Riverside Cement Company

A GIFFORD-HILL COMPANY

GIFFORD·HILL

Post Office Box 832
Riverside, California 92502

1500 Rubidoux Boulevard
Telephone: 714/683-3660

January 13, 1986

Mr. S. C. (Kim) Hunter
Manager, Industrial Services
Engineering & Research Division
KVB, a Research-Cottrell Company
18006 Skypark Blvd.
P. O. Box 19518
Irvine, CA., 92714

Dear Mr. Hunter:

Enclosed you will find Gifford-Hill and Company's response to the report issued by KVB on September 3, 1985, identified as KVB71-71901/2/R/GH Audit, concerning your findings of an intensive audit of the quality assurance plan, instrumentation, staff procedures, data handling, etc., associated with the NOx project at the Crestmore, CA. plant of Gifford-Hill and Company, Inc.

If you have any questions or if I can be of further help, please contact me as soon as possible.

Gerald L Young

Gerald L. Young
Production Engineer
Gifford-Hill and Company, Inc.

I. INTRODUCTION

KVB, Inc. was retained by Riverside Cement Company ("RCC"), a division of Gifford-Hill and Company, Inc., to perform a thorough evaluation of the activities undertaken at RCC's Crestmore facility to reduce NOx emissions in its effort to meet the requirements of SCAQMD Rule 1112. Specifically, KVB was instructed to review the NOx emissions control project (the "NOx project") undertaken at the Crestmore facility in order to evaluate the emissions monitoring program instituted at the facility. Gifford-Hill believes that the KVB evaluation of the Crestmore facility was unprecedented; no other facility hsa undertaken such a thorough review of its NOx control program.

The KVB evaluation included an examination of all equipment, procedures, calibrations and calculations that affect the measurement of NOx emissions at the facility and a review of the quality control documentation and staff procedures followed at the facility. In particular the procedures followed at the facility were compared with specifications devised by the Environmental Protection Agency for air pollution monitoring programs.

KVB completed its review and prepared a report of its findings dated September 3, 1985. See KVB 71-71901/2/R/GH Audit, hereinafter the "Audit Report".

The Audit Report made numerous recommendations for improving the NOx control program which RCC intends to implement at the Crestmore facility. All of the recommendations or suggested revisions or additions in the Audit Report (See Attachment A) relating to the QA Manual have been reviewed and accepted. These changes have been implemented and are reflected in the attached copy of the revised Quality Assurance Manual (the "QA Manual")> See Attachment B.

All of the recommendations relating to the sampling and testing of kiln feed and coal fuel (See Attachment A) have bene reviewed and accepted. These changes have been implemented and are reflected in the revised QA Manual (See Attachment B). The recommendations relating to updating the engineering constants also have been reviewed and accepted. These changes are reflected in the attached copy of the revised QA Manual and in Attachment C containing examples of the updated constants.

All of the recommendations in the Audit Report relating to the frequency and procedures employed to calibrate and maintain the field instrumentation have been reviewed and accepted and have been implemented. Most of these changes are reflected in the revised QA Manual. See Attachment B. The Audit Report recommended that Gifford-Hill employ KVB to certify the LSI SM-810 NOx/SOx gas analyzer and the LSI CM-50 oxygen analyzer. These recommendations have been carefully reviewed and at this time Gifford-Hill does not feel the implementation of these recommendations is necessary.

All of the recommendations in the Audit Report relating to the software used by the NOx project IBM-PC to calculate pounds of NOx per ton of clinker have been carefully reviewed and generally accepted. KVB also provided a suggested IBM program. The program supplied by KVB was not accepted without modification; however, a revised program to calculate pounds of NOx per ton of clinker was developed which satisfies all of the recommednations in the Audit Report relating to the IBM program and makes use of several ideas developed in the KVB program. This revised IBM program was installed in the NOx project IBM-PC on or about September 17, 1985 and currently is in use.

The specific recommendations that have been or will be, implemented at the facility in response to the Audit Report have been outlined in more detail below.

II. IMPLEMENTION OF IMPROVEMENTS/RECOMMENDATIONS

A. QUALITY ASSURANCE MANUAL

1. In the section titled "RIVERSIDE CEMENT QA PLAN" on page 12 of the Audit Report, Attachment A, it was noted that the quality assurance manual did not adequately address the data analysis, validation, and reporting aspects. It was also noted in this section that the procedures for calculating the engineering constants and a plan to update these constants were not addressed.

   In the revised Crestmore NOx Project Quality Assurance Manual, Attachment B, on page 11, the data validation and reporting aspects of this project are now outlined. On page 13 of the

Quality Assurance Manual, the responsibility for data analysis has been assigned. And on pages 8-10 inclusive, of the Quality Assurance Manual, procedures for updating the engineering constants are provided.

2. In Table 5, titled "QA PLAN CHECKLIST FOR RIVERSIDE CEMENT - CRESTMORE PLANT" on page 14 of the Audit Report, it was noted that the degree of precision and accuracy were not quantified for the field signals, engineering constants, or calculations.

On page 2, section B, of the revised Quality Assurance Manual, the expected degree of precision and accuracy of the pounds of NOx per ton of clinker values calculated are quantified. The precision and accuracy of the pertinent field signals are provided in the Audit Report in Table 2, on page 6. The precision and accuracy of the engineering constants are provided in the Audit Report in Table 3, on page 7. In addition, the values and variability of the engineering constants are updated, as outlined on pages 8-10 inclusive in the Quality Assurance Manual, refer to Attachment C for examples.

3. In Table 5, on page 14 of the Audit Report, it was recommended that the sampling and analysis of the coal feed and kiln feed should be addressed.

In the revised Quality Assurance Manual, on pages 8 - 10 inclusive, the frequency of sampling, testing, and updating of the coal feed/kiln feed analyses is addressed. The responsibility for the above is assigned on page 12 of the Quality Assurance Manual.

4. In Table 5, on page 14 of the Audit Report, methods of determining sample custody are suggested and it was further recommended that a brief discussion of how the data are handled be provided.

The collection and analyses of the coal feed/kiln feed samples are covered on pages 8 - 10 inclusive, while responsibility for sampling, analyses, and maintaining a record of custody is provided in section D on page 12. A form, to be used for tracking sample custody, is provided in Appendix A, page 113 of the revised Quality Assurance Manual.

A discussion of how the data are handled and recorded is provided in Section II on pages 2 - 5 inclusive.

5. In Table 5, on page 14 of the Audit Report, a recommendation was made to identify the equipment used during calibrations. A question was also raised as to whether this equipment was calibrated against an appropriate standard.

In Appendix A of the revised Quality

Assurance Manual, each of the Zero/Span Checklists, Full Electronic Calibration Worksheets, and Dynamic Calibration Worksheets now have a location in which each instrument used in the procedure may be identified. All of the equipment required for the calibration of the field signals used in the pounds of NOx per ton of clinker calculation is calibrated against appropriate standards. The responsibility for performing the calibration of field signals, calibration of the test equipment, and for maintaining these records is outlined in Section C on page 12 of the Quality Assurance Manual.

6. In Table 5, on page 14 of the Audit Report, a discussion of the equations/assumptions used to calculate pounds of NOx per ton of clinker is recommended.

In section II, "DATA HANDLING AND REDUCTION", on pages 2 - 5 inclusive, the equation specified by the SCAQMD Rule 1112 that is used to calculate the pounds of NOx per ton of clinker is discussed. Various parameters affecting this calculated value are also discussed in this section of the Quality Assurance Manual.

7. In Table 5, on page 15 of the Audit Report, it is recommended that goals and the means to attain these goals should be outlined.

The revised Quality Assurance Manual addresses these goals and outlines the means to achieve the stated goals of the Crestmore Plant NOx project.

8. In Table 5, on page 15 of the Audit Report, it is recommended that corrective action required for proper operation be outlined for the field instrumentation and for the engineering constants used in the calculation of pounds of NOx per ton of clinker value.

Section IV, Frequency of Calibration, on pages 6 - 8 inclusive, Section VIII, Methods for Zero/Span Checks and Full Calibrations, on pages 13 - 69 inclusive, and Appendix A on pages 70 - 121 inclusive, in the revised Quality Assurance Manual, Attachment B, provide a detailed outline of corrective actions required to maintain the instrumentation which generates the field signals used in the pounds of NOx per ton of clinker calculation.

Section V, Frequency of Sampling and Testing, on pages 8 - 10 inclusive and Section VII, part D, on page 12 of the Quality Assurance Manual provide a detailed outline for maintaining the required accuracy of the engineering constants used for the calculation of pounds of NOx per ton of clinker.

9. In Table 5, on page 15 of the Audit Report, it was noted that it might be useful to prepare a

periodic report documenting the steps taken to maintain as accurate and precise a pounds of NOx per ton of clinker value as possible.

At present the Manager of the Crestmore NOx Project, Gerald L. Young, documents the steps taken to maintain as accurate and precise a pounds of NOx per ton of clinker value as possible and summarizes these steps in a monthly report to the Plant Manager, Mr. R. B. Rieser, of the Crestmore Plant.

B. CALCULATION

1. On page 8 in the Audit Report and again on page 16, under the "For new program" subsection of the "Calculation" subsection of the Improvements/ Recommendations section, it is recommended that the portion of the NOx project IBM-PC program that is used to calculate pounds of NOx per ton of clinker, hereafter called the IBM program, be restructured so that each element required by the SCAQMD Rule 1112 equation is clearly developed in an understandable way.

An in depth review of the inputs and equations involved in determining each element of the SCAQMD Rule 1112 equation was performed by Mr. R. S. MacMann, Manager of Process Engineering, for the Cement Division of Gifford-Hill and Company, Inc., Mr. Craig Phillips, President of JCP

Associates, and Gerald L. Young, Production Engineer for the Cement Division of Gifford-Hill and Company, Inc. and Manager of the Crestmore Plant NOx Project. The above mentioned group restructured the IBM-PC program in a manner that is easy to understand and which clearly develops each element required by the SCAQMD Rule 1112 equation, refer to Attachment D.

2. On page 16, under the "For existing program" subsection of the "Calculations" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that the equations and assumptions used in the IBM-PC program be further scrutinized to insure accuracy.

One of the tasks assigned to KVB was to scrutinize these equations and assumptions. KVB completed this task and made several observations which were incorporated into the revised IBM program discussed in part II, B, 1 of this letter. In addition, during the development of the revised IBM program, each of the assumptions and equations were again examined for accuracy.

3. On page 16, under the "For existing program" subsection of the "Calculations" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that the engineering constants used in the IBM program should be updated on a weekly basis.

The engineering constants are presently updated on a weekly basis, except for the coal ultimate analyses, as outlined on pages 8 - 10 inclusive, in the Quality Assurance Manual.

4. On page 16, under the "For existing program" subsection of the "Calculations" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that the weekly rolling averages of the engineering constants should be calculated based on kiln feed/coal feed analyses.

Weekly rolling averages of the engineering constants are, at present, calculated based on kiln feed/coal fuel analyses, as oulined on pages 8 - 10 inclusive in the Quality Assurance Manual. Copies of typical calculated weekly rolling averages have been included as examples, refer to Attachment C.

5. On page 16, under the "For existing program" subsection of the "Calculations" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that the value of 385.2 rather than 379.48 standard dry cubic feet per mole of gas be used.

This recommendation has been accepted and implemented.

6. On page 16, under the "For existing program" subsection of the "Calculations" subsection of the

Improvements/Recommendations section in the Audit Report, it was recommended that the molecular weight of flue gas used in the "bottom line" calculation of pounds of NOx per ton of clinker should be changed to a wet basis since NOx ppm and the exit gas flow rate (scfm) are on a wet basis.

This recommendation has been accepted and incorporated into the IBM program revision, a copy of the program listing of the revised IBM program has been enclosed for examination, refer to Attachment D.

7. On page 16, under the "For existing program" subsection of the "Calculations" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that the current engineering constants should be recalculated to reflect the as-fired coal moisture of 2.5 percent, rather than 1.0 percent.

The as-fired coal moisture content is being updated as outlined on page 8 of the Quality Assurance Manual, refer to Attachment B. The current as-fired coal moisture averages 4.54 percent, update sheet attached, refer to Attachment C.

C. KILN FEED/COAL FEED SAMPLES

On page 16, under the "Raw Feed/Coal Feed Samples" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that enough coal and kiln feed samples should be collected so that statistically meaningful means and standard deviations may be calculated.

Samples of coal and kiln feed are being collected and analyzed in accordance with the procedures outlined on pages 8 - 10 of the Quality Assurance Manual. The mean, standard deviation, and coefficient of variation are determined on the results of these analyses, refer to Attachment C for a typical update sheet.

D. <u>LEAR SIEGLER SM 810 NOx/SO2 ANALYZER</u>

1. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that Gifford-Hill and Company, Inc. employ KVB, Inc. to certify that the Lear Siegler SM-810 analyzer meets EPA specifications for continuous gas analyzers.

   At this time, Gifford-Hill and Company, Inc. is performing dynamic calibrations using EPA protocol standard gases, on a weekly basis. Gifford-Hill does not, at this time, feel that certification of the Lear-Siegler SM-810 gas analyzer is necessary.

2. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that a series of 2-hour and 24-

hour drift tests should be performed over a several day period on the Lear-Siegler SM-810 gas analyzer.

The plant staff at the Crestmore plant has performed 24-hour drift tests on this instrument. The plant staff will perform a series of 2-hour drift tests over a several day period.

3. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that a dynamic calibration of the Lear-Siegler SM-810 should be performed immediately following a full electronic calibration to ensure the electronic calibration was successfully performed.

The above recommendation has been implemented.

4. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that a multipoint dynamic calibration be performed on the Lear-Siegler SM-810 gas analyzer to check the linearity of the instrument.

The suggested multipoint dynamic calibration has become part of the weekly dynamic calibration of the Lear-Siegler SM-810.

5. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/

Recommendations section in the Audit Report, it was recommended that the full calibration/dynamic calibration section of the Quality Assurance Manual should be revised to reflect changes noted during the two full electronic calibrations of 7/25, 26/85 and 7/29, 30/85.

The above recommendation has been completed. Please refer to pages 15 - 25 inclusive, in the Quality Assurance Manual.

6. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that certified nitrogen zero gas should be used to zero the LSI SM-810 rather than SO2 gas to zero NO and vice versa.

This recommendation was implemented during the first part of August, 1985.

7. On page 19, under the "Lear SM 810 NOx/SO2 Analyzer" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that a list of any auxiliary equipment used to complete calibrations should be recorded on the zero and span checklists and on the full electronic calibration/dynamic calibration worksheets.

The above recommendation has been completed. Please refer to pages 70 - 111 inclusive in the

Quality Assurance Manual.

E. **KILN EXIT WATER SPRAY FLOWMETER.**

On page 19, under the "Kiln Exit Water Spray Flowmeter" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that the existing differential pressure flowmeter should be replaced by a turbine flowmeter for improved accuracy.

A new turbine flowmeter was installed on 8/8/85. The turbine meter is certified to be accurate to within one percent of the actual flowrate.

F. **KILN FEED SANKYO IMPACT FLOWMETER**

1. On page 19, under the "Kiln Feed Sankyo Impact Flowmeter" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that several kiln feed samples should be taken and analyzed for loss on ignition prior to and during the course of clinker weighings to verify the ignition loss value.

   This recommendation has been implemented. When a clinker weighing is used to verify the performance of the kiln feed Sankyo, at least three kiln feed samples are taken which reflect the chemistry of the kiln feed used to produce the clinker that is collected for comparison to the kiln feed Sankyo Flowmeter to insure that the kiln feed-to-clinker conversion factor is correct.

2. On page 19, under the "Kiln Feed Sankyo

Impact Flowmeter" subsection of the Improvements/ Recommendations section in the Audit Report, it was recommended that the kiln feed Sankyo Impact Flowmeter should be checked with static test weights each time the kiln is down for sufficient time.

The above mentioned recommendation has been implemented.

G. FURTHER WORK

1. On page 19, under the "Further Work" subsection of the Improvements/Recommendations section of the Audit Report, it was recommended that short-term monitoring (one day) of the kiln exit gas for CO2, H2O, CO, NO, and SO2 should be performed.

   Gifford-Hill and Company, Inc. had KVB, Inc. perform kiln exit gas monitoring for CO2, H2O, CO, NO, and SO2 on 8/29, 30/85.

2. On page 19, under the "Further Work" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that the LSI SM-810 NOx/SOx gas analyzer and the LSI CM-50 oxygen analyzer should be certified by KVB, Inc. as meeting EPA specifications.

   The Crestmore plant staff is using EPA protocol standard gases to perform dynamic calibrations on these instruments. At this time, Gifford-Hill and Company, Inc. does not feel that it is necessary to employ KVB Inc, to certify either instrument.

3. On page 20, under the "Further Work" subsection of the Improvements/Recommendations section in the Audit Report, it was recommended that a velocity traverse of the ID fan outlet should be performed in conjunction with the exit gas chemical analysis.

KVB, Inc. performed velocity traverses on 8/29/85 and 8/30/85 while also performing a kiln exit gas analysis.

Gerald L Young

Gerald L. Young
Production Engineer

ATTACHMENT A

AUDIT OF CURRENT NOx MONITORING PROJECT

PREPARED FOR:

GIFFORD-HILL & COMPANY, INC.
RIVERSIDE CEMENT
1500 RUBIDOUX BOULEVARD
RIVERSIDE, CA 92502

PREPARED BY:

KVB, INC.
18006 SKYPARK BOULEVARD
IRVINE, CA 92714

SEPTEMBER 3, 1985

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FIGURES

TABLES

INTRODUCTION/PROGRAM OBJECTIVES

KVB was retained by Riverside Cement to perform a complete and thorough audit of all activities at the Riverside Cement plant related to the requirements of SCAQMD Rule 1112 for NO_x emissions. The audit was to include an examination of all equipment, procedures, calibrations and calculations that lead to the expression of pounds of NO_x per ton of clinker. Another objective of KVB's audit was to review the quality control documentation and staff procedures in comparison with regulatory agency specifications. Riverside Cement has prepared a preliminary draft of a quality assurance plan documenting the field input signals used in the calculations and procedures to zero and calibrate the instrumentation.

This report details the methods and results of the audit, identifying the areas which are currently deemed acceptable and recommending modifications where necessary to improve the quality of the data.

SUMMARY OF AUDIT METHODS

An audit checklist of the five field signals and measurements as input to the pounds NO_x per ton of clinker calculation is shown in Figure 1. The initial plan was to perform a zero and span check on all five measurements but time constraints did not allow for such a check. The most extensive work was conducted on the Lear Siegler SM 810 NO_x/SO_2 analyzer. Two full calibrations, a dynamic calibration and zero/span check were executed during the audit time period. The worksheets for the calibrations are shown in Appendices C-E. Zero and span checks for the Lear Siegler CM-50, coal feed Sankyo impact flowmeter and kiln feed Sankyo impact flowmeter were performed prior to the audit period and are included in the appendices.

KVB received several data packages from the Crestmore plant regarding supporting documentation for the NO_x program. A summary of those data packages received is shown in Table 1. The key information received were the

Figure 1. Audit Checklist (July 24-August 2, 1985)

	Yes	No	If Yes, Which Date(s)	If No, Reason(s)	Any Other Data Available	Reference
Lear Siegler SM-810						
• Zero and Span Check	X		8/3		6/26-8/2/85	Appendix E
• Full Calibration	X		7/25-7/26 7/29-7/30			Appendix F
• Dynamic Calibration w/Certified Gas	X		7/29-7/30			Appendix G
• Multipoint Check with Appropriate Standards to Prove Linearity and Accuracy of the Output Signal		X		No calibrated flowmeters for diluting primary standard gas	---	---
• 24 Hour Drift Test	X		7/30-8/1			Appendix H
Lear Sigler CM-50						
• Zero and Span Check	X		8/2	Zero span--no info from manufacturer		Appendix I
• Full Calibration		X		time constraints	---	
• Dynamic Calibration		X			---	
• Multipoint Check with Appropriate Standards to Prove Linearity and Accuracy of the Output Signal		X			---	
• 24 Hour Drift Test		X			---	
Coal Feed Sankyo Flowmeter						
• Zero and Span Check		X			7/18, 7/23, 7/24	Appendix J
• Full Calibration		X		Kiln not offline		
Kiln Feed Sankyo Flowmeter						
• Zero and Span Check		X			7/18	Appendix K
• Full Calibration		X		Kiln not offline	---	
• Certified Weights for Calibration		X				Appendix L
Differential Pressure Water Spray Flowmeter						
• Zero and Span Check		X		Kiln not offline		

TABLE 1. QA NOx PLAN INFORMATION RECEIVED FROM GIFFORD-HILL CRESTMORE PLANT

1. Listing of computer program with supporting calculations and assumptions for determining pounds NO_x/ton clinker.
2. Floppy disk with computer program described above.
3. Q/A Plan with full calibration worksheets.
4. Completed zero and span worksheets for kiln feed, coal feed, NO_x, SO_x, O_2
5. 8-Hour Statistical Report and 8-Hour averaging (including pounds NO_x/ton clinker, MMBtu/ton clinker, etc.)
6. 6-minute average for NO_x (pounds/ton clinker) for each hour of a 24-hour period with hourly averages and 24-hour average.
7. Three coal samples with ultimate analysis.
8. Twenty-four raw feed samples with ignition loss.
9. Three-page report prepared by Russ McMahn, including a suggested program for updating engineering constants.
10. Coal system diagram and mechanical flow diagram for feed and dust recovery.

CALCULATION OF POUNDS NOx/TON CLINKER

The computer program calculation of pounds NO_x/ton clinker depends on five signals supplied to the NO_x/Digilink/IBM-PC and nine engineering constants based on analyzed coal feed and kiln feed samples. The five field signals are listed below:

- ppm NO_x at the ID fan outlet (Lear Siegler SM 810)
- percent O_2 at the ID fan outlet (Lear Siegler CM-50)
- tons per hour kiln feed (Sankyo impact flowmeter)

- tons per hour coal feed (Sankyo impact flowmeter)
- gallons per minute kiln exit water spray (differential pressure flowmeter)

Specifications on the equipment and field signal inputs is shown in Table 2.

The nine engineering constants have been identified as the coal ultimate analysis (% C, % H, % N, % O, % S), as fired coal moisture, kiln feed moisture and the kiln feed to clinker ratio. The current values being used in the computer program are shown in Table 3. The measurement uncertainty and analysis frequency is also shown in Table 3.

The program (Appendix A) systematically calculates the flue gas mass flow rate (combustion + calcination + excess air) in pounds per minute under several operating conditions. These operating conditions include stoichiometric conditions (no excess air), kiln exit (with excess air), ID fan outlet (excess air plus moisture from kiln exit water spray). The flue gas mass flow rate at the ID fan outlet is converted into a volumetric flow rate (both wet and dry at standard conditions) using the perfect gas law. Clinker rate is calculated with the kiln feed rate measurement with adjustments made for feed moisture and the evolution of CO_2 during the calcination process.

The original equation for pounds NO_x per ton of clinker was based on a dry NO_x measurement rather than a wet measurement. Since the Lear Siegler SM 810 measures NO_x and SO_2 on a wet basis, the volumetric flow rate under standard conditions should also be on a wet basis to calculate pounds NO_x per ton of clinker. A modification was made to the program (7/25/85) to change the molecular weight of the flue gas at the ID fan exit to 31.11 (wet basis) and 32.42 on a dry basis (used to calculate pounds NO_x per ton of clinker.) However, the use of flue gas molecular weight in these equations is incorrect, as discussed in Appendix B. The molecular weight of NO (30) should be used at this point in the calculation. The program should be scrutinized for those constants (e.g. molecular weight of flue gas at ID fan exit) which will vary because of a change (e.g. kiln feed or ignition loss).

TABLE 2. SPECIFICATIONS ON FIELD SIGNAL INPUTS NEEDED TO CALCULATE POUNDS NO_x PER TON CLINKER

	Coal Feed	NO_x ID Fan Inlet	Kiln Feed	Kiln Water Spray	O_2 ID Fan Inlet	Comments
Manufacturer	SANKYO	LEAR SIEGLER	SANKYO	FOXBORO	LEAR SIEGLER	
Model No.	ILE-61	SM810	ILE-61	?	CM50	
Measurement Method	impact flowmeter with a strain gauge to measure arm deflctn	Second derivative spectroscopic measurement	impact flowmeter with a strain gauge to measure arm deflecti	differential pressure flowmeter		
Range	0-15 tph	0-1500 ppm	0-110 tph	0-100 gpm	0-25%	
Manufacturer's Stated Accuracy	±1%	within 20% of EPA ref. method value where measurement values are at least 30% of the maximum measurement range	±1% to full scale	±1-2%	±1%	factory adjustments to match buffered current output are made with better than .1% full scale accuracy
Type of Signal	10-50 ma	4-20 ma	10-50 ma	10-50 ma	4-20 ma	
Calibration Method	material flowrates using Known weight of material	Zero and span cells; accuracy of span cells ±2-5%	Kiln feed is run over the Sankyo, diverted into a truck and the truck is weighed on a certified scale	Span check by applying Known pressure to positive side of transmitter using ammeter and adjusting milliamp signal appropriately	Zero and span cells; zero and span cells accuracy ±5%	Calibration error of NO_x within 5% of calibration gas value for values greater than 30% of maximum measurement range
Loop Number	62	11A	19	13	11C	
Digilink Channel	305	102	114	313	104	
Digistrip Channel	112	110	204		112	
Calibration Freq.		zero and span check once a day	Kiln off line	Kiln off line	Zero and span check once daily	
Repeatability	±.2%		±.2%			

TABLE 3. GIFFORD-HILL - CRESTMORE PLANT
Updated Engineering Constants (August 1, 1985)

	n	$\overline{x}$	s	CI95	Current Sampling Analysis Frequency	Measurement Uncertainty	Reference Method Measurement Uncertainty	Analysis by
Coal (As Fired)								
% C	2	70.55	-	-	represents monthly composite for April and May of 1985	± 0.3%	ASTM	Commercial Testing
% H	2	5.20	-	-		± 0.07%	ASTM	
% N	2	1.49	-	-		± 0.05%	ASTM	
% O	2	10.31	-	-		± 0.5%	ASTM	
% S	2	.67	-	-		± 0.10%	ASTM	
% Ash	2	9.12	-	-		-		
% H_2O	2	2.50	-	-		-		
Raw Feed (Type II)								
Ignition Loss, %	24	34.19	.49	.21	Once a shift	± 0.1 absolute	ASTM	Riverside Cement
% H_2O	-	.4	-	-	daily composite	-	-	Riverside Cement
KFLOI*	24	1.52						

n = number of samples: $\overline{x}$: mean; s = standard deviation; CI95 is the 95% confidence level

Note: Ignition loss shown is used in the computer program.
Ultimate analysis of the coal shown is not used in the computer program.

$$^{*}\ \frac{1}{1 - \frac{\text{Ignition Loss}}{100}} \equiv \text{KFLOI}$$

The calculation of wet standard cubic feet per minute at the ID fan exit is complicated by the fact that the engineering constants may not reflect the current raw feed/coal feed composition. The engineering constants used in this original program were not documented properly in terms of coal source, time when analyzed, number of samples analyzed, standard deviation, etc. A look at the program shows that these engineering constants are used repeatedly to calculate mass and volumetric flow rates. Updating these engineering constants will lend more credibility to the pounds NO_x/ton clinker value.

An update was made on 7/25/85 regarding the kiln feed to clinker ratio. The mean value was changed from 1.6 to 1.52 to reflect the change in loss of ignition values of the raw feed. The new loss on ignition value was based on 24 daily composite samples from 6/14/85 to 7/16/85 (mean value of 35.2 percent with a standard deviation of 0.49 percent). The number of samples collected and analyzed provide a good statistical indication of variability (coefficient of variation of 1.4 percent). No updates have been made regarding the "engineering constants" since only two coal analyses are currently available.

The California Air Resources Board/South Coast Air Quality Management District has based the pounds NO_x per ton of clinker on a measured volumetric basis for NO_x (ppm), a dry flue gas flow rate at standard conditions (68°F and 29.92 inches of mercury) and the clinker rate in tons per hour. The expression for pounds NO_x per ton of clinker is as follows:

$$\frac{(\mathrm{PPM}_v\ \mathrm{NO}_x) \times (46\ \mathrm{grams/mole}) \times (1.56 \times 10^{-7}) \times (\mathrm{SDCFM})}{\mathrm{Ton/hour\ of\ clinker}}$$

The expression requires three inputs (NO_x ppm_v as measured, standard dry* cubic feet per minute flow rate and tons/hour clinker). The present Riverside Cement equation for "NOLB" (C[26]) should be written as above*. The IBM program should be restructured so that each element required for the equation is clearly developed from inputs in an understandable way. (Appendix B, pages B-17, B-18).

---

*If NO_x ppm_v is on wet basis, the wet flow rate should be used.

KVB has revised the combustion equations for the Riverside Cement IBM program. The revisions are shown in Appendix B. For the same input values, the IBM program calculates 3.5230 pounds NO_x per ton of clinker compared to 3.6605 pounds NO_x per ton of clinker based on the revised equations. The difference between the two calculated values is 3.8 percent.

Each of the inputs to the calculated pounds NO_x per ton of clinker value was varied by one percent to see the effect on the calculated value. For example, the kiln feed loss on ignition number was varied by one percent while holding all other inputs constant. The pounds NO_x per ton of clinker increased by 1.27 percent. The effect of each input variable on the calculated NO_x value is shown in Appendix C. The three most significant factors affecting the NO_x value are the kiln feed loss on ignition, NO_x ppm and kiln feed rate.

In lieu of a stack gas flow rate determination with a pitot tube or a permanent in-situ flowmeter, the suggested approach for determining the pounds NO_x per ton of clinker should be that of the new computer program (see Appendix A for identification of the new program). The program is more straightforward and direct in calculating the pounds NO_x per ton of clinker. However, the program should be modified to calculate standard dry cubic feet per minute from lb moles wet flue gas per minute. Also, the percent moisture in the flue gas should be calculated to determine NO_x, on a dry basis. The conversion of NO_x to a dry basis and the moles per minute of flue gas to a standard dry cubic feet per minute basis will then be on a common basis to the 1112 rule.

LEAR SIEGLER SM 810 NOx/SO_2 ANALYZER

A full and dynamic calibration (as described in the quality assurance plan) was performed on the Lear Siegler SM 810 NO_x/SO_2 analyzer. The full calibration is a rather involved process; essentially (1) peaking the SO_2 and NO signal; (2) adjusting the output drive signal which interacts with linearity and the zero and span adjustments in the control unit; (3) adjusting the d2 zero which compensates for inherent offsets and those coming from the transceiver; (4) adjusting the temperature compensation board multiplier to 1.0 at 75°F and 3.65 at 800°F; (5) adjusting the integrator sample/hold board for a multiplication factor of 1.075 at 75°F and 2.74 at 800°F. Some of the difficulties with the full calibration are listed below:

Item 3 & 4:

> It is very difficult to read the scanner frequency accurately with the oscilloscope and checking for symmetrical half waveforms. A new oscilloscope is being purchased to alleviate these problems.
>
> Some SO_2 adjustments must coincide with the LSI SM 810 reading SO_2 rather than NO and some NO adjustments must coincide with the LSI SM 810 reading NO rather than SO_2.

After the full calibration was completed on Friday July 26, a dynamic calibration was run during the following Monday afternoon. The SO_2 span gas is a certified grade with 52 ppm, balance N_2 and the NO span gas was a primary standard grade with 1019 ppm, balance N_2. The flow plateau check was run from 0-2.5 liters/minute on SO_2 and from 0-4.5 liters/minute on NO. The SO_2 readings at 2.5 liters/minute were approximately 25-28 ppm and the NO readings at 2.5 liters/minute were approximately 690 ppm. The low readings prompted a rerun of the full calibration on the following day. The major reason for the low span value readings of the previous day was the Lear Siegler temperature sensor erroneously reading the flue gas temperature as being 420°F rather than 520°F. The thermocouple at the transceiver bulkhead was disconnected and the thermocouple probe temperature was read with a digimite temperature recorder. The multiclone outlet and the baghouse inlet temperatures (525°F and 528°F respectively) were also read to determine a realistic temperature associated with the Lear Siegler SM 810 analyzer position. The baghouse inlet temperature wire signal is now being used for the voltage representing the temperature recorded. R-72 was adjusted at the transceiver to receive the proper voltage [(525/800) x 10 volts] at TP-16. After the full calibration was completed, another dynamic calibration of the Lear Siegler SM 810 NO_x/SO_2 analyzer was performed. The results of the dynamic calibration show much better correlation of the span gas values with the instrument values. The NO_x value was 970 ppm prior to adjustment with R-2 and the SO_2 value was approximately 40-44 ppm prior to adjustment. On the following day (7/31/85), another dynamic calibration was performed to determine how much drift had occurred in a 24-hour period. The NO_x reading was 1032 ppm (1.3 percent higher than the span value and the SO_2 reading was 36 ppm (30.8 percent lower than the span value).

The SO_2 and NO span gases were also used as each other's zero gas. It is not evident from the manufacturer's users guide what type of interference would result from using a 52 ppm SO_2 gas, balance N_2 to zero the NO or what type of interference would result from using a 1019 ppm NO gas, balance N_2 to zero the SO_2. In any case, a dry N_2 zero gas is recommended as the zero gas.

The linearity of the LSI SM 810 analyzer was not checked prior to the audit or during the audit. Calibrated flowmeters were unavailable at the time to perform the linearity check.

Although the span cells for the LSI SM 810 are certified by the manufacturer to an accuracy of ±2-5 percent, these span cell values changed considerably when the dynamic calibration was performed. The NO front panel meter readings were between 510-516 ppm prior to dynamic calibration/full calibration and the NO internal span cell value is listed as 516 ppm. The NO value for the internal span cell was 20 percent lower prior to dynamic calibration. After dynamic calibration, the NO internal span cell value was now up to 645 ppm.

KILN FEED CALIBRATION AND CLINKER PRODUCTION

To date, the Crestmore facility has conducted two six hour tests (July 16, 1985 and July 24, 1985) weighing clinker with certified scales and then comparing the total clinker weighed versus what is expected from the measured kiln feed rate. Kiln feed rate is measured with a Sankyo impact flowmeter. Ignition loss and moisture loss are included with kiln feed rate in the calculation of clinker rate. The first test showed that the total clinker weighed was approximately nine percent more than expected from the kiln feed. The production factor used was 1.6 pounds dry feed per pound of clinker. A second six-hour test was conducted with a new production factor. The production factor update was 1.52 pounds dry feed per pound of clinker. This updated factor was based on 24 raw feed samples collected between 6/14/85 and 7/16/85 and the new average ignition loss value. This time, the total clinker weighed was approximately three and one half percent more than expected from the kiln feed.

The correlation between the clinker production and the kiln feed helps validate the kiln feed rate being used in the pounds NO_x per ton clinker calculation. Since the location of the Sankyo impact flowmeter to the clinker weigh box is approximately four hours travel time, it is recommended that raw feed samples be collected approximately four hours prior to the start of the clinker weighing. A sample every half hour (12 samples total) would provide a good data base from which to base an ignition loss and moisture loss calculation. The pounds dry feed per ton of clinker would be a more up-to-date value for the test and may explain a partial variation in the previous two tests.

