INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	165.8	1.48	-2.0	0.32	167.9	0.0	******	******			30	142.0	0.49	-6.9	1.10	148.9	0.0	******	******
	1	90	491.6	2.20	3.2	0.11	488.3	0.0	******	******		1	90	490.1	2.49	-7.1	0.75	497.2	0.0	******	******
		60	317.8	1.33	3.0	0.75	314.7	0.0	******	******			60	297.1	0.89	-6.5	0.55	303.7	0.0	******	******
		30	162.2	0.85	4.4	0.96	157.7	0.0	******	******			30	137.3	0.31	-7.9	0.26	145.3	0.0	******	******
	2	90	449.9	2.67	4.5	0.45	445.3	0.0	******	******		2	90	443.3	2.04	-8.6	0.63	451.9	0.0	******	******
		60	319.7	0.82	7.6	0.05	312.1	0.0	******	******			60	303.4	1.94	0.0	0.25	303.3	0.0	******	******
		30	148.7	14.35	6.9	0.40	141.7	0.0	******	******			30	121.3	13.07	-7.5	0.70	128.8	0.0	******	******
	3	90	470.2	3.33	4.6	0.55	465.5	0.0	******	******		3	90	438.3	2.79	-12.9	0.58	451.3	0.0	******	******
		60	324.0	0.92	10.2	1.70	313.6	0.0	******	******			60	286.0	0.80	-14.6	0.62	300.6	0.0	******	******
		30	159.0	0.72	10.7	1.38	148.2	116.6	24.96	34.03			30	120.1	0.87	-17.7	0.60	137.8	118.6	16.16	1.22
A	4	90	410.0	1.33	9.3	2.41	400.7	384.2	4.30	6.74	D	4	90	388.4	1.62	-15.1	0.30	403.6	384.2	5.05	1.11
		60	285.4	0.59	10.7	2.00	274.6	254.2	8.03	12.27			60	253.7	0.79	-15.0	0.32	268.7	254.2	5.72	-0.20
		30	147.8	1.57	10.0	1.35	137.7	109.6	25.71	34.90			30	110.1	0.43	-17.5	1.10	127.7	109.6	16.56	0.53
	5	90	412.7	1.32	9.6	0.86	403.0	390.9	3.09	5.57		5	90	393.7	1.21	-19.0	0.40	412.7	390.9	5.56	0.69
		60	286.2	1.40	10.7	0.92	275.4	254.2	8.34	12.56			60	250.2	0.82	-21.6	0.73	271.9	254.2	6.95	-1.56
		30	147.6	0.69	10.1	0.68	137.4	111.8	22.88	31.96			30	104.4	0.96	-22.2	0.49	126.6	111.8	13.22	-6.64
	6	90	405.1	1.11	10.3	0.37	394.8	389.8	1.27	3.92		6	90	380.2	1.46	-22.9	0.15	403.2	389.8	3.44	-2.44
		60	282.0	1.05	2.4	0.30	279.6	285.8	-2.16	-1.32			60	248.8	0.79	-23.4	0.17	272.2	285.8	-4.76	-12.95
		30	142.3	0.44	4.7	0.35	137.5	103.9	32.32	36.91			30	104.8	0.20	-23.9	0.30	128.7	103.9	23.89	0.67
	7	90	413.4	1.14	3.0	0.17	410.3	392.1	4.64	5.43		7	90	393.6	1.83	-24.8	0.66	418.4	392.1	6.72	0.38
		60	282.4	0.65	3.3	0.28	279.1	0.0	******	******			60	246.5	0.58	-26.3	0.38	272.8	0.0	******	******
		30	165.1	0.69	14.3	0.26	150.7	0.0	******	******			30	140.1	0.52	-3.8	0.05	143.9	0.0	******	******
	1	90	487.5	2.65	18.0	0.47	469.4	0.0	******	******		1	90	140.1	12.98	1.9	0.15	138.1	0.0	******	******
		60	309.8	2.32	16.7	0.55	293.0	0.0	******	******			60	297.4	1.59	2.0	0.05	295.3	0.0	******	******
		30	160.3	0.29	16.9	0.40	143.3	0.0	******	******			30	138.8	0.38	1.9	0.65	136.9	0.0	******	******
	2	90	442.3	2.00	17.7	0.76	424.6	0.0	******	******		2	90	333.4	14.90	2.8	0.26	330.6	0.0	******	******
		60	309.4	1.20	17.8	1.78	291.5	0.0	******	******			60	298.6	0.60	2.0	0.05	296.5	0.0	******	******
		30	158.5	4.35	17.5	1.10	141.0	0.0	******	******			30	142.4	1.21	5.8	0.11	136.5	0.0	******	******
	3	90	462.7	1.60	17.5	0.50	445.1	0.0	******	******		3	90	226.5	19.16	5.9	0.17	220.5	0.0	******	******
		60	311.2	0.85	17.6	0.61	293.6	0.0	******	******			60	304.0	0.70	6.8	0.10	297.1	0.0	******	******
		30	151.8	1.64	14.7	1.17	137.1	118.6	15.60	27.99			30	134.1	0.31	4.4	0.55	129.7	118.6	9.36	13.07
B	4	90	399.4	1.59	17.3	1.19	382.1	384.2	-0.52	3.98	E	4	90	130.9	6.36	19.5	0.79	111.4	384.2	-70.98	-65.91
		60	274.4	1.23	17.2	0.87	257.1	254.2	1.14	7.95			60	335.0	0.79	66.5	0.27	268.5	254.2	5.60	31.77
		30	141.9	1.09	17.8	0.08	124.0	109.5	13.21	29.51			30	195.5	0.60	67.4	0.85	128.1	109.6	16.89	78.42
	5	90	404.2	0.82	17.8	0.30	386.3	390.9	-1.17	3.29		5	90	92.4	15.63	71.1	0.12	21.3	390.9	-94.53	-76.34
		60	276.1	1.39	17.7	0.86	258.4	254.2	1.63	8.60			60	342.4	0.71	72.4	0.47	270.0	254.2	6.22	34.70
		30	143.2	1.38	17.9	1.12	125.2	111.8	12.00	28.03			30	201.1	1.41	73.6	0.87	127.4	111.8	13.94	79.82
	6	90	396.9	1.08	17.2	0.90	379.6	389.8	-2.60	1.83		6	90	130.0	26.89	73.2	0.39	56.8	389.8	-85.43	-66.64
		60	277.1	1.00	17.2	0.26	259.9	285.8	-9.09	-3.07			60	343.7	1.15	73.3	0.96	270.4	285.8	-5.40	20.23
		30	143.5	0.38	18.9	0.37	124.9	103.9	20.20	38.03			30	200.2	0.66	74.1	0.13	126.0	103.9	21.29	92.63
	7	90	409.7	1.51	17.2	0.10	392.4	392.1	0.09	4.51		7	90	86.8	10.71	72.6	0.85	14.2	392.1	-96.36	-77.83
		60	276.9	0.53	16.8	0.69	260.0	0.0	******	******			60	344.3	1.00	74.1	0.13	270.1	0.0	******	******
		30	169.3	0.78	12.7	0.36	156.6	0.0	******	******			30	128.6	0.62	-5.6	0.23	134.3	0.0	******	******
	1	90	479.0	0.99	14.1	0.97	484.8	0.0	******	******		1	90	486.1	2.25	-3.7	0.20	489.8	0.0	******	******
		60	324.9	1.47	17.2	0.87	307.7	0.0	******	******			60	290.3	1.40	-4.0	0.30	294.4	0.0	******	******
		30	167.1	1.34	15.2	0.86	151.9	0.0	******	******			30	123.4	0.43	-3.7	0.10	127.2	0.0	******	******
	2	90	469.7	2.31	16.7	0.40	452.9	0.0	******	******		2	90	437.1	2.81	-3.6	0.20	440.7	0.0	******	******
		60	331.3	0.62	18.2	2.68	313.1	0.0	******	******			60	288.8	0.57	-3.8	0.15	292.6	0.0	******	******
		30	162.2	7.98	18.7	0.20	143.5	0.0	******	******			30	113.0	10.50	-3.9	0.40	117.0	0.0	******	******
	3	90	495.1	1.66	17.4	0.85	477.7	0.0	******	******		3	90	456.3	3.93	-3.8	0.25	460.2	0.0	******	******
		60	329.5	1.44	16.4	0.97	313.1	0.0	******	******			60	291.1	0.59	-3.7	0.11	294.8	0.0	******	******
		30	158.6	0.99	14.7	1.65	143.9	118.6	21.30	33.75			30	114.0	1.18	-4.7	0.70	118.8	118.6	0.12	-3.89
C	4	90	423.0	1.60	17.1	0.45	405.9	384.2	5.66	10.12	F	4	90	387.3	2.20	-3.7	0.20	391.1	384.2	1.82	0.83
		60	290.9	0.84	18.8	0.11	272.0	254.2	7.30	14.42			60	249.0	0.66	-3.9	0.17	252.9	254.2	-0.51	-2.05
		30	151.1	1.10	17.5	1.18	133.6	109.6	21.51	37.91			30	103.3	0.41	-3.9	0.20	107.2	109.6	-2.13	-5.72
	5	90	432.5	2.24	21.3	0.60	411.1	390.9	5.17	10.64		5	90	392.5	1.20	-3.8	0.20	396.3	390.9	1.37	0.39
		60	299.3	1.46	25.4	0.38	273.8	254.2	7.72	17.74			60	249.8	0.75	-3.6	0.11	253.4	254.2	-0.29	-1.72
		30	158.6	0.75	27.4	1.05	131.2	111.8	17.36	41.86			30	103.1	1.28	-3.4	0.43	106.6	111.8	-4.62	-7.75
	6	90	431.7	2.33	29.4	0.58	402.2	389.8	3.19	10.75		6	90	384.0	1.51	-3.6	0.11	387.7	389.8	-0.54	-1.48
		60	303.6	0.55	32.6	0.41	270.9	285.8	-5.21	6.19			60	250.8	0.89	-3.7	0.00	254.6	285.8	-10.93	-14.26
		30	163.6	0.96	31.4	0.41	132.1	103.9	27.16	57.40			30	103.7	0.28	-3.8	0.26	107.5	103.9	3.46	-0.18
	7	90	448.3	2.09	35.0	1.08	413.2	392.1	5.40	14.35		7	90	395.2	2.61	-3.7	0.26	399.0	392.1	1.78	0.81
		60	309.1	2.04	36.5	1.35	272.5	0.0	******	******			60	250.3	0.76	-3.4	0.20	253.8	0.0	******	******

Table 7 - (Cont'd)

RUN 4 — 70 DEG F — 40 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	134.5	0.55	-1.4	0.65	136.0	0.0	******	******
	1	90	380.3	1.61	2.3	1.18	378.0	0.0	******	******
		60	291.5	0.99	5.3	0.41	286.2	0.0	******	******
		30	138.8	0.65	5.3	1.77	133.5	0.0	******	******
	2	90	383.5	2.23	7.4	0.83	376.1	0.0	******	******
		60	289.6	6.31	7.8	1.80	281.7	0.0	******	******
		30	124.0	1.41	-8.6	1.37	132.7	0.0	******	******
	3	90	371.9	1.09	-8.8	0.69	380.8	0.0	******	******
		60	278.6	0.81	-9.6	0.70	287.3	0.0	******	******
		30	123.5	0.88	-9.4	0.60	132.9	0.0	******	******
A	4	90	369.8	1.59	-10.9	0.92	380.8	380.8	0.00	-2.87
		60	278.1	1.71	-10.1	0.35	288.2	265.5	8.55	4.72
		30	123.8	2.06	-7.9	0.17	131.8	101.6	29.62	21.76
	5	90	365.9	1.42	-7.0	0.30	373.0	364.9	2.20	0.27
		60	277.6	0.82	-5.7	0.32	283.3	265.5	6.70	4.55
		30	123.8	1.30	-7.1	0.75	131.0	101.6	28.81	21.76
	6	90	372.7	1.23	-9.3	1.06	382.1	369.5	3.42	0.89
		60	278.8	1.27	-6.4	2.13	285.3	264.4	7.90	5.46
		30	126.2	2.16	-7.8	1.90	134.0	105.0	27.56	20.11
	7	90	372.0	1.16	-8.1	0.72	380.1	367.2	3.50	1.30
		60	280.0	1.27	-5.4	2.59	285.4	262.1	8.90	6.83
		30	140.2	1.12	16.1	1.67	124.1	0.0	******	******
	1	90	381.9	1.59	19.5	0.26	362.3	0.0	******	******
		60	287.0	0.64	17.7	0.34	269.2	0.0	******	******
		30	139.2	0.50	18.7	0.26	120.5	0.0	******	******
	2	90	377.7	1.34	18.8	0.35	358.8	0.0	******	******
		60	287.6	0.74	18.2	0.25	269.4	0.0	******	******
		30	139.1	1.47	18.1	0.55	120.9	0.0	******	******
	3	90	377.0	1.51	18.7	0.50	358.3	0.0	******	******
		60	284.8	0.90	18.0	0.26	266.8	0.0	******	******
		30	137.5	0.51	17.7	0.32	119.8	0.0	******	******
B	4	90	375.7	2.21	17.0	0.50	358.7	380.8	-5.78	-1.31
		60	283.5	1.98	16.9	0.65	266.5	265.5	0.39	6.75
		30	136.3	0.69	16.4	0.61	119.8	101.6	17.89	34.05
	5	90	372.3	1.77	18.5	0.72	353.8	364.9	-3.04	2.02
		60	281.0	1.16	15.9	1.00	265.1	265.5	-0.16	5.84
		30	135.3	0.99	15.2	0.62	120.0	101.6	18.02	33.07
	6	90	375.5	0.87	15.1	1.05	360.4	369.5	-2.44	1.63
		60	280.3	1.62	13.9	0.81	266.3	264.4	0.74	6.01
		30	133.5	1.69	13.3	0.76	120.1	105.0	14.34	27.03
	7	90	372.3	0.77	13.3	0.20	359.0	367.2	-2.23	1.39
		60	278.8	1.99	13.4	0.60	265.3	262.1	1.21	6.35
		30	139.1	0.65	11.0	2.02	128.1	0.0	******	******
	1	90	394.2	1.35	6.4	0.97	387.8	0.0	******	******
		60	287.9	0.89	1.9	1.60	285.9	0.0	******	******
		30	127.6	0.70	-2.9	1.28	130.5	0.0	******	******
	2	90	389.3	1.72	-4.5	0.65	393.9	0.0	******	******
		60	286.2	1.45	-3.9	1.17	290.1	0.0	******	******
		30	124.0	1.51	-5.4	1.47	129.5	0.0	******	******
	3	90	384.7	2.12	-9.6	0.52	394.3	0.0	******	******
		60	281.5	1.13	-11.2	0.80	292.8	0.0	******	******
		30	118.7	0.75	-13.0	1.00	131.7	0.0	******	******
C	4	90	378.9	1.01	-16.0	0.55	395.0	380.8	3.74	-0.47
		60	275.3	2.03	-17.6	0.83	293.0	265.5	10.36	3.70
		30	112.5	1.47	-19.2	0.43	131.7	101.6	29.53	10.65
	5	90	376.2	1.29	-19.8	0.55	396.1	364.9	8.53	3.08
		60	279.4	1.32	-17.8	1.64	297.3	265.5	11.96	5.22
		30	127.3	0.91	-8.8	0.55	136.2	101.6	34.02	25.27
	6	90	399.7	1.79	-1.4	1.40	401.2	369.5	8.58	8.17
		60	295.9	1.44	3.5	1.12	292.3	264.4	10.55	11.91
		30	133.2	0.57	0.7	0.97	132.4	105.0	26.05	26.74
	7	90	397.1	3.45	0.1	0.79	397.0	367.2	8.12	8.13
		60	295.3	1.71	2.3	0.90	292.9	262.1	11.76	12.66

RUN 4 — 70 DEG F — 40 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	127.4	1.12	0.6	0.85	126.8	0.0	******	******
	1	90	394.8	2.23	18.6	1.15	376.2	0.0	******	******
		60	302.6	0.62	27.3	0.23	275.2	0.0	******	******
		30	151.2	0.38	30.3	0.81	120.8	0.0	******	******
	2	90	405.5	1.81	34.8	0.12	370.7	0.0	******	******
		60	308.2	1.84	36.9	0.20	271.2	0.0	******	******
		30	155.8	0.43	37.2	0.53	118.6	0.0	******	******
	3	90	408.7	1.68	40.3	0.40	368.3	0.0	******	******
		60	314.7	0.64	44.7	0.09	269.9	0.0	******	******
		30	165.5	0.45	47.2	0.21	118.3	0.0	******	******
D	4	90	415.2	2.27	51.1	0.31	364.1	380.8	-4.37	9.05
		60	321.7	1.07	54.5	0.12	267.1	265.5	0.60	21.16
		30	174.1	0.92	58.0	0.30	116.0	101.6	14.12	71.18
	5	90	420.3	1.13	60.7	0.11	359.5	364.9	-1.47	15.17
		60	326.2	1.24	61.4	0.19	264.8	265.5	-0.26	22.85
		30	178.9	0.59	62.9	0.14	115.9	101.6	14.02	75.97
	6	90	426.2	1.87	63.4	0.41	362.7	369.5	-1.82	15.35
		60	325.3	1.49	61.5	0.25	263.7	264.4	-0.23	23.03
		30	173.7	0.85	58.5	0.14	115.2	105.0	9.65	65.35
	7	90	418.0	1.70	56.4	0.57	361.5	367.2	-1.53	13.83
		60	317.8	1.46	54.0	0.53	263.7	262.1	.0.61	21.24
		30	154.6	0.91	31.5	0.07	123.0	0.0	******	******
	1	90	344.7	10.79	31.8	0.21	312.8	0.0	******	******
		60	308.3	0.69	31.2	0.18	277.0	0.0	******	******
		30	151.6	1.06	30.2	0.34	121.3	0.0	******	******
	2	90	359.0	9.78	29.8	0.59	329.1	0.0	******	******
		60	306.8	1.13	30.0	0.96	276.7	0.0	******	******
		30	130.3	1.32	-69.8	32.77	200.1	0.0	******	******
	3	90	447.2	9.02	-1.8	0.76	449.1	0.0	******	******
		60	280.2	37.05	-4.5	0.92	284.7	0.0	******	******
		30	107.3	0.23	-4.6	0.75	111.9	0.0	******	******
F	4	90	358.7	1.61	-5.0	0.45	363.7	380.8	-4.46	-5.78
		60	254.7	1.65	-5.4	0.64	260.1	265.5	-2.02	-4.07
		30	105.4	0.72	-6.3	0.52	111.7	101.6	9.93	3.73
	5	90	355.1	1.50	-6.5	0.61	361.7	364.9	-0.90	-2.70
		60	252.8	0.69	-6.4	0.46	259.2	265.5	-2.36	-4.78
		30	106.7	0.50	-5.8	0.20	112.5	101.6	10.68	4.94
	6	90	361.5	1.58	-5.6	0.17	367.2	369.5	-0.60	-2.14
		60	255.1	1.43	-4.6	0.17	259.7	264.4	-1.78	-3.52
		30	108.6	0.68	-4.1	0.05	112.7	105.0	7.33	3.37
	7	90	362.0	2.09	-3.9	0.00	365.9	367.2	-0.35	-1.42
		60	255.7	0.75	-3.3	0.26	259.0	262.1	-1.19	-2.45
		30	97.8	0.64	-4.8	0.45	102.7	0.0	******	******
	1	90	363.2	1.41	-5.1	0.23	368.4	0.0	******	******
		60	258.7	1.13	-5.5	0.20	264.3	0.0	******	******
		30	95.9	0.29	-5.6	0.20	101.6	0.0	******	******
	2	90	358.5	1.36	-5.4	0.15	363.9	0.0	******	******
		60	256.9	0.45	-5.6	0.20	262.5	0.0	******	******
		30	94.3	0.44	-5.9	0.28	100.2	0.0	******	******
	3	90	356.9	1.54	-6.0	0.37	362.9	0.0	******	******
		60	255.1	0.59	-6.2	0.40	261.3	0.0	******	******
		30	93.5	0.43	-6.2	0.23	99.8	0.0	******	******
F	4	90	356.0	1.99	-6.5	0.11	362.5	380.8	-4.78	-6.49
		60	253.3	1.60	-6.9	0.17	260.3	265.5	-1.95	-4.58
		30	91.6	1.16	-7.0	0.41	98.6	101.6	-2.98	-9.89
	5	90	351.9	1.06	-7.0	0.37	359.0	364.9	-1.64	-3.56
		60	250.9	0.65	-7.5	0.30	258.5	265.5	-2.65	-5.50
		30	90.9	0.67	-7.6	0.10	98.5	101.6	-3.04	-10.52
	6	90	356.4	1.62	-7.4	0.15	363.8	369.5	-1.53	-3.54
		60	251.5	1.03	-7.3	0.20	258.9	264.4	-2.07	-4.87
		30	91.4	1.55	-7.2	0.55	98.6	105.0	-6.11	-12.99
	7	90	355.2	1.54	-7.0	0.25	362.2	367.2	-1.35	-3.28
		60	251.5	0.88	-7.4	0.15	258.9	262.1	-1.20	-4.05

Table 7 - (Cont'd)

RUN 5 90 DEG F 40 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	139.1	0.46	4.1	0.50	134.9	102.8	31.21	35.27
	1	90	374.7	2.18	5.4	1.25	369.2	358.2	3.08	4.60
		60	285.4	1.05	5.1	1.10	280.2	254.2	10.24	12.27
		30	136.6	0.64	3.7	4.15	132.9	101.6	30.71	34.41
	2	90	378.3	1.91	4.8	1.76	373.5	353.6	5.61	6.96
		60	282.7	0.88	9.0	0.46	277.6	0.0	******	******
		30	136.9	0.61	5.6	0.17	131.3	101.6	29.17	34.67
	3	90	377.2	1.84	5.0	0.15	372.1	0.0	******	******
		60	283.8	0.74	5.8	0.37	277.9	0.0	******	******
		30	136.6	0.56	0.6	2.65	135.9	101.6	33.69	34.38
A	4	90	377.3	1.23	5.6	0.11	371.6	0.0	******	******
		60	277.5	1.76	-2.0	1.20	279.6	249.5	12.48	11.65
		30	130.4	1.82	-2.1	1.49	132.5	101.6	30.35	28.25
	5	90	371.3	0.99	-2.2	1.28	373.5	350.2	6.65	6.01
		60	275.5	1.69	-1.3	2.13	276.8	251.9	9.87	9.32
		30	128.4	1.18	-1.0	1.19	129.5	101.6	27.35	26.31
	6	90	377.5	1.65	-5.0	2.91	382.5	357.0	7.11	5.71
		60	276.9	0.64	-2.0	1.47	279.0	248.5	12.22	11.38
		30	130.9	0.87	-1.0	0.80	132.0	97.1	35.83	34.76
	7	90	379.3	2.38	-4.0	2.80	383.3	355.9	7.71	6.57
		60	276.9	1.29	-2.7	0.89	279.7	246.3	13.54	12.41
		30	133.5	0.41	14.8	1.79	118.7	102.8	15.46	29.89
	1	90	366.6	1.21	14.6	0.94	351.9	358.2	-1.73	2.36
		60	274.2	0.81	15.1	0.78	259.1	254.2	1.93	7.87
		30	131.0	0.73	13.7	0.35	117.2	101.6	15.27	28.81
	2	90	365.7	1.87	12.1	0.60	353.5	353.6	-0.02	3.39
		60	269.5	0.95	10.9	0.34	258.5	0.0	******	******
		30	128.2	0.41	10.1	0.66	118.1	101.6	16.15	26.12
	3	90	360.5	1.91	9.1	0.90	351.3	0.0	******	******
		60	266.5	0.98	8.2	0.34	258.2	0.0	******	******
		30	126.6	1.50	8.2	0.56	118.3	101.6	16.38	24.68
B	4	90	359.2	1.12	7.1	0.41	352.0	0.0	******	******
		60	263.7	1.58	6.1	0.52	257.5	248.5	3.62	6.11
		30	126.0	0.46	7.1	0.55	118.8	101.6	16.84	23.92
	5	90	356.6	1.46	5.6	0.76	350.9	350.2	0.19	1.80
		60	263.9	1.86	4.7	0.75	259.1	251.9	2.84	4.73
		30	124.9	0.33	5.2	0.05	119.6	101.6	17.69	22.87
	6	90	362.8	1.20	4.9	1.01	357.9	357.0	0.24	1.62
		60	262.5	0.98	5.0	0.55	257.4	248.5	3.56	5.61
		30	123.6	0.37	4.2	1.42	119.3	97.1	22.83	27.22
	7	90	364.5	2.29	3.4	0.49	361.0	355.9	1.44	2.41
		60	260.9	1.18	2.2	0.65	258.7	246.3	5.03	5.93
		30	155.0	0.96	15.5	1.70	139.4	102.8	35.62	50.76
	1	90	422.1	2.31	27.4	0.85	394.6	358.2	10.17	17.85
		60	324.5	2.08	32.0	0.30	292.4	254.2	15.01	27.64
		30	168.6	0.83	34.5	0.72	134.1	101.6	31.92	65.84
	2	90	432.8	1.59	35.4	1.43	397.3	353.6	12.35	22.39
		60	331.3	0.87	36.0	1.08	295.2	0.0	******	******
		30	178.8	0.45	42.9	0.61	135.9	101.6	33.72	75.90
	3	90	445.2	2.33	46.4	1.24	398.7	0.0	******	******
		60	338.9	0.92	48.2	0.91	290.6	0.0	******	******
		30	156.8	1.82	30.9	4.11	125.9	101.6	23.82	56.27
C	4	90	423.9	2.11	20.5	0.80	403.4	0.0	******	******
		60	315.5	1.63	21.8	1.04	293.5	248.5	18.10	26.91
		30	154.5	1.01	17.6	0.86	136.8	101.6	34.41	51.98
	5	90	420.7	3.11	18.5	1.40	402.2	350.2	14.83	20.12
		60	309.7	1.21	16.3	0.43	293.3	251.9	16.43	22.94
		30	152.3	1.51	15.8	0.92	136.4	101.6	34.15	49.75
	6	90	428.7	1.74	16.4	0.90	412.3	357.0	15.48	20.08
		60	310.6	1.83	14.8	1.41	295.7	248.5	18.98	24.96
		30	154.8	0.80	17.2	2.02	137.5	97.1	41.55	59.36
	7	90	434.4	4.06	16.8	0.80	417.5	355.9	17.30	22.03
		60	319.0	1.06	20.7	1.07	298.2	246.3	21.09	29.52

RUN 5 90 DEG F 40 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	121.8	0.64	0.2	1.20	121.5	102.8	18.22	18.46
	1	90	372.5	2.27	16.6	1.00	355.9	358.2	-0.61	4.01
		60	285.2	0.81	27.7	0.07	257.4	254.2	1.25	12.17
		30	146.6	0.51	33.0	0.11	113.4	101.6	11.56	44.01
	2	90	389.0	2.05	37.1	0.12	351.9	353.6	-0.49	10.01
		60	294.9	0.66	39.2	0.16	255.6	0.0	******	******
		30	154.6	0.29	42.1	0.25	112.4	101.6	10.58	52.04
	3	90	394.2	2.20	44.5	0.71	349.7	0.0	******	******
		60	298.8	0.62	45.9	0.51	252.8	0.0	******	******
		30	156.6	0.45	43.8	0.35	112.8	101.6	10.94	54.04
D	4	90	397.6	1.13	45.5	0.47	352.0	0.0	******	******
		60	301.6	1.11	46.6	0.22	254.9	248.5	2.54	21.31
		30	161.3	0.99	47.5	0.32	113.7	101.6	11.86	58.60
	5	90	398.5	1.28	47.9	0.12	350.6	350.2	0.09	13.76
		60	301.8	0.98	49.2	0.57	252.6	251.9	0.25	19.79
		30	163.9	0.71	49.2	0.08	114.6	101.6	12.74	61.22
	6	90	408.9	1.48	51.3	0.10	357.6	357.0	0.16	14.54
		60	304.9	0.63	50.3	0.36	254.6	248.5	2.42	22.66
		30	166.7	0.54	52.6	0.17	114.1	97.1	17.47	71.64
	7	90	413.4	2.76	54.1	0.50	359.2	355.9	0.93	16.15
		60	309.4	0.71	55.1	0.22	254.2	246.3	3.23	25.62
		30	111.8	0.98	-1.2	0.17	113.0	102.8	9.92	8.75
	1	90	359.7	2.19	0.0	0.55	359.6	358.2	0.41	0.42
		60	254.9	0.88	0.1	0.32	254.7	254.2	0.21	0.26
		30	111.2	0.29	-0.0	0.19	111.3	101.6	9.50	9.40
	2	90	361.2	1.99	-0.0	0.11	361.3	353.6	2.17	2.15
		60	253.6	0.52	-0.1	0.11	253.7	0.0	******	******
		30	111.6	0.32	-0.1	0.17	111.8	101.6	9.93	9.73
	3	90	359.6	1.45	-0.1	0.15	359.7	0.0	******	******
		60	252.9	0.85	-0.1	0.32	253.0	0.0	******	******
		30	111.4	0.63	-0.1	0.45	111.6	101.6	9.83	9.63
E	4	90	360.8	1.35	0.0	0.17	360.7	0.0	******	******
		60	253.1	1.29	0.0	0.11	253.0	248.5	1.78	1.81
		30	112.4	1.09	0.1	0.05	112.3	101.6	10.48	10.61
	5	90	360.2	1.91	0.0	0.09	360.1	350.2	2.80	2.83
		60	255.8	0.79	2.0	0.40	253.7	251.9	0.70	1.53
		30	114.5	0.29	1.9	0.60	112.5	101.6	10.65	12.61
	6	90	369.1	1.94	2.1	0.45	367.0	357.0	2.78	3.38
		60	255.8	0.57	1.9	0.25	253.9	248.5	2.15	2.93
		30	115.5	0.27	2.3	0.20	113.1	97.1	16.48	18.88
	7	90	371.9	2.44	2.3	0.15	369.5	355.9	3.81	4.48
		60	256.5	0.72	2.5	0.37	254.0	246.3	3.12	4.15
		30	90.1	0.90	-7.7	0.05	97.8	102.8	-4.79	-12.34
	1	90	348.3	1.75	-7.6	0.26	355.9	358.2	-0.61	-2.73
		60	244.5	1.34	-7.8	0.26	252.3	254.2	-0.74	-3.80
		30	88.3	0.51	-7.9	0.23	96.2	101.6	-5.37	-13.17
	2	90	347.9	1.54	-8.1	0.25	356.0	353.6	0.67	-1.62
		60	242.8	0.77	-8.6	0.30	251.5	0.0	******	******
		30	87.6	0.19	-8.6	0.43	96.3	101.6	-5.27	-13.83
	3	90	345.5	1.63	-8.7	0.30	354.2	0.0	******	******
		60	241.1	1.02	-8.7	0.10	249.9	0.0	******	******
		30	87.2	0.60	-8.4	0.41	95.6	101.6	-5.89	-14.22
F	4	90	346.4	1.02	-8.7	0.25	355.2	0.0	******	******
		60	240.6	1.02	-9.8	0.15	249.4	248.5	0.36	-3.19
		30	87.1	0.77	-8.6	0.17	95.7	101.6	-5.83	-14.29
	5	90	344.2	1.37	-8.8	0.11	353.0	350.2	0.78	-1.74
		60	240.0	0.91	-9.0	0.11	249.1	251.9	-1.13	-4.73
		30	86.8	1.06	-9.0	0.32	95.8	101.6	-5.73	-14.65
	6	90	352.4	1.62	-8.7	0.11	361.2	357.0	1.17	-1.28
		60	239.4	0.89	-8.6	0.51	248.1	248.5	-0.17	-3.66
		30	86.7	0.49	-9.5	0.32	96.3	97.1	-0.87	-10.71
	7	90	355.0	2.12	-9.3	0.40	364.3	355.9	2.36	-0.25
		60	238.8	0.45	-9.4	0.32	248.3	246.3	0.80	-3.02

Table 7 - (Cont'd)

RUN 6 — 50 DEG F — 40 PCNT HUMIDITY

INSTR	REFP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	126.3	0.83	-6.3	0.40	132.6	0.0	******	******
	1	90	443.8	2.37	-4.7	0.41	448.5	0.0	******	******
		60	275.7	0.80	-3.0	0.58	278.8	0.0	******	******
		30	130.9	0.55	-2.2	0.30	133.2	0.0	******	******
	2	90	438.9	3.37	-4.4	1.11	443.4	0.0	******	******
		60	278.6	0.71	-4.1	0.72	282.7	0.0	******	******
		30	128.9	0.59	-5.1	0.32	134.0	0.0	******	******
	3	90	441.9	3.04	-5.7	0.30	447.6	0.0	******	******
		60	277.7	0.90	-5.9	0.81	283.6	0.0	******	******
		30	129.6	0.29	-4.8	0.83	134.4	0.0	******	******
A	4	90	439.9	3.03	-4.4	0.81	444.4	0.0	******	******
		60	277.1	1.42	-4.9	0.80	282.0	0.0	******	*****
		30	134.1	0.75	-3.9	0.91	138.0	0.0	******	*****
	5	90	457.3	4.34	-3.4	1.21	460.8	0.0	******	*****
		60	280.2	1.17	-3.7	0.66	283.9	254.2	11.67	10.2
		30	133.7	0.35	-2.2	0.26	136.0	109.6	24.07	21.9
	6	90	446.9	2.78	-1.4	0.32	448.3	477.9	-6.19	-6.5
		60	278.8	0.67	-2.0	0.95	280.9	276.8	1.47	0.7
		30	131.7	0.50	-3.6	0.40	135.3	116.3	16.33	13.2
	7	90	444.8	2.55	-4.8	0.45	449.6	477.9	-5.91	-6.9
		60	278.9	1.52	-5.8	0.52	284.8	276.8	2.88	0.75
		30	137.4	1.12	12.7	1.70	124.6	0.0	******	******
	1	90	454.4	2.37	16.3	2.05	438.1	0.0	******	******
		60	282.7	0.59	15.2	0.73	267.5	0.0	******	******
		30	140.1	1.77	18.0	0.62	122.1	0.0	******	******
	2	90	451.1	2.37	17.5	0.52	433.5	0.0	******	******
		60	285.1	1.16	18.4	1.05	266.7	0.0	******	******
		30	142.5	1.63	19.2	1.65	123.2	0.0	******	******
	3	90	455.3	2.75	18.2	1.73	437.1	0.0	******	******
		60	286.4	0.65	18.8	0.98	267.6	0.0	******	******
		30	142.8	0.71	18.6	0.80	124.2	0.0	******	******
B	4	90	452.2	2.63	19.1	0.85	433.0	0.0	******	******
		60	288.7	0.77	20.4	0.60	268.3	0.0	******	******
		30	143.4	1.23	19.4	0.95	124.0	0.0	******	******
	5	90	468.5	3.89	18.4	0.66	450.1	0.0	******	******
		60	285.1	1.65	18.2	1.40	266.9	254.2	4.98	12.15
		30	141.4	1.19	17.5	0.98	123.9	104.6	23.09	29.06
	6	90	455.5	2.69	17.7	0.20	437.7	477.9	-8.44	-4.69
		60	286.0	0.61	17.2	0.25	268.8	276.8	-2.89	3.32
		30	142.3	1.95	16.7	0.70	125.6	116.3	7.94	22.29
	7	90	455.7	2.84	17.5	0.70	438.2	477.9	-8.42	-4.66
		60	284.9	0.65	17.3	0.83	267.5	276.8	-3.34	2.91
		30	146.0	0.84	11.7	1.20	134.2	0.0	******	******
	1	90	491.8	2.99	15.5	1.05	476.2	0.0	******	******
		60	301.8	1.15	18.6	0.41	283.2	0.0	******	******
		30	150.7	0.94	19.7	1.27	131.0	0.0	******	******
	2	90	482.9	3.01	22.8	0.55	460.0	0.0	******	******
		60	305.5	0.87	22.8	1.20	282.6	0.0	******	******
		30	156.8	0.45	23.8	1.15	133.0	0.0	******	******
	3	90	489.7	3.68	27.9	0.98	461.7	0.0	******	******
		60	312.5	0.67	29.8	0.81	282.7	0.0	******	******
		30	164.3	0.62	- 32.8	0.68	131.5	0.0	******	******
C	4	90	492.2	6.94	34.1	1.40	458.0	0.0	******	******
		60	315.7	1.45	35.8	0.87	279.9	0.0	******	******
		30	159.0	1.84	33.1	2.49	125.8	0.0	******	******
	5	90	493.8	4.07	23.7	0.32	470.1	0.0	******	******
		60	284.1	1.36	7.8	5.17	276.2	254.2	8.65	11.76
		30	132.7	0.84	3.6	1.50	129.0	109.6	17.78	21.09
	6	90	463.5	3.25	1.9	0.32	461.5	477.9	-3.42	-4.01
		60	282.4	0.90	11.0	0.77	271.4	276.8	-1.89	2.02
		30	132.5	1.47	2.3	0.79	130.2	116.3	11.89	13.87
	7	90	467.2	3.24	0.6	0.20	466.5	477.9	-2.40	-2.25
		60	284.6	0.73	11.7	0.73	272.8	276.8	-1.45	2.79

RUN 6 — 50 DEG F — 40 PCNT HUMIDITY

INSTR	REFP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	88.2	1.03	-24.9	1.75	113.2	0.0	******	******
	1	90	412.8	2.77	-42.8	1.20	455.6	0.0	******	******
		60	219.8	0.84	-54.4	0.87	274.3	0.0	******	******
		30	60.8	0.28	-62.1	0.73	122.9	0.0	******	******
	2	90	395.8	3.29	-66.8	0.56	462.7	0.0	******	******
		60	209.8	0.57	-71.5	0.51	281.4	0.0	******	******
		30	53.0	0.27	-74.7	0.62	127.8	0.0	******	******
	3	90	395.9	3.14	-77.0	0.56	472.9	0.0	******	******
		60	205.4	0.42	-78.5	0.20	284.0	0.0	******	******
		30	48.9	0.29	-80.1	0.28	129.1	0.0	******	******
D	4	90	388.7	3.53	-81.8	0.32	470.5	0.0	******	******
		60	202.4	0.48	-82.5	0.52	285.0	0.0	******	******
		30	45.2	0.41	-84.3	0.38	129.6	0.0	******	******
	5	90	401.6	4.10	-86.6	0.29	488.3	0.0	******	******
		60	197.8	1.60	-86.8	0.15	284.6	254.2	11.97	-22.18
		30	46.1	0.76	-84.1	0.29	130.3	109.6	18.90	-57.91
	6	90	391.2	3.35	-79.7	0.20	470.9	477.9	-1.46	-18.15
		60	206.1	0.59	-77.2	0.19	283.3	276.8	2.35	-25.54
		30	53.9	0.61	-75.2	0.13	129.1	116.3	11.00	-55.66
	7	90	396.8	2.77	-75.5	0.47	472.3	477.9	-1.17	-16.97
		60	207.5	0.93	-76.3	0.24	283.8	276.8	2.53	-25.02
		30	117.1	0.50	1.7	0.25	115.3	0.0	******	******
	1	90	224.9	11.83	5.9	0.05	219.0	0.0	******	******
		60	267.6	0.55	7.5	0.10	260.0	0.0	******	******
		30	124.4	0.39	9.0	0.20	115.4	0.0	******	******
	2	90	243.9	18.31	11.5	0.20	232.3	0.0	******	******
		60	273.4	0.57	12.1	0.36	261.2	0.0	******	******
		30	128.8	0.28	13.5	0.23	115.3	0.0	******	******
	3	90	229.0	17.26	14.1	0.20	214.8	0.0	******	******
		60	277.4	0.66	15.0	0.41	262.3	0.0	******	******
		30	132.0	0.41	15.6	0.10	116.2	0.0	******	******
E	4	90	230.8	21.75	16.3	0.29	214.5	0.0	******	******
		60	279.8	0.55	16.5	0.15	263.3	0.0	******	******
		30	134.5	0.24	17.5	0.06	116.9	0.0	******	******
	5	90	146.7	15.86	17.8	0.55	128.8	0.0	******	******
		60	279.5	1.23	17.2	0.30	262.3	254.2	3.17	9.94
		30	132.1	0.72	16.2	0.32	115.9	109.6	5.79	20.60
	6	90	196.6	14.07	15.6	0.10	181.0	477.9	-62.12	-58.86
		60	278.8	0.64	15.8	0.40	262.9	276.8	-5.01	0.72
		30	133.0	0.73	15.7	0.06	117.2	116.3	0.75	14.27
	7	90	172.6	14.89	17.9	0.32	154.6	477.9	-67.64	-63.89
		60	283.2	0.82	18.5	0.17	264.7	276.8	-4.37	2.30
		30	98.1	0.86	-4.6	0.26	102.8	0.0	******	******
	1	90	450.9	3.04	-2.9	0.40	453.8	0.0	******	******
		60	259.5	0.51	-2.2	0.10	261.7	0.0	******	******
		30	102.9	0.54	-1.5	0.00	104.5	0.0	******	******
	2	90	444.4	3.30	-1.8	0.26	446.2	0.0	******	******
		60	261.5	0.62	-1.7	0.43	263.2	0.0	******	******
		30	104.5	0.96	-1.5	0.28	106.0	0.0	******	******
	3	90	449.3	4.00	-1.3	0.15	450.7	0.0	******	******
		60	262.4	0.59	-1.2	0.15	263.6	0.0	******	******
		30	105.8	0.55	-0.9	0.11	106.8	0.0	******	******
F	4	90	446.9	3.35	-1.2	0.40	448.1	0.0	******	******
		60	263.5	0.75	-0.9	0.49	264.5	0.0	******	******
		30	106.3	0.61	-0.9	0.73	107.3	0.0	******	******
	5	90	464.5	4.49	-0.6	0.32	465.1	0.0	******	******
		60	263.9	1.68	-0.8	0.41	264.8	254.2	4.16	3.82
		30	106.5	0.65	-0.8	0.49	107.3	109.6	-2.01	-2.80
	6	90	450.8	2.98	-0.8	0.17	451.7	477.9	-5.47	-5.66
		60	263.5	0.52	-1.1	0.30	264.6	276.8	-4.40	-4.79
		30	106.7	0.91	-1.2	0.25	107.9	116.3	-7.20	-8.29
	7	90	451.7	2.45	-1.1	0.23	452.9	477.9	-5.26	-5.47
		60	264.7	1.01	-0.9	0.43	265.7	276.8	-4.01	-4.37

Table 7 - (Cont'd)

RUN 7 50 DEG F 60 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	135.1	0.74	-3.7	0.10	138.9	115.2	20.56	17.27
	1	90	448.4	1.70	-0.4	0.80	448.9	479.1	-6.30	-6.39
		60	282.2	0.58	-1.9	0.45	284.2	274.5	3.52	2.79
		30	134.6	1.16	-2.0	0.11	136.6	114.1	19.77	17.99
	2	90	448.0	2.92	-2.0	0.20	450.1	480.2	-6.27	-6.69
		60	281.8	1.33	-2.2	0.80	284.0	275.7	3.03	2.21
		30	134.3	0.34	-2.0	0.62	136.4	113.0	20.79	18.93
	3	90	448.7	3.56	-1.5	0.43	450.3	480.2	-6.22	-6.55
		60	281.0	0.58	-2.3	0.83	283.3	276.8	2.36	1.51
		30	134.6	1.23	-3.2	0.30	137.8	116.3	18.45	15.67
A	4	90	449.1	3.00	-3.0	0.20	452.2	482.5	-6.28	-6.91
		60	281.8	0.83	-3.4	0.30	285.2	280.2	1.79	0.58
		30	133.4	0.46	-3.2	0.55	136.7	116.3	17.47	14.67
	5	90	450.5	2.63	-3.4	0.32	454.0	482.5	-5.90	-6.61
		60	281.9	0.72	-3.5	0.35	285.4	276.8	3.12	1.83
		30	134.1	0.66	-3.5	0.72	137.7	118.6	16.13	13.10
	6	90	450.2	1.98	-3.3	0.40	453.5	480.2	-5.55	-6.25
		60	282.9	0.93	-3.9	0.77	286.8	276.8	3.60	2.18
		30	135.3	0.68	-3.4	0.32	138.8	118.6	17.01	14.08
	7	90	454.5	2.16	-3.0	1.08	457.6	485.8	-5.82	-6.46
		60	253.2	1.41	-3.4	0.20	286.6	282.5	1.46	0.24
		30	142.0	0.68	15.3	1.51	126.7	115.2	9.95	23.25
	1	90	455.9	3.12	17.1	0.55	438.8	479.1	-8.40	-4.83
		60	285.5	0.79	16.8	0.55	268.5	274.5	-2.18	3.97
		30	141.8	0.71	16.6	0.11	125.1	114.1	9.69	24.30
	2	90	455.2	4.43	16.8	0.92	438.3	480.2	-8.71	-5.20
		60	283.5	0.72	15.9	0.43	267.5	275.7	-2.95	2.84
		30	139.8	0.65	14.2	0.61	125.6	113.0	11.17	23.80
	3	90	454.0	2.65	14.4	0.10	439.5	480.2	-8.47	-5.45
		60	281.3	0.59	15.0	0.47	266.3	276.8	-3.79	1.63
		30	139.6	1.30	14.1	0.62	125.4	116.3	7.76	19.97
B	4	90	452.1	3.76	14.1	0.20	437.9	484.5	-9.23	-6.29
		60	281.3	0.84	13.3	0.10	267.9	280.2	-4.37	0.40
		30	138.0	0.74	13.3	0.81	124.6	116.3	7.11	18.62
	5	90	452.6	2.92	12.7	0.35	439.9	482.5	-8.83	-6.19
		60	281.2	0.80	12.2	0.50	269.0	276.8	-2.83	1.58
		30	138.8	0.38	12.7	0.28	126.0	118.6	6.25	17.01
	6	90	451.9	2.19	13.0	0.20	438.8	480.2	-8.61	-5.89
		60	281.4	1.01	12.6	0.95	268.8	276.8	-2.88	1.66
		30	136.6	1.04	11.2	0.49	125.3	118.6	5.66	15.12
	7	90	451.6	1.94	10.8	0.92	440.8	485.8	-9.27	-7.04
		60	278.9	1.31	8.9	0.57	269.9	282.5	-4.44	-1.27
		30	152.3	1.79	17.7	2.74	134.6	115.2	16.77	32.16
	1	90	486.9	3.14	21.9	0.61	464.9	479.1	-2.94	1.63
		60	305.8	0.61	21.9	0.86	283.8	274.5	3.39	11.39
		30	153.7	0.52	22.6	0.73	131.0	114.1	14.86	34.70
	2	90	491.7	3.27	21.5	0.65	470.2	480.2	-2.08	2.39
		60	309.2	2.93	24.5	0.45	284.6	275.7	3.24	12.16
		30	158.7	0.64	28.5	0.52	130.1	113.0	15.16	40.47
	3	90	497.4	1.71	29.0	1.00	468.3	480.2	-2.48	3.57
		60	317.4	0.78	33.2	0.57	284.1	276.8	2.64	14.64
		30	167.8	1.18	35.4	1.16	132.4	116.3	13.81	44.25
C	4	90	499.0	0.99	38.4	0.49	460.5	482.5	-4.54	3.41
		60	326.3	0.73	43.1	0.24	283.1	280.2	1.05	16.44
		30	177.7	0.49	46.3	0.66	131.4	116.3	12.92	52.73
	5	90	499.0	0.99	47.3	0.22	451.4	482.5	-6.43	3.41
		60	334.1	2.00	51.5	0.55	282.6	276.8	2.08	20.70
		30	185.7	1.43	53.3	1.10	132.3	118.6	11.56	56.53
	6	90	499.0	0.99	55.7	1.37	443.7	480.2	-7.71	3.90
		60	340.6	1.13	57.9	1.19	292.6	276.8	2.10	23.02
		30	184.4	1.05	58.0	1.63	126.3	118.6	6.50	55.47
		90	499.0	0.99	44.2	1.07	454.7	485.8	-6.41	2.69
		60	308.0	1.55	33.0	1.54	275.0	282.5	-2.64	9.03