RIVERSIDE CEMENT QA PLAN

The Riverside Cement preliminary draft QA plan was reviewed by KVB. The plan was examined for quality control documentation and staff procedures in comparison with regulatory agency specifications. An outline of the preliminary draft was prepared by KVB (shown as Table 4) to highlight the organization and the contents of the report. The basis for reviewing the report is the EPA Quality Assurance Handbook EPA 600/9-76-005. The Handbook identifies twelve specific areas which should be addressed in a quality assurance plan. Each of the twelve areas is listed in Table 5 and whether or not these areas have been addressed in part in the Riverside Cement QA plan.

The QA plan has been very well documented in calibration procedures and sampling and analysis procedures. The frequency of calibration with calibration worksheets as documentation is a good approach for updating the validity of the measurements. However, the plan does not adequately address the data analysis, validation and reporting aspects. Also, the procedures for calculating the engineering constants and a plan to update these constants were not addressed.

QUALITY ASSURANCE CHECKLIST

Based on the findings of the audit, a set of quality assurance checklists was devised to pursue the quality assurance objectives. The

TABLE 4. RIVERSIDE CEMENT COMPANY
NO_x PROJECT QUALITY ASSURANCE PROGRAM

I. INTRODUCTION

- Purpose
- Precision, accuracy, completeness (75 percent)

II. RELATIVE IMPORTANCE OF MEASUREMENTS

- Field signals used for calculating pounds NO_x/ton clinker
- Field signals which might correlate with pounds NO_x/ton clinker
- Field signals used for information on kiln operation

III. FREQUENCY OF CALIBRATION

- Daily zero/span of NO_x/SO_2 analyzer and O_2 analyzer at ID fan
- Weekly zero/span of Bailey O_2 analyzer
- Monthly zero/span of coal feed to kiln
- When kiln is down, flowmeter on exit gas water spray and kiln feed

IV. METHODS FOR ZERO/SPAN CHECKS AND FULL CALIBRATIONS

A. Lear Siegler SM 810 NO_x/SO_2 Gas Analyzer
  - Zero/span
  - Full calibration
  - Dynamic calibration

B. Lear Siegler CM-50 Oxygen Analyzer
  - Zero/span check
  - Full calibration

C. Sankyo Impact Flowmeter
  - Zero/span check (kiln feed and coal to kiln)
  - Full calibration

D. Pressure Transmitter
  - Zero/span check
  - Full calibration

TABLE 5. QA PLAN CHECKLIST* FOR RIVERSIDE CEMENT - CRESTMORE PLANT

	In Current Plan			Notes/Recommendations
	Yes	No	Partially	
Project Description	X			
Project Organization and Responsibilities	X			Identify the people responsible for various aspects of quality assurance
QA Objectives (precision, accuracy, completeness, representativeness.			X	Only completeness is quantified (75%). Precision and accuracy are defined but not quantified for the field signals, engineering constants and calculations. Representativeness and comparability should be addressed as well.
Sampling and Analysis Procedures	X			Sampling procedure for the NO_x, O_2, is very well covered. Sampling and analysis of the coal feed/kiln feed analyses should also be addressed.
Sample Custody		X		This would involve primarily the collection and analysis of raw feed and coal samples. A brief discussion of how the data are handled is recommended (i.e., Digilink microprocessor/IBM personal computer.)
Calibration Procedures	X			Very well covered by sections III and IV (frequency of calibration and methods for zero/span checks and full calibrations). Identify equipment used during the full calibration. (Is this equipment calibrated against a standard?) Training procedure for those involved during the full calibration.
Data Analysis, Validation, Reporting		X		A discussion of the equations/assumptions used to calculate pounds NO_x per ton of clinker is recommended.
Internal Quality Control Checks	X			Comparing kiln feed rate with clinker weighings (certified scale) with the production factor is a good quality control check. Certification of the LSI SM 810 will lend more credibility to the NO_x values.

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*EPA Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I Principles EPA/600/9-76-005, December 1984.

TABLE 5. (CONTINUED)

	In Current Plan			Notes/Recommendations
	Yes	No	Partially	
Performance and System Audits		X		Currently being performed by KVB.
Routine Assessment of QA Objectives			X	Reviewing the goals set forth in the QA objectives and the means to attain these goals. QA checklist will help.
Corrective Action			X	Examples would be zero/span, full calibration, dynamic calibration of the LSI SM 810, updating engineering constants in the computer program, calibrating Sankyo kiln feed flowmeter with clinker weighings.
Quality Assurance Reports to Management		X		It may be useful to prepare a periodic report documenting the steps taken to maintain as accurate and precise a pounds NO_x per ton of clinker value.

checklist shown as Attachment A divides the tasks into a timeframe basis (i.e., daily, weekly, monthly, every three months, or when the kiln is offline). The checklist identifies the importance of daily data validation and checking the values for any anomalies. The data checks should include all instrument measurements for calculating pounds NO_x per ton of clinker. Zero and span checks for the NO_x and O_2 are important in case any significant 24-hour drifts in the zero and span do occur. Since the Lear Siegler NO_x value is very much temperature dependent, the baghouse inlet temperature's signal currently used to temperature compensate the signal should be monitored daily. The weekly checklist includes dynamic calibration of the Lear Siegler SM810 and an updating of the engineering constants.

IMPROVEMENTS/RECOMMENDATIONS

Calculations

- For existing program
  - Scrutinize further the program equations and assumptions used in the program.
  - Update the engineering constants used in the computer program on a weekly basis (including kiln feed ignition loss, moisture of the pulverized coal delivered to the burner, kiln feed moisture, coal ultimate analysis).
  - Calculate a weekly rolling average for the engineering constants based on kiln feed/coal analyses.
  - Use 385.2 rather than 379.48 standard dry cubic feet per mole gas.
  - Change molecular weight of flue gas used in the "bottom line" NO_x pounds per clinker to a wet basis since NO_x, ppm and the flow rate (scfm) are on a wet basis.
  - Recalculate the current engineering constants to reflect the as-fired coal moisture of 2.5 percent, rather than 1.0 percent.
- For new program
  - Restructure IBM program to calculate each element of the Rule 1112 equation in a clear and understandable manner.

Raw Feed/Coal Feed Samples

- Collect enough samples to calculate a statistically meaningful mean and standard deviation.

ATTACHMENT A
QUALITY ASSURANCE CHECKLIST

	Completed		When	Comments
	Yes	No		
Daily Basis				
• Data Validation (document any suspicious-looking data) - Instrument Calibration - Instrument Repair - Kiln Offline - Kiln Startup - Kiln Shutdown - Coal Offline				
• Zero and span check of Lear Siegler NO_x Analyzer and Lear Siegler O_2 Analyzer; if necessary dynamic calibration.				
• Check baghouse inlet temperatures for any anomalies.				
• Signal output checks.				
Weekly Basis				
• Dynamic calibration of NO_x and O_2 analyzers.				
• Update engineering constants based on kiln feed analyses and coal analyses as need be.				
Monthly Basis				
• Coal feed to Sankyo flowmeter.				

ATTACHMENT A (CONTINUED)

	Completed		When	Comments
	Yes	No		
Three-Month Basis				
• Full Calibration Lear Siegler SM810				
• UV Lamp Replacement Lear Siegler				
Kiln Off Line				
• Kiln Feed Flowmeter				
• Kiln Exit Water Spray				

Lear SM 810 NO_x/SO_2 Analyzer

- Certify the monitor.
- Perform 2-hour and 24-hour drift tests over a several day period.
- Perform dynamic calibration of the analyzer after the full calibration to ensure the full calibration is successful.
- Check multipoint linearity (as a minimum 0 ppm, 500 ppm, 1000 ppm).
- Revise full calibration/dynamic calibration section of the QA manual to reflect changes noted during the two full calibrations of 7/25-7/26/85 and 7/29-7/30/85.
- Use certified nitrogen zero gas to zero the LSI SM 810 rather than SO_2 gas to zero NO and vice versa.
- Add to the zero and span checklist and full calibration/dynamic calibration any auxiliary equipment used to complete the calibration (i.e., ID equipment model, next cal date, accuracy, calibrated value.)

Kiln Exit Water Spray Flowmeter

- Replace the differential pressure flowmeter with a turbine flowmeter for better accuracy (currently being implemented by the plant).

Kiln Feed Sankyo Impact Flowmeter

- Collect several kiln feed samples prior to and during the course of clinker weighings to calculate an up-to-date ignition loss.
- The weight checks should be run at least once every time the kiln is down.

FURTHER WORK

- Short-term monitoring (one day) of the kiln exit gas volume for CO_2, H_2O, CO, NO, SO_2 should be performed. KVB will provide a mobile laboratory to measure these flue gas components enabling a dry and wet molecular weight to be calculated. Also, the NO concentration measured on a wet basis by the Lear Siegler SM 810 can be compared to the NO concentration measured on a dry basis by the Thermo Electron 10A Chemiluminescent Analyzer. The accuracy and precision of the current methods used to calculate pounds NO_x per ton of clinker can be crosschecked with a complete flue gas analysis at the ID fan outlet.
- Monitor Certification of the LSI SM 810 and CM-50 analyzers.

- Velocity traverse of the ID fan outlet with the flue gas analysis at the ID fan outlet will enable a stack gas flow rate to be calculated. The pounds NO_x per ton of clinker based on a measured gas flow rate can then be compared to calculations using the current methodology.

APPENDIX A

COMPUTER PROGRAM TO CALCULATE POUNDS NOx PER TON OF CLINKER

```
***********************************************************************
****    HTBALC.SYM    CCD    06-05-1985    ****
***********************************************************************

1  **************  HEAT BALANCE OF KILN/COAL MILL  ***************
2 '
0 'E(1)=.01
0 C(1)=(VM(37)*2000/60)*(1-E(1))
0 'E(2)=.7305
0 'E(3)=.0543
0 'E(4)=.0095
0 'E(5)=.1057
0 'E(6)=.0933
0 C(2)=E(3)-(E(5)/7.937001)
0 'E(7)=.0065
0 '
1 '****************  REQ. FOR COMB. AT 0% EXCESS O2  ***************
2 '
0 C(3)=(2.664*E(2)+7.936001*C(2)+1.142*E(4)+.998*E(7))*C(1)
0 C(4)=3.2543*C(3)
0 'C(3)=952.8313
0 C(5)=.0579*C(3)
0 C(6)=.01495*C(3)+VM(37)*E(1)*2000/60+(E(5)*8.936001/7.937001)*C(1)
0 C(7)=C(1)*E(6)
0 C(8)=4.3271*C(3)
0 C(9)=C(6)+8.936001*C(2)*C(1)
0 C(10)=3.664*E(2)*C(1)+VM(14)*(1-E(11))*(1-1/E(13))*100/3
0 C(11)=C(8)*10.73*520/(14.696*28.9)
   12)=VM(13)*(C(4)/28.013+C(10)/44.01+C(5)/39.675)/(100/32-VM(13)*.14888)
0 IF VM(13)>20 THEN C(12)=1000
0 C(13)=4.3271*(C(3)+C(12))
0 C(14)=1000:IF C(1)<1 THEN 2360
0 C(14)=C(13)/C(1)
0 C(15)=1000:IF C(3)<1 THEN 2380
0 C(15)=C(12)*100/C(3)
0 C(16)=(C(12)/32!+(C(4)+3.2543*C(12))/28.013+C(10)/44.01+(C(5)+.0574*C(12))/39.675+C(9)/18.015)
0 C(17)=C(16)*379.48
0 C(18)=21:IF C(16)<1 THEN 2420
0 C(18)=(C(12)/32!)*100/C(16)
0 C(19)=.20874*((C(16)+(VM(45)*8.3453/18.015))*(VM(4)/100)-(C(16)*C(18)*.01))/(.20874-VM(4)/100)
0 IF C(19)>1000 THEN C(19)=1000
0 C(20)=C(12)+C(19)*32!
0 C(21)=C(16)-(C(9)/18.015)+C(19)*(1+(.77598+9.739999E-03)/.20874)
0 C(22)=C(21)+(VM(45)*8.3453+C(9))/18.015
0 C(23)=C(22)*379.48
0 C(24)=((VM(2)*14.696*32.4/(10.73*520))*.000001)*C(21)*379.48
0 C(25)=C(24)*46/30.01
0 C(26)=0:IF VM(14)=0 THEN 2510
2 C(26)=C(25)/(VM(14)*(1-E(11))*(1/E(13))/60)
0 IF C(26)<0 THEN C(26)=0
0 C(27)=1000:IF VM(37)<1 THEN 2540
0 C(27)=C(25)/((VM(37)*(1-E(1))*(2000/60)*E(12)))*.000001
0 C(28)=21:C(29)=0:IF C(21)<1 THEN 2570
0 C(28)=(C(20)/32)*100/C(21)
   29)=VM(2)*(19/(21-C(28)))
0 C(30)=100:IF C(16)<1 THEN 2590
0 C(30)=((C(19)/.20874)*28.9/(C(16)*31.74))*100
0 '
```

[C] Matrix   1/4

```
1 '*************** COAL MILL BALANCE *****************
2 '
0 C(31)=VM(44)*100/3
0 C(32)=(VM(44)-VM(37))*100/3
  (33)=10.4*VM(48)-295.9
  (34)=C(33)-C(32)-6.7124
0 C=VM(40)
0 C(35)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3+6.951E-13*C^4-7.6193
0 C=VM(42)
0 C(36)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
0 C(37)=.4421*C+2.434E-05*C^2+1.0636E-08*C^3-2.043E-12*C^4-14.172
  C(38)=VM(1)+30
0 C=C(38)
0 C(39)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
0 C=VM(38)
0 C(40)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
0 C(41)=C(1)*(C(38)-32)*.3
  C(42)=C(31)*.0795973
60 C(43)=C(42)*(C(38)-32)
70 C(44)=C(41)+C(43)
80 C(45)=C(1)*(140-32)*.3
90 'E(8)=454
0 C(46)=C(34)*C(36)
0 C(47)=C(32)*971.3
20 C(48)=C(32)*C(37)
30 C(49)=C(45)+E(8)+C(46)+C(47)+C(48)
40 C(50)=100:IF C(39)=C(35) OR C(34)<1 THEN 2860
50 C(50)=(C(49)-C(44)-C(34)*C(35))*100/(C(34)*(C(39)-C(35)))
0 C(51)=1000:IF C(40)=C(39) THEN 2880
  C(51)=C(34)*(C(35)-C(39))/(C(40)-C(39))
  (52)=100:IF C(42)<1 THEN 2900
90 C(52)=C(32)*100/C(42)
00 '
01 '****************** CLINKER COOLER BALANCE ********************
2 '
10 C(53)=VM(17)*100/122
20 C(54)=VM(18)*100/112
30 C(55)=VM(19)*100/91.5
40 C(56)=VM(20)*100/127
50 C(57)=VM(21)*100/188
0 C(58)=.07:IF VM(1)>400 THEN 2980
70 C(58)=38.396/(460+VM(1))
80 C(59)=0:IF C(53)<2 THEN 3000
90 C(59)=VM(17)*1.8868E-05*(460+VM(1))*(7.49*LOG(C(53))+57.66)*(.0002*C(53)+.88)
00 C(60)=0:IF C(54)<2 THEN 3020
10 C(60)=VM(18)*1.9153E-05*(460+VM(1))*(7.49*LOG(C(54))+57.66)*(.0002*C(54)+.88)
0 C(61)=0:IF C(55)<2 THEN 3040
30 C(61)=VM(19)*1.7537E-05*(460+VM(1))*(6.15*LOG(C(55))+63.1)*(.0002*C(55)+.8750001)
40 C(62)=0:IF C(56)<2 THEN 3060
50 C(62)=VM(20)*1.6622E-05*(460+VM(1))*(7.49*LOG(C(56))+57.66)*(.0002*C(56)+.88)
60 C(63)=0:IF C(57)<2 THEN 3080
70 C(63)=VM(21)*1.6608E-05*(460+VM(1))*(7.39*LOG(C(57))+58.39)*(.0003*C(57)+.88)
0 C(64)=476*C(59)-19620:IF C(59)>75 THEN 3100
90 C(64)=305*C(59)+1.3*((C(59)-62.5)^2)-6671
00 C(65)=235.3*C(60)-2624
(   (66)=312.9*C(61)-6033
20 C(67)=632*C(62)+10.8*((C(62)-83)^2)-25690:IF C(62)>75 THEN 3140
30 C(67)=447.4*C(62)-11281
0 C(68)=965*C(63)+12.5*((C(63)-117.5)^2)-58460!:IF C(63)>110 THEN 3160
50 C(68)=652.3*C(63)+3.1*((C(63)-90)^2)-24716
```

```
60 C(69)=0:IF VM(34)<1.5 THEN 3180
70 C(69)=EXP(LOG(VM(34)/.00005)/1.75)
80 C(70)=VM(14)*(1-E(11))*(1/E(13))*100/3
90 C(71)=(C(64)+C(65)+C(66)+C(67)+C(68))*C(53)
00 C(72)=C(71)-C(51)-C(69)
   'E(9)=639.0741
10 C(73)=.2057*VM(29)+.0000217*((VM(29)-340)^2)-9.82
30 C(74)=C(70)*E(9)
40 C(75)=C(71)*C(39)
50 C(76)=C(70)*C(73)
60 C(77)=.1*(C(74)+C(75))
70 C(78)=C(51)*C(40)
80 C(79)=C(69)*C(36)
90 C(80)=1000:IF C(72)<10 THEN 3310
00 C(80)=(C(74)+C(75)-C(76)-C(77)-C(78)-C(79))/C(72)
10 C(81)=0:IF C(80)<-1000 THEN 3330
20 C(81)=(-.2383+SQR((.2383^2)+4*4.979E-06*C(80)))/(2*4.979E-06)
30 C(82)=0:IF C(74)+C(75)<1000 THEN 3350
40 C(82)=(C(78)+C(72)*C(80))*100/(C(74)+C(75))
50 C(83)=0:C(84)=0:C(85)=0:C(86)=0:C(87)=0:IF C(70)<10 THEN 3410
60 C(83)=C(71)/C(70)
70 C(84)=C(72)/C(70)
80 C(85)=C(51)/C(70)
90 C(86)=C(69)/C(70)
00 C(87)=C(83)+C(84)+C(85)+C(86)
10 '
11 '********************  KILN BALANCE  *************************
12 '
20 C(88)=4.75*VM(31)-61.1
30 C(89)=-2.31*VM(27)+158.1
   C(90)=C(13)-C(72)-C(88)-C(89)
50 C(91)=0:IF C(72)<10 THEN 3470
60 C(91)=C(88)/C(72)
70 C(92)=0:C(93)=0:C(94)=0:IF C(13)=<10 THEN 3510
80 C(92)=C(88)*100/C(13)
90 C(93)=C(72)*100/C(13)
00 C(94)=C(90)*100/C(13)
10 C(95)=C(88)/.0763
20 C(96)=C(72)/.0763
30 C(97)=C(90)/.0763
40 C(98)=C(89)/.0763
50 C(99)=C(95)+C(96)+C(97)+C(98)
60 C(100)=VM(1)+70
70 C(101)=.2383*C(100)+4.979E-06*(C(100)^2)-7.619001
80 C(102)=(.21*C(100)-6.72)*.9000001+(.24*C(100)-7.68)*.1
90 C(103)=.3*(VM(1)+50)-9.600001
00 C(104)=VM(1)+50
10 C(105)=.4421*C(104)+2.4339E-05*(C(104)^2)-14.17
20 'E(10)=19.1
30 C(106)=.4421*C(100)+2.4339E-05*(C(100)^2)-14.17
40 C=VM(11)
50 C(107)=.2315*C+3.262E-05*C^2-6.0393E-09*C^3+5.6E-13*C^4-7.44
60 C(108)=(.21*C-6.72)*.9000001+(.24*C-7.68)*.1
70 C(109)=C(88)*C(39)
80 C(110)=C(89)*C(39)
90 C(111)=C(90)*C(101)
   C(112)=C(72)*C(80)
10 C(113)=C(1)*E(12)
20 C(114)=C(1)*C(103)
30 C(115)=VM(14)*(1-E(11))*C(102)*100/3
```

```
0 C(116)=VM(14)*E(11)*C(108)*100/2
0 C(117)=VM(45)*8.3453*E(10)
0 C(118)=C(109)+C(110)+C(111)+C(112)+C(113)+BH+C(114)+C(115)+C(116)+C(117)
0 C(119)=1000:IF C(113)+C(112)<1000 THEN C(23)=0:GOTO 3790
  C(119)=C(112)*100/(C(113)+C(112))
  .120)=C(16)*31.73655
0 C(121)=C(120)*C(107)
0 C(122)=C(120)*C(108)*.3
0 C(123)=VM(45)*8.3453*971.3
0 C(124)=C(70)*E(9)
  C(125)=C(70)*1124
0 C(126)=C(121)+C(122)+C(123)+C(124)+C(125)
0 C(127)=C(118)-C(126)
0 C(128)=100:IF C(119)<1000 THEN 3890
0 C(128)=C(127)*100/C(118)
0 C(129)=0:IF VM(14)<1 THEN 3910
  C(129)=(VM(37)*(1-E(1))*2000*E(12)*E(13))/(VM(14)*(1-E(11)))
0 'E(14)=.35968
2 'E(15)=.35
0 C(130)=E(1)*2000/18.016
2 C(131)=(1-E(1))*2000*E(14)
4 C(132)=(C(130)+C(131))*VM(37)/60
  C(133)=E(11)*2000/18.016
2 C(134)=(1-E(11))*2000*E(15)/44.01
4 C(135)=(C(133)+C(134))*VM(14)/60
0 C(136)=VM(45)*8.34/18.016
0 C(137)=C(132)+C(135)+C(136)
0 C(138)=VM(4)*C(137)/(20.88-VM(4))
  C(139)=C(137)+C(138)
0 C(140)=(C(139)*VM(2)*46*60*E(13))/(VM(14)*(1-E(11))*1000000!)
    .TURN
```

[illegible] IC !

?

NO→NOX

?

Kiln raw feed

Kiln Feed moisture

6/3/95 JCI

? stoichiometric basis

E(14) = $\frac{\text{moles flue gas}}{\text{lb fuel}}$ (based on coal analysis)

E(15) = Kiln feed loss on ignition

E(1) = coal moisture

✓ VM(37) = Kiln coal feed, tph

E(11) = Kiln Feed Moisture

✓ VM(14) = Kiln raw feed, tph

✓ VM(45) = Back End cooling water spray, gpm

✓ VM(4) = NO ppm at ID fan inlet

✓ VM(2) = O_2, % at ID fan inlet

4 Engineering Constants
5 Inputs

```
50 AENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3+6.951E-13*C^4-7.6193
60 C=VM(42)
70 BENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
   ENT=.4421*C+2.434E-05*C^2+1.0636E-08*C^3-2.043E-12*C^4-14.172
90 AMB=VM(1)+30
00 C=AMB
10 DENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
20 C=VM(38)
30 EENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
40 AAA=DCOAL*(AMB-32)*.3
50 COALWAT=WCOAL*.0795873
60 BBB=COALWAT*(AMB-32)
70 J=AAA+BBB
80 CCC=DCOAL*(140-32)*.3
90 DDD=454
00 EEE=DAIR*EENT
10 FFF=WATER*971.3
20 GGG=WATER*CENT
30 ZZZ=CCC+DDD+EEE+FFF+GGG
40 CINF=100:IF DENT=AENT OR DAIR<1 THEN 2860
50 CINF=(ZZZ-J-DAIR*AENT)*100/(DAIR*(DENT-AENT))
60 CCAIR=1000:IF EENT=DENT THEN 2880
70 CCAIR=DAIR*(AENT-DENT)/(EENT-DENT)
80 MILLEFF=100:IF COALWAT<1 THEN 2900
90 MILLEFF=WATER*100/COALWAT
00 '************ CLINKER COOLER BALANCE***************
10 LLA=VM(17)*100/122
20 LLB=VM(18)*100/112
    LC=VM(19)*100/91.5
40 LLD=VM(20)*100/127.
50 LLE=VM(21)*100/188
60 DENS=.07:IF VM(1)>400 THEN 2980
70 DENS=38.396/(460+VM(1))
80 BHPA=0:IF LLA<2 THEN 3000
90 BHPA=VM(17)*1.8868E-05*(460+VM(1))*(7.49*LOG(LLA)+57.66)*(.0002*LLA+.88)
00 BHPB=0:IF LLB<2 THEN 3020
10 BHPB=VM(18)*1.9153E-05*(460+VM(1))*(7.49*LOG(LLB)+57.66)*(.0002*LLB+.88)
20 BHPC=0:IF LLC<2 THEN 3040
30 BHPC=VM(19)*1.7537E-05*(460+VM(1))*(6.15*LOG(LLC)+63.1)*(.0002*LLC+.875)
40 BHPD=0:IF LLD<2 THEN 3060
50 BHPD=VM(20)*1.6622E-05*(460+VM(1))*(7.49*LOG(LLD)+57.66)*(.0002*LLD+.88)
60 BHPE=0:IF LLE<2 THEN 3080
70 BHPE=VM(21)*1.6608E-05*(460+VM(1))*(7.39*LOG(LLE)+58.39)*(.0003*LLE+.86)
80 CFMA=476*BHPA-19620:IF BHPA>75 THEN 3100
90 CFMA=305*BHPA+1.3*((BHPA-62.5)^2)-6671
100 CFMB=235.3*BHPB-2824
110 CFMC=312.9*BHPC-6033
120 CFMD=632*BHPD+10.8*((BHPD-83)^2)-25690:IF BHPD>75 THEN 3140
130 CFMD=447.4*BHPD-11281
140 CFME=966*BHPE+12.5*((BHPE-117.5)^2)-58460!:IF BHPE>110 THEN 3160
150 CFME=652.3*BHPE+3.1*((BHPE-90)^2)-24716
160 CYCFLO=0:IF VM(34)<1.5 THEN 3180
170 CYCFLO=EXP(LOG(VM(34)/.000005)/1.75)
    CLINN=VM(14)*(1-.004)*(1/1.6)*100/3
    FANFLOW=(CFMA+CFMB+CFMC+CFMD+CFME)*DENS
200 SECFLO=FANFLOW-CCAIR-CYCFLO
210 ENTA=638.0741
220 ENTB=.2057*VM(29)+.0000217*((VM(29)-340)^2)-9.82
230 AAAA=CLINN*ENTA
```

KEY 2/4

```
0 CCCC=CLINN+ENTB
0 DDDD=.1*(AAAA+BBBB)
0 EEEE=CCAIR*EENT
  FF=CYCFLO*BENT
0 ENTHSEC=1000:IF SECFLO<10 THEN 3310
0 ENTHSEC=(AAAA+BBBB-CCCC-DDDD-EEEE-FFFF)/SECFLD
0 SECTEM=0:IF ENTHSEC<-1000 THEN 3330
0 SECTEM=(-.2383+SQR((.2383^2)+4*4.979E-06*ENTHSEC))/(2*4.979E-06)
  CODEFF=0:IF AAAA+BBBB<1000 THEN 3380
  CODEFF=(EEEE+SECFLO*ENTHSEC)*100/(AAAA+BBBB)
0 ARA=0:ARB=0:ARC=0:ARD=0:TOTAR=0:IF CLINN<10 THEN 3410
0 ARA=FANFLOW/CLINN
0 ARB=SECFLO/CLINN
0 ARC=CCAIR/CLINN
0 ARD=CYCFLO/CLINN
  TOTAR=ARA+ARB+ARC+ARD
0 '*************KILN BALANCE********************
0 PAIRA=4.75*VM(31)-61.1
0 TAIRP=-2.31*VM(27)+158.1
0 KILNINF=TAIR-SECFLO-PAIRA-TAIRP
0 HHH=0:IF SECFLO<10 THEN 3470
  HHH=PAIRA/SECFLO
0 III=0:JJJ=0:KKK=0:IF TAIR=<10 THEN 3510
0 III=PAIRA*100/TAIR
0 JJJ=SECFLO*100/TAIR
0 KKK=KILNINF*100/TAIR
0 LLL=PAIRA/.0763
  MMM=SECFLO/.0763
  NN=KILNINF/.0763
0 OOO=TAIRP/.0763
0 PPP=LLL+MMM+NNN+OOO
0 AMBB=VM(1)+70
0 AF=.2383*AMBB+4.979E-06*(AMBB^2)-7.619001
  AS=(.21*AMBB-6.72)*.9000001+(.24*AMBB-7.68)*.1
0 AI=.3*(VM(1)+50)-9.600001
0 AAMBB=VM(1)+50
0 AJ=.4421*AAMBB+2.4339E-05*(AAMBB^2)-14.17
0 AK=19.1
  AL=.4421*AMBB+2.4339E-05*(AMBB^2)-14.17
  C=VM(11)
0 AM=.2315*C+3.262E-05*C^2-6.0393E-09*C^3+5.6E-13*C^4-7.44
0 AN=(.21*C-6.72)*.9+(.24*C-7.68)*.1
0 BC=PAIRA*DENT
30 BD=TAIRP*DENT
  BE=KILNINF*AF
  BF=SECFLO*ENTHSEC
0 BG=DCOAL*12437
0 BI=DCOAL*AI
30 BJ=VM(14)*(1-.004)*AG*100/3
0 BK=VM(14)*.004*AL*100/3
  BL=VM(45)*8.3453*AK
50 BM=BC+BD+BE+BF+BG+BH+BI+BJ+BK+BL
70 KILNHET=1000:IF BG+BF<1000 THEN EESCFM=0:GOTO 3790
   ILNHET=BF*100/(BG+BF)
  NT=MOLEN*31.73665
0 CB=ENT*AM
  CC=ENT*AN*.3
0 CD=VM(45)*8.3453*971.3
30 CE=CLINN*ENTA
```

KEY 3/4

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M & E BALANCE

PLANT: ________ DATE: 4-29-84

PREPARED BY: ________ DISTRIBUTION: ________

Excess Oxygen: $O_2\%$ (dry)

$$\frac{\text{lbs } O_2 \text{ Excess}}{\text{Min}} = \frac{-\%\text{ stack } O_2 \left(\frac{\text{lb } N_2}{28.013} + \frac{\text{lb } CO_2}{44.01} + \frac{\text{lb Ar}}{39.675} + \overset{\text{Use if } O_2 \%(\text{wet})}{\left(\frac{\text{lb } H_2O}{18.015}\right)} + \frac{\text{lb NO}}{30.01} + \frac{\overset{\text{MOST Absorbed}}{\text{lb } SO_2}}{64.06} \right)}{-\frac{1}{32.00} + \%\text{ Stack } O_2 \underbrace{\left(\frac{1}{32.00} + \frac{3.2543}{28.013} + \frac{.0579}{39.675} + \left(\frac{.01495}{18.015} \right)_{(\text{if } O_2\% \text{ wet})} \right)}_{.148880 \text{ (dry)} \quad .149710 \text{ (wet)}}}$$

$\frac{\text{lb } O_2}{\text{lb } O_2}$ $\frac{\text{lb } N_2}{\text{lb } O_2}$

The products @ 0% O_2 - 0

$$\text{lb/M } O_2 \text{ Excess} = \frac{-\% O_2 (\text{dry}) \left(\frac{\text{lb } N_2}{28.013} + \frac{\text{lb } CO_2}{44.01} + \frac{\text{lb Ar}}{39.675} + \frac{\text{lb NO}^*}{30.01} \right)}{-\frac{1}{32} + \% O_2 \text{ dry} (.14888)}$$

* NO - either as N_2 or O_2 or NO is in Flue - So kept in.

EXOTWO

$$\text{lb/M } O_2 \text{ Excess} = \frac{-.02 \left(\frac{3,100.799}{28.013} + \frac{2,214.3438}{44.01} + \frac{55.1689}{39.675} + \frac{9.54382}{30.01} \right)}{-\frac{1}{32} + .02(.14888)}$$

neglect

$\frac{\text{lb/min}}{\text{lb/lb mole}}$

lb/M O_2 Excess = 115.10486 lb/M. ([illegible])

$$\frac{3.2543 \frac{\text{lb } N_2}{\text{lb } O_2}}{28.013 \frac{\text{lb } N_2}{\text{lb mol } N_2}}$$

Total Flue Products : OUT: @ 2% stack O_2

O_2: lb/M O_2 = 115.10486

N_2: lb/M N_2 = 3,100.799 + 3.2543(115.10486) = 3,100.799 + 374.5557 = 3,475.3847

Ar: lb/M Ar = 55.1689 + .0579(115.10486) = 55.1689 + 6.66457 = 61.83347

CO_2: lb/M CO_2 = 2,214.3438

NO: lb/M NO = 9.54382 If None Reduced

SO_2: lb/M SO_2 = 5.40693 If None Absorbed

H_2O: lb/M H_2O = 219.2753 + .01495(115.10486) = 219.2753 + 1.72083 = 220.99612 lb/M

neglect

└ No water Spray Yet

EAIR

Total Air : 4.3271 (lb/M O_2 req + lb/M O_2 excess) = 4.3271 (952.8313 + 115.10486)

lb/M Air = 4,621.06655

BLB

lb Air / lb Fuel = 4,621.0655 / 416.3346 = 11.0994 dry Coal, wet Air @ 2% (dry)

$$\frac{\text{Moles Flue (dry)}}{\text{Min}} = \left(\frac{\text{lb } O_2}{32.00} + \frac{\text{lb } N_2}{28.013} + \frac{\text{lb } CO_2}{44.01} + \frac{\text{lb Ar}}{39.675} + \frac{\text{lb NO}}{30.01} \right) = \frac{115.10486}{32.00} + \frac{3,475.3847}{28.013} + \frac{2,214.3438}{44.01} + \frac{61.83347}{39.675} + \frac{9.543}{30.01}$$

= 179.85139

MOLEW

$$\frac{\text{Moles Flue (wet)}}{\text{Min}} = 179.85139 + \frac{\text{lb } H_2O}{18.015} = 179.85139 + \frac{220.99612}{18.015} = 192.11873$$

= 192.11873

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M+E Balance

PLANT:

DATE: 4-29-84

PREPARED BY:

DISTRIBUTION:

Check Calculation of Excess O_2:

$$\text{Vol } \%O_2 \text{ (dry)} = \frac{\frac{lb\, O_2}{Mol\, wt\, O_2}}{\frac{lb\, O_2}{mwt\, O_2} + \frac{lb\, N_2}{mwt\, O_2} \ldots} = \frac{\text{Moles } O_2}{\text{Total Moles (dry)}}$$

$$\text{Vol } \%O_2 \text{ (dry)} = \frac{(115.10486/32.00)100}{179.85139} = 1.999999486 \sim 2\%$$ Checks

STACK Analysis: 16.6 % (O2 (dry) % L.D.

NOTWO

		Vol %		(100 moles) lbs	
Species	mol wT	D	W	D	W
O_2	32.000	2.000	1.87229	64.000	59.913
Ar	39.675	.8665	.811	34.380	32.185
N_2	28.013	68.981	64.576	1,932.365	1,808.977
CO_2	44.010	27.976	26.189	1,231.207	1,152.591
H_2O	18.015	0	6.385	0	115.031
NO	30.01	.177	.1655	5.3065	4.968
NO	1768 PPM	1675 PPM 3% O_2		3267.259	3,173.665

Mol wT (Dry) = 32.67
Mol wT (WET) = 31.74 ✓

E.G. O_2:

$$\text{Vol\% (dry)} = \frac{(115.10486/32.00)100}{179.95139} = 2.000\%$$

$$\text{Vol\% (WET)} = \frac{(115.10486/32.00)100}{192.11973} = 1.87229$$

lbs (dry) = 2.000(32.000) = 64.000 lb's

lbs (WET) = 1.851 (32.000) = 59.913 lbs

Mol wT (dry) = Σ lbs Dry / 100

Mol wT (WET) = Σ lbs WET / 100

$$\text{VPPM NO (dry)} = \frac{\text{moles NO}}{\text{Total moles}} \times 10^6 = \frac{(9.54392/30.01)}{179.95139} \times 10^6 = 1768 \text{ PPM (dry)}$$ If No Reduction

$$\text{VPPM NO (dry) } 3\% O_2 = 1768\left(\frac{18}{21-2}\right) = 1675 \text{ PPM}$$ If No Reduction

XAIR

% Excess Air (r2):

$$\% = \frac{O_2 IN - O_2 \text{ req}}{O_2 \text{ req}} \times 100 = \frac{952.9:13 + 115.10486 - 952.933}{952.933} = \frac{115.10486}{952.5312} \times 100 = 12.08\%$$

@ 2% O_2

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M+E Balance

PLANT:

DATE: 4-29-84

PREPARED BY:

DISTRIBUTION:

O2 AT Burner:

$$\%O_2(\text{dry}) = \frac{(115.10486/32.00)\,100}{179.85139 - \frac{1100.066}{44.01}}$$ — CO2 from C.D

$$\%O_2(\text{dry}) = 2.3228$$

Exit Gas Flow: (Wet) (Actual) (not Inc. water Spray.)

SCFM

$$\text{SCFM} = 192.11873\,\frac{\text{moles}}{\text{Min}} \times \frac{379.48\ \text{FT}^3}{\text{mole}} = 72{,}905\ \text{SCFM}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \therefore V_2 = \frac{P_1}{P_2}\frac{T_2}{T_1}V_1$$

$$\text{ACFM} = 72{,}905\,\frac{\text{FT}^3}{\text{Min}}\,\frac{14.696}{14.255}\cdot\frac{460+750}{520} = 174{,}892\ \text{ACFM}$$

EWT

Assume const for computing 16M

$$\text{lb/M} = 192.11873\,\frac{\text{moles}}{\text{Min}} \times \frac{31.73665\ \text{lb.}}{\text{Mole}} = 6{,}097.2\ \text{lb/M}$$

Check lb/M:

O_2 — 115.10486

N_2 — 3,475.3847

Ar — 61.83347

CO_2 — 2214.3438

NO — 9.54382

H_2O — 220.99612

6,097.2 lb/M checks!

Combustion Air Flow: (AT Burner) (Actual) (2% O2).

wet Air = 28.904 $\frac{\text{lb}}{\text{lb mole}}$

Total Air = 4,621.06655 lb/M

P(12)

$$\text{SCFM} = 4{,}621.06655\,\frac{\text{lb}}{\text{M}} \times \frac{379.48\ \text{FT}^3}{\text{lb Mole}} \times \frac{\text{lb mole}}{28.904\ \text{lb}} = 60{,}669.9\ \text{SCFM}$$

$$\text{or}\quad \text{SCFM} = \frac{\text{lb/M}}{\rho} = \frac{4{,}621.06655}{\frac{(14.696)(28.904)\,P}{(10.731)(459.7+60)}} = 60{,}670.6$$

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M&E Balance

PLANT:

DATE: 4-28-84

PREPARED BY:

DISTRIBUTION:

DIGI-LINK PROCESS SIGNALS

Ambient Temp - 72°F
NO @ I.D - 250 v PPM
SO2 @ I.D - 100 v PPM
O2 @ I.D - 3% (wet)
°F @ I.D - 620°F
Baghouse Inlet P - 6" w.c
I.D Fan Speed - 400
I.D Fan Amps - 115
Kiln Speed - 75
Kiln Amps - 350
°F @ Kiln Exit - 750°F
Press @ Kiln Exit - 2.5" w.c
O2 @ Kiln Exit - 2.0% (dry)

Kiln Raw Feed - 93.374 TPH (.4% H2O)
± Primary ~~Radial~~ Swirl P - ~~50~~ 20
Ŧ Primary Axial P - ~~45~~ 15
Cooler Amps 6A - 77.0
Cooler Amps 6 - 79.0
Cooler Amps 5A - 77.0
Cooler Amps 4,5 - 108.0
Cooler Amps 1,2,3 - 125.0
Under G. CC. UG P - 10" w.c
Upper CC. drive Amp - ~~50~~ 25
Lower CC. drive Amp - ~~50~~ 25
Hood Pressure - -.03" w.c
Ŧ Conv. Air Press - 7.4 PSIG

Clinker Disch Temp - 200°F
Conv. Air Amps - Need ? NS
Ŧ Primary Air Amps - ~~272~~ 4
Kiln Dust Return - 0 TPH
Cooler Vent Temp - 180°F
Ŧ ΔP on Cyclone - 9.44
Cooler BGHSE Inlet T - 170°F
Cooler BGHSE Outlet T - 140°F
Coal To Kiln - 12.61T (1% H
Raw Cyc Inlet T - 700°F
Raw Cyc. Out T - 600°F
Mill Inlet T - 450°F
Mill Inlet P - -2" w.c
Mill Outlet T - 180°F
Mill Outlet P - -18" w.c
Mill Coal Feed - 13.57 (7.95
GPM To Kiln Exit - 15.06
Ŧ Coal Mill Amps - 200
Chain Zone Temp - ~~450~~ 1522°F
Coal Mill System Fan Amp - 92.4

CALCULATED VALUES

LB NOx / T clinker -
T clinker -
Btu / T clinker -
SCFM Exit Gas -
SCFM I.D Fan Gas -
% Infiltration To Kiln -
SCFM Primary Air -
SCFM Secondary Air -
% Primary Air -
% Secondary Air -
SCFM Combustion Air @ Stack O2 -
Total heat From C.C To Kiln -
% Heat To Kiln From C.C -

% Coal Mill Infiltration -
Coal Mill Efficiency -
Secondary Air Temp -
Primary / Secondary Air -
% N conversion to NO -
NO @ 3% O2 -
lb/hr NO -
lb Air / lb clinker For Sec -
lb Air / lb clinker Total -
Radial / Axial -
% Cooler Efficiency -

Flame Temp -
Burner Tip vel -
Sec. Air Vel To Kiln -
lb Air / lb Fuel -
Stack @ Kiln Exit Analys

GIFFORD-HILL

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M+E Balance

PLANT: DATE: 4-28-84

PREPARED BY: DISTRIBUTION:

] FLUE GAS ANALYSIS:

[A] KILN EXIT:

Fr's

Coal Feed - 12.6162 TPH (wet)

M(oal Coal H_2O - 1% (computer(1.5)

COAL Coal C - 73.05% (dry)

COAL Coal H - 5.43% (dry)

COAL Coal N - 0.95% (dry)

COAL Coal O - 10.57% (dry)

SH(OAL) Coal Ash - 9.33% (dry) Coal S - 0.65% (dry)

COAL Coal S_2 - .65% (dry)

COAL Dry Coal = $12.6162\,(1-\overset{.015}{.01}) = 12.49$ TPH $\quad 12.49\,\frac{2000}{60} = 416.3346$ lb/M

LHV Coal = 14.093 (Fr C dry) + 51.623 (Fr H available) + 3983 (Fr S dry)

FQ/M LHV Coal = 14,093 (.7305) + 51,623 (.0410) + 3983 (.0065)

LHV Coal = 12,437 Btu/lb (Dry)

AVAH

Available H For Combustion = $\%H - \frac{\%O}{7.937}$

$= 5.43 - \frac{10.57}{7.937}$

$= 4.10\,\% = 4.09826$

∴ $\frac{10.57}{7.937} = 1.33\,\%H$ as H_2O. \ Fr on longitude

Air:

✓ 4.3271 lb Air / lb O_2 (...

3.2543 lb N_2 / lb O_2

0.0579 lb Ar / lb O_2

0.01495 lb H_2O / lb O_2

Requirements For Combustion @ 0% Excess O_2: IN!

OTWO O_2: lb O_2/lb coal (dry) = 2.664 (Fr C) ✓ + 7.936 (Fr H Ava.) ✓ + 1.142 (Fr N) ✓ + .998 (Fr S) ✓

lb O_2/lb coal (dry) = 2.664 (.7305) + 7.936 (.0410) + 1.142 (.0095) + .998 (.0065)

lb O_2/lb coal (dry) = 2.289 = 2.288626

$$\text{LB/Min } O_2 = 2.289\left(12.49\,\frac{\text{Ton}}{\text{H}}\right) \times \frac{2000\text{ lb}}{\text{T}} \times \frac{1\text{ Hr}}{60\text{ min}} = 952.8313\ \text{lb/m}$$

NTWO N_2: lb/M N_2 = 3.2543 (lb/M O_2) = 3.2543 (952.8313) = 3,100.799 lb/M

ARG Ar: lb/M Ar = .0579 (lb/M O_2) = .0579 (952.8313) = 55.1689 lb/M

HTWOD H_2O: lb/M H_2O = Air H_2O + Coal Surface H_2O + Coal H-H_2O

$$\text{lb/M } H_2O = .01495\,(\text{lb/M } O_2) + 12.6162\,(\text{Fr } H_2O) \times \frac{2000}{60} + \frac{O_2}{7.937} \times 8.936 \times \text{TPH Coal} \times .0$$

$$\text{lb/M } H_2O = .01495\,(952.8313) + 12.6162\,(.01)\,\frac{2000}{60} + 10.57\,(.01)\,\frac{8.936}{7.937} \times 12.49 \times \frac{2000}{60}$$

lb/M H_2O = 66.8055 lb/M

ASHC Ash: lb/M Ash = $12.49\,(.0933)\,\frac{2000}{60} = 38.844$ lb/M

NOT USED Org N_2: lb/M Org N_2 = $12.49\,(\text{Fr N})\,\frac{2000}{60} = 12.49\,(.0095)\,\frac{2000}{60} = 3.95517$ lb/M

NOT USED S: lb/M S = $12.49\,(.0065)\,\frac{2000}{60} = 2.76617$ lb/M

AIR Air: lb/M Air = 4.3271 (lb/M O_2) = 4.3271 (952.8313) = 4,122.996 lb/M

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M & E BALANCE

PLANT:

DATE: 4-28-84

PREPARED BY:

DISTRIBUTION:

Flue Products @ 0% Excess O_2: OUT:

O_2: 0 lb/M

WET Kiln Feed $(1-\%H_2O) \times \left(1-\frac{1}{1.55}\right) \times \frac{2000}{60} = $ lb/M CO_2

1.60 ↳ Assuming All Feed Decomposes before dust blows to Baghouse

N_2: 3,100.799 lb/M

Ar: 55.1689 lb/M

OUT H_2O: 66.8055 lb/M + 8.936(% ava H_2) × 12.49 × $\frac{2000}{60}$

66.8055 + 8.936(.0409826) × 12.49 × $\frac{2000}{60}$

219.2753 lb/M — NO water Spray Yet.

CO TWO CO_2: 3.664 (%C) × 12.49 × $\frac{2000}{60}$ + $\boxed{93.374}$(1-.004) $\left(1-\frac{1}{1.55}\right)\frac{2000}{60}$ = 1,114.3378 + 1,100.0060

1.60 110 $\not{c}$/M

2,214.3438

Nerf NO: 2.143 (Org N) = 2.143(3.95517) = 9.54382 lb/M — 60-70% reduces To

Nufact SO_2: 1.998 (S) = 1.998(2.70617) = 5.40693 lb/M — most absorbed

MASS IN:

Coal – 12.6162 × $\frac{2000}{60}$ = 420.54 lb/M

Air – 4,122.996 lb/Min

Total = 4,543.536 lb/M

MASS OUT:

N_2 – 3,100.799 lb/M

Ar – 55.1689

H_2O – 219.2753

CO_2 – 1114.3378 (not inc CO_2 from Carb Dec)

NO – 9.54382

SO_2 – 5.40693

Ash – 38.844

Total = 4,543.376 lb/M

SCFM Comb AIR REQ (0% O_2)

Checks

SCFM

SCFM = 4,122.996 lb/Min / [illegible] = 54,170.0 SCFM

.0761

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— Mass Balance —

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			Page*	Line #
WATCoal	— .01	Fr H_2O in Coal feed To Kiln	3	2064
DCoal	— Calc.	LB/Min Dry Coal feed to Kiln	"	"
CCCoal	— .7305	Fr Carbon in dry Coal	"	"
HCoal	— .0543	Fr. Hydrogen in dry Coal	"	"
NCoal	— .0095	Fr. Nitrogen in dry Coal	"	"
OCoal	— .1057	Fr Oxygen in dry Coal	"	"
ASHCoal	— .0933	Fr. Ash in dry Coal	"	"
AVAH	— Calc.	Available hydrogen in Coal for Combustion	"	"
SCoal	— .0065	Fr Sulfur in dry Coal	"	"
OTWO	— Calc	LB/Min O_2 req. for Combustion at 0% Stack O_2	"	2110
NTWO	— Calc	LB/Min N_2 added by air	"	"
ARG	— Calc.	LB/Min Argon added by air	"	"
HTWOO	— Calc.	LB/Min water added (does not inc water spray)	"	"
ASHC	— Calc	LB/Min Ash in Coal	"	"
AIR	— Calc.	LB/Min Air Added For Combustion at 0% stack Oxygen.	"	"
HOUT	— Calc.	LB/Min water inc. Coal $H_2 \rightarrow H_2O$ (does not inc. water spray).	4	2120
COTWO	— Calc.	LB/Min CO_2 From Combustion and Carbonate Decomposition	"	"
SCFM	— Calc.	SCFM Combustion Air Required to Burn Coal at 0% Excess Oxygen	"	"
EXOTWO	— Calc. (= 1000 IF VM(13) > 20)	LB/Min Excess Oxygen required To produce the measured stack oxygen Concentration found in the field. AT The back end of the Kiln (before the multicyclone)	5	2122
TAIR	— Calc.	LB/Min Air Required For Combustion at measured stack oxygen Concentration	"	2125

* All page references refer to the "Mass and Energy Balance" Section.

— Program Variable Identification —

— Mass Balance —

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		Page	Line #
LBLB — Calc. (= 1000 IF XCOAL < 1)	LB Air / LB Fuel Required	5	2125
ExAir — Calc. (= 1000 IF OTWO < 1)	Percent Excess Air	6	2127
MOLEW — Calc.	Moles / Min WET Flue GAS w/o water Spray.	5	2130
ESCFM - Calc.	SCFM Combustion Air Required To burn Coal at measured Stack Oxygen Concentration (NO water spray included).	7	2134
WOTWO — Calc. (= 21 IF MOLEW < 1)	Vol % Oxygen in stack on WET Basis (before water spray) at Kiln exit.	6	"
IDOMOL — Calc. (= 1000 IF vr(4) > 19)	moles/Min Air Added by infilltration between Kiln Exit and I.D FAN	8	2140
OOUT — Calc.	LB/Min O_2 add by infilltration @ I.D FAN	"	"
DMOLE — Calc.	moles/Min Dry Moles Flue gas OUT I.D FAN	"	2150
WMOLE — Calc.	moles/Min WET moles Flue gas (Actual) OUT I.D FAN. (Includes Water spray)	"	"
EESCFM - Calc.	SCFM Flue gas (Actual) OUT I.D FAN (Inc. water spray)	9	"
NO — Calc.	LB/Min NO in Flue GAS	"	"
NoTwo - Calc.	LB/Min NO on NO_2 Basis	"	2152
NOLB - Calc. (= 1 IF vm(14) < 1	LB NO_2 / Ton clinker.	10	"
NOBTU - Calc. (= 1000 IF vm(37) < 1	LB NO_2 / million BTU Coal	"	2154
DDTWO - Calc. (= 21 IF Dmole < 1)	Vol % Dry O_2 OUT I.D FAN Back Calculated from measured wet O_2 at I.D fan	9	2156

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		Page	Line
NOTHR - Calc. (=0 IF DMOLE<1)	VPPM NO at 3% Stack O_2 at I.D Fan Exit.	10	215
INF - Calc. (=100 IF MOLEW<1)	% Air Infiltration Between Kiln Exit and I.D Fan. (Excludes water Spray)	"	2160
WCOAL - measured	LB/Min wet Coal Feed To Coal Mill	12	2210
WATER - Measured.	LB/Min Water Evaporated in Coal Mill	"	"
Pounds - Calc.	LB/Min Air from System Fan. (Includes water Evaporated and Pulse Air)	"	"
DAIR - Calc.	LB/Min Dry Air Through Coal mill	"	"
AENT - Calc.	Enthalpy, Btu/lb, of Air Entering Coal mill. ~450°F	"	"
BENT - Calc.	Enthalpy out of Coal mill. (Excludes Moisture)	"	2220
CENT - Calc.	Enthalpy of water vapor out Coal mill	"	"
AMB - measured.	Ambient Temperature + 30°F. Used as Temperature for Coal as mill feed.	"	"
DENT - Calc.	Enthalpy of "AMB" Air.	"	2230
EENT - Calc.	Enthalpy of Clinker Cooler Air (on its way to the Coal mill).	"	"
AAA - Calc.	Btu/Min To mill From Coal (dry)	"	"
COALWAT - Calc.	LB/Min water in Coal feeding To mill	"	2240
BBB - Calc.	Btu/Min To mill From water in Coal	"	"
J - Calc.	J = AAA + BBB.		
CCC - Calc.	Btu/Min out Mill From Dry Coal	"	"
DDD - 454	Btu/Min out mill from water in Coal	"	"
EEE - Calc	Btu/Min out Mill from Dry Air	"	"

APPENDIX B

REVISED COMBUSTION EQUATIONS FOR RIVERSIDE CEMENT IBM PROGRAM

REVISED COMBUSTION EQUATIONS FOR RIVERSIDE CEMENT IBM PROGRAM

Objective of revision: Clarify the calculations relative to the formula for lbs NO_2 / ton of clinker in SCAQMD Rule 1112:

$$\frac{\text{lbs } NO_x}{\text{Ton of Clinker}} = \frac{(\text{ppm}_v\ NO_x)(46\ \text{grams/mole})(1.56 \times 10^{-7})(\text{SDCFM})}{\text{Ton/hour of clinker}}$$

Standard conditions: T = 68 F, P = 29.92 inches of mercury. Although SCAQMD Rule 103 specifies Tstd as 60 F, provisions of specific rules are superceding. Note that T=60 F should be used for other rules (particulates, etc.).

Basis of ppm_v: Although Rule 1112 states that ppm_v is to be "uncorrected observed" value, ppm_v and SDCFM must be on consistent basis (both wet or both dry) for calculation to be correct.

Equation Constant:

$$1.56 \times 10^{-7} = \frac{60\ \text{min/hr} \times 10^{-6}\ \text{mole/ppm}}{.7302\ (68 + 459.7)}$$

.7302 = Universal gas constant, atm-ft^3 / lb-mol R
.7302 (68 + 459.7) = 385.3 ft^3 / lb-mole R

Since equation is on a mass basis, the "standard conditions" should cancel out and have no effect, if all calculations are consistent.

MOLECULAR WEIGHTS

C = 12.011, CO_2 = 44.011
H_2 = 2.016, H_2O = 18.016
N_2 = 28.016, NO = 30.008, NO_2 = 46.008
O_2 = 32.000
S = 32.066, SO_2 = 64.066
Air = 28.965 (dry), 0.209 O_2 by volume, dry

KILN FEED CALCULATIONS

Given:
KFEED = VM(14) = Kiln feed, TPH (90.9)
KFLOI = E(13) = Kiln feed loss on ignition (1.6)
KFH20 = E(11) = Kiln feed moisture (.004)

Calculate: Ton/hour of clinker = KFEED * (1 - KFH20) / KFLOI
= 90.9 * (1 - 0.004) / 1.6
= 56.58 TPH

Kiln feed moisture, TPH = VM(14) * E(11)
= 90.9 * 0.004
= 0.3636 TPH of H_2O

Kiln feed moisture, lb/min = VM(14) * E(11) * 2000 / 60
= 90.9 * 0.004 * 2000 / 60
= 12.12 lb/min

Kiln feed moisture, moles/min = VM(14) * E(11) * 2000 / 60 / 18.016
= 90.9 * 0.004 * 2000 / 60 / 18.016
= 0.6727 mole/min

KILN FEED CALCULATIONS, Continued

Kiln feed CO_2, TPH = VM(14) * (1 - E(11)) * (1 - 1 / E(13))
= 90.9 * (1 - 0.004) * (1 - 1 / 1.6)
= 33.9512 TPH of CO_2

Kiln feed CO_2, lb/min
= VM(14) * (1 - E(11)) * (1 - 1 / E(13)) * 2000 / 60
= 33.95 * 2000 / 60
= 1131.7050 lb/min of CO_2

Kiln feed CO_2, moles/min
= VM(14) * (1 - E(11)) * (1 - 1 / E(13)) * 2000 / 60 / 44.01
= 1131.7050 / 44.011
= 25.7141 moles/min of CO_2

Note: None of the above for kiln feed are printed out by the IBM program. But clinker rate, TPH, is printed on the output as PROD, and must be calculated somewhere else in the program. Make sure the calc is consistent with above. Should be, since this form is used in Line 2500 for NOLB = C(26).

COAL CALCULATIONS

Required: Coal contribution to SDCFM and moisture correction for ppm_v.

Given:

KCOAL = VM(37) = Kiln coal feed, TPH (11.34)
WATCOAL = E(1) = Coal moisture, lb/lb (0.01)
CCCOAL = E(2) = Coal carbon, dry, lb/lb (0.7305) *
HCOAL = E(3) = Coal hydrogen, dry, lb/lb (0.0543) *
NCOAL = E(4) = Coal nitrogen, dry, lb/lb (0.0095) *
OCOAL = E(5) = Coal oxygen, dry, lb/lb (0.1057) *
ASHCOAL = E(6) = Coal ash, dry, lb/lb (0.0933) *
SCOAL = E(7) = Coal sulfur, dry, lb/lb (0.0065) *
BTUC = E(12) = Coal heating value, BTU/lb (12437)

* values should sum to 1.0000, but = 0.9998

Products of combustion, dry coal basis:

Coal Compound	Mol. Wt. lb/mole	moles / lb dry coal	Gas formed	Mole O_2 req / mole gas	Mole O_2 req / lb dry coal
C	12.011	CCCOAL/12.011	CO_2	1.0	CCCOAL/12.011
H_2	2.016	HCOAL/2.016	H_2O	0.5	0.5*HCOAL/2.016
N_2	28.016	NCOAL/28.016	N_2	1.0	*
O_2	32.000	OCOAL/32	O_2	-1.0	- OCOAL/32
S	32.066	SCOAL/32.066	SO_2	1.0	SCOAL/32.066

* Equations in IBM program assume all NCOAL -> NO, and include the O_2 required. This has been neglected above.

COAL CALCULATIONS, Continued

$$\frac{\text{moles dry gas}}{\text{lb dry coal}} = \frac{\text{CCCOAL}}{12.011} + \frac{\text{NCOAL}}{28.016} + \frac{\text{SCOAL}}{32.066}$$

$$\frac{\text{moles } H_2O}{\text{lb wet coal}} = \frac{\text{WATCOAL}}{18.016} + \frac{\text{HCOAL}}{2.016} * (1 - \text{WATCOAL})$$

$$\frac{\text{lb wet coal}}{\text{lb dry coal}} = \frac{1}{1 - \text{WATCOAL}}$$

$$\frac{\text{moles } H_2O}{\text{lb dry coal}} = \frac{\text{WATCOAL}}{18.016 * (1 - \text{WATCOAL})} + \frac{\text{HCOAL}}{2.016}$$

$$\frac{\text{moles } O_2 \text{ reqd}}{\text{lb dry coal}} = \frac{\text{CCCOAL}}{12.011} + \frac{0.5 * \text{HCOAL}}{2.016} - \frac{\text{OCOAL}}{32} + \frac{\text{SCOAL}}{32.066}$$

$$\frac{\text{lb } O_2 \text{ reqd}}{\text{lb dry coal}} = 32 * \left(\frac{\text{CCCOAL}}{12.011} + \frac{0.5 * \text{HCOAL}}{2.016} - \frac{\text{OCOAL}}{32} + \frac{\text{SCOAL}}{32.066} \right)$$

$$\begin{aligned} \text{lb dry coal / min} = \text{DCOAL} &= (\text{VM}(37) * 2000 / 60) * (1 - \text{WATCOAL}) \\ &= (11.34 * 2000 / 60) * (1 - 0.01) \\ &= 374.22 \text{ lb dry coal/min} \end{aligned}$$

(DCOAL is the same as in the IBM program)

$\text{lb } O_2 \text{ reqd / min} =$

$$\text{OTWO} = \text{C}(3) = 32 * \left(\frac{\text{CCCOAL}}{12.011} + \frac{0.5 * \text{HCOAL}}{2.016} - \frac{\text{OCOAL}}{32} + \frac{\text{SCOAL}}{32.066} \right) * \text{DCOAL}$$

$$\text{OTWO} = \text{C}(3) = 32 * \left(\frac{0.7305}{12.011} + \frac{0.5 * .0543}{2.016} - \frac{.1057}{32} + \frac{.0065}{32.066} \right) * 374.22$$

OTWO = C(3) = 852.4563 lb/min vs 856.4497 in program.

This formula for OTWO, C(3) is almost the same in the program, except that the program formula assumes NCOAL -> NO which is only partially true. Formation of NO from coal nitrogen is neglected in the above formula. Also, the division of coal hydrogen to "available" hydrogen is an un-necessary step. AVAH is not required.

Coal calculations are complete. Only formula for OTWO = C(3) requires changing.

COMBUSTION AIR

From coal calculation, above:

$$\frac{\text{moles } O_2 \text{ reqd}}{\text{lb dry coal}} = \frac{CCCOAL}{12.011} + \frac{0.5 * HCOAL}{2.016} - \frac{OCOAL}{32} + \frac{SCOAL}{32.066}$$

Assume dry air is defined as:

O_2 = 20.9 % by volume
molecular weight of dry air = 28.965 lb/mole

assume composition of dry air is O_2 plus "inerts" (N_2, argon, etc.)
$28.965 = 0.209 * 32 + 0.791 * MW_{inerts}$

$MW_{inerts} = (28.965 - 0.209 * 32) / 0.791 = 28.163$ lb/mole of inerts

It is not necessary to keep track of what species the inerts are.

$$\frac{\text{moles air inerts}}{\text{mole } O_2 \text{ reqd}} = \frac{0.791}{0.209} = \frac{1 - 0.209}{0.209} = 3.7847$$

$$\frac{\text{moles air inerts}}{\text{lb dry coal}} = \frac{1 - 0.209}{0.209} * \left(\frac{CCCOAL}{12.011} + \frac{0.5*HCOAL}{2.016} - \frac{OCOAL}{32} + \frac{SCOAL}{32.066}\right) + \frac{NCOAL}{28.016}$$

$$\frac{\text{moles inerts}}{\text{min}} = \frac{1 - 0.209}{0.209} * \left(\frac{CCCOAL}{12.011} + \frac{0.5*HCOAL}{2.016} - \frac{OCOAL}{32} + \frac{SCOAL}{32.066}\right) * DCOAL + \frac{NCOAL*DCOAL}{28.016}$$

$$\frac{\text{moles inerts}}{\text{min}} = \frac{1 - 0.209}{0.209} * \frac{OTWO}{32} + \frac{NCOAL}{28.016} * DCOAL$$

$$\frac{\text{lb inerts}}{\text{min}} = 28.163 * \frac{1 - 0.209}{0.209} * \frac{OTWO}{32} + NCOAL * DCOAL$$

This term is essentially the NTWO term in the IBM program

$$\begin{aligned} NTWO = C(4) &= 3.3309 * OTWO + 0.0095 * 374.22 \\ &= 3.3309 * 852.4563 + 3.555 \\ &= 2842.9857 \text{ lb / min} \end{aligned}$$

The term NTWO now takes care of all inerts, so ARG for Argon is not required.

ARG = C(5) = 0.0

IBM program gives NTWO + ARG = 2787.1442 + 49.5884 = 2836.7326 lb/min

COMBUSTION AIR, Continued

Now, for combustion air humidity.

The IBM program uses 0.01495 lb water/lb O_2, and 4.3271 lb air/lb O_2. The humidity is:

lb water/lb dry air = 0.01495/(4.3271-0.01495) = 0.00347 lb water/lb dry air.

The humidity perhaps should be taken as one of the engineering values input to the program, say HUMID.

$$\frac{\text{mole water}}{\text{mole dry air}} = \text{HUMID}\ \frac{\text{lb } H_2O}{\text{lb dry air}} * 28.965\ \frac{\text{lb dry air}}{\text{mole dry air}} * \frac{1}{18.016}\ \frac{\text{mole } H_2O}{\text{lb } H_2O}$$

$$= \text{HUMID} * 28.965 / 18.016 = 0.00563 \text{ mole water/mole dry air}$$

$$\frac{\text{mole water}}{\text{min}} = \frac{\text{mole water}}{\text{mole dry air}} * \frac{\text{mole dry air}}{\text{mole } O_2} * \frac{\text{moles } O_2 \text{ reqd}}{\text{min}}$$

$$= \frac{\text{HUMID} * 28.965}{18.016} * \frac{1}{0.209} * \frac{\text{OTWO}}{32}$$

$$\frac{\text{mole water}}{\text{min}} = \frac{\text{HUMID} * 28.965}{18.016 * 0.209} * \frac{\text{OTWO}}{32}$$

= 0.00347 * 28.965 * OTWO / (18.016 * 0.209 * 32)
= 0.000841 * OTWO
= 0.7111 moles water in comb air/min

lb water/min = moles water/min * 18.016 lb/mole

= 0.00347 * 28.965 * OTWO / (0.209 * 32)
= 0.0152 * OTWO
= 0.0152 * 852.4563
= 12.8109 lb water/min

EXCESS AIR AT ID FAN

Given: VM(4) = O_2, % volume, wet, at ID fan (from Lear-Siegler) (5.5 %)

$$O_{2\ wet} = \frac{\text{moles } O_2 \text{ excess/min}}{\text{total wet moles of gas/min}}$$

Since the "total wet moles of gas" includes the excess O_2, this equation must be solved as follows.

$$O_{2\ wet} = \frac{\text{moles } O_{2EA}\text{ /min}}{(\text{moles } O_{2EA} + \text{moles inert}_{EA} + \text{moles water}_{EA} + \text{moles of other})\text{/min}}$$

$$= \frac{\text{moles } O_{2EA}\text{ /min}}{\text{moles } O_{2EA}\text{/min} * (1 + \frac{\text{mole inert}}{\text{mole } O_2} + \frac{\text{mole } H_2O}{\text{mole } O_2}) + \text{moles other/min}}$$

This equation has the form:

$$O_{2\ wet} = \frac{\text{moles } O_{2EA}\text{ /min}}{\text{moles } O_{2EA}\text{ /min} * A + B}$$

and can be solved for "moles O_{2EA} /min" to get:

$$\text{moles } O_{2EA}\text{ /min} = \frac{O_{2\ wet} * B}{1 - O_{2\ wet} * A}$$

$$= \frac{O_{2\ wet} * \text{moles other/min}}{1 - O_{2\ wet} * (1 + \frac{\text{mole inert}_{EA}}{\text{mole } O_2} + \frac{\text{mole } H_2O_{EA}}{\text{mole } O_2})}$$

The "moles other/min" term includes all the gases not related to excess air:

B = moles/min kiln dry gas
+ moles/min kiln coal water
+ moles/min combustion air inerts
+ moles/min combustion air water
+ moles/min feed CO_2
+ moles/min feed H_2O
+ moles/min water spray H_2O

These terms have all been obtained above, except for water spray H_2O:
moles/min water spray H_2O = VM(45) * 8.3453 lb/gal /18.016
= 26 * 8.3453 /18.016
= 12.0436 moles H_2O / min

EXCESS AIR AT ID FAN, Continued

The B expression can be written out (units are moles/min):

$$B = \left(\frac{CCCOAL}{12.011} + \frac{NCOAL}{28.016} + \frac{SCOAL}{32.066}\right) * DCOAL$$

[kiln coal dry gas]
(CO_2, N_2, & SO_2)

$$+ \left(\frac{WATCOAL}{1 - WATCOAL} * \frac{1}{18.016} + \frac{HCOAL}{2.016}\right) * DCOAL$$

[kiln coal water]

$$+ \frac{1 - 0.209}{0.209} * \frac{OTWO}{32}$$

[comb air inerts]

$$+ \frac{HUMID * 28.965}{0.209 * 18.016} * \frac{OTWO}{32}$$

[comb air water]

$$+ \frac{VM(14) * (1 - E(11)) * (1 - 1/E(13)) * 2000}{44.011 * 60}$$

[feed CO_2]

$$+ \frac{VM(14) * E(11) * 2000}{18.016 * 60}$$

[feed H_2O]

$$+ \frac{VM(45) * 8.3453}{18.016}$$

[spray H_2O]

Solving for each term, B is:

B = (0.7305/12.011 + 0.0095/28.016 + 0.0065/32.066) * 374.22
+ (0.01/(1 - 0.01)/18.016 + 0.0543/2.016) * 374.22
+ (1 - 0.209)/0.209 * 852.4563/32
+ 0.00347 * 28.965 * 852.4563 / (0.209 * 18.016 * 32)
+ 90.9 * (1 - 0.004) * (1 - 1/1.6) * 2000 / (44.011 * 60)
+ 90.9 * 0.004 * 2000 / (18.016 * 60)
+ 26 * 8.3453 / 18.016

B = 22.9625 [kiln coal dry gas, moles/min]
+ 10.2893 [kiln coal H_2O, moles/min]
+ 100.8213 [comb air inerts, moles/min]
+ 0.7111 [comb air H_2O, moles/min]
+ 25.7141 [feed CO_2, moles/min]
+ 0.6727 [feed H_2O, moles/min]
+ 12.0436 [spray H_2O, moles/min]

B = 173.2146 moles/min (water = 23.7167 moles/min)

EXCESS AIR AT ID FAN, Continued

To solve for moles excess O_{2EA}, need the terms in A above:

$$A = 1 + \frac{\text{moles inert}}{\text{mole } O_{2EA}} + \frac{\text{moles } H_2O}{\text{mole } O_{2EA}}$$

$$= 1 + \frac{1 - 0.209}{0.209} + \frac{\text{HUMID} * 28.965}{18.016 * 0.209}$$

$$= 1 + 3.7847 + 0.026693$$

A = 4.8114 moles wet excess air/ mole O_{2EA}

Now can solve for moles excess O_2/min, using O_{2wet} = VM(4)/100 = .055:

$$\frac{\text{moles } O_{2EA}}{\text{min}} = \frac{O_{2wet} * B}{1 - O_{2wet} * A}$$

$$= \frac{.055 * 173.2146}{1 - 0.055 * 4.8114}$$

$$= 12.9551 \text{ moles } O_2/\text{min}$$

lb O_2 / min = 12.9551 * 32
= 414.5620 lb O_2/min

This is OOUT = C(20) in IBM program (which gives OOUT = 411.5114).