RUN 7 50 DEG F 60 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	122.3	0.94	-8.5	0.45	130.8	115.2	13.54	6.16
	1	90	467.1	2.96	-5.5	0.11	472.6	479.1	-1.34	-2.50
		60	279.8	0.59	-4.6	0.55	284.5	274.5	3.62	1.92
		30	126.2	0.47	-3.4	0.30	129.7	114.1	13.67	10.63
	7	90	471.6	3.85	-1.8	0.15	473.4	480.2	-1.41	-1.79
		60	282.1	0.64	-1.6	0.25	283.8	275.7	2.94	2.33
		30	127.0	0.73	-1.3	0.15	128.4	113.0	13.68	12.47
	3	90	467.2	2.86	-2.1	0.85	469.3	480.2	-2.26	-2.71
		60	275.7	0.94	-1.8	0.25	277.5	276.8	0.27	-0.40
		30	125.8	0.80	-1.6	0.20	127.4	116.3	9.48	8.08
D	4	90	469.9	3.32	-1.3	0.05	471.2	482.5	-2.32	-2.60
		60	280.8	0.64	-1.8	0.15	282.7	280.2	0.90	0.23
		30	126.5	0.33	-2.1	0.20	128.7	116.3	10.60	8.74
	5	90	473.0	3.12	-2.0	0.11	475.1	482.5	-1.52	-1.95
		60	282.5	0.79	-2.3	0.20	284.8	276.8	2.90	2.06
		30	125.5	0.44	-2.5	0.17	128.0	118.6	7.93	5.82
	6	90	471.2	3.14	-2.2	0.23	473.4	480.2	-1.41	-1.88
		60	282.7	1.06	-2.2	0.43	285.0	276.8	2.96	2.13
		30	126.1	0.57	-2.9	0.40	129.0	118.6	8.75	6.27
	7	90	475.0	2.92	-2.0	0.05	477.1	485.8	-1.79	-2.22
		60	284.5	0.75	0.0	0.00	284.5	282.5	0.70	0.70
		30	133.7	0.38	15.4	0.06	118.2	115.2	2.60	16.02
	1	90	159.8	23.14	16.0	0.66	143.7	479.1	-69.98	-66.64
		60	278.4	0.69	15.5	0.11	262.8	274.5	-4.25	1.39
		30	132.1	0.45	15.2	0.35	116.8	114.1	2.42	15.77
	2	90	174.9	29.23	15.4	0.17	159.4	480.2	-66.79	-63.56
		60	277.6	0.65	14.7	0.35	262.9	275.7	-4.64	0.69
		30	131.3	0.73	14.9	0.26	116.3	113.0	2.94	16.22
	3	90	180.1	9.57	15.6	0.11	164.4	480.2	-65.75	-62.49
		60	277.9	0.61	15.2	0.20	262.7	276.8	-5.11	0.37
		30	133.0	0.28	15.3	0.26	117.5	116.3	1.03	14.27
E	4	90	197.1	18.39	15.1	0.20	182.0	482.5	-62.27	-59.14
		60	281.0	0.62	16.3	0.41	264.6	280.2	-5.56	0.27
		30	133.5	0.31	16.5	0.30	116.8	116.3	0.43	14.70
	5	90	184.6	17.55	17.4	0.23	167.1	482.5	-65.34	-61.72
		60	283.2	1.06	17.4	0.26	265.7	276.8	-3.99	2.29
		30	134.5	0.65	17.3	0.20	117.1	118.6	-1.22	13.41
	6	90	188.5	9.60	17.6	0.35	170.9	480.2	-64.40	-60.73
		60	282.3	1.27	16.4	0.06	265.8	276.8	-3.96	1.98
		30	133.2	0.46	16.2	0.36	117.0	118.6	-1.33	12.31
	7	90	184.4	7.53	14.1	0.51	170.2	485.8	-64.95	-62.04
		60	276.0	1.25	13.6	0.05	262.3	282.5	-7.12	-2.30
		30	103.4	0.27	-4.9	0.30	108.3	115.2	-5.95	-10.23
	1	90	449.7	3.12	-3.5	0.05	453.2	479.1	-5.39	-6.13
		60	261.6	0.59	-3.6	0.23	265.2	274.5	-3.38	-4.71
		30	103.9	0.82	-3.8	0.49	107.7	114.1	-5.57	-8.93
	2	90	450.5	4.23	-3.6	0.15	454.1	480.2	-5.42	-6.18
		60	261.0	1.40	-3.8	0.23	264.8	275.7	-3.93	-5.32
		30	103.8	1.80	-3.6	0.15	107.5	113.0	-4.80	-8.05
	3	90	451.6	3.80	-3.7	0.25	455.4	480.2	-5.16	-5.95
		60	261.6	0.58	-3.7	0.11	265.3	276.8	-4.14	-5.49
		30	104.9	1.11	-3.8	0.11	108.8	116.3	-6.49	-9.78
F	4	90	451.9	3.26	-3.6	0.15	455.8	482.5	-5.52	-6.32
		60	262.6	0.79	-3.5	0.55	266.2	280.2	-4.99	-6.28
		30	104.6	0.42	-3.4	0.05	108.1	116.3	-7.09	-10.07
	5	90	453.1	2.72	-3.2	0.17	456.4	482.5	-5.39	-6.08
		60	263.6	0.71	-3.6	0.10	267.2	276.8	-3.46	-4.78
		30	105.8	0.63	-3.4	0.41	109.2	118.6	-7.93	-10.83
	6	90	453.8	3.26	-2.9	0.17	456.8	480.2	-4.87	-5.50
		60	264.7	1.46	-2.9	0.15	267.7	276.8	-3.29	-4.36
		30	105.5	0.98	-3.1	0.17	108.7	118.6	-8.32	-11.02
	7	90	455.7	2.97	-3.5	0.20	459.3	485.8	-5.45	-6.19
		60	263.3	1.34	-3.5	0.55	266.8	282.5	-5.52	-6.78

Table 7 - (Cont'd)

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		RUN 8			90 DEG F		50 PCNT HUMIDITY			
		30	131.8	1.12	-3.1	0.90	134.9	110.7	21.87	19.04
	1	90	425.0	3.68	3.6	0.91	421.6	440.7	-4.31	-3.53
		60	274.2	3.59	0.3	1.15	273.8	257.6	6.31	6.66
		30	133.5	1.44	1.4	1.11	132.0	109.6	20.45	21.82
	2	90	441.9	2.48	2.4	2.26	439.5	467.8	-6.04	-5.53
		60	272.5	2.24	2.2	2.60	270.3	248.5	8.72	9.62
		30	131.5	3.27	0.7	1.87	130.7	113.0	15.69	16.40
	3	90	438.0	2.03	-1.5	3.18	439.5	455.3	-3.46	-3.81
		60	269.0	2.25	-3.3	1.96	272.4	256.5	6.20	4.88
		30	130.2	2.81	-1.8	0.77	132.0	107.3	23.02	21.28
A	4	90	437.8	1.59	-1.6	1.47	439.4	0.0	******	******
		60	269.7	0.68	-1.1	1.71	270.8	254.2	6.54	6.10
		30	130.5	0.92	-1.2	3.02	131.8	107.3	22.80	21.62
	5	90	441.7	3.42	-0.5	1.18	442.3	463.2	-4.52	-4.64
		60	267.6	3.67	-1.9	1.68	269.5	254.2	6.02	5.26
		30	127.9	1.57	-3.1	1.71	131.1	107.3	22.18	19.23
	6	90	437.6	3.14	-4.9	3.04	442.5	0.0	******	******
		60	267.6	1.57	-4.5	2.95	272.1	0.0	******	******
		30	128.4	1.64	-1.6	2.04	130.1	0.0	******	******
	7	90	436.1	3.14	-2.2	1.00	438.3	0.0	******	******
		60	266.8	0.55	-3.6	2.77	270.5	0.0	******	******
		30	137.2	0.31	15.4	0.49	121.7	110.7	9.98	23.95
	1	90	418.3	3.15	16.6	0.11	401.6	440.7	-8.84	-5.07
		60	267.3	1.61	16.3	0.49	250.9	257.6	-2.57	3.76
		30	133.3	1.31	15.6	0.30	117.6	109.6	7.28	21.61
	2	90	437.3	2.22	15.4	0.66	421.9	467.8	-9.80	-6.50
		60	266.1	0.91	15.1	0.43	251.0	248.5	0.97	7.05
		30	131.3	0.45	14.2	0.81	117.0	113.0	3.62	16.22
	3	90	434.5	2.48	14.2	0.87	420.2	455.3	-7.70	-4.56
		60	264.7	0.59	12.6	1.33	251.8	256.5	-1.81	3.20
		30	131.1	0.59	13.4	0.79	117.6	107.3	9.61	22.18
B	4	90	435.2	2.37	13.6	1.30	421.5	0.0	******	******
		60	263.0	0.66	12.4	0.41	250.6	254.2	-1.40	3.48
		30	133.5	0.71	12.0	0.63	118.5	107.3	10.41	21.62
	5	90	436.7	2.30	12.1	0.35	424.5	463.2	-8.35	-5.73
		60	262.9	0.94	11.5	1.02	251.3	254.2	-1.14	3.40
		30	129.0	0.90	11.7	0.65	117.3	107.3	9.26	20.19
	6	90	434.0	2.90	11.1	0.34	422.9	0.0	******	******
		60	261.1	1.19	10.6	0.69	250.4	0.0	******	******
		30	128.8	1.30	10.9	1.17	117.8	0.0	******	******
	7	90	433.7	3.52	10.1	0.95	423.5	0.0	******	******
		60	259.5	0.80	10.4	0.85	249.1	0.0	******	******
		30	149.8	0.44	19.1	0.30	134.6	110.7	21.63	35.26
	1	90	480.2	3.77	19.8	0.83	460.3	440.7	4.47	8.97
		60	309.1	1.39	19.0	0.10	290.1	257.6	12.61	19.98
		30	147.6	1.22	13.2	0.57	134.6	109.6	22.84	34.72
	2	90	498.7	0.99	12.1	1.17	486.6	467.8	4.02	6.60
		60	301.7	1.18	9.6	0.97	292.0	248.5	17.48	21.35
		30	146.7	1.49	9.8	1.00	136.9	113.0	21.20	29.91
	3	90	499.0	0.99	14.9	1.30	484.0	455.3	6.28	9.57
		60	316.8	0.71	23.0	1.25	293.7	256.5	14.52	23.52
		30	168.9	0.57	29.5	0.17	139.3	107.3	29.79	57.36
C	4	90	499.0	0.99	34.3	0.66	464.6	0.0	******	******
		60	333.1	2.03	39.6	0.21	293.6	254.2	15.41	31.01
		30	185.6	1.23	45.9	1.10	139.6	107.3	30.13	72.95
	5	90	499.0	0.99	51.6	0.24	447.3	463.2	-3.43	7.70
		60	347.3	1.22	57.1	1.70	289.8	254.2	14.00	36.49
		30	198.6	1.53	60.1	0.92	138.5	107.3	28.92	85.00
	6	90	499.0	0.99	62.1	0.41	436.8	0.0	******	******
		60	355.2	1.82	66.1	1.57	289.0	0.0	******	******
		30	206.8	1.52	68.6	0.61	137.9	0.0	******	******
	7	90	499.0	0.99	70.6	0.42	428.3	0.0	******	******
		60	363.0	0.99	73.2	0.81	289.8	0.0	******	******

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		RUN 8			90 DEG F		50 PCNT HUMIDITY			
		30	123.1	1.27	-1.4	0.90	124.6	110.7	12.54	11.19
	1	90	433.8	3.39	15.2	0.90	418.5	440.7	-5.02	-1.55
		60	282.3	1.49	26.8	0.72	255.4	257.6	-0.83	9.58
		30	149.4	0.71	33.5	0.16	115.9	109.6	5.76	36.36
	2	90	474.0	1.89	37.9	0.51	436.1	467.8	-6.77	1.34
		60	296.8	1.18	42.8	0.32	253.9	248.5	2.17	19.41
		30	160.5	0.45	45.8	0.81	114.7	113.0	1.50	42.09
	3	90	480.7	2.21	48.9	0.35	431.7	455.3	-5.18	5.57
		60	300.7	0.97	48.4	0.66	252.3	256.5	-1.61	17.25
		30	165.6	0.70	49.5	0.12	116.0	107.3	8.11	54.32
D	4	90	489.4	3.06	51.3	0.31	438.1	0.0	******	******
		60	308.1	0.63	53.1	0.36	254.9	254.2	0.28	21.20
		30	169.8	0.39	54.1	0.17	115.7	107.3	7.80	58.26
	5	90	495.8	2.62	54.6	0.10	441.1	463.2	-4.77	7.02
		60	307.4	1.77	54.4	0.37	253.0	254.2	-0.47	20.91
		30	170.0	0.67	53.9	0.50	116.1	107.3	8.15	58.42
	6	90	492.7	2.43	54.6	0.22	438.0	0.0	******	******
		60	306.9	1.23	54.7	0.09	252.1	0.0	******	******
		30	170.3	0.55	55.2	0.45	115.1	0.0	******	******
	7	90	490.9	2.51	54.8	0.24	436.1	0.0	******	******
		60	308.0	1.36	56.3	0.11	251.6	0.0	******	******
		30	115.2	0.54	0.5	0.15	114.6	110.7	3.57	4.08
	1	90	334.6	7.75	1.8	0.40	332.7	440.7	-24.49	-24.06
		60	246.9	1.20	0.3	0.46	246.6	257.6	-4.27	-4.12
		30	109.8	0.97	-1.5	0.37	111.4	109.6	1.66	0.26
	2	90	275.1	14.14	-3.0	0.55	278.2	467.8	-40.51	-41.18
		60	242.1	0.91	-3.9	0.30	246.0	248.5	-1.04	-2.61
		30	106.1	0.87	-5.1	0.41	111.2	113.0	-1.50	-6.04
	3	90	292.3	14.70	-5.6	0.30	298.0	455.3	-34.55	-35.79
		60	240.8	0.62	-5.6	0.17	246.5	256.5	-3.87	-6.09
		30	106.4	0.31	-5.3	0.20	111.8	107.3	4.17	-0.79
E	4	90	291.3	5.05	-5.0	0.43	296.4	0.0	******	******
		60	240.4	1.09	-4.8	0.52	245.2	254.2	-3.54	-5.43
		30	107.4	0.74	-5.1	0.65	112.6	107.3	4.92	0.13
	5	90	296.2	12.31	-5.5	0.55	301.8	463.2	-34.85	-36.04
		60	241.3	1.02	-4.6	0.50	245.9	254.2	-3.24	-5.06
		30	107.6	0.45	-4.5	0.15	112.1	107.3	4.51	0.26
	6	90	309.1	10.34	-4.6	0.25	313.8	0.0	******	******
		60	240.7	0.86	-4.4	0.11	245.1	0.0	******	******
		30	107.7	0.36	-4.1	0.43	111.9	0.0	******	******
	7	90	310.7	5.35	-4.3	0.66	315.0	0.0	******	******
		60	240.2	0.50	-4.5	0.51	244.7	0.0	******	******
		30	97.2	0.17	-6.3	0.20	103.5	110.7	-6.47	-12.19
	1	90	416.1	3.46	-5.4	0.05	421.5	440.7	-4.36	-5.57
		60	245.2	1.54	-5.8	0.20	251.0	257.6	-2.55	-4.81
		30	94.9	1.05	-6.0	0.15	100.9	109.6	-7.94	-13.48
	2	90	437.0	2.56	-6.1	0.05	443.1	467.8	-5.26	-6.58
		60	243.7	0.57	-6.1	0.36	249.8	248.5	0.50	-1.94
		30	93.0	0.88	-6.3	0.40	99.3	113.0	-12.06	-17.66
	3	90	431.4	2.36	-7.1	0.46	438.6	455.3	-3.67	-5.25
		60	[illegible]	0.86	-7.8	0.10	246.4	256.5	-3.92	-6.96
		30	90.1	0.26	-8.4	0.05	98.6	107.3	-8.11	-16.00
F	4	90	429.9	3.11	-8.3	0.41	438.3	0.0	******	******
		60	236.9	0.86	-8.1	0.05	245.1	254.2	-3.58	-6.79
		30	89.6	0.67	-8.6	0.20	98.3	107.3	-8.36	-16.44
	5	90	431.4	2.96	-8.6	0.05	440.1	463.2	-4.99	-6.86
		60	236.9	1.42	-8.6	0.37	245.5	254.2	-3.40	-6.81
		30	88.5	0.83	-8.5	0.45	97.1	107.3	-9.51	-17.46
	6	90	427.9	3.73	-8.4	0.40	436.3	0.0	******	******
		60	236.0	0.48	-8.4	0.23	244.4	0.0	******	******
		30	88.3	0.24	-8.6	0.20	97.0	0.0	******	******
	7	90	431.9	3.06	-8.6	0.40	440.5	0.0	******	******
		60	235.2	0.63	-8.5	0.30	243.7	0.0	******	******

Table 7 - (Cont'd)

RUN 9 90 DEG F 60 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	131.5	1.13	-5.2	2.21	136.7	107.3	27.40	22.'
	1	90	436.5	1.29	-0.0	1.71	436.6	463.2	-5.74	-5.
		60	270.3	2.35	-0.6	1.16	271.0	254.2	6.61	6.
		30	130.1	0.55	-2.6	2.45	132.7	107.3	23.70	21.
	2	90	439.2	1.60	-1.2	2.47	440.5	463.2	-4.91	-5.
		60	262.7	1.61	-2.2	1.76	265.0	256.5	3.32	2.
		30	127.9	0.32	-3.3	1.95	131.2	107.3	22.31	19.
	3	90	432.9	2.33	-7.7	3.46	440.6	463.2	-4.88	-6.
		60	261.4	1.74	-4.9	3.92	266.4	254.2	4.79	2.
		30	125.0	0.93	-4.0	0.30	129.1	105.0	22.84	18.
A	4	90	430.3	1.87	-3.5	0.52	433.9	457.6	-5.18	-5.
		60	259.2	1.10	-4.0	3.07	263.3	248.5	5.92	4.
		30	121.8	2.45	-4.3	1.47	126.1	106.2	18.81	14.
	5	90	432.7	1.85	-2.4	1.45	435.0	457.6	-4.92	-5.
		60	259.8	2.10	-2.2	2.65	262.0	248.5	5.41	4.
		30	124.9	1.27	-2.2	0.92	127.2	101.6	25.10	22.
	6	90	432.0	2.07	-3.6	2.30	435.7	459.9	-5.25	-6.
		60	258.7	1.11	-8.6	1.68	267.5	248.5	7.62	4.
		30	123.8	1.72	-4.4	2.08	128.2	106.2	20.78	16.
	7	90	431.4	4.75	-3.4	0.41	434.8	457.6	-4.97	-5.
		60	256.5	0.69	-4.8	2.36	261.3	254.2	2.78	0.
		30	139.2	0.55	19.5	0.90	119.6	107.3	11.47	29.70
	1	90	439.9	2.22	21.8	0.98	418.1	463.2	-9.74	-5.02
		60	268.0	1.59	21.5	0.10	246.4	254.2	-3.07	5.42
		30	135.4	0.81	21.1	0.75	114.3	107.3	6.50	26.19
	2	90	438.0	3.02	18.0	0.25	419.9	463.2	-9.34	-5.45
		60	265.3	1.52	19.5	0.25	245.7	256.5	-4.17	3.45
		30	134.1	1.36	17.7	2.06	116.4	107.3	8.46	25.01
	3	90	428.6	3.00	13.0	1.26	415.5	463.2	-10.29	-7.48
		60	257.7	0.87	15.4	0.34	242.1	254.2	-4.73	1.35
		30	131.4	1.51	16.0	0.40	115.3	105.0	9.81	25.06
	4	90	428.0	2.13	15.6	0.26	412.4	457.6	-9.87	-6.46
		60	257.4	0.48	15.0	0.28	242.4	248.5	-2.48	3.56
		30	132.0	0.59	17.1	0.17	114.9	106.2	8.20	24.30
	5	90	430.3	2.45	17.2	1.38	413.0	457.6	-9.74	-5.96
		60	254.2	2.13	15.9	0.55	238.2	248.5	-4.15	2.27
		30	128.6	0.73	15.1	0.50	113.5	101.6	11.63	26.51
	6	90	428.3	3.00	14.1	0.58	413.8	459.9	-10.01	-6.93
		60	253.2	0.82	13.8	0.45	239.3	248.5	-3.72	1.85
		30	127.8	0.44	13.1	1.41	114.7	106.2	8.04	20.37
	7	90	427.2	3.52	13.6	1.47	413.6	457.6	-9.60	-6.63
		60	252.5	0.67	13.0	0.25	239.5	254.2	-5.80	-0.67
		30	150.2	1.28	13.9	1.22	136.2	107.3	26.90	39.94
	1	90	487.2	2.89	8.8	0.20	478.4	463.2	3.27	5.18
		60	282.2	0.67	-0.9	1.07	283.2	254.2	11.39	11.03
		30	130.1	1.92	-5.6	0.52	135.8	107.3	26.56	21.25
	2	90	476.7	2.51	-7.7	0.95	484.5	463.2	4.58	2.90
		60	279.3	0.86	-5.7	0.32	285.0	256.5	11.14	8.89
		30	135.5	0.93	-0.6	0.81	136.2	107.3	26.90	26.25
	3	90	465.8	2.20	-9.7	1.52	475.6	463.2	2.66	0.56
		60	267.8	1.20	-9.4	0.05	277.2	254.2	9.06	5.35
		30	123.2	0.88	-10.8	0.77	134.0	105.0	27.57	17.26
	4	90	451.7	2.55	-6.7	0.45	458.4	457.6	2.36	0.88
		60	268.1	1.59	-5.8	0.64	274.0	248.5	10.21	7.87
		30	128.6	0.94	-2.9	0.25	131.5	106.2	23.83	21.06
	5	90	476.3	3.43	4.6	1.21	471.4	457.6	3.01	4.02
		60	283.7	0.72	12.8	1.01	270.8	248.5	8.97	14.15
		30	141.0	0.90	13.8	0.43	127.7	101.6	25.59	39.26
	6	90	474.4	3.47	11.7	0.15	462.6	459.9	0.60	3.16
		60	276.3	1.14	10.9	0.20	265.3	248.5	6.75	11.16
		30	138.5	0.39	10.2	1.48	128.6	106.2	21.16	30.42
	7	90	471.1	3.24	10.3	0.43	460.8	457.6	0.70	2.95
		60	273.7	1.05	9.8	0.20	263.9	254.2	3.80	7.67

RUN 9 90 DEG F 60 PCNT HUMIDITY

INSTR	REP	LEVEL	AVG	SD	ZERO	SD	1-3	TV	ERR1	ERR2
		30	107.2	0.86	-8.2	0.26	115.4	107.3	7.56	-0.07
	1	90	428.4	3.16	-7.3	0.15	435.8	463.2	-5.92	-7.51
		60	244.4	0.79	-7.2	0.20	251.6	254.2	-1.00	-3.86
		30	110.3	0.89	-5.6	0.20	116.0	107.3	8.11	2.81
	2	90	435.5	2.97	-4.1	0.26	439.6	463.2	-5.09	-5.97
		60	249.6	0.88	-2.9	0.35	252.6	256.5	-1.51	-2.66
		30	112.4	0.58	-2.3	0.11	114.8	107.3	6.97	4.76
	3	90	430.3	3.05	-4.5	0.45	434.8	463.2	-6.12	-7.10
		60	243.7	1.27	-3.1	0.45	246.9	254.2	-2.87	-4.13
		30	113.0	0.45	-0.9	0.17	114.0	105.0	8.51	7.55
D	4	90	434.9	2.53	-0.7	0.15	435.7	457.6	-4.78	-4.94
		60	247.1	0.72	1.0	0.55	246.0	248.5	-1.01	-0.58
		30	116.1	0.90	1.3	0.11	114.8	106.2	8.10	9.36
	5	90	437.7	3.27	1.5	0.66	436.2	457.6	-4.67	-4.33
		60	247.9	1.15	3.8	0.35	244.0	248.5	-1.82	-0.26
		30	116.3	0.74	1.9	0.17	114.3	101.6	12.48	14.35
	6	90	436.9	3.32	2.9	0.40	433.9	459.9	-5.64	-4.98
		60	247.2	1.37	2.2	0.00	245.0	248.5	-1.42	-0.53
		30	115.8	0.71	2.0	0.26	113.7	106.2	7.10	9.08
	7	90	437.0	2.98	2.0	0.05	435.0	457.6	-4.94	-4.49
		60	246.3	0.68	1.2	0.43	245.0	254.2	-3.61	-3.10
		30	111.1	0.22	-3.0	0.35	114.1	107.3	6.38	3.52
	1	90	294.9	14.40	-2.2	0.37	297.2	463.2	-35.85	-36.34
		60	241.2	1.71	-4.0	0.47	245.3	254.2	-3.50	-5.10
		30	107.2	0.48	-5.6	0.40	112.9	107.3	5.20	-0.07
	2	90	287.6	6.83	-6.5	0.32	294.2	463.2	-36.49	-37.90
		60	236.1	1.75	-7.5	0.43	243.6	256.5	-4.99	-7.95
		30	103.2	0.54	-8.9	0.50	112.1	107.3	4.51	-3.80
	3	90	332.4	23.45	-13.0	0.28	345.5	463.2	-25.41	-28.23
		60	228.2	0.59	-11.0	0.89	239.2	254.2	-5.90	-10.24
		30	98.6	0.20	-12.0	0.37	110.6	105.0	5.33	-6.11
E	4	90	338.5	5.23	-12.0	0.25	350.5	457.6	-23.39	-26.02
		60	226.9	0.96	-11.6	0.10	238.6	248.5	-3.98	-8.68
		30	98.9	1.02	-11.6	0.05	110.6	106.2	4.15	-6.79
	5	90	330.0	6.14	-11.8	0.43	341.9	457.6	-25.28	-27.88
		60	225.2	1.11	-11.9	0.46	237.2	248.5	-4.55	-9.37
		30	97.7	0.67	-12.2	0.40	110.0	101.6	8.19	-3.86
	6	90	339.2	7.99	-12.6	0.30	351.7	459.9	-23.50	-26.24
		60	224.6	0.43	-12.6	0.10	237.2	248.5	-4.57	-9.64
		30	98.1	0.44	-12.3	0.06	110.4	106.2	4.02	-7.61
	7	90	334.6	8.88	-12.0	0.32	346.7	457.6	-24.24	-26.87
		60	224.4	0.51	-12.2	0.37	236.7	254.2	-6.88	-11.71
		30	95.2	1.05	-4.1	0.30	99.3	107.3	-7.43	-11.28
	1	90	437.5	3.37	-2.9	0.50	440.4	463.2	-4.92	-5.56
		60	242.8	1.05	-2.9	0.40	245.7	254.2	-3.34	-4.49
		30	96.0	1.21	-3.1	0.25	99.1	107.3	-7.62	-10.54
	2	90	441.0	2.49	-2.8	0.20	443.8	463.2	-4.18	-4.80
		60	241.8	0.74	-3.1	0.45	245.0	256.5	-4.48	-5.70
		30	95.8	0.52	-3.0	0.40	98.9	107.3	-7.84	-10.69
	3	90	432.3	2.78	-3.6	0.05	435.9	463.2	-5.89	-6.67
		60	236.7	0.75	-3.0	0.20	239.8	254.2	-5.67	-6.88
		30	93.4	0.19	-2.8	0.37	96.3	105.0	-8.30	-11.02
F	4	90	430.4	1.99	-2.9	0.46	433.4	457.6	-5.29	-5.93
		60	235.1	1.12	-3.1	0.43	238.2	248.5	-4.14	-5.43
		30	92.7	0.42	-3.3	0.30	96.1	106.2	-9.49	-12.66
	5	90	433.2	2.43	-2.9	0.35	436.2	457.6	-4.67	-5.32
		60	234.1	1.39	-2.9	0.15	237.0	248.5	-4.62	-5.81
		30	92.3	0.86	-2.9	0.20	95.2	101.6	-6.29	-9.17
	6	90	433.3	2.97	-3.4	0.05	436.7	459.9	-5.02	-5.77
		60	233.1	0.87	-2.9	0.37	236.0	248.5	-5.02	-6.22
		30	92.9	0.30	-3.0	0.55	95.9	106.2	-9.62	-12.50
	7	90	434.1	3.49	-3.2	0.15	437.4	457.6	-4.41	-5.13
		60	233.5	0.65	-3.2	0.11	236.8	254.2	-6.86	-8.14

(i) Column 7, labeled ERR1, is the zero-drift corrected, relative error (in percent), defined as follows:

$$\text{ERR1} = 100 \times \frac{[(1-3) - \text{TV}]}{\text{TV}}$$

(j) Column 8, labeled ERR2, is then the total relative error (in percent):

$$\text{ERR2} = 100 \times \left(\frac{\text{AVG} - \text{TV}}{\text{TV}}\right)$$

Lack of complete data on true value of nitric oxide concentration in column 6 is due to two factors. First, the Model 461 instrument was not installed during runs 1 and 2. In this case the true value was obtained by correlation of the phenol/disulfonic acid analysis with manual operation of a modified DuPont 460 analyzer. Second, during runs 3-9, failure of the 461 pen recorder to function properly during unattended test time periods resulted in some instances of data omission.

The gross discrepancies (ERR1 and ERR2) for instrument E at the 90% span level cannot be attributed to inaccuracy of the instrument at the 450 ppm nitric oxide level. The large apparent errors reflect our inability to property match impedance of the instrument in interfacing the instrument output with the computer system. A digital voltmeter placed directly on the instrument output indicated that the instrument was performing accurately at the 90% span level.

The summarized data in Table 7 were employed to conduct an analysis of zero drift and repeatability.

<u>Zero Drift Analysis</u>

During the temperature, humidity effects test program, each instrument was cycled through seven replicates. Each replicate consisted of three span levels preceded by a zero level. At each span and zero level, three 10-sample averages were reported. Thus, one 17.5-hour run provided 63 zero points for each instrument.

In the zero drift analysis, the first 10-point zero average was considered the true value, X_o. The zero drift parameters are then defined as follows:

$$\text{STANDARD DEVIATION (ppm NO)} = \sqrt{\frac{\sum_{i=1}^{62} (X_o - X_i)^2}{61}} \tag{1}$$

$$\text{MEAN DEVIATION (ppm NO)} = \frac{\sum_{i=1}^{62} |X_o - X_i|}{62} \tag{2}$$

$$\text{MEAN DEVIATION INTEGRAL (ppm NO·Hours)} = \sum_{i=1}^{62} [(X_o - X_i)\cdot\Delta T] \tag{3}$$

where $\Delta T = \frac{2}{36}$ Hours

$$\text{MAXIMUM DEVIATION (ppm NO)} = \operatorname{Max}_{i=1}^{62} [X_o - X_i] \tag{4}$$

INDEX = The point where maximum deviation occurred (2-63).

Table 8 presents the zero drift parameters for the nine conditions of external temperature and humidity.

The data in Table 8 are plotted in Figures 19 through 23 where the standard deviation in ppm NO_X is plotted versus temperature for three conditions of external relative humidity.

A number of conclusions can be drawn from the data of Table 8 and from the figures. The index corresponding to the maximum deviation from the initial zero appears to be random - this observation results in a conclusion that the drift of zero does not occur monatomically with time thereby defying any attempt to employ a straightforward linear dirft/unit time relationship. From the figures, no simple relationship connecting zero drift with either external humidity or temperature is evident. It is presumed that other uncontrolled parameters in the laboratory test sequence could have affected the observed zero drift trends. Finally, except for a few instances, the standard deviation in zero drift (ppm NO_X) is less than 25 ppm or 5% of the full scale reading. This limit was considered a permissible maximum range of deviation in the zero drift performance parameter (Table 4). Exceptions to this observation are noted for instruments C, D and E at isolated points in the test program.

Table 8

ZERO DRIFT ANALYSIS

INSTR	STANDARD DEVIATION	MEAN DEVIATION	MEAN DEVIATION INTEGRAL	MAXIMUM DEVIATION	INDEX
	RUN 6	50 DEG F	40 PCNT HUMIDITY		
A	0.22951E 01	0.18917E 01	0.64110E 01	4.80	50
B	0.47987E 01	0.45917E 01	0.15561E 02	7.69	34
C	0.14185E 02	0.12106E 02	0.41027E 02	26.20	34
D	0.52430E 02	0.50988E 02	0.17279E 03	63.80	40
E	0.13355E 02	0.12811E 02	0.43416E 02	17.10	61
F	0.31128E 01	0.30409E 01	0.10305E 02	4.10	47
	RUN 4	70 DEG F	40 PCNT HUMIDITY		
A	0.68120E 01	0.64770E 01	0.21949E 02	11.50	17
B	0.23377E 01	0.21278E 01	0.72110E 01	4.20	4
C	0.20651E 02	0.18881E 02	0.63988E 02	32.70	41
D	0.49577E 02	0.47480E 02	0.16090E 03	63.90	49
E	0.38112E 02	0.30265E 02	0.10256E 03	123.00	20
F	0.23007E 01	0.21540E 01	0.72999E 01	3.50	44
	RUN 5	90 DEG F	40 PCNT HUMIDITY		
A	0.49597E 01	0.40409E 01	0.13694E 02	11.60	51
B	0.90106E 01	0.81983E 01	0.27783E 02	14.59	61
C	0.16187E 02	0.12150E 02	0.41177E 02	34.59	25
D	0.45468E 02	0.44226E 02	0.14987E 03	56.29	62
E	0.21370E 01	0.18245E 01	0.61833E 01	3.90	61
F	0.11241E 01	0.99835E 00	0.33833E 01	2.09	57

Table 8 - (Cont'd)

I N S T R	STANDARD DEVIATION	MEAN DEVIATION	MEAN DEVIATION INTEGRAL	MAXIMUM DEVIATION	INDEX
	RUN 3	50 DEG F	50 PCNT HUMIDITY		
A	0.92396E 01	0.85999E 01	0.29144E 02	14.60	35
B	0.28563E 01	0.27147E 01	0.91999E 01	4.19	16
C	0.11508E 02	0.89639E 01	0.30377E 02	25.00	61
D	0.10506E 02	0.87245E 01	0.29566E 02	18.50	63
E	0.53604E 02	0.41714E 02	0.14136E 03	78.00	46
F	0.16923E 01	0.16508E 01	0.55944E 01	2.50	46
	RUN 1	70 DEG F	50 PCNT HUMIDITY		
A	0.85698E 00	0.73114E 00	0.24777E 01	1.69	24
B	0.33810E 01	0.24704E 01	0.83722E 01	8.00	60
C	0.12821E 02	0.10470E 02	0.35483E 02	21.39	52
D	0.37078E 01	0.35049E 01	0.11877E 02	4.90	35
E	0.58673E-01	0.31147E-01	0.10555E 00	0.20	31
F	0.59986E 00	0.49344E 00	0.16722E 01	1.39	50
	RUN 8	90 DEG F	50 PCNT HUMIDITY		
A	0.29734E 01	0.23278E 01	0.78888E 01	6.89	17
B	0.27655E 01	0.23213E 01	0.78666E 01	5.60	59
C	0.32339E 02	0.24975E 02	0.84638E 02	58.59	61
D	0.50474E 02	0.48973E 02	0.16596E 03	58.79	63
E	0.50615E 01	0.47540E 01	0.16111E 02	6.60	23
F	0.16384E 01	0.14557E 01	0.49333E 01	2.59	43

Table 8 - (Cont'd)

INSTR	STANDARD DEVIATION	MEAN DEVIATION	MEAN DEVIATION INTEGRAL	MAXIMUM DEVIATION	INDEX
	RUN 7	50 DEG F	60 PCNT HUMIDITY		
A	0.13216E 01	0.99671E 00	0.33777E 01	4.10	5
B	0.27919E 01	0.23180E 01	0.78555E 01	7.30	63
C	0.25535E 02	0.22140E 02	0.75033E 02	43.50	55
D	0.61622E 01	0.60147E 01	0.20383E 02	8.40	61
E	0.11846E 01	0.91639E 00	0.31055E 01	2.60	49
F	0.10886E 01	0.10393E 01	0.35222E 01	1.79	50
	RUN 2	70 DEG F	60 PCNT HUMIDITY		
A	0.21707E 01	0.16836E 01	0.57055E 01	4.89	4
B	0.31285E 01	0.26262E 01	0.88999E 01	6.10	53
C	0.35215E 02	0.31165E 02	0.10561E 03	51.29	55
D	0.49531E 01	0.44114E 01	0.14949E 02	10.40	28
E	0.51808E 01	0.47376E 01	0.16055E 02	7.80	10
F	0.14120E 01	0.13934E 01	0.47222E 01	2.20	4
	RUN 9	90 DEG F	60 PCNT HUMIDITY		
A	0.30128E 01	0.25393E 01	0.86055E 01	6.69	22
B	0.41680E 01	0.36885E 01	0.12499E 02	7.70	56
C	0.15977E 02	0.13375E 02	0.45327E 02	26.60	30
D	0.77820E 01	0.69524E 01	0.23561E 02	12.20	43
E	0.77320E 01	0.71065E 01	0.24083E 02	10.30	22
F	0.77681E 00	0.70327E 00	0.23833E 01	1.40	6

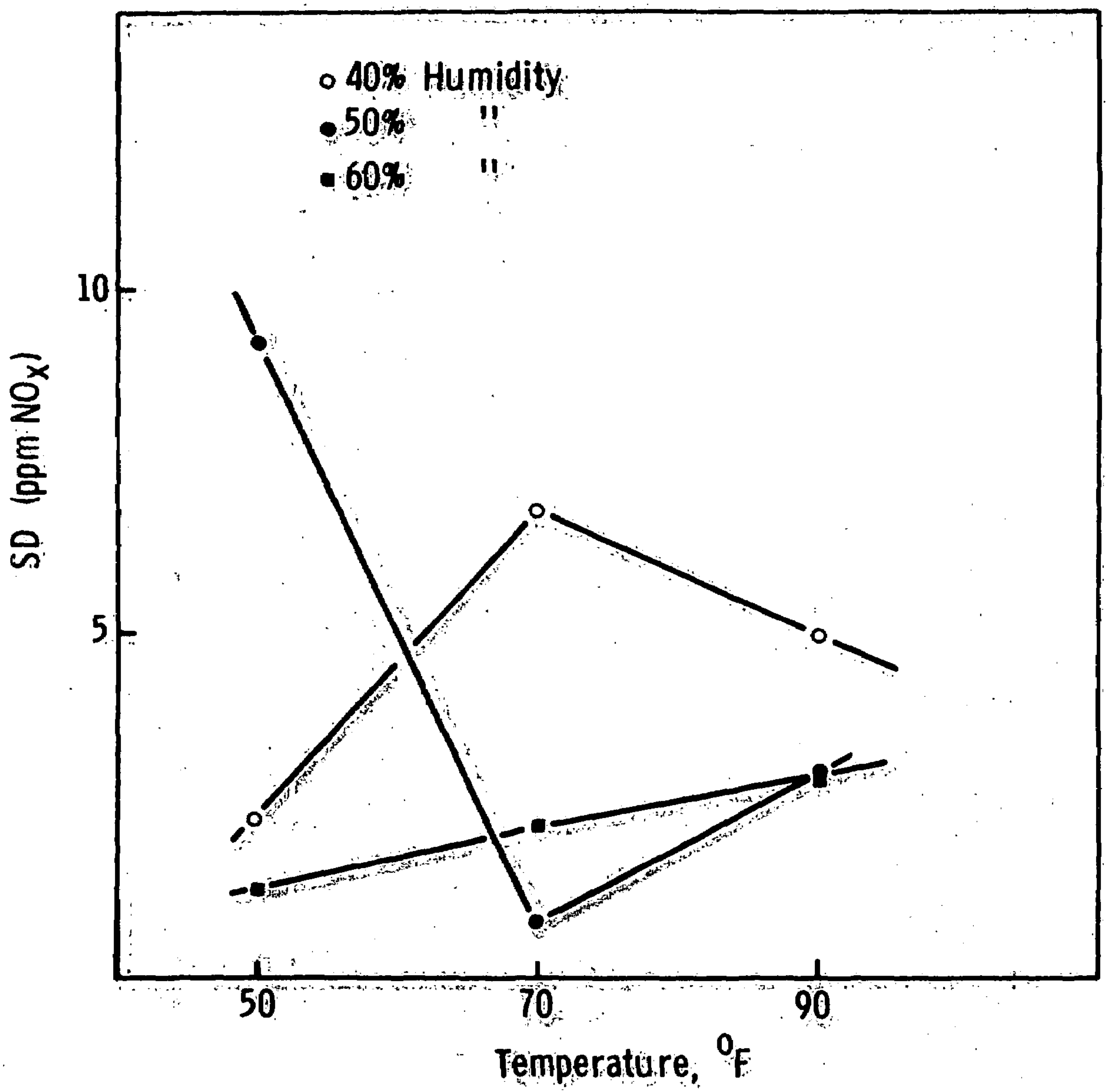

Figure 19. Instrument A: Zero Standard Deviation vs. Temperature.

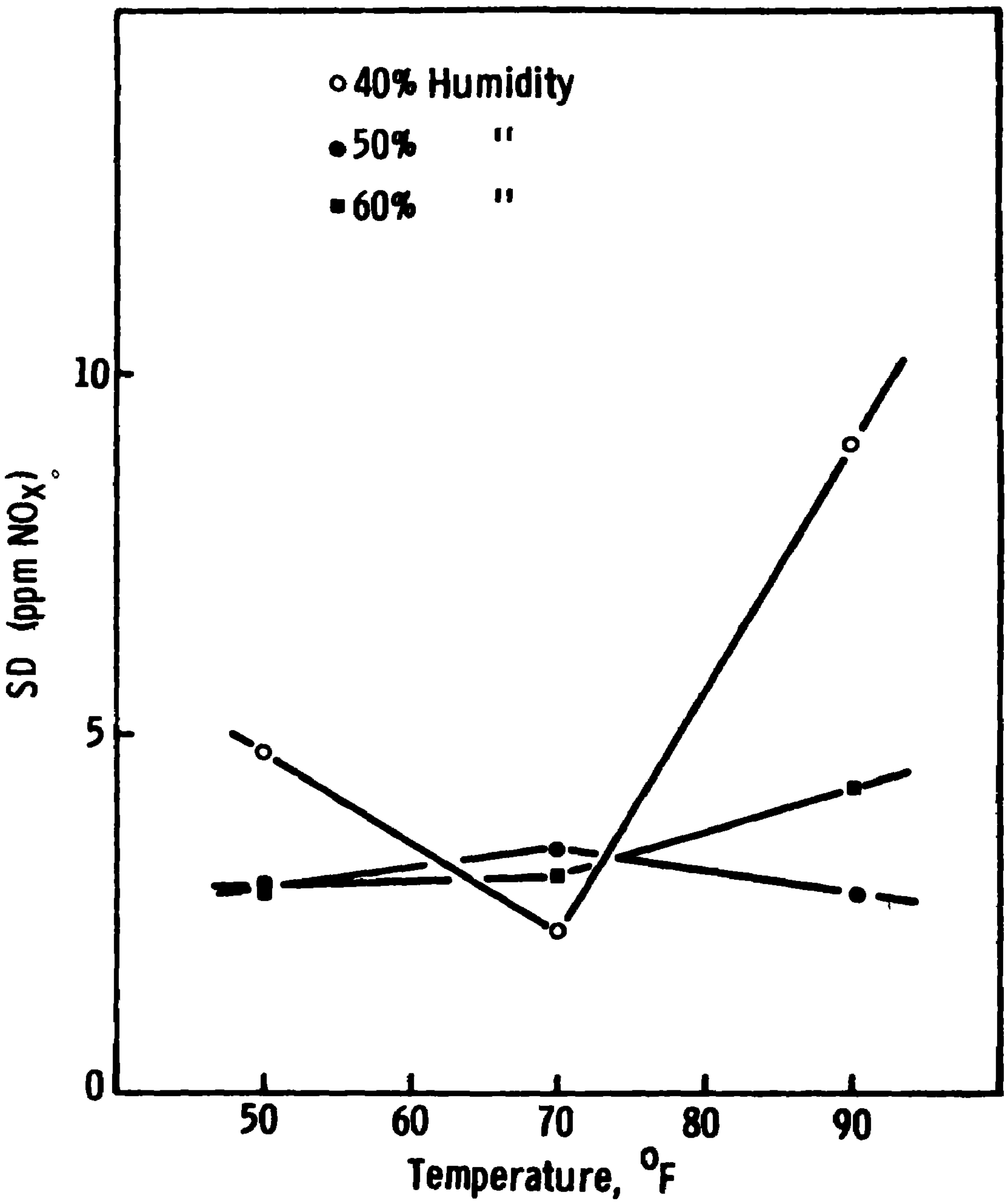

Figure 20. Instrument B: Zero Standard Deviation vs. Temperature.