STACK FLOW WET AND DRY

Now can calculate the total wet gas moles/min:

Total wet moles/min = B + moles O_{2EA} * A
= 173.2146 + 12.9551 * 4.8114
= 235.5468 total wet moles/min at ID fan

This gives us the wet stack flow rate:

SWCFM = 385.3 * (B + moles O_{2EA} * A)
= 385.3 * 235.5468
= 90,756.1698 ft^3/min wet

To get the dry flow rate, subtract the water flows:

moles total water/min		
	= 10.2893	[kiln coal water]
	+ 0.7111	[comb air water]
	+ 0.6727	[feed water]
	+ 12.0436	[spray water]
	+ 0.3458	[excess air water = 0.026693*12.9551]
	24.0625 moles H_2O/min	

STACK FLOW WET AND DRY, Continued

Total dry moles/min = 235.5468 - 24.0625 = 211.4843

SDCFM = 211.4843 * 385.3 = 81,484.9008 dry cu.ft./min

The ratio of dry gas to wet gas is:

SDCFM / SWCFM = 81,484.9008 / 90,756.1698 = 0.89781 dry volume/wet volume

CONVERSION OF PPM NO FROM WET TO DRY

Given: VM(2) = ppm_v NO measured by Lear-Siegler, wet basis

$$\text{NO, ppm}_v\text{, dry} = \text{VM(2)} / \text{(SDCFM/SWCFM)}$$

$$= 318 \ / \ (0.89781)$$

$$= 354.1952 \ \text{ppm}_v\text{, dry}$$

CALCULATION OF LB NO_x / TON

$$\frac{\text{lbs } NO_x}{\text{Ton of Clinker}} = \frac{(\text{ppm}_v\ NO_x)(46 \text{ grams/mole})(1.56 \times 10^{-7})(\text{SDCFM})}{\text{Ton/hour of clinker}}$$

$$= \frac{(\ 354.1952\ )(46)(1.56 \times 10^{-7})(\ 81{,}484.9008\ )}{56.58}$$

$$= \underline{3.6605 \text{ lbs } NO_x \ / \text{ ton of clinker}}$$

Verify that we get the same answer if wet values are used:

$$\frac{\text{lbs } NO_x}{\text{Ton of Clinker}} = \frac{(\text{ppm}_v\ NO_x)(46 \text{ grams/mole})(1.56 \times 10^{-7})(\text{SWCFM})}{\text{Ton/hour of clinker}}$$

$$= \frac{(318)(46)(1.56 \times 10^{-7})(\ 90{,}756.1698\ )}{56.58}$$

$$= \underline{3.6605 \text{ lbs } NO_x \ / \text{ ton of clinker}}$$

IBM program for same data gives 3.5230, which is low by 3.8 %.

Now that the basic equations are derived for direct calculation of lb NO_2/ton of clinker, the equations used in the Riverside Cement IBM-PC computer program can be examined with the objective first of reconciling the engineering constants (i.e., given exactly the same constants are the answers the same) and second of revising the IBM-PC program to emphasize a more direct calculation with the minimum number of changes to the computer program itself.

RECONCILIATION OF COMBUSTION EQUATIONS IN RIVERSIDE IBM PROGRAM WITH THOSE DERIVED BY S C HUNTER

The coal composition should be revised to the actual coal now being fired:

```
2110 WATCOAL=.01                            'COAL MOISTURE
2120 DCOAL=(VM(37)*2000/60)*(1-WATCOAL)     'COAL FLOW, DRY, LB/MIN
2130 CCCOAL=.7305                           'COAL CARBON, DRY, LB/LB COAL
2140 HCOAL=.0543                            'COAL HYDROGEN, DRY, LB/LB COAL
2150 NCOAL=.0095                            'COAL NITROGEN, DRY, LB/LB COAL
2160 OCOAL=.1057                            'COAL OXYGEN, DRY, LB/LB COAL
2170 ASHCOAL=.0933                          'COAL ASH, DRY, LB/LB COAL
2180 AVAH=HCOAL-(OCOAL/7.937001)            'COAL AVAILABLE HYDROGEN
2190 SCOAL=.0065                            'COAL SULFUR, DRY, LB/LB COAL
```

In above, AVAH is only required for calculation of heating value. Add the coal heating value, either input from analysis, or calculated by modified DuLong formula:

```
ADD *****************
2191 BTUC=14093 * CCCOAL + 51623 * AVAH + 3983 * SCOAL : BTUC=12437
2192 CMW=12.011                                         'MOL. WT. OF CARBON
2193 H2MW=2.016 : H2OMW=18.016                          'MOL. WT. OF H2, H2O
2194 O2MW=32                                            'MOL. WT. OF O2
2195 N2MW=28.106                                        'MOL. WT. OF N2
2196 SMW=32.066                                         'MOL. WT. OF SULFUR
2197 AIRMW=28.965:AIRO2=.209:HUMID=.00347               'MW, O2, HUMIDITY OF AIR
2198 INRTMW=28.163: INERT=(1-AIRO2)/AIRO2*INERTMW/O2MW  'INERTS IN AIR
********************
```

The following comb. air equations should be modified:

```
2210 OTWO=(2.664*CCCOAL+7.936001*AVAH+1.142*NCOAL+.998*SCOAL)*DCOAL
2220 NTWO=3.2543*OTWO
2230 'OTWO=952.8313
2240 ARG=.0579*OTWO
```

Constants in the above are:

```
OTWO= 32   *CCCOAL +  32    *AVAH +  16     *NCOAL +  32    *SCOAL)*DCOAL
      ----          ------        ------           ------
      12.01         2*2.016       14.008           32.064

NTWO=  .7803 * 28.013 * OTWO = 3.2543 * OTWO
       -------------
       .2099 * 32

ARG=   .0098 * 39.675 * OTWO = .0579 * OTWO
       -------------
       .2099 * 32
```

```
CHANGE TO ************
2210 OTWO=O2MW*(CCCOAL/CMW+HCOAL/(2*H2MW)-OCOAL/O2MW+SCOAL/SMW)*DCOAL
2220 NTWO=INERT*OTWO + NCOAL*DCOAL
2230 'OTWO=952.8313
2240 ARG=0.000001                       'SET NEAR 0, NOT REQ'D
*********************
```

The current equations for water from air humidity, wet coal, and comb. are:

```
2250 HTWO=.01495*OTWO+VM(37)*WATCOAL*2000/60+(OCOAL*8.936001/7.937001)*DCOAL
2260 ASHC=DCOAL*ASHCOAL  'NOT USED FOR NO2 LB/TON
2270 AIR=4.3271*OTWO     'NOT USED FOR NO2 LB/TON
2280 HOUT=HTWO+8.936001*AVAH*DCOAL
```

The constant .01495 in HTWO is derived from the assumed air:

```
Given: 4.3271 lb wet air/lb O2
       3.2543 lb N2/lb O2
       0.0570 lb argon/lb O2
       0.01495 lb H2O/lb O2
```

Need to do calc backwards to find out what was assumed for dry air composition:

```
4.3271 - 0.01495 = 4.31215 lb dry air/lb O2
 0.01495/4.31215 = 0.003467 lb H2O/lb dry air = HUMID, air specific humidity

3.2543/4.31215 /28.103 = 0.026940 mole N2/lb dry air  -> 0.7803 mole frac N2
0.0579/4.31215 /39.675 = 0.000338 mole Ar/lb dry air  -> 0.0098 mole frac Ar
1.0   /4.31215 /32     = 0.007247 mole O2/lb dry air  -> 0.2099 mole frac O2
                         --------
                         0.034525 mole dry air/lb dry air ->28.964 dry air MW
```

Now can reverse and go forward to derive formulas used for constants in program:

```
Given: specific humidity = .003467
       Dry air: .7803 N2, .2099 O2, .0098 Ar by volume

lb N2/lb O2 = .7803/.2099 * 28.103/32 = 3.2543 (Checks)

lb Ar/lb O2 = .0098/.2099 * 39.675/32 = 0.0579 (Checks)

lb dry air/lb O2 = 3.2543 + .0579 + 1 = 4.3122  (4.31215 above)

lb H2O/lb O2 = 0.003467 * 4.3122 = 0.01495 lb H2O/lb O2  (checks)

lb wet air/lb O2 = 4.31215 + .01495 = 4.3271 lb wet air/lb O2
```

Restating these formulas in terms of defined constants:

```
lb "N2"/lb O2 = (1 - AIRO2)/AIRO2*INRTMW/O2MW = 3.33088 lb Inerts/lb O2

Let     INERT = (1 - AIRO2)/AIRO2*INRTMW/O2MW = 3.33088

lb Ar/lb O2 = 0

lb dry air /lb O2 = lb (O2 + inerts)/lb O2 = 1 + 3.3309 = 4.3309

lb H2O/lb O2 = HUMID * (1 + INERT)
             = HUMID * 4.3309 = 0.01502

lb wet air/lb O2 = lb (dry air + H2O)/lb O2
                 = (1 + HUMID)*(1 + INERT) = 4.3460
```

Now, restate the HTWO equation, which currently is:

```
2250 HTWOO=.01495*OTWO + VM(37)*WATCOAL*2000/60 +
(OCOAL*8.936001/7.937001)*DCOAL

   .01495*OTWO = HUMID*(1+INERT)*OTWO = lb H2O in air/min

    VM(37)*WATCOAL*2000/60 = lb H2O in coal/min
```

The third term in HTWOO can be combined with the second term in HOUT:

```
(OCOAL*8.936001/7.937001)  +  8.936001*AVAH
     =  OCOAL*8.936001/7.937001 + 8.936001*(HCOAL-(OCOAL/7.937001))
     =  OCOAL*8.936001/7.937001 - 8.936001*OCOAL/7.937001 + 8.936001*HCOAL
```

The first two terms above cancel out. There appears to be no need for keeping HTWOO and HOUT separate, except for calc of BTU/lb coal.

```
8.936001 = H2OMW/H2MW = H2OMW/H2MW = 18.016/2.016 = 8.936508

7.937001 = O2MW/2/H2MW = 32/2/2.016 = 7.936508
```

These numbers do not match exactly, suspect 7.937 and 8.936 where used without direct reference to the molecular weights being used in the rest of the analysis, and someone added the 0.000001 for a rounding problem on the computer (?). Probably irrelevent anyway.

However this is handled, the net result is the lb H2O/min of combustion and/or evaporation of the hydrogen in the coal. Lets assume we need to keep HTWOO and HOUT separate.

```
CHANGE TO *********
2250 HTWOO= HUMID*(1+INERT)*OTWO + VM(37)*WATCOAL*2000/60
                   + (OCOAL*H2OMW/(O2MW/2))*DCOAL
...
...
2280 HOUT=HTWOO + H2OMW/H2MW*AVAH*DCOAL
*******************
```

Note that between 2250 and 2280 is

```
2260 ASHC=DCOAL*ASHCOAL
2270 AIR=4.3271*OTWO
```

These aren't need to get lb NOx/ton. ASHC is OK as is, but, to make consistent, AIR changes:

```
CHANGE TO *********
2270 AIR=(1+HUMID) * (1 + INERT) * OTWO
*******************
        =lb wet air/lb dry air * lb dry air/lb O2 * lb O2/min
```

Now, for the COTWO equation, which currently is:

```
2290 COTWO=3.664*CCCOAL*DCOAL + VM(14)*(1-0.004)*(1-(1/1.6))*100/3
          = lb coal CO2/min   + lb feed CO2/min

          3.664 = 44.01/12.01 = (CMW+O2MW)/CMW
          100/3 = 2000/60   (just shorthand, not used elsewhere)
```

So 2290 becomes:

```
CHANGE *************
2290 COTWO=(CMW+O2MW)/CMW*CCCOAL*DCOAL + VM(14)*(1-E(11))*(1-1/E(13))*2000/60
********************
```

Now, for SCFM equation 2300, program currently is:

```
2300 SCFM=AIR*10.73*520/(14.696*28.9)
```

AIR   = lb wet comb. air/min, see line 2270
10.73 = Gas constant
520   = "Standard Temperature, R" - should be 68+459.7= 527.7
14.696 = 1 atm pressure = 29.92 inches mercury - OK
28.9   = wet air molecular weight (right for the humidity assumed)

Since SCFM is not used in the lb NO/ton calc, leave it alone. It could be tuned up to have MW vary with humidity and be based on Rule 1112 Tstd=68 F.

Now, for ESCFM equation 2310, program currently is:

```
2310 EXOTWO=VM(13)*(NTWO/28.013+COTWO/44.01+ARG/39.675)/(100/32-VM(13)*.14888)
```

This form assumes VM(13), measured kiln exit O2, is on a dry basis.

```
.14888 = 1/32 + 3.2543/28.013 + .0579/39.675 + .01495/18.015
       (mole O2 + mole N2     + mole Argon )/lb excess O2

       = moles dry excess air/lb excess O2
```

From Page 2, this is (1 + INERT) / AIRMW

Restating with new values:

```
CHANGE TO ***********
2310 EXOTWO=VM(13)*(NTWO/INRTMW+COTWO/(CMW+O2MW))
             / ((100/32)-VM(13)*(1+INERT)/ AIRMW)
*********************
```

Now, for TAIR line 2330:

```
2330 TAIR = 4.3271 * (1+INERT) * (OTWO + EXOTWO)
```

4.3271 = lb wet air / lb O2, per Page 2 this changes as below:

```
CHANGE TO **********
2330 TAIR = (1+HUMID)*(1+INERT)*(OTWO+EXOTWO)
********************
```

Now, for MOLEW, line 2380

```
2380 MOLEW = (EXOTWO/32!+(NTWO+3.2543*EXOTWO)/28.013+COTWO/44.01+
                              (ARG+.0574*EXOTWO)/39.675+HOUT/18.015)
```

MOLEW = wet moles/min at kiln exit
          BUT NOTE, WATER IN EXCESS AIR IS NEGLECTED

```
CHANGE TO ************
2380 MOLEW=EXOTWO/O2MW + (NTWO+INERT*EXOTWO)/INRTMW
           + COTWO/(CMW+O2MW) + HOUT/H2OMW
**********************
```

Now, for ESCFM, line 2390, kiln exit SCFM

T STANDARD = 68 F, .7302*(68+459.7) = 385.3
   .7302 = Gas Constant, (atm)(cu. ft)/(lb-mole)(°R)

```
CHANGE TO ************
2390 ESCFM = MOLEW*385.3
**********************
```

Now, for WOTWO, line 2410, only need to change the O2 mole weight:

```
CHANGE TO ************
2410 WOTWO = (EXOTWO/O2MW)*100/MOLEW
**********************
```

Now, for IDOMOL & OOUT, line 2420-2440, currently is:

```
2420
IDOMOL=.20874*((MOLEW+(VM(45)*8.3453/18.015))*(VM(4)/100)-(MOLEW*WOTWO*.01))
           /(.20874-VM(4)/100)
2430 IF IDOMOL>1000 THEN IDOMOL=1000
2440 OOUT = EXOTWO + IDOMOL * 32
```

```
CHANGE TO ***********
2419 WAIRO2=AIRO2/(1+HUMID*AIRMW/H2OMW)
2420
IDOMOL=WAIRO2*((MOLEW+(VM(45)*8.3453/H2OMW))*(VM(4)/100)-(MOLEW*WOTWO/100))
/(WAIRO2-VM(4)/100)
2430 IF IDOMOL>1000 THEN IDOMOL=1000
2440 OOUT=EXOTWO+IDOMOL*O2MW
********************
```

Now for DMOLE & WMOLE, line 2450-2460, currently is:

```
2450 DMOLE = MOLEW-(HOUT/18.015)+IDOMOL*(1+(.77598+9.739999E-03)/.20874)
2460 WMOLE = DMOLE+(VM(45)*8.3453+HOUT)/18.015
```

```
.77598 = .7803 mole N2/mole dry air/ (1+HUMID*AIRMW/H2OMW)
       = .7803/(1+.00347*28.965/18.015)
9.739999E-03 = .0098 mole Argon in dry air/ (1+HUMID*AIRMW/H2OMW)
       = .0098/(1+.00347*28.965/18.015) = .009746 (close)
```

These can be combined as "inerts" in air and the dry values can be used instead of wet

1 + (1-AIRO2)/AIRO2 -> (lb O2 + lb inert)/lb ID O2

```
CHANGE TO ******************
2450 DMOLE=MOLEW-(HOUT/H2OMW)+IDOMOL*(1+ (1-AIRO2)/AIRO2)
2460 WMOLE=DMOLE+(VM(45)*8.3453+HOUT)/H2MW
****************************
```

Now, for EESCFM, line 2470, is

```
2470 EESCFM=WMOLE*379.48
```

```
CHANGE TO *************
2470 EESCFM=WMOLE*385.3
***********************
```

Now, for NO, line 2480 is

```
2480 NO=((VM(2)*14.696*32.4/(10.73*520))*.000001)*DMOLE*379.48
```

THIS EQUATION IS INCORRECT - SHOULD USE WMOLE INSTEAD OF DMOLE AND THE CONCENTRATION CONVERSION IS WRONG. THE MOLECULAR WEIGHT OF NO SHOULD BE USED INSTEAD OF THE FLUE GAS.

NO = lb of NO/min
VM(2) = ppm by volume, wet as measured by Lear-Siegler
VM(2)*.000001 = moles NO/mole wet gas
DMOLE = moles of dry gas/min, use WMOLE instead

$$NO = \underset{\frac{\text{moles NO}}{\text{moles wet gas}}}{VM(2) * .000001} * \underset{\frac{\text{moles wet gas}}{\text{min}}}{WMOLE} = \frac{\text{moles NO}}{\text{min}}$$

To obtain Lb NO/min, this needs to be multiplied by the molecular weight of NO, not the molecular of the flue gas. To be consistent with correct molecular weights used for air, O_2, etc. 30.008 should be used for NO (and 46.008 should be used for NO_2). However, since the Rule 1112 equation uses 46 for NO_2 it is best to use 30 for NO and 46 for NO_2. The difference is negligible.

NO = VM(2) * .000001 * WMOLE * 30

The numbers used in line 2480 give:

14.696 * 32.4 / (10.73 * 520) * 379.48 = 32.38 because

14.696 / (10.73 * 520) = 1/379.6679 almost cancels 379.48.

The calculated NO is high by 32.38/30 = 1.079 or 7.9 % high

But since WMOLE/DMOLE = 1.1 then 1.1/1.08 is 1.04, NO is high by only 2 %.

Rather than using the original equation in the IBM program for NOLB (which is the NO_2 in lb/ton of clinker), we will use the direct equation from Rule 1112 and the raw data for NO as measured (VM(2), the wet flue gas flow (EESCFM from Line 2470), and the clinker rate calculated from feed (VM(37)), feed water content (E(11)), and feed loss on ignition (E(13)).

```
CHANGE TO ************
2480 NO = VM(2) * .000001 * 30 * WMOLE
2490 NOTWO = NO * 46/30
2500 NOLB=0 : IF VM(14)=0 THEN 2510
2502 NOLB = VM(2) * 46 * 1.56E-7 * EESCFM/(VM(14)*(1- E(11))*(1/E(13)))
2510 IF NOLB < 0 THEN NOLB = 0
2520 NOBTU = 1000 : IF VM(37) < 1 THEN 2540
2530 NOBTU = NOTWO/(VM(37)*(1-WATCOAL)*2000/60*BTUC)*1.0E6
**********************
```

The foregoing equations will produce the correct calculated lb NO_2/ton of clinker (Line 2502). However, the equations are still obscured by the fact that EESCFM is calculated through a chain of equations which involves an unecessarily complex use of the kiln exit O_2. The procedure would be clarified by a direct equation for EESCFM which is reduced only to the minimum necessary input, and eliminating the intermediate step involving kiln exit O_2.

The following equations, based on both the existing IBM-PC equations and the ones developed by KVB, allow direct calculation of the lb NO_2/ton of clinker.

Define:

MKDG = moles/min of kiln dry gas (inerts, CO_2)
MKW = mole/min of kiln coal and spray water
MKWG = mole/min of kiln wet gas
MIDO2 = moles/min of O_2 in excess air at ID fan
MIDXSDA = moles/min of ID fan excess dry air
MIDXSW = moles/min of ID fan water from the excess air humidity
SDCFM = standard dry cubic feet per min. of gas at ID fan
SWCFM = standard wet cubic feet per min. of gas at ID fan
NOLBNU = lb NO_2/ton of clinker by new equations

The equations are:

```
MKDG = NTWO / INRTMW + COTWO / (CMW + O2MW)
MKW = HOUT / H2OMW + VM(45) * 8.3453 / H2OMW
MKWG = MKDG + MKW
MIDO2 = VM(4) * MKWG / (100 - VM(4) / AIRO2 * (1 + HUMID * AIRMW/H2OMW))
MIDXSDA = MIDO2 * (1 + (1 - AIRO2) / AIRO2)
MIDXSW = MIDXSDA * HUMID * AIRMW / H2OMW
SDCFM = (MKDG + MIDXSDA) * 385.3
SWCFM = SDCFM + (MKW + MIDXSW) * 385.3
NOLBNU = VM(2) * 46 * 1.56E-7 * SWCFM / (VM(14) * (1 - E(11)) * (1/E(13))
```

The following constants and equations are sufficient to solve these equations:

Basic Constants:

AIRMW = 28.965 molecular weight of dry air, lb/lb-mole
INRTMW = 28.163 molecular weight of inerts in dry air, lb/lb-mole
CMW = 12.011 molecular weight of carbon, lb/lb-mole
O2MW = 32 molecular weight of oxygen, lb/lb-mole
H2MW = 2.016 molecular weight of hydrogen, lb/lb-mole
H2OMW = 18.016 molecular weight of water, lb/lb-mole
SMW = 32.066 molecular weight of sulfur, lb/lb-mole
AIRO2 = 0.209 mole fraction of oxygen in dry air, moles/mole
8.3453 = lb of water/gallon
385.3 = standard cubic feet of gas/mole of gas at 68 °F

Engineering Constants required are (example values are used):

WATCOAL = E(1) = 0.01 coal moisture, lb H_2O/lb coal
CCCOAL = E(2) = 0.7305 coal carbon content, lb C/lb dry coal
HCOAL = E(3) = 0.0543 coal hydrogen content, lb H/lb dry coal
NCOAL = E(4) = 0.0095 coal nitrogen content, lb N_2/lb dry coal
OCOAL = E(5) = 0.1057 coal oxygen content, lb O_2/lb dry coal
SCOAL = E(7) = 0.0065 coal sulfur content, lb S/lb dry coal
KFH2O = E(11) = 0.004 kiln feed moisture, lb water/lb wet feed
KFLOI = E(13) = 1.6 kiln feed loss on ignition, lb dry feed/lb clinker
HUMID = 0.00347 humidity of combustion air, lb H_2O/lb dry air

Measured values required are:

VM(2) = 318 ppm NO, wet
VM(4) = 5.5 ID fan O_2, % wet
VM(14) = 90.9 kiln feed, tons/hr
VM(37) = 11.34 kiln coal flow, tons coal/hr
VM(45) = 26 kiln exit cooling water spray, gallons/min.

The equations above require three values calculated by the existing IBM-PC program:

NTWO = C(4) = INERT * OTWO + NCOAL * DCOAL = 2842.99
COTWO = C(10) = (CMW+O2MW)/CMW * CCCOAL *DCOAL + VM(14)*(1-E(11))*(1-1/E(13))*2000/60 = 2133.39
HOUT = C(9) = HTWOO + H2OMW/H2MW*AVAH*DCOAL = 198.77

These three equations in turn require the following additional values:

INERT = (1-AIRO2)/AIRO2*INRTMW/O2MW = 3.3309
DCOAL = C(1) = (VM(37) * 2000 / 60) * (1 - WATCOAL) = 374.22
AVAH = C(2) = HCOAL - (OCOAL / 7.937) = .041
OTWO = C(3) = O2MW * (CCCOAL/CMW+HCOAL/(2*H2MW) -OCOAL/O2MW+SCOAL/SMW) * DCOAL = 852.457
HTWOO = C(6) = HUMID*(1+INERT)*OTWO + VM(37)*WATCOAL*2000/60 + (OCOAL*H2OMW/(O2MW/2))*DCOAL = 61.1298

Using these equations and constants, the following values are calculated for the new equations:

MKDG = 149.422 moles dry gas/min
MKW = 23.0437 moles water/min
MKWG = 172.465 mole/min of wet combustion gas
MIDO2 = 12.899 moles/min of ID fan O_2 from excess air
MIDXSDA = 61.7177 moles/min of ID fan excess dry air
MIDXSW = 0.3443 moles/min of ID fan water in excess air
SDCFM = 81,351.9 standard dry cu.ft./min @ 68 °F
SWCFM = 90,363.3 standard wet cu.ft./min @ 68 °F
NOLBNU = 3.6442 lb NO_2/ton of clinker

APPENDIX C

ORIGINAL AND MODIFIED NOx STUDY INPUTS AND OUTPUTS

```
EFFECT OF 1% VARIATION IN EACH FACTOR ON NOX/TON (NOLB)

                                ---ORIGINAL CALCULATION---         ---MODIFIED CALCULATION---

FACTOR          NOM. VALUE     NO/TON    % PREC      % SQR        NO/TON    % PREC      % SQR
  NOMINAL          -----       3.5230      --                     3.6442

  KFLOI    E(13)     1.6       3.5680    1.2761  1.6284312        3.6897    1.2485  1.5587523
  NOPPM   VM( 2)     318       3.5582    1.0001  1.0002000        3.6806    1.0001  1.0002000
  KFEED   VM(14)    90.9       3.4939    -.8261   .68244121       3.6135    -.8425   .70980625
  COALC    E( 2)   .7305       3.5477     .6998   .48972004       3.6673     .6354   .40373316
 ID O2%   VM( 4)     5.5       3.5370     .3967   .15737089       3.6573     .3612   .13046544
  COAL H   E( 3)   .0543       3.5279     .1387   .01923769       3.6503     .1689   .02852721
  COAL O   E( 5)   .1057       3.5219    -.0301   .00090601       3.6432    -.0274   .00075076
  SPRYW   VM(45)      26       3.5237     .0204   .00041616       3.6467     .0698   .00487204

  KFH2O    E(11)    .004       3.5231     .0034   .00001156       3.6443     .0034   .00001156
  COAL N   E( 4)   .0095       3.5231     .0032   .00001024       3.6442     .0007   .00000049
  COAL S   E( 7)   .0065       3.5231     .0021   .00000441       3.6442     .0016   .00000256

  COALH2O E( 1)      .01       3.5230     .0004   .00000016       3.6442     .0012   .00000144
KCOALTPH VM(37)    11.34       3.5230     .0004   .00000016       3.6442     .0012   .00000144
  EXITO2 VM(13)      1.3       3.5230     .0001   .00000001       3.6442         0           0

COAL BTUC E(12)    12437       3.5230         0           0       3.6442         0           0
 COAL ASH E( 6)    .0933       3.5230         0           0       3.6442         0           0
                                                  ---------                           ---------
SQRT(SUM(PREC^2))         (APPROX PRECISION)      1.9946804                           1.9588580
```

```
                ORIGINAL

           NOX STUDY INPUTS

(1) COAL H20     E( 1)= .01
(2) COAL  C      E( 2)= .7305
(3) COAL  H      E( 3)= .0543
(4) COAL  N      E( 4)= .0095
(5) COAL  O      E( 5)= .1057
(6) COAL ASH     E( 6)= .0933
(7) COAL  S      E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1 )=  374.22
  AVAH= C( 2 )=  .041
  OTWO= C( 3 )=  856.45
  NTWO= C( 4 )=  2787.14
   ARG= C( 5 )=  49.5884
 HTWOO= C( 6 )=  61.1176
  ASHC= C( 7 )=  34.9147
   AIR= C( 8 )=  3705.94
  HOUT= C( 9 )=  198.165
 COTWO= C( 10 )=  2133.32
  SCFM= C( 11 )=  48686.1
EXOTWO= C( 12 )=  66.1731
  TAIR= C( 13 )=  3992.28
  LBLB= C( 14 )=  10.6683
 EXAIR= C( 15 )=  7.7264
 MOLEW= C( 16 )=  170.069
 ESCFM= C( 17 )=  64537.9
 WOTWO= C( 18 )=  1.2159
IDOMOL= C( 19 )=  10.7918
  OOUT= C( 20 )=  411.511
 DMOLE= C( 21 )=  210.483
 WMOLE= C( 22 )=  233.527
EESCFM= C( 23 )=  88618.8
    NO= C( 24 )=  2.1676
 NOTWO= C( 25 )=  3.3225
  NOLB= C( 26 )=  3.523
 NOBTU= C( 27 )=  .7139
 DOTWO= C( 28 )=  6.1096
 NOTHR= C( 29 )=  384.41
   INF= C( 30 )=  27.6792
```

```
                MODIFIED
                --
           NOX STUDY INPUTS

(1) COAL H20     E( 1)= .01
(2) COAL  C      E( 2)= .7305
(3) COAL  H      E( 3)= .0543
(4) COAL  N      E( 4)= .0095
(5) COAL  O      E( 5)= .1057
(6) COAL ASH     E( 6)= .0933
(7) COAL  S      E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22
  AVAH= C( 2)=  .041
  OTWO= C( 3)=  852.457
  NTWO= C( 4)=  2842.99
   ARG= C( 5)=  0
 HTWOO= C( 6)=  61.1298
  ASHC= C( 7)=  34.9147
   AIR= C( 8)=  3704.7
  HOUT= C( 9)=  198.177
 COTWO= C( 10)=  2133.39
  SCFM= C( 11)=  48669.7
EXOTWO= C( 12)=  66.2821
  TAIR= C( 13)=  3992.76
  LBLB= C( 14)=  10.6695
 EXAIR= C( 15)=  7.7754
 MOLEW= C( 16)=  170.332
 ESCFM= C( 17)=  65629
 WOTWO= C( 18)=  1.216
IDOMOL= C( 19)=  10.8235
  OOUT= C( 20)=  412.635
 DMOLE= C( 21)=  211.119
 WMOLE= C( 22)=  234.163
EESCFM= C( 23)=  90223
    NO= C( 24)=  2.2339
 NOTWO= C( 25)=  3.4253
  NOLB= C( 26)=  3.6385
 NOBTU= C( 27)=  .736

NEW KVB EQUATIONS

   MKDG=            149.422
    MKW=            23.0437
   MKWG=            172.465
  MIDO2=            12.899
MIDXSDA=            61.7177
 MIDXSW=            .3443
  SDCFM=            81351.9
  SWCFM=            90363.3
 NOLBNU=            3.6442
```

KVB MICROSOFT BASIC NOX STUDY COMPUTER PROGRAM

```
10  TEXT : HOME : CLEAR
15  PRINT : PRINT : PRINT
20 :
25  PRINT : PRINT : INVERSE : PRINT " IBM.NOX.CALCS": NORMAL
30 : REM   NOX.VARIATION.CALC.8/21 (RAF/SCH)
40 : REM   KVBNOX.BAS MODIFIED EQUATIONS, MICROSOFT BASIC VERSION
50 :
90  DEF  FN RD(X) =  INT (X * 10 ^ ND + .5) / 10 ^ ND
91 ND = 4
100  REM
110  REM   IBM NOX PROJECT 7/22
120  REM   RIVERSIDE CEMENT
130  REM   APL CPM VERSION
140  REM   CASE STUDY SUBROUTINE
150  REM
200  DIM E(14),VM(46),C(36),C$(36),CS(36),CP$(36),VA$(36),SH$(17)
300 :
350 DATA "(1) COAL H20   E( 1)=","(2) COAL  C    E( 2)=","(3) COAL  H    E( 3)=","(4) COAL  N    E( 4)=",
    "(5) COAL  0    E( 5)=","(6) COAL ASH  E( 6)=","(7) COAL  S    E( 7)=","(8) FEED KFH20 E(11)=",
    "(9) COAL BTUC  E(12)=","(10)FEED KFLOI E(13)="
351 DATA "(11)                      ","(12)KCOAL TPH VM(37)","(13)KFEED TPH VM(14)=","(14)SPRYW GPM VM(45)=",
    "(15)WT ID 02% VM(4) =","(16)ID NO PPM VM(2 =","(17)EXIT 02 % VM(13)="
360 FOR I = 1 TO 17 : READ SH$(I) :NEXT
400 D$ =  CHR$ (4)
420  DATA   " DCOAL= ","  AVAH= ","  OTWO= ","  NTWO= ","   ARG= "," HTWOO= ","  ASHC= ","   AIR= ",
     "  HOUT= "," COTWO= ","  SCFM= ","EXOTWO= ","  TAIR= ","  LBLB= "," EXAIR= "," MOLEW= "," ESCFM= ",
     " WOTWO= ","IDOMOL= ","  OOUT= "," DMOLE= "
421  DATA    " WMOLE= ","EESCFM= ","    NO= "," NOTWO= ","  NOLB= "," NOBTU= "
422  FOR I = 1 TO 27: READ C$(I): NEXT I
425 DATA "  MKDG= ","   MKW= ","  MKWG= "," MIDO2= ","MIDXSDA=","MIDXSW= "," SDCFM= "," SWCFM= ","NOLBNU= "
426 FOR I = 28 TO 36: READ C$(I) : NEXT I
427 FOR I = 1 TO 27: CP$(I)="C("+STR$(I)+")= ":NEXT I
428 FOR I = 28 TO 36: CP$(I)="          " : NEXT I
430  FOR I = 1 TO 33:VA$(I) = " ": NEXT
460 PAR = 0:P1 = 0
500 :
1000  REM   VM VALUES GIVEN
1002 :
1010 VM(37) = 11.34: REM    KILN COAL TPH
1020 VM(14) = 90.9: REM    KILN FEED TPH
1025 VM(13) = 1.3: REM     KILN EXIT 02 %
1030 VM(45) = 26!: REM    BACK END H20 SPRAY GPM
1040 VM(4) = 5.5: REM    02% WET AT ID OUTLET
1050 VM(2) = 318!: REM    NO PPM AT ID OUTLET
1060 :
1070 :
1080  REM   E(X) VALUES
1082 :
1084 :
1090 E(11) = .004: REM   KILN FEED H20
1100 E(12) = 12437: REM   BTU E+6 /T(BTUC)
1110 E(13) = 1.6: REM   LB FEED/ LB CLINKER (KFLOI)
1120 :
```

```
1130 :
1140 :
1150 :
1200 : REM   INPUT VARIABILITIES
1201 :
1202  GOSUB 2000: HOME
1210  HTAB 10: VTAB 1: INVERSE : PRINT "NOX STUDY INPUTS": NORMAL : PRINT
1220  HTAB 1: VTAB 3: PRINT "(1) COAL H20   E( 1)=";E(1);: HTAB 33: PRINT VA$(1)
1230  HTAB 1: VTAB 4: PRINT "(2) COAL  C    E( 2)=";E(2);: HTAB 33: PRINT VA$(2)
1240  HTAB 1: VTAB 5: PRINT "(3) COAL  H    E( 3)=";E(3);: HTAB 33: PRINT VA$(3)
1250  HTAB 1: VTAB 6: PRINT "(4) COAL  N    E( 4)=";E(4);: HTAB 33: PRINT VA$(4)
1260  HTAB 1: VTAB 7: PRINT "(5) COAL  O    E( 5)=";E(5);: HTAB 33: PRINT VA$(5)
1270  HTAB 1: VTAB 8: PRINT "(6) COAL ASH   E( 6)=";E(6);: HTAB 33: PRINT VA$(6)
1280  HTAB 1: VTAB 9: PRINT "(7) COAL  S    E( 7)=";E(7);: HTAB 33: PRINT VA$(7)
1290  HTAB 1: VTAB 10: PRINT "(8) FEED KFH20 E(11)=";E(11);: HTAB 33: PRINT VA$(8)
1300  HTAB 1: VTAB 11: PRINT "(9) COAL BTUC  E(12)=";E(12);: HTAB 33: PRINT VA$(9)
1310  HTAB 1: VTAB 12: PRINT "(10)FEED KFLOI E(13)=";E(13);: HTAB 33: PRINT VA$(10)
1320  HTAB 1: VTAB 13
1330  HTAB 1: VTAB 14: PRINT "(12)KCOAL TPH VM(37)=";VM(37);: HTAB 33: PRINT VA$(12)
1340  HTAB 1: VTAB 15: PRINT "(13)KFEED TPH VM(14)=";VM(14);: HTAB 33: PRINT VA$(13)
1350  HTAB 1: VTAB 16: PRINT "(14)SPRYW GPM VM(45)=";VM(45);: HTAB 33: PRINT VA$(14)
1360  HTAB 1: VTAB 17: PRINT "(15)WT ID 02% VM(4) =";VM(4);: HTAB 33: PRINT VA$(15)
1370  HTAB 1: VTAB 18: PRINT "(16)ID NO PPM VM(2) =";VM(2);: HTAB 33: PRINT VA$(16)
1375  HTAB 1: VTAB 19: PRINT "(17)EXIT 02 % VM(13)=";VM(13);: HTAB 33: PRINT VA$(17)
1377  IF P1 = 1 THEN  RETURN
1380  IF PAR > 0 THEN  HTAB 1: VTAB PAR + 2: INVERSE :  PRINT PAR :NORMAL
1400 GOSUB 6000 :  INVERSE : INPUT "ANY VARIATIONS? (Y/N, Q TO QUIT)) :";YN$: NORMAL:
     IF  LEFT$ (YN$,1) = "Y" OR  LEFT$ (YN$,1) = "Y" THEN 1410
1402 IF LEFT$(YN$,1) = "Q" THEN END
1405 GOTO 2200
1410 GOSUB 6000 :  INVERSE : INPUT "ENTER NUMBER OF PARAMETER TO VARY ";PAR: NORMAL : HTAB 1: GOSUB 6000
1415  IF PAR > 99 THEN  END
1416  IF PAR = 99 THEN  CLEAR : RESTORE : GOTO 100
1420 GOSUB 6000: INVERSE : INPUT "ENTER % VARIATION FOR PARAMETER ";VAR: NORMAL :
     VA$(PAR) =  STR$ (VAR) + " %":VAR = VAR / 100:  GOSUB 6000
1425 :
1430  IF PAR < 1 OR PAR > 7 THEN 1450
1440 E(PAR) =  INT ((E(PAR) * (1 + VAR) * 100000!) + .5) / 100000!
1450  IF PAR < 8 OR PAR > 10 THEN 1470
1460 E(PAR + 3) =  INT ((E(PAR + 3) * (1 + VAR) * 100000!) + .5) / 100000!
1470 :
1480  IF PAR = 12 THEN VM(37) = ((VM(37) * (1 + VAR) * 100000!) + .5) / 100000!
1490  IF PAR = 13 THEN VM(14) =  INT ((VM(14) * (1 + VAR) * 100000!) + .5) / 100000!
1500  IF PAR = 14 THEN VM(45) = ((VM(45) * (1 + VAR) * 100000!) + .5) / 100000!
1510  IF PAR = 15 THEN VM(4) = ((VM(4) * (1 + VAR) * 100000!) + .5) / 100000!
1520  IF PAR = 16 THEN VM(2) = ((VM(2) * (1 + VAR) * 100000!) + .5) / 100000!
1522  IF PAR = 17 THEN VM(13) = ((VM(13) * (1 + VAR) * 100000!) + .5) / 100000!
1525  HOME
1540  GOTO 1210
1550  HOME :1400
1920 :: REM    PASS RETURN
1999 GOTO 2200
2000  REM    IBM PROGRAM SECTION
2101  REM   ********** HEAT BALANCE FOR KILN/COAL MILL **********
2102 :
```

```
2110 E(1) = .01   'WATCOAL
2120 C(1) = (VM(37) * 2000 / 60) * (1 - E(1))   'DCOAL
2130 E(2) = .7305  'CCCOAL
2140 E(3) = .0543  'HCOAL
2150 E(4) = .0095  'NCOAL
2160 E(5) = .1057  'OCOAL
2170 E(6) = .0933  'ASHC
2180 C(2) = E(3) - (E(5) / 7.937)  'AVAH
2190 E(7) = .0065  'SCOAL
2191 BTUC=14093*E(2)+51623!*C(2)+3983*E(7) : BTUC=12437
2192 CMW=12.011
2193 H2MW=2.016 : H2OMW=18.016
2194 O2MW=32
2195 N2MW=28.016
2196 SMW=32.066
2197 AIRMW=28.965 : AIRO2= .209 : HUMID=.00347
2198 INRTMW=28.163 : INERT=(1-AIRO2)/AIRO2*INRTMW/O2MW
2199 RETURN     'SPECIAL LINE FOR KVB APPLE PROGRAM ONLY
2200 C(2)=E(3) - (E(5) / 7.937) 'SPECIAL LINE FOR KVB APPLE PROGRAM ONLY
2201  REM   ********** REQ. FOR COMB. AT 0% EXCESS O2 **********
2210 C(3)=O2MW*(E(2)/CMW+E(3)/(2*H2MW)-E(5)/O2MW+E(7)/SMW)*C(1)
2220 C(4)=INERT*C(3) + E(4)*C(1)
2230 'CPRIME(3) = 952.831
2240 C(5) = .000001
2250 C(6) =  HUMID*(1+INERT)* C(3) + VM(37) * E(1) * 2000 / 60 + (E(5) * H2OMW/(O2MW/2)) * C(1)
2260 C(7) = C(1) * E(6)
2270 C(8)=(1+HUMID)*(1+INERT)*C(3)
2280 C(9) = C(6) + 8.936 * C(2) * C(1)
2290 C(10) = (CMW+O2MW)/CMW * E(2) * C(1) + VM(14) * (1 - E(11)) * (1 - 1 / E(13)) * 2000 / 60
2300 C(11) = C(8) * 10.73 * 520 / (14.696 * 28.9)
2310 C(12) = VM(13) * (C(4)/INRTMW+C(10)/(CMW+O2MW))/((100/32)-VM(13)*(1+INERT)/AIRMW)
2311 '**** DELETE ****  DENOM = 100/32-VM(13)*(1+(1-AIRO2)/AIRO2*INRTMW/O2MW)/AIRMW
2312 '**** DELETE ****  C(12) = C(12)/DENOM
2320  IF VM(13) > 20 THEN C(12) = 1000
2330 C(13) = (1+HUMID)*(1+INERT)*(C(3)+C(12))
2340 C(14) = 1000: IF C(1) < 1 THEN 2360
2350 C(14) = C(13) / C(1)
2360 C(15) = 1000: IF C(3) < 1 THEN 2380
2370 C(15) = C(12) * 100 / C(3)
2380 C(16) = C(12)/O2MW + (C(4)+INERT*C(12))/INRTMW + C(10)/(CMW+O2MW) + C(9)/H2OMW
2390 C(17) = C(16) * 385.3
2400 C(18) = 21: IF C(16) < 1 THEN 2420
2410 C(18) = (C(12) / O2MW) * 100 / C(16)
2419 WAIRO2=AIRO2/(1+HUMID*AIRMW/H2OMW)
2420 C(19) = WAIRO2*((C(16) + (VM(45) * 8.3453 / H2OMW)) * (VM(4)/100) - (C(16) * C(18) /100 )) /(WAIRO2 - VM(4)/100)
2430  IF C(19) > 1000 THEN C(19) = 1000
2440 C(20) = C(12) + C(19) * O2MW
2450 C(21) = C(16) - (C(9)/H2OMW) + C(19) * (1+ (1-AIRO2)/AIRO2)
2460 C(22) = C(21) + (VM(45) * 8.3453 + C(9)) / H2OMW
2470 C(23) = C(22) * 385.3
2480 C(24) = VM(2) * .000001 * 30 * C(22)
2490 C(25) = C(24) * 46 / 30
2500 C(26) = 0: IF VM(14) = 0 THEN 2510
2502 C(26) = VM(2) * 46 * 1.56E-07 * C(23) / (VM(14) * (1-E(11)) * (1/E(13)))
2510  IF C(26) < 0 THEN C(26) = 0
```

```
2520 C(27) = 1000: IF VM(37) < 1 THEN 2540
2530 C(27) = C(25) / ((VM(37) * (1 - E(1)) * (2000 / 60) * E(12)) * 1E+06
2540 C(28) = 21:C(29) = 0: IF C(21) < 1 THEN 2570
2550 C(28) = (C(20) / 32) * 100 / C(21)
2560 'C(29) = VM(2) * (18 / (21 - C(28)))
2570 'C(30) = 100: IF C(16) < 1 THEN 2590
2580 'C(30) = ((C(19) / .20874) * 28.9 / (C(16) * 31.74)) * 100
2590 :
2595 :
2600 :
2602 MKDG = C(4)/INRTMW + C(10)/(CMW+02MW) : C(28)=MKDG
2604 MKW = C(9)/H20MW + VM(45)*8.3453/H20MW : C(29)= MKW
2606 MKWG = MKDG + MKW : C(30) = MKWG
2608 MID02 = VM(4)*MKWG/(100-VM(4)/AIR02*(1+HUMID*AIRMW/H20MW)) : C(31) = MID02
2610 MIDXSDA = MID02*(1+(1-AIR02)/AIR02) : C(32) = MIDXSDA
2612 MIDXSW = MIDXSDA * HUMID * AIRMW/H20MW : C(33) = MIDXSW
2614 SDCFM = (MKDG + MIDXSDA) * 385.3 : C(34) = SDCFM
2616 SWCFM = SDCFM + (MKW + MIDXSW) * 385.3 : C(35) = SWCFM
2620 NOLBNU = VM(2)*46*1.56E-07*SWCFM/(VM(14)*(1-E(11))*(1/E(13))) : C(36) = NOLBNU
2650 IF PAR > 0 THEN GOTO 9000
2700  FOR I = 1 TO 36:CS(I) = C(I): NEXT I
3000 GOTO 9000
6000 HTAB 1 : VTAB 23 :PRINT "                                     ": HTAB 1 : VTAB 23 : RETURN
9000 P1 = 1
9900 GOSUB 6000 :  INPUT "OUTPUT TO PRINTER? (Y/N) : ";YN$:PS% = 0:
     IF  LEFT$ (YN$,1) = "Y" OR  LEFT$ (YN$,1) = "Y" THEN PS% = 1
9901 GOSUB 6000
10000  IF PS%=1 THEN GOSUB 31210: REM PRINT VARIABLES
10100  GOSUB 1210: REM DISPLAY VARIABLES
20000 :
20005  PRINT : PRINT "NOX STUDY OUTPUTS": PRINT
20006 IF PS% = 1 THEN LPRINT : LPRINT "NOX STUDY OUTPUTS": LPRINT
20007  IF PAR > 0 GOTO 20020
20008 FOR I = 1 TO 36
20009 IF I = 28 THEN PRINT : PRINT "NEW KVB EQUATIONS" : PRINT
20010 IF I = 28 AND PS%=1 THEN LPRINT : LPRINT "NEW KVB EQUATIONS" : LPRINT
20011 PRINT C$(I);CP$(I); FN RD(C(I))
20012 IF PS% = 1 THEN  LPRINT C$(I);CP$(I); FN RD(C(I))
20014 NEXT
20015  GOTO 20040
20020 :
20021 FOR I = 1 TO 36
20023 IF I = 28 THEN PRINT : PRINT "NEW KVB EQUATIONS" : PRINT
20024 IF I = 28 AND PS% = 1 THEN LPRINT : LPRINT "NEW KVB EQUATIONS" : LPRINT
20025 ER=0:IF ABS(CS(I)) > .00001 THEN ER= FN RD((C(I)-CS(I))/CS(I)*100)
20030 PRINT C$(I);CP$(I); FN RD(C(I)); TAB(33) ; ER;" % "
20032 IF PS% = 1 THEN  LPRINT C$(I);CP$(I); FN RD(C(I)); TAB(33); ER;" % "
20034 NEXT
20040 PRINT CHR$(12): IF PS% = 1 THEN LPRINT CHR$(12)
20100  :
20200 GOSUB 6000: INVERSE : PRINT "SPACE BAR TO CONTINUE ": NORMAL : GET YN$:PRINT : GOSUB 6000
30000  GOTO 430
31210 LPRINT TAB(10);"NOX STUDY INPUTS": LPRINT
31220 LPRINT "(1) COAL H20   E( 1)=";E(1); TAB(33); VA$(1)
31230 LPRINT "(2) COAL  C    E( 2)=";E(2); TAB(33); VA$(2)
```

```
31240 LPRINT "(3) COAL  H    E( 3)=";E(3); TAB(33); VA$(3)
31250 LPRINT "(4) COAL  N    E( 4)=";E(4); TAB(33); VA$(4)
31260 LPRINT "(5) COAL  O    E( 5)=";E(5); TAB(33); VA$(5)
31270 LPRINT "(6) COAL ASH   E( 6)=";E(6); TAB(33); VA$(6)
31280 LPRINT "(7) COAL  S    E( 7)=";E(7); TAB(33); VA$(7)
31290 LPRINT "(8) FEED KFH20 E(11)=";E(11); TAB(33); VA$(8)
31300 LPRINT "(9) COAL BTUC  E(12)=";E(12); TAB(33); VA$(9)
31310 LPRINT "(10)FEED KFLOI E(13)=";E(13); TAB(33); VA$(10)
31320 :
31330 LPRINT "(12)KCOAL TPH VM(37)=";VM(37); TAB(33); VA$(12)
31340 LPRINT "(13)KFEED TPH VM(14)=";VM(14); TAB(33); VA$(13)
31350 LPRINT "(14)SPRYW GPM VM(45)=";VM(45); TAB(33); VA$(14)
31360 LPRINT "(15)WT ID 02% VM(4) =";VM(4); TAB(33); VA$(15)
31370 LPRINT "(16)ID NO PPM VM(2) =";VM(2); TAB(33); VA$(16)
31375 LPRINT "(17)EXIT 02 % VM(13)=";VM(13); TAB(33); VA$(17)
31999 RETURN
```

```
              NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20  E(11)= .004
(9) COAL BTUC   E(12)= 12437
(10)FEED KFLOI  E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4)  = 5.5
(16)ID NO PPM VM(2)  = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22
  AVAH= C( 2)=  .041
  OTWO= C( 3)=  852.457
  NTWO= C( 4)=  2842.99
   ARG= C( 5)=  0
 HTWOO= C( 6)=  61.1298
  ASHC= C( 7)=  34.9147
   AIR= C( 8)=  3704.7
  HOUT= C( 9)=  198.177
 COTWO= C( 10)=  2133.39
  SCFM= C( 11)=  48669.7
EXOTWO= C( 12)=  66.2821
  TAIR= C( 13)=  3992.76
  LBLB= C( 14)=  10.6695
 EXAIR= C( 15)=  7.7754
 MOLEW= C( 16)=  170.332
 ESCFM= C( 17)=  65629
 WOTWO= C( 18)=  1.216
IDOMOL= C( 19)=  10.8235
  OOUT= C( 20)=  412.635
 DMOLE= C( 21)=  211.119
 WMOLE= C( 22)=  234.163
EESCFM= C( 23)=  90223
    NO= C( 24)=  2.2339
 NOTWO= C( 25)=  3.4253
  NOLB= C( 26)=  3.6385
 NOBTU= C( 27)=  .736

NEW KVB EQUATIONS

  MKDG=            149.422
   MKW=            23.0437
  MKWG=            172.465
 MIDO2=            12.899
MIDXSDA=           61.7177
MIDXSW=            .3443
 SDCFM=            81351.9
 SWCFM=            90363.3
NOLBNU=            3.6442
```

```
          NOX STUDY INPUTS

(1) COAL H20    E( 1)= .0101        1 %
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC   E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID 02% VM(4)  = 5.5
(16)ID NO PPM VM(2)  = 318
(17)EXIT 02 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22          0  %
  AVAH= C( 2)=  .041            0  %
  OTWO= C( 3)=  852.457         0  %
  NTWO= C( 4)=  2842.99         0  %
   ARG= C( 5)=  0               0  %
 HTWOO= C( 6)=  61.1676         .0618  %
  ASHC= C( 7)=  34.9147         0  %
   AIR= C( 8)=  3704.7          0  %
  HOUT= C( 9)=  198.215         .0191  %
 COTWO= C( 10)=  2133.39        0  %
  SCFM= C( 11)=  48669.7        0  %
EXOTWO= C( 12)=  66.2821        0  %
  TAIR= C( 13)=  3992.76        0  %
  LBLB= C( 14)=  10.6695        0  %
 EXAIR= C( 15)=  7.7754         0  %
 MOLEW= C( 16)=  170.334        .0012  %
 ESCFM= C( 17)=  65629.8        .0012  %
 WOTWO= C( 18)=  1.216          -.0012  %
IDOMOL= C( 19)=  10.8237        .0014  %
  OOUT= C( 20)=  412.64         .0012  %
 DMOLE= C( 21)=  211.12         .0004  %
 WMOLE= C( 22)=  234.166        .0012  %
EESCFM= C( 23)=  90224.1        .0012  %
    NO= C( 24)=  2.2339         .0012  %
 NOTWO= C( 25)=  3.4254         .0012  %
  NOLB= C( 26)=  3.6386         .0012  %
 NOBTU= C( 27)=  .7361          .0113  %

NEW KVB EQUATIONS

  MKDG=              149.422    0  %
   MKW=              23.0458    .0091  %
  MKWG=              172.467    .0012  %
 MIDO2=              12.8991    .0012  %
MIDXSDA=             61.7184    .0012  %
MIDXSW=              .3443      .0012  %
 SDCFM=              81352.2    .0004  %
 SWCFM=              90364.4    .0012  %
NOLBNU=              3.6442     .0012  %
```

```
          NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .73781      1 %
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22           0  %
  AVAH= C( 2)=  .041             0  %
  OTWO= C( 3)=  859.745          .855  %
  NTWO= C( 4)=  2867.26          .8539  %
   ARG= C( 5)=  0                0  %
 HTWOO= C( 6)=  61.2394          .1792  %
  ASHC= C( 7)=  34.9147          0  %
   AIR= C( 8)=  3736.37          .855  %
  HOUT= C( 9)=  198.287          .0553  %
 COTWO= C( 10)=  2143.41         .4698  %
  SCFM= C( 11)=  49085.8         .8549  %
EXOTWO= C( 12)=  66.7655         .7293  %
  TAIR= C( 13)=  4026.53         .8459  %
  LBLB= C( 14)=  10.7598         .8459  %
 EXAIR= C( 15)=  7.7657         -.1246  %
 MOLEW= C( 16)=  171.5           .6858  %
 ESCFM= C( 17)=  66079           .6858  %
 WOTWO= C( 18)=  1.2166          .0432  %
IDOMOL= C( 19)=  10.8904         .6174  %
  OOUT= C( 20)=  415.257         .6353  %
 DMOLE= C( 21)=  212.601         .7018  %
 WMOLE= C( 22)=  235.651         .6354  %
EESCFM= C( 23)=  90796.3         .6354  %
    NO= C( 24)=  2.2481          .6354  %
 NOTWO= C( 25)=  3.4471          .6354  %
  NOLB= C( 26)=  3.6616          .6354  %
 NOBTU= C( 27)=  .7406           .6354  %

NEW KVB EQUATIONS

  MKDG=            150.511       .7293  %
   MKW=            23.0497       .0264  %
  MKWG=            173.561       .6354  %
 MIDO2=            12.9809       .6354  %
MIDXSDA=           62.1098       .6354  %
MIDXSW=            .3465         .6354  %
 SDCFM=            81922.9       .7018  %
 SWCFM=            90937.4       .6354  %
NOLBNU=            3.6673        .6354  %
```

```
          NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .05484      1 %
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20  E(11)= .004
(9) COAL BTUC   E(12)= 12437
(10)FEED KFLOI  E(13)= 1.6
(12)KCOAL TPH  VM(37)= 11.34
(13)KFEED TPH  VM(14)= 90.9
(14)SPRYW GPM  VM(45)= 26
(15)WT ID O2%  VM(4)  = 5.5
(16)ID NO PPM  VM(2)  = 318
(17)EXIT O2 %  VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22            0  %
  AVAH= C( 2)=  .0415             1.3176  %
  OTWO= C( 3)=  854.06            .1881  %
  NTWO= C( 4)=  2848.33           .1879  %
   ARG= C( 5)=  0                 0  %
 HTWOO= C( 6)=  61.1539           .0394  %
  ASHC= C( 7)=  34.9147           0  %
   AIR= C( 8)=  3711.67           .1881  %
  HOUT= C( 9)=  200.007           .9234  %
 COTWO= C( 10)=  2133.39          0  %
  SCFM= C( 11)=  48761.3          .1881  %
EXOTWO= C( 12)=  66.3663          .127  %
  TAIR= C( 13)=  4000.09          .1837  %
  LBLB= C( 14)=  10.6891          .1837  %
 EXAIR= C( 15)=  7.7707          -.0611  %
 MOLEW= C( 16)=  170.636          .1784  %
 ESCFM= C( 17)=  65746.1          .1784  %
 WOTWO= C( 18)=  1.2154          -.0513  %
IDOMOL= C( 19)=  10.8427          .1769  %
  OOUT= C( 20)=  413.332          .1689  %
 DMOLE= C( 21)=  211.413          .1392  %
 WMOLE= C( 22)=  234.559          .1689  %
EESCFM= C( 23)=  90375.4          .1689  %
    NO= C( 24)=  2.2377           .1689  %
 NOTWO= C( 25)=  3.4311           .1689  %
  NOLB= C( 26)=  3.6447           .1689  %
 NOBTU= C( 27)=  .7372            .1689  %

NEW KVB EQUATIONS

  MKDG=              149.611      .127  %
   MKW=              23.1452      .4408  %
  MKWG=              172.756      .1689  %
 MIDO2=              12.9208      .1689  %
MIDXSDA=             61.8219      .1689  %
MIDXSW=              .3449        .1689  %
 SDCFM=              81465.2      .1392  %
 SWCFM=              90515.9      .1689  %
NOLBNU=              3.6503       .1689  %
```

```
                NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .00959      1 %
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID 02% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT 02 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22           0  %
  AVAH= C( 2)=  .041             0  %
  OTWO= C( 3)=  852.457          0  %
  NTWO= C( 4)=  2843.02          .0012  %
   ARG= C( 5)=  0                0  %
 HTWOO= C( 6)=  61.1298          0  %
  ASHC= C( 7)=  34.9147          0  %
   AIR= C( 8)=  3704.7           0  %
  HOUT= C( 9)=  198.177          0  %
 COTWO= C( 10)=  2133.39         0  %
  SCFM= C( 11)=  48669.7         0  %
EXOTWO= C( 12)=  66.2827         .0008  %
  TAIR= C( 13)=  3992.76         0  %
  LBLB= C( 14)=  10.6695         0  %
 EXAIR= C( 15)=  7.7755          .0008  %
 MOLEW= C( 16)=  170.333         .0008  %
 ESCFM= C( 17)=  65629.5         .0008  %
 WOTWO= C( 18)=  1.216           .0001  %
IDOMOL= C( 19)=  10.8236         .0007  %
  OOUT= C( 20)=  412.638         .0007  %
 DMOLE= C( 21)=  211.121         .0008  %
 WMOLE= C( 22)=  234.165         .0007  %
EESCFM= C( 23)=  90223.6         .0007  %
    NO= C( 24)=  2.2339          .0007  %
 NOTWO= C( 25)=  3.4254          .0007  %
  NOLB= C( 26)=  3.6385          .0007  %
 NOBTU= C( 27)=  .736            .0007  %

NEW KVB EQUATIONS

  MKDG=            149.423       .0008  %
   MKW=            23.0437       0  %
  MKWG=            172.466       .0007  %
 MIDO2=            12.8991       .0007  %
MIDXSDA=           61.7181       .0007  %
MIDXSW=            .3443         .0007  %
 SDCFM=            81352.5       .0008  %
 SWCFM=            90363.9       .0007  %
NOLBNU=            3.6442        .0007  %
```

```
            NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .10676      1 %
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID 02% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT 02 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22            0  %
  AVAH= C( 2)=  .0408            -.3259  %
  OTWO= C( 3)=  852.06           -.0465  %
  NTWO= C( 4)=  2841.67          -.0465  %
   ARG= C( 5)=  0                 0  %
 HTWOO= C( 6)=  61.5705           .7209  %
  ASHC= C( 7)=  34.9147           0  %
   AIR= C( 8)=  3702.97          -.0465  %
  HOUT= C( 9)=  198.171          -.003  %
 COTWO= C( 10)=  2133.39          0  %
  SCFM= C( 11)=  48647.1         -.0465  %
EXOTWO= C( 12)=  66.2613         -.0314  %
  TAIR= C( 13)=  3990.94         -.0454  %
  LBLB= C( 14)=  10.6647         -.0454  %
 EXAIR= C( 15)=  7.7766           .0152  %
 MOLEW= C( 16)=  170.282         -.0295  %
 ESCFM= C( 17)=  65609.6         -.0295  %
 WOTWO= C( 18)=  1.216           -.0018  %
IDOMOL= C( 19)=  10.8207         -.0266  %
  OOUT= C( 20)=  412.522         -.0274  %
 DMOLE= C( 21)=  211.056         -.0302  %
 WMOLE= C( 22)=  234.099         -.0274  %
EESCFM= C( 23)=  90198.3         -.0274  %
    NO= C( 24)=  2.2333          -.0274  %
 NOTWO= C( 25)=  3.4244          -.0274  %
  NOLB= C( 26)=  3.6375          -.0274  %
 NOBTU= C( 27)=  .7358           -.0274  %

NEW KVB EQUATIONS

  MKDG=            149.375       -.0314  %
   MKW=            23.0433       -.0014  %
  MKWG=            172.418       -.0274  %
 MIDO2=            12.8955       -.0274  %
MIDXSDA=           61.7008       -.0274  %
MIDXSW=            .3442         -.0274  %
 SDCFM=            81327.3       -.0302  %
 SWCFM=            90338.6       -.0274  %
NOLBNU=            3.6432        -.0274  %
```

```
          NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .09423      1 %
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22           0  %
  AVAH= C( 2)=  .041             0  %
  OTWO= C( 3)=  852.457          0  %
  NTWO= C( 4)=  2842.99          0  %
   ARG= C( 5)=  0                0  %
 HTWOO= C( 6)=  61.1298          0  %
  ASHC= C( 7)=  35.2627          .9968  %
   AIR= C( 8)=  3704.7           0  %
  HOUT= C( 9)=  198.177          0  %
 COTWO= C( 10)=  2133.39         0  %
  SCFM= C( 11)=  48669.7         0  %
EXOTWO= C( 12)=  66.2821         0  %
  TAIR= C( 13)=  3992.76         0  %
  LBLB= C( 14)=  10.6695         0  %
 EXAIR= C( 15)=  7.7754          0  %
 MOLEW= C( 16)=  170.332         0  %
 ESCFM= C( 17)=  65629           0  %
 WOTWO= C( 18)=  1.216           0  %
IDOMOL= C( 19)=  10.8235         0  %
  OOUT= C( 20)=  412.635         0  %
 DMOLE= C( 21)=  211.119         0  %
 WMOLE= C( 22)=  234.163         0  %
EESCFM= C( 23)=  90223           0  %
    NO= C( 24)=  2.2339          0  %
 NOTWO= C( 25)=  3.4253          0  %
  NOLB= C( 26)=  3.6385          0  %
 NOBTU= C( 27)=  .736            0  %

NEW KVB EQUATIONS

  MKDG=            149.422       0  %
   MKW=            23.0437       0  %
  MKWG=            172.465       0  %
 MIDO2=            12.899        0  %
MIDXSDA=           61.7177       0  %
MIDXSW=            .3443         0  %
 SDCFM=            81351.9       0  %
 SWCFM=            90363.3       0  %
NOLBNU=            3.6442        0  %
```

```
         NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .00656      1 %
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22           0  %
  AVAH= C( 2)=  .041             0  %
  OTWO= C( 3)=  852.479          .0026  %
  NTWO= C( 4)=  2843.06          .0026  %
   ARG= C( 5)=  0                0  %
 HTWOO= C( 6)=  61.1302          .0005  %
  ASHC= C( 7)=  34.9147          0  %
   AIR= C( 8)=  3704.8           .0026  %
  HOUT= C( 9)=  198.177          .0002  %
 COTWO= C( 10)=  2133.39         0  %
  SCFM= C( 11)=  48671           .0026  %
EXOTWO= C( 12)=  66.2833         .0018  %
  TAIR= C( 13)=  3992.86         .0026  %
  LBLB= C( 14)=  10.6698         .0026  %
 EXAIR= C( 15)=  7.7754         -.0008  %
 MOLEW= C( 16)=  170.335         .0017  %
 ESCFM= C( 17)=  65630.1         .0017  %
 WOTWO= C( 18)=  1.216           .0001  %
IDOMOL= C( 19)=  10.8237         .0015  %
  OOUT= C( 20)=  412.642         .0016  %
 DMOLE= C( 21)=  211.123         .0017  %
 WMOLE= C( 22)=  234.167         .0016  %
EESCFM= C( 23)=  90224.4         .0015  %
    NO= C( 24)=  2.2339          .0015  %
 NOTWO= C( 25)=  3.4254          .0016  %
  NOLB= C( 26)=  3.6386          .0015  %
 NOBTU= C( 27)=  .736            .0015  %

NEW KVB EQUATIONS

  MKDG=            149.424       .0018  %
   MKW=            23.0437       .0001  %
  MKWG=            172.468       .0015  %
 MIDO2=            12.8992       .0015  %
MIDXSDA=           61.7186       .0015  %
MIDXSW=            .3443         .0015  %
 SDCFM=            81353.3       .0017  %
 SWCFM=            90364.7       .0015  %
NOLBNU=            3.6442        .0016  %
```

```
         NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20  E(11)= .00404      1 %
(9) COAL BTUC   E(12)= 12437
(10)FEED KFLOI  E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22           0  %
  AVAH= C( 2)=  .041             0  %
  OTWO= C( 3)=  852.457          0  %
  NTWO= C( 4)=  2842.99          0  %
   ARG= C( 5)=  0                0  %
 HTWOO= C( 6)=  61.1298          0  %
  ASHC= C( 7)=  34.9147          0  %
   AIR= C( 8)=  3704.7           0  %
  HOUT= C( 9)=  198.177          0  %
 COTWO= C( 10)=  2133.34       -.0021  %
  SCFM= C( 11)=  48669.7         0  %
EXOTWO= C( 12)=  66.2817       -.0007  %
  TAIR= C( 13)=  3992.75       -.0001  %
  LBLB= C( 14)=  10.6695       -.0001  %
 EXAIR= C( 15)=  7.7754        -.0007  %
 MOLEW= C( 16)=  170.331       -.0006  %
 ESCFM= C( 17)=  65628.6       -.0006  %
 WOTWO= C( 18)=  1.216           0  %
IDOMOL= C( 19)=  10.8235       -.0006  %
  OOUT= C( 20)=  412.633       -.0006  %
 DMOLE= C( 21)=  211.118       -.0007  %
 WMOLE= C( 22)=  234.162       -.0006  %
EESCFM= C( 23)=  90222.5       -.0006  %
    NO= C( 24)=  2.2339        -.0006  %
 NOTWO= C( 25)=  3.4253        -.0006  %
  NOLB= C( 26)=  3.6386         .0034  %
 NOBTU= C( 27)=  .736          -.0006  %

NEW KVB EQUATIONS

  MKDG=            149.42      -.0007  %
   MKW=            23.0437       0  %
  MKWG=            172.464     -.0006  %
 MIDO2=            12.8989     -.0006  %
MIDXSDA=           61.7173     -.0006  %
MIDXSW=            .3443       -.0006  %
 SDCFM=            81351.4     -.0007  %
 SWCFM=            90362.8     -.0006  %
NOLBNU=            3.6443       .0034  %
```

NOX STUDY INPUTS

```
(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12561.4     1 %
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID 02% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT 02 % VM(13)= 1.3
```

NOX STUDY OUTPUTS

```
 DCOAL= C( 1)=  374.22          0  %
  AVAH= C( 2)=  .041            0  %
  OTWO= C( 3)=  852.457         0  %
  NTWO= C( 4)=  2842.99         0  %
   ARG= C( 5)=  0               0  %
 HTWOO= C( 6)=  61.1298         0  %
  ASHC= C( 7)=  34.9147         0  %
   AIR= C( 8)=  3704.7          0  %
  HOUT= C( 9)=  198.177         0  %
 COTWO= C( 10)=  2133.39        0  %
  SCFM= C( 11)=  48669.7        0  %
EXOTWO= C( 12)=  66.2821        0  %
  TAIR= C( 13)=  3992.76        0  %
  LBLB= C( 14)=  10.6695        0  %
 EXAIR= C( 15)=  7.7754         0  %
 MOLEW= C( 16)=  170.332        0  %
 ESCFM= C( 17)=  65629          0  %
 WOTWO= C( 18)=  1.216          0  %
IDOMOL= C( 19)=  10.8235        0  %
  OOUT= C( 20)=  412.635        0  %
 DMOLE= C( 21)=  211.119        0  %
 WMOLE= C( 22)=  234.163        0  %
EESCFM= C( 23)=  90223          0  %
    NO= C( 24)=  2.2339         0  %
 NOTWO= C( 25)=  3.4253         0  %
  NOLB= C( 26)=  3.6385         0  %
 NOBTU= C( 27)=  .7287         -.9901  %
```