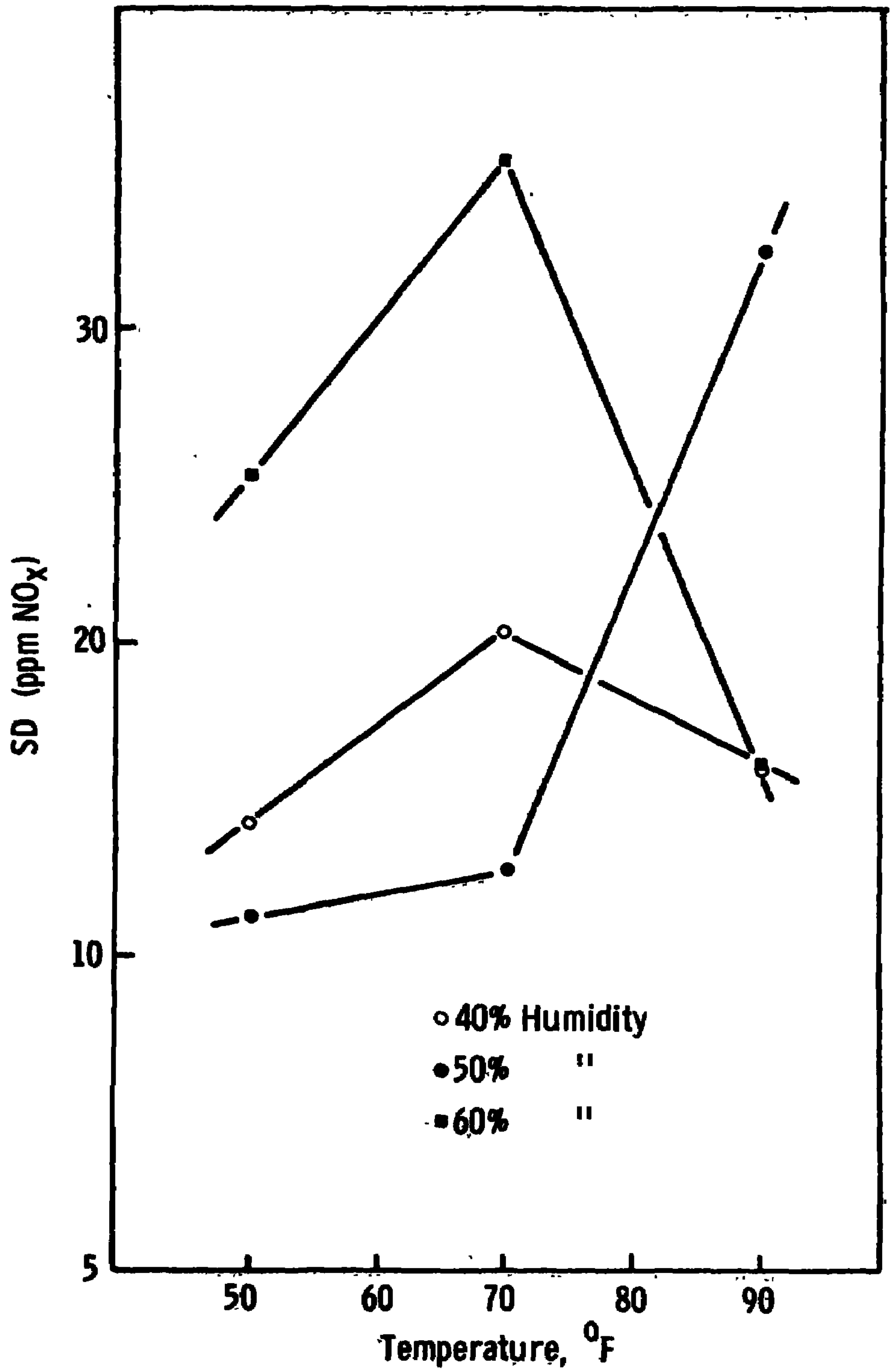

Figure 21. Instrument C: Zero Standard Deviation vs. Temperature.

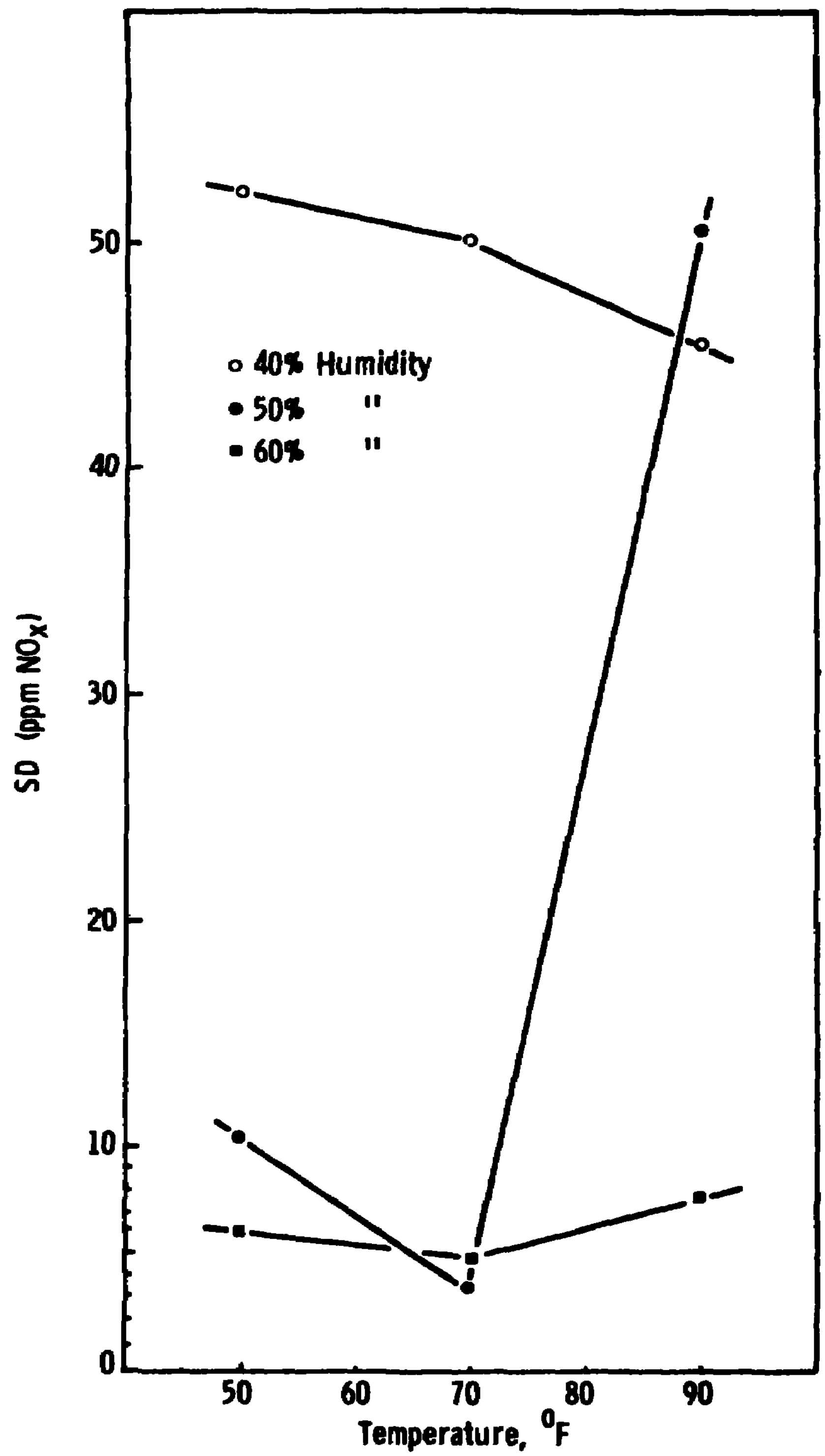

Figure 22. Instrument D: Zero Standard Deviation vs. Temperature.

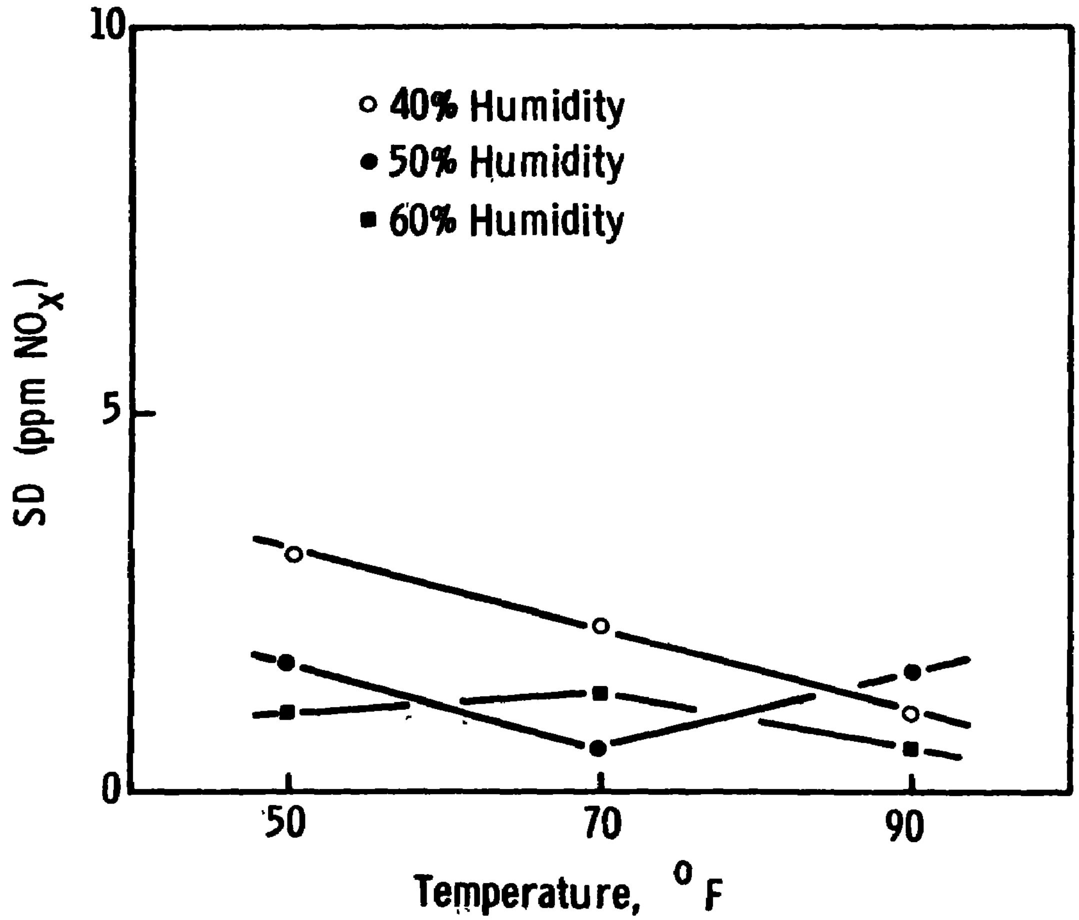

Figure 23. Instrument F: Zero Standard Deviation vs. Temperature.

Repeatability

Data employed for test of repeatability were taken from Run 1 of the summary data sheet (Table 7), and are expressed as differences in the nitrogen oxide readings (ppm) between replicate one and replicate two. These data are presented in Table 9.

Table 9

REPEATABILITY OF NITROGEN OXIDE MONITORS
(Corrected for Zero Drift)

Instrument	Span 30%	Span 90%	Span 60%	AVG	% of Full Scale
A	2.5	1.7	2.2	2.1	<2%
B	1.3	2.6	2.3	2.1	<2%
C	2.4	7.0	2.1	3.8	<2%
D	0.3	2.1	1.3	1.2	<2%
*E	5.3	**	5.3	5.3	<2%
F	1.3	2.4	2.7	2.1	<2%

*Data taken from Run #2, replicates 2 & 3.

**All 90% Span data for instrument E are invalid due to impedance matching problems between instrument and computer.

While further analysis of repeatability can be reported for subsequent runs, replicates 1 and 2 of run 1 were selected since other factors which could influence repeatability such as span drift and temperature and humidity variations were not operative during the initial run. A similar analysis for replicates 1 and 2 of run 6 indicate average differences of 3.2, 2.6, 6.6, 8.0, 0.4 and 3.6 ppm NO_x for instruments A through F, respectively. This degree of repeatability is within the target limit of [illegible] of full scale reading (±10 ppm NO_x).

The performance parameters sensitivity, resolution, response time and lag, and interferences were determined in separate tests after the external temperature and humidity variation test series. A description of the test procedures and results for these parameters is presented as follows:

Sensitivity

The sensitivities of the six continuous monitors were tested by the following procedure. First, dry nitrogen gas was passed through the sample distribution manifold and all instruments were adjusted to zero reading. The zero readings were taken by the PDP-12A computer every 20 seconds for ten minutes. A calibrated gas mixture (370 ppm NO in N_2) was then metered into the gas stream to yield successive nitric oxide concentrations of 16.8, 8.8, 3.9 and 2.0 ppm of NO. The sequence of data acquisition is presented in Figure 24.

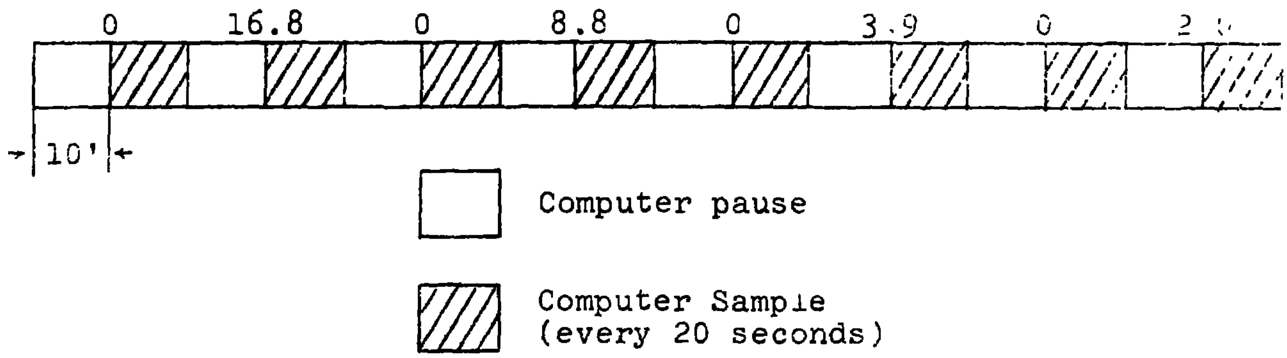

Figure 24. Time Sequence for Sensitivity Tests.

The computer printout of the data is presented in Table 10.

The sensitivity results are presented in Table 11. The results were computed by subtracting the third zero value immediately preceding the first level value. These values represented an average of ten readings in each case. As a result, the readings of all instruments in ppm NO are compared to the known concentrations.

Table 11

SENSITIVITY OF NO_x CONTINUOUS MONITORS

Instrument	ppm NO 16.8	8.8	3.9	2.0
A	19.2	8.5	1.7	0
B	19.4	9.1	1.5	0.7
C	16.1	0	0	0
D	10.0	7.2	1.9	0
E	18.5	6.8	1.3	(2.2)
F	7.8	2.4	0	0

Table 10

NO_x MONITOR SENSITIVITY DATA

(Computer Printout)

NO Conc. (ppm)	Replicate	Reading (ppm)	Variance	Reading (ppm)	Variance
		A		B	
	1.0000 -	7.4219	1.9497 -	2.3438	2.5855
	2.0000 -	7.9102	3.4862 -	0.6836	0.2225
	3.0000 -	8.6914	1.1550 -	2.9297	4.6624
		C		D	
	4.0000	76.6602	4.0778	7.9102	0.0954
0	5.0000	75.3906	2.9208	8.2031	0.2543
	6.0000	78.2227	4.3306	8.4961	1.7060
		E		F	
	7.0000 -	22.0703	0.2542 -	3.7981	1.3213
	8.0000 -	22.1680	0.2223 -	3.4726 -	0.0000
	9.0000 -	22.4609 -	0.0002 -	4.1237	1.0989
		A		B	
	1.0000	10.4492	2.3418	16.5039	1.3668
	2.0000	10.7422	1.2715	17.2852	2.1298
	3.0000	11.1328	2.7974	16.3086	0.8583
		C		D	
	4.0000	94.3359	12.7542	18.4570	0.5192
16.8	5.0000	90.4297	17.2056	18.1641	0.2543
	6.0000	91.1133	4.2444	17.4805	0.5191
		E		F	
	7.0000 -	41.0156	0.0000	3.6888	8.1631
	8.0000 -	41.0156	0.0000	3.6888	0.8372
	9.0000 -	40.9180	0.0951	3.9059	2.0408
		A		B	
	1.0000 -	6.5430	2.1299 -	2.7344	2.5007
	2.0000 -	8.1055	2.7656 -	2.3438	2.1617
	3.0000 -	7.2266	4.2809 -	2.3438	1.5259
		C		D	
	4.0000	65.3320	5.8153	2.2461	0.2225
0	5.0000	64.8438	8.7299	2.8320	0.5192
	6.0000	62.9883	5.5618	3.5156	0.2543
		E		F	
	7.0000 -	22.0703	0.2542 -	3.6896	1.2559
	8.0000 -	21.7773	0.2224 -	3.0386	1.3605
	9.0000 -	21.4844 -	0.0002 -	3.4726	1.3082

Table 10 - (Cont'd)

NO Conc. (ppm)	Replicate	Reading (ppm)		Variance	Reading (ppm)		Variance
			A			B	
	1.0000	1.2695		2.3418	6.8359		2.1193
	2.0000	0.7813		2.0769	4.3945		0.6888
	3.0000	1.4648		6.1989	4.8828		2.1193
			C			D	
	4.0000	63.3789		3.6965	10.7422		0.8477
8.8	5.0000	66.0156		2.3722	10.3516		0.2543
	6.0000	65.1367		4.8840	10.2539		0.2649
			E			F	
	7.0000 -	28.3203		0.0000 -	1.0855		2.0408
	8.0000 -	28.4180		0.0951 -	1.4110		0.6410
	9.0000 -	28.4180		0.0951 -	1.5195		0.4710
			A			B	
	1.0000 -	7.3242		1.7484 -	2.7344		1.2292
	2.0000 -	7.2266		0.6782 -	2.8320		2.4266
	3.0000 -	6.4453		2.5855 -	1.1719		2.7127
			C			D	
	4.0000	54.1992		4.0785	2.5391		0.2543
0	5.0000	54.8828		2.2882	3.0273		0.0954
	6.0000	51.9531		5.8903	2.9297		0.0000
			E			F	
	7.0000 -	22.0703		0.2542 -	3.5811		8.4902
	8.0000 -	21.6797		0.1693 -	2.7131		3.9377
	9.0000 -	21.7773		0.2224 -	3.0386		4.5002
			A			B	
	1.0000 -	4.6875		3.3485	0.2930		2.1299
	2.0000 -	4.1016		2.0769	0.0977		2.0027
	3.0000 -	4.9805		4.9697 -	0.6836		2.1299
			C			D	
	4.0000	51.3672		5.9750	4.8828		1.0596
3.9	5.0000	50.5859		5.0427	5.2734		0.6782
	6.0000	51.3672		7.6708	5.9570		0.0954
			E			F	
	7.0000 -	23.1445		0.2225 -	2.2790		2.4725
	8.0000 -	23.0469		0.2543 -	2.9301		2.1585
	9.0000 -	22.7539		0.2223 -	3.0386		1.8838

Table 10 - (Cont'd)

NO Conc. (ppm)	Replicate	Reading (ppm)		Variance		Reading (ppm)		Variance
			A				B	
	1.0000 -	8.3008		2.1722	-	2.1484		4.6200
	2.0000 -	7.6172		2.9246	-	3.7109		3.1365
	3.0000 -	6.8359		3.1789	-	2.1484		1.2292
			C				D	
	4.0000	48.7305		10.6913		3.7109		0.3815
0	5.0000	49.0234		6.3146		2.7344		0.5934
	6.0000	47.6563		6.1024		1.8555		1.3669
			E				F	
	7.0000 -	22.6563		0.1694	-	3.7981		3.6760
	8.0000 -	23.0469		0.2542	-	3.6896		1.7791
	9.0000 -	23.2422		0.1695	-	4.1237		3.1920
			A				B	
	1.0000 -	8.1055		1.2822	-	1.4646		2.3642
	2.0000 -	7.4219		0.6782	-	1.3672		1.5259
	3.0000 -	7.6172		0.5934	-	1.5625		1.5259
			C				D	
	4.0000	50.9766		5.8906	-	3.4180		0.4768
2.0	5.0000	51.2695		5.3507	-	4.9805		1.3669
	6.0000	51.1719		8.9431	-	6.3477		0.2649
			E				F	
	7.0000 -	25.3906	-	0.0002	-	3.4726		1.0466
	8.0000 -	25.3906	-	0.0002	-	3.3641		0.9026
	9.0000 -	25.6836		0.2224	-	3.5811		2.4725
			A				B	
	1.0000 -	9.2773		1.3245	-	4.0039		2.8504
	2.0000 -	8.5938		2.2888	-	3.6133		1.4941
	3.0000 -	7.9102		1.7908	-	1.1719		1.8650
			C				D	
	4.0000	51.5625		2.2882	-	11.6211		0.0954
0	5.0000	51.6602		2.2146	-	12.3047		0.2543
	6.0000	48.9258		2.8493	-	12.2070		0.2649
			E				F	
	7.0000 -	24.9023		0.2646	-	3.6896		1.7791
	8.0000 -	24.7070		0.2222	-	3.2556		1.2559
	9.0000 -	25.3906	-	0.0002	-	2.7131		2.3678

If sensitivity is defined as the concentration above which the instrument reading exceeds the noise level, instruments A, B, D and E can be considered sensitive at the 3.9 ppm level, instrument F at the 8.8 ppm level and instrument C at a level between 8.8 and 16.8 ppm of NO.

Response Time and Lag

All six of the instruments were purged with dry nitrogen and the valves to the instruments closed. A 450 ppm NO concentration was then fed through the manifold system. A computer-activated solenoid valve was sequentially installed in the lines between the manifold and the instruments. The manifold valve was opened and the computer initiated each test by opening the solenoid valve. Instrument readings were taken every 0.2 seconds for 50 seconds and stored on magnetic tape. The results were also displayed on the PDP-12A scope and photographed with a Polaroid camera. The response time data in Table 12 were interpolated from the computer printout while the response lag was measured from the photographs.

Table 12

RESPONSE TIME AND LAG OF NITROGEN OXIDE MONITORS

Instrument	Response Lag (sec)	Response Time (sec) 66.7%	90%
A	0	3.7	5.9
B	1.9	4.2	7.6
*C	7.8	25.8	45.0
D	3.9	9.7	26.8
E	7.8	13.2	14.9
F	6.2	11.7	15.7

*Times include residence time in SO_2 scrubber volume.

Table 13 presents the computer printout of the instrument responses. While the sampling interval was 0.2 second, in every case the print interval was 5, resulting in one-second periods between successive data points.

Interferences

A series of tests were conducted to define the level of interference of known flue gas constituents with the accurate analysis of nitrogen oxides by the continuous monitors. Computer

Table 13

RESPONSE OF NO_x INSTRUMENTS AT 1-sec TIME INTERVALS

(Computer Printout - Arbitrary Units)

Instrument					
A	B	C	D	E	F
19.0000	37.0000	78.0000	15.0000	50.0000	93.0000
248.0000	39.0000	74.0000	15.0000	50.0000	95.0000
363.0000	125.0000	74.0000	15.0000	56.0000	97.0000
464.0000	310.0000	74.0000	15.0000	62.0000	97.0000
558.0000	488.0000	74.0000	46.0000	70.0000	99.0000
644.0000	585.0000	74.0000	117.0000	78.0000	105.0000
726.0000	630.0000	78.0000	207.0000	82.0000	132.0000
792.0000	662.0000	83.0000	304.0000	89.0000	191.0000
826.0000	681.0000	103.0000	390.0000	105.0000	273.0000
839.0000	693.0000	121.0000	457.0000	138.0000	367.0000
835.0000	699.0000	144.0000	505.0000	199.0000	457.0000
824.0000	703.0000	173.0000	537.0000	283.0000	537.0000
816.0000	707.0000	205.0000	558.0000	378.0000	603.0000
812.0000	707.0000	232.0000	574.0000	478.0000	656.0000
810.0000	710.0000	261.0000	585.0000	574.0000	701.0000
806.0000	714.0000	289.0000	593.0000	660.0000	734.0000
804.0000	718.0000	318.0000	599.0000	734.0000	761.0000
804.0000	720.0000	349.0000	607.0000	738.0000	781.0000
804.0000	722.0000	375.0000	613.0000	722.0000	796.0000
804.0000	722.0000	396.0000	617.0000	705.0000	808.0000
804.0000	724.0000	417.0000	623.0000	691.0000	814.0000
800.0000	726.0000	439.0000	628.0000	683.0000	820.0000
796.0000	726.0000	460.0000	632.0000	681.0000	826.0000
796.0000	728.0000	478.0000	636.0000	679.0000	828.0000
802.0000	732.0000	496.0000	642.0000	679.0000	828.0000
798.0000	734.0000	511.0000	648.0000	679.0000	828.0000
796.0000	736.0000	527.0000	652.0000	679.0000	830.0000
796.0000	736.0000	541.0000	656.0000	679.0000	832.0000
796.0000	738.0000	564.0000	662.0000	681.0000	832.0000
800.0000	742.0000	568.0000	666.0000	681.0000	832.0000
802.0000	746.0000	576.0000	671.0000	683.0000	832.0000
796.0000	750.0000	585.0000	675.0000	687.0000	832.0000
796.0000	750.0000	589.0000	679.0000	689.0000	832.0000
796.0000	753.0000	603.0000	683.0000	693.0000	832.0000
800.0000	755.0000	613.0000	687.0000	697.0000	832.0000
800.0000	761.0000	623.0000	691.0000	701.0000	832.0000
796.0000	761.0000	632.0000	693.0000	705.0000	830.0000
800.0000	753.0000	638.0000	697.0000	707.0000	832.0000
800.0000	753.0000	642.0000	701.0000	710.0000	828.0000
796.0000	757.0000	652.0000	703.0000	714.0000	826.0000
800.0000	755.0000	656.0000	707.0000	716.0000	828.0000
800.0000	750.0000	660.0000	708.0000	718.0000	828.0000
798.0000	746.0000	664.0000	710.0000	720.0000	826.0000
796.0000	742.0000	671.0000	714.0000	722.0000	824.0000
796.0000	742.0000	679.0000	716.0000	722.0000	826.0000
800.0000	740.0000	679.0000	718.0000	724.0000	826.0000
800.0000	738.0000	683.0000	720.0000	726.0000	824.0000
796.0000	734.0000	687.0000	722.0000	726.0000	822.0000
796.0000	734.0000	689.0000	724.0000	726.0000	820.0000
796.0000	730.0000	697.0000	726.0000	728.0000	820.0000

readings were taken at 20-second intervals over ten-minute time periods. Every ten readings were averaged to give three data values during each test cycle. In every case, the test sequence involved four steps: (1) nitrogen gas, (2) nitrogen + interfering gas, (3) nitrogen + interfering gas + nitric oxide, and (4) nitrogen + nitric oxide. The interferences tested were: (1) carbon dioxide, (2) water vapor, (3) oxygen, (4) nitrogen dioxide, (5) carbon monoxide, (6) pressure variation, and (7) sulfur dioxide. The concentrations of the interfering materials were set at, or in excess of, the values expected in a power plant stack situation.

The test sequence is shown in Table 14. In every case a ten-minute time period was allowed for computer access of instrument data at each stage.

Two measures of interference can be identified. If X is the interfering component, its influence on the zero reading (N_2) would be given by the difference in zero caused by the presence of the component, i.e., N_2-[N_2 + X]. The influence on the nitrogen oxide reading by component X could also be expressed as a difference; i.e., [X + NO]-NO, where NO is the reading for the nitric oxide/nitrogen mixture without component X. The values of these differences for the six instruments are presented in Table 15. The last column of this table gives the % deviation in the nitrogen oxide reading (ppm) caused by the interfering component.

Cases where the percent deviation from the nitrogen oxide reading exceeded 5 percent include: instrument F with CO_2; instruments A, B and C with H_2O; instrument D with NO_2; instruments C and D with pressure; and instruments D and E with SO_2. While nondispersive infrared instruments (A, B, E and F) are known to be sensitive to water vapor, the response of instrument B is greatest while that of instrument F appears to be minimal. While instruments C and D (electrochemical) should respond to NO_2, this response is evident only in the difference based on the zero reading. In the presence of nitric oxide, the response was negative in both cases. In the case of instrument D, this negative response exceeded five percent of the nitric oxide reading. Both of the electrochemical instruments appear to be sensitive to changes in pressure. The behavior of instrument D must be reexamined since the response recorded exceeds the value which the computer should have been capable of printing in our program. The expected result on dilution of the 350 ppm mixture at the higher pressure (Δ = 29 mm Hg) would be a difference ([X + NO]-NO) of -12 ppm. As mentioned in the footnote of Table 15, the 11,250 ppm concentration employed with SO_2 is unrealistically high compared to normal stack gas effluent concentrations. At the 2,000 to 3,000 ppm SO_2 range the percent deviation of instrument E would be expected to be less than 5 percent.

Table 14

TEST SEQUENCE FOR INTERFERENCE TESTING OF NITROGEN OXIDE MONITORS

Carbon Dioxide

N_2
N_2 + 15% CO_2
N_2 + 15% CO_2 + 410 ppm NO
N_2 + 410 ppm NO

Water

N_2
N_2 + 7% H_2O
N_2 + 7% H_2O + 370 ppm NO
N_2 + 370 ppm NO

Oxygen

N_2
N_2 + 3% O_2
N_2 + 3% O_2 + 370 ppm NO
N_2 + 370 ppm NO

Nitrogen Dioxide

N_2
N_2 + 40 ppm NO_2
N_2 + 40 ppm NO_2 + 283 ppm NO
N_2 + 283 ppm NO

Carbon Monoxide

N_2
N_2 + 230 ppm CO
N_2 + 1800 ppm CO
N_2 + 1800 ppm CO + 350 ppm NO
N_2 + 350 ppm NO

Pressure

3.1 cm Hg
6.0 cm Hg
6.0 cm Hg + 350 ppm NO
3.1 cm Hg + 350 ppm NO
3.1 cm Hg

Sulfur Dioxide

N_2
N_2 + 1.125% SO_2
N_2 + 1.125% SO_2 + 360 ppm NO
N_2 + 360 ppm NO

Table 15

EXTENT OF INTERFERENCE OF FLUE GAS CONSTITUENTS ON NITROGEN OXIDE MONITORS

Interference & Concentration	Nitric Oxide (ppm)	Instrument	N_2-[N_2 + X] (ppm NO_x)	[X + NO]-NO (ppm NO_x)	% Deviation From NO Reading
15% CO_2	410	A	1.0	19.6	4.5
		B	8.5	3.6	0.8
		C	-4.2	8.1	2.2
		D	-2.7	16.6	3.5
		E	-11.4	6.1	1.5
		F	-5.7	34.4	7.6
7% H_2O	370	A	1.4	22.2	7.0
		B	-3.7	76.7	20.4
		C	8.5	-4.3	-1.2
		D	5.8	-0.6	-0.2
		E	1.1	44.4	12.4
		F	4.3	-2.2	-0.5
3% O_2	370	A	-0.8	-10.8	-2.8
		B	-0.2	-11.1	-2.9
		C	-1.2	-9.8	-2.8
		D	0	-9.3	-2.4
		E	-1.1	2.8	0.8
		F	-0.7	14.5	3.7
40 ppm NO_2	283	A	6.0	3.0	1.0
		B	6.0	1.9	0.8
		C	14.1	-3.7	-1.1
		D	20.0	-30.5	-9.3
		E	-3.0	-0.1	0
		F	1.2	-4.8	-1.6
1800 ppm CO	350	A	-4.8	0.7	0.2
		B	-4.4	0.4	0.1
		C	2.6	-1.3	-0.4
		D	-4.9	-7.0	-3.5
		E	2.0	2.9	0.8
		F	-2.5	1.4	0.4
2.9 cm Hg (ΔP)	350	A	0.2	-0.4	-0.1
		B	0.5	-6.9	-1.9
		C	0.2	-43.5	-13.4
		D	-5.8	-1157.3[a]	-
		E	0.2	-4.0	-1.1
		F	0.4	-2.9	-0.8
1.125% SO_2	360	A	1.7	-1.5	-0.4
		B	3.5	-5.9	-1.7
		C	3.8	-6.4	-2.0
		D	*b*	*b*	*b*
		E	-27.3	-27.3	-7.9
		F	-0.2	-0.4	-0.1

[a]This value must be an error in the computer A/D converter since values in excess of 499.9--- should not be printable by the program.

[b]A large variation was observed in instrument D response on exposure to 11,250 ppm SO_2 (ΔC from +140 to -140 ppm). This behavior can be related to the inability of the instrument to internally compensate for SO_2 at this high concentration. A further experiment is planned for SO_2 concentrations in the 2 to 3,000 ppm range more characteristic of power plant stack emissions.

4.3.1 Statistical Analyses of Laboratory Test Data

The following error analyses were performed using data in Table 7. These data were stored on magnetic disk in the MRC IBM/1130. Several versions of existing data reduction programs were used to generate the tables described in this section.

We will first define the two types of errors that we have treated. Type 1 error, E1, corrected for zero drift:

$$E1 = \frac{[(AVG-ZERO)-TV]}{TV}100$$

and, type 2 error, E2, uncorrected for zero drift:

$$E2 = \left(\frac{AVG-TV}{TV}\right) 100$$

If we express E as an error of either type 1 or type 2, then we can define the average error, $\bar{E}$, as follows:

$$\bar{E} = \frac{\Sigma E}{N}$$

where N is the number of terms entering the calculation.

The corresponding standard deviation, SD, about $\bar{E}$ can be expressed as:

$$SD = \sqrt{\frac{N\Sigma E^2 - (\Sigma E)^2}{N(N-1)}}$$

A more meaningful measure of accuracy in this particular analysis is the mean deviation, MD:

$$MD = \frac{\Sigma|E|}{N}$$

and the corresponding "true" standard deviation, TSD:

$$TSD = \sqrt{\frac{\Sigma E^2}{N-1}}$$

The error analysis relative to percent of true nitrogen oxide values during the laboratory evaluation program (Table 7) is presented in Table 16. Table 16 presents the detailed analysis of relative error (percent of actual NO_x reading) for all experiments by instrument and span level.

The corresponding analysis of absolute error - accuracy expressed as percent of full scale reading - is presented in Table 17. In this case the analysis was modified as follows:

$$E1 = \left\{\frac{[(AVG-ZERO)-TV]}{500}\right\} 100$$

and

$$E2 = \left[\frac{(AVG-TV)}{500}\right] 100$$

where 500 ppm NO_x corresponds to the full scale reading of all instruments.

Since the 90% span level of instrument E presented impedance matching problems, this instrument was treated separately. Tables 18 and 19 present the relative and absolute error analyses, respectively, for this instrument at the 30% and 60% span levels.

The previous analyses all assumed Gaussian error distributions; in order to check this assumption, we plotted the frequency of occurrence of E1. The resulting graphs in Figures 26-30 show that the Gaussian assumption is probably invalid. Instrument A points this out most dramatically, showing what is obviously a tri-modal distribution. The data in Table 16 again show the strong dependence of the relative error upon the span level. While it may be tempting to ascribe these seemingly inexplicable results to exo-instrumental artifacts, the fact that Instrument A was connected directly to the PDP-12 caused us to look at the problem from a broader point of view. Some of the other instruments, however, still tend to exhibit a similar behavior even when going through the signal conditioning, amplication circuitry. The trend, expressed qualitatively, is shown below.

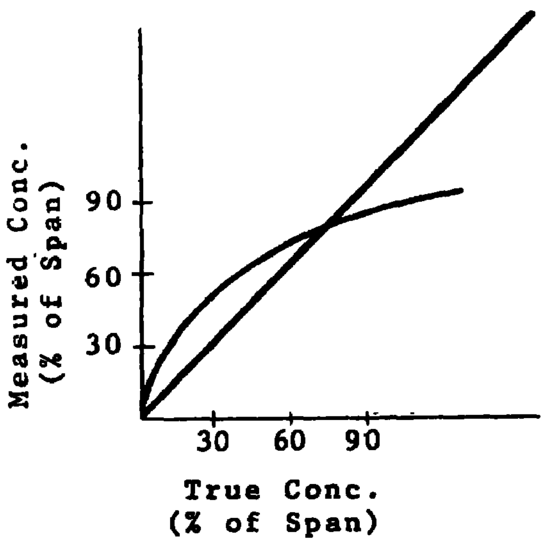

Figure 25. Qualitative Trends of NO_x Instrument Accuracy vs. Span Level.

Table 16

RELATIVE ACCURACY OF INSTRUMENTS IN LABORATORY TESTS - INDIVIDUAL INSTRUMENT AND SEPARATE SPAN LEVEL

(Based on Percent of NO_x True Value)

		A			B			C			D			F		
Span Level -		30%	90%	60%	30%	90%	60%	30%	90%	60%	30%	90%	60%	30%	90%	60%
Avg SD (ppm NO_x)	±	1.1	2.1	1.4	0.86	2.2	1.1	1.0	2.2	1.2	0.65	2.4	1.0	0.73	2.4	0.97
Avg ERR1	%	22.5	-2.4	5.5	10.4	-6.6	-1.9	22.2	2.4	7.8	10.1	-2.4	0.61	-6.9	-3.7	-3.4
Avg ERR2	%	21.4	-2.7	4.7	23.4	-3.2	3.4	39.5	6.2	14.5	20.6	0.2	4.6	-11.9	-4.9	-5.3
SD1	%±	8.5	5.5	4.5	7.4	4.7	3.9	11.1	7.3	7.6	7.1	4.0	3.6	5.2	3.8	3.3
SD2	%±	10.4	5.9	4.9	8.2	4.7	3.8	20.0	7.8	9.5	33.0	9.2	14.4	5.4	3.5	3.0
Mean Dev 1	%	23.2	5.4	6.3	11.9	6.8	3.5	23.4	6.2	9.3	11.6	3.7	2.6	7.1	4.3	3.7
Mean Dev 2	%	22.4	5.8	5.5	23.9	5.0	4.4	39.7	7.6	14.7	29.0	7.1	11.4	11.9	5.0	5.6
TSD1	%±	24.4	6.0	7.2	12.9	8.2	4.4	25.1	7.7	11.0	12.5	4.7	3.7	8.7	5.3	4.8
TSD2	%±	24.0	6.5	6.9	25.1	5.8	5.2	44.8	10.0	17.5	39.1	9.2	15.1	13.2	6.1	6.2
N		38	35	36	38	35	36	38	35	36	38	35	36	38	35	36

Table 17

ABSOLUTE ACCURACY OF INSTRUMENTS IN LABORATORY TESTS
INDIVIDUAL INSTRUMENT AND SEPARATE SPAN LEVEL
ANALYSIS BASED ON PERCENT OF FULL SCALE READING

	A			B			C			D			F			
Span Level -		30%	90%	60%	30%	90%	60%	30%	90%	60%	30%	90%	60%	30%	90%	60%
Avg ERR1		4.8	-2.6	2.8	2.1	-6.2	-1.1	4.7	1.4	3.9	2.1	-2.3	0.25	-1.7	-3.5	-1.9
Avg ERR2		4.5	-2.9	2.3	5.0	-3.3	1.7	8.5	4.8	7.5	4.1	-5.8	2.2	-2.7	-4.5	-2.9
SD1	±	1.9	4.9	2.4	1.9	4.6	2.4	2.5	6.2	4.0	1.9	3.7	2.0	1.7	3.7	2.0
SD2	±	2.3	5.2	2.7	1.8	4.4	2.1	4.3	6.0	4.9	7.1	7.8	7.6	1.8	3.5	2.0
Mean Dev 1		5.0	4.8	3.3	2.6	6.3	1.9	5.1	5.2	4.8	2.6	3.3	1.4	1.7	4.0	2.1
Mean Dev 2		4.9	5.2	2.9	5.2	4.6	2.3	8.6	6.2	7.6	6.3	6.0	6.0	2.7	4.6	3.0
TSD1	±	5.2	5.6	3.7	2.9	7.8	2.6	5.3	6.4	5.6	2.8	4.4	2.0	2.4	5.1	2.8
TSD2	±	5.2	6.0	3.6	5.4	5.5	2.8	9.6	7.7	9.0	8.3	7.8	7.9	3.3	5.8	3.6
N		38	35	36	38	35	36	38	35	36	38	35	36	38	35	36

Table 18

INSTRUMENT E RELATIVE ERROR ANALYSIS
(Based on Percent of NO_x True Value)

Span Level		30%	60%
Avg SD (ppm NO_x)		0.59	0.96
Avg ERR1	%	6.5	-2.5
Avg ERR2	%	13.0	0.42
SD1	±%	5.3	3.4
SD2	±%	23.1	10.4
Mean Dev 1	%	6.8	3.8
Mean Dev 2	%	14.9	6.5
TSD1	±%	8.5	4.3
TSD2	±%	26.6	10.4
N		36	34

Table 19

INSTRUMENT E ABSOLUTE ERROR ANALYSIS
(Based on Percent of Full Scale Reading)

	Level			
	30%	60%	90%	All Spans
Avg ERR1	1.37	-1.33	0.42	0.10
Avg ERR2	2.83	0.26	0.05	1.41
Mean Dev 1	1.43	2.02	1.48	1.69
Mean Dev 2	3.25	3.35	2.05	3.16
TSD1	1.78	2.26	1.94	1.99
TSD2	5.76	5.35	2.49	5.25
N	36	34	9	79

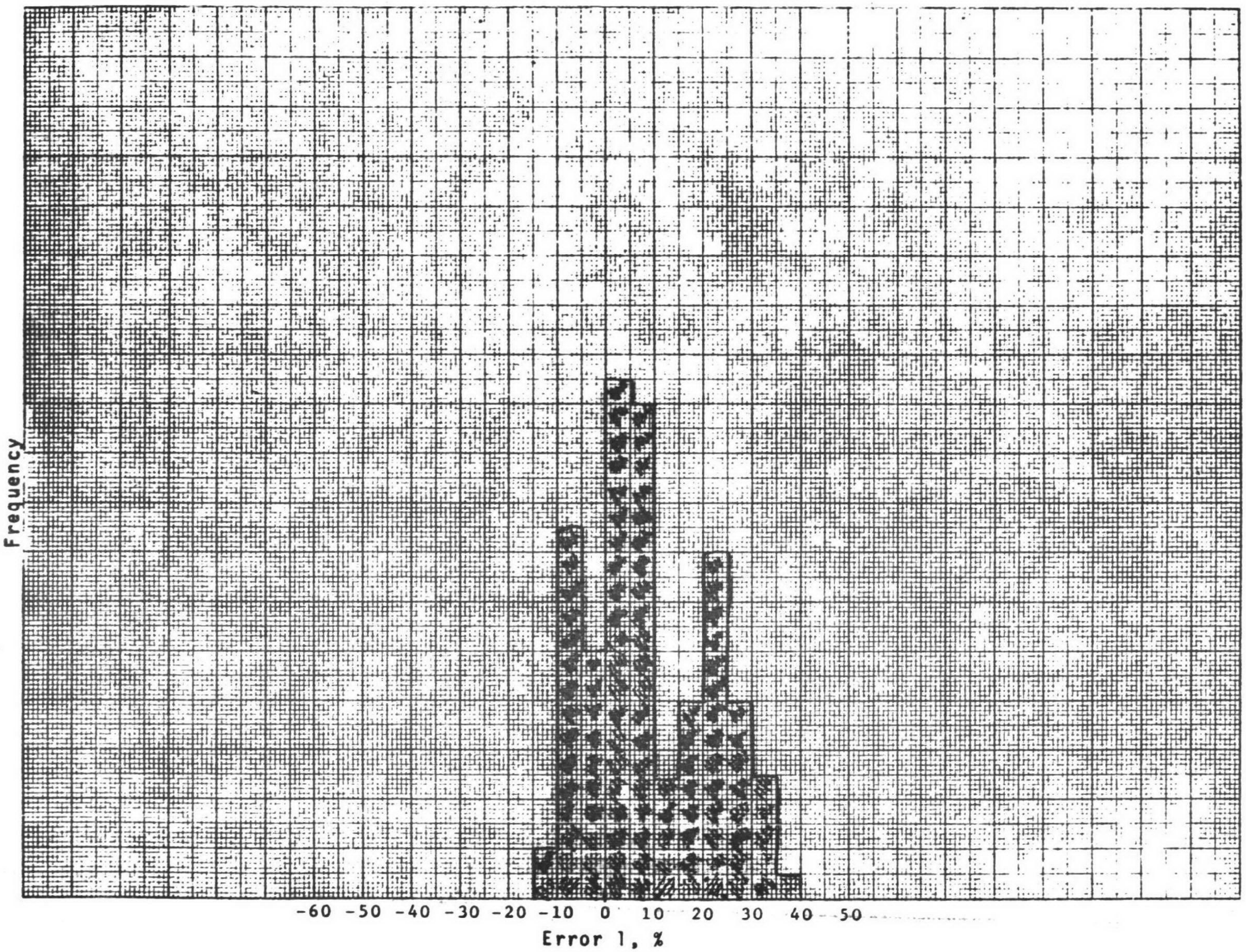

Figure 26. Instrument A - Error 1 Distribution for All Span Levels and All Experiments.

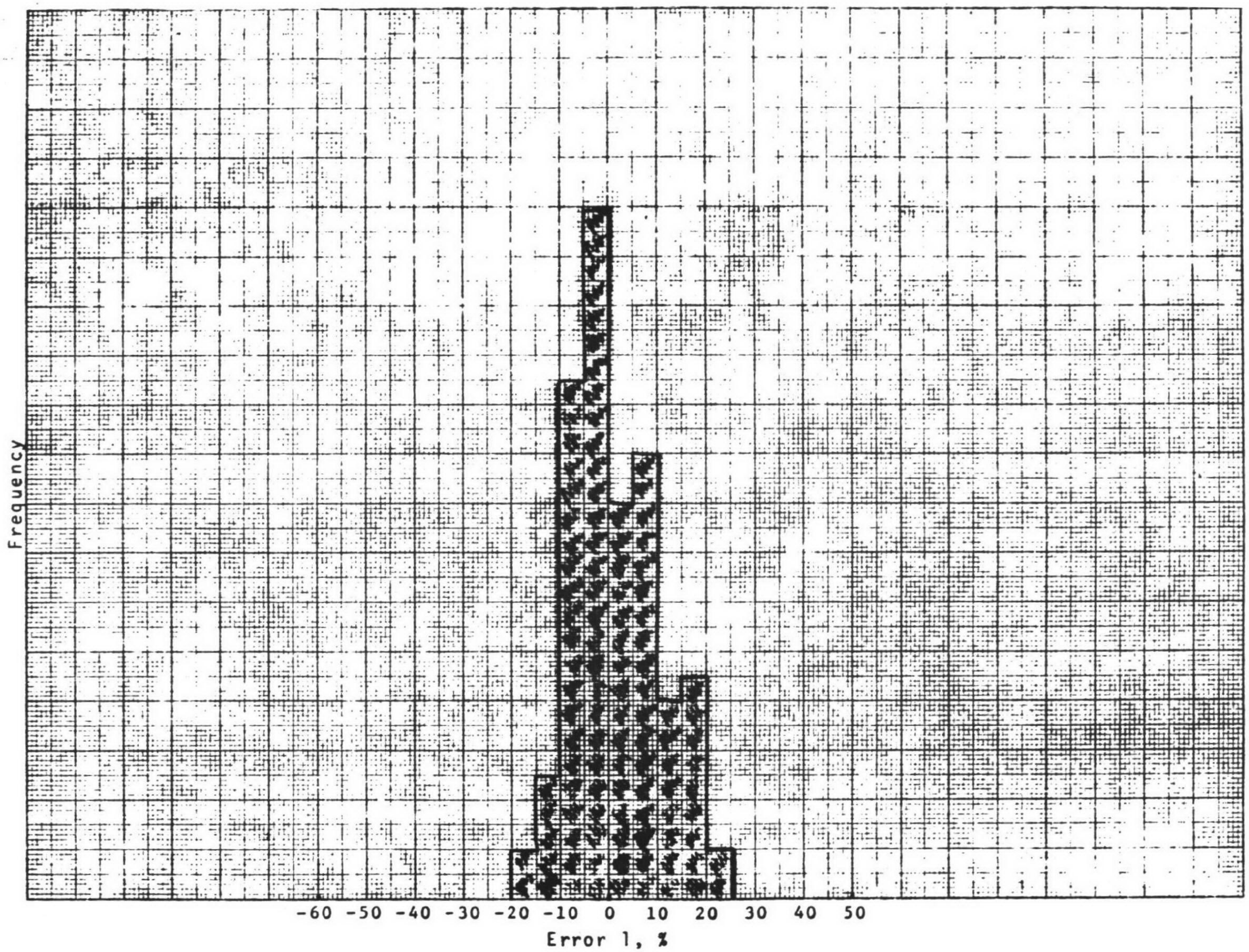

Figure 27. Instrument B - Error 1 Distribution for All Span Levels and All Experiments.

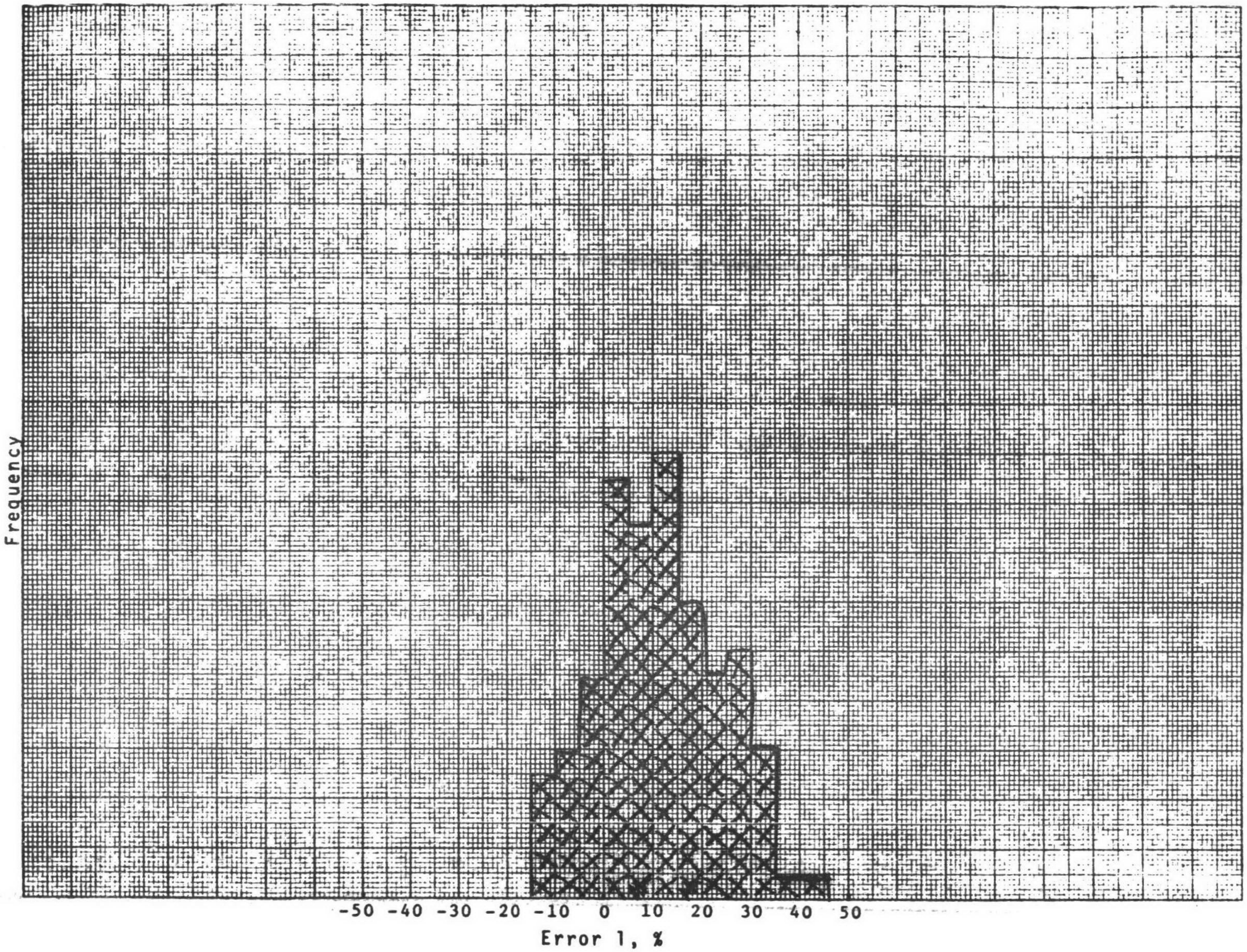

Figure 28. Instrument C - Error 1 Distribution for All Span Levels and All Experiments.

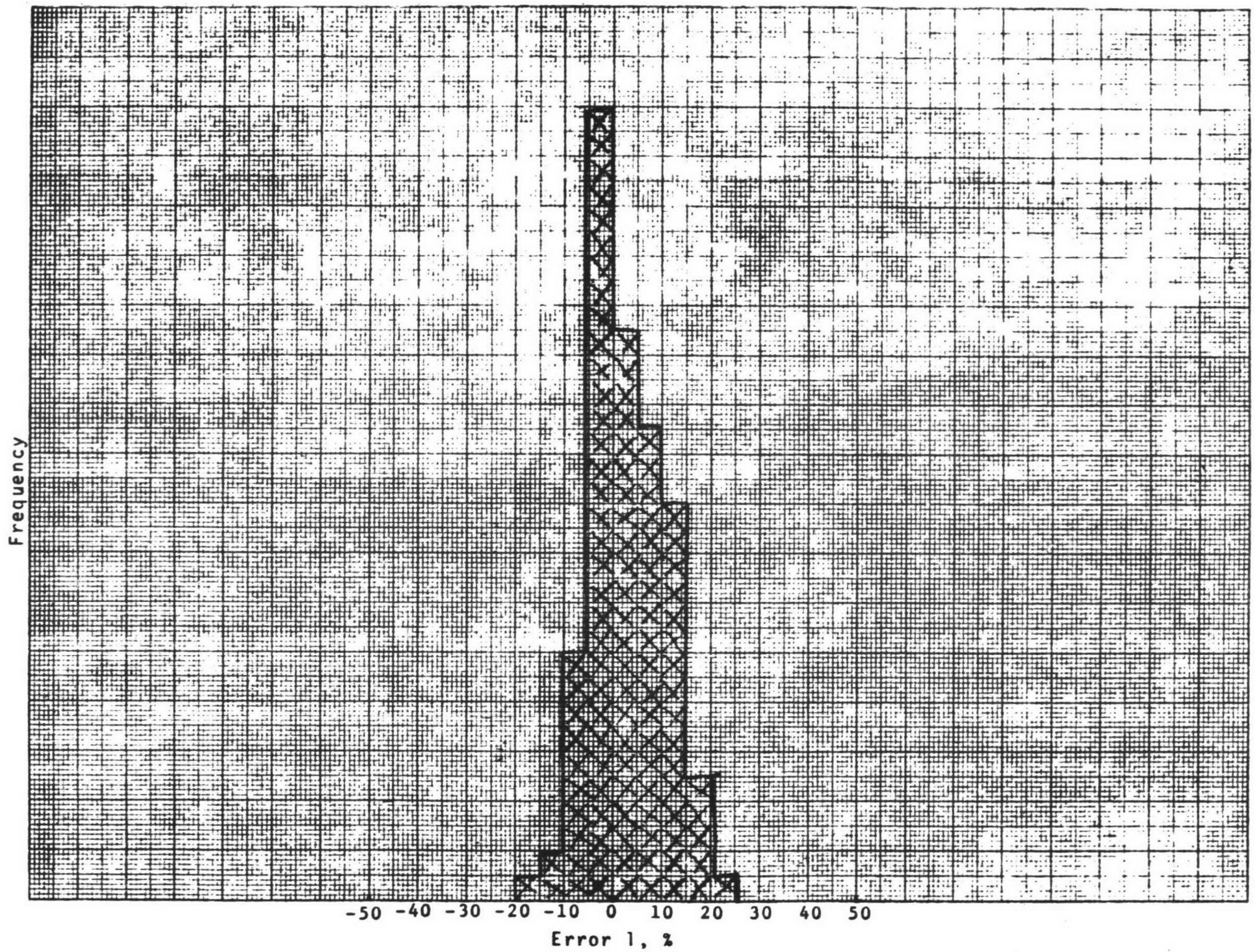

Figure 29. Instrument D - Error 1 Distribution for All Span Levels and Experiments.

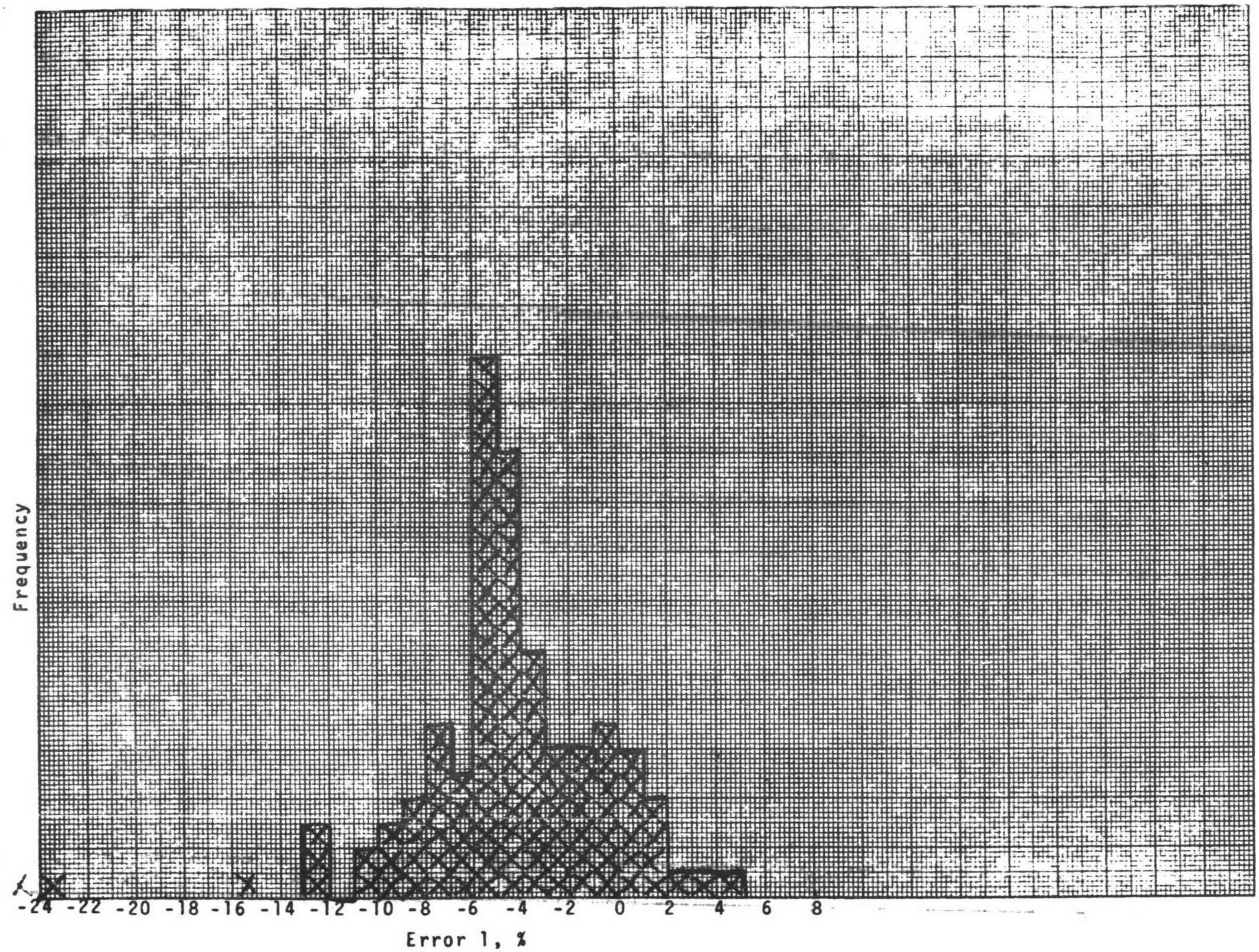

Figure 30. Instrument F - Error 1 Distribution for All Span Levels and All Experiments. (Note change in scale from previous figures.)

The straight line represents the case of zero error, and the curved line represents what we actually find. While it is difficult to draw conclusions from the results of one unamplified instrument, the fact that the amplified instruments behave in a similar fashion makes the interface seem less suspect.

There are a few other sources of potential error in dealing with the A/D conversion system of the PDP-12. There may be common ground, impedance matching, and A/D calibration stability problems in the PDP-12. While Digital Equipment Corp. (DEC) proved to be fairly responsive to our maintenance problems, the DEC service personnel were reluctant to discuss potential problems resulting from customer fabricated interface components.

A third and final source of this anomalous error at the 30% span level was pointed out to us by Fred Jaye. A brief look at Table 5 shows that the precision of the wet chemical method is poor, especially at the lower concentration. If then, the wet chemical procedure yields a low value, then the corresponding correction factor will be low. This problem is again clouded due to the poor precision which in turn makes statistical confidence limits about the correction factor quite large. For example, in Table 6a the 95% confidence band about the 30% span correction factor is 1.10 ± 0.22 (Mean ±2 x Standard Deviation).

4.4 FIELD EVALUATION TEST PROGRAM

The short-term field tests of NO_x monitors for accuracy were conducted between 7 June and 30 July. Table 20 presents the monitor data from instruments A through E. Column G is the DuPont 461 NO_x response and Column H represents the DuPont 400 sulfur dioxide analysis of the same stack sample. The data in Table 20 were read from the computer in octal formal. Table 21 data are presented as printed from the computer. In this case the readings are averages of ten values (first column under A) and the variance of the ten values is presented in each case (second column under A).

The gas sample analyzed June 7-10, 1971, came from unit #5 on the Dayton Power & Light Tait Power Station. The sample passed through a cyclone separator, H_2SO_4 scrubber and a glass wool filter. The gas samples analyzed during the balance of the test series were from unit #4 on the DP&L Tait Power Station. The sample passed through an H_2SO_4 scrubber and a glass wool filter.

The Monitor C scrubber solution for removal of SO_2 from the flue gas sample was observed to plug very rapidly (e.g., 2 hrs). By diluting the solution 50% with H_2O it is possible to run 8 hours without crystal formation becoming great enough to plug the inlet tube. A discussion of this problem with the instrument supplier yielded no information explaining this phenomenon.

Table 20

SHORT-TERM FIELD TEST DATA (ppm NO_x)

Date	Hr	A	B	C	D	E	G	H	Comment
		Instrument							
6- 7-71	1404	168	160	154	164	163	160	1850	
	1504	166	150	167	193	166	158	1890	
	1605	155	150	135	130	155	167	1750	
	1705	180	160	152	170	190	175	2570	
	1805	170	165	165	155	156	180	2670	
	1905	175	170	165	155	148	185	2675	
	2005	180	165	170	175	148	190	2710	
	2105	186	165	150	223	164	195	2830	
	2205	182	160	142	236	165	190	3000	
	2330	162	140	127	188	174	160	3000	
6- 8-71	005	166	140	123	199	151	158	3000	
	105	159	140	124	226	159	165	3000	
	205	150	140	134	199	143	155	3000	
	305	144	130	136	166	148	143	2856	
	405	142	140	103	162	144	150	2990	
	505	152	130	118	152	160	155	3000	
	605	170	140	144	231	182	175	2818	
	705	141	130	98	206	156	135	2940	
	825	-3	-5	-80	+134	+14	5	+96	Zero gas

A-E - Letter code of instruments same as previously stated
G - DuPont 461 NO_x monitor
H - DuPont 400 SO_2 monitor

Table 20 - (Cont'd)

Date	Hr	Instrument A	B	C	D	E	G	H	Comment
6- 8-71	830	0	0	0	7	6	0	0	Zeroed
	935	208	198	204	206	216	185	1602	Spanned
	1035	208	203	204	206	210	180	1614	
	1135	206	200	211	185	229	196	1632	
	1235	207	199	200	-	224	190	1548	
	1325	212	210	206	158	240	188	1380	
	1445	181	180	194	186	176	175	1152	Acid changed
	1535	168	153	190	176	159	173	1110	
	1635	188	168	234	164	179	190	1578	
	1735	190	153	232	145	176	188	1740	
	1835	176	138	236	125	167	173	1596	
	1935	190	145	256	116	168	183	1308	
	2035	178	140	243	82	167	175	1306	
	2135	178	143	254	58	166	170	1156	
	2235	180	145	260	25	167	165	984	
	2335	162	123	224	6	167	150	1008	
6- 9-71	035	172	133	268	23	152	180	1134	
	135	136	100	238	-31	132	150	1404	
	235	142	100	242	-40	143	150	1356	
	335	135	90	234	-57	130	140	1416	
	435	158	103	275	-36	141	155	1836	
	535	184	130	284	-9	143	210	1596	
	635	176	120	265	+1	172	195	1728	
	735	185	124	268	+19	143	198	1470	
	835	-16	-20	+42	-159	-16	0	-78	Zero gas

Table 20 - (Cont'd)

Date	Hr	Instrument A	B	C	D	E	G	H	Comment
6- 9-71	1155	-2	0	0	-3	21	0	-5	Zeroes
	1528	205	220	210	270	187	195	1769	
	1728	205	210	215	238	207	196	1465	
	1828	209	213	210	226	208	193	1383	
	1928	204	215	207	210	209	188	1412	
	2028	217	220	218	214	217	188	1383	
	2128	210	220	221	192	215	193	1236	
	2228	207	220	230	174	219	193	1213	
	2328	206	225	164	221	223	190	1277	
6-10-71	028	176	200	144	149	168	160	1523	
	128	183	210	168	171	152	160	1488	
	228	141	190	123	118	185	125	1611	
	328	141	160	127	118	127	120	1593	
	428	143	196	117	108	149	130	1488	
	528	155	190	135	115	145	135	1578	
	628	168	190	158	123	149	130	1599	
	758	133	160	113	84	138	95	1441	
	828	166	203	143	120	184	141	1512	

Table 21

S[illegible]-TERM FIELD TEST DATA (p[illegible])

Date	Time	A		B		C		D		E		G	H	
[illegible]	[illegible]	251.5630	1.0778	227.4300	1.5333	238.1840	1.1222	261.3280	0.6444	229.8830	790.2330	250	1492.3800	7.4667
	[illegible]	245.8980	4.8111	221.3540	0.5111	272.3630	0.9111	336.0350	0.0889	251.0740	583.4890	263	1025.9800	10.1333
	1[illegible]	217.6760	2.4111	179.3620	0.8778	271.6800	0.9778	324.1210	0.0444	223.2420	27.1444	253	814.4530	22.4889
	[illegible]	197.3630	1.9889	160.6[illegible]	0.5500	280.3910	0.5667	297.9700	0.1556	213.3790	559.3110	2[illegible]	465.8200	24.7111
	[illegible]	194.6290	8.6833	166.3410	0.5833	279.6880	0.2000	273.4380	0.0111	216.1130	74.1667	223	351.5630	0.0667
	2125	193.9450	1.7222	156.1410	0.3722	287.3050	0.1444	244.8430	0.0667	215.5270	296.2670	254	257.2270	3.4000
	2225	153.8090	1.9444	102.9730	0.1139	280.1760	0.2778	169.2380	0.4222	171.5820	29.0389	195	181.0550	3.4278
	2325	191.6990	4.0167	148.8710	0.6000	270.3130	0.5444	273.6330	0.1333	220.4100	21.8111	270	93.7500	0.0000
[illegible]	[illegible]25	195.6050	4.2333	152.7770	0.0111	220.1170	1.5000	246.1910	0.0778	223.5350	110.2780	253	94.9219	6.1014
	0125	178.7110	4.8667	125.5420	0.3861	231.1520	0.8333	215.5270	0.2111	202.4410	94.7277	241	80.8594	6.1014
	0225	151.2700	3.2556	90.1689	0.2778	219.1410	0.6667	177.7343	0.0056	174.7070	143.1330	219	59.7656	6.1028
	0325	172.0700	0.7944	110.2430	0.7278	240.8200	0.8444	201.8550	0.1889	174.5310	84.5056	233	20.5079	9.5367
	0425	144.1410	1.9444	74.9779	0.2836	214.5510	0.2000	165.5270	0.4722	162.3050	15.4222	233	15.2344	16.7846
	0525	134.7660	1.0500	56.3147	0.6424	217.0900	0.4222	155.6640	0.4500	143.5550	99.5944	212	35.1563	0.0005
	0625	128.9060	1.9000	53.8190	0.9986	204.6880	0.6611	147.8520	0.2500	151.7580	268.3330	195	34.5703	3.4330
	0725	131.4450	1.5139	52.1915	0.2778	196.6830	0.4500	137.5000	0.5778	153.1250	10.7500	*	41.6016	3.4330
	0825	130.6640	3.9778	54.7956	0.2771	195.5080	0.3667	135.2540	0.2528	143.6520	38.8667	*	5.2734	18.6920
	0925	187.9880	1.1000	122.8300	2.1389	209.5700	0.6667	188.5740	0.0778	216.3090	180.8110	*	70.8984	3.4312
	1025	193.9450	1.3000	131.4020	0.2917	210.9380	0.0000	192.9690	0.2444	214.1600	29.6667	*	80.2734	8.0083
	1125	211.5230	4.0556	156.3580	1.3278	209.7660	0.8000	212.6950	0.3556	227.0510	101.9670	*	80.2734	8.0097
Zeroes	1[illegible]	62.5000		58.5938		[illegible].5313		-29.2969		63.4766			123.0470	

*[illegible] valve problems.

Table 21 - (Cont'd)

Date	Hr	Instrument A		Instrument B		Instrument C		Instrument D		Instrument E		Instrument G	Instrument H	
7-13-71	1119	268.6520	10.6556	239.4740	0.6333	257.8130	4.4222	253.5160	0.2222	266.7970	550.0670	288	1128.5200	16.1778
	1219	264.4530	2.6778	244.9000	1.7111	253.8090	0.9000	321.5820	349.0000	262.1090	11.2222	284	1045.3100	8.3556
	119	257.0310	7.1222	229.1660	5.8556	245.5080	1.9222	301.2700	18.0000	256.4450	10.1889	274	1099.2200	31.1111
	219	263.7730	2.8000	240.4510	2.0556	239.4530	2.4778	390.9180	0.1776	259.5700	266.9560	270	1089.8400	0.7111
	319	260.3520	2.9778	234.1580	1.3333	246.4840	0.2333	314.0630	0.2222	256.5430	8.8778	274	1054.6900	0.7111
7-14-71	1116	299.2190	5.4889	285.4810	1.3444	309.8630	1.6444	317.8710	7.2222	303.5160	63.4889	278	795.1170	167.9110
	1216	304.1990	4.8667	295.4640	0.6444	311.3280	0.5333	313.4770	0.0444	304.2970	64.0000	261	760.5470	5.6889
	116	278.8090	4.4667	275.3900	1.3333	287.5000	1.9111	288.4770	5.1111	278.8090	59.3555	243	714.8440	0.1778
	216	293.7500	1.8222	289.3980	0.1333	299.9020	0.2444	299.1210	1.0000	292.9690	178.3780	268	778.1250	104.9780
	316	222.5590	4.9444	239.5830	0.2667	194.1410	1.0000	312.8910	0.2222	208.3010	107.0110	170	822.0700	7.6444
	416	291.0160	5.0667	284.3960	1.0889	293.4570	0.6444	372.1680	1.8222	284.9610	133.2110	233	914.0630	0.3556
	516	291.7970	8.4222	300.1300	0.2444	296.3870	0.4667	310.3520	0.1111	283.6910	171.4560	237	864.2580	9.4222
7-15-71	1140	262.2070	4.0444	239.6910	0.6556	268.4570	2.3778	251.8550	0.2889	254.3950	22.5000	291	762.8910	5.7778
	1240	250.6840	2.5444	232.6390	0.8667	243.9450	1.2111	155.4690	0.1611	250.0980	438.5560	283	855.4690	0.5333
	1340	239.2580	3.7889	229.3830	1.4222	219.5310	1.4333	195.3130	0.0167	199.9020	51.0667	256	925.7810	0.8889
	1440	230.6840	6.3944	200.1950	0.2944	188.2810	0.5833	175.3910	0.2333	192.9690	255.1940	272	878.9060	0.1778
	1540	244.3360	3.3111	237.6300	1.0333	258.4960	1.8778	138.9650	0.2083	206.1520	82.3111	255	890.6250	0.5333
	1640	221.8750	3.7444	213.9750	11.5778	231.8360	1.0556	81.2500	0.1667	188.3790	62.1722	186	963.8670	16.5333
	1740	279.8830	4.3778	271.9180	0.5778	299.7070	1.4889	132.1290	0.2111	260.6450	204.1440	276	1037.1100	44.8000
7-16-71	105	248.5350	1.7222	224.7180	0.3000	254.1990	1.6889	245.5080	0.2111	252.4410	302.0220	280	925.7810	0.8889
	205	241.1130	3.2333	222.0050	0.2333	246.2890	0.7778	237.3050	0.0111	246.4840	150.6890	268	969.7270	9.2444
	305	247.6560	4.4556	220.8110	0.5667	248.1450	0.0889	240.8200	1.0667	253.6130	75.4222	284	1033.0100	7.2889
	405	243.0660	2.6111	213.8670	0.2889	250.4880	0.4778	245.4100	0.6222	228.4180	19.5667	240	1063.4800	16.7111
	505	244.7270	3.6222	213.7580	0.2111	245.2420	0.3778	238.0860	0.3556	238.2860	448.5780	270	1066.4100	0.3556

Table 21 - (Cont'd)

Date	Hr	A										G	H	
[illegible]	[illegible]	238.9650	2.3111	212.2220	1.9333	240.4330	0.7667	230.4690	0.6[illegible]	234.4730	31.6444	261	1746.6800	0.7111
	[illegible]	242.0930	0.7330	224.0600	0.[illegible]	241.89[illegible]	1.6778	257.3310	1.4111	22[illegible].7810	70.0889	[illegible]	1559.1800	2.1333
	[illegible]44	241.8950	1.8889	223.6323	0.4222	241.8951	0.4110	279.5930	0.1556	223.0343	13.3778	26[illegible]	1688.6730	5.6889
	[illegible]44	238.0860	1.2111	222.544[illegible]	3.[illegible]	240.5[illegible]	0.8111	304.5930	1.5333	221.4840	113.5330	261	1804.1000	9.2444
	[illegible]44	241.1130	4.0778	224.633[illegible]	0.7556	244.4340	2.3111	311.2330	0.3556	225.3930	164.6890	[illegible]67	1850.9800	1.4222
	[illegible]44	240.6257	4.4667	227.6473	0.5556	241.7973	0.6556	315.3320	0.9111	225.2930	31.5667	261	1874.4100	1.4222
	[illegible]44	251.4650	3.0333	232.4213	0.6111	250.2933	1.0556	329.1990	0.2444	242.5780	65.7111	265	2041.4100	6.4[illegible]
7-[illegible]	[illegible]42	242.3830	2.4778	213.2160	2.1111	243.8480	2.3222	237.5930	1.4667	244.5510	77.1556	275	1934.1800	2.1333
	[illegible]042	239.9410	1.8889	217.1223	0.5444	243.1640	1.6667	246.2390	1.4111	243.5480	147.7003	268	2040.2300	2.1333
	[illegible]42	246.4840	2.9889	217.0142	0.7333	246.4840	0.6556	282.5204	1.2556	254.4923	24.6000	266	2111.7200	8.5333
	1242	246.0940	3.3667	215.7110	0.2778	259.4730	1.2333	287.1090	0.0333	263.4770	156.5330	268	2199.6130	13.5111
	1342	240.6250	3.8222	217.8823	0.2778	239.3551	0.2667	289.0630	0.0000	252.6370	36.0111	250	2296.8800	2.1333
	1442	234.8630	1.2889	216.6983	3.6444	229.9800	0.2333	283.3313	0.3778	242.0900	130.8220	248	2334.9600	14.2222
	[illegible]42	238.6720	1.5333	219.618[illegible]	0.3556	239.1633	1.9667	300.9770	0.1333	251.8550	220.6780	256	2194.9200	8.5333
	1642	245.9960	3.6667	218.0393	3.2111	243.6250	0.4222	311.5230	0.0667	273.5353	907.3223	246	2082.4200	74.6667
7-[illegible]-7[illegible]	[illegible]125	222.4610	2.4889	192.9253	3.1556	221.0940	1.7111	186.7190	0.3556	220.4100	109.7670	262	2104.1000	0.7111
	1225	243.0660	1.5556	224.9352	4.0000	238.2810	1.4556	212.8910	0.0222	251.6600	28.8111	288	1895.5100	30.5778
	1325	254.1990	2.5333	241.2110	9.0111	248.6330	0.2333	226.3670	0.1667	266.7970	226.4780	277	1976.3700	22.0444
	1425	249.6090	1.0778	240.3430	1.3556	242.2850	5.1556	222.5590	0.7030	262.7930	113.2330	280	1910.7400	2.1333
	1525	244.7270	1.4889	230.7940	1.7333	237.2070	0.2778	226.3670	0.3667	253.4180	90.3000	270	1793.5500	2.1333
	1625	246.6800	1.9333	233.1810	6.1667	240.5270	3.1667	233.7890	1.7111	256.4450	51.0889	254	1502.3400	9.2444
7-2[illegible]-71	1100	257.1290	1.0444	228.5150	3.3889	237.5030	0.5667	235.8400	0.2222	268.5550	225.0330	276	1837.5000	31.2889
	[illegible]	255.4690	2.5556	234.4433	3.2556	227.7340	2.0667	235.5470	0.3333	268.0663	521.1443	289	1748.4400	6.4000
	[illegible]	258.9840	4.5889	244.1433	2.5667	225.2430	0.6222	235.3520	0.0333	265.7230	168.5330	285	1640.0400	2.1333
	1400	270.0200	3.4000	254.4453	1.1111	233.2033	0.3556	252.6379	0.1889	271.9730	60.8444	284	1613.0900	6.7556
	15[illegible]	257.3240	1.7222	241.2110	1.3778	223.2420	0.6444	253.7110	1.2111	261.9160	408.0220	262	1897.2700	4.2667
	[illegible]	249.0233	6.9556	231.9570	1.0667	213.5740	1.8667	242.1883	3.0222	250.2930	146.2110	255	2262.3000	0.0000
7-[illegible]	[illegible]40	270.3130	1.4111	172.5262	1.5444	283.5660	2.3111	306.2500	0.2222	292.7730	136.1780	260	2255.2700	39.1111
	[illegible]	254.9800	2.8333	165.5113	0.6956	253.6130	0.8444	237.8910	0.2444	267.0903	40.9222	231	2151.5600	26.3111
	1140	256.3480	4.2556	168.9451	0.9333	252.3440	0.6778	226.9530	0.2333	269.1410	134.7300	233	1981.0500	32.0000
	124[illegible]	262.4020	2.9333	171.1150	8.2333	213.2540	0.8444	265.9160	0.2111	271.0940	53.8222	270	1833.9800	14.2222
	13[illegible]0	267.5470	2.4556	161.7833	12.5833	95.3984	2.7083	254.1990	1.4667	269.8240	155.3000	273	1953.5200	83.9111
	[illegible]	251.9530	2.9444	153.6373	1.3222	64.7461	0.4326	264.5510	0.3556	254.1253	22.6556	268	2020.9300	39.8222
	15[illegible]	252.5390	3.4000	156.7923	2.3722	48.2422	1.1010	264.2580	0.6444	263.2540	232.7110	256	1851.5600	3.5556
	[illegible]	251.8550	3.0444	165.5813	0.7167	251.8550	1.3444	241.1130	0.6889	256.4450	258.1440	256	1754.3000	15.6444

Table 21 - (Cont'd)

Date	Hr	Instrument A		B		C		D		E		G	H	
7-26-71	1226	241.9920	1.4111	208.1160	1.6222	241.9920	0.5667	223.4380	2.9111	257.4220	378.5110	229	2223.0500	51.9111
	1326	243.1640	4.4111	220.1600	0.6889	279.8830	0.6111	500.0000	0.0000	263.9650	56.5555	256	2291.6000	24.8889
	1426	230.2730	3.3111	214.1920	0.5889	251.5630	1.9222	206.5430	0.4667	261.7190	733.6440	257	2327.3400	25.6000
	1526	225.2930	3.9889	221.3540	0.7444	251.8550	0.5000	215.9180	0.9333	258.3983	41.9555	232	2414.6500	1.4222
	1626	240.0390	1.6222	233.6150	3.2111	260.5470	0.5444	199.9020	0.6222	265.7230	481.7783	243	2320.3100	1.4222
7-27-71	1233	252.5390	2.5667	171.4410	1.5222	250.7810	2.4889	211.6210	0.6444	276.6600	111.6440	228	1635.3500	1.7778
	1333	261.6210	1.3222	197.5910	1.3222	257.9100	1.9778	208.6910	0.2111	262.7930	72.1222	272[a]	1739.6500	24.1778
	1433	250.9770	1.6667	212.9990	2.9667	266.8950	1.0222	290.8200[b]	0.1333	302.9300	95.9333	264	1761.9100	29.8667
	1533	255.5660	3.3667	195.9630	2.3000	247.2660	1.4333	147.7540[b]	1.9056	271.8750	680.9330	274	2040.2300	71.8222
	1633	254.1020	3.3111	204.2100	1.8778	256.9340	0.4889	217.0930	0.2000	264.1600	2.1444	247	1832.8100	19.9111
7-28-71	900	12.0000		4.0000		-35.0000		-39.0000		-13.0000			17.0000	
7-28-71	1027	247.2660	2.7000	220.8110	2.6333	252.5390	0.4444	240.4300[b]	0.1333	261.1330	888.6220	278	1432.6200	23.8222
	1127	247.8520	1.2111	218.7500	2.6556	250.7810	1.2111	218.8480[b]	0.1300	264.6480	1332.4800	273	1251.5600	8.1778
	1227	254.9830	1.8778	222.9810	1.6000	257.0310	0.5556	219.3360	0.2444	272.8520	556.1110	284	1037.5000	8.8889
	1327	255.8590	2.3000	225.2690	1.5333	255.8590	0.6222	463.1840	33.5556	270.5080	379.3330	298	1037.7000	2.4889
	1427	265.6250	5.2444	227.6470	0.8111	261.5230	0.3444	499.0230	0.1333	293.7500	725.5560	280	1014.2600	18.1333
	1527	282.1290	3.0222	236.4360	2.2222	270.4100	1.9556	287.3050	0.1333	308.7890	409.5780	270	1060.5500	22.4000
	1627	279.8830	3.8222	238.8230	2.1111	271.6800	0.3556	268.4570	0.0333	299.4140	460.4890	281	1019.5300	0.7111
7-29-71	902	47.0000		16.0000		0		70.0000		22.0000		0	-46.0000	
7-29-71	1054	271.9730	4.2556	276.9090	3.7222	285.6450	1.9222	242.2850	0.0778	287.2070	91.8222	220	1701.5600	15.6444
	1154	261.4260	3.1556	275.2820	0.6889	263.3790	0.3778	205.0780	0.0222	289.4530	287.1670	246	1687.5000	0.0000
	1254	267.3830	3.1000	280.1650	1.9222	260.2540	0.4222	197.2660	0.0222	270.2150	66.7222	250	1873.9000	98.8444
	1354	258.2030	7.2222	270.3990	0.6111	253.1250	2.0556	189.5510	0.0722	258.3010	526.4670	251	1966.9900	6.4000
	1454	252.1460	3.7556	268.0120	0.9778	240.7770	2.1222	205.7620	4.0333	268.0660	100.0330	233	2067.1900	4.2667
	1554	275.3910	2.2889	280.5990	1.5333	262.6950	0.8111	178.5160	0.7944	260.3520	219.1440	255	2197.8500	2.8444
	1654	259.5700	2.9000	269.6390	1.5889	250.3910	1.0778	172.5590	1.2667	240.2340	611.3890	225	2296.8800	2.1333
7-30-71	840	42.0000		134.0000		130.0000		393.0000		17.0000		0	0	
7-30-71	1108	260.0590	2.7222	237.8470	5.3556	271.6840	0.7778	274.1210	0.3889	254.7850	91.4000	262	1395.7000	12.4444
	1208	257.9100	3.0333	243.8150	0.3489	259.9610	0.5444	236.1330	0.1333	254.3950	377.8890	272	1659.9600	6.4000
	1308	241.5040	4.8667	226.8880	1.6111	246.3870	0.4111	200.9770	0.1389	237.9880	456.6750	245	1868.5500	32.0000
	1408	253.0270	3.6889	234.0490	0.9030	255.2730	0.6556	195.2150	0.0778	253.3200	67.1889	267	1675.2000	1.4222
	1508	257.6170	3.1111	235.2430	1.3556	257.9130	0.7000	193.3590	0.0111	250.3910	47.6889	277	1567.9700	23.1111
	1608	259.0820	3.1556	238.4980	0.8111	257.4220	0.6556	191.9920	0.2389	259.2770	576.8780	269	1740.8200	8.5333

[a] Glass wool in "G" sample line changed.

[b] "D" changed - 7-28-71 - 1115 - 1615
7-27-71 - 1333

In the case of Monitor D, the method used for compensating for SO_2 present in a sample when measuring NO_x did not work when the SO_2 concentration is continuously varying. It therefore was necessary to use a scrubber solution (similar to that supplied with instrument C) to remove the SO_2. This behavior was also reported by other users (see Appendix I).

In using the DuPont 461, one of the pneumatic valves in the instrument failed July 1. A call to the supplier resulted in a new valve arriving July 6. This problem was corrected by removing the high temperature grease originally employed in the valves and replacing it with a silicone oil.

Instrument F was returned to MRC after 40 days at the factory for repairs. It was used two hours and turned off overnight. The next morning the instrument registered on a full scale reading. All attempts to zero the instrument were in vain. Inspection of the measuring cell revealed a deposit on the gold lined walls of the cell. To date, no reasonable explanation of the cause for these deposits is apparent and no method for removing them has been found.

4.4.1 Analyses of Power Plant Stack Gas by the Phenoldisulfonic Acid (PDS) Method

Integrated samples were taken of the flue gas at two different positions on the sampling train. The results of three days of testing are shown in Table 22. The 10-29-71 PDS samples were taken from the manifold which also supplied flue gas to all other instruments. The 10-30-71 PDS and DuPont samples were taken from the untreated sample line, while the other four instruments were receiving dry, filtered gas from the manifold. The 11-1-71 PDS samples were collected from the manifold gas stream being delivered to five other instruments. The DuPont 461 was again drawing samples from the untreated sample line.

An analysis of the comparison between the DuPont 461 readings and the PDS samples on 10-29-71 and 10-30-71 indicate a consistent realtionship of $\frac{\text{PDS}}{\text{DuPont}} = 1.12$.

Since this is the same as the relationship derived in the laboratory tests, we conclude that the 461 does not suffer from appreciable H_2O, CO_2, SO_2 interferences.

In the field evaluation tests the DuPont 461 strip-chart record was, however, employed as the reference value for two reasons:

Table 22

ANALYSES OF POWER PLANT STACK GAS BY THE PHENOLDISULFONIC ACID METHOD

PDS	Date	Hour	Beckman	MSA	Dyna	Enviro	Inter.	Bendix	DuPont 461	Pan[b]
300	10-29-71	1618	290	*	280	290	290	*	265	*
353		1628	290		300	290	290		285	
329		1638	300		310	300	300		295	
297		1648	305		305	300	310		290	
301	10-30-71	1837	305	*	305	305	300	*	280	*
346		1847	285		290	295	280		275	
321		1857	300		320	320	310		300	
213[a]		1907	305		310	310	310		308	
285	11- 1-71	1600	280	*	280	280	275	*	330	300
289		1610	285		280	295	270		328	280
287		1620	290		275	315	275		333	275
289		1630	295		290	330	275		310	290

*Inoperative

[a]Silica suspension in sample, resulting in low value.

[b]Pan - Panametrics, Inc.—Krypton Clathrate Prototype Monitor.

The instruments were zeroed and spanned daily versus the DuPont 461 readings and therefore the responses of the evaluated instruments can only be compared with the 461 record.

Statistical analysis of the field test data exhibited a closer agreement for all instruments tested to the uncorrected 461 response rather than to the adjusted response (461 readings x 1.12).

4.4.2 Statistical Analysis of Field Test Data

Preliminary statistical evaluation of the data in Tables 20 and 21 were conducted. Correlation coefficients were derived to examine correlation between the NO_x monitors, and correlations with sulfur dioxide reading and time. Assuming a correlation coefficient ≥ 0.9 to be of statistical significance, the frequency of established correlations was very small. In 20 days of test, instruments A and C correlated with the DuPont 461 on three days, instrument E on two days, and instruments B and D on one day.

One source of low incidences of correlation between the five continuous monitors and the DuPont 461 readings was the location of the DuPont instrument with respect to the sulfuric acid scrubber and the manifold gas distribution system supplying the continuous NO_x analyzers. The data recorded before June 25 were taken with the DuPont 461 monitor located after the scrubber and before the manifold. On 25 June, the DuPont instrument was moved upstream of the scrubber so that it was seeing unscrubbed stack gas containing a higher water vapor and particulate loading. The incidences of correlation between the continuous monitors and the DuPont occurred 1/3 of the time with the 461 downstream of the scrubber and only 1/12 of the time when it was positioned upstream.

In instances where correlation was found, a least squares treatment was conducted and intercepts and slopes of the instrument readings versus the DuPont 461 were calculated. In general, the nondispersive infrared instrument data exhibited a large positive intercept (40-120 ppm) and a small slope (0.5-0.9), while the intercept on electrochemical monitor C was near zero and exhibited a slope near unity. Electrochemical monitor D exhibited a large negative intercept (-80 ppm) and a large slope (1.55) in the one case where correlation was found.