NEW KVB EQUATIONS

```
  MKDG=           149.422       0  %
   MKW=           23.0437       0  %
  MKWG=           172.465       0  %
 MIDO2=           12.899        0  %
MIDXSDA=          61.7177       0  %
MIDXSW=           .3443         0  %
 SDCFM=           81351.9       0  %
 SWCFM=           90363.3       0  %
NOLBNU=           3.6442        0  %
```

```
          NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.616       1 %
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22          0  %
  AVAH= C( 2)=  .041            0  %
  OTWO= C( 3)=  852.457         0  %
  NTWO= C( 4)=  2842.99         0  %
   ARG= C( 5)=  0               0  %
 HTWOO= C( 6)=  61.1298         0  %
  ASHC= C( 7)=  34.9147         0  %
   AIR= C( 8)=  3704.7          0  %
  HOUT= C( 9)=  198.177         0  %
 COTWO= C( 10)=  2152.06        .8754  %
  SCFM= C( 11)=  48669.7        0  %
EXOTWO= C( 12)=  66.4704        .284  %
  TAIR= C( 13)=  3993.57        .0205  %
  LBLB= C( 14)=  10.6717        .0205  %
 EXAIR= C( 15)=  7.7975         .284  %
 MOLEW= C( 16)=  170.785        .2656  %
 ESCFM= C( 17)=  65803.3        .2657  %
 WOTWO= C( 18)=  1.2163         .0183  %
IDOMOL= C( 19)=  10.8494        .2388  %
  OOUT= C( 20)=  413.651        .246  %
 DMOLE= C( 21)=  211.696        .2729  %
 WMOLE= C( 22)=  234.739        .246  %
EESCFM= C( 23)=  90445          .246  %
    NO= C( 24)=  2.2394         .246  %
 NOTWO= C( 25)=  3.4338         .246  %
  NOLB= C( 26)=  3.6839         1.2485  %
 NOBTU= C( 27)=  .7378          .246  %

NEW KVB EQUATIONS

  MKDG=            149.846      .284  %
   MKW=            23.0437      0  %
  MKWG=            172.89       .246  %
 MIDO2=            12.9307      .246  %
MIDXSDA=           61.8695      .246  %
MIDXSW=            .3452        .246  %
 SDCFM=            81573.9      .2729  %
 SWCFM=            90585.6      .246  %
NOLBNU=            3.6897       1.2485  %
```

```
                    NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.4534     1 %
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4)  = 5.5
(16)ID NO PPM VM(2)  = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22            0  %
  AVAH= C( 2)=  .041              0  %
  OTWO= C( 3)=  852.457           0  %
  NTWO= C( 4)=  2842.99           0  %
   ARG= C( 5)=  0                 0  %
 HTWOO= C( 6)=  61.1676           .0618  %
  ASHC= C( 7)=  34.9147           0  %
   AIR= C( 8)=  3704.7            0  %
  HOUT= C( 9)=  198.215           .0191  %
 COTWO= C( 10)=  2133.39          0  %
  SCFM= C( 11)=  48669.7          0  %
EXOTWO= C( 12)=  66.2821          0  %
  TAIR= C( 13)=  3992.76          0  %
  LBLB= C( 14)=  10.6695          0  %
 EXAIR= C( 15)=  7.7754           0  %
 MOLEW= C( 16)=  170.334          .0012  %
 ESCFM= C( 17)=  65629.8          .0012  %
 WOTWO= C( 18)=  1.216           -.0012  %
IDOMOL= C( 19)=  10.8237          .0014  %
  OOUT= C( 20)=  412.64           .0012  %
 DMOLE= C( 21)=  211.12           .0004  %
 WMOLE= C( 22)=  234.166          .0012  %
EESCFM= C( 23)=  90224.1          .0012  %
    NO= C( 24)=  2.2339           .0012  %
 NOTWO= C( 25)=  3.4254           .0012  %
  NOLB= C( 26)=  3.6386           .0012  %
 NOBTU= C( 27)=  .7287           -.9889  %

NEW KVB EQUATIONS

  MKDG=             149.422       0  %
   MKW=             23.0458       .0091  %
  MKWG=             172.467       .0012  %
 MIDO2=             12.8991       .0012  %
MIDXSDA=            61.7184       .0012  %
MIDXSW=             .3443         .0012  %
 SDCFM=             81352.2       .0004  %
 SWCFM=             90364.4       .0012  %
NOLBNU=             3.6442        .0012  %
```

```
          NOX STUDY INPUTS

(1) COAL H20    E( 1)= .01
(2) COAL  C     E( 2)= .7305
(3) COAL  H     E( 3)= .0543
(4) COAL  N     E( 4)= .0095
(5) COAL  O     E( 5)= .1057
(6) COAL ASH    E( 6)= .0933
(7) COAL  S     E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 91.809      1 %
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22          0  %
  AVAH= C( 2)=  .041            0  %
  OTWO= C( 3)=  852.457         0  %
  NTWO= C( 4)=  2842.99         0  %
   ARG= C( 5)=  0               0  %
 HTWOO= C( 6)=  61.1298         0  %
  ASHC= C( 7)=  34.9147         0  %
   AIR= C( 8)=  3704.7          0  %
  HOUT= C( 9)=  198.177         0  %
 COTWO= C( 10)=  2144.7         .5305  %
  SCFM= C( 11)=  48669.7        0  %
EXOTWO= C( 12)=  66.3962        .1721  %
  TAIR= C( 13)=  3993.25        .0124  %
  LBLB= C( 14)=  10.6709        .0124  %
 EXAIR= C( 15)=  7.7888         .1721  %
 MOLEW= C( 16)=  170.606        .161  %
 ESCFM= C( 17)=  65734.6        .161  %
 WOTWO= C( 18)=  1.2162         .0111  %
IDOMOL= C( 19)=  10.8392        .1447  %
  OOUT= C( 20)=  413.251        .1491  %
 DMOLE= C( 21)=  211.469        .1654  %
 WMOLE= C( 22)=  234.512        .1491  %
EESCFM= C( 23)=  90357.5        .1491  %
    NO= C( 24)=  2.2372         .1491  %
 NOTWO= C( 25)=  3.4304         .1491  %
  NOLB= C( 26)=  3.6079        -.8425  %
 NOBTU= C( 27)=  .7371          .1491  %

NEW KVB EQUATIONS

  MKDG=              149.679    .1721  %
   MKW=              23.0437    0  %
  MKWG=              172.722    .1491  %
 MIDO2=              12.9182    .1491  %
MIDXSDA=             61.8097    .1491  %
MIDXSW=              .3448      .1491  %
 SDCFM=              81486.4    .1654  %
 SWCFM=              90498      .1491  %
NOLBNU=              3.6135    -.8425  %
```

```
          NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26.26       1 %
(15)WT ID O2% VM(4) = 5.5
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22         0  %
  AVAH= C( 2)=  .041           0  %
  OTWO= C( 3)=  852.457        0  %
  NTWO= C( 4)=  2842.99        0  %
   ARG= C( 5)=  0              0  %
 HTWOO= C( 6)=  61.1298        0  %
  ASHC= C( 7)=  34.9147        0  %
   AIR= C( 8)=  3704.7         0  %
  HOUT= C( 9)=  198.177        0  %
 COTWO= C( 10)=  2133.39       0  %
  SCFM= C( 11)=  48669.7       0  %
EXOTWO= C( 12)=  66.2821       0  %
  TAIR= C( 13)=  3992.76       0  %
  LBLB= C( 14)=  10.6695       0  %
 EXAIR= C( 15)=  7.7754        0  %
 MOLEW= C( 16)=  170.332       0  %
 ESCFM= C( 17)=  65629         0  %
 WOTWO= C( 18)=  1.216         0  %
IDOMOL= C( 19)=  10.8325       .0832  %
  OOUT= C( 20)=  412.924       .0699  %
 DMOLE= C( 21)=  211.162       .0204  %
 WMOLE= C( 22)=  234.327       .0698  %
EESCFM= C( 23)=  90286         .0698  %
    NO= C( 24)=  2.2355        .0698  %
 NOTWO= C( 25)=  3.4277        .0698  %
  NOLB= C( 26)=  3.6411        .0698  %
 NOBTU= C( 27)=  .7365         .0698  %

NEW KVB EQUATIONS

  MKDG=            149.422     0  %
   MKW=            23.1641     .5227  %
  MKWG=            172.586     .0698  %
 MIDO2=            12.908      .0698  %
MIDXSDA=           61.7608     .0698  %
MIDXSW=            .3446       .0698  %
 SDCFM=            81368.5     .0204  %
 SWCFM=            90426.4     .0698  %
NOLBNU=            3.6467      .0698  %
```

```
        NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
(10)FEED KFLOI E(13)= 1.6
(12)KCOAL TPH VM(37)= 11.34
(13)KFEED TPH VM(14)= 90.9
(14)SPRYW GPM VM(45)= 26
(15)WT ID O2% VM(4) = 5.55501      1 %
(16)ID NO PPM VM(2) = 318
(17)EXIT O2 % VM(13)= 1.3

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22          0  %
   AVAH= C( 2)=  .041           0  %
   OTWO= C( 3)=  852.457        0  %
   NTWO= C( 4)=  2842.99        0  %
    ARG= C( 5)=  0              0  %
  HTWOO= C( 6)=  61.1298        0  %
   ASHC= C( 7)=  34.9147        0  %
    AIR= C( 8)=  3704.7         0  %
   HOUT= C( 9)=  198.177        0  %
  COTWO= C( 10)=  2133.39       0  %
   SCFM= C( 11)=  48669.7       0  %
 EXOTWO= C( 12)=  66.2821       0  %
   TAIR= C( 13)=  3992.76       0  %
   LBLB= C( 14)=  10.6695       0  %
  EXAIR= C( 15)=  7.7754        0  %
  MOLEW= C( 16)=  170.332       0  %
  ESCFM= C( 17)=  65629         0  %
  WOTWO= C( 18)=  1.216         0  %
 IDOMOL= C( 19)=  10.9995       1.6261  %
   OOUT= C( 20)=  418.267       1.3649  %
  DMOLE= C( 21)=  211.961       .3989  %
  WMOLE= C( 22)=  235.005       .3596  %
 EESCFM= C( 23)=  90547.5       .3596  %
     NO= C( 24)=  2.2419        .3596  %
  NOTWO= C( 25)=  3.4377        .3596  %
   NOLB= C( 26)=  3.6516        .3596  %
  NOBTU= C( 27)=  .7386         .3596  %

NEW KVB EQUATIONS

   MKDG=            149.422      0  %
    MKW=            23.0437      0  %
   MKWG=            172.465      0  %
  MIDO2=            13.075       1.3649  %
 MIDXSDA=           62.56        1.3649  %
 MIDXSW=            .349         1.3649  %
  SDCFM=            81676.5      .399  %
  SWCFM=            90689.7      .3612  %
 NOLBNU=            3.6573       .3612  %
```

```
NEW KVB EQUATIONS

   MKDG=            149.422      0  %
    MKW=            23.0437      0  %
   MKWG=            172.465      0  %
  MIDO2=            12.899       0  %
 MIDXSDA=           61.7177      0  %
 MIDXSW=            .3443        0  %
  SDCFM=            81351.9      0  %
  SWCFM=            90363.3      0  %
 NOLBNU=            3.6442       0  %
```

```
                    NOX STUDY INPUTS

(1) COAL H20   E( 1)= .01
(2) COAL  C    E( 2)= .7305
(3) COAL  H    E( 3)= .0543
(4) COAL  N    E( 4)= .0095
(5) COAL  O    E( 5)= .1057
(6) COAL ASH   E( 6)= .0933
(7) COAL  S    E( 7)= .0065
(8) FEED KFH20 E(11)= .004
(9) COAL BTUC  E(12)= 12437
```

```
                    NOX STUDY INPUTS

(1) COAL H20   E( 1)= .0101          1 %
(2) COAL  C    E( 2)= .73781         1 %
(3) COAL  H    E( 3)= .05484         1 %
(4) COAL  N    E( 4)= .00959         1 %
(5) COAL  O    E( 5)= .10676         1 %
(6) COAL ASH   E( 6)= .09423         1 %
(7) COAL  S    E( 7)= .00656         1 %
(8) FEED KFH20 E(11)= .00404         1 %
(9) COAL BTUC  E(12)= 12561.4        1 %
(10)FEED KFLOI E(13)= 1.616          1 %
(12)KCOAL TPH VM(37)= 11.4534        1 %
(13)KFEED TPH VM(14)= 91.809         1 %
(14)SPRYW GPM VM(45)= 26.26          1 %
(15)WT ID O2% VM(4) = 5.55501        1 %
(16)ID NO PPM VM(2) = 321.18         1 %
(17)EXIT O2 % VM(13)= 1.313          1 %

NOX STUDY OUTPUTS

 DCOAL= C( 1)=  374.22            0  %
  AVAH= C( 2)=  .0414             .9918  %
  OTWO= C( 3)=  860.974           .9992  %
  NTWO= C( 4)=  2871.39           .9991  %
   ARG= C( 5)=  0                 0  %
 HTWOO= C( 6)=  61.7805           1.0644  %
  ASHC= C( 7)=  35.2627           .9968  %
   AIR= C( 8)=  3741.72           .9992  %
  HOUT= C( 9)=  200.187           1.0142  %
 COTWO= C( 10)=  2173.54          1.8823  %
  SCFM= C( 11)=  49156            .9992  %
EXOTWO= C( 12)=  67.8509          2.3668  %
  TAIR= C( 13)=  4036.59          1.0979  %
  LBLB= C( 14)=  10.7867          1.0978  %
 EXAIR= C( 15)=  7.8807           1.3541  %
 MOLEW= C( 16)=  172.599          1.331  %
 ESCFM= C( 17)=  66502.5          1.331  %
 WOTWO= C( 18)=  1.2285           1.0222  %
IDOMOL= C( 19)=  11.1136          2.6803  %
  OOUT= C( 20)=  423.488          2.63  %
 DMOLE= C( 21)=  214.663          1.6785  %
 WMOLE= C( 22)=  237.939          1.6124  %
EESCFM= C( 23)=  91677.8          1.6124  %
    NO= C( 24)=  2.2926           2.6285  %
 NOTWO= C( 25)=  3.5154           2.6285  %
  NOLB= C( 26)=  3.7343           2.6326  %
 NOBTU= C( 27)=  .7405            .6164  %

NEW KVB EQUATIONS

  MKDG=              151.343      1.2856  %
   MKW=              23.2757      1.0068  %
  MKWG=              174.618      1.2484  %
 MIDO2=              13.2383      2.6303  %
MIDXSDA=             63.341       2.6303  %
MIDXSW=              .3534        2.6303  %
 SDCFM=              82717.6      1.6787  %
 SWCFM=              91821.8      1.6141  %
NOLBNU=              3.7402       2.6343  %
```

APPENDIX D

COAL AND KILN FEED ANALYSES

Getty

Getty Minerals Marketing, Inc | 215 East Main Street Price, Utah 84501 • Telephone (801) 637-7747

Telecopy 801-637 2205 TWX 910 971-4215

Kay [illegible] 1/4

Mine Operator:	Utah Fuel Company
Mine Owner:	Getty Mining Company/Coastal States Energy Co. Joint Venture
Type of Mine & Location:	Underground Drift, Eccles Canyon, Utah (5 Miles SW of Scofield, Utah)
Seam(s) Mined:	Upper O'Connor, Lower O'Connor "A" and "B"
Preparation Facilities:	Crushing and Screening
Reserves:	Approx. 80 Million Tons Recoverable
Loading:	Conveyor Directly from Mine to Truck Loadout
Freight Rate District:	Scofield, Utah
Production, TPD:	2,000 Tons Per Day
Coal Size:	2" x 0"

Proximate Analysis, As Received:	
% Moisture Total	10.0
% Moisture Surface	5.0
% Ash	11.0
Volatile Matter	38.50
Fixed Carbon	41.50
Btu/lb.	11,200
% Sulfur	0.65

Ultimate Analysis:	**Dry**
Carbon	61.00
Hydrogen	4.95
Nitrogen	1.57
Chlorine	0.02
Sulfur	0.65
Ash	12.0
Oxygen (diff.)	9.35
Grindability	45-50

Ash Mineral Composition, % Wt.:		
Phos. Pentoxide	P_2O_5	0.13
Silica	SiO_2	64.06
Ferric Oxide	Fe_2O_3	5.78
Alumina	Al_2O_3	13.65
Titania	TiO_2	0.74
Lime	CaO	10.77
Magnesia	MgO	1.15
Sulfur Trioxide	SO_3	2.93
Potassium Oxide	K_2O	1.20
Sodium Oxide	Na_2O	0.63
Undetermined		0.13

Ash Fusibility, °F:	**Reducing**
I.D.	2160
Softening (H=W)	2190
Softening (H=W/2)	2220
Fluid	2260

Ultimate Analysis AS RECEIVED

C
H
N
Cl
Sulfur
Ash
O_2
H_2O

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES 1919 SOUTH HIGHLAND AVE. SUITE 210-B, LOMBARD, ILLINOIS 60148 [illegible]

PLEASE ADDRESS ALL CORRESPONDENCE
334 S. CARBON AVE. [illegible]
[illegible]

3/

Utah Fuel Company
P O Box 719
Helper, Utah 84526

July 18, 1985

Sample identification
by Utah Fuel Co.

Monthly Composite
May 1985

nd of sample eported to us	Coal
mple taken at	Skyline
mple taken by	Utah Fuel Co.
Date sampled	May 1985
Date received	6-26-85

Analysis report no. 57-19174 Page 1

PROXIMATE ANALYSIS

	As Received	Dry Basis
% Moisture	9.84	xxxxx
% Ash	8.12	9.01
% Volatile	40.66	45.10
% Fixed Carbon	41.38	45.89
	100.00	100.00
Btu/lb.	11607	12874
% Sulfur	0.61	0.68

isture, Ash-Free Btu = 14149

ULTIMATE ANALYSIS

	As Received	Dry
% Moisture	9.84	xxxx
% Carbon	65.32✓	72.4
% Hydrogen	4.76	5.2
% Nitrogen	1.27	1.4
% Chlorine	0.02	0.0
% Sulfur	0.61	0.6
% Ash	8.12	9.0
% Oxygen (diff)	10.06	11.1
	100.00	100.0

SULFUR FORMS

	As Received	Dry Basis
% Pyritic Sulfur	xxxx	xxxx
% Sulfate Sulfur	xxxx	xxxx
% Organic Sulfur (Diff)	xxxx	xxxx
% Total Sulfur	xxxx	xxxx

FUSION TEMPERATURE OF ASH

	Reducing		Oxidizing
Initial Deformation	2155	°F	xxxx
Softening (H=W)	2255	°F	xxxx
Softening (H=½W)	2390	°F	xxxx
Fluid	2450	°F	xxxx

IDGROVE GRINDABILITY INDEX = 46 at 3.97 % Moisture

Sisners 2/4

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES 1919 SOUTH HIGHLAND AVE. SUITE 210 B, LOMBARD, ILLINOIS 60148 • (312) 953-9300

E SELDON
...ER
...EST DIVISION

PLEASE ADDRESS ALL CORRESPONDENCE TO:
224 S. CARBON AVE.
OFFICE TEL (801) 637-

UTAH FUEL COMPANY
P O Box 719
Helper, Utah 84526

May 23, 1985

Sample identification
by

Utah Fuel Co.

Monthly Composite of April 1985
18706
18776
18777
18865

of sample orted to us	Coal
le taken at	Skyline
e taken by	Utah Fuel Co.
e sampled	April 1985
e received	May 17, 1985

Analysis report no. 57-18866 Page 1

PROXIMATE ANALYSIS

	As Received	Dry Basis
% Moisture	8.67	xxxxx
% Ash	8.86	9.70
% Volatile	40.69	44.55
% Fixed Carbon	41.78	45.75
	100.00	100.00
Btu/lb.	11791	12910
% Sulfur	0.70	0.77

sture, Ash-free Btu = 14297

ULTIMATE ANALYSIS

	As Received	Dry Basis
% Moisture	8.67	xxxxx
% Carbon	66.04	72.31
% Hydrogen	5.00	5.47
% Nitrogen	1.52	1.66
% Chlorine	0.04	0.04
% Sulfur	0.70	0.77
% Ash	8.86	9.70
% Oxygen (diff)	9.17	10.05
	100.00	100.00

SULFUR FORMS

	As Received	Dry Basis
% Pyritic Sulfur	xxxx	xxxx
% Sulfate Sulfur	xxxx	xxxx
% Organic Sulfur (Diff)	xxxx	xxxx
% Total Sulfur	xxxx	xxxx

FUSION TEMPERATURE OF ASH

	Reducing	Oxidizing
Initial Deformation	2180 °F	2260 °F
Softening (H = W)	2300 °F	2410 °F
Softening (H = ½W)	2350 °F	2460 °F
Fluid	2400 °F	2560 °F

GROVE GRINDABILITY INDEX = 50.0 at 3.32 % Moisture

ELLING INDEX = xxxx
B/ap

COMMERCIAL TESTING & ENGINEERING CO.

Jeff Garnie
Manager, Price Laboratory
Jeff G

40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS.
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

GIFFORD-HILL

Riverside Cement Company

INTER-OFFICE CORRESPONDENCE

July 22, 1985

TO: G. Young

FROM: Ray Sisneros

SUBJECT:

6 piles Kept
(Crosscheck on sampling system)

Date	Mound	Loss
3/25	D	35.32
3/26	D	34.40
4/6	D	35.79
4/7	D	35.14
4/8	D/E	35.62
4/9	D/E	35.06
4/10	E	34.54
4/11	B	35.38
4/12	B	35.05
4/13	B	35.84
4/14	B	35.65
4/15	B	34.80
4/16	B	34.23
4/17	B	34.85
4/19	B	33.91
4/29	C	35.24
5/4	C	35.30
5/5	C	35.39
5/6	C	35.40
5/7	C	35.45
5/8	C	34.74
5/9	C	35.82
5/10	C	34.65
5/11	C	35.63
5/12	C	36.22
5/13	C/E	35.03
5/14	E	36.33
5/15	E	35.62
5/16	E	35.70

Date	Mound	Loss
5/17	E	35.59
5/18	E	35.65
5/19	E	34.51
5/20	E	35.12
5/21	E/F	34.79
5/22	E/F	34.87
5/23	F	35.50
5/24	F	35.63
5/25	F	34.66
5/26	F	34.88
6/5	F	35.96
6/6	F	35.70
6/7	F	35.28
6/8	F	35.36
6/12	F	36.22
6/13	F/A	36.63
6/14	F/A	33.20
6/16	A	34.02
6/17	A	33.81
6/18	A	34.76
6/19	A	34.54
6/20	A	33.96
6/21	A	33.47
6/22	A	33.50
6/23	A/F	33.51
6/24	A/F	34.00
6/25	F	34.65
6/26	F	34.84
6/27	F	34.92
6/28	F	34.60
6/29	F	34.99
7/7		33.85
7/8		34.14
7/10		34.41
7/11		34.67
7/12		34.08
7/13		34.31
7/14		34.24
7/15		34.15
7/16		34.15

NO MORE MINE LIMESTONE
AVERAGE LOSS 34.17
STD DEVIATION .472

3 times daily
1 a shift

34.19
.49

Average = 34.92
Std. Dev. = 0.7564

cc: R.B. Rieser
R. McMann

RS:kk

Ray Sisneros
Asst. Chief Chemist

APPENDIX E

LEAR SIEGLER SM 810 NO_x/SO_2 GAS ANALYZER

O₂ GAS 2.14

Time	Date	Mach.	Gas	Zero	Span
8:33 AM	6-26-85	SM 810	SO2	4	740P
"	"	"	NO	0	460
9:38 AM	"	CM50	O2	1%	22%
8:34 AM	6-27-85	SM 810	SO2	4	740
"	"	"	NO	0	500
"	"	CM50	O2	1%	22%
11:55 AM	7-10-85	CM50	O2	1%	21%
7:25 AM	7-11-85	CM50	O2	.90%	21.2%
7:25 AM	"	SM810	SO2	4	740 PPM
"	"	"	NO	0	500 PPM
13:35	7-13-85	SM810	SO2	0	781 PPM
"	7-13-85	"	NO	0	516 PPM
"	7-13-85	CM50	O2	.90%	20.5%
0717	7-15-85	CM50	~~S~~O2	1%	20.5%
"	"	SM810	SO2	6	919
"	"	SM810	NO	0	482
0712	7-17-85	SM810	SO2	-2	914
"	"	"	NO	-2	475
	"	CM50	O2	2.0	20.3
9:38	7-21-85	SM 810	SO2	4	852
			NO	0	500
		CM50	O2	.90	20.5

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-17-85 TIME : 9:38 Am NAME: C Longberry

RANGE: SOx: 0 - 1500 ppm

NOx: 0 - 1500 ppm

OUTPUT SIGNAL: 4 - 20 ma

	NOx	SOx
LOOP NUMBER.	11A	11B
DIGILINK CHANNEL:	102	103
DIGISTRIP CHANNEL:	110	111

SO2 INTERNAL SPAN CELL VALUE

NO INTERNAL SPAN CELL VALUE

FRONT PANEL METER READINGS

TEST	AS FOUND	8-2-85	AFTER CALIBRATION
SO2 Zero	4	7	
NO Zero	0		
SO2 Span	852		
NO Span	500		

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero		
NO Zero		
SO2 Span		
NO Span		

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-[illegible]-85 TIME : 0800 NAME: [illegible]

RANGE: SOx: 0 - 1500 ppm

NOx: 0 - 1500 ppm

OUTPUT SIGNAL: 4 - 20 ma

	NOx	SOx
LOOP NUMBER:	11A	11B
DIGILINK CHANNEL:	102	103
DIGISTRIP CHANNEL:	110	111

SO2 INTERNAL SPAN CELL VALUE

NO INTERNAL SPAN CELL VALUE

FRONT PANEL METER READINGS

	TEST	AS FOUND	AFTER CALIBRATION
23	SO2 Zero	0	0
25X	NO Zero	0	0
	SO2 Span	850	781
	NO Span	516	51[illegible]

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	4.00	4.00
NO Zero	4.04	4.[illegible]
SO2 Span	12.09	12.32
NO Span	12.00	12.25

[illegible] DIFFCK [illegible]

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: [illegible] TIME : 0730 NAME: [illegible]

Beckman RCC 102

RANGE: SOx: 0 - 1500 ppm

NOx: 0 - 1500 ppm

OUTPUT SIGNAL: 4 - 20 ma

	NOx	SOx
LOOP NUMBER:	11A	11B
DIGILINK CHANNEL:	102	103
DIGISTRIP CHANNEL:	110	111

After dynamic calibration 930

SO2 INTERNAL SPAN CELL VALUE 931 12.33 MA 3.08 VDC

NO INTERNAL SPAN CELL VALUE 516 632 12.25 MA 3.06 VDC

FRONT PANEL METER READINGS

TEST	AS FOUND	8/2/85	AFTER CALIBRATION
SO2 Zero	0	7	
NO Zero	0	2	
SO2 Span	931	919-922)	
NO Span	516	642	

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	4.00	4.03
NO Zero	3.96	3.99
SO2 Span	12.33	N/R
NO Span	12.29	12.25

SO2 Span	3.34	
NO Span	3.57	

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-31-85 TIME : 11:47 NAME: WALT

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 8/2/85 TIME : 0900 NAME: Jerry Young
Ron Benson from KVB

RANGE: SOx: 0 - 1500 ppm

NOx: 0 - 1500 ppm

OUTPUT SIGNAL: 4 - 20 ma

	NOx	SOx
LOOP NUMBER:	11A	11B
DIGILINK CHANNEL:	102	103
DIGISTRIP CHANNEL:	110	111

SO2 INTERNAL SPAN CELL VALUE

NO INTERNAL SPAN CELL VALUE

FRONT PANEL METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	0	–
NO Zero	4	–
SO2 Span	913/906	–
NO Span	642/638	–

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	–	–
NO Zero	–	–
SO2 Span	–	–
NO Span	–	–

APPENDIX F

FULL CALIBRATION WORKSHEETS

LEAR SIEGLER SM 810 NO_x/SO_2 GAS ANALYZER

T/C Simulator	RCC 103	Digimite
Multimeter	RCC 104	Fluke
Multimeter	RCC 102	Beckman

FULL CALIBRATION WORKSHEET

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7/25/85 START TIME: 9:40 AM NAME: Jerry Young, Charlie Floyd, Wayne, Paul Fogg

STOP TIME 10:45 AM

RESTART TIME- 1:18 PM

7/26/85

Audit Team: Ron Benson, Adam Frohoff, KVB

	NOx	SO2
RANGE	0 - 1500 ppm	0 - 1500 ppm
OUTPUT SIGNAL	4 - 20 ma	4 - 20 ma
LOOP NUMBER	11A	11B
DIGILINK CHANNEL	102	103
DIGISTRIP CHANNEL	110	111

1. Was the UV lamp replaced prior to beginning the full calibration:

   Yes ______ No ✓

2. Adjust R-5 to get 3.25 - 3.59 vdc at TP-10 on the transceiver:

   *Value of TP-10 before calibration: 3.31

   **Value at TP-10 after calibration: 3.31

3. Set the scanner frequency at 26 - 28 milliseconds when viewed on an oscilloscope connected to TP-3 at the transceiver. Adjust the scanner frequency with R-2.

   Comment: very difficult to read accurately

   *Scanner frequency at TP-3 before calibration: 22-24

   **Scanner frequency at TP-3 after calibration: 25-30

4. Connect an oscilloscope to TP-5 at the transceiver, and

check for a symetrical S02 half waveform. Adjust R-3, as coarse adjustment, to get the best symetrical, half wave signal possible then adjust R-2 to bring both halves of the waveform to ground.

*Was the waveform symetrical before calibration? [✓ YES] NO

**Was the waveform symetrical after calibration? [✓ YES] NO

5. Connect the oscilloscope to TP-6 at the transceiver and observe the scanner drive signal. This signal should be a 0.35 - 0.85 volt triangular waveform with slightly rounded peaks. Span switch should be in the "up" position (there is also an internal span in the analyzer)

*Was the shape of the waveform proper: [✓ YES] NO

**Record the observed voltage of the waveform: .6

NO span cell 546 ppm
SO_2 span cell 649 ppm

6. Connect the oscilloscope to TP-5, at the transceiver, and check for a symetrical NO half waveform. Adjust R-88 to achieve a symetrical half wave signal.

*Was the waveform symetrical before calibration: YES [✓ NO]

**Record the voltage of this signal: ~2

7. Connect the oscilloscope to TP-7, at the transceiver and observe the scanner feedback signal. This signal should be -8 to -6 volts which does not go above ground.

*Are there any irregularities in this signal: YES [✓ NO]

**Record the voltage of this signal: -6

8. Connect the oscilloscope to TP-12 at the transceiver to check the scanner level detect signal. This signal should

be -50 to 50 mvdc and may be adjusted with R-4.

*Voltage of signal before calibration: -50 to 50

**Voltage of signal after calibration: -50 to 50

9. Output drive signal adjustment.

With the zero mirror in and the front panel selector switch in the INPUT position:

*Does the front panel meter read approximately zero: [✓ YES] NO

Compute the expected voltage with a high SO2 span cell inserted with the following equation:

$$\text{Expected Voltage} = \frac{(\text{Span } \overset{649}{\text{cell}} \text{ value})(7)}{750}$$

The voltage may also be checked at TP-5 at the transceiver.

Use R-15 to adjust the voltage.

testing conducted at the control unit not the transceiver

**Expected voltage at TP-5: 6.06

***Voltage at TP-5 before calibration: 3

****Voltage at TP-5 after calibration: 5.95 (could not adjust voltage any furth

7/26 Restart Friday morning at 0800 hours; voltage rechecked ~6.05 volts

10. Temperature Compensation Calibration.

Check the voltage at TP-4 on the Integrator, Sample, and Hold board. It should read zero volts and can be adjusted with R-4.

*Voltage at TP-4 before calibration: 25 millivolts

**Voltage at TP-4 after calibration: 0.3 volts (NO reading)

11. Check the voltage at TP-16 at the transceiver. Use the following equation to calculate the expected voltage:

$$\text{Expected volts} = \frac{(\overset{500}{\text{Actual}}\text{ Temperature})}{(800)}\ 1.0 \text{ volts}$$

Simulated signal with a Digimite

Milliamps should be used rather than voltage at the control unit
connect an ammeter in series with the output signal

adjustments made at the transceiver but voltage readings taken at control unit

This voltage can be adjusted with R-72 at the transceiver.
(Adjust at control unit w J1 or 21)

*Expected voltage at TP-16: .625 (12.5 ma)

(Milliamps) (J1 or 21)
**Voltage at TP-16 before calibration: 1.01 (9.5 ma)

(Milliamps) (J1 or 21)
***Voltage at TP-16 after calibration: .625 (12.5 ma)
(we were reading 380°F at the meter in the control room)

12. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board. Use the following equation to calculate the expected voltage:

Expected volts = $\frac{(\text{Actual } \overset{500}{\text{Temperature}})}{(800)}$ × ~~10.0 vo~~lts 20 milliamps

This voltage may be adjusted with R-5.

*Expected voltage at TP-4: 6.25

**Voltage at TP-4 before calibration: 4.98 7.45

***Voltage at TP-4 after calibration: 5.10 (out of pot) 6.25

13. Connect a voltmeter to TP-2 on the Temperature Compensation board. The average voltage over several SO2 sample periods should be 0.0 volts. This voltage may be adjusted with R-30.

Redo 7/26 1320 hours

*Voltage at TP-2 before calibration: 0.00

**Voltage at TP-2 after calibration: 0.00 0.0002

14. During an NO sample period, adjust R-32 for 0.0 volts at TP-2, also.

*Voltage at TP-2 before calibration: 0.80

**Voltage at TP-2 after calibration: 0 0.0004 redo

15. Connect a voltmeter to TP-4 on the Integrator, Sample and Hold board and adjust R-4 to get 0.9375 volts:

simulates 75F

*Voltage at TP-4 after adjusting R-4: 0.9375 .9375

16. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 1.0 volts and may be adjusted with R-29 on the Temperature Compensation board.

*Voltage at TP-2 before calibration: 1.035

**Voltage at TP-2 after calibration: 1.0134 (SO_2)
1.0138 (NO)

17. Adjust R-4 on the Temperature Compensation board so there is no change in the voltage at TP-2 with the switch S-2 in the "up" or "down" position.

18. Adjust R-4 on the Integrator, Sample, and Hold board to get 10.0 volts at TP-4.

*Voltage at TP-4 after adjusting R-4: 10.0006

19. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be (3.49891) 3.65 volts and may be adjusted with R-2 on the Temperature Compensation board. S2 switch down

*Voltage at TP-2 before calibration: 3.67

**Voltage at TP-2 after calibration: 3.705

20. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board and adjust R-4 to get 0.9375 volts.

*Voltage at TP-4 after adjusting R-4: .9372

21. Connect a voltmeter to TP-3 on the Integrator, Sample, and Hold board and record the voltage during an SO2 sample period with (zero switch) switch S-2 in the "up" position.

*Voltage at TP-3: 1690-1693 1.682

22. Place switch S-2 in the down position and record the

voltage. Use the following equation to calculate the expected voltage:

Expected voltage = $\underline{\overset{1.693}{\text{(Voltage at TP-3, from \#21 above)}}}\text{X}1.075$

Use R-64 on the Integrator, Sample, and Hold board to adjust this voltage.

SO$_2$ multiplier is 10 at 800 °F (365x2.74)

*Expected voltage at TP-3: 1.8199

**Voltage at TP-3 before calibration: 1.795

***Voltage at TP-3 after calibration: 1.8185

3. The full calibration ~~is~~ was completed at 1425 hours, 7/26/85

Return instrument to service

- Temperature input wire disconnected at TP4
- Rewire temperature compensation board

Redo starting at step 6

FULL CALIBRATION WORKSHEETF

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7/30/85 START TIME: 0800 NAMES Jerry Young
Charlie Floyd
Wayne
Paul Fogg
Audit Team: Ron Benson of KVB

	NOx	SO2
RANGE	0 - 1500 ppm	0 - 1500 ppm
OUTPUT SIGNAL	4 - 20 ma	4 - 20 ma
LOOP NUMBER	11A	11B
DIGILINK CHANNEL	102	103
DIGISTRIP CHANNEL	110	111

1. Was the UV lamp replaced prior to beginning the full calibration:

   Yes ________ No ____________

2. Adjust R-5 to get 3.25 - 3.59 vdc at TP-10 on the transceiver:

   *Value of TP-10 before calibration:_______________

   **Value at TP-10 after calibration:_______________

3. Set the scanner frequency at 26 - 28 milliseconds when viewed on an oscilloscope connected to TP-3 at the transceiver. Adjust the scanner frequency with R-2.