The frequency of correlation between all instruments and time are shown in the following Table 23 where 18 sets of data were examined.

Table 23

FREQUENCY OF CORRELATIONS (DAYS)
BETWEEN INSTRUMENT READINGS AND TIME

	A	B	C	D	E	G[a]	H[b]	I[c]
A	///	7	6	2	7	3	0	2
B	7	///	4	2	5	1	1	3
C	6	4	///	2	3	3	1	1
D	2	2	2	///	0	1	0	4
E	7	5	3	0	///	2	2	2
G	3	1	3	1	2	///	0	0
H	0	1	1	0	2	0	///	2
I	2	3	1	4	2	0	2	///

[a] DuPont 461 NO_x monitor

[b] DuPont 400 SO_2 monitor

[c] Time

In general, it is observed that the frequencies of correlation between the five continuous monitors (A-E) are higher than that for correlation with the DuPont 461. The notable exception is instrument D where few instances of correlation are observed. This could be explained by the higher correlation frequency of instrument D readings with time (I) indicating a zero-drift problem. The incidences of correlation of NO_x instrument readings with the SO_2 value from the DuPont 400 monitor were very low, indicating a minor influence of SO_2 concentration on the nondispersive infrared NO_x monitors. The electrochemical monitors as mentioned above were equipped with in-line SO_2 absorbers.

Absolute and relative average and mean errors and mean deviations were calculated for all data with reference to the DuPont 461 analyzer. The relative error data are presented, by days, in Table 24 and summarized at the bottom of the table in terms of weighted average error, straight average error and straight standard deviation for all data. The corresponding absolute error analysis is presented in Table 25.

The sources of inaccuracy include (1) difficulties in accurate zeroing of instrument, (2) difficulties in accurate spanning of instruments, and (3) zero drift during an extended analysis period. In some cases, high variances in the readings (Tables 20 and 21) were caused by random noise in instruments that had not been observed earlier in the controlled laboratory tests. This was especially true of instrument E. The standard deviation is considered to be the best indicator of accuracy during these short-term runs.

Table 24

ACCURACY OF NO_x MONITORS - SHORT-TERM FIELD TESTS
(All data expressed as % of true value)

Run Date		Instrument A	B	C	D	E	No. of Points
6/7/71-6/8/71	Avg Error	-1.4	-10.5	-16.4	12.0	-3.4	
	Mean Dev.	4.1	10.5	17.0	19.2	9.0	18
	Std Dev.	4.5	11.9	19.4	23.7	11.1	
6/8/71-6/9/71		1.2	-17.6	36.3	-58.2	-3.1	
		6.2	20.9	36.3	61.3	11.4	22
		7.7	24.4	42.7	78.4	14.6	
6/9/71-6/10/71		13.7	29.4	6.1	2.5	14.4	
		13.7	29.4	10.2	12.9	15.4	17
		16.8	35.3	12.3	16.1	20.8	
6/25/71-6/26/71		-21.5	-42.9	4.8	-3.3	-14.5	
		21.6	42.9	9.0	17.3	15.3	15
		25.5	48.9	15.0	22.0	18.1	
7/13/71		-5.4	-14.4	-10.4	14.2	-6.2	
		5.4	14.4	10.4	18.9	6.2	5
		6.3	16.3	11.7	25.7	7.1	
7/14/71		18.3	18.1	18.0	34.3	16.4	
		18.3	18.1	18.0	34.3	16.4	7
		21.5	23.5	20.3	46.0	18.5	
7/15/71		-5.4	-9.3	-4.5	-38.8	-14.1	
		11.3	13.6	14.5	38.8	14.4	7
		15.0	16.9	18.7	44.7	18.3	
7/16/71		-8.4	-18.1	-6.7	-9.7	-9.1	
		8.9	18.1	8.6	10.6	9.1	5
		10.9	20.7	10.0	12.8	10.5	
7/19/71		-8.2	-15.2	-7.9	9.8	-13.1	
		8.2	15.2	7.9	14.3	13.1	7
		9.0	16.6	8.6	17.1	14.4	
7/20/71		-6.7	-16.3	-6.4	8.2	-2.1	
		6.7	16.3	6.4	13.7	5.3	8
		8.1	17.9	7.5	16.1	7.1	

Table 24 - (Cont'd)

Run Date		Instrument A	B	C	D	E	No. of Points
7/21/71	Avg Error	-10.3	-16.4	-12.3	-19.6	-7.3	
	Mean Dev.	10.3	16.4	12.3	19.6	7.5	6
		12.2	19.1	14.2	22.7	10.0	
7/22/71		-6.1	-12.9	-17.5	-11.6	-3.8	
		6.1	12.9	17.5	11.6	3.8	6
		7.7	14.9	19.4	14.2	5.0	
7/23/71		1.0	-35.3	-27.4	0.7	5.1	
		5.0	35.3	34.0	5.2	6.3	8
		6.4	38.2	49.7	7.8	9.7	
7/26/71		-2.8	-9.7	5.8	-11.9	7.6	
		5.1	9.7	6.6	11.9	7.6	5
		6.7	12.2	8.0	15.1	9.7	
7/27/71		-3.1	-23.1	-2.5	-17.5	4.3	
		4.5	23.1	5.1	22.5	6.5	4
		5.45	27.3	6.9	30.5	9.7	
7/28/71		-6.4	-18.8	-7.1	11.5	0.7	
		7.6	18.8	7.1	28.9	6.7	7
		9.4	20.7	8.8	41.9	8.2	
7/29/71		10.1	14.6	8.9	-16.7	11.8	
		10.1	14.6	8.9	19.5	11.8	7
		13.0	1[illegible].0	13.7	22.3	16.3	
7/30/71		-4.0	-11.1	-2.9	-18.9	-5.3	
		4.0	11.1	4.1	20.4	5.3	6
		4.9	12.4	4.9	24.6	6.4	
Weighted Avg Error (%)		-2.1	-10.7	-2.5	-1.5	-2.3	
Straight Avg Error (%)		-2.5	-11.6	-2.3	-6.3	-1.2	
Straight Std Dev. (%)		9.6	21.1	14.6	22.3	9.5	

Table 25

ACCURACY OF NO_x MONITORS - SHORT-TERM FIELD TESTS

(All Data Expressed as Percent of Full Scale)

Run Date		A	B	C	D	E	No. of Points
6/ 7/71	Avg Error	-0.5	-3.6	-5.4	3.7	-1.3	18
	Mean Dev	1.4	3.6	5.6	6.3	3.1	
	Std Dev	1.5	4.1	6.4	7.6	4.0	
6/ 8/71		0.6	-6.0	12.4	-19.7	-0.8	22
		2.4	7.4	12.4	20.8	4.5	
		2.9	8.6	14.1	26.2	5.8	
6/ 9 71		4.0	8.4	2.0	1.5	4.1	17
		4.0	8.4	3.4	4.4	4.5	
		4.4	9.3	4.1	5.8	5.5	
6/25/71		-9.9	-19.7	2.0	-1.5	-6.7	15
		10.0	19.7	4.0	7.7	7.1	
		11.8	22.1	6.4	9.6	8.3	
7/13/71		-3.0	-8.0	-5.8	7.7	-3.5	5
		3.0	8.0	5.8	10.4	3.5	
		3.5	9.1	6.5	14.0	4.0	
7/14/71		8.3	8.0	8.6	15.0	7.6	7
		8.3	8.0	8.6	15.0	7.6	
		9.5	9.7	9.7	18.7	8.5	
7/15/71		-3.4	-5.5	-3.1	-19.7	-7.6	7
		5.7	7.1	7.3	19.7	7.7	
		7.6	9.0	9.3	22.5	9.8	

Table 25 - (Cont'd)

Run Date		A	B	C	D	D	No. of Points
7/16/71	Avg Error	-4.6	-9.8	-3.8	-5.4	-4.9	5
	Mean Dev	4.9	9.8	4.7	4.8	4.9	
	Std Dev	6.0	11.4	5.5	7.1	5.7	
7/19/71		-4.3	-8.0	-4.2	5.2	-6.9	7
		4.3	8.0	4.2	7.5	6.9	
		4.8	8.7	4.6	9.0	7.6	
7/20/71		-3.5	-8.5	-3.4	4.1	-1.2	8
		3.5	8.5	3.4	7.0	2.8	
		4.3	9.4	4.0	8.2	3.7	
7/21/71		-5.6	-8.9	-6.8	-10.7	-4.0	6
		5.6	8.9	6.8	10.7	4.1	
		6.7	10.4	7.8	12.5	5.5	
7/22/71		-3.4	-7.2	-9.7	-6.5	-2.1	6
		3.4	7.2	9.7	6.5	2.1	
		4.4	8.3	10.8	8.1	2.9	
7/23/71		0.4	-18.2	-14.7	0.4	2.4	8
		2.5	18.2	17.9	2.7	3.1	
		3.1	19.9	26.3	4.1	4.7	
7/26/71		-1.5	-4.8	2.8	-5.9	3.6	5
		2.5	4.8	3.2	5.9	3.6	
		3.4	6.2	3.9	7.6	4.6	
7/27/71		-0.4	-12.1	-0.2	-8.3	3.7	4
		2.9	12.1	3.1	10.5	4.7	
		3.6	13.9	4.0	14.7	6.6	

Table 25 (Cont'd)

Run Date		A	B	C	D	E	No. of Points
7/28/71	Avg Error	-3.6	-10.6	-4.0	6.7	0.3	7
	Mean Dev	4.3	10.6	4.0	16.4	3.7	
	Std Dev	5.3	11.7	5.0	23.8	4.5	
7/29/71		4.7	6.9	4.1	-8.2	5.5	7
		4.7	6.9	4.1	9.5	5.5	
		5.9	7.9	6.1	10.9	7.5	
7/30/71		-2.2	-5.9	-1.6	-10.1	-2.9	6
		2.2	5.9	2.2	10.9	2.9	
		2.7	6.7	2.7	13.2	3.5	
Grand Means	Avg Error	-1.6	-6.3	-1.7	-2.9	-0.8	
	Mean Dev	4.2	9.1	6.1	9.9	4.6	
	Std Dev	5.1	10.4	7.6	12.4	5.7	

A more detailed analysis of the data may be justified in the case of instrument B where the correlation coefficients with the DuPont 461 were consistently higher than that for instruments C, D and E, but lower than that for instrument A. There may be a consistent error with instrument B data which could be corrected by a relatively simple adjustment which could increase its accuracy rating in the field toward the level demonstrated by instruments A and E.

The complete analysis of the field evaluation data is presented in Appendix II of this report.

The data and analyses presented in Tables 24 and 25 for instrument readings on and after 6/25/71 were adjusted for water vapor content of the flue gas stream. During this portion of the field test, the instruments were spanned and zeroed with respect to the DuPont 461 which was located upstream of the sulfuric acid trap and was therefore sampling the water vapor component of the stack gas. Water vapor was determined by a procedure similar to Method 4 - Determination of Moisture in Stack Gas of Standards of Performance for New Stationary Sources[1]. The only changes from this procedure were substitution of concentrated H_2SO_4 for H_2O as the absorbing solution and substitution of a critical flow orifice for the rotameter. The volume of H_2O collected was determined by weighing the impingers on an analytical balance before and after each test. Substitution of H_2SO_4 as the impinger liquid closely resembled the actual operating conditions employed in the field evaluation test sequence on the NO_x monitors.

The average % moisture of the stack gas for two determinations was 3.28 ± 0.04% (V/V). Field data taken on and after 25 June 1971 were adjusted to reflect the absence of water vapor and new statistical data for NO_x monitor accuracy in the field were generated. The absolute error (% of full scale response) of the instruments are shown in Table 26 with and without adjustment for water vapor. It can be seen that the water vapor adjustment increases the error and standard deviation values for all instruments. The unadjusted values were employed for field accuracy in the overall performance evaluation of the NO_x monitors.

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[1] "Standards of Performance for New Stationary Sources," Federal Register, Vol. 36, No. 159, p. 15712, Tuesday, 17 August 1971.

Table 26

FIELD ACCURACY SUMMARY

(With and Without Adjustments for Water Vapor Content)
Absolute Error (% of Full Scale)

	Instrument				
	A	B	C	D	E
With H_2O Vapor Adjustment					
Avg Error	-2.92	-7.53	-3.04	-4.23	-2.21
Mean Dev	4.91	9.86	6.61	10.1	5.04
Std Dev	5.83	11.2	8.13	12.6	6.07
Without H_2O Vapor Adjustment					
Avg Error	-1.57	-6.32	-1.70	-2.89	-0.82
Mean Dev	4.21	9.07	6.12	9.87	4.57
Std Dev	5.07	10.4	7.62	12.4	5.70

5. DATA EVALUATION, CONCLUSIONS, AND RECOMMENDATIONS

The ranking, utility factors and ranges of performance parameters listed in Table 4 serve as a frame-of-reference against which the laboratory and field evaluation test data can be compared to derive a ranking of instrument overall performance. The mechanism employed here for overall performance ranking is the "index of performance" (IP).

Combining all test data with the performance requirements in Table 4, the individual performance values for each parameter and instrument were derived as presented in Table 27. The data in this table were obtained as follows:

1. Accuracy refers to the average of the 60% and 90% span readings of TSD1 in the Individual Instrument and Separate Span Level Table (Table 17) for the laboratory and corresponding data in Table 25 for the field test evaluations.

2. Values of repeatability and the interferences were taken from Tables 9 and 15, respectively.

3. Zero instability data were taken from the column labeled Standard Deviation in Table 7, Run #1, and divided by 500 ppm NO_x.

4. Calibration instability values were taken as TSD1 readings at the 90% span level in Table 17.

5. Estimates of routine maintenance, ruggedness, and repair were a consensus of opinion based on the experience of the lab and field workers.

6. Response time was taken from Table 12.

7. Precision was calculated from the average of the zero standard deviations in Table 5 summarizing the laboratory tests.

8. Sensitivity was defined as the level at which an instrument would register 1 ppm NO_x. Interpolation of the data in Table 11 gave the required values.

Entries in Column G corresponding to the DuPont 461 monitor were transcribed or obtained from strip chart records where available. In some cases, median values of the parameters were employed when the instrument was not in use.

Table 27

PERFORMANCE VALUES FOR NO_x MONITORS

Performance Parameter	Q	Range 0.99 - 0.01	Instruments A	B	C	D	E	F	G[a]
1. Accuracy (Lab)	1.00	±2 - ±10%	4.7 0.6	5.2 0.60	6.0 0.5	3.2 0.84	2.0[b] 0.99	4.0 0.75	>10 0.01
(Field)	1.00	±2 - ±20%	5.1 0.82	10.4 0.54	7.6 0.68	12.4 0.42	5.7 0.79	c	13.0 0.39
2. Repeatability	0.964	±2 - ±5%	<2% 0.99	<2% 0.99	<2% 0.99	<2% 0.99	<2% 0.99	<2% 0.99	<2% 0.99
Interferences									
3. H_2O (<14%)	0.929	0 - ±5%	7% 0.01	20.4 0.01	1.2 0.76	0.2 0.95	12.4 0.01	0.5 0.89	2.8 0.44
4. SO_2 (<3000 ppm)[d]	0.893	0 - ±5%	0.1 0.97	0.43 0.91	0.5 0.89	0.5[e] 0.89	2.0 0.6	0.04 0.98	0.47[f] 0.90
5. CO_2	0.857	0 - ±5%	4.5 0.11	0.8 0.83	2.2 0.56	3.5 0.3	1.5 0.7	7.6 0.01	1.0 0.79
6. O_2	0.857	0 - ±5%	2.8 0.44	2.9 0.42	2.8 0.44	2.4 0.52	0.8 0.83	3.7 0.26	0.8 0.83
7. Pressure Change	0.679	0 - ±5%	0.1 0.97	1.9 0.62	>5 0.01	>5 0.01	1.1 0.77	0.8 0.83	g 0.99
8. Zero Instability	0.821	0 - ±5%[h]	0.17 0.96	0.68 0.86	2.57 0.48	0.74 0.85	0.43[i] 0.91	0.12 0.97	0 0.99
9. Calibration Instability	0.786	0 - ±10%[j]	6.0 0.40	8.2 0.19	7.7 0.24	4.7 0.53	4.3[k] 0.57	5.3 0.47	0.9 0.90
10. Routine Maintenance	0.75	0 - 4 man-hours per week	0.75 0.81	2.0 0.5	1.5 0.62	1.5 0.62	0.75 0.81	1.0 0.75	0.75 0.81
11. Ruggedness[l]	0.714	0.99 - 0.01	- 0.57	- 0.57	- 0.50	- 0.50	- 0.72	- 0.72	- 0.99
12. Repair[m]	0.643	0 - 5 incidents per year	- 0.90	- 0.30	- 0.60	- 0.60	- 0.85	- 0.01	- 0.85
13. Precision	0.571	1 - 5%	<1% 0.99	<1% 0.99	<1% 0.99	<1% 0.99	<1% 0.99	<1% 0.99	<1% 0.99
14. Sensitivity	0.536	1 ppm - 10 ppm	3 ppm 0.77	2.0 0.88	12.0 0.01	3.0 0.77	2.0 0.88	7.0 0.34	3.0[f] 0.77
15. Response Time[n]	0.500	5 sec - 180 sec	5.9 sec 0.98	7.6 0.98	45.0 0.78	26.8 0.87	14.9 0.94	15.7 0.93	>180 0.01

[a] Instrument G performance data transcribed from strip chart records.

[b] Based on the average of the 30% and 60% span levels.

[c] Instrument did not operate in the field.

[d] The SO_2 deviations in the Interferences Table (Table 15) were reduced by 1/4 to make the concentration range comparable to $\sim$3000 ppm.

[e] Missing datum: value of 0.5 arbitrarily chosen.

[f] Median performance values assigned.

[g] Automatic pressure control feature.

[h] Over 17.5-hour measuring period. Expressed as % of full scale (500 ppm) reading.

[i] Based on results from Laboratory Run #5.

[j] Over 17.5-hour measuring period. Expressed as TSD1 relative error.

[k] Based upon the 60% span level.

[l] Based upon the subjective experience of the field workers.

[m] Based on incidents that occurred during the test period.

[n] Based on time to reach 90% of actual level.

For each performance parameter the first row corresponds to the actual value found in the evaluation tests, while in the second row this value is linearly transformed into the 0.01 to 0.99 scale.

No programming was required in the calculation of the overall index of performance (IP) values since the IBM APL/1130 system has a complete set of matrix algebra operations which can be accessed in an interactive fashion directly from the computer keyboard. The values of Q_i (importance or weight of a performance parameter) were normalized:

$$N = \frac{Q_i}{\sum_{i=1}^{N} Q_i}$$

and the following matrix multiplication gave the IP values:

$$IP = [NQ] \times [P]$$

where [P] is the matrix of performance parameters for all instruments. An IP value of 0.99 would thus indicate perfect performance and a value of 0.01 completely unacceptable performance.

The IP values calculated from data in Table 27 are presented in Tables 28 through 31. In Tables 28 and 29 the IP values are listed using both laboratory and field accuracy data and including the interference parameters based on O_2 and CO_2 content of the flue gas stream. Since these interferences had not been selected initially (Table 4) as performance parameters, the IP values based on laboratory and field accuracy data are presented without the O_2 and CO_2 interference parameter in Tables 30 and 31.

5.1 DISCUSSION OF INDEX OF PERFORMANCE

Over the period of this contract, considerable operational experience has led to the following observations concerning the performance evaluation parameters employed in this study:

1. Accuracy is still the most important parameter; however, its definition should be changed as follows. From the lab test we have seen that zero and calibration drift does not exist, at least in the normal sense, where it is monotonic with time and can therefore often be taken into account. There is, however, considerable zero and span "instability" which at any point in time after calibration creates an uncertainty in determining the "true value." The degree of this uncertainty is a measure of the inaccuracy of an instrument.

Table 28

IP USING LAB DATA FOR ACCURACY
(CO_2 and O_2 interferences included)

Instrument	IP
E	0.755
G	0.748
D	0.689
A	0.677
F	0.667
B	0.627
C	0.571

Table 29

IP USING FIELD DATA FOR ACCURACY
(CO_2 and O_2 interferences included)

Instrument	IP
G	0.781
E	0.738
A	0.691
D	0.652
B	0.622
C	0.587
F	- [a]

[a] Instrument F nonfunctional in field.

Table 30

IP USING LAB DATA FOR ACCURACY
(CO_2 and O_2 interferences excluded)

Instrument	IP
F	0.760
E	0.754
A	0.748
D	0.738
G	0.737
B	0.627
C	0.583

Table 31

IP USING FIELD DATA FOR ACCURACY
(CO_2 and O_2 interferences excluded)

Instrument	IP
G	0.776
A	0.764
E	0.733
D	0.695
B	0.621
C	0.602
F	- [a]

[a] Instrument F nonfunctional in field.

We have expressed this uncertainty as the standard deviation about the "true value." Again, since we do not have a way of correcting for zero and span instability, the type 2 error is the one in question. The statement that we can now make is that at any point in time, 95% of the time, we will be able to determine the "true value" within ±2·TSD2%. Even after excluding the 30% span level, we find the 2·TSD2 statistic ranges from ±10.4% to ±35.0%. Therefore, zero and span instabilities should be dropped from the IP calculation. The accuracy term employed is the absolute error term (standard deviation) derived from the field tests.

2. In our consensus rank of the performance parameters, precision was rated 14th and repeatability second. After the initial analysis of the data, we began to realize that precision and repeatability are related. Indeed, as J. Mandel (1971) has shown

$$\text{Repeatability} = 2.77 \frac{\sigma}{\sqrt{m}}$$

where σ = precision within a run
m = number of replicates

It was therefore not too surprising that since the variances of all instruments were much less than ±2% that repeatability data were all less than ±2%. The variance of a method is often a function of the level being measured. A cursory glance at the lab data shows this effect to be negligible (except for the 90% level of instrument E where this was an interface phenomenon). Therefore, the theoretical resolution, which can be defined as repeatability at some level, should be comparable to the repeatability at the zero level. While the experiments for resolution were anomalous, we used values less than ±2% for all instruments. Repeatability and resolution should be deleted from the IP calculation.

3. Ruggedness should be deleted from the performance parameter list since it will be reflected in the repair term. The repair term should have a higher ranking, certainly higher than routine maintenance, since an instrument that doesn't work is of questionable value.

4. The interference terms are important since they directly affect the ultimate accuracy of an instrument.

With these points in mind, we redetermined the IP using the performance parameters and values of Q shown in Table 32. The performance indices resulting from the selected parameters are listed in Tables 33 and 34, instrument F being omitted due to field operational difficulties.

Table 32

PERFORMANCE PARAMETERS USED AND CORRESPONDING WEIGHTS

Performance Parameter	Q
Accuracy	1.0
Repair	0.75
H_2O	0.75
SO_2	0.75
Routine Maintenance	0.5
Press	0.5
CO_2	0.5
O_2	0.5
Precision	0.25
Response Time	0.25

Table 33

IP BASED ON SELECT PARAMETERS

Instrument	IP
G	0.695
E	0.681
A	0.676
C	0.631
D	0.600
B	0.543

Table 34

IP BASED ON SELECT PARAMETERS
(with CO_2 and O_2 interferences deleted)

Instrument	IP
A	0.761
G	0.670
E	0.664
C	0.658
D	0.639
B	0.525

5.2 CONCLUSIONS

Based on a perfect performance rating of 0.99, performance of the six nitrogen oxide monitors leaves much to be desired. An analysis of the IP data in Tables 28 through 31 indicates that the specific order of ranking is rather unimportant since the average IP of all options (e.g., laboratory and field accruacy, with and without consideration of CO_2 and O_2 interference) are extremely close for the nondispersive infrared instruments and these averages are nearly identical. For example:

Instrument	IP x 10^2 (Avg, Tables 28-31)
A	72 ± 4
B	62 ± 1
E	75 ± 1
F	71 ± 5

Two of these instruments, however, exhibited failure in the field tests on the power plant effluent stream. Instrument F was inoperative over the complete series of field tests due to deposit formation on the gold-lined walls of the measuring cell. This could be due to amalgamation by elemental mercury in the flue gas stream. This behavior was observed initially and after repair by the manufacturer. Instrument B failed with similar symptoms at the completion of the program.

With this information in hand, either instruments A or E would be a preferred choice in selection of a nondispersive infrared analyzer for NO_X continuous monitoring of a combustion source. The deficiency in performance of instruments B and F could possibly be corrected by redesign of the measurement cell wall materials.

The two electrochemical instruments exhibited the following IP averages:

Instrument	IP x 10^2 (Avg, Tables 28-31)
C	59 ± 1
D	69 ± 2

The ranking of instrument D was greatly enhanced by a modification made in the field test series. The instruments internal compensation for SO_2 did not perform under the highly variable SO_2 concentrations prevalent in the power plant flue gas stream. An SO_2 scrubber specified by manufacturer C was placed at the inlet thereby permitting meaningful measurements to be made. While the electrochemical instruments, in general, did not perform as well as the infrared monitors, one or two comments should be made. First, these instruments have been commercialized quite recently and do not have the years of application-experience exhibited by the nondispersive infrared monitors. Successive models of the electrochemical instruments are improving with time due to continual development. Second, the electrochemical monitors are more compact and ligher in weight than the infrared analyzers.

The average value of IP for instrument G (the ultraviolet absorption monitor) was 0.76 ± 0.02, a value slightly higher than the better infrared monitors. The rating of this instrument suffered from a consistent error of 12 to 13% in accuracy, which could be readily corrected by the instrument manufacturer by altering the absorbance of the standard filters employed for calibration. While the instrument operates on a timed cycle (and therefore is not truly continuous), its major drawbacks are cost, size and weight.

The altered IP ratings presented in the previous section do not seriously change these conclusions, the major effect being a lowering of ratings for the infrared monitors from an average of 0.70 to an average of 0.64. The corresponding decrease for the electrochemical instruments is from 0.64 to 0.63, and that for instrument G is from 0.76 to 0.68. While the electrochemical average IP based on select parameters was unaffected, the comparative ratings of instruments C and D were inverted with instrument C increasing in overall performance from 59 to 64 and instrument D decreasing from 69 to 62.

Another compact, light-weight instrument was studied briefly near the end of the program. This instrument was a development prototype of Panametrics, Inc. Krypton Clathrate Monitor which operates by inverse radioactive tracing. During our brief experience with this instrument it can be concluded that the technique shows promise since quite reasonable response to NO_x flue gas content was obtainable. Further development is required since this instrument failed on two different occasions during a three-month time period.

5.3 RECOMMENDATIONS

5.3.1 Advanced Nitrogen Oxide Monitor Development

As was stated in the conclusions, the nitrogen oxide monitors evaluated on this program demonstrated performances between 0.57 to 0.78, based on a perfect performance rating of 0.99. Volume I of this report discussed in some detail advanced methods for NO_x monitoring which are at the prototype development or research stage employing novel detection concepts. This work should be encouraged since there is much room for improvement.

Preferred analysis concepts suggested for further development in Volume I of this report included chemiliminescence, correlation spectrometry, mass spectrometry and selective photoionization. To this list should be added a redesign of the nondispersive visible absorption method to yield a more inexpensive and lighter weight monitor. Continuing improvement in the electrochemical detection concept cannot be ruled out as a valid detection concept. Long-range, the use of the evolving laser technology in optical instrumentation based on absorption and Raman scattering spectroscopy will find application to nitrogen oxide continuous monitoring.

5.3.2 Sample Pretreatment Systems

A major concern of nitrogen oxide monitor users was borne out by experience on this program. This concern is that the monitors commonly available on the market require sample pretreatment systems in order to perform on the extremely hostile atmosphere of a power plant flue gas stream. It is recommended that the Environmental Protection Agency support a contract with a concern exhibiting a firm background experience in process engineering to conduct a systematic study of alternate methods for sampling the effluent streams from stationary combustion sources and removal of water vapor, particulate and sulfur dioxide with minimum alteration in the nitrogen oxides content of the flue gas. The objective of this study should be to develop and demonstrate a sample pretreatment system optimized on the basis of performance, cost and weight which could then be adopted by EPA as a preferred standard technique.

5.3.3. Interface Recommendations

Considerable difficulty was encountered during the course of this contract which stemmed directly from the signal conditioning (interface) unit. First, a signal conditioning unit was required since the A/D converters on the computer accept only a 0-1 volt input. (Autoranging A/D's do exist but they are normally one to two orders of magnitude higher in cost.) Second, the instruments had widely different outputs both in magnitude and in type (millivolts vs. milliamps). This complicated the design of the interface unit and created additional sources of potential instability due to impedance mismatch, common ground problems, AC 60 cycle noise, etc.

While commercial, off-the-shelf laboratory interfaces do exist, they are again expensive and would not eliminate the need for additional signal filtering. Since continuous monitoring instruments are ideally suited for on-line data acquisition techniques and since these techniques are becoming widely accepted, we recommend that the instrument manufacturers provide multiple types of output. One manufacturer, instrument A, has already done this and no signal conditioning was needed for this instrument.

APPENDIX I

REPORT OF SJ&H WORK ON "EVALUATION AND DEVELOPMENT OF NITROGEN OXIDE MONITORS FOR COMBUSTION SOURCES"

TABLE OF CONTENTS

I. CONCLUSIONS

The following summarizes our conclusions drawn from the in-depth field work performed in the study.

1. Experience of users is mainly limited to periodic operation of their monitors, generally in connection with R&D on NO_x abatement techniques.

2. Users and manufacturers are not certain that regulatory compliance will require full-time operation of dedicated monitoring systems. Rather, two principal alternatives are envisioned:
   a. Dedicated monitoring systems operating only during episodal conditions.
   b. Periodic (e.g., semi-annual) compliance inspection with non-dedicated movable instruments.

   Nevertheless, the need for dedicated monitoring instruments is now beginning to appear in California. One installation is already in place and the following are scheduled:

	20-30	installations starting mid-1971
	30-45	installations complete 1974
Total:	50-75	installations (all for backfit)

3. Users' preference is unequivocally strong for a monitoring system that obviates a sampling train. This preference is so pronounced that California utilities are committing themselves to a relatively unproven instrument concept which has no sampling train in the conventional sense.

4. Every instrument type now in use needs improvements in performance. Also, the need for better standards of measurement is widely felt.

5. In addition to the instruments now commercially available, a number of companies are developing NO_x monitors using techniques that may be promising -- i.e., provide capability comparable to instruments in use.

6. Manufacturers appear to be unable to supply sampling trains that consistently satisfy the needs of the application -- in terms of suitability for unattended operation, in some cases the ability to function properly, and sometimes the certainty that constituents of the sample are not being lost or modified.

Users therefore mainly tailor-make their own systems.

7. Users with meaningful experience are very few. Significantly, very few users of NO_x instruments were found among electric utilities. We observe that among utilities burning coal and/or oil, the current emphasis is almost solely on SO_2 abatement and monitoring. Concern with NO_x is more likely to be found among utilities that burn predominantly natural gas (i.e., along the Gulf and Pacific Coast). At the time of the interviews, conducted in this study, it was found that NO_x abatement and monitoring activity has progressed only in California utilities to the point that meaningful NO_x instrument experience has been accumulated.

Also, there were more installations than "users" -- a number of utilities merely made facilities available to organizations like Esso, and did not themselves participate in the testing or evaluation of instruments.

II. DESCRIPTION OF INSTRUMENT APPLICATIONS

A. USERS OF NO_x MONITORING INSTRUMENTS

The users of NO_x monitoring instruments who were identified in this study included electric utilities, manufacturers of boilers and ancillary equipment, and others engaged in short-term field tests of combustion and abatement techniques, as well as laboratories engaged in bench tests of combustion and abatement techniques. The establishments that were interviewed are listed in an appendix to this report.

The electric utilities currently interested in using NO_x monitoring instruments are concentrated in California where the utilities are under pressure to reduce the emissions of nitrogen oxides. Southern California Edison, for example, is being required to install permanent monitoring instrumentation in its major plants. Pacific Gas & Electric also has a permanently installed monitor for NO_x at its Moss Landing plant near Salinas, California.

Boiler manufacturers and others conduct field tests on their customers' boilers to study abatement techniques and to provide emissions compliance tests. These tests are being conducted for product improvement studies, or to accomodate their customers, or as a service for a fee. Several instrument users are monitoring NO_x emissions from sulfur dioxide abatement tests.

B. NATURE OF NO_x MONITORING INSTRUMENT APPLICATIONS

Applications of NO_x monitoring instruments can be classed according to whether the instruments are in permanent installations or in non-permanent installations. A permanent installation is one in which the monitoring instrument is dedicated to measuring emissions from a specific boiler or smoke stack. A non-permanent installation is one in which the instrument can be moved by itself or in a portable laboratory from one installation to another installation.

At the time of the interviews, Southern California Edison was in the process of procuring monitoring instruments for permanent installation at all of their major plants in the Los Angeles metropolitan area as required by the authorities. Pacific Gas & Electric also has a permanent installation at its Moss Landing plant where NO_x emissions have presented a problem that brought the plant under the scrutiny of the air pollution control authorities. San Diego Gas & Electric has a permanent installation at a plant where a long range NO_x abatement development program is under way.

These utilities and other utilities also have portable NO_x monitoring instruments for short term NO_x emissions control projects or to make spot checks at a number of plants. Several utilities mentioned that they believe that NO_x monitoring on a spot basis with portable instruments will satisfy anticipated air pollution control regulations in their areas.

III. ANALYSIS OF USER EXPERIENCE

Interviews with 12 users of NO_x stack monitors produced comments on the operation of 22 instrument installations (seven users each have more than one instrument installation). More than 12 users were interviewed but their experience was not appropriate to this evaluation. Instrument installations according to instrument model are as follows:

INSTALLATIONS OF NO_x MONITORING INSTRUMENTS

Model	Number of Installations
Beckman 315A	6
Dynasciences NX130	7
EnviroMetrics NS200A	4
DuPont 461	2
Others*	3
	22

On the following pages are user comments on performance parameters for the instruments in use, with manufacturers' data shown for comparison. Comments on these seven parameters of greatest concern to users are summarized in the following discussion.

It was determined in the course of the study that there were seven performance parameters of greatest concern to users, while others were of marginal importance. The seven were:

*Mast, EDC, Beckman 255

A. Accuracy
B. Repeatability
C. Moisture Tolerance
D. SO_2 Tolerance
E. Particulate Tolerance
F. Zero Drift
G. Calibration Drift

Instrument Accuracy

Reported accuracies range from less than ± 1% of full scale and ± 1½% of true value to levels such as ± 10% of true value and ± 17% of true value. Several users point out that it is not of great value to have accuracies of better than 5% of true value until radical improvements are made in laboratory techniques that are used as standards for comparison. The instrument users report that standard wet techniques for checking instruments can show ± 5-10 ppm repeatability, ± 5% accuracy, or 10-15% variations among different laboratories.

The ranges of accuracy reported by the users of NO_x monitoring instruments preclude a determination of one instrument's superiority over another. According to statements from the manufacturers with respect to their own instruments, the accuracies of the instruments presently in use are about the same (± 1% of true reading), expect for the duPont 461 for which the manufacturer states ± 2% of full scale.

Repeatability

Repeatability of the four models of instrument now in general use are in the range of ± ½% of full scale to ± 2% of full scale for 100% of the readings. Except for one user who had considerable trouble with an EnvironMetrics unit, the poorest repeatability mentioned was ± 2% of full scale for 80% of the readings. The best repeatability quoted by a manufacturer is from Beckman who says 100% of the readings by its instrument are within a range of ½% full scale.

Moisture Tolerance

Instrument problems caused by moisture have been most frequently found in the electro-chemical type of instruments made by EnviroMetrics and Dynasciences. In neither of these instruments does moisture represent an interference but presents mechanical problems of flooding the detector cell which makes the cell inoperative or slow in response.

Beckman supplies a sample preparation system that includes a cold trap that maintains a constant moisture level which is calibrated out. Beckman says that 3.5% moisture is equivalent to 5 ppm NO (additive). One user says that he has experienced interference equivalent to 200 ppm NO with the same amount of moisture. Another user of the Beckman instrument is concerned that the moisture levels in the stack will not be held sufficiently constant and thus will upset the instrument reading. The user of the duPont 461 reports that the level of condensate in the instrument affects the zero drift of the instrument although the manufacturer says that there is no interference presented by water vapor.

SO_2 Tolerance

The electro-chemical instruments are inherently sensitive to SO_2 approximately on a 1:1 basis (additive). In one instance 100 ppm SO_2 was found equivalent to 142 ppm NO_x. In this particular installation a scrubber was introduced but the readings still average 7 ppm higher when SO_2 is present in the stack. Another user suspects that although the scrubber is effective, it also removes 20% of NO_x in concentrations of around the 300 ppm level.

According to most of the users, SO_2 does not present an interference problem with Beckman instruments. However, one laboratory suspects that when SO_2 and CO_2 are combined, the results are analogous to 2+2=5.

Particulate Tolerance

Users of the electro-chemical instruments report that particulates represent no interference, but do present mechanical problems such as clogging and adding to response time. Beckman says that particulates cannot be tolerated by its instrument and there seem to be no problems reported by users of Beckman instruments, presumably because of the effectiveness of the sample preparation system.

Zero Drift

Comments by users of the Dynasciences electro-chemical instrument suggest that there is a fairly wide variation in zero drifts experienced, ranging from no drift or less than ± ½% in an 8 hour period up to as much as a 5% drift in 2 hours or a 10% drift over no specified time lapse. Users of the Beckman instrument say that they have experienced from zero to ± 1% drift in 8 hours; the greatest drift that one Beckman user says he has experienced is 5% in two days. The user of the EnviroMetrics instrument says that he has experienced no zero drift once he has allowed a new instrument 5 or 6 hours of operation in which to stabilize (not the ½ hour that the manufacturer had recommended to him). The user of the duPont 461 experienced 10% drift due to condensate accumulations in a 4 to 8 hour period.

Calibration Drift

Users of Dynasciences instruments report calibration drifts of 9½% in 4 days and 2 to 5% (full scale) downward drift in 8 hours, and 10% over no specified time lapse. Another user reports no calibration drift during the measurement of the test point. Beckman instrument users report calibration drifts of ± 1% per day and less than 10 ppm. One user reports a calibration drift of 4% per day which he attributes to vibrations in the instrument operating area. One user of both Dynasciences and Beckman instruments says that he has experienced drifts on both instruments of 5 ppm per day in 25% of the operating days. This user adds that he has had to increase the gain of the Beckman instrument over a 6-month period.

The following tables summarize the experience accumulated by users with the four instruments found in the study to be in general use. It should be noted that the use of particular instruments was distributed among the organizations interviewed as shown in Table 1. Tables 2 through 5 contain the evaluations. Where no information is indicated, user experience was inadequate for measuring full evaluation.

TABLE 1

USERS OF NO_x SOURCE MONITORS

Instruments Used

Users Interviewed	Beckman 315A	Dynasciences NX130	EnviroMetric NS200A	DuPont 461
A. Electric Utilities				
User #1. So.Calif Edison	X	X		
#2. L.A. Water & Power		X		
#3. San Diego G&E	X	X		
#4. Pacific Gas & Electric	X	X		
B. Equipment Manufacturers				
User #5. Research Cottrell			X	
#6. Babcock & Wilcox		X	X	
#7. Foster-Wheeler		X		
#8. Combustion Engineering		X		
C. Laboratories & Others				
User #9. Battelle Memorial			X	
#10. Tyco Labs	X			
#11. Bureau of Mines	X			X
#12. Esso R&E	X		X	X
	6	7	4	2

TABLE 2

USER COMMENTS ON SELECTED PERFORMANCE PARAMETERS OF THE ENVIRO METRICS NS-200A

	USER#5	USER#9	USER#6
ACCURACY	(no information)	± 1% (or less) of full scale	(no information)
REPEATABILITY	Very poor for unknown reasons	± 1%	(no information)
MOISTURE TOLERANCE	(no information)	Adds to response time, does not affect true reading	No problem: Seems to work better with some moisture in cell
SO_2 TOLERANCE	(no information)	1:1 additive interference in 1200-1300 ppm SO_2 range	Compensation works well
PARTICULATE TOLERANCE	(no information)	Adds to response time does not affect true reading	Adequately absorbed in sample treatment
ZERO DRIFT	(no information)	None: New instrument requires 5-6 hrs to stabilize, not ½ hr as mfr recommends	(no information)
CALIBRATION DRIFT	(no information)	None: New instrument required 5-6 hrs. to stabilize, not ½ hr as mfr recommends	Sensitive to ambient temperatures. At constant temperature drift=10% in 8 hrs.

TABLE 2 (continued)

USER COMMENTS ON SELECTED PERFORMANCE PARAMETERS OF THE ENVIRO METRICS NS-200A

	USER#12	MANUFACTURER'S DATA
ACCURACY	Affected by "noise"	(no information)
REPEATABILITY	(no information)	100% of readings to ± 2%
MOISTURE TOLERANCE	(no information)	no interference but clogs
SO_2 TOLERANCE	Compensator causes NO reading to double	compensated
PARTICULATE TOLERANCE	(no information)	no interference but clogs
ZERO DRIFT	Sensitive to 1-10% concentrations of CO	(no information)
CALIBRIATION DRIFT	(no information)	(no information)

TABLE 3

USER COMMENTS ON SELECTED PERFORMANCE PARAMETERS OF THE DuPONT 461

PARAMETER	USER#10	USER#12	MANUFACTURERS DATA
ACCURACY	(no information)	Uncertain about when reading maximizes at < 300 ppm.	± 2% Full Scale
REPEATABILITY	Better than Beckman	(no information)	1% Full Scale
MOISTURE TOLERANCE	Condensate affects zero drift	no problem if cell is kept hot	no interference
SO_2 TOLERANCE	No interference (in presence of 4000 ppm NO_2)	(no information)	no interference
PARTICULATE TOLERANCE	None present	duPont sample system offers blowback to remove particulates	no interference but clogs
ZERO DRIFT	10% drift in 4-8 hrs. due to condensate	(no information)	less than ± ½% Full Scale
CALIBRATION DRIFT	(no information)	(no information)	less than ± ½% Full Scale

TABLE 4

USER COMMENTS ON SELECTED PARAMETERS OF THE BECKMAN 315-A

	USER#11	USER#3	USER#4	USER#10
ACCURACY	High side of 10% NO tab std (Truesdale)	± 10 ppm NO	± 1% NO	10-15 error due to 1000cc/min.sample flow (200-400 cc/ min recommended)
REPEATABILITY	(no information)	100% within ± 1% of full scale	± 2% full scale	OK if on 0-5000 ppm scale. Not as good as duPont
MOISTURE TOLERANCE	Sample prep keeps H_2O constant and is calibrated out. But H_2O level must be held constant	(no information)	Good when H_2O doesn't condense: 3.5% (MOL)= 200 ppm NO	all lines hot after leaving cold trap where H_2O is removed
SO_2 TOLERANCE	(no information)	(no information)	(no information)	no interference
PARTICULATE TOLERANCE	(no information)	(no information)	Low	Lab test: no particulate
ZERO DRIFT	Max observed: 5% in 2 days	none detectable in 8 hour day	± 1% in 8 hrs	(no information)
CALIBRATION DRIFT	Max observed: 4% in 1 day (caused by vibration?)	5ppm drift 25% of days in use. Have had to increase gain over 6 months of use.	± 1% in 24 hrs.	(no information)

TABLE 4 (continued)

USER COMMENTS ON SELECTED PARAMETERS OF THE BECKMAN 315-A

	USER#11	USER#12	MANUFACTURER'S DATA
ACCURACY	Lab std (PDA) has ± 5-10 ppm repeatability	(no information)	
REPEATABILITY	(no information)	1% (acceptable)	½% of full scale
MOISTURE TOLERANCE	(no information)	cal gas with moisture is needed to cancel moisture interference. Such gas not obtainable	3.5% max = 5 ppm NO (additive)
SO_2 TOLERANCE	Suspect SO_2 + CO_2 combination (up to 1600 ppm SO_2, 10-15% CO_2) causes greater interference than what is attributed to gases individually (i.e., 2+2=5)	(no information)	no interference. SO_2 corrodes.
PARTICULATE TOLERANCE	Lab test: no particulate	(no information)	Cannot be tolerated
ZERO DRIFT	None	2% due to cabinet thermostat -- insignificant	1% of full scale in 8 hours
CALIBRATION DRIFT	less than 10 ppm	too low to be significant	1% of full scale in 24 hours

TABLE 5

USER COMMENTS ON SELECTED PARAMETERS OF THE DYNASCIENCES NX 130

	USER#1	USER#2	USER#3	USER#4
ACCURACY	Low side of 10% NO_x Lab std (Truesdale) used for checks is ± 5% accurate.	Selection of test points shows readings 1½% higher than lab analysis	+ 10 ppm @ 100ppm, +50 ppm @ 300 ppm (consistently read high)	(no information)
REPEATABILITY	(no information)	(no information)	80% within ±2% of full scale	(no information)
MOISTURE TOLERANCE	Cell floods with high moisture level	(no information)	Have not seen significant difference with/without moisture removal	(no information)
SO_2 TOLERANCE	(no information)	100 ppm SO_2 = 142 ppm NO_x (additive) Removed by scrubber but readings still average 7 ppm higher NO_x	high readings could be caused by SO_2 -- has not been investigated	(no information)
PARTICULATE TOLERANCE	(no information)	(no information)	(no information)	(no information)
ZERO DRIFT	Max observed 1% in 3 days	0 to ± ½% in 8 hrs	5% or 25 ppm typical in 1-2 hrs	no perceptible drift during measurement of test point
CALIBRATION	Max observed 9½% in 4 days	2-5% (full scale) downward drift in 8 hrs. (i.e., would read 190 with 200 ppm span gas)	5 ppm drift 25% of days in use	no perceptible drift during measurement of test point

TABLE 5 (continued)

USER COMMENTS OF SELECTED PARAMETERS OF THE DYNASCIENCES NX 130

	USER#6	USER#7	USER#8	MANUFACTURER'S DATA
ACCURACY	± 10% based on PDA lab std.	10-15% variations among different labs using standard wet techniques for checking instrument	10%	± 1%
REPEATABILITY	(no information)	(no information)	(no information)	95% of readings within ± 1%
MOISTURE TOLERANCE	(no information)	(no information)	(no information)	Vapor: no interference Condensate: slows response but no interference
SO_2 TOLERANCE	(no information)	Dynasciences scrubber is effective (checked with SO_2 cal. gas at 1900 ppm)	Scrubber is affective but also removes 20% of 300 ppm NO_x	1:1 (additive). Scrubber inadequate at SO_2 over 2500ppm
PARTICULATE TOLERANCE	(no information)	(no information)	(no information)	clogging only
ZERO DRIFT	(no information)	Drift occurs only if calibrated on ambient air	10%	+ 2% per week ± ½% per day
CALIBRATION DRIFT	Sensitive to ambient temperature. At constant temperature drift =10% in 8 hours	(no information)	10%	+ 3% per week ± 1% per day

IV. OTHER PARAMETERS

The discussion below deals with performance parameters which are not among the seven most critical but,which in certain cases were found to have special importance.

The principal complaint regarding the ruggedness and maintenance of NO_x monitoring instruments was addressed to frequent contamination of the Dynasciences detector cell from accumulated condensate. One user with only a few months experience anticipates having to replace a flooded cell once per month and a depleted cell 3 or 4 times per year. This user mentioned, however, that the one hour of manpower required per replacement can be fitted into existing manpower loads with no need for additional staff.

The major complaint with the Beckman instrument is having to clean the window of the detector once every 6 months to 2 years. One Beckman user complains that he finds it awkward to gain access to the dirty window.

All of the users operate their instruments at nearly ambient conditions. They say that by the time that the sample has passed through the sample train, it enters the monitoring instrument at about ambient temperature.

The response lag (i.e., the time required for the dial needle to begin to move) is subject mainly to the length of the sample lines such that lags of as much as 2 minutes are experienced. One user who was able to operate a Dynasciences instrument and a Beckman instrument side by side off of the sample train reports that the Dynasciences instrument is 15 to 20 seconds slower than the Beckman instrument in response lags but that the response time, once the needle begins to move, is about the same for both instruments. One user believes response time is important because NO_x concentrations change with the power load.

The monitoring precision allowed by the users is in the 50 to 80 ppm range, the latter being the lowest measured sensitivity with laboratory verification.

V. FACTORS INVOLVED IN NON-PERMANENT INSTALLATIONS

Since the majority of users are employing instrumentation in temporary installations their views are slanted toward concern for portability and other characteristics associated with short-term use.

Many of the users that were interviewed employ NO_x monitoring instruments in connection with NO_x and other abatement tests in the field and in the laboratory. Some of the users in the field anticipate that non-permanent monitors also will be suitable for compliance monitoring. Because of the nature of the field tests being monitored, a high level of instrument capability (accuracy, repeatability, etc.) is not as important as other operating factors.

Six of the ten users of electro-chemical instruments said that portability was a major consideration. Other factors that apply include capability of operating under conditions of high vibration since many of the temporary locations selected for instrumentation are chosen on the basis of expediency. For the same reason, long sample trains also are encountered, especially in the case of mobile laboratories. Accordingly, instrument response times are relatively insignificant.

Instrument users applying instruments on a non-permanent basis prefer instruments that require only a short time to set up and place in operation because of the relative frequency and short durations of the tests.

Instruments used in this manner are typically operated for periods of 2 to 8 hours at a time. Calibration is performed at least daily and sometimes twice daily (before and after a test); instruments in this kind of application are constantly manned on a one-for-one basis. The users report that frequency of routine servicing is not a problem of the availability of manpower and because the instruments are not needed for continuous operation.

A. <u>OTHER CONSIDERATIONS OF USER EXPERIENCE</u>

Information was developed on installation characteristics that would relate mainly to application but would indirectly relate to instrument parameters. This information is summarized below.

1. <u>Data Handling</u>

The majority of the instrument users are employing strip chart recorders to retain test data or to satisfy regulatory requirements. The recorders would be in the proximity of the monitors but it also is possible to have the recorders in the control room several hundred feet from the monitoring instruments, as is customarily done with other instruments. Instrument users recognize the possibility of using NO_x monitors as an input for automatic boiler control, but are not undertaking serious development at this time.

2. Use of Monitors for low NO_x Emissions

Instrument users were asked what would be the major problem areas if NO_x regulations become more stringent, such as being lowered to the 10 to 100 ppm range. Several users doubt that the present wet lab standards are suitable for this lower range. One user also mentions that the zero gas is inadequate at the 10 ppm level and that the ambient background around his power plants is 2 ppm NO_x. Several users mention that the suspected NO loss in the sample train would become significant. One of the boiler manufacturers interviewed says that at present levels of NO_x concentration, stack traverse measurements now show variations of 20%, which would become greater at lower concentrations. One instrument user who is obtaining instruments for permanent installations says that he would have to replace or alter these instruments. But another user, in discussing this problem, says that such replacement would be "cheap when compared to a \$500,000 NO_x control project on a boiler installation".

3. Major problems expected

Instrument users were asked what were the major problems or needs that must be resolved to have a satisfactory permanently installed full-time NO_x monitoring system. The majority of the users believe that reliability and low maintenance and attendance requirements are paramount. Several users see that the best way to attain these reliability goals is to eliminate the sample train and incorporate automatic zero and calibration capabilities in the instruments. One user's attitude is that it is "better to spend for the first cost than for the labor".

Accuracy and precision are desirable but are not important until wet lab standards improve.

Several instrument users cite stratification problems with their calibrating gases as affecting accuracy of the instrument.

B. OTHER USER COMMENTS

Several instrument users had suggestions that would improve monitoring system performance. One user suggests that "a gas should always be passing through the instrument" by alternating calibrating gases with samples. Another user suggests that instruments should be capable of relatively high rates of gas flow so as to improve flushing and response time characteristics.

One user compares likely evolvement of an NO_x monitor to the use of O_2 instrumentation by itilities, stated that five years ago such instruments were undependable and that even now, utilities do not calibrate regularly even though plant operating costs and dangers would be minimized.

VI. NEW TECHNIQUES APPROACHING THE MARKET

A number of instruments -- not among those now commercially available are under development. Some of these appear to be capable of equal or better performance as compared to the former.

Chemiluminescence

Prototype would be available by mid-1971. One potential user believes that this concept is not practical for operational monitors. M.R.C. and Aerochem are both working on this principle.

Concept Developed by Environmental Data Corp, Monrovia, Calif

EDC is highly secretive about the concept, which is an in-stack monitor not requiring a sample train. Southern California Edison reportedly has ordered EDC units for 26 stacks and other California utilities are interested in purchasing trial units.

Comments regarding the EDC unit by instrument users indicate that the instrument is heavy (over 100 lbs.) due to its ruggedness necessary to minimize optical warp. A significant advantage of an in-stack monitor is that only one unit is required per stack on a two boiler stack. According to one organization that has used the EDC unit for several months, it has demonstrated the best accuracy, reliability and freedom from maintenance. The EDC unit does not require calibration gases. One other instrument user says that there are too many variables associated with in-stack monitoring, such as draft due to steam loads and wind, and the diluting effect of air admitted to the stack.

Raman (laser) Spectroscopy

NO_x monitor for bench test is more than one year away. Raman units for process applications are just now being developed for high gaseous concentrations. Sensitivities less than 200 ppm may be unattainable. G.E. and Jarrell-Ash are both working on this principle.

UV Ionization

Prototype would be available in early 1971. Walden Research is working on this principle.

Mass Spectrometry

Potential concept has not been adapted to stack gas monitoring. Aero-Vac is working on this principle.

Radioactive Isotope Release

This technique is being developed for monitoring automobile emissions. Applicability to stack NO_x and on temperature limits and H_2O and SO_3 levels. Panametrics is working on this principle.

Condensation Nuclei Monitor

This variation of the Wilson cloud chamber is appropriate for low concentrations (50 ppm NO_2). The first bench test model would not be available before 1972. Environment/one is working on this principle.

Dispersive IR

Moisture interference is considerable. Otherwise this concept is capable of in-stack operation. Wilks Scientific is working on this principle.

UV Spectrometer

The instrument as seen by one electric utility is relatively slow in response and cannot discriminate less than 100 ppm NO_x. Honeywell is working on this principle.

Gas Chromatography

Leeds & Northrup has a prototype instrument utilizing this principle. Potentially, simultaneous or consecutive measurement of NO_x and SO_2 is possible. The instrument has proved to be excellent with simulated stock gases.

Flame Photometry

Meloy Laboratories has introduced the concept for NO_x

measurement on the basis of a modification of an SO_2 instrument.

APPENDIX A

ORGANIZATIONS CONTACTED

COMPANY	LOCATION
AERO CHEM COMPANY	PRINCENTON, N.J.
AERO VAC CORP	TROY, N.Y.
AMERICAN ELECTRIC POWER	NEW YORK, N.Y.
AMERICAN OPTICAL CORP	SOUTHBRIDGE, MASS
ATLAS ELECTRIC DEVICES	CHICAGO, ILL
ANTEK INSTRUMENTS, INC.	HOUSTON, TEXAS
AUTOMATED ENVIRONMENTAL SYSTEMS	WOODBURY, N.Y.
BABCOCK & WILCOX	BARBERTON, OHIO
BACHARACH INSTRUMENT CO	MOUNTAIN VIEW, CALIF
BAIRD ATOMIC, INC	BEDFORD, MASS
BALTIMORE GAS & ELECTRIC	BALTIMORE, MD
BARNES ENGINEERING	STAMFORD, CONN
BARRINGER RESEARCH	REXDALE, ONTARIO, CANADA
BATELLE MEMORIAL INSTITUTE	COLUMBUS, OHIO
BECKMAN INSTRUMENTS	FULLERTON, CALIF
BENDIX CORP	RONCEVERTE, W. VA
BENDIX CORP	BALTIMORE, MD
BENDIX CORP	ROCHESTER, N.Y.
BRISTOL DIV of ACCO	WATERBURY, CONN
BUREAU OF MINES	PITTSBURGH, PA
CALIFORNIA STATE AIR RESOURCES	LOS ANGELES, CALIF
CALIBRATED INSTRUMENTS	NEW YORK, N.Y.
COMBUSTION ENGINEERING, INC.	WINDSOR, CONN
CURTIN SCIENTIFIC CO	HOUSTON, TEXAS
DAVIS INSTRUMENTS	NEWARK, N.J.
DEPT. OF WATER & POWER	LOS ANGELES, CALIF
DEVCO ENGINEERING, INC.	FAIRFIELD, N.J.
DOHRMANN INSTRUMENTS CO.	MOUNTAIN VIEW, CALIF
E.I.duPONT de NEMOURS & CO	WILMINGTON, DELA.

COMPANY	LOCATION
DYNASCIENCES CORP	CHATSWORTH, CALIF
DYNASCIENCES CORP	LOS ANGELES, CALIF
ENVIRONMETRICS, INC	MARINA DEL REY, CALIF
ENVIRONMENT/one CORP.	SCHENECTADY, N.Y.
ENVIRONMENTAL DATA CORP	MONROVIA, CALIF
ESSO RESEARCH & ENGINEERING	LINDEN, N.J.
FISHER-PORTER CO	WARMINSTER, PA
FOSTER-WHEELER CORP	LIVINGSTON, N.J.
FOXBORO CO.	FOXBORO, MASS
GCA CORP	BEDFORD, MASS
GENERAL ELECTRIC	SCHENECTADY, N.Y.
GELMAN INSTRUMENT CO	ANN ARBOR, MICH
GELMAN INSTRUMENT CO.	VAN NUYS, CALIF
HEWLETT-PACKARD	PALO ALTO, CALIF
HONEYWELL INDUSTRIAL DIV	FORT WASHINGTON, PA
INTER-TECH	PRINCETON, N.J.
IONICS, INC	WATERTOWN, MASS
JARRELL-ASH	WALTHAM, MASS
JARRELL-ASH	PITTSBURGH, PA
KAMAN SCIENCE CORP	COLORADO SPRINGS, COLO
KEM-TECH LABORATORIES, INC	BATON ROUGE, LA
LEEDS & NORTHRUP CO	NORTH WALES, PA
LITTON ENVIRONMENTAL SYSTEMS	CAMARILLO, CALIF
LITTON INDUSTRIES, INC	MINNEAPOLIS, MINN
MAST DEVELOPMENT	DAVENPORT, IOWA
MELPAR	FALLS CHURCH, VA
MINE SAFETY APPLIANCES CO	PITTSBURGH, PA
MONSANTO RESEARCH CORP	DAYTON, OHIO
NATIONAL ENVIRONMENTAL INSTRUMENTS	FALL RIVER, MASS
NUCLEAR-CHICAGO	DES PLAINES, ILL

COMPANY	LOCATION
PACIFIC ELECTRIC & GAS	SAN FRANCISCO, CALIF
PANAMETRICS	WALTHAM, MASS
PERKIN-ELMER	NORWALK, CONN
PHILIPS ELECTRONIC INSTRUMENTS	MT. VERNON, N.Y.
POLLUTION CONTROL INDUSTRIES, INC.	STAMFORD, CONN
POLLUTION MONITORS, INC	CHICAGO, ILL
PRECISION SCIENTIFIC CO	CHICAGO, ILL
RESEARCH APPLIANCE CO	ALLISON PARK, PA
RESEARCH-COTTRELL	BOUND BROOK, N.J.
RESOURCE CONTROL, INC	WEST HAVEN, CONN
RILEY STOKER	WORCESTER, MASS
SAN DIEGO GAS & ELECTRIC	SAN DIEGO, CALIF
SCIENTIFIC GAS PRODUCTS, INC	EDISON, N.J.
SCIENTIFIC INDUSTRIES, INC	MINEOLA, N.Y.
SCOTT AVIATION	LANCASTER, N.Y.
SOUTHERN CALIFORNIA EDISON	LOS ANGELES, CALIF
TECHNICON	TARRYTOWN, N.Y.
TRACOR, INC	AUSTIN, TEXAS
TYCO LABS	WALTHAM, MASS
UNION CARBIDE CORP	WHITE PLAINS, N.Y.
UNIVERSAL OIL PRODUCTS	GREENWICH, CONN
WALDEN RESEARCH CORP	CAMBRIDGE, MASS
WEATHER MEASURE CORP	SACRAMENTO, CALIF
ROY F. WESTON, INC	WEST CHESTER, PA
WILKENS ANDERSON	CHICAGO, ILL
WILKS SCIENTIFIC CORP	SOUTH NORWALK, CONN
ZURN INDUSTRIES	ERIE, PA

APPENDIX B: INTERVIEW PROCEDURE

1. Nature of Interviews

Considerable telephone screening was conducted among more than 100 instrument manufacturers, boiler equipment manufacturers, electric utilities and research laboratories to identify the establishments that should be interviewed. In addition, requests for literature were mailed to a broad selection of instrument manufacturers (including those also contacted by telephone).

Personal interviews by technically qualified consultants skilled in interview techniques were then arranged with the establishments listed in Appendix A. Each interview was in two parts:

1. General questions regarding instrument applications and instrument development efforts.
2. A discussion of specific instrument performance parameters and characteristics

For the first part of the interview, separate sets of questions were developed for instrument manufacturers and for instrument users. The interview guides containing these questions are attached as Appendix C.

For the second part of the interview, instrument specification sheets (also includes in this appendix) were prepared under the guidance of MRC and were used for both instrument user and manufacturer for gaining detailed information on specified capabilities and on actual experience. It can be seen that some questions regarding usage specifications are answerable only by the users. Generally, it was helpful to leave a blank set of specifications to be completed and returned by those interviewed inasmuch as some detailed information was not always available during the interview.

2. <u>Interview questions</u>

Following are interviews forms containing the questions that were asked of NO_x instrument manufacturers and users:

a) Manufacturer

b) User

c) Instrument specifications (used in interviews with manufacturers and users)

STEVENSON, JORDAN & HARRISON
MANAGEMENT CONSULTANTS, INC.
200 Park Avenue
New York, N.Y.

INTERVIEW GUIDE FOR MANUFACTURERS OF NITROGEN OXIDES MONITORS

COMPANY: ____________________

ADDRESS: ____________________

RESPONDENT AND TITLE	TELEPHONE NUMBER
____________	____________
____________	____________
____________	____________

SUMMARY:

INTERVIEWER ____________ DATE ____________

CALLBACK BY ____________ DATE ____________

INTRODUCTORY:

1. Do you make NO_x monitors?

2. Do you make the NO_x detector component?
(if purchased, indicate below from whom)

I. TYPES OF INSTRUMENTS MADE

A. Specifically for NO_x in combustion gases:

1. Type/Method

2. Model Nos.

3. NO and/or NO_2?

B. Ambient NO_x adaptable to combustion gas streams:

1. Type/Method

2. Model Nos.

3. NO and/or NO_2?

4. Modification required

I-C Other NO_x instruments (e.g. for lab use):

1. Type/Method

2. Model Nos.

3. NO and/or NO_2?

4. Present Use

5. Potential Use

6. Modification Required

I-D Non-NO_x monitors capable of being modified to measure NO_x in combustion gases:

1. Type/Method

2. Model Nos.

3. NO and/or NO_2?

4. Present Use

5. Potential Use

6. Modification Required

II. INSTALLATION INFORMATION

Where are your NO_x instruments installed?

1. User and location*

2. Instrument(s) used

3. Application (lab, ambient, combustion gas stream)

4. Installation date

5. Operational results (problems?)

* Include name of person to contact if installation appears to merit a user interview.

III. R&D EFFORTS TOWARD NO_x MONITORS:

A. Applied R&D Programs (toward product improvement):

1. Nature, purpose of program

2. Anticipated timing*

3. Desired/Expected results

4. Extent to which needs of application will be satisfied

* Completion of scheduled program or introduction of product to market place. Also dates of prototype test.

III-B Basic R&D programs (toward user concepts, e.g. lasers, acoustics, UHF, etc.):

1. Nature, purpose of program

2. Anticipated timing

3. Advantages over existing approaches

III.-C Are there concepts presently inactive but could be developed if funds were available (such as from NAPCA)?

IV. INSTRUMENT MANUFACTURERS' OPINIONS

A. Need for 2nd Generation NO_x Instrumentation

B. Need for 3rd, 4th, etc. Generation NO_x Instrumentation

C. Estimated Dates When New Generation Instrumentation Will Realize Substantial Sales

D. Willingness of Customers to Pay for Higher Performance Characteristics

V. Request Literature from Instrument Manufacturers on:

- Cost of instruments
  - Total installation
  - Operating
- Product specifications
- Installation instructions
- Operation/maintenance manuals
- Sampling and pretreatment requirements
- Electronic circuitry
- Papers/articles descibing test studies and installations

VI. If you were asked in the next several weeks to deliver an instrument, how soon could you do it? ______

VII. What are the specifications of instruments currently available?

of instruments about to be available?

considered necessary/desirable in the future (1975-80)?

<u>GO TO "NO_x INSTRUMENT SPECIFICATIONS"</u>

STEVENSON, JORDAN & HARRISON
MANAGEMENT CONSULTANTS, INC.
200 Park Avenue
New York, N.Y.

INTERVIEW GUIDE FOR USERS OF NITROGEN OXIDES MONITORS

COMPANY: ______________________________

ADDRESS: ______________________________

RESPONDENT AND TITLE	TELEPHONE
____________	____________
____________	____________
____________	____________

SUMMARY:

INTERVIEWER ____________________ DATE ____________

CALLBACK BY ____________________ DATE ____________

I. NATURE OF PROJECT

A. Are you presently engaged in a program for measuring nitrogen oxides in combustion gases? Nature, purpose and scope of program:

B. What are your future plans and objectives for an NO_x program? What are your ultimate objectives?

C. To what extent will new instrument types or concepts be involved?

I-D. How would your program have to be enlarged or modified to meet the ultimate objectives?

1. Scope

2. Timing

3. Monitoring Equipment Needs

E. How freauent is the operation of the NO_x monitoring system(s) used in this program?

Hours of Operation per unit time

1. Experienced

2. Anticipated

3. Desired

II. INSTRUMENTATION

A. What NO_x monitoring instruments (do you) / (will you) use:

Equipment Used

1. Sampling and/or pretreatment

2. NO_x monitors

3. Recorders

4. Data handling/ transmission

5. Other related monitoring functions or capabilities

B. At what state of design is the instrumentation?

1. Experimental

2. Prototype

3. Production

III. INSTRUMENT OPERATION

A. Pretreatment procedures:

	Recommended by Manufacturer	Modifications

B. Why were modifications introduced? How was their need determined?

III. C. Instrument Calibration:

	Recommended	Actual	Desired
1. Frequency			
2. Procedure			

3. Instrument reliability/accuracy:

Actual	Desired

D. Instrument suitability in this application.

In other applications at this facility

In applications elsewhere

III. E. What problems (were resolved) / (are continuing)?

Installation/startup

Performance

Applicability

Interference from other gases

From particulates

Pretreatment (including loss of NO_x)

Human factors

III. F. What problems of ruggedness (do you have?) / (do you anticipate?)

1. Optical components

2. Electrical components

3. Mechanical components

III.G. If NO_x emission abatement lowers concentrations to 10-100 ppm which then must be measured, what additional operational problems would you anticipate?

H. What monitor performance do you think is necessary for operational application? (refer to specification list).

IV. FUTURE NEEDS

A. What other monitoring concepts do you think should be considered?

B. What do you think will be the major problems of making operational use of currently available equipment?

C. Of equipment now under development?

V. OTHER INDUSTRY ACTIVITY

A. Who else in the industry is using NO_x Monitors that you know of?

B. Who in the industry is studying advanced concepts and what are these concepts?

VI. <u>SPECIFICATIONS</u> (refer to specication list)

A. What are the specifications:

1. Compare actual performance to published specifications

2. What are desired specifications or specifications necessary for instruments that would be incorporated in an operational plant monitor and/or control system?

B. How would you rank the specifications (i.e. characteristics) in terms of being important to the operational use of the instruments? (Rank the most important as number one.)

NO_x INSTRUMENT SPECIFICATIONS

Manufacturer________________

User________________

Company________________ Respondent________________

A. Instrument Make, Model			
B. Installation (month, year)			
C. Hours operated per unit of time			
D. What is the accuracy? 1. NO			
2. NO_2			
3. NO_x			
E. All other things being equal, what is the accuracy as it is influenced by:			
1. Base line drift (deviation from zero)			
2. Calibration drift			
3. Range drift			
4. Internal calibration capability?			
5. Automatic Zero Capability?			
F. Precision (allowable fluctuation around true value)			
G. Repeatability			
H. Sensitivity (lowest concentration detectable)			

I. Responses:			
1. Response time			
2. Response lag			
J. Resolution (ability to discriminate between levels of concentration)			
K. Detector/Monitor performance without sample pretreatment:			
1. Identity of interfering gases			
2. Comparative values of interference			
3. Particulates			
4. Moisture and water vapor			
L. System performance with sample pretreatment:			
1. Flow rate			
2. Concentration ranges of			
a.) NO			
b.) NO_2			
c.) NO_x			
3. Concentration ranges of interferences			
4. Temperature tolerance			
5. Moisture tolerance			
6. Particulate tolerance			
7. Pressure/ vacuum tolerance			

M. Sample loss as it affects accuracy			
N. Sample metering system instability as it affects accuracy			
O. Environmental operating conditions (around the instrument) as they affect accuracy:			
1. Ambient temperature range			
2. Humidity			
3. RF, electrical radiation			
4. Vibrational susceptibility			
P. Range(s)			
Q. Operation Mode			
1. Sampling (continuous/ cyclical)			
2. Output (continuous/ sequential)			
R. Dependability (reliability)			
S. Repair requirements for monitor/detector:			
1. Frequency of incidents/year			
a.) optical			
b.) electric			
c.) mechanical			
d.) total (a+b+c)			

2. Downtime (hours) as % of scheduled operation (hours)

a.) optical			
b.) electric			
c.) mechanical			
d.) total (a+b+c)			

3. Labor (including burden), materials cost:

a.) cost/unit of time or			
b.) cost/incident			

T. Attendance Requirements (scheduled) for monitor/detector:

1. Man-hours/ hours of operation			
2. Cost/hours of operation			
3. Labor rate (with burden)			
U. Do you need readable output on instrument?			
V. Utilities 1. What, how much?			
2. What cannot be used?			
W. Required accessories			

X. Costs			
1. Initial cost			
a.) system			
b.) monitor			
2. Operating Cost			
Y. Physical Limits			
1. Dimensional limits			
2. Weight limits			
Z. Materials of Construction			
1. Incidents of material failure			
2. Preferred materials			
3. Materials not allowable			

DEFINITIONS

Accuracy: Extent to which true value is measured

Interference: Effect on receiving, processing, measuring sample

Comparative Values of Interference: "x" ppm of SO_2 (for example) introduces error eouivalent to "Y" ppm of NO_x

Test Stack Gas Composition:	SO_2	700-1450 ppm
	SO_3	50-200 ppm
	NO_x	300-500 ppm
	CO_2	12.5-13.5 %
	O_2	3.5 %

Precision: Allowable fluctuation around true value

Sensitivity: Lowest concentration detectable

Resolution: Ability to discriminate between levels of concentration

Response lag: Time for instrument to begin to cahnge reading with a change in concentration

Repeatability: Percent of instances in which readings fall within a given degree of precision

Dependability (reliability): Mean time to failure (i.e. event beyond ability of instrument to self correct to within prescribed accuracy and precision).

Repair Requirements: Unscheduled maintenance to correct instrument to within prescribed accuracy and precision.

APPENDIX II

FIELD DATA ANALYSES

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The data are tabulated for each run as follows:

1. RUN DATE

2. ORIGINAL DATA MATRIX, Rows Correspond to Observation, Columns to Instruments.

   Column 1-A - Beckman
   Column 2-B - Dynasciences
   Column 3-C - EnviroMetrics
   Column 4-D - Intertech
   Column 5-E - MSA
   Column 6-F - DuPont 461
   Column 7-G - SO_2
   Column 8-H - Time (ca. hours since start)

3. CM1 (Correlation Matrix #1) - Simple correlation coefficients, r., e.g., coefficient in row column 3 is the simple correlation coefficient between column B and column C in the DATA MATRIX. Coefficient in row 8 column 1 is the simple correlation coefficient between time and the Beckman Instrument.

4. If any element in column 6 of CM1 (rows 1 through 5) was greater than 0.9, then a regression analysis was performed between the DuPont 461 and the corresponding instrument.

5. The REGRESSION RESULTS MATRIX is composed of 5 columns:

   Row 1: Column 2 is the intercept (ppm).

   Row 2: Column 2 - slope, Column 3 - standard error of the slope, Column 4 - T-value.

   Row 3: Column 2 - degrees of freedom for regression, Column 3 - sum of squares, Column 4 - mean square, Column 5 - F-value.

   Row 4: Column 2 - degrees of freedom for error, Column 3 - sum of squares, Column 4 - mean square.

   Row 5: Column 2 - degrees of freedom for total, Column 3 - sum of squares, Column 4 - standard error of estimate, Column 5 - square of the simple correlation coefficient.

6. ABSOLUTE ERROR MATRIX (AEM) - Generated by subtracting column 6 from columns 1-5 of the DATA MATRIX. Columns 6, 7, 8 are shown unchanged.

7. CM2 - Correlation analysis identical in definition to CM1, performed on the ABSOLUTE ERROR MATRIX.

8. AVG ERROR - e.g., using column A of ABSOLUTE ERROR MATRIX.

MEAN ERR:

$$\frac{A_i}{N}$$

MEAN DEV:

$$\frac{\sum_{i=1}^{N} |A_i|}{N}$$

$$\sqrt{\frac{\sum_{i=1}^{N} A_i^2}{N-1}}$$

9. RELATIVE ERROR MATRIX (REM) - Columns 1-5 of ABSOLUTE ERROR MATRIX were divided by column 6 (X100) to yield the REM. Columns 6-8 remain unchanged.

10. CM3 - Correlation analysis performed on the REM. Definition identical to CM1 and CM2.

11. ERROR ANALYSIS performed on the REM. Definition identical to Step #8.

12. Calculations performed on APL/360 TIME-SHARING SYSTEM IBM Prog #360D-03.3.007 using K. W. Smilie's STATPACK 2: An APL Statistical Package, 2nd edition, Publication number 17, Feb. 1969, Univ. of Alberta, Alberta, Canada.

13. Programs run on the IBM 1130 used Fortran IV as described in IBM publication GC 26-3715.

14. The 1130 uses the Version 2 Disk Monitor system, Publication GC-26-3709.

RUN DATE 6/7/71

DATA

A	*B*	*C*	*D*	*E*	461	*SO2*	*TIME*
168	154	164	163	160	160	1850	1
166	167	193	166	150	158	1890	2
155	135	130	155	150	167	1750	3
160	152	170	190	160	175	2570	4
170	165	155	156	165	180	2670	5
175	165	155	148	170	185	2675	6
180	170	175	148	165	190	2710	7
186	150	223	164	165	195	2830	8
182	142	236	165	160	190	3000	9
162	127	188	174	140	160	3000	10
166	123	199	151	140	158	3000	11
159	124	226	159	140	165	3000	12
150	134	199	143	140	155	3000	13
144	136	166	148	130	143	2856	14
142	103	162	144	140	150	2990	15
152	118	152	160	130	155	3000	16
170	144	231	182	140	175	2888	17
141	98	206	156	130	135	2940	18

CM1

A	*B*	*C*	*D*	*E*	461	*SO2*	*TIME*
1	0.742741	0.264112	0.452378	0.827774	0.909152	¯0.135092	¯0.564947
0.742741	0.999999	¯0.121299	0.185095	0.800708	0.690619	¯0.47213	¯0.738818
0.264112	¯0.121299	0.999999	0.29376	¯0.113153	0.176053	0.461608	0.359915
0.452378	0.185095	0.29376	1	0.114729	0.243023	¯0.124411	¯0.17324
0.827774	0.800708	¯0.113153	0.114729	1	0.840405	¯0.370676	¯0.764101
0.909152	0.690619	0.176053	0.243023	0.840405	1	¯0.0433819	¯0.457628
¯0.135092	¯0.47213	0.461608	¯0.124411	¯0.370676	¯0.0433819	1	0.78303
¯0.564947	¯0.738818	0.359915	¯0.17324	¯0.764101	¯0.457628	0.78303	1

1	37.7231	0	0	0
6	0.757338	0.0867309	8.73204	0
0	1	2809.55	2809.55	76.2486
0	16	589.557	36.8473	0
0	17	3399.11	6.0702	0.826556

Absolute Errors (ppm NO_x)

A	B	C	C	E	461	SO_2	Time
8	¯6	4	3	0	160	1850	1
8	9	35	8	¯8	158	1890	2
¯12	¯32	¯37	¯12	¯17	167	1750	3
5	¯23	¯5	15	¯15	175	2570	4
¯10	¯15	¯25	¯24	¯15	180	2670	5
¯10	¯20	¯30	¯37	¯15	185	2675	6
¯10	¯20	¯15	¯42	¯25	190	2710	7
¯9	¯45	28	¯31	¯30	195	2830	8
¯8	¯48	46	¯25	¯30	190	3000	9
2	¯33	28	14	¯20	160	3000	10
8	¯35	41	¯7	¯18	158	3000	11
¯6	¯41	61	¯6	¯25	165	3000	12
¯5	¯21	44	¯12	¯15	155	3000	13
1	¯7	23	5	¯13	143	2856	14
¯8	¯47	12	¯6	¯10	150	2990	15
¯3	¯37	¯3	5	¯25	155	3000	16
¯5	¯31	56	7	¯35	175	2888	17
6	¯37	71	21	¯5	135	2940	18

CM2

1	0.391638	0.397107	0.740179	0.529746	¯0.57317	¯0.163337	¯0.0306645
0.391638	1	¯0.265053	0.123369	0.530691	¯0.143729	¯0.598808	¯0.512724
0.397107	¯0.265053	0.999998	0.427312	¯0.152898	¯0.35337	0.461267	0.580314
0.740179	0.123369	0.427312	1	0.358089	¯0.745433	¯0.0459101	0.298508
0.529746	0.530691	¯0.152898	0.358089	1	¯0.601956	¯0.466327	¯0.283699
¯0.57317	¯0.143729	¯0.35337	¯0.745433	¯0.601956	1	¯0.0433819	¯0.457628
¯0.163337	¯0.598808	0.461267	¯0.0459101	¯0.466327	¯0.0433819	1	0.78303
¯0.0306645	¯0.512724	0.580314	0.298508	¯0.283699	¯0.457628	0.78303	1

AVG ERR, MEAN ERR, MEAN DEV

A	B	C	D	E
¯2.66667	¯27.1667	18.5556	¯6.88889	¯17.8333
6.88889	28.1667	31.3333	15.5556	17.8333
7.69263	32.0083	37.7811	19.9086	20.5383

RELATIVE ERRORS

A	B	C	C	E	461	SO_2	Time
5	¯3.75	2.5	1.875	0	160	1850	1
5.06329	5.6962	22.1519	5.06329	¯5.06329	158	1890	2
¯7.18563	¯19.1617	¯22.1557	¯7.18563	¯10.1796	167	1750	3
2.85714	¯13.1429	¯2.85714	8.57143	¯8.57143	175	2570	4
¯5.55556	¯8.33333	¯13.8889	¯13.3333	¯8.33333	180	2670	5
¯5.40541	¯10.8108	¯16.2162	¯20	¯8.10811	185	2675	6
¯5.26316	¯10.5263	¯7.89474	¯22.1053	¯13.1579	190	2710	7
¯4.61538	¯23.0769	14.359	¯15.8974	¯15.3846	195	2830	8
¯4.21053	¯25.2632	24.2105	¯13.1579	¯15.7895	190	3000	9
1.25	¯20.625	17.5	8.75	¯12.5	160	3000	10
5.06329	¯22.1519	25.9494	¯4.43038	¯11.3924	158	3000	11
¯3.63636	¯24.8485	36.9697	¯3.63636	¯15.1515	165	3000	12
¯3.22581	¯13.5484	28.3871	¯7.74194	¯9.67742	155	3000	13
0.699301	¯4.89511	16.0839	3.4965	¯9.09091	143	2856	14
¯5.33333	¯31.3333	8	¯4	¯6.66667	150	2990	15
¯1.93548	¯23.871	¯1.93548	3.22581	¯16.129	155	3000	16
¯2.85714	¯17.7143	32	4	¯20	175	2888	17
4.44445	¯27.4074	52.5926	15.5556	¯3.7037	135	2940	18

CM3

A	B	C	D	E	461	SO_2	Time
0.999999	0.299169	0.440925	0.718572	0.474024	¯0.535453	¯0.165697	¯0.0460097
0.299169	0.999999	¯0.296631	¯0.0259118	0.422867	0.058064	¯0.612473	¯0.608844
0.440925	¯0.296631	0.999999	0.48423	¯0.117421	¯0.429216	0.455058	0.602109
0.718572	¯0.0259118	0.48423	1	0.25249	¯0.738014	¯0.0331752	0.311975
0.474024	0.422867	¯0.117421	0.25249	1	¯0.456625	¯0.521185	¯0.392227
¯0.535453	0.058064	¯0.429216	¯0.738014	¯0.456625	1	¯0.0433819	¯0.457628
¯0.165697	¯0.612473	0.455058	¯0.0331752	¯0.521185	¯0.0433819	1	0.78303
¯0.0460097	¯0.608844	0.602109	0.311975	¯0.392227	¯0.457628	0.78303	1

AVG CRR, MEAN ERR, MEAN DEV

¯1.38035	¯16.3758	11.9864	¯3.38615	¯10.4944
4.08896	17.0087	19.2029	9.00144	10.4944
4.52881	19.4209	23.7328	11.1474	11.8997

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DATA

A	B	C	D	E	461	SO_2	Time
208	204	206	216	198	185	1602	1
208	204	206	210	203	180	1614	2
206	211	185	229	200	196	1632	3
207	200	182	224	199	190	1548	4
212	206	158	240	210	188	1383	5
181	194	186	176	180	175	1152	6
168	190	176	159	153	173	1110	7
188	234	164	179	168	190	1578	8
190	232	145	176	153	188	1740	9
176	236	125	167	138	173	1596	10
190	256	116	168	145	183	1308	11
178	243	82	167	140	175	1306	12
178	254	58	166	143	170	1156	13
180	260	25	167	145	165	984	14
162	224	6	167	123	150	1008	15
172	268	23	152	133	180	1134	16
136	238	¯31	132	100	150	1404	17
142	242	¯40	143	100	150	1356	18
135	234	¯57	130	90	140	1416	19
158	275	¯36	141	103	155	1836	20
184	284	¯9	143	130	210	1596	21
176	265	1	172	120	195	1728	22
185	268	19	143	125	198	1470	23

CM1

A	B	C	E	E	461	SO_2	Time
1	¯0.344818	0.792681	0.856412	0.903057	0.778529	0.242995	¯0.681665
¯0.344818	0.999999	¯0.745028	¯0.635254	¯0.671873	0.0416025	0.103598	0.832045
0.792681	¯0.745028	1	0.795962	0.914616	0.487748	0.111872	¯0.934871
0.856412	¯0.635254	0.795962	0.999999	0.931585	0.471646	0.189862	¯0.825782
0.903057	¯0.671873	0.914616	0.931585	1	0.556833	0.0968919	¯0.894818
0.778529	0.0416025	0.487748	0.471646	0.556833	0.999999	0.376712	¯0.239285
0.242995	0.103598	0.111872	0.189862	0.0968919	0.376712	1	¯0.0207965
¯0.681665	0.832045	¯0.934871	¯0.825782	¯0.894818	¯0.239285	¯0.0207965	1

ABSOLUTE ERRORS

A	B	C	D	E	461	SO_2	Time
23	19	21	31	13	185	1602	1
28	24	26	30	23	180	1614	2
10	15	¯11	33	4	196	1632	3
17	10	¯8	34	9	190	1548	4
24	18	¯30	52	22	188	1383	5
6	19	11	1	5	175	1152	6
¯5	17	3	¯14	¯20	173	1110	7
¯2	44	¯26	¯11	¯22	190	1578	8
2	44	¯43	¯12	¯35	188	1740	9
3	63	¯48	¯6	¯35	173	1596	10
7	73	¯67	¯15	¯38	183	1308	11
3	68	¯93	¯8	¯35	175	1306	12
-8	84	¯112	¯4	¯27	170	1156	13
15	95	¯140	2	¯20	165	984	14
12	74	¯144	17	¯27	150	1008	15
¯8	88	¯157	¯28	¯47	180	1134	16
¯14	88	¯181	¯18	¯50	150	1404	17
¯8	92	¯190	¯7	¯50	150	1356	18
¯5	94	¯197	¯10	¯50	140	1416	19
3	120	¯191	¯14	¯52	155	1836	20
¯26	74	¯219	¯67	¯80	210	1596	21
¯19	70	¯194	¯23	¯75	195	1728	22
¯13	70	¯179	¯55	¯73	198	1470	23

CM2

A	B	C	D	E	461	SO_2	Time
1	¯0.480807	0.6945	0.883433	0.892523	¯0.0617685	¯0.103239	¯0.773016
¯0.480807	1	¯0.875179	¯0.569178	¯0.749858	¯0.519792	¯0.120633	0.844315
0.6945	¯0.875179	1	0.655623	0.861472	0.315081	0.0405635	¯0.964859
0.883433	¯0.569178	0.655623	0.999999	0.896542	¯0.118095	¯0.0307632	¯0.774582
0.892523	¯0.749858	0.861472	0.896542	0.999999	0.0694979	¯0.109382	¯0.931285
¯0.0617685	¯0.519792	0.315081	¯0.118095	0.0694979	0.999999	0.376712	¯0.239285
¯0.103239	¯0.120633	0.0405635	¯0.0307632	¯0.109382	0.376712	1	¯0.0207965
¯0.773016	0.844315	¯0.964859	¯0.774582	¯0.931285	¯0.239285	¯0.0207965	1

AVG ERR, MEAN ERR, MEAN DEV

A	B	C	D	E
2	61.5	¯98.2273	¯5.72727	¯30.4091
11.0909	61.5	103.773	20.8182	36.5
14.0102	70.3566	130.85	27.814	43.0122

RELATIVE ERRORS

A	B	C	D	E	461	SO_2	Time
12.4324	10.2703	11.3514	16.7568	7.02703	185	1602	1
15.5556	13.3333	14.4444	16.6667	12.7778	180	1614	2
5.10204	7.65306	¯5.61225	16.8367	2.04082	196	1632	3
8.94737	5.26316	¯4.21053	17.8947	4.73684	190	1548	4
12.766	9.57447	¯15.9574	27.6596	11.7021	188	1383	5
3.42857	10.8571	6.28571	0.571429	2.85714	175	1152	6
¯2.89017	9.82659	1.7341	¯8.09249	¯11.5607	173	1110	7
¯1.05263	23.1579	¯13.6842	¯5.78947	¯11.5789	190	1578	8
1.06383	23.4043	¯22.8723	¯6.38298	¯18.617	188	1740	9
1.7341	36.4162	¯27.7457	¯3.46821	¯20.2312	173	1596	10
3.82514	39.8907	¯36.612	¯8.19672	¯20.765	183	1308	11
1.71429	38.8572	¯53.1429	¯4.57143	¯20	175	1306	12
4.70588	49.4118	¯65.8824	¯2.35294	¯15.8824	170	1156	13
9.09091	57.5758	¯84.8485	1.21212	¯12.1212	165	984	14
8	49.3333	¯96	11.3333	¯18	150	1008	15
¯4.44444	48.8889	¯87.2222	¯15.5556	¯26.1111	180	1134	16
¯9.33333	58.6667	¯120.667	¯12	¯33.3333	150	1404	17
¯5.33333	61.3333	¯126.667	¯4.66667	¯33.3333	150	1356	18
¯3.57143	67.1429	¯140.714	¯7.14286	¯35.7143	140	1416	19
1.93548	77.4194	¯123.226	¯9.03226	¯33.5484	155	1836	20
¯12.381	35.2381	¯104.286	¯31.9048	¯38.0952	210	1596	21
¯9.74359	35.8974	¯99.4872	¯11.7949	¯38.4615	195	1728	22
¯6.56566	35.3535	¯90.4041	¯27.7778	¯36.8687	198	1470	23

CM2

A	B	C	D	E	461	SO_2	Time
1	0.402188	0.614059	0.871548	0.852445	0.0246227	0.112171	0.752109
¯0.402188	1	¯0.899664	¯0.482356	¯0.759675	¯0.672312	¯0.149562	0.785204
0.614059	¯0.899664	0.999999	0.573376	0.861496	0.490161	0.0798888	¯0.923631
0.871548	¯0.482356	0.573376	1	0.854917	¯0.0711619	¯0.0341655	¯0.779662
0.852445	¯0.759675	0.861496	0.854917	1	0.241075	¯0.0756985	¯0.942277
¯0.0246227	¯0.672312	0.490161	¯0.0711619	0.241075	0.999999	0.376712	¯0.239285
¯0.112171	¯0.149562	0.0798888	¯0.0341655	¯0.0756985	0.376712	1	¯0.0207965
¯0.752109	0.785204	¯0.923631	¯0.779662	¯0.942277	¯0.239285	¯0.0207965	1

AVG ERR, MEAN ERR, MEAN DEV

A	B	C	D	E
1.18358	36.341	¯58.2371	¯3.07693	¯17.6281
6.21226	36.341	61.3112	11.353	20.9376
7.68548	42.6645	78.4404	14.5598	24.4314

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DATA

205	210	270	187	220	195	1769	1
205	215	238	207	210	196	1465	2
209	210	236	208	213	193	1383	3
204	207	210	209	215	188	1412	4
217	218	214	217	220	188	1383	5
210	221	192	215	220	193	1236	6
207	230	174	219	220	193	1213	7
206	164	221	223	225	190	1277	8
176	144	149	168	200	160	1523	9
183	168	171	152	210	160	1488	10
141	123	118	185	190	125	1611	11
141	127	118	127	160	120	1593	12
143	117	108	149	196	130	1488	13
155	135	115	145	190	135	1578	14
168	158	123	149	190	130	1599	15
133	113	84	138	160	95	1441	16
166	143	120	184	203	141	1512	17

CM1

A	B	C	D	E	461	SO_2	Time
1	0.939976	0.902658	0.849078	0.893009	0.971974	¯0.487582	¯0.823766
0.939976	1	0.841536	0.789844	0.784539	0.915245	¯0.447133	¯0.833461
0.902658	0.841536	0.999999	0.743011	0.792463	0.926607	¯0.199468	¯0.934878
0.849078	0.789844	0.743011	0.999999	0.845519	0.857067	¯0.605727	¯0.704161
0.893009	0.784539	0.792463	0.845519	1	0.910521	¯0.430979	¯0.689386
0.971974	0.915245	0.926607	0.857067	0.910521	0.999999	¯0.443079	¯0.883199
¯0.487582	¯0.447133	¯0.199468	¯0.605727	¯0.430979	¯0.443079	0.999999	0.205182
¯0.823766	¯0.833461	¯0.934878	¯0.704161	¯0.689386	¯0.883199	0.205182	1

REGRESSION ON INSTRUMENT A

1	43.3549	0	0	0
6	0.853575	0.0533051	16.013	0
0	1	13175.5	13175.5	256.416
0	15	770.748	51.3832	0
0	16	13946.2	7.16821	0.944734