   *Scanner frequency at TP-3 before calibration:_____________

   **Scanner frequency at TP-3 after calibration:_____________

4. Connect an oscilloscope to TP-5 at the transceiver. and

check for a symetrical S02 half waveform. Adjust R-3, as coarse adjustment, to get the best symetrical, half wave signal possible then adjust R-2 to bring both halves of the waveform to ground.

*Was the waveform symetrical before calibration? YES NO

**Was the waveform symetrical after calibration? YES NO

5. Connect the oscilloscope to TP-6 at the transceiver and observe the scanner drive signal. This signal should be a 0.35 - 0.85 volt triangular waveform with slightly rounded peaks.

*Was the shape of the waveform proper: YES NO

**Record the observed voltage of the waveform:____________

6. Connect the oscilloscope to TP-5, at the transceiver, and check for a symetrical NO half waveform. Adjust R-88 to achieve a symetrical half wave signal.

*Was the waveform symetrical before calibration:
YES NO

**Record the voltage of this signal:_________________

7. Connect the oscilloscope to TP-7, at the transceiver and observe the scanner feedback signal. This signal should be -8 to -6 volts which does not go above ground.

*Are there any irregularities in this signal: YES NO

**Record the voltage of this signal:______________

8. Connect the oscilloscope to TP-12 at the transceiver to check the scanner level detect signal. This signal should

be -50 to 50 mvdc and may be adjusted with R-4.

*Voltage of signal before calibration:______________

**Voltage of signal after calibration:______________

9. Output drive signal adjustment.

With the zero mirror in and the front panel selector switch in the INPUT position:

*Does the front panel meter read approximately zero:
YES NO

Compute the expected voltage with a high SO2 span cell inserted with the following equation:

$$\text{Expected Voltage} = \frac{(\text{Span } \overset{649}{\text{cell}} \text{ value})(7)}{750}$$

The voltage may also be checked at TP-5 at the transceiver. Use R-15 to adjust the voltage.

**Expected voltage at TP-5: 6.06

***Voltage at TP-5 before calibration: 5.6

****Voltage at TP-5 after calibration: 6.05-6.15

10. Temperature Compensation Calibration.

Check the voltage at TP-4 on the Integrator, Sample, and Hold board. It should read zero volts and can be adjusted with R-4.

*Voltage at TP-4 before calibration:______________

**Voltage at TP-4 after calibration:______________

11. Check the voltae at TP-16 at the transceiver. Use the following equation to calculate the expected voltage:

$$\text{Expected volts} = \frac{(\text{Actual Temperature})}{(800)} \text{ 1.0 volts}$$

Adjust R-15 at transceiver to receive proper voltage at TP-5

This voltage can be adjusted with R-72 at the transceiver.

*Expected voltage at TP-16:____________

**Voltage at TP-16 before calibration:____________

***Voltage at TP-16 after calibration:____________

12. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board. Use the following equation to calculate the expected voltage:

$$\text{Expected volts} = \frac{(\text{Actual Temperature})}{(800)} \quad 10.0 \text{ volts}$$

This voltage may be adjusted with R-5.

*Expected voltage at TP-4: 6.5

**Voltage at TP-4 before calibration: 6.4

***Voltage at TP-4 after calibration: 6.5

13. Connect a voltmeter to TP-2 on the Temperature Compensation board. The average voltage over several SO2 sample periods should be 0.0 volts. This voltage may be adjusted with R-30.

*Voltage at TP-2 before calibration: 0.02

**Voltage at TP-2 after calibration: 0

zero on SO_2 scale of 0-1500ppm is ~7ppm

14. During an NO sample period, adjust R-32 for 0.0 volts at TP-2, also.

*Voltage at TP-2 before calibration: 0

**Voltage at TP-2 after calibration: 0

zero or NO_x scale of 0-1500ppm is 11ppm

15. Connect a voltmeter to TP-4 on the Integrator, Sample and Hold board and adjust R-4 on integrator bord to get 0.9375 volts:

Recheck

*Voltage at TP-4 after adjusting R-4: .9365 jumper TP5 to TP3

16. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 1.0 volts and may be adjusted with R-29 on the Temperature Compensation board.

*Voltage at TP-2 before calibration: 1.0

**Voltage at TP-2 after calibration: 1.0001 (use Pronak calibrator to put in 1 volt)

17. Adjust R-4 on the Temperature Compensation board so there is no change in the voltage at TP-2 with the switch S-2 in the [✓ "up"] or "down" position.

18. Adjust R-4 on the Integrator, Sample, and Hold board to get 10.0 volts at TP-4. (switch down)

*Voltage at TP-4 after adjusting R-4: 10.0

19. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 3.65 volts and may be adjusted with R-2 on the Temperature Compensation board. double check

*Voltage at TP-2 before calibration: initially 4.74

**Voltage at TP-2 after calibration: 4.02 (ran out of adj.) 4.05 second time 3.65

20. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board (ISHB) and adjust R-4 to get 0.9375 volts.

*Voltage at TP-4 after adjusting R-4: .9375

21. Connect a voltmeter to TP-3 on the Integrator, Sample, and Hold board and record the voltage during an SO2 sample period with switch S-2 in the "up" position.

*Voltage at TP-3: 1.801 switch (up position)
1.96 switch (down position)

22. Place switch S-2 in the down position and record the

voltage. Use the following equation to calculate the expected voltage:

1.805

Expected voltage = <u>(Voltage at TP-3, from #21 above)</u> 1.075

Use R-64 on the Integrator, Sample, and Hold board to adjust this voltage.

*Expected voltage at TP-3: 1.94

**Voltage at TP-3 before calibration: 1.932

***Voltage at TP-3 after calibration: __________

3. The full calibration is completed

T/c simulator	RCC107	Digimite
multimeter	RCC104	Fluke
Multimeter	RCC102	Beckman

FULL CALIBRATION WORKSHEETF

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-25/26-85 TIME: 0940 NAME: C. FLOYD

	NOx	SO2
RANGE	0 - 1500 ppm	0 - 1500 ppm
OUTPUT SIGNAL	4 - 20 ma	4 - 20 ma
LOOP NUMBER	11A	11B
DIGILINK CHANNEL	102	103
DIGISTRIP CHANNEL	110	111

1. Was the UV lamp replaced prior to beginning the full calibration:

   Yes ______ No ✓

2. Adjust R-5 to get 3.25 - 3.59 vdc at TP-10 on the transceiver:

   *Value of TP-10 before calibration: 3.31

   **Value at TP-10 after calibration: 3.31

3. Set the scanner frequency at 26 - 28 milliseconds when viewed on an oscilloscope connected to TP-3 at the transceiver. Adjust the scanner frequency with R-2.

   *Scanner frequency at TP-3 before calibration: 23

   **Scanner frequency at TP-3 after calibration: 27

4. Connect an oscilloscope to TP-5 at the transceiver, and

check for a symetrical S02 half waveform. Adjust R-3, as coarse adjustment, to get the best symetrical, half wave signal possible then adjust R-2 to bring both halves of the waveform to ground.

*Was the waveform symetrical before calibration? [✓ YES] NO

**Was the waveform symetrical after calibration? [✓ YES] NO

5. Connect the oscilloscope to TP-6 at the transceiver and observe the scanner drive signal. This signal should be a 0.35 - 0.85 volt triangular waveform with slightly rounded peaks.

*Was the shape of the waveform proper: [✓ YES] NO

**Record the observed voltage of the waveform: .6

6. Connect the oscilloscope to TP-5, at the transceiver, and check for a symetrical NO half waveform. Adjust R-88 to achieve a symetrical half wave signal.

*Was the waveform symetrical before calibration: " [✓ YES] NO

Was the wf " " after " [✓ YES] . NO

**Record the voltage of this signal: 2v

7. Connect the oscilloscope to TP-7, at the transceiver and observe the scanner feedback signal. This signal should be -8 to -6 volts which does not go above ground.

*Are there any irregularities in this signal: YES [✓ NO]

**Record the voltage of this signal: -6

8. Connect the oscilloscope to TP-12 at the transceiver to check the scanner level detect signal. This signal should

be -50 to 50 mvdc and may be adjusted with R-4.

*Voltage of signal before calibration: -20 [illegible]

**Voltage of signal after calibration: -20 [illegible]

9. Output drive signal adjustment.

With the zero mirror in and the front panel selector switch in the INPUT position:

*Does the front panel meter read approximately zero: [✓ YES] NO

Compute the expected voltage with a high SO2 span cell ✓ inserted with the following equation:

[illegible] x 7 / 750

Expected Voltage = (Span cell value)(7) / 750

6.05

The voltage may also be checked at TP-5 at the transceiver. Use R-15 to adjust the voltage.

**Expected voltage at TP-5: 6.05

***Voltage at TP-5 before calibration: 3

****Voltage at TP-5 after calibration: ~~5.9 - 6~~ 6.05

10. Temperature Compensation Calibration.

Check the voltage at TP-4 on the Integrator, Sample, and Hold board. It should read zero volts and can be adjusted with R-4.

*Voltage at TP-4 before calibration: -10 mV

**Voltage at TP-4 after calibration: .7 mV

11. Check the voltae at TP-16 at the transceiver. Use the following equation to calculate the expected voltage:

Expected volts = (Actual Temperature) / (800) 1.0 volts

This ~~voltage~~ MA can be adjusted with R-72 at the transceiver.

*Expected ~~voltage~~ MA at ~~TP-16:~~ J1 21 ~~.625~~ 125 MA AT 500°F

**~~Voltage~~ mA at ~~TP-16~~ J1 21 before calibration: ~~7.01~~ 9.5 mA

***~~Voltage~~ mA at ~~TP-16~~ J1 21 after calibration: ~~6.25~~ 12.5 mA

12. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board. Use the following equation to calculate the expected voltage:

Expected volts = $\frac{\text{(Actual Temperature)}}{(800)}$ 10.0 volts

This voltage may be adjusted with R-5.

*Expected voltage at TP-4: 6.25 ~~[illegible]~~ 6.25

**Voltage at TP-4 before calibration: ~~4.98~~ ~~[illegible]~~ 7.45

***Voltage at TP-4 after calibration: ~~5.10 END OF pot~~ 6.25

13. Connect a voltmeter to TP-2 on the Temperature Compensation board. The average voltage over several SO2 sample periods should be 0.0 volts. This voltage may be adjusted with R-30.

*Voltage at TP-2 before calibration: .02

**Voltage at TP-2 after calibration: .02

14. During an NO sample period, adjust R-32 for 0.0 volts at TP-2, also.

*Voltage at TP-2 before calibration: .75

**Voltage at TP-2 after calibration: .0

15. Connect a voltmeter to TP-4 on the Integrator, Sample and Hold board and adjust R-4 to get 0.9375 volts:

*Voltage at TP-4 after adjusting R-4: ~~1.02~~ .9355

16. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 1.0 volts and may be adjusted with R-29 on the Temperature Compensation board.

*Voltage at TP-2 before calibration:____________

**Voltage at TP-2 after calibration: 1.0134
1.0138

17. Adjust R-4 on the Temperature Compensation board so there is no change in the voltage at TP-2 with the switch S-2 in the "up" or "down" position.

S-2 Swith in down Position

18. Adjust R-4 on the Integrator, Sample, and Hold board to get 10.0 volts at TP-4.

*Voltage at TP-4 after adjusting R-4: 10.006

19. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 3.65 volts and may be adjusted with R-2 on the Temperature Compensation board.

*Voltage at TP-2 before calibration: 3.667

**Voltage at TP-2 after calibration: ~~3.667~~ 3.704

20. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board and adjust R-4 to get 0.9375 volts.

*Voltage at TP-4 after adjusting R-4: .9372

21. Connect a voltmeter to TP-3 on the Integrator, Sample, and Hold board and record the voltage during an SO2 sample period with switch S-2 in the "up" position.

*Voltage at TP-3: 1.693

22. Place switch S-2 in the down position and record the voltage. Use the following equation to calculate the

expected voltage:

Expected voltage = (Voltage at TP-3, from #21 above) 1.075

Use R-64 on the Integrator, Sample, and Hold board to adjust this voltage.

1.828

*Expected voltage at TP-3: 1.820

2ND

**Voltage at TP-3 before calibration: 1.797 1.682

***Voltage at TP-3 after calibration: 1.808

~~3. The full calibration is completed~~

Rezero R-4 with TP-4 at 0 Volts

complete

APPENDIX G

DYNAMIC CALIBRATION OF LEAR SIEGLER SM 810 NO_x/SO_2 ANALYZER

RCB
7-29-85
KVB 71901-2

DYNAMIC CALIBRATION OF
LEAR SIEGLER SM 810 NO_x/SO_2 Analyzer

Span Gases

1019 ppm NO, bal N_2 NBS Traceable ± __ %
52 ppm SO_2, bal N_2 Certified ± 2%

July 29th, 1985

Time: 1515 hours

[NO], ppm	NO Flowrate (liters/min)
610-650	1.0
670	1.5
685	2.0
682	2.5
693	3.0
690	3.5
---- -	4.0

Time: 1420 hours

[SO_2], ppm	SO_2 Flowrate (liters/min)
18 (?)	1.62
25-28	1.40
13 (?)	1.0
28	1.3

July 30th, 1985 (Redo the July 29th, 1985 test since LS temperature sensor was approximately 100 deg F too low)

[NO], ppm	NO Flowrate (liters/minute)
950	2.0
967	2.5
970	2.3

Adjust R2 to give 1010 ppm NO ± 5 ppm

July 30th, 1985 (Continued)

[SO_2], ppm	SO_2 Flowrate (liters/minute)
44	2.3
39	2.5
40	2.5

July 31st, 1985

[NO], ppm	NO Flowrate (liters/min)
1032	?

[SO_2], ppm	SO_2 Flowrate (liters/min)
36	?

APPENDIX H

LABORATORY REPORT ON GAS ANALYSIS

Gas Mixture Specifications

Category	Range	Preparation Tolerance	Certification Accuracy
Primary Standard	5% to 50%	± 1% of Component	±0.02% absolute or 1% of the component whichever is smaller**
	1% to 5%	± 2% of Component	
	500 ppm-1%	± 2% of Component	
	10 ppm - 499 ppm	± 5% of Component	±4% of Component
Certified	10% to 50%	± 5% of Component*	2% of Component
	50 ppm to 10%	±10% of Component*	2% of Component
	10 ppm to 50 ppm	±20% of Component*	5% of Component
	3 ppm to 10 ppm	± 2 ppm	5% of Component
Unanalyzed Mixture	This group of mixtures is expected to have essentially the same preparation tolerance as the Certified Standard, but cannot be guaranteed as such because these mixtures are not checked by analysis.		

*The values presented may vary for components that tend to be unstable or present other blending problems. Our technical personnel will be pleased to comment on your particular requirements. Certification accuracy for smaller size cylinders and/or multi-component mixtures may vary.

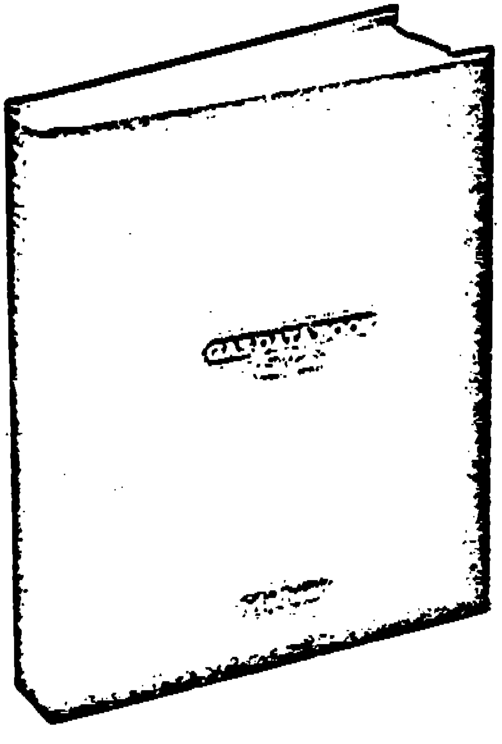
**Accuracies for Hydrogen and Helium components may vary from those stated due to their low molecular weight.

Tighter Preparation Tolerances

Matheson is aware of certain special applications that do not require the extremely close tolerances of Primary Standards, but do require preparation tolerances exceeding those of Certified Standards. In the process control industry, for example, consistent minor component concentrations are at least as important as the accuracy of the certification. With these thoughts in mind Matheson has developed a *dynamic blending system* that delivers mixtures with tighter preparation tolerances than those listed for Certified Standards at economical prices. This system is available at selected Matheson plants and it is suggested that you contact your nearest Matheson location prior to placement of an order.

Special Accuracy Mixtures

When a lack of suitable standards exists or a standard proves impractical, Matheson will prepare a gas or liquid phase mixture gravimetrically on one of its many precision balances. These mixtures will not be given the Matheson Primary Standard label but they are expected to be of the highest accuracy possible. If you have an unusual requirement contact your local Matheson plant.



MATHESON GAS DATA BOOK — SIXTH EDITION

Anyone who handles compressed gases — in the laboratory, in the plant, or anywhere — will benefit from this book.

See page 207 for details.

APPENDIX I

ZERO AND SPAN CHECKLIST

LEAR SIEGLER CM-50 OXYGEN ANALYZER AND BAILEY OXYGEN ANALYZER

ZERO AND SPAN CHECKLIST

LEAR SIEGLER CM-50 OXYGEN ANALYZER

DATE: 7-23-85 TIME: 0930 NAME: FLOYD

RANGE: 0 - 25 percent oxygen

OUTPUT SIGNAL: 4 - 20 ma.

LOOP NUMBER: 11C

DIGILINK CHANNEL: 104

DIGISTRIP CHANNEL: 112

FRONT PANEL METER READING

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO	.90%	
OXYGEN SPAN	21%	

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO	5.27	
OXYGEN SPAN	17.37	

BECKMAN
RCC 102

ZERO AND SPAN CHECKLIST

LEAR SIEGLER CM-50 OXYGEN ANALYZER

DATE: [illegible] TIME: [illegible] NAME: [illegible]

[illegible] CC 102

RANGE: 0 - 25 percent oxygen

OUTPUT SIGNAL: 4 - 20 ma.

LOOP NUMBER: 11C

DIGIL-AA CHANNEL: 104

DIGISTRIP CHANNEL: 112

FRONT PANEL METER READING

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO		
OXYGEN SPAN	21.7%	

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO	5.25	
OXYGEN SPAN	17.50	

ZERO AND SPAN CHECKLIST

LEAR SIEGLER CM-50 OXYGEN ANALYZER

DATE: 8-2-85 TIME: 0900 NAME: Jerry Young
Observed by Ron Benson, KVB

RANGE: 0 - 25 percent oxygen

OUTPUT SIGNAL: 4 - 20 ma.

LOOP NUMBER: 11C

DIGILINK CHANNEL: 104

DIGISTRIP CHANNEL: 112

FRONT PANEL METER READING

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO	2.0	2.0
OXYGEN SPAN	21.4	21.4

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO	-	
OXYGEN SPAN	-	

APPENDIX J

COAL FEED SANKYO IMPACT FLOWMETER

ZERO AND SPAN CHECKLIST

COAL FEED SANKYO IMPACT FLOWMETER

DATE: 7-23-85 TIME: AM NAME: WALT

RANGE: 0 - 15 tons per hour

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER: 62

DIGILINK CHANNEL: 305

DIGISTRIP CHANNEL: 112

STATIC TEST WEIGHT: COAL BIN

WITH D.C. SCREW
RUNNING

	ZERO POT	SPAN POT
START	9.1%	622
FINISH	9.2	540

EXPECTED READINGS WITH STATIC TEST WEIGHT:

2.000 TONS ~~TPH~~ —— ma

FRONT PANEL METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	—	—
WITH STATIC TEST WEIGHT	2.516	2.021

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	—	
WITH .73 % ~~STATIC~~ ~~TEST~~ WEIGHT	39.2	39.2

APPENDIX K

ZERO AND SPAN CHECKLIST
KILN FEED SANKYO IMPACT FLOWMETER

APPENDIX L

CERTIFIED TEST WEIGHTS

PAUL B ENGLER
DIRECTOR

DEPARTMENT OF WEIGHTS AND MEASURES
DIVISION OF METROLOGICAL SERVICES

Certificate of Accuracy

CERTIFICATE M.S. 8022

ON WRITTEN REQUEST BY AMERICAN SCALE CO., INCORPORATED

THIS CERTIFIES THAT THE DEVICES DESIGNATED BELOW HAVE BEEN TESTED TO SPECIFICATIONS AND TOLERANCES OF:
THE NATIONAL BUREAU OF STANDARDS ☒ THE MANUFACTURER ☐ THE OWNER ☐.
THE STANDARDS USED IN THE CALIBRATIONS ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS THROUGH
TEST NUMBER: MAP 737/202491, 213.09/0656

DESIGNATION		CALIBRATION DATA			
ITEM	DESCRIPTION	NOMINAL	MEASURED		TOLERANCE
			APPARENT MASS VS:	BRASS	
1.	3 Each Cast Iron Weights		ADJUSTED TO CONFORM		CLASS "F"
	S/N TI-01, TI-005, TI-08	1000 Lbs.			0.10 Lbs.

AMBIENT TEMPERATURE 22.2 °C
RELATIVE HUMIDITY 40%
BAROMETRIC PRESSURE 757.3 mm Hg

William D. Moore
METROLOGIST

APRIL 26, 1985
DATE

ATTACHMENT B

CRESTMORE NOx PROJECT
QUALITY ASSURANCE MANUAL

Prepared by
Gerald L. Young
Production Engineer
July 1, 1985

TABLE OF CONTENTS

APPENDIX A

NOx PROJECT QUALITY ASSURANCE PROGRAM

I. INTRODUCTION

A. PURPOSE

The purpose of this quality assurance (QA) program is to assure the accuracy and precision of the data collected and the reliability of the instruments associated with the NOx project at Gifford-Hill and Company, Inc.'s cement plant at Crestmore, California.

The data collected must be both precise and accurate. Precision is a measure of how closely the results of a method of analysis or measurement can be repeated. Accuracy refers to how closely the measured values compare to the true value. The reliability of the instrumentation is also very important. The completeness of the data must be as high as possible.

Following the introductory section will be a brief description of the data handling hardware and a short description of the equations used to calculate the pounds of NOx per ton of clinker. Included in this section will be a discussion of the variables used in these equations and their impact on the pounds of NOx per ton of clinker value.

This document will then provide a list of the measurements and instruments that are critical to the project and a list of the instruments that are important to this project. The instruments considered important to this project are those that measure parameters that may influence the generation of NOx in a rotary cement kiln.

Following these lists, will be a table that lists the frequency of zero and span checks and the frequency of multipoint calibrations on these instruments.

In addition to the instructions pertaining to frequency of calibration, this Quality Assurance plan will discuss the test equipment that will be used during these calibrations and procedures for insuring the accuracy of this test equipment.

The Quality Assurance plan will then outline the personnel responsible for implementing the various aspects of the Gifford-Hill and Company, Crestmore plant, NOx Project.

Finally, this document will present the accepted methods of calibrating each type of instrument associated with this project. These methods will be presented in a step-by-step, or "cookbook", type format with examples of any mathematical calculations that must be performed during a calibration check.

B. DATE QUALITY AND COMPLETENESS

The goal of this project will be to generate pounds of NOx per ton of clinker values with a precision of plus or minus five percent; the pounds of NOx per ton of clinker values should have an accuracy of within plus or minus fifteen percent of the true value; and, the goal for completeness of the data will be to record valid data for at least 75 percent of the possible measurements.

II. DATA HANDLING AND REDUCTION

The analog field signals are supplied to a Kaye Digilink system. The Kaye Digilink converts these signals to digital signals, accumulates and averages each signal for six minutes, and then sends these six minute averaged signals to an IBM-PC for storage and data reduction.

The IBM-PC stores each of the raw field signals, performs various calculations, and stores the resultant, and prints out selected raw and calculated data to three hardcopy printers.

Although the IBM-PC stores and may print all of the raw field signals and numerous calculated values, the NOx project will be primarily concerned with signals that have been determined to be "critical" and "important" field signals and the pounds of NOx per ton of clinker calculated value. The remaining field signals and calculated values have been collected and printed as an aid to the operation of the kiln. The relative importance of the field signals will be discussed in the section following.

The most important calculated value is the pounds of NOx per ton of clinker figure. It is calculated according to Rule 1112 of the South Coast Air Quality Management District. The equation used is:

$$\frac{(\text{ppm of NO})(46\ \text{grams/mole})(\text{SDCFM})(1.56 \times 10^{-7})}{\text{Tons/Hour of Clinker}}$$

The tons of clinker value is determined by multiplying the kiln feed rate signal by a factor that is determined by the loss on ignition of the kiln feed.

FOR EXAMPLE:

Assume the kiln feed rate is 100 TPH

the loss on ignition is 35.00 percent

Then the clinker production rate is:

(100 TPH)(1.00 - 0.3500) = 65.00 TPH

The ppm NOx value used in the equation is an "as measured" value, corrected to standard, dry conditions.

The SCFM value is calculated by summing the products of fuel combustion, the water from the kiln feed, coal, and water spray, the carbon dioxide liberated from the limestone in the kiln feed, and any infiltrated air and correcting to standard, dry conditions.

The remaining value is a constant used to convert SCFM and ppm of NOx to pounds of NOx at standard, dry conditions. Standard conditions have been defined as an atmospheric pressure of 29.92 inches of mercury and 68 degrees F.

Five values that are continuously monitored by field instruments, two test results of the coal fuel chemistry, and two test results of the kiln feed chemistry are used to calculate the pounds of NOx per ton of clinker.

Of these data inputs used to calculate pounds of NOx per ton of clinker, six values must be as accurately measured as possible because of the effect an error in their values have on the calculated pounds of NOx per ton of clinker.

A 1.00 percent increase in the kiln feed loss on ignition value will increase the calculated pounds of NOx per ton of clinker by about 1.28 percent. A 1.00 percent increase in the measured NO ppm value will increase the calculated pounds of NOx per ton of clinker by 1.00 percent. A 1.00 percent increase in the kiln feed rate value will decrease the calculated pounds of NOx per ton of clinker by about 0.83 percent. A 1.00 percent increase in the carbon content of the coal value used will increase the calculated pounds of NOx per ton of clinker by about 0.70 percent. And a 1.00 percent increase in the measured oxygen content of the exit gas stream at the NOx analyzer will result in an increase in the calculated pounds of NOx per ton of clinker by approximately 0.40 percent. A 1.00 percent increase in the value of the hydrogen content of the coal used will increase the calculated pounds of NOx per ton of clinker by approximately 0.14 percent.

A one percent change in any one of the remaining values will result in less than a 0.04 percent change in the calculated pounds of Nox per ton of clinker value.

Therefore, the six values that must be known as accurately as possible are, in descending order of importance: the kiln feed loss on ignition, the measured ppm of NOx, the tons per hour of kiln feed supplied to the kiln, the carbon content of the coal, the oxygen content of the exit gas stream at the NOx analyzer, and the hydrogen content of the coal.

III. RELATIVE IMPORTANCE OF THE FIELD INSTRUMENTS

The field signals supplied to the NOx/Digilink/IBM-PC fall into three catagories. The critical data is that data which are used to calculate the pounds of NOx per ton of clinker. Below, is a list of the signals that are used in this calculation, and are therefore considered critical:

1. PPM of NOx (Lear-Siegler SM 810)
2. Percent oxygen at the ID fan (Lear-Siegler CM 50)
3. Kiln feed rate (Sankyo flowmeter)
4. Coal feed rate to the kiln (Sankyo flowmeter)
5. GPM of the kiln exit water spray (Turbine meter)

The second category is those field signals that may show a correlation to the generation of NOx in a rotary cement kiln.

Below, the signals that may show a correlation to NOx per ton of clinker are listed:

1. Primary air fan amps
2. Axial air pressure on the Pillard burner
3. Swirl air pressure on the Pillard burner
4. Burning zone temperature
5. Kiln drive amps
6. Secondary air temperature
7. Percent oxygen at the kiln exit
8. Chain inlet temperature.

The above eight signals are only slightly less important than the previously listed critical signals.

The remaining signals are generally used for information on the kiln operation. Most of these signals are important to the operation of the kiln, but may be considered of secondary importance to the NOx project.

Another type of information is also considered critical. This information is the chemical properties of the kiln feed and the coal fuel. Samples of kiln feed must be analyzed to determine the moisture content and the loss on ignition. These values are used in the determination of both the exit gas volume of the kiln and the production rate of the kiln. Samples of the coal must be analyzed to determine the moisture content and the ultimate analysis. These values are used in the determination of the kiln exit gas volume.

IV. FREQUENCY OF CALIBRATION

The instruments that measure the critical signals and the signals that may show a correlation to NOx generation should have the zero/span checked according to the following schedule:

INSTRUMENT	DAILY	WEEKLY	MONTHLY	KILN DOWNS
1. NOx/SOx analyzer	X			
2. O2 analyzer at ID fan	X			
3. Bailey O2 analyzer		X		
4. Flow meter on exit gas water spray				X
5. Kiln feed Sankyo				X
6. Coal feed to kiln Sankyo			X	
7. Primary air fan ammeter			X	
8. Pressure transmitter - axial air			X	
9. Pressure transmitter - swirl air			X	
10. Pyrometer-Burning zone temp.			X	
11. Kiln drive motors - ammeter			X	
12. Thermocouple - Secondary air temp.			X	
13. Thermocouple - Chain inlet temperature				X

The remaining instruments are supplying signals to provide information as an aid to the operation of the kiln. These instruments should have the zero/span checked periodically, according to previous maintenance practices.

In addition to zero/span checks on the above instruments, full calibrations of these instruments should be done on a fixed schedule. Each of the instruments on the zero/span check schedule above should undergo a full calibration procedure once every three months. This procedure will include a multipoint check with appropriate standards to prove linearity and accuracy of the output signal. The Lear-Siegler SM-810 NOx/SOx gas analyzer will have a dynamic calibration once per week.

In Section VIII, the procedures for the zero/span checks and for the full calibrations of each type of instrument are outlined. Appendix A will contain appropriate checklists, work sheets, data validation sheets, and sample custody sheets to be filled out during these zero/span checks, calibrations, etc.

V. FREQUENCY OF SAMPLING AND TESTING

A. COAL FUEL

1. Moisture Content

A grab sample of the pulverized coal being burned in the kiln will be taken and analyzed for moisture content at a frequency of at least three samples per week. These values will be averaged over a rolling four week period. This average value will be updated by discarding the oldest week's data and including the most recent week's data, once per week.

If the updated value differs from the value used in the IBM-PC program to calculate pounds of NOx per ton of clinker by more than two standard deviations of the four week data population, then the updated value will be used as the coal moisture value in the IBM-PC equations.

2. Ultimate Analysis

The ultimate analysis will be performed on a representative sample from each lot of delivered coal (not to exceed 3000 tons per lot). These analysis will be averaged over a rolling three month period. These values will be updated by deleting the oldest analysis and including the most recent analysis received. If the average value of the dry carbon content of the coal varies from the value that is being used in the IBM-PC equations to calculate pounds of NOx per ton of clinker by more that one standard deviation of the three month data population, then the most recent three month average ultimate analysis will be used.

As an exception to the above, if the source of the coal is changed, the ultimate analysis of the new coal will be used in the calculation of pounds of NOx per ton of clinker.

B. KILN FEED

1. Moisture Content

A grab sample of the kiln feed will be taken and analyzed for moisture content at a frequency of at least three samples per week. These values will be averaged over a rolling four week period. This average value will be updated by discarding the oldest week's data and including the most recent week's data, once per week.

If the updated value differs from the value used in the IBM-PC program to calculate pounds of

NOx per ton of clinker by more than two standard deviations of the four week data population, the updated value will be used as the kiln feed moisture in the IBM-PC equations.

2. Kiln Feed Loss on Ignition

A grab sample of the raw material feed to the kiln will be taken and analyzed for loss on ignition at a frequency of at least three per week These values will be averaged over a rolling four week period. This average value will be updated by discarding the oldest week's data and including the most recent week's data, once per week.

If the updated value differs from the value used in the IBM-PC program to calculate pounds of NOx per ton of clinker by more than one standard deviation of the four week data population, then the updated value will be used as the kiln feed loss on ignition value in the IBM-PC equations.

VI. ACCURACY OF TESTS AND TEST EQUIPMENT USED FOR CALIBRATION

When the various pieces of equipment considered to be critical or important to the NOx project are calibrated, certain insruments, weights, etc. are used. The instruments used during a calibration will be, when possible, certified by an independent laboratory as to their accuracy and precision. Generally, these certifications will link these instruments to an appropriate standard of the National Bureau of Standards. When scales or weights are used during a calibration, these scales or weights will be certified as conforming to the California Division of Weights and Measures as to their accuracy. In the absence of this certification, a certification linking these weights to an appropriate standard of the National Bureau of Standards is acceptable. When gases are used for a calibration, a certification sheet attesting to the accuracy of the published value of the gas will be provided by the vendor supplying the standard gas. The test procedures used to determine the various chemical properties of the kiln feed and coal fuel, when possible, will conform to generally accepted methods, as published in the appropriate A.S.T.M. manual.

VII. IMPLEMENTATION OF THIS QUALITY ASSURANCE PLAN

A. MANAGER OF THIS PROJECT

Mr. Gerald L. Young, Production Engineer of Gifford-Hill and Company, Inc., will assume overall responsibility for the design and implementation of this Quality Assurance Plan. He will assemble the appropriate data, validate the collected data, and insure that the procedures outlined in this manual are followed. To accomplish this, he will insure that appropriate documentation, certifications, test results, and other items of interest are recorded and saved until termination of this project.

Mr. Young will also be responsible for the issuance of a monthly status report on this project to appropriate upper management personnel.

B. IBM-PC EQUATIONS

The development of correct equations to be used to calculate pounds of NOx per ton of clinker will be the responsibility of Mr. Russ MacMann, Manager of Process Engineering, Gifford-Hill and Company, Inc. and Mr. Kim Hunter of KVB, Inc.

C. CALIBRATION OF EQUIPMENT AND CERTIFICATION OF TEST EQUIPMENT

Mr. Paul Fogg, Electrical and Instrumentation Foreman of the Crestmore plant of Riverside Cement Company, a division of Gifford-Hill and Company, Inc. will be responsible for the zero and span checks, full calibrations, and dynamic gas calibrations of the field instrumentation associated with the NOx project He will be responsible for the timely certification as to the accuracy of the equipment he uses to calibrate the field instrumentation. He will also be responsible for maintaining the records of zero and span checks, full calibrations, dynamic calibrations, and the certifications of the test equipment used.

D. COAL FUEL AND KILN FEED SAMPLING AND TESTING

Mr. Ray Sisneros, Assistant Chief Chemist of the Crestmore plant of Riverside Cement, a division of Gifford-Hill and Company, Inc., will be responsible for the sampling and testing of the kiln feed and coal fuel. He will also be responsible for maintaining records of these tests and a record of the custody of these samples.