REGRESSION ON INSTRUMENT B

2	¯12.3209	0	0	0
6	1.13926	0.12949	8.79808	0
0	1	23470.8	23470.8	77.4062
0	15	4548.24	303.216	0
0	16	28019.1	17.4131	0.837673

INSTRUMENT C

3	¯80.2846	0	0	0
6	1.54679	0.162076	9.54362	0
0	1	43266.1	43266.1	91.0807
0	15	7125.45	475.03	0
0	16	50391.5	21.7952	0.858598

INSTRUMENT E

5	116.514	0	0	0
6	0.534871	0.0627118	8.52904	0
0	1	5173.46	5173.46	72.7445
0	15	1066.77	71.1182	0
0	16	6240.24	8.43316	0.829049

ABSOLUTE ERRORS

10	15	75	¯8	25	195	1769	1
9	19	42	11	14	196	1465	2
16	17	43	15	20	193	1383	3
16	19	22	21	27	188	1412	4
29	30	26	29	32	188	1383	5
17	28	¯1	22	27	193	1236	6
14	37	¯19	26	27	193	1213	7
16	¯26	31	33	35	190	1277	8
16	¯16	¯11	8	40	160	1523	9
23	8	11	¯8	50	160	1488	10
16	¯2	¯7	60	65	125	1611	11
21	7	¯2	7	40	120	1593	12
13	¯13	¯22	19	66	130	1488	13
20	0	¯20	10	55	135	1578	14
38	28	¯7	19	60	130	1599	15
38	18	¯11	43	65	95	1441	16
25	2	¯21	43	62	141	1512	17

CM2

A	B	C	D	E	461	SO_2	Time
1	0.263267	¯0.365916	0.286924	0.543907	¯0.578515	0.0588359	0.631273
0.263267	1	0.144397	¯0.0615475	¯0.367853	0.267556	¯0.21805	¯0.296369
¯0.365916	0.144397	1	¯0.398286	¯0.697237	0.656828	0.132263	¯0.81372
0.286924	¯0.0615475	¯0.398286	1	0.417011	¯0.319107	¯0.274298	0.378961
0.543907	¯0.367853	¯0.697237	0.417011	1	¯0.886424	0.361918	0.911393
¯0.578515	0.267556	0.656828	¯0.319107	¯0.886424	0.999999	¯0.443079	¯0.883199
0.0588359	¯0.21805	0.132263	¯0.274298	0.361918	¯0.443079	0.999999	0.205182
0.631273	¯0.296369	¯0.81372	0.378961	0.911393	¯0.883199	0.205182	1

AVG ERR, MEAN ERR, MEAN DEV

A	B	C	D	E
19.8235	10.0588	7.58824	20.5882	41.7647
19.8235	16.7647	21.8235	22.4706	41.7647
22.1345	20.3393	29.0592	27.6564	46.5242

RELATIVE ERRORS

A	B	C	D	E	461	SO_2	Time
5.12821	7.69231	38.4615	-4.10256	12.8205	195	1769	1
4.59184	9.69388	21.4286	5.61225	7.14286	196	1465	2
8.29016	8.80829	22.2798	7.77202	10.3627	193	1383	3
8.51064	10.1064	11.7021	11.1702	14.3617	188	1412	4
15.4255	15.9574	13.8298	15.4255	17.0213	188	1383	5
8.80829	14.5078	-0.518135	11.399	13.9896	193	1236	6
7.25389	19.171	-9.84456	13.4715	13.9896	193	1213	7
8.42105	-13.6842	16.3158	17.3684	18.4211	190	1277	8
10	-10	-6.875	5	25	160	1523	9
14.375	5	6.875	-5	31.25	160	1488	10
12.8	-1.6	-5.6	48	52	125	1611	11
17.5	5.83333	-1.66667	5.83333	33.3333	120	1593	12
10	-10	-16.9231	14.6154	50.7692	130	1488	13
14.8148	0	-14.8148	7.40741	40.7407	135	1578	14
29.2308	21.5385	-5.38461	14.6154	46.1538	130	1599	15
40	18.9474	-11.5789	45.2632	68.4211	95	1441	16
17.7305	1.41844	-14.8936	30.4965	43.9716	141	1512	17

CM3

A	B	C	D	E	461	SO_2	Time
1	0.384571	-0.469028	0.534477	0.775032	-0.767614	0.16961	0.723299
0.384571	0.999999	0.101377	0.0409757	-0.0913194	0.0846832	-0.158035	-0.130638
-0.469028	0.101377	1	-0.471325	-0.712746	0.704809	0.0814859	-0.844417
0.534477	0.0409757	-0.471325	1	0.658137	-0.542616	-0.0753473	0.510668
0.775032	-0.0913194	-0.712746	0.658137	1	-0.955084	0.361203	0.892168
-0.767614	0.0846832	0.704809	-0.542616	-0.955084	0.999999	-0.443079	-0.883199
0.16961	-0.158035	0.0814859	-0.0753473	0.361203	-0.443079	0.999999	0.205182
0.723299	-0.130638	-0.844417	0.510668	0.892168	-0.883199	0.205182	1

AVG ERR, MEAN ERR, MEAN DEV

A	B	C	D	E
13.6989	6.08179	2.51724	14.3734	29.397
13.6989	10.2329	12.8819	15.4443	29.397
16.7568	12.3473	16.0971	20.8168	35.3099

RUN DATE 6/25/71

DATA

252	238	261	230	227	250	1492	1
246	272	236	251	221	260	1026	2
218	272	324	223	179	253	815	3
197	200	297	213	161	200	466	4
195	280	273	216	166	223	352	5
194	287	244	216	156	254	257	6
154	280	169	172	103	195	181	7
192	270	274	220	149	270	94	8
196	220	246	224	153	258	95	9
179	231	216	202	126	241	81	10
151	219	178	175	90	218	60	11
172	241	202	195	110	238	21	12
144	215	166	162	75	233	15	13
135	217	156	144	56	212	35	14
129	205	148	152	54	195	35	15

CM1

A	B	C	D	E	461	SO_2	Time
0.999999	0.433955	0.781953	0.943459	0.991688	0.649677	0.855294	¯0.908239
0.433955	1	0.38107	0.48809	0.481003	0.422826	0.272076	¯0.541132
0.781953	0.38107	0.999998	0.826723	0.804937	0.512311	0.538558	¯0.788607
0.943459	0.48809	0.826723	0.999999	0.954994	0.713205	0.648084	¯0.840226
0.991688	0.481003	0.804937	0.954994	0.999999	0.609527	0.830121	¯0.938685
0.649677	0.422826	0.512311	0.713205	0.609527	1	0.3309	¯0.384153
0.855294	0.272076	0.538558	0.648084	0.830121	0.3309	1	¯0.840446
¯0.908239	¯0.541132	¯0.788607	¯0.840226	¯0.938685	¯0.384153	¯0.840446	1

ABSOLUTE ERRORS

2	¯12	11	¯20	¯23	250	1492	1
¯14	12	¯24	¯9	¯39	260	1026	2
¯35	19	71	¯30	¯74	253	815	3
¯3	0	97	13	¯39	200	466	4
¯28	57	50	¯7	¯57	223	352	5
¯60	33	¯10	¯38	¯98	254	257	6
¯41	85	¯26	¯23	¯92	195	181	7
¯78	0	4	¯50	¯121	270	94	8
¯62	¯38	¯12	¯34	¯105	258	95	9
¯62	¯10	¯25	¯39	¯115	241	81	10
¯67	1	¯40	¯43	¯128	218	60	11
¯66	3	¯36	¯43	¯128	238	21	12
¯89	¯18	¯67	¯71	¯158	233	15	13
¯77	5	¯56	¯68	¯156	212	35	14
¯66	10	¯47	¯43	¯141	195	35	15

CM2

1	0.222243	0.684441	0.898358	0.966975	¯0.0253607	0.833626	¯0.856403
0.222243	1	0.167034	0.309797	0.208513	¯0.396029	0.00286987	¯0.231593
0.684441	0.167034	1	0.75335	0.722151	0.067066	0.450932	¯0.713314
0.898358	0.309797	0.75335	1	0.896361	¯0.105184	0.549822	¯0.762933
0.966975	0.208513	0.722151	0.896361	0.999999	0.182058	0.839699	¯0.94379
¯0.0253607	¯0.396029	0.067066	¯0.105184	0.182058	1	0.3309	¯0.384153
0.833626	0.00286987	0.450932	0.549822	0.839699	0.3309	1	¯0.840446
¯0.856403	¯0.231593	¯0.713314	¯0.762933	¯0.94379	¯0.384153	¯0.840446	1

AVG ERR, MEAN ERR, MEAN DEV

¯49.7333	9.8	¯7.33333	¯33.6667	¯98.2667
50	20.2	38.4	35.4	98.2667
58.7501	31.8647	47.7628	41.3703	110.584

RELATIVE ERRORS

0.8	¯4.8	4.4	¯8	¯9.2	250	1492	1
¯5.38461	4.61538	¯9.23077	¯3.46154	¯15	260	1026	2
¯13.834	7.50988	28.0632	¯11.8577	¯29.249	253	815	3
¯1.5	0	48.5	6.5	¯19.5	200	466	4
¯12.5561	25.5605	22.4215	¯3.13901	¯25.5605	223	352	5
¯23.622	12.9921	¯3.93701	¯14.9606	¯38.5827	254	257	6
¯21.0256	43.5897	¯13.3333	¯11.7949	¯47.1795	195	181	7
¯28.8889	0	1.48148	¯18.5185	¯44.8148	270	94	8
¯24.031	¯14.7287	¯4.65116	¯13.1783	¯40.6977	258	95	9
¯25.7261	¯4.14938	¯10.3734	¯16.1826	¯47.7178	241	81	10
¯30.7339	0.458716	¯18.3486	¯19.7248	¯58.7156	218	60	11
¯27.7311	1.2605	¯15.126	¯18.0672	¯53.7815	238	21	12
¯38.1974	¯7.72532	¯28.7554	¯30.4721	¯67.8112	233	15	13
¯36.3208	2.35849	¯26.4151	¯32.0755	¯73.5849	212	35	14
¯33.8462	5.12821	¯24.1026	¯22.0513	¯72.3077	195	35	15

CM3

1	0.130417	0.747477	0.90649	0.959165	0.155559	0.84659	¯0.922698
0.130417	1	0.103708	0.231312	0.0790391	¯0.428894	¯0.0200942	¯0.20662
0.747477	0.103708	1	0.815608	0.738008	0.0698962	0.438846	¯0.712945
0.90649	0.231312	0.815608	1	0.879934	0.0367728	0.564253	¯0.813704
0.959165	0.0790391	0.738008	0.879934	1	0.39374	0.820938	¯0.967614
0.155559	¯0.428894	0.0698962	0.0367728	0.39374	1	0.3309	¯0.384153
0.84659	¯0.0200942	0.438846	0.564253	0.820938	0.3309	1	¯0.840446
¯0.922698	¯0.20662	¯0.712945	¯0.813704	¯0.967614	¯0.384153	¯0.840446	1

AVG ERR, MEAN ERR, MEAN DEV

¯21.5065	4.80468	¯3.29381	¯14.4656	¯42.9135
21.6132	8.9918	17.276	15.3323	42.9135
25.4843	15.001	21.9461	18.0658	48.8704

RUN DATE 7/13/71

DATA

269	258	254	267	240	288	1129	1
265	254	322	262	245	284	1045	2
257	246	301	257	229	274	1099	3
264	240	391	260	241	270	1090	4
260	247	314	257	234	274	1055	5

CM1

1	0.602369	¯0.206578	0.946282	0.812922	0.707957	0.308454	¯0.647895
0.602369	1	¯0.82711	0.748022	0.342286	0.984186	0.175298	¯0.804985
¯0.206578	¯0.82711	1	¯0.453519	0.230367	¯0.742664	¯0.407436	0.605806
0.946282	0.748022	¯0.453519	1	0.644864	0.836582	0.494105	¯0.836315
0.812922	0.342286	0.230367	0.644864	1	0.468892	¯0.214655	¯0.401508
0.707957	0.984186	¯0.742664	0.836582	0.468892	1	0.215729	¯0.871977
0.308454	0.175298	¯0.407436	0.494105	¯0.214655	0.215729	1	¯0.477795
¯0.647895	¯0.804985	0.605806	¯0.836315	¯0.401508	¯0.871977	¯0.477795	0.999999

REGRESSION ON INSTRUMENT B

2	¯5.03452	0	0	0
6	0.913793	0.0949581	9.62313	0
0	1	193.724	193.724	92.6046
0	3	6.27585	2.09195	0
0	4	200	1.44636	0.968621

ABSOLUTE ERRORS

¯19	¯30	¯34	¯21	¯48	288	1129	1
¯19	¯30	38	¯22	¯39	284	1045	2
¯17	¯28	27	¯17	¯45	274	1099	3
¯6	¯30	121	¯10	¯29	270	1090	4
¯14	¯27	40	¯17	¯40	274	1055	5

CM2

1	¯0.0325472	0.882724	0.964965	0.868649	¯0.797791	¯0.0391617	0.669556
¯0.0325472	1	¯0.0576232	0.0748691	¯0.21916	¯0.464238	¯0.285248	0.570821
0.882724	¯0.0576232	1	0.833886	0.963151	¯0.801338	¯0.393715	0.661427
0.964965	0.0748691	0.833886	1	0.755513	¯0.875878	0.0872888	0.669649
0.868649	¯0.21916	0.963151	0.755513	1	¯0.642109	¯0.412624	0.566289
¯0.797791	¯0.464238	¯0.801338	¯0.875878	¯0.642109	1	0.215729	¯0.871977
¯0.0391617	¯0.285248	¯0.393715	0.0872888	¯0.412624	0.215729	1	¯0.477795
0.669556	0.670821	0.661427	0.669649	0.566289	¯0.871977	¯0.477795	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯15	¯29	38.4	¯17.4	¯40.2
15	29	52	17.4	40.2
17.6281	32.4538	69.9464	20.0188	45.5275

RELATIVE ERRORS

¯6.59722	¯10.4167	¯11.8056	¯7.29167	¯16.6667	288	1129	1
¯6.69014	¯10.5634	13.3803	¯7.74648	¯13.7324	284	1045	2
¯6.20438	¯10.219	9.85401	¯6.20438	¯16.4234	274	1099	3
¯2.22222	¯11.1111	44.8148	¯3.7037	¯10.7407	270	1090	4
¯5.10949	¯9.85401	14.5985	¯6.20438	¯14.5985	274	1055	5

CM3

1	¯0.581602	0.882668	0.962005	0.839567	¯0.758037	¯0.0193146	0.630857
¯0.581602	1	¯0.581703	¯0.521257	¯0.708241	0.115798	¯0.187314	0.197167
0.882668	¯0.581703	1	0.838141	0.922209	¯0.802684	¯0.374372	0.659178
0.962005	¯0.521257	0.838141	1	0.70288	¯0.841187	0.122549	0.627716
0.839567	¯0.708241	0.922209	0.70288	1	¯0.533367	¯0.39901	0.468963
¯0.758037	0.115798	¯0.802684	¯0.841187	¯0.533367	1	0.215729	¯0.871977
¯0.0193146	¯0.187314	¯0.374372	0.122549	¯0.39901	0.215729	1	¯0.477795
0.630857	0.197167	0.659178	0.627716	0.468963	¯0.871977	¯0.477795	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯5.36469	¯10.4328	14.1684	¯6.23012	¯14.4323
5.36469	10.4328	18.8906	6.23012	14.4323
6.28134	11.6735	25.6758	7.13937	16.3138

RUN DATE 7/14/71

DATA

299	310	318	304	286	278	795	1
304	311	314	304	296	261	761	2
279	288	289	279	275	243	715	3
294	300	299	293	289	268	778	4
223	194	313	208	240	170	822	5
291	293	372	285	284	233	914	6
292	296	310	284	300	237	864	7

CM1

1	0.993469	0.110423	0.992104	0.953773	0.924345	¯0.0581135	¯0.28766
0.993469	1	0.04908	0.995088	0.935424	0.940454	¯0.128357	¯0.325054
0.110423	0.04908	1	0.0532293	0.0571991	¯0.122099	0.819543	0.338033
0.992104	0.995088	0.0532293	1	0.916981	0.959088	¯0.151434	¯0.394756
0.953773	0.935424	0.0571991	0.916981	0.999999	0.818092	0.0450288	¯0.0655829
0.924345	0.940454	¯0.122099	0.959088	0.818092	1	¯0.315302	¯0.5455
¯0.0581135	¯0.128357	0.819543	¯0.151434	0.0450288	¯0.315302	0.999999	0.719927
¯0.28766	¯0.325054	0.338033	¯0.394756	¯0.0655829	¯0.5455	0.719927	1

REGRESSION ON INSTRUMENT A

1	110.172	0	0	0
6	0.716449	0.132261	5.41693	0
0	1	3912.22	3912.22	29.3431
0	5	666.633	133.327	0
0	6	4578.86	11.5467	0.854411

INSTRUMENT B

2	24.4991	0	0	0
6	1.07722	0.174123	6.18655	0
0	1	8844.31	8844.31	38.2734
0	5	1155.41	231.082	0
0	6	9999.72	15.2014	0.884456

INSTRUMENT D

4	64.9863	0	0	0
6	0.888814	0.117332	7.57521	0
0	1	6021.08	6021.08	57.3838
0	5	524.633	104.927	0
0	6	6545.71	10.2434	0.919851

.ABSOLUTE-ERRORS

21	32	40	26	8	278	795	1
43	50	53	43	35	261	761	2
36	45	46	36	32	243	715	3
26	32	31	25	21	268	778	4
53	24	143	38	70	170	822	5
58	60	139	52	51	233	914	6
55	59	73	47	63	237	864	7

CM2

1	0.543182	0.811702	0.919606	0.927312	¯0.69207	0.659627	0.787226
0.543182	1	0.105702	0.797916	0.259758	0.194548	0.423945	0.43628
0.811702	0.105702	1	0.63584	0.790461	¯0.828476	0.701921	0.805086
0.919606	0.797916	0.63584	1	0.718567	¯0.390195	0.614019	0.630527
0.927312	0.259758	0.790461	0.718567	1	¯0.858809	0.540679	0.807603
¯0.69207	0.194548	¯0.828476	¯0.390195	¯0.858809	1	¯0.315302	¯0.5455
0.659627	0.423945	0.701921	0.614019	0.540679	¯0.315302	0.999999	0.719927
0.787226	0.43628	0.605086	0.630527	0.807603	¯0.5455	0.719927	1

AVG ERR, MEAN ERR, MEAN DEV

41.7143	43.1429	75	38.1429	40
41.7143	43.1429	75	38.1429	40
47.3638	48.6998	93.6172	42.4323	48.6895

RELATIVE ERRORS

7.55396	11.5108	14.3885	9.35252	2.8777	278	795	1
16.4751	19.1571	20.3065	16.4751	13.41	261	761	2
14.8148	18.5185	18.93	14.8148	13.1687	243	715	3
9.70149	11.9403	11.5672	9.32836	7.83582	268	778	4
31.1765	14.1176	84.1177	22.3529	41.1765	170	822	5
24.8927	25.7511	59.6567	22.3176	21.8884	233	914	6
23.2068	24.8945	30.8017	19.8312	26.5823	237	864	7

CM3

0.999999	0.512332	0.913306	0.965322	0.967738	¯0.908154	0.575624	0.723613
0.512332	1	0.232463	0.693699	0.335234	¯0.155457	0.567692	0.64892
0.913306	0.232463	0.999999	0.83483	0.893558	¯0.921644	0.570563	0.545149
0.965322	0.693699	0.83483	1	0.875171	¯0.790311	0.610869	0.705003
0.967738	0.335234	0.893558	0.875171	1	¯0.957669	0.462849	0.692939
¯0.908154	¯0.155457	¯0.921644	¯0.790311	¯0.957669	1	¯0.315302	¯0.5455
0.575624	0.567692	0.570563	0.610869	0.462849	¯0.315302	0.999999	0.719927
0.723613	0.64892	0.545149	0.705003	0.692939	¯0.5455	0.719927	1

AVG ERR, MEAN ERR, MEAN DEV

18.2602	17.9843	34.2526	16.3532	18.1342
18.2602	17.9843	34.2526	16.3532	18.1342
21.4952	20.2779	45.9982	18.5131	23.4668

RUN DATE 7/15/71

DATA

262	269	252	254	240	291	763	1
251	244	156	250	233	283	856	2
239	220	195	200	229	256	926	3
201	188	175	193	200	272	879	4
244	259	139	206	238	255	891	5
222	232	81	188	214	186	964	6
280	300	132	261	272	276	1037	7

CM1

1 [illegible]	0.938058	0.185635	0.866937	0.96482	0.444792	0.115174	0.00298233
0.938058	0.999999	¯0.027474	0.769336	0.94138	0.250461	0.207559	0.230512
0.185635	¯0.027474	1	0.346702	0.0439156	0.731891	¯0.737305	¯0.811318
0.866937	0.769336	0.346702	1	0.778983	0.685655	¯0.137414	¯0.235376
0.96482	0.94138	0.0439156	0.778983	1	0.386925	0.318389	0.228991
0.444792	0.250461	0.731891	0.685655	0.386925	1	¯0.445645	¯0.527005
0.115174	0.207559	¯0.737305	¯0.137414	0.318389	¯0.445645	0.999999	0.896222
0.00298233	0.230512	¯0.811318	¯0.235376	0.228991	¯0.527005	0.896222	1

ABSOLUTE ERRORS

¯29	¯22	¯39	¯37	¯51	291	763	1
¯32	¯39	¯127	¯33	¯50	283	856	2
¯17	¯36	¯61	¯56	¯27	256	926	3
¯71	¯84	¯97	¯79	¯72	272	879	4
¯11	4	¯116	¯49	¯17	255	891	5
36	46	¯105	2	28	186	964	6
4	24	¯144	¯15	¯4	276	1037	7

CM2

1	0.961877	¯0.241762	0.879365	0.976777	¯0.714004	0.56318	0.561859
0.961877	1	¯0.32339	0.88747	0.938871	¯0.597583	0.530653	0.615159
¯0.241762	¯0.32339	1	¯0.326734	¯0.324747	0.115314	¯0.65072	¯0.681192
0.879365	0.88747	¯0.326734	1	0.802591	¯0.499231	0.422626	0.41304
0.976777	0.938871	¯0.324747	0.802591	1	¯0.785277	0.679512	0.704514
¯0.714004	¯0.597583	0.115314	¯0.499231	¯0.785277	1	¯0.445645	¯0.527005
0.56318	0.530653	¯0.65072	0.422626	0.679512	¯0.445645	0.999999	0.896222
0.561859	0.615159	¯0.681192	0.41304	0.704514	¯0.527005	0.896222	1

AVG ERR, MEAN ERR, MEAN DEV

¯17.1429	¯15.2857	¯98.4286	¯38.1429	¯27.5714
28.5714	36.4286	98.4286	38.7143	35.5714
37.921	46.6637	112.544	49.1003	44.9129

RELATIVE ERRORS

¯9.96564	¯7.56014	¯13.4021	¯12.7148	¯17.5258	291	763	1
¯11.3074	¯13.7809	¯44.8763	¯11.6608	¯17.6678	283	856	2
¯6.64063	¯14.0625	¯23.8281	¯21.875	¯10.5469	256	926	3
¯26.1029	¯30.8824	¯35.6618	¯29.0441	¯26.4706	272	879	4
¯4.31373	1.56863	¯45.4902	¯19.2157	¯6.66667	255	891	5
19.3548	24.7312	¯56.4516	1.07527	15.0538	186	964	6
1.44928	8.69565	¯52.1739	¯5.43478	¯1.44928	276	1037	7

CM3

1	0.968326	¯0.542181	0.860874	0.984445	¯0.771515	0.530589	0.54632
0.968326	0.999999	¯0.583014	0.879044	0.957631	¯0.676243	0.509501	0.605485
¯0.542181	¯0.583014	1	¯0.517871	¯0.621041	0.534085	¯0.718625	¯0.799344
0.860874	0.879044	¯0.517871	1	0.797021	¯0.469155	0.38247	0.378297
0.984445	0.957631	¯0.621041	0.797021	1	¯0.820779	0.633362	0.671122
¯0.771515	¯0.676243	0.534085	¯0.469155	¯0.820779	1	¯0.445645	¯0.527005
0.530589	0.509501	¯0.718625	0.38247	0.633362	¯0.445645	0.999999	0.896222
0.54632	0.605485	¯0.799344	0.378297	0.671122	¯0.527005	0.896222	1

AVG ERR, MEAN ERR, MEAN DEV

¯5.36089	¯4.47006	¯38.8406	¯14.1243	¯9.32475
11.3049	14.4688	38.8406	14.4315	13.6258
14.9886	18.6559	44.7424	18.3469	16.8543

RUN DATE 7/16/71
DATA

249	254	246	252	225	280	926	1
241	246	237	247	222	268	970	2
248	248	241	254	221	284	1033	3
243	251	245	228	214	240	1063	4
245	248	238	238	214	270	1066	5

CM1

1	0.58702	0.510677	0.569638	0.417857	¯0.657352	¯0.260768	¯0.283473
0.58702	1	0.93363	¯0.0340786	0.218533	¯0.0686053	¯0.358794	¯0.353553
0.510677	0.93363	1	¯0.101101	0.156989	¯0.211345	¯0.220791	¯0.313304
0.569638	¯0.0340786	¯0.101101	0.999999	0.873563	0.932099	¯0.658078	¯0.68939
0.417857	¯0.218533	¯0.156989	0.873563	1	0.682075	¯0.920204	¯0.954427
¯0.657352	¯0.0686053	¯0.211345	¯0.932099	¯0.682075	¯1	¯0.475686	¯0.440534
¯0.260768	¯0.358794	¯0.220791	¯0.658078	¯0.920204	¯0.475686	1	0.959341
¯0.283473	¯0.353553	¯0.313304	¯0.68939	¯0.954427	¯0.440534	0.959341	0.999999

REGRESSION ON INSTRUMENT D

4	87.2684	0	0	0
6	0.583221	0.130847	4.45728	0
0	1	403.822	403.822	19.8673
0	3	60.9778	20.3259	0
0	4	464.8	4.50843	0.868809

ABSOLUTE ERRORS

¯31	¯26	¯34	¯28	¯55	280	926	1
¯27	¯22	¯31	¯21	¯46	268	970	2
¯36	¯36	¯43	¯30	¯63	284	1033	3
¯3	¯11	¯5	¯12	¯26	240	1063	4
¯25	¯22	¯32	¯32	¯56	270	1066	5

CM2

1	0.995296	0.994653	0.853921	0.951532	¯0.986209	0.48053	0.435801
0.995296	1	0.997132	0.871722	0.96834	¯0.984346	0.399088	0.365838
0.994653	0.997132	1	0.885903	0.967775	¯0.977002	0.394649	0.341743
0.853921	0.871722	0.885903	1	0.958646	¯0.878515	0.134739	0.0193456
0.951532	0.96834	0.967775	0.958646	1	¯0.967198	0.253139	0.198922
¯0.986209	¯0.984346	¯0.977002	¯0.878515	¯0.967198	1	¯0.475686	¯0.440534
0.48053	0.399088	0.394649	0.134739	0.253139	¯0.475686	1	0.959341
0.435801	0.365838	0.341743	0.0193456	0.198922	¯0.440534	0.959341	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯23.2	¯19	¯27	¯24.6	¯49.2
24.4	23.4	29	24.6	49.2
30.0832	27.6632	35.4083	28.6923	56.8375

RELATIVE ERRORS

¯11.0714	¯9.28571	¯12.1429	¯10	¯19.6429	280	926	1
¯10.0746	¯8.20896	¯11.5672	¯7.83582	¯17.1642	268	970	2
¯12.6761	¯12.6761	¯15.1408	¯10.5634	¯22.1831	284	1033	3
1.25	4.58333	2.08333	¯5	¯10.8333	240	1063	4
¯9.25926	¯8.14815	¯11.8519	¯11.8519	¯20.7407	270	1066	5

CM3

1	0.995518	0.994664	0.815669	0.936798	¯0.97835	0.482957	0.427846
0.995518	1	0.996978	0.837508	0.957556	¯0.979716	0.405255	0.361135
0.994664	0.996978	1	0.853886	0.957932	¯0.967874	0.396688	0.333129
0.815669	0.837508	0.853886	1	0.949993	¯0.834445	0.0819311	¯0.0510344
0.936798	0.957556	0.957932	0.949993	1	¯0.951085	0.214643	0.146467
¯0.97835	¯0.979716	¯0.967874	¯0.834445	¯0.951085	1	¯0.475686	¯0.440534
0.482957	0.405255	0.396688	0.0819311	0.214643	¯0.475686	1	0.959341
0.427846	0.361135	0.333129	¯0.0510344	0.146467	¯0.440534	0.959341	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯8.36628	¯6.74711	¯9.72388	¯9.05021	¯18.1128
8.86627	8.58044	10.5572	9.05021	18.1128
10.8634	10.0211	12.7994	10.4696	20.7369

RUN DATE 7/19/71

DATA

239	240	231	235	212	261	1747	1
242	242	257	226	224	268	1559	2
242	242	280	229	224	264	1689	3
238	241	305	222	221	261	1804	4
241	244	311	225	225	267	1851	5
241	242	315	225	228	261	1874	6
252	250	329	243	232	265	2041	7

CM1

1	0.950801	0.4735	0.781037	0.716438	0.38032	0.578961	0.60404
0.950801	1	0.653204	0.665974	0.765375	0.406338	0.714912	0.744387
0.4735	0.653204	1	0.00165824	0.828923	0.0424815	0.761029	0.963534
0.781037	0.665974	0.00165824	0.999999	0.151766	0.0405517	0.487499	0.189737
0.716438	0.765375	0.828923	0.151766	1	0.393545	0.506798	0.853479
0.38032	0.406338	0.0424815	0.0405517	0.393545	1	¯0.239622	0.0259938
0.578961	0.714912	0.761029	0.487499	0.506798	¯0.239622	1	0.847893
0.60404	0.744387	0.963534	0.189737	0.853479	0.0259938	0.847893	1

ABSOLUTE ERRORS

¯22	¯21	¯30	¯26	¯49	261	1747	1
¯26	¯26	¯11	¯42	¯44	268	1559	2
¯22	¯22	16	¯35	¯40	264	1689	3
¯23	¯20	44	¯39	¯40	261	1804	4
¯26	¯23	44	¯42	¯42	267	1851	5
¯20	¯19	54	¯36	¯33	261	1874	6
¯13	¯15	64	¯22	¯33	265	2041	7

CM2

1	0.928705	0.486826	0.842633	0.662813	¯0.275618	0.76252	0.610382
0.928705	1	0.633386	0.751056	0.675153	¯0.471531	0.896934	0.69597
0.486826	0.633386	1	0.0142033	0.88372	¯0.0415744	0.781201	0.961386
0.842633	0.751056	0.0142033	1	0.168919	¯0.343095	0.549632	0.168457
0.662813	0.675153	0.88372	0.168919	1	¯0.0891784	0.672628	0.911295
¯0.275618	¯0.471531	¯0.0415744	¯0.343095	¯0.0891784	1	¯0.239622	0.0259938
0.76252	0.896934	0.781201	0.549632	0.672628	¯0.239622	1	0.847893
0.610382	0.69597	0.961386	0.168457	0.911295	0.0259938	0.847893	1

AVG ERR, MEAN ERR, MEAN DEV

¯21.7143	¯20.8571	25.8571	¯34.5714	¯40.1429
21.7143	20.8571	37.5714	34.5714	40.1429
23.8677	22.7889	45.0204	38.1445	43.7398

RELATIVE ERRORS

¯8.42912	¯8.04598	¯11.4943	¯9.96169	¯18.7739	261	1747	1
¯9.70149	¯9.70149	¯4.10448	¯15.6716	¯16.4179	268	1559	2
¯8.33333	¯8.33333	6.06061	¯13.2576	¯15.1515	264	1689	3
¯8.81226	¯7.66284	16.8582	¯14.9425	¯15.3257	261	1804	4
¯9.73783	¯8.61423	16.4794	¯15.7303	¯15.7303	267	1851	5
¯7.66284	¯7.27969	20.6897	¯13.7931	¯12.6437	261	1874	6
¯4.90566	¯5.66038	24.1509	¯8.30189	¯12.4528	265	2041	7

CM3

1	0.927637	0.489862	0.832711	0.64786	¯0.220022	0.759565	0.621789
0.927637	1	0.650176	0.734989	0.656425	¯0.414201	0.908267	0.721555
0.489862	0.650176	1	0.00108948	0.885416	¯0.0468151	0.777169	0.960132
0.832711	0.734989	0.00108948	1	0.130283	¯0.294422	0.542152	0.1669
0.64786	0.656425	0.885416	0.130283	1	¯0.00769315	0.651485	0.915832
¯0.220022	¯0.414201	¯0.0468151	¯0.294422	¯0.00769315	1	¯0.239622	0.0259938
0.759565	0.908267	0.777169	0.542152	0.651485	¯0.239622	1	0.847893
0.621789	0.721555	0.960132	0.1669	0.915832	0.0259938	0.847893	1

AVG ERR, MEAN ERR, MEAN DEV

¯8.22608	¯7.89971	9.80573	¯13.0941	¯15.2137
8.22608	7.89971	14.2625	13.0941	15.2137
9.03585	8.62418	17.0919	14.4366	16.5773

RUN DATE 7/20/71

DATA

242	244	238	245	213	275	1934	1
240	243	246	244	217	268	2040	2
247	247	283	255	217	266	2111	3
246	260	287	264	216	268	2199	4
241	239	289	253	218	250	2297	5
235	230	283	242	217	248	2335	6
239	239	301	252	220	256	2195	7
246	241	312	274	218	246	2082	8

CM1

1	0.755255	0.197959	0.74785	¯0.172516	0.301676	¯0.420088	¯0.126773
0.755255	1	¯0.0881384	0.449415	¯0.326083	0.63148	¯0.322264	¯0.385715
0.197959	¯0.0881384	1	0.692763	0.743841	¯0.75998	0.574522	0.911015
0.74785	0.449415	0.692763	1	0.255846	¯0.2965	¯0.0318531	0.516888
¯0.172516	¯0.326083	0.743841	0.255846	1	¯0.676574	0.549683	0.758176
0.301676	0.63148	¯0.75998	¯0.2965	¯0.676574	1	¯0.669717	¯0.889716
¯0.420088	¯0.322264	0.574522	¯0.0318531	0.549683	¯0.669717	0.999999	0.562872
¯0.126773	¯0.385715	0.911015	0.516888	0.758176	¯0.889716	0.562872	1

ABSOLUTE ERRORS

¯33	¯31	¯37	¯30	¯62	275	1934	1
¯28	¯25	¯22	¯24	¯51	268	2040	2
¯19	¯19	17	¯11	¯49	266	2111	3
¯22	¯8	19	¯4	¯52	268	2199	4
¯9	¯11	39	3	¯32	250	2297	5
¯13	¯18	35	¯6	¯31	248	2335	6
¯17	¯17	45	¯4	¯36	256	2195	7
0	¯5	66	28	¯28	246	2082	8

CM2

1	0.816869	0.937603	0.951934	0.92212	¯0.926652	0.534619	0.880301
0.816869	0.999999	0.85049	0.908355	0.656105	¯0.644592	0.530931	0.747157
0.937603	0.85049	1	0.921398	0.898931	¯0.877876	0.636227	0.954099
0.951934	0.908355	0.921398	1	0.806771	¯0.806963	0.39794	0.874479
0.92212	0.656105	0.898931	0.806771	1	¯0.992945	0.680542	0.908594
¯0.926652	¯0.644592	¯0.877876	¯0.806963	¯0.992945	1	¯0.669717	¯0.889716
0.534619	0.530931	0.636227	0.39794	0.680542	¯0.669717	0.999999	0.562872
0.880301	0.747157	0.954099	0.874479	0.908594	¯0.889716	0.562872	1

AVG ERR, MEAN ERR, MEAN DEV

¯17.625	¯16.75	20.25	¯6	¯42.625
17.625	16.75	35	13.75	42.625
21.5705	19.8926	40.7606	18.7388	47.2304

RELATIVE ERRORS

¯12	¯11.2727	¯13.4545	¯10.9091	¯22.5455	275	1934	1
¯10.4478	¯9.32836	¯8.20896	¯8.95522	¯19.0299	268	2040	2
¯7.14286	¯7.14286	6.39098	¯4.13534	¯18.4211	266	2111	3
¯8.20896	¯2.98507	7.08955	¯1.49254	¯19.403	268	2199	4
¯3.6	¯4.4	15.6	1.2	¯12.8	250	2297	5
¯5.24194	¯7.25807	14.1129	¯2.41936	¯12.5	248	2335	6
¯6.64063	¯6.64063	17.5781	¯1.5625	¯14.0625	256	2195	7
0	¯2.03252	26.8293	11.3821	¯11.3821	246	2082	8

CM3

1	0.795196	0.93714	0.955212	0.906434	¯0.912259	0.498176	0.869184
0.795196	1	0.814959	0.890682	0.605943	¯0.597246	0.477983	0.712335
0.93714	0.814959	1	0.915509	0.906535	¯0.888611	0.622158	0.959181
0.955212	0.890682	0.915509	1	0.795109	¯0.794847	0.362114	0.863316
0.906434	0.605943	0.906535	0.795109	0.999999	¯0.993249	0.671588	0.910427
¯0.912259	¯0.597246	¯0.888611	¯0.794847	¯0.993249	1	¯0.669717	¯0.889716
0.498176	0.477983	0.622158	0.362114	0.671588	¯0.669717	0.999999	0.562872
0.869184	0.712335	0.959181	0.863316	0.910427	¯0.889716	0.562872	1

AVG ERR, MEAN ERR, MEAN DEV

¯6.66027	¯6.38253	8.24217	¯2.11149	¯16.268
6.66027	6.38253	13.658	5.25702	16.268
8.07199	7.50516	16.0839	7.14963	17.8631

RUN DATE 7/21/71

DATA

223	221	187	220	193	262	2104	1
243	238	213	252	225	288	1896	2
254	249	226	267	241	277	1976	3
250	242	223	263	240	280	1911	4
245	237	226	253	231	270	1794	5
247	241	234	256	233	254	1502	6

CM1

0.999999	0.986086	0.908541	0.997952	0.993743	0.349795	¯0.43528	0.601684
0.986086	1	0.865564	0.982512	0.962425	0.353157	¯0.384792	0.515169
0.908541	0.865564	1	0.890956	0.922989	0.00593947	¯0.750323	0.86728
0.997952	0.982512	0.890956	1	0.993496	0.394904	¯0.410915	0.574502
0.993743	0.962425	0.922989	0.993496	0.999999	0.331698	¯0.467689	0.653158
0.349795	0.353157	0.00593947	0.394904	0.331698	1	0.448454	¯0.391245
¯0.43528	¯0.384792	¯0.750323	¯0.410915	¯0.467689	0.448454	1	¯0.883262
0.601684	0.515169	0.86728	0.574502	0.653158	¯0.391245	¯0.883262	1

ABSOLUTE ERRORS

¯39	¯41	¯75	¯42	¯69	262	2104	1
¯45	¯50	¯75	¯36	¯63	288	1896	2
¯23	¯28	¯51	¯10	¯36	277	1976	3
¯30	¯38	¯57	¯17	¯40	280	1911	4
¯25	¯33	¯44	¯17	¯39	270	1794	5
¯7	¯13	¯20	2	¯21	254	1502	6

CM2

1	0.986394	0.977771	0.94217	0.940248	¯0.648121	¯0.772004	0.853926
0.986394	1	0.942469	0.891451	0.879483	¯0.722686	¯0.725372	0.765422
0.977771	0.942469	0.999999	0.939013	0.94766	¯0.594027	¯0.872142	0.931971
0.94217	0.891451	0.939013	1	0.995759	¯0.357423	¯0.75804	0.880924
0.940248	0.879483	0.94766	0.995759	0.999999	¯0.363744	¯0.771796	0.915381
¯0.648121	¯0.722686	¯0.594027	¯0.357423	¯0.363744	1	0.448454	¯0.391245
¯0.772004	¯0.725372	¯0.872142	¯0.75804	¯0.771796	0.448454	1	¯0.883262
0.853926	0.765422	0.931971	0.880924	0.915381	¯0.391245	¯0.883262	1

AVG ERR, MEAN ERR, MEAN DEV

¯28.1667	¯33.8333	¯53.6667	¯20	¯44.6667
28.1667	33.8333	53.6667	20.6667	44.6667
33.6125	39.1587	62.3474	27.3569	52.1306

RELATIVE ERRORS

¯14.8855	¯15.6489	¯28.626	¯16.0305	¯26.3359	262	2104	1
¯15.625	¯17.3611	¯26.0417	¯12.5	¯21.875	288	1896	2
¯8.30325	¯10.1083	¯18.4116	¯3.61011	¯12.9964	277	1976	3
¯10.7143	¯13.5714	¯20.3571	¯6.07143	¯14.2857	280	1911	4
¯9.25926	¯12.2222	¯16.2963	¯6.2963	¯14.4444	270	1794	5
¯2.75591	¯5.11811	¯7.87402	0.787402	¯8.26772	254	1502	6

CM3

1	0.986806	0.975213	0.951755	0.930664	¯0.580781	¯0.801078	0.875252
0.986806	1	0.937048	0.90834	0.871274	¯0.650766	¯0.759846	0.792989
0.975213	0.937048	1	0.95169	0.946128	¯0.5017	¯0.892457	0.94737
0.951755	0.90834	0.95169	1	0.994529	¯0.304789	¯0.769932	0.881332
0.930664	0.871274	0.946128	0.994529	1	¯0.256708	¯0.769702	0.908227
¯0.580781	¯0.650766	¯0.5017	¯0.304789	¯0.256708	1	0.448454	¯0.391245
¯0.801078	¯0.759846	¯0.892457	¯0.769932	¯0.769702	0.448454	1	¯0.883262
0.875252	0.792989	0.94737	0.881332	0.908227	¯0.391245	¯0.883262	1

AVG ERR, MEAN ERR, MEAN DEV

¯10.2572	¯12.3383	¯19.6011	¯7.28683	¯16.3675
10.2572	12.3383	19.6011	7.54929	16.3675
12.1884	14.2002	22.7094	10.0338	19.0897

RUN DATE 7/22/71

DATA

257	238	236	269	229	276	1838	1
256	228	236	268	235	289	1748	2
259	225	235	266	244	285	1640	3
270	233	253	272	254	284	1613	4
257	223	254	262	241	262	1897	5
249	214	242	250	232	255	2262	6

CM1

1	0.627503	0.439277	0.797467	0.846914	0.601683	¯0.816503	¯0.204023
0.627503	1	¯0.107873	0.898721	0.129	0.647696	¯0.688456	¯0.815069
0.439277	¯0.107873	1	¯0.0174759	0.592311	¯0.361299	0.0172458	0.622677
0.797467	0.898721	¯0.0174759	1	0.438871	0.849728	¯0.924574	¯0.72931
0.846914	0.129	0.592311	0.438871	0.999999	0.369733	¯0.631378	0.25113
0.601683	0.647696	¯0.361299	0.849728	0.369733	1	¯0.889322	¯0.726366
¯0.816503	¯0.688456	0.0172458	¯0.924574	¯0.631378	¯0.889322	0.999998	0.572669
¯0.204023	¯0.815069	0.622677	¯0.72931	0.25113	¯0.726366	0.572669	1

ABSOLUTE ERRORS

¯19	¯38	¯40	¯7	¯47	276	1838	1
¯33	¯61	¯53	¯21	¯54	289	1748	2
¯26	¯60	¯50	¯19	¯41	285	1640	3
¯14	¯51	¯31	¯12	¯30	284	1613	4
¯5	¯39	¯8	0	¯21	262	1897	5
¯6	¯41	¯13	¯5	¯23	255	2262	6

CM2

1	0.81012	0.972772	0.920769	0.935641	¯0.87136	0.602055	0.776065
0.81012	1	0.764241	0.952254	0.55649	¯0.796759	0.619393	0.305418
0.972772	0.764241	1	0.907057	0.927383	¯0.900676	0.659309	0.822082
0.920769	0.952254	0.907057	1	0.749548	¯0.864071	0.607189	0.520608
0.935641	0.55649	0.927383	0.749548	1	¯0.773464	0.481455	0.916342
¯0.87136	¯0.796759	¯0.900676	¯0.864071	¯0.773464	1	¯0.889322	¯0.726366
0.602055	0.619393	0.659309	0.607189	0.481455	¯0.889322	0.999998	0.572669
0.776065	0.305418	0.822082	0.520608	0.916342	¯0.726366	0.572669	1

AV
G
ERR, MEAN ERR, MEAN DEV

¯17.1667	¯48.3333	¯32.5	¯10.6667	¯36
17.1667	48.3333	32.5	10.6667	36
21.8312	53.9778	40.2567	14.2829	41.6557

RELATIVE ERRORS

¯6.88406	¯13.7681	¯14.4928	¯2.53623	¯17.029	276	1838	1
¯11.4187	¯21.1073	¯18.3391	¯7.26644	¯18.6851	289	1748	2
¯9.12281	¯21.0526	¯17.5439	¯6.66667	¯14.386	285	1640	3
¯4.92958	¯17.9577	¯10.9155	¯4.22535	¯10.5634	284	1613	4
¯1.9084	¯14.8855	¯3.05343	0	¯8.01527	262	1897	5
¯2.35294	¯16.0784	¯5.09804	¯1.96078	¯9.01961	255	2262	6

CM3

1	0.727472	0.970456	0.910635	0.918231	¯0.865237	0.593124	0.785435
0.727472	1	0.660248	0.912233	0.407003	¯0.693784	0.510964	0.174984
0.970456	0.660248	1	0.895336	0.909998	¯0.889276	0.644573	0.830477
0.910635	0.912233	0.895336	1	0.70446	¯0.854634	0.591807	0.513564
0.918231	0.407003	0.909998	0.70446	1	¯0.725647	0.42522	0.920432
¯0.865237	¯0.693784	¯0.889276	¯0.854634	¯0.725647	1	¯0.889322	¯0.726366
0.593124	0.510964	0.644573	0.591807	0.42522	¯0.889322	0.999998	0.572669
0.785435	0.174984	0.830477	0.513564	0.920432	¯0.726366	0.572669	1

AVG ERR, MEAN ERR, MEAN DEV

¯6.10275	¯17.475	¯11.5738	¯3.77591	¯12.9497
6.10274	17.475	11.5738	3.77591	12.9497
7.67439	19.3952	14.2029	5.00752	14.8544

RUN DATE 7/23/71

DATA

270	281	306	293	173	260	2255	1
255	254	238	267	169	231	2152	2
256	252	227	269	169	233	1981	3
262	210	266	271	171	270	1834	4
261	96	254	270	162	273	1954	5
252	65	265	258	151	268	2021	6
253	48	264	260	157	256	1852	7
252	252	241	256	166	256	1754	8

CM1

1	0.386758	0.698211	0.956648	0.623473	0.288009	0.522285	¯0.689615
0.386758	1	¯0.0675764	0.483885	0.896588	¯0.509033	0.305301	¯0.579129
0.698211	¯0.0675764	0.999999	0.653409	0.0593008	0.563118	0.422635	¯0.26811
0.956648	0.483885	0.653409	1	0.654839	0.0444143	0.699562	¯0.821893
0.623473	0.896588	0.0593008	0.654839	1	¯0.347414	0.260145	¯0.662264
0.288009	¯0.509033	0.563118	0.0444143	¯0.347414	1	¯0.277963	0.372906
0.522285	0.305301	0.422635	0.699562	0.260145	¯0.277963	1	¯0.830371
¯0.689615	¯0.579129	¯0.26811	¯0.821893	¯0.662264	0.372906	¯0.830371	1

ABSOLUTE ERRORS

10	21	46	33	¯87	260	2255	1
24	23	7	36	¯62	231	2152	2
23	19	¯6	36	¯64	233	1981	3
¯8	¯60	¯4	1	¯99	270	1834	4
¯12	¯177	¯19	¯3	¯111	273	1954	5
¯16	¯203	¯3	¯10	¯117	268	2021	6
¯3	¯208	8	4	¯99	256	1852	7
¯4	¯4	¯15	0	¯90	256	1754	8

CM2

1	0.767336	0.371011	0.967783	0.972293	¯0.920523	0.50161	¯0.668429
0.767336	0.999999	0.313151	0.772029	0.826651	¯0.617591	0.321346	¯0.58603
0.371011	0.313151	1	0.547378	0.22607	¯0.117558	0.728659	¯0.618376
0.967783	0.772029	0.547378	1	0.900517	¯0.800234	0.649779	¯0.80172
0.972293	0.826651	0.22607	0.900517	1	¯0.934613	0.321831	¯0.550575
¯0.920523	¯0.617591	¯0.117558	¯0.800234	¯0.934613	1	¯0.277963	0.372906
0.50161	0.321346	0.728659	0.649779	0.321831	¯0.277963	1	¯0.830371
¯0.668429	¯0.58603	¯0.618376	¯0.80172	¯0.550575	0.372906	¯0.830371	1

AVG ERR, MEAN ERR, MEAN DEV

1.75	¯73.625	1.75	12.125	¯91.125
12.5	89.375	13.5	15.375	91.125
15.5563	131.339	20.2696	23.3207	99.4421

RELATIVE ERRORS

3.84615	8.07692	17.6923	12.6923	¯33.4615	260	2255	1
10.3896	9.95671	3.0303	15.5844	¯26.8398	231	2152	2
9.87124	8.15451	¯2.57511	15.4506	¯27.4678	233	1981	3
¯2.96296	¯22.2222	¯1.48148	0.37037	¯36.6667	270	1834	4
¯4.3956	¯64.8352	¯6.95971	¯1.0989	¯40.6593	273	1954	5
¯5.97015	¯75.7463	¯1.1194	¯3.73134	¯43.6567	268	2021	6
¯1.17188	¯81.25	3.125	1.5625	¯38.6719	256	1852	7
¯1.5625	¯1.5625	¯5.85938	0	¯35.1563	256	1754	8

CM3

1	0.753377	0.336467	0.974234	0.963103	¯0.92806	0.499144	¯0.66724
0.753377	1	0.292751	0.763709	0.863419	¯0.612127	0.330023	¯0.594848
0.336467	0.292751	1	0.500662	0.233506	¯0.11212	0.736191	¯0.622646
0.974234	0.763709	0.500662	0.999999	0.920936	¯0.828823	0.636822	¯0.790985
0.963103	0.863419	0.233506	0.920936	1	¯0.890381	0.33872	¯0.605315
¯0.92806	¯0.612127	¯0.11212	¯0.828823	¯0.890381	1	¯0.277963	0.372906
0.499144	0.330023	0.736191	0.636822	0.33872	¯0.277963	1	¯0.830371
¯0.66724	¯0.594848	¯0.622646	¯0.790985	¯0.605315	0.372906	¯0.830371	1

AVG ERR, MEAN ERR, MEAN DEV

1.00549	¯27.4285	0.731567	5.10375	¯35.3225
5.02126	33.9755	5.23034	6.31131	35.3225
6.41133	49.6701	7.79024	9.71303	38.2278

RUN DATE 7/26/71

DATA

242	242	223	257	208	229	2223	1
243	280	223	264	220	256	2292	2
230	252	207	262	214	257	2327	3
225	252	216	258	221	232	2415	4
240	261	200	266	234	243	2320	5

CM1

1	0.374131	0.248806	0.356026	0.0289269	0.104956	¯0.838798	¯0.433124
0.374131	1	0.0713657	0.718374	0.47294	0.660224	0.0782952	0.110485
0.248806	0.0713657	1	¯0.58738	¯0.663785	¯0.243102	¯0.352366	¯0.826915
0.356026	0.718374	¯0.58738	1	0.739417	0.703132	0.0330499	0.493197
0.0289269	0.47294	¯0.663785	0.739417	1	0.146769	0.448741	0.865256
0.104956	0.660224	¯0.243102	0.703132	0.146769	1	0.0155556	0.0484644
¯0.838798	0.0782952	¯0.352366	0.0330499	0.448741	0.0155556	0.999999	0.724182
¯0.433124	0.110485	¯0.826915	0.493197	0.865256	0.0484644	0.724182	0.999999

ABSOLUTE ERRORS

13	13	¯6	28	¯21	229	2223	1
¯13	24	¯33	8	¯36	256	2292	2
¯27	¯5	¯50	5	¯43	257	2327	3
¯7	20	¯16	26	¯11	232	2415	4
¯3	18	¯43	23	¯9	243	2320	5

CM2

1	0.477738	0.790181	0.864859	0.650635	¯0.836802	¯0.475714	¯0.281811
0.477738	1	0.429896	0.422512	0.550381	¯0.317716	0.0809359	0.0836893
0.790181	0.429896	0.999999	0.734015	0.429154	¯0.8447	¯0.205487	¯0.490723
0.864859	0.422512	0.734015	0.999999	0.893197	¯0.966771	¯0.00708885	0.118211
0.650635	0.550381	0.429154	0.893197	1	¯0.771807	0.274985	0.514225
¯0.836802	¯0.317716	¯0.8447	¯0.966771	¯0.771807	1	0.0155556	0.0484644
¯0.475714	0.0809359	¯0.205487	¯0.00708885	0.274985	0.0155556	0.999999	0.724182
¯0.281811	0.0836893	¯0.490723	0.118211	0.514225	0.0484644	0.724182	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯7.4	14	¯29.6	18	¯24
12.6	16	29.6	18	24
16.7705	19.3261	37.8484	22.7926	30.7734

RELATIVE ERRORS

5.67686	5.67686	¯2.62009	12.2271	¯9.17031	229	2223	1
¯5.07813	9.375	¯12.8906	3.125	¯14.0625	256	2292	2
¯10.5058	¯1.94553	¯19.4553	1.94553	¯16.7315	257	2327	3
¯3.01724	8.62069	¯6.89655	11.2069	¯4.74138	232	2415	4
¯1.23457	7.40741	¯17.6955	9.46502	¯3.7037	243	2320	5

CM3

1	0.487086	0.76843	0.851221	0.573972	¯0.824775	¯0.511042	¯0.315572
0.487086	1	0.451052	0.466808	0.601413	¯0.3833	0.0998837	0.0937706
0.76843	0.451052	1	0.720848	0.323731	¯0.816785	¯0.228401	¯0.536417
0.851221	0.466808	0.720848	1	0.842228	¯0.977041	¯0.0156903	0.0853087
0.573972	0.601413	0.323731	0.842228	0.999999	¯0.731696	0.313237	0.563281
¯0.824775	¯0.3833	¯0.816785	¯0.977041	¯0.731696	1	0.0155556	0.0484644
¯0.511042	0.0998837	¯0.228401	¯0.0156903	0.313237	0.0155556	0.999999	0.724182
¯0.315572	0.0937706	¯0.536417	0.0853087	0.563281	0.0484644	0.724182	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯2.83178	5.82689	¯11.9116	7.5939	¯9.68188
5.10253	6.60509	11.9116	7.5939	9.68188
6.68982	7.95438	15.1016	9.72411	12.2269

RUN DATE 7/27/71

DATA

253	251	212	277	171	228	1635	1
262	258	209	262	198	272	1740	2
251	267	291	303	213	264	1762	3
256	247	148	272	196	274	2040	4
254	257	217	264	204	247	1833	5

CM1

1	¯0.234078	¯0.479109	¯0.720094	¯0.0470464	0.496449	0.105226	¯0.150329
¯0.234078	1	0.933526	0.573975	0.679082	0.150668	¯0.400591	0.0207614
¯0.479109	0.933526	0.999999	0.710762	0.430734	¯0.159963	¯0.58943	¯0.158808
¯0.720094	0.573975	0.710762	1	0.301195	0.00156549	¯0.17143	¯0.153591
¯0.0470464	0.679082	0.430734	0.301195	1	0.653609	0.383122	0.646102
0.496449	0.150668	¯0.159963	0.00156549	0.653609	1	0.630103	0.326164
0.105226	¯0.400591	¯0.58943	¯0.17143	0.383122	0.630103	1	0.729855
¯0.150329	0.0207614	¯0.158808	¯0.153591	0.646102	0.326164	0.729855	0.999999

ABSOLUTE ERRORS

25	23	¯16	49	¯57	228	1635	1
¯10	¯14	¯63	¯10	¯74	272	1740	2
¯13	3	27	39	¯51	264	1762	3
¯18	¯27	¯126	¯2	¯78	274	2040	4
7	10	¯30	17	¯43	247	1833	5

CM2

1	0.87609	0.386364	0.634185	0.505594	¯0.978441	¯0.665907	¯0.393422
0.87609	1	0.772965	0.847566	0.799289	¯0.924376	¯0.77367	¯0.31245
0.386364	0.772965	1	0.775628	0.791225	¯0.481186	¯0.737133	¯0.251643
0.634185	0.847566	0.775628	1	0.668955	¯0.761726	¯0.591674	¯0.34829
0.505594	0.799289	0.791225	0.668955	1	¯0.611209	¯0.415158	0.253377
¯0.978441	¯0.924376	¯0.481186	¯0.761726	¯0.611209	1	0.630103	0.326164
¯0.665907	¯0.77367	¯0.737133	¯0.591674	¯0.415158	0.630103	1	0.729855
¯0.393422	¯0.31245	¯0.251643	¯0.34829	0.253377	0.326164	0.729855	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯1.8	¯1	¯41.6	18.6	¯60.6
14.6	15.4	52.4	23.4	60.6
17.7975	19.7674	73.7056	32.8443	69.3884

RELATIVE ERRORS

10.9649	10.0877	¯7.01754	21.4912	¯25	228	1635	1
¯3.67647	¯5.14706	¯23.1618	¯3.67647	¯27.2059	272	1740	2
¯4.92424	1.13636	10.2273	14.7727	¯19.3182	264	1762	3
¯6.56934	¯9.85401	¯45.9854	¯0.729927	¯28.4672	274	2040	4
2.83401	4.04858	¯12.1457	6.88259	¯17.4089	247	1833	5

CM3

1	0.88882	0.339291	0.696181	0.187952	¯0.977198	¯0.66135	¯0.419183
0.88882	1	0.721519	0.871612	0.540927	¯0.942483	¯0.772321	¯0.340489
0.339291	0.721519	0.999999	0.732203	0.726405	¯0.45378	¯0.726633	¯0.251279
0.696181	0.871612	0.732203	0.999999	0.428909	¯0.805425	¯0.617544	¯0.395433
0.187952	0.540927	0.726405	0.428909	1	¯0.33864	¯0.231182	0.451077
¯0.977198	¯0.942483	¯0.45378	¯0.805425	¯0.33864	1	0.630103	0.326164
¯0.66135	¯0.772321	¯0.726633	¯0.617544	¯0.231182	0.630103	1	0.729855
¯0.419183	¯0.340489	¯0.251279	¯0.395433	0.451077	0.326164	0.729855	0.999999

AVG ERR, MEAN ERR, MEAN DEV

¯0.274227	0.0543186	¯15.6166	7.74803	¯23.48
5.79379	6.05475	19.7075	9.51059	23.48
7.23156	7.79484	27.1684	13.6155	26.7011

RUN DATE 7/28/71

DATA

247	253	240	261	221	278	1433	1
248	251	219	265	219	273	1252	2
255	257	219	273	223	284	1088	3
256	256	463	271	225	295	1038	4
266	262	499	294	228	280	1014	5
282	270	287	309	236	270	1061	6
280	272	268	299	239	281	1020	7

CM1

1	0.988015	0.155854	0.975817	0.978582	¯0.245216	¯0.681527	0.952976
0.988015	0.999999	0.105695	0.946581	0.991086	¯0.208463	¯0.644855	0.941554
0.155854	0.105695	1	0.234946	0.126565	0.50587	¯0.527746	0.328388
0.975817	0.946581	0.234946	1	0.916743	¯0.321955	¯0.693373	0.921079
0.978582	0.991086	0.126565	0.916743	0.999999	¯0.152405	¯0.630696	0.945638
¯0.245216	¯0.208463	0.50587	¯0.321955	¯0.152405	1	¯0.318361	¯0.00951044
¯0.681527	¯0.644855	¯0.527746	¯0.693373	¯0.630696	¯0.318361	1	¯0.834803
0.952976	0.941554	0.328388	0.921079	0.945638	¯0.00951044	¯0.834803	1

ABSOLUTE ERRORS

¯31	¯25	¯38	¯17	¯57	278	1433	1
¯25	¯22	¯54	¯8	¯54	273	1252	2
¯29	¯27	¯65	¯11	¯61	284	1088	3
¯39	¯39	168	¯24	¯70	295	1038	4
¯14	¯18	219	14	¯52	280	1014	5
12	0	17	39	¯34	270	1061	6
¯1	¯9	¯13	18	¯42	281	1020	7

CM2

1	0.975957	¯0.0599084	0.986063	0.972381	¯0.640308	¯0.397984	0.759293
0.975957	1	¯0.208839	0.952738	0.996992	¯0.774764	¯0.213117	0.614758
¯0.0599084	¯0.208839	0.999999	0.0575883	¯0.21716	0.451764	¯0.523073	0.340308
0.986063	0.952738	0.0575883	1	0.940919	¯0.624117	¯0.458116	0.76355
0.972381	0.996992	¯0.21716	0.940919	1	¯0.77742	¯0.184763	0.608291
¯0.640308	¯0.774764	0.451764	¯0.624117	¯0.77742	1	¯0.318361	¯0.00951044
¯0.397984	¯0.213117	¯0.523073	¯0.458116	¯0.184763	¯0.318361	1	¯0.834803
0.759293	0.614758	0.340308	0.76355	0.608291	¯0.00951044	¯0.834803	1

AVG ERR, MEAN ERR, MEAN DEV

¯18.1429	¯20	33.4286	1.57143	¯52.8571
21.5714	20	82	18.7143	52.8571
26.7364	25.0466	119.183	22.6973	58.3238

RELATIVE ERRORS

¯11.1511	¯8.99281	¯13.6691	¯6.11511	¯20.5036	278	1433	1
¯9.15751	¯8.05861	¯19.7802	¯2.9304	¯19.7802	273	1252	2
¯10.2113	¯9.50704	¯22.8873	¯3.87324	¯21.4789	284	1088	3
¯13.2203	¯13.2203	56.9492	¯8.13559	¯23.7288	295	1038	4
¯5	¯6.42857	78.2143	5	¯18.5714	280	1014	5
4.44445	0	6.2963	14.4444	¯12.5926	270	1061	6
¯0.355872	¯3.20285	¯4.62633	6.40569	¯14.9466	281	1020	7

CM3

1	0.977842	¯0.0217986	0.986256	0.982352	¯0.611747	¯0.424885	0.778719
0.977842	0.999999	¯0.165316	0.958755	0.99522	¯0.745775	¯0.249833	0.647799
¯0.0217986	¯0.165316	0.999999	0.0839112	¯0.149016	0.436316	¯0.526318	0.347957
0.986256	0.958755	0.0839112	0.999999	0.953022	¯0.613826	¯0.467047	0.768513
0.982352	0.99522	¯0.149016	0.953022	1	¯0.708272	¯0.26237	0.68106
¯0.611747	¯0.745775	0.436316	¯0.613826	¯0.708272	1	¯0.318361	¯0.00951044
¯0.424885	¯0.249833	¯0.526318	¯0.467047	¯0.26237	¯0.318361	1	¯0.834803
0.778719	0.647799	0.347957	0.768513	0.68106	¯0.00951044	¯0.834803	1

AVG ERR, MEAN ERR, MEAN DEV

¯6.3788	¯7.0586	11.4995	0.685113	¯18.8003
7.64864	7.0586	28.9175	6.70064	18.8003
9.41748	8.78026	41.8801	8.18379	20.6677

RUN DATE 7/29/71

DATA

272	286	242	287	277	220	1702	1
261	263	205	290	275	246	1688	2
267	260	197	270	280	250	1871	3
258	253	190	258	270	251	1967	4
252	247	206	268	268	233	2067	5
275	263	179	260	281	255	2198	6
260	250	173	240	270	225	2297	7

CM1

1	0.742397	0.156449	0.20674	0.904101	0.140107	¯0.134618	¯0.217953
0.742397	1	0.73946	0.658063	0.611091	¯0.27097	¯0.637632	¯0.719016
0.156449	0.73946	1	0.815536	0.115102	¯0.476878	¯0.79461	¯0.84926
0.20674	0.658063	0.815536	0.999999	0.349401	¯0.0263746	¯0.922714	¯0.905312
0.904101	0.611091	0.115102	0.349401	1	0.390871	¯0.268788	¯0.31208
0.140107	¯0.27097	¯0.476878	¯0.0263746	0.390871	1	0.0246463	0.0889328
¯0.134618	¯0.637632	¯0.79461	¯0.922714	¯0.268788	0.0246463	1	0.988037
¯0.217953	¯0.719016	¯0.84926	¯0.905312	¯0.31208	0.0889328	0.988037	1

ABSOLUTE ERRORS

52	66	22	67	57	220	1702	1
15	17	¯41	44	29	246	1688	2
17	10	¯53	20	30	250	1871	3
7	2	¯61	7	19	251	1967	4
19	14	¯27	35	35	233	2067	5
20	8	¯76	5	26	255	2198	6
35	25	¯52	15	45	225	2297	7

CM2

0.999999	0.941738	0.743539	0.626834	0.970074	¯0.845035	¯0.0953904	¯0.199583
0.941738	1	0.896205	0.822168	0.929807	¯0.812181	¯0.402427	¯0.493407
0.743539	0.896205	1	0.938561	0.80902	¯0.777883	¯0.578866	¯0.646027
0.626834	0.822168	0.938561	1	0.704459	¯0.638216	¯0.725835	¯0.752156
0.970074	0.929807	0.80902	0.704459	1	¯0.927446	¯0.135975	¯0.223395
¯0.845035	¯0.812181	¯0.777883	¯0.638216	¯0.927446	1	0.0246463	0.0889328
¯0.0953904	¯0.402427	¯0.578866	¯0.725835	¯0.135975	0.0246463	1	0.988037
¯0.199583	¯0.493407	¯0.646027	¯0.752156	¯0.223395	0.0889328	0.988037	1

AVG ERR, MEAN ERR, MEAN DEV

23.5714	20.2857	¯41.1429	27.5714	34.4286
23.5714	20.2857	47.4286	27.5714	34.4286
29.5889	30.6431	54.626	37.3028	39.3213

RELATIVE ERRORS

23.6364	30	10	30.4546	25.9091	220	1702	1
6.09756	6.91057	¯16.6667	17.8862	11.7886	246	1688	2
6.8	4	¯21.2	8	12	250	1871	3
2.78884	0.796813	¯24.3028	2.78884	7.56972	251	1967	4
8.15451	6.00858	¯11.588	15.0215	15.0215	233	2067	5
7.84314	3.13725	¯29.8039	1.96078	10.1961	255	2198	6
15.5556	11.1111	¯23.1111	6.66667	20	225	2297	7

CM3

1	0.950334	0.7463	0.683541	0.974669	¯0.863213	¯0.107199	¯0.210853
0.950334	0.999999	0.893282	0.849251	0.932584	¯0.816292	¯0.392875	¯0.485917
0.7463	0.893282	1	0.958327	0.787804	¯0.731914	¯0.612619	¯0.683077
0.683541	0.849251	0.958327	1	0.738739	¯0.672697	¯0.697467	¯0.73351
0.974669	0.932584	0.787804	0.738739	1	¯0.94103	¯0.129914	¯0.217927
¯0.863213	¯0.816292	¯0.731914	¯0.672697	¯0.94103	1	0.0246463	0.0889328
¯0.107199	¯0.392875	¯0.612619	¯0.697467	¯0.129914	0.0246463	1	0.988037
¯0.210853	¯0.485917	¯0.683077	¯0.73351	¯0.217927	0.0889328	0.988037	1

AVG ERR, MEAN ERR, MEAN DEV

10.1251	8.85205	¯16.6675	11.8255	14.6407
10.1251	8.85205	19.5246	11.8255	14.6407
13.0375	13.7465	22.2655	16.2947	17.035

RUN DATE 7/30M71

DATA

260	272	274	255	238	262	1396	1
258	260	236	254	244	272	1660	2
242	246	201	238	227	248	1869	3
253	255	195	253	234	267	1675	4
258	258	193	250	235	277	1568	5
259	257	192	259	239	269	1741	6

CM1

1	0.816527	0.37254	0.905368	0.843779	0.801967	¯0.736956	0.0470823
0.816527	1	0.799711	0.67049	0.645592	0.391899	¯0.939657	¯0.457385
0.37254	0.799711	1	0.231576	0.426589	¯0.112785	¯0.69975	¯0.875895
0.905368	0.67049	0.231576	1	0.821415	0.690827	¯0.514261	0.169998
0.843779	0.645592	0.426589	0.821415	1	0.689805	¯0.458652	¯0.140498
0.801967	0.391899	¯0.112785	0.690827	0.689805	0.999989	¯0.430305	0.366326
¯0.736956	¯0.939657	¯0.69975	¯0.514261	¯0.458652	¯0.430305	0.999999	0.41895
0.0470823	¯0.457385	¯0.875895	0.169998	¯0.140498	0.366326	0.41895	1

ABSOLUTE ERRORS

¯2	10	12	¯7	¯24	262	1396	1
¯14	¯12	¯36	¯18	¯28	272	1660	2
¯6	¯2	¯47	¯10	¯21	248	1869	3
¯14	¯12	¯72	¯14	¯33	267	1675	4
¯19	¯19	¯84	¯27	¯42	277	1568	5
¯10	¯12	¯77	¯10	¯30	269	1741	6

CM2

1	0.948815	0.765609	0.908392	0.870057	¯0.749383	¯0.111888	¯0.547964
0.948815	1	0.895083	0.78308	0.782933	¯0.65834	¯0.347537	¯0.732842
0.765609	0.895083	1	0.553901	0.681414	¯0.385797	¯0.528776	¯0.916241
0.908392	0.78308	0.553901	1	0.841677	¯0.696272	0.0841885	¯0.33753
0.870057	0.782933	0.681414	0.841677	1	¯0.829298	0.231948	¯0.607273
¯0.749383	¯0.65834	¯0.385797	¯0.696272	¯0.829298	0.999999	¯0.430305	0.366326
¯0.111888	¯0.347537	¯0.528776	0.0841885	0.231948	¯0.430305	0.999989	0.41895
¯0.547964	¯0.732842	¯0.916241	¯0.33753	¯0.607273	0.366326	0.41895	1

AVG ERR, MEAN ERR, MEAN DEV

¯10.8333	¯7.83333	¯50.6667	¯14.3333	¯29.6667
10.8333	11.1667	54.6667	14.3333	29.6667
13.3641	13.394	66.0575	17.309	33.3287

RELATIVE ERRORS

¯0.763359	3.81679	4.58015	¯2.67176	¯9.16031	262	1396	1
¯5.14706	¯4.41176	¯13.2353	¯6.61765	¯10.2941	272	1660	2
¯2.41936	¯0.806452	¯18.9516	¯4.03226	¯8.46774	248	1869	3
¯5.24345	¯4.49438	¯26.9663	¯5.24345	¯12.3596	267	1675	4
¯6.85921	¯6.85921	¯30.3249	¯9.74729	¯15.1625	277	1568	5
¯3.71747	¯4.46097	¯28.6245	¯3.71747	¯11.1524	269	1741	6

CM3

1	0.949242	0.753926	0.897016	0.851828	¯0.725422	¯0.146887	¯0.553576
0.949242	1	0.883812	0.769554	0.768744	¯0.644149	¯0.367627	¯0.736165
0.753926	0.883812	1	0.528814	0.667644	¯0.333542	¯0.573426	¯0.911124
0.897016	0.769554	0.528814	1	0.817203	¯0.665055	0.0525611	¯0.331716
0.851828	0.768744	0.667644	0.817203	1	¯0.789328	0.200106	¯0.626939
¯0.725422	¯0.644149	¯0.333542	¯0.665055	¯0.789328	0.999999	¯0.430305	0.366326
¯0.146887	¯0.367627	¯0.573426	0.0525611	0.200106	¯0.430305	0.999999	0.41895
¯0.553576	¯0.736165	¯0.911124	¯0.331716	¯0.626939	0.366326	0.41895	1

AVG ERR, MEAN ERR, MEAN DEV

¯4.02498	¯2.86933	¯18.9204	¯5.33831	¯11.0994
4.02498	4.14159	20.4471	5.33831	11.0994
4.92525	4.9362	24.5824	6.37987	12.3985

APPENDIX III

COMPUTER PROGRAMS
USED IN
LAB DATA ANALYSES

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***** ZERO DRIFT ANALYSIS PROGRAM

```
      DIMENSION X(378),ITITL(40),INT(6)
  100 FORMAT(I2)
  101 FORMAT(6A1)
  110 FORMAT(40A2)
  120 FORMAT(12F6.0)
  200 FORMAT(/40A2//)
      READ(2,101)INT
      CALL H1
      IP=0
    2 READ(2,100)N
      IF(N-9)3,3,99
    3 READ(2,110)ITITL
      IP=IP+1
      IF(IP-3)7,7,4
    4 CALL H1
      IP=1
    7 M=0
      INST=0
      WRITE(3,200)ITITL
      READ(2,120)(X(IX),IX=1,378)
    5 INST=INST+1
      IF(INST-6)9,9,2
    9 L=0
      AVG=X(M+1)
      PMAX=0.
      SUMA=0.
      SUMB=0.
      SUMC=0.
   10 L=L+1
      IF(L-63)35,35,15
   15 CALL H2(SUMA,SUMB,SUMC,MBIG,PMAX,INST,INT)
      GO TO 5
   35 M=M+1
      DIFF=ABS(AVG-X(M))
      IF(DIFF-PMAX)37,37,36
   36 PMAX=DIFF
      MBIG=L
   37 SUMA=SUMA+DIFF*DIFF
      SUMC=SUMC+DIFF
      SUMB=SUMB+DIFF*2./36.
      GO TO 10
   99 CONTINUE
      CALL EXIT
      END
```

** PROGRAM GETIT STORES SPAN DATA ****

```
      DEFINE FILE 1(126,2,U,K1),2(126,2,U,K1),3(126,2,U,K1),
     1            4(126,2,U,K1),5(126,2,U,K1),6(126,2,U,K1),
     2            7(126,2,U,K1),8(126,2,U,K1),9(126,2,U,K1)
      DEFINE FILE 11(126,2,U,K2),12(126,2,U,K2),13(126,2,U,K2),
     1            14(126,2,U,K2),15(126,2,U,K2),16(126,2,U,K2),
     2            17(126,2,U,K2),18(126,2,U,K2),19(126,2,U,K2)
      DIMENSION X(378)
  120 FORMAT(12F6.0)
C       N   COUNTS THE RUNS
      N=0
    2 N=N+1
      NN=N+10
C        FINISHED WITH THE RUNS&
      IF(N-9)3,3,99
    3 KF=0
      M=0
C       INST   IS THE INSTRUMENT COUNTER
      INST=0
      READ(2,120)(X(IX),IX=1,378)
    5 INST=INST+1
C          FINISHED WITH THE INSTRUMENTS&
      IF(INST-6)7,7,2
C       L     IS THE REPLICATE COUNTER
    7 L=0
   10 L=L+1
C       FINISHED WITH THE REPLICATES&
      IF(L-7)15,15,5
C     I     IS THE SPAN COUNTER
   15 I=0
   20 I=I+1
C     FINISHED WITH THE SPANS&
      IF(I-3)25,25,10
   25 SUMA=0.
      SUMB=0.
C     J     IS THE SPAN REPLICATE COUNTER
      J=0
   30 J=J+1
C     FINISHED WITH THE SPAN REPLICATES&
      IF(J-3)35,35,40
   35 M=M+1
      SUMA=SUMA+X(M)
      SUMB=SUMB+X(M)*X(M)
      GO TO 30
   40 KF=KF+1
C     CALCULATE AVERAGE AND STANDARD DEVIATION
      AVG=SUMA/3.
      SD=SQRT(ABS((3.*SUMB-SUMA**2.)/6.))
C     SAVE DATA ON DISK
      WRITE(N'KF)AVG
      WRITE(NN'KF)SD
      GO TO 20
   99 CONTINUE
      CALL EXIT
      END
```

```
      SUBROUTINE HEAD(IT)
      DIMENSION IT(40)
      WRITE(3,200)IT
  200 FORMAT(1H1,//////,40A2)
      WRITE(3,210)
  210 FORMAT(' I         L')
      WRITE(3,220)
  220 FORMAT(' N    R    E')
      WRITE(3,230)
  230 FORMAT(' S    E    V',T13,'AVG',T23,'SD',T32,'ZERO',T42,'SD',
     1T52,'1-3',T61,'TV',T69,'ERR1',T78,'ERR2')
      WRITE(3,240)
  240 FORMAT(' T    R    E')
      WRITE(3,250)
  250 FORMAT(' R         L'/)
      RETURN
      END
```

```
      SUBROUTINE H1
  200 FORMAT(1H1,///  T35,'ZERO DRIFT ANALYSIS'/T6,'I',T35,
     1'----- ----- --------'/T6,'N')
  210 FORMAT(1H ,T6,'S',T16,'STANDARD'     ,T33,'MEAN',T44,'MEAN DEVIATION
     1',T63,'MAXIMUM',T74,'INDEX')
  220 FORMAT(1H ,T6,'T',T15,'DEVIATION',T31,'DEVIATION',T46,'INTEGRAL',
     1T62,'DEVIATION'/T6,'R'//)
      WRITE(3,200)
      WRITE(3,210)
      WRITE(3,220)
      RETURN
      END
```

```
      SUBROUTINE H2(A,B,C,M,PM,I,IN)
      DIMENSION IN(6)
  200 FORMAT(1H ,T6,A1,T11,3E15.5,7X,F7.2,5X,I2/)
      XMSD=SQRT(A/61.)
      XMD=C/61.
      XMDI=B
      WRITE(3,200)IN(I),XMSD,XMD,XMDI,PM,M
      RETURN
      END
```

**** PROGRAM GETZE STORES ZERO DATA**

```
      DEFINE FILE 21(126,2,U,K1),22(126,2,U,K1),23(126,2,U,K1),
     1            24(126,2,U,K1),25(126,2,U,K1),26(126,2,U,K1),
     2            27(126,2,U,K1),28(126,2,U,K1),29(126,2,U,K1)
      DEFINE FILE 31(126,2,U,K1),32(126,2,U,K1),33(126,2,U,K1),
     1            34(126,2,U,K1),35(126,2,U,K1),36(126,2,U,K1),
     2            37(126,2,U,K1),38(126,2,U,K1),39(126,2,U,K1)
      DIMENSION X(378)
  120 FORMAT(12F6.0)
C        N   COUNTS THE RUNS
      N=0
    2 N=N+1
      K=20+N
      KK=K+10
C        FINISHED WITH THE RUNS&
      IF(N-9)3,3,99
    3 KF=0
      M=0
C        INST   IS THE INSTRUMENT COUNTER
      INST=0
      READ(2,120)(X(IX),IX=1,378)
    5 INST=INST+1
C          FINISHED WITH THE INSTRUMENTS&
      IF(INST-6)7,7,2
C      L     IS THE REPLICATE COUNTER
    7 L=0
   10 L=L+1
C      FINISHED WITH THE REPLICATES&
      IF(L-7)15,15,5
C     I     IS THE SPAN COUNTER
   15 I=0
   20 I=I+1
C     FINISHED WITH THE SPANS&
      IF(I-3)25,25,10
   25 SUMA=0.
      SUMB=0.
C     J     IS THE SPAN REPLICATE COUNTER
      J=0
   30 J=J+1
C     FINISHED WITH THE SPAN REPLICATES&
      IF(J-3)35,35,40
   35 M=M+1
      SUMA=SUMA+X(M)
      SUMB=SUMB+X(M)*X(M)
      GO TO 30
   40 KF=KF+1
C     CALCULATE AVERAGE AND STANDARD DEVIATION
      AVG=SUMA/3.
      SD=SQRT(ABS((3.*SUMB-SUMA**2.)/6.))
C     SAVE DATA ON DISK
      WRITE(K'KF)AVG
      WRITE(KK'KF)SD
      GO TO 20
   99 CONTINUE
      CALL EXIT
      END
```

```
      DEFINE FILE 1(126,2,U,K1),2(126,2,U,K1),3(126,2,U,K1),
     1             4(126,2,U,K1),5(126,2,U,K1),6(126,2,U,K1),
     2             7(126,2,U,K1),8(126,2,U,K1),9(126,2,U,K1)
      DEFINE FILE 11(126,2,U,K2),12(126,2,U,K2),13(126,2,U,K2),
     1             14(126,2,U,K2),15(126,2,U,K2),16(126,2,U,K2),
     2             17(126,2,U,K2),18(126,2,U,K2),19(126,2,U,K2)
      DEFINE FILE 21(126,2,U,K1),22(126,2,U,K1),23(126,2,U,K1),
     1             24(126,2,U,K1),25(126,2,U,K1),26(126,2,U,K1),
     2             27(126,2,U,K1),28(126,2,U,K1),29(126,2,U,K1)
      DEFINE FILE 31(126,2,U,K1),32(126,2,U,K1),33(126,2,U,K1),
     1             34(126,2,U,K1),35(126,2,U,K1),36(126,2,U,K1),
     2             37(126,2,U,K1),38(126,2,U,K1),39(126,2,U,K1)
      DIMENSION TV(21,9)
  100 FORMAT(8F10.0)
  110 FORMAT(I2)
  140 FORMAT(6A1)
  150 FORMAT(40A2)
  300 FORMAT(1H ,A1,'   ',I1,' ',I2,T12,F5.1,T21,F6.2,T30,F6.1,
     1T40,F6.2,T50,F5.1,T59,F5.1,T67,F6.2,T76,F6.2)
  320 FORMAT('      ',      I1,' ',I2,T12,F5.1,T21,F6.2,T30,F6.1,
     1T40,F6.2,T50,F5.1,T59,F5.1,T67,F6.2,T76,F6.2)
  330 FORMAT('           ',           I2,T12,F5.1,T21,F6.2,T30,F6.1,
     1T40,F6.2,T50,F5.1,T59,F5.1,T67,F6.2,T76,F6.2)
  340 FORMAT(//)
  350 FORMAT(1H ,I4,4E20.6)
  355 FORMAT(1H ,7(4X,I4))
  360 FORMAT(1H ,E20.6)
  365 FORMAT(1H1)
  370 FORMAT(//1H ,'INSTR   ',I2,'   LEVEL    ',I2)
      READ(2,100)((TV(I,J),I=1,21),J=1,9)
      DO 6 J=1,9
      DO 6 I=1,21
      TV(I,J)=TV(I,J)*1.13
    6 CONTINUE
      WRITE(3,365)
      IIK=0
  540 IIK=IIK+1
      IF(IIK-6)550,550,999
  550 IRK=0
  555 IRK=IRK+1
      IF(IRK-3)560,560,540
  560 CONTINUE
      NERR=0
      SSD=0.
      ATR1=0.
      ATR2=0.
      TSD1=0.
      TSD2=0.
      TR1=0.
      TR2=0.
C     N  IS THE FILE NUMBER
      N=0
    3 N=N+1
      IF(N-9)5,5,99
C     KF  IS THE FILE RECORD COUNTER
    5 KF=0
      IH=0
C     INK   IS THE INSTRUMENT COUNTER
      INK=0
C     NSD IS THE LOGICAL DESIGNATION FOR FILE SD
```

```
      NSD=N+10
      NZ    IS THE LOGICAL DESIGNATION FOR FILES ZER
      NZ=N+20
      NZSD    IS THE LOGICAL DESIGNATION FO FILES SZ
      NZSD=N+30
   25 INK=INK+1
      IFLAG=0
      ITV=0
      IF(INK-6)14,14,3
   14 IF(INK-IIK)15,16,15
   16 IFLAG=1
   15 IH=IH+1
      IF(IH-2)30,30,20
   20 CONTINUE
      IH=1
   30 L=0
   35 L=L+1
      IF(L-7)40,40,38
   38 CONTINUE
      GO TO 25
   40 I=0
   45 I=I+1
      IFL1=0
      IF(I-3)49,49,35
   49 IF(I-IRK)50,51,50
   51 IFL1=1
   50 KF=KF+1
      ITV=ITV+1
      IF(IFLAG)62,62,61
   61 IF(IFL1)62,62,54
   54 IF(N-5)454,62,454
  454 IF(N-8)455,62,455
  455 IF(TV(ITV,N)-1.)62,55,55
   55 X=TV(ITV,N)
      READ(N'KF)AVG
      READ(NSD'KF)SD
      READ(NZ'KF)ZER
      READ(NZSD'KF)ZSD
      D1=AVG-ZER
      ERR1=((D1-X)/    X)*100.
      ERR2=((AVG-X)/    X)*100.
      NERR=NERR+1
      SSD=SSD+SD
      TR1=TR1+ERR1
      TR2=TR2+ERR2
      ATR1=ATR1+ABS(ERR1)
      ATR2=ATR2+ABS(ERR2)
      TSD1=TSD1+ERR1*ERR1
      TSD2=TSD2+ERR2*ERR2
```

```
 62 IF(L-4)90,70,90
 70 IF(I-2)95,85,95
 85 CONTINUE
    GO TO 45
 90 IF(I-2)95,92,95
 92 CONTINUE
    GO TO 45
 95 CONTINUE
    GO TO 45
 99 CONTINUE
    ENRR=NERR
    SER1=((ENRR*TSD1)-TR1*TR1)/(ENRR*(ENRR-1.))
    SER2=((ENRR*TSD2)-TR2*TR2)/(ENRR*(ENRR-1.))
    ASER1=TSD1/(ENRR-1.)
    ASER2=TSD2/(ENRR-1.)
    AVG1=TR1/ENRR
    AVG2=TR2/ENRR
    AAVG1=ATR1/ENRR
    AAVG2=ATR2/ENRR
    SER1=SQRT(SER1)
    SER2=SQRT(SER2)
    ASER1=SQRT(ASER1)
    ASER2=SQRT(ASER2)
    ASSD=SSD/ENRR
    WRITE(3,370)IIK,IRK
    WRITE(3,360)ASSD
    WRITE(3,350)NERR,AVG1,AVG2,SER1,SER2
    WRITE(3,350)NERR,AAVG1,AAVG2,ASER1,ASER2
    GO TO 555
999 CONTINUE
    CALL EXIT
    END
```

****** THIS PROGRAM PERFORMS A PARTIAL SUMMARY

```
      DEFINE FILE 1(126,2,U,K1),2(126,2,U,K1),3(126,2,U,K1),
     1            4(126,2,U,K1),5(126,2,U,K1),6(126,2,U,K1),
     2            7(126,2,U,K1),8(126,2,U,K1),9(126,2,U,K1)
      DEFINE FILE 11(126,2,U,K2),12(126,2,U,K2),13(126,2,U,K2),
     1            14(126,2,U,K2),15(126,2,U,K2),16(126,2,U,K2),
     2            17(126,2,U,K2),18(126,2,U,K2),19(126,2,U,K2)
      DEFINE FILE 21(126,2,U,K1),22(126,2,U,K1),23(126,2,U,K1),
     1            24(126,2,U,K1),25(126,2,U,K1),26(126,2,U,K1),
     2            27(126,2,U,K1),28(126,2,U,K1),29(126,2,U,K1)
      DEFINE FILE 31(126,2,U,K1),32(126,2,U,K1),33(126,2,U,K1),
     1            34(126,2,U,K1),35(126,2,U,K1),36(126,2,U,K1),
     2            37(126,2,U,K1),38(126,2,U,K1),39(126,2,U,K1)
      DIMENSION TV(21,9)
  100 FORMAT(8F10.0)
  110 FORMAT(I2)
  140 FORMAT(6A1)
  150 FORMAT(40A2)
  300 FORMAT(1H ,A1,'   ',I1,' ',I2,T12,F5.1,T21,F6.2,T30,F6.1,
     1T40,F6.2,T50,F5.1,T59,F5.1,T67,F6.2,T76,F6.2)
  320 FORMAT('     ',     I1,' ',I2,T12,F5.1,T21,F6.2,T30,F6.1,
     1T40,F6.2,T50,F5.1,T59,F5.1,T67,F6.2,T76,F6.2)
  330 FORMAT('       ',           I2,T12,F5.1,T21,F6.2,T30,F6.1,
     1T40,F6.2,T50,F5.1,T59,F5.1,T67,F6.2,T76,F6.2)
  340 FORMAT(//)
  350 FORMAT(1H ,I4,4E20.6)
  355 FORMAT(1H ,7(4X,I4))
  360 FORMAT(1H ,E20.6)
  365 FORMAT(1H1)
  370 FORMAT(//1H ,'INSTR   ',I2,'   LEVEL    ',I2)
      READ(2,100)((TV(I,J),I=1,21),J=1,9)
      DO 6 J=1,9
      DO 6 I=1,21
      TV(I,J)=TV(I,J)*1.13
    6 CONTINUE
      WRITE(3,365)
      I120=0
      I110=0
      I105=0
      I220=0
      I210=0
      I205=0
      NERR=0
      SSD=0.
      ATR1=0.
      ATR2=0.
      TSD1=0.
      TSD2=0.
      TR1=0.
      TR2=0.
C     N  IS THE FILE NUMBER
      N=0
    3 N=N+1
      IF(N-9)5,5,99
C     KF  IS THE FILE RECORD COUNTER
    5 KF=0
      IH=0
C     INK   IS THE INSTRUMENT COUNTER
      INK=0
C     NSD IS THE LOGICAL DESIGNATION FOR FILE SD
      NSD=N+10
C     NZ   IS THE LOGICAL DESIGNATION FOR FILES ZER
      NZ=N+20
C     NZSD   IS THE LOGICAL DESIGNATION FO FILES SZ
```

```
      NZSD=N+30
   25 INK=INK+1
      IFLAG=0
      ITV=0
      IF(INK-6)14,14,3
   14 IF(INK-5   )15,16,15
   16 IFLAG=1
   15 IH=IH+1
      IF(IH-2)30,30,20
   20 CONTINUE
      IH=1
   30 L=0
   35 L=L+1
      IF(L-7)40,40,38
   38 CONTINUE
      GO TO 25
   40 I=0
   45 I=I+1
      IFL1=0
      IF(I-3)49,49,35
   49 IF(I-1   )50,51,50
   51 IFL1=1
   50 KF=KF+1
      ITV=ITV+1
      IF(IFLAG)61,61,62
   61 IF(IFL1)455,455,62
  455 IF(TV(ITV,N)-1.)62,55,55
   55 X=TV(ITV,N)
      READ(N'KF)AVG
      READ(NSD'KF)SD
      READ(NZ'KF)ZER
      READ(NZSD'KF)ZSD
      D1=AVG-ZER
      ERR1=((D1-X)/    X)*100.
      ERR2=((AVG-X)/    X)*100.
      NERR=NERR+1
      A1=ABS(ERR1)
      A2=ABS(ERR2)
      IF(A1-20.)605,605,650
  605 I120=I120+1
      IF(A1-10.)610,610,650
  610 I110=I110+1
      IF(A1-5.)620,620,650
  620 I105=I105+1
  650 IF(A2-20.)655,655,62
  655 I220=I220+1
      IF(A2-10.)660,660,62
  660 I210=I210+1
      IF(A2-5.)670,670,62
  670 I205=I205+1
   62 GO TO 45
   99 CONTINUE
      WRITE(3,355)NERR,I120,I110,I105,I220,I210,I205
      CALL EXIT
      END
```