E. NOx PROJECT AUDITS

Mr. Ron Benson, of KVB, Inc., will be responsible for an intensive audit of this project and Quality Assurance Plan. He will issue a report of any deficiencies and detail the modifications required to correct these deficiencies.

Mr. Benson will also be responsible for a weekly audit of this project to insure the procedures outlined in this Quality Assurance Plan are followed.

F. STATISTICAL ANALYSIS OF COLLECTED DATA

Dr. John Croom, Quantative Applications, Stone Mountain, GA., will be responsible for a statistical analysis of the collected data to determine the validity of that data. He will also attempt to correlate various operating parameters that influence the generation of NOx in a rotary cement kiln.

VIII METHODS FOR ZERO/SPAN CHECKS AND FULL CALIBRATIONS

A. LEAR SIEGLER SM 810 NOx/SO2 GAS ANALYZER

1. Zero/span check of SM 810

A zero and span check should be performed once per day. Long-term drift of the zero and span may occur. The zero and span may be re-established by adjusting the proper potentiometers on the Integration, Sample and Hold board inside the control unit. To perform this adjustment follow the procedure outlined below:

a. Depress the REQUEST CAL button.

b. While the SO2 ZERO indicator is illuminated adjust potentiometer R-2 on the Integration, Sample and Hold board to produce a zero reading on the front panel of the control unit.

c. While the NO ZERO indicator light is illuminated, adjust potentiometer R-6 on the Integrator, Sample and Hold board to produce a zero reading on the front panel of the control unit.

d. While the SO2 SPAN indicator light is illuminated, adjust potentiometer R-1 on the Integrator, Sample and Hold board to produce the correct span cell ppm reading on the front panel meter of the control unit.

e. While the NO SPAN indicator light is illuminated, adjust potentiometer R-7 on the Integrator, Sample and Hold board to produce the correct span cell ppm reading on the front panel meter of the control unit.

After performing the zero/span adjustments on the Integrator, Sample and Hold board, any significant differences between the front panel meter on the control unit and the current-loop outputs may be corrected by adjusting the zero/span potentiometers on the Output and Alarm board according to the following procedures:

a. Depress the REQUEST CAL button.

b. While the SO2 ZERO indicator light is illuminated, adjust potentiometer R-1 on the Output and Alarm board to get 4 ma out at TB 1-27. (For a 4 to 20 milliamp signal.)

c. While the NO ZERO indicator light is illuminated, adjust potentiometer R-7 on the Output and Alarm board to get 4 ma out at TB 1-28. (For a 4 to 20 milliamp signal.)

d. While the SO2 SPAN indicator light is illuminated, adjust potentiometer R-2 on the Output and Alarm board to get the proper milliamp signal out at TB 1-27. To calculate the proper milliamp signal, use the following formula, for a 4-20 milliamp signal:

$$\text{milliamps} = \frac{(\text{span cell SO2 value})\ (16)}{(1500)} + 4$$

e. While the NO SPAN indicator light is illuminated, adjust potentiometer R-8 on the Output and Alarm board to get the proper milliamp signal out at TB 1-28. To calculate the proper milliamp signal, use the formula in part "d" above, except substitute the "span cell NO value" for the SO2 value.

2. Full Electronic Calibration of SM 810

Before doing a regularly scheduled, full calibration of the SM 810 Gas Analyzer, replace the UV lamp in the transceiver with a new lamp.

a. Transceiver

No attempt to calibrate the transceiver should be made until it has reached full operating temperature. A cold transceiver requires a minimum of three hours to reach a stable operating temperature with all access doors and ports sealed. If possible, the transceiver should be allowed to warm up overnight.

1) UV Lamp Current:

The UV lamp current should be set at 325-350 ma by adjusting R-5 to 3.25 - 3.50 V DC at TP-10 on the transceiver.

2) Oscillator/SO2 Scan Offset:

These two adjustments work together to "peak" the instrument for SO2. First, connect an oscilloscope to TP-3 at the transceiver and check for a frequency on the scanner of 26-28 milliseconds. Adjust R-2 to get the desired frequency. Then connect the oscilloscope to TP-5, move the zero mirror into position, and insert a high value SO2 span cell. If the d2 signal requires peaking (to get a symetrical half wave signal), adjust R-3 (SO2 scan offset) for the best half wave signal possible. Then, using R-2 as a fine adjustment, bring both halves of the waveform to ground. Move the oscilloscope to TP-6 and observe the scanner drive signal. This signal should be a 0.6 plus or minus 0.25 volt triangular waveform with slightly rounded peaks.

3) NO Scan Offset:

Before peaking the NO signal, the SO2 signal must be peaked first, as explained above in step 2. To peak the NO waveform, move the zero mirror into position and insert a high value NO span cell. Connect the oscilloscope to TP-5 and adjust R-88 to achieve a symetrical half wave. Failure to get a good NO peak may indicate a problem with optics alignment.

4) Scanner Feedback:

The scanner feedback is checked at TP-7 at the transceiver. The wave on an oscilloscope at TP-7 should be -7 plus or minus 1.0 volt, which does not go above ground. Major irregularities in this waveform may indicate a defective scanner motor.

5) Scanner Level Detect:

The scanner level detect signal

should be 0 plus or minus 50 mVDC when checked at TP-12. This signal may be adjusted with R-4.

6) Output Drive:

The output drive signal adjustment is important because it interacts with linearity and the zero and span adjustments in the control unit, therefore it is important to have it initially adjusted properly. To adjust the output drive, first set up the control unit as follows:

a) Turn the front panel selector switch to INPUT.

b) Place the top switch on the Calibration and Timer board in the up position. This takes out the temperature compensation and moves the zero mirror into place in the transceiver.

c) Verify an approximte zero on the front panel meter.

d) Install a high value SO2 span cell in the tranceiver.

e) Compute the expected voltage with the following equation:

$$\text{Volts} = \frac{(\text{span cell value})\ (2)\ (7)}{1500}$$

or

$$= \frac{\text{(span cell value)}\quad(7)}{750}$$

NOTES: * 7 volts is the full scale reading on the meter.

** Span cells are named on a 750 ppm instrument, so on a 1500 ppm instrument, the expected value of the span cell is twice the named value.

f) Adjust R-15 at the transceiver to achieve the computed value on the front panel meter of the control unit.

b. Temperature Compensation Calibration:

1) Transceiver Thermocouple Amplifier

a) Disconnect the temperature input from the transceiver by disconnecting TB 1-29 and TB 1-15 in the back of the control unit and short the two wires together.

b) Adjust R-4 on the Integrator, Sample and Hold board to read zero (0) volts at TP-4. Reconnect #15 and #29 on TB-1 of the control unit.

c) At the transceiver, simulate a temperature with a transmation at J2-7 and J2-4, or use the duct temperature if it can be independently measured with a calibrated thermometer or thermocouple. Then adjust R-72 for the correct amperage, with the ammeter in series with the output wires at J-1 or 21, as calculated by the following formula:

$$\text{Amperage} = \frac{\text{(Simulated or actual temperature) (20ma)}}{(800)}$$

d) At TP-4 on the Integrator, Sample and Hold board in the control unit adjust R-5 for the correct volts as calculated by the following formula:

$$\text{Volts} = \frac{\text{(10) (Simulated or actual temperature) (1.0 volts)}}{(800)}$$

c. d2 Zero Adjust

This adjustment compensates for inherent offsets and those coming from the transceiver. This adjustment tends to drift when it is set before the transceiver is fully stabilized and for this reason it is advised that this setting be periodically checked during the calibration process.

1) Place the S-2 switch (the top switch on the Calibration and Timer board) in the up position. This will put the zero

mirror in and take out the temperature compensation circuitry.

2) During an SO2 sample period, adjust R-30 on the Temperature Compensation board for an average (averaged over several sample periods) of 0.0 volts at TP-2.

   NOTE: R-30 is located in the middle of the board and must be adjusted with an insulated screwdriver.

3) During an NO sample period, adjust R-32 on the Temperature Compensation board for an average of 0.0 volts at TP-2.

   NOTE: If R-30 requires readjustment R-32 may also have to be readjusted.

d. Temperature Compensation Multiplier (NO & SO2)

The Temperature Compensation board multiplier is initially adjusted for a multiplication factor of 1.0 at 75 degrees F. and 3.65 at 800 degrees F. This adjustment affects both SO2 and NO measurements when the Temperature Compensation is in. To perform this adjustment, set up the control unit and perform the adjustments as outlined below:

1) Disconnect the temperature wires and the d2 wires at TB 1-29, TB 1-30, TB 1-15, and TB 1-16 at the back of the control unit.

2) Connect a jumper between TP-5 and TP-3 on the Temperature Compensation Board. Adjust R-4 for 0.9375 volts at TP-4 on the Integrator, Sample and Hold board. (This represents 75 degrees F.)

3) Connect a DVM to TP-2 on the Temperature Compensation board, put switch S-2 (the top switch) on the Calibration and Timer board in the up position, and adjust R-29 on the Temperature Compensation board for 1.0 volts.

5) Place switch S-2 in the down position and adjust R-4 on the Temperature Compensation board, if required, so there is no change in the DVM voltage with the temperature compensation in or out (switch S-2 down or up).

6) With switch S-2 in the down position, adjust R-4 on the Integrator, Sample and Hold board for 10.0 volts at TP-4. (This represents 800 degrees F.)

7) Adjust R-2 on the Temperature Compensation board to get 3.65 volts at TP-2 on the Temperature Compensation board.

e. Integrator Sample/Hold Multiplier (SO2)

The Integrator Sample/Hold board

multiplier is adjusted for a multiplication factor of 1.075 at 75 degrees F. and 2.74 at 800 degrees F.

1) With the control unit set-up as described above, in section 3),a), and b), adjust R-4 on the Integrator, Sample and Hold board for 0.9375 volts at TP-4. (This represents 75 degrees F.)

2) Place switch S-2 (the top switch on the Calibration and Timer board) in the up position and allow at least two full SO2 sample periods to pass.

3) Connect a DVM to TP-3 on the IS/H board and record the voltage.

4) Place switch S-2 (the top switch on the Calibration and Timer board) in the down position. The voltage at TP-3 on the Integrator, Sample and Hold board should increase by a factor of 1.075 over the voltage recorded in step c). Adjust R-64 on the IS/H board as required to get the voltage as calculated below:

volts = (1.075) (the voltage as recorded in step c).

NOTE: *R-64 is the top, grey potentiometer located near the center of the board.

**The voltage at TP-3 should not exceed 10 VDC with the temperature compensation in (switch S-2 down); if it is above 10 DVC, decrease R-29 on the Temperature Compensation board as required.

*** New SO2 updates may change the voltage at TP-3 with the temperature compensation out (switch S-2 up), in which case the new voltage must be multiplied by 1.075 to get the desired voltage with the Temperature Compensation in (switch S-2 down).

5) Adjust R-4 on the Integrator, Sample, and Hold board for 10 volts at TP-4. (This represents 800 degrees F.)

6) Place switch S-2 in the up position and allow at least two full SO2 sample periods to pass.

7) Connect a DVM to TP-3 on the IS/H board and record the voltage.

8) Place switch S-2 in the down position during the SO2 sample period. The voltage at TP-3 should increase by a factor of 2.74 over the voltage in step 7). . Adjust R-65 on the IS/H board as required to get the voltage as calculated below:

volts = (2.74)(voltage recorded in step 7)

The voltage at TP-3 should not exceed 10 vdc with the temperature compensation in (switch S-2 down); if it is above 10 vdc, decrease R-29 on the Temperature Compensation board as required.

NOTE: *R-65 is the top, blue potentiometer located near the center of the board.

** New SO2 updates may change the voltage at TP-3 with the temperature compensation out (switch S-2 up), in which case, the new voltage must be multiplied by 2.74 to get the desired voltage with the temperature compensation in (switch S-2 down).

9) Disconnect the temperature input wires, TB 1-29 and TB 1-15 in the back of the control unit and short the two wires together. Adjust R-4 on the IS/H board to read zero (0.0) volts at TP-4.

10) Reconnect all wires disconnected and remove all jumpers and test equipment.

3. Dynamic Calibration (with NBS gas or EPA protocol gas)

NOTES: * When flowing standard gases, which are at room temperature, into a probe at an elevated temperature, it is important that the gas flow is just slightly more than the plateau beyond which increases in gas flow cause insignificant increases in readings. Excessive gas flow rates will not allow the gas to reach the probe temperature which will result in erroneous readings.

** Standard gas dilution ratios of other than 1:1 should not be attempted unless calibrated flow meters are available. Calibrated flow meters are defined as flow meters that have calibration data sheets which relate the scale readings to standard liters/minute for the individual flow meters.

a. Temperature Verification:

This is one of the most important steps in the process of calibrating the instrument to read gases accurately. A very small error in reading the temperature will cause a relatively large error in reading gas concentrations.

NOTE: If it is necessary to repair a thermocouple solder joint, use silver base solder (solder, LSI P/N 54000038 - Flux, LSI P/N 54000039, is a low temperature silver base solder which can be used with a standard soldering iron).

1) Disconnect the thermocouple at the transceiver bulkhead. Verify the probe temperature by reading the thermocouple with the transmation. Record the temperature.

NOTE: * The probe must be temperature stabilized. This takes approximately one hour.

** Temperature measuring instruments equivalent to the transmation may be used provided the junction at the instrument input terminals is compensated as required by the device in use.

*** When possible, the temperature measured by the probe should be compared to an independent source at, or near, the measurement point. This will verify the thermocouple performance.

2) Disconnect the temperature current wires from the transceiver at TB 1-29 and TB 1-15 in the control unit, and short the two wires together. Adjust R-4 to get zero volts at TP-4 on the Integrator, Sample and Hold board. Then reconnect the temperature wires at TB 1-29 and TB 1-15.

3) Calculate the voltage that represents

the temperature recorded above in step 1) according to the following formula:

$$\text{Voltage} = \frac{\text{(Step 1 actual temp.)} \times 10}{800}$$

4) Adjust R-72 on the transceiver, if required, to get the calculated voltage at TP-4 on the Integrator, Sample and Hold board.

b. Flow NO standard gas:

Flow NO gas with the temperature and altitude compensation in (zero mirror out) at the lowest flow rate beyond which increases in flow rate result in no significant increase in concentration (low end of the "plateau").

NOTES: * Standard gas bottles with less than 200 psi pressure should not be used for calibration purposes.

** The pressure at the final stage of the standard gas bottle pressure regulator should be set at 15-20 psi.

Record the error in the NO reading of standard gas concentration.

c. Flow Zero Gas:

Flow a zero gas under the same conditions as above and verify that the NO concentration reading returns to zero (plus or minus 1% full scale) within three sample periods.

NOTE: If sufficient zero gas is being flowed and good zeros cannot be achieved, it may be necessary to check the probe for leaks. (Refer to Lear-Siegler drawing 81000897, sheet 3, paragraph 1.3).

d. Flow SO2 standard gas

Flow SO2 standard gas under the same conditions as above, in step b. Record the error in the reading of the gas concentration.

e. Flow Zero Gas:

Flow zero gas under the conditions described above in step b. and verify that the SO2 concentration readings return to zero (plus or minus 1% full scale) within three sample periods. (See NOTE in step c. above if readings do not return to zero.)

f. Gas Calibrations:

Adjustments are required only if either or both gas concentrations have an error in excess of 5 percent. If adjustments are required, proceed with the following steps:

1) Average the errors recorded above in steps b) and d).

NOTE: Typically the errors will be negative; if the errors are significantly positive, suspect a problem such as gas in the probe body.

2) Flow NO standard gas as prescribed in step b for a sufficient time to get stable readings. Record the readings.

3) Correct the NO gas concentration read in step 2, immediately above, by the percentage error averaged in step 1 above. This is done by adjusting R-2 on the Temperature Compensation board. Wait for new NO updates to see the effect of the adjustment of R-2.

NOTE: It may be necessary to replace the R-2 potentiometer with a 20K potentiometer (LSI P/N 47500014).

4) If R-2 was readjusted in step 3 above, then it is mandatory that the origin of the multiplication curve be verified at 75 degrees F. Disconnect the temperaure input wire at TB 1-29 (Temp. +) and adjust R-4 on the Integrator, Sample and Hold board for the voltage which represents 75 degrees F. (0.9375 volts) at TP-4. Insert an NO span cell, place switch S-2 (the top switch) on the Temperature Compensation board in the up position and wait until stable voltage readings are achieved at TP-2 on the Temperature Compensation board. Adjust

R-2 on the Temperature Compensation board to achieve no change in the voltage readings at TP-2 when switch S-2 is in either the up or down position.

5) If step 4, immediately above, was done, reconnect the temperature input wire, TB 1-29 and repeat the entire section a. (Temperature Verification.)

6) The dynamic calibration procedure is now completed and the instrument may be returned to service.

B. LEAR-SIEGLER CM-50 OXYGEN ANALYZER

1. Dynamic Calibration

a. Select channel number 104 on the Kaye Digilink.

b. Turn the CM-50 control unit front panel "Calibration" switch to the "LOW" position. (This allows a low value oxygen standard gas to flow into the analyzer.)

c. Allow the reading on the Kaye Digilink to stabilize. Adjust R-3 zero potentiometer to yield the percent oxygen of the low range standard gas as observed on channel 104 of the Kaye Digilink.

d. Turn the CM-50 control unit front panel "Calibration" switch to the "HIGH" position. (This allows ambient air, with an oxygen content of 20.9 percent to enter the analyzer.)

e. Allow the reading on the Kaye Digilink to stabilize. Adjust R-2 span potentiometer to yield 20.9 percent oxygen as observed on channel 104 of the Kaye Digilink.

f. Turn the CM-50 control unit front panel "Calibration" switch to the "OPERATE" position.

g. The dynamic calibration is completed.

2. Full Electronic Calibration

a. Heater Control Board

1) Before calibrating the Heater Controller board the following conditions must exist:

a) Verify the pressure regulator is indicating 18 - 22 psi. If not, unlock the screw in the center of the knob and adjust the regulator to 20 psi. (A clockwise rotation of the knob will increase the pressure.)

b) Verify the reference flow indicates the standard cubic feet per hour (scfh) printed on the top of the meter (usually 2 scfh). Adjust the flowmeter valve as required.

c) With the calibration switch positioned to "HIGH", verify that the calibration flowmeter indicates the scfh printed on the top of the flow meter (usually 5 scfh). Adjust the flowmeter valve, if required.

d) With the calibration switch positioned to "LOW", verify that the calibration flowmeter indicates the scfh printed on the top of the flowmeter. Adjust the calibration bottle pressure regulator as required. Note that this adjustment has a locking nut.

e) Lock both regulators and position the calibration switch to "REMOTE".

f) Verify that the power supply is within the 104-126 volts ac specification and that the ambient temperature is within the 0-120 degrees F. limit.

2) Calibrate the Heater Controller Board according to the following procedure. NOTE: Unless otherwise noted, reference all voltage measurements to TP-9 on the Heater Controller Board.

a) Remove the heater fuse and the

instrument fuse.

b) Remove the thermocouple connection, TB 2-4 (red wire).

c) Install a jumper from TP-4 to TP-8.

d) Install a jumper from TP-2 to TP-3 to TP-9.

e) Connect a voltmeter to TP-8.

NOTE: Inspect all connections to the test points. All connections must be made lengthwise with the test points. Any connection made perpendicular to the board will short to the foil that is underneath the test point.

f) Install the instrument fuse.

g) Adjust R-2 for -50 to +50 MV at TP-8. This is a very sensitive adjustment. The adjustment must be sealed.

h) Remove all jumpers and reconnect the thermocouple wire at TB 2-4.

i) Adjust R-3 to -374 MV at TP-2. This is just a coarse adjustment and will be trimmed later.

NOTE: At this point, it is assumed that the Heater Controller Board is a working board that only requires adjustment. If the board is known to be inoperative, the heater fuse must remain removed while troubleshooting, to prevent the destruction of the probe heater.

j) Connect a voltmeter to TP-3. This will monitor the negative millivolt output of the probe thermocouple.

k) Install the heater fuse.

NOTE: If the board is operating properly, the following sequence of events should occur:

*Both the neon lamp (located below the flowmeter panel) and the "LOW" calibration indicator will light.

**After approximately 30 seconds, the neon lamp should start flashing about 5 times per second and the thermocouple millivolt output should become increasingly negative. If the thermocouple output is positive, the thermocouple is wired backwards and MUST be corrected or the probe heater will be destroyed.

***About one minute after installing the heater fuse, the "TEMPERATURE FAULT" light will come on, the "LOW" calibration light will go out, and the "HIGH" calibration light will come on.

****About 30 minutes after installing the heater fuse, the thermocouple output should increase to about -34.5 MV. The thermocouple output will then slowly decrease to about -34 MV (The thermocouple output should be compensated for the ambient temperature of the card cage as described in step k following.) The "TEMPERATURE FAULT" light and the "HIGH" calibration light will go out.

l) With the "TEMPERATURE FAULT" push button depressed, the meter should now indicate a stable reading in the green zone. If the meter indication is not in the green zone, adjust R-4 on the Heater Controller Board counter-clockwise to move the meter indication counter-clockwise. Wait 5 minutes after adjusting R-4 for the meter to stabilize.

DO NOT PROCEED TO THE NEXT STEP IF THE ABOVE OPERATION IN THE GREEN ZONE HAS NOT BEEN OBTAINED.

m) The probe temperature can now be trimmed in. This trimming should not require more than one-half turn of R-3 on the Heater Controller Board. The normal output of the thermocouple is -34.07 MV, under the standard condition of 77 degrees F. card cage temperature. If the card cage is operating at a temperature other than 77 degrees F., the temperature difference times -0.022 MV per degree F. must be subtracted from -34.07 MV.

EXAMPLE:

Card cage temperature = 107 degrees F.

Temperature difference = 107-77 = 30 degrees F.

Compensation = (30) (-0.022) = -0.66 MV

Compensated Thermocouple Output =

-34.07 MV - (-0.66 MV) = -33.41 MV

n) This completes the Heater Controller Board calibration.

b. Percent Oxygen Board (O2 Board)

NOTE: Unless otherwise noted, reference all voltage measurements to TP-9 on the Heater

Controller Board.

1) Before calibrating the Percent Oxygen Board, insure that the CM-50 is up to operating temperature as follows:
   a) Connect a voltmeter to TP-3 on the Heater Controller Board. This will measure the thermocouple output.
   b) The thermocouple output should be -34.07 MV with a card cage temperature of 77 degrees F. If the card cage is at a temperature other than 77 degrees F., the expected thermocouple output can be calculated as explained in section k on page 37 to assure accuracy.
2) Use the following procedure to verify the cell constant (Item 4 on the probe data sheet.)
   a) Disconnect TB 2-2 on the Percent Oxygen Board.
   b) Connect a voltmeter to the wire removed from TB 2-2. Connect the return to TB 2-1 on the Percent Oxygen Board.
   c) The calibration switch, on the front panel, should be placed in the "HIGH" position and the range switch is placed in the "25%"

position.

d) Read the cell constant on the voltmeter and record the reading. (This will be a negative millivolt output.)

e) If the measured cell constant differs from item 4 on the probe data sheet by more than 0.2 MV, the probe calibration should be recalculated, as described in section c on page 43.

3) Use the following procedure to verify the zero:

a) Connect a voltmeter to TP-4 and adjust R-4 on the Percent Oxygen Board to get 400 MV plus or minus 100 MV.

b) Connect a jumper between TP-4 and TP-3 on the Percent Oxygen Board.

c) Measure 0.00 vdc plus or minus 10 MV at TP-1 on the Percent Oxygen Board.

d) Connect an ammeter to TB 1-11 on the Percent Oxygen Board and adjust R-1 to get 4.00 ma plus or minus 0.01 ma.

e) Disconnect the jumper between TP-4

and TP-3.

4) Use the following procedure to calibrate the output for a zero input.

   a) Connect a jumper from TP-9 on the Heater Controller Board to TP-3 on the Percent Oxygen Board.

   b) Adjust R-68 for 0.00 vdc plus or minus 1.0 mv at TP-2 on the Percent Oxygen Board.

   c) Adjust R-7 for the specified output (item 6 on the probe data sheet) for a zero input when measured at TP-1 on the Percent Oxygen Board.

   d) Disconnect the jumper between TP-9 on the Heater Controller Board and TP-3 on the Percent Oxygen Board.

5) 25 Percent Range Calibration

   a) Connect a voltmeter to TP-1 on the Heater Controller Board and adjust R-1 on the Heater Board for the specified cell constant (item 4 on the probe data sheet).

   b) Connect a jumper from TP-1 on the Heater Controller Board to TP-3 on the Percent Oxygen Board.

   c) Connect a voltmeter to TP-1 on the Percent Oxygen Board and adjust R-3 to get 8.38 vdc plus or minus 0.01

volt.

d) Observe the front panel meter reading at this time. The meter should read the green calibration dot. If not, power down the CM-50 unit by removing the instrument fuse. Using the board extender, extend the Percent Oxygen Board, and adjust R-52 until the meter reads the green calibration dot.

e) Disconnect the jumper between TP-1 on the Heater Controller Board and TP-3 on the Percent Oxygen Board.

6) 10 Percent Range Calibration

a) Place the range switch in the "10%" position and the calibration switch in the "AUTO" position on the front panel.

b) Refer to Item 3, 10 Percent Calibration, on the probe data sheet.

*If the 10 percent calibration voltage on the probe data sheet is positive, adjust R-4 on the Percent Oxygen Board to get the specified 10 percent calibration voltage at TP-4 on the Percent Oxygen Board.

Then connect a jumper between TP-4 and TP-3 on the Percent Oxygen Board.

**If the 10 percent calibration voltage on the probe data sheet is negative, adjust R-1 on the Heater Controller Board for the specified 10% calibration voltage at TP-1 on the Heater Controller Board. Then connect a jumper from TP-1 on the Heater Controller Board to TP-3 on the Percent Oxygen Board.

c) Connect a voltmeter to TP-1 on the Percent Oxygen Board and adjust R-6 on this board to get 10.00 vdc plus or minus 10 MV.

d) Connect an ammeter to TB 1-11 and adjust R-2 on the Percent Oxygen Board to get 20.00 ma plus or minus 0.01 ma.

e) Disconnect the jumper installed in step b.

7) 2.5 Percent Range Calibration

a) Connect a voltmeter to TP-4 on the Oxygen Board and adjust R-4 on the Percent Oxygen Board to get the specified 2.095 calibration voltage (Item 5 on the probe data sheet).

b) Place the range switch on the front panel in the "2.5%" position.

c) Connect a jumper between TP-4 and TP-3 on the Percent Oxygen Board.

d) Connect a voltmeter to TP-1 on the Percent Oxygen Board and adjust R-5 on this board to get 8.38 vdc plus or minus 1 MV.

e) Disconnect all jumpers that have been installed and reconnect the wire that was disconnected from TB 2-2.

f) Set the range switch in the "25.0%" position and the calibration switch to the "AUTO" position.

g) The calibration is now complete.

c Calculating the Oxygen Probe Calibration

1) Insure proper probe heater temperature by using the following procedure:

a) Connect a voltmeter to TP-3, with the ground at TP-9, on the Heater Controller Board and measure the thermocouple output.

b) The thermocouple output should be -34.07 MV, with the card cage at 77 degrees F. If the card cage temperature is not 77 degrees F., subtract -0.022 MV for every degree above 77 degrees F. or add -0.022 MV for every degree below 77 degrees F.

2) Determine the fuel cell outputs by using the following procedure:
   a) Connect a voltmeter to TP-3 on the Percent Oxygen board with the ground to TP-9 on the Heater Controller Board.
   b) Place the calibration switch, on the front panel, in the "HIGH" position and read the cell output on the voltmeter. This will be the cell constant (cc). Record the cell constant. This will be a negative millivolt signal.
   c) Place the calibration switch in the "LOW" position and read the cell output or "E". This will be the millivolt output using the low calibration gas. Record the cell output, E.
3) Calculate the probe calibration by using the following procedures and equations:
   a) MV Decade

$$\text{MV/DEC} = \frac{\text{E} - \text{cc}}{\text{Log} \dfrac{(20.95)}{(\%\ \text{O2 of low cal gas})}}$$

RECORD MV/DEC: ____________________

b) 10 Percent Calibration

10% Cal = (MV/DEC)(0.3212) + cc

RECORD 10% CAL: ____________________

c) 2.095 Percent Calibration

2.095% Cal = MV/DEC + cc

RECORD 2.095 % CAL: ________________

d) Output for Zero Input

Output for zero input = $8.38 \times 10^{\frac{(cc)}{(MV/DEC)}}$

RECORD OUTPUT FOR ZERO INPUT: __________________

C. SANKYO IMPACT FLOWMETERS

1. Zero and Span check for Sankyo Impact Flowmeter (Kiln Feed and Coal to Kiln)

   Check the zero and span of the kiln feed Sankyo flowmeter and the pulverized coal feed to the kiln Sankyo according to the following procedure:

   a. With no material flowing across the Sankyo flowmeter, adjust the coarse and fine adjustments until both fine zero indicating lights, mounted between the coarse and fine adjustments, are illuminated to equal intensity. This completes the zero calibration.

b. Attach a weight, by means of a string, over the calibration pulley to the mechanism. NOTE: The weight that is to be used for this span check is determined during a prior dynamic calibration. This weight will be approximately 60 grams per ton per hour of full scale flow rate and will produce at least a 50 percent indication on the output meter.

c. Adjust the "SPAN" controls on the amplifier to produce the proper indication on the output meter.

*NOTE: The "proper indication on the output meter" is a value that has been determined as correct for the suspended calibration weight, used in step b, during a prior dynamic calibration.

EXAMPLE: Assume that during the most recent dynamic calibration a 6000 gram weight suspended over the calibration pulley resulted in an indicated flow rate of 80 percent of the full scale flow. Then, after establishing the zero, as outlined in step VIII,C,1,a, the span would be set by suspending a 6000 gram weight over the calibration pulley and adjusting the "SPAN" controls to produce an indicated flow rate of 80 percent of the full scale flow.

2. Dynamic Calibration of the Sankyo Impact Flowmeter

During a dynamic calibration of a Sankyo Impact flowmeter, a series of material flow tests must be performed using a known weight of material. When the initial material tests for the kiln feed scale are performed, the sample is run through the Sankyo, collected in a truck, and weighed.

This initial dynamic calibration is used to achieve a calibration that is accurate to within plus or minus 10 percent of the true value for tons per hour of kiln feed. After performing this initial dynamic calibration, a four to six hour clinker production check, which will be described in detail later, is used to calibrate the kiln feed Sankyo to within plus or minus five percent of the true value for tons per hour of clinker.

When the material tests for the coal feed Sankyo are performed, the load cells on the pulverized fuel bin are used to determine the weight of the material used for the test. A more complete description of these procedures will follow as a note to the section on determining the span of the Sankyo. Use the following procedure to perform a dynamic calibration of the Sankyo Flowmeter.

a. First, establish the scale zero by adjusting the coarse and fine zero adjustments with no material flowing over the Sankyo. True zero is attained when both fine zero indicating lights, mounted between the coarse and fine adjustments, are illuminated to equal intensity.

b. After establishing zero on the Sankyo, run a known weight of material through the Sankyo (see NOTE on page 50 following this section) and record the number of counts on the Sankyo totalizer that represents the material's weight. The sample run should be at least three minutes in duration at a rate of 75 percent or more of the full scale flow rate. Repeat this material test three times and record the counts on the totalizer and the sample material weights for each run. Compare the weight of the material from each test run to the number of counts on the totalizer for each run and calculate the flow factor of tons per count (w/c), then average the three calculated flow factors together:

w = weight of test material
c = number of counts on totalizer

FOR EXAMPLE:

ASSUME:

TEST NUMBER	SAMPLE WEIGHT	COUNTS ON TOTALIZER	FLOW FACTOR W/C
1	4.02 tons	140 cts	0.0287 T/C
2	3.51 tons	125 cts	0.0281 T/C
3	4.25 tons	150 cts	0.0283 T/C

Average flow factor = 0.0284 T/C

c. Attach a weight, by means of a string over the calibration pulley, to the mechanism. This weight should be approximately 60 grams per ton per hour of the full scale flow rate and must give at least a 50 percent indication on the flowrate meter. (For the kiln feed scale use about 6600 grams and use about 900 grams for the coal Sankyo.) Record the exact weight of each of these static test weights for use in future zero/span checks. Record the present indicated flow rate.

d. Calculate the registration flow factor. The registration flow factor is determined by the following equation:

$$\text{Reg. flow factor} = \frac{\text{full scale calibration}}{3600}$$

for the kiln feed scale:

$$\frac{110 \text{ tons/hr}}{3600 \text{ ct/hr}} = 0.0306 \text{ T/ct}$$

e. Adjust the "SPAN" controls on the amplifier to correct the present indicated flow rate to the correct indicated flow rate with the static test weight attached. Calculate the correct indicated flow rate according to the following procedure:

1) Compare the registration flow factor, determined in step VIII,C,2,d. to the average flow factor determined in step VIII,C,2,b., to calculate the correct indicated flow rate for the static test weight. For example: Assume the present indicated flow rate, with the static test weight attached, was 70 percent of full scale. Then,

$$\text{corrected indicated flow rate} = \frac{(\text{average flow factor})}{(\text{reg. flow factor})} (\text{present indicated flow rate})$$

$$\text{correct indicated flow rate (for static test wt)} = \frac{(0.0284)(70\%)}{(0.0306)} = 65\%$$

2) Adjust the "SPAN" controls to achieve the correct indicated flow rate, as determined above.

f. If the span adjustment required was more than 5 percent of full range, repeat section VIII,C,2,a-f.

NOTE: *To determine the weight of the material used in the initial dynamic flow rate test on the kiln feed Sankyo, kiln feed is run over the Sankyo, diverted into a truck and the truck is then weighed on a certified scale. Before beginning each material test run, the truck should be weighed on a certified scale while empty.

**After performing the initial dynamic calibration, future dynamic calibrations will rely on a series of clinker production checks. This dynamic calibration is performed by diverting the clinker being produced, collecting the clinker for four to six hours, and weighing the collected clinker on a certified scale. At the beginning of the clinker collection period, an initial reading is taken on the kiln feed Sankyo totalizer; at the conclusion of the collection period a final reading is taken. The tons of kiln feed used is multiplied by the appropriate kiln feed loss on ignition factor to give the tons of clinker produced during the test period, according to the Sankyo kiln feed scale. This value is then compared to the actual tons of clinker produced as weighed on a certified scale.

Generally, several dynamic weighed clinker production versus Sankyo kiln feed tons tests will be performed between kiln downtimes. During a kiln downtime period, the average error of the production checks preceeding the kiln downtime will be used to calibrate the Sankyo kiln feed flowmeter.

***Before the material test on the coal Sankyo can be performed, the pulverized fuel bin load cells must be calibrated. First, empty the pulverized fuel bin completely and establish the zero reading for the bin. Then suspend certified test weights from the bin and adjust the span adjustments for the load cells so that they register the certified value of the test weights. The pulverized fuel bin load cells are now calibrated. The bin is then filled and the weight of material used for the dynamic material flow test through the Sankyo can be determined from the fuel bin load cells.

g. Load Distribution Compensation Calibration.

This calibration is to compensate for cases in which the flow pattern of the material through the Sankyo creates a non-linear output.

1) After the span calibration procedures at a material test flow rate of 75 - 100 percent of full scale, have been completed, perform another series of

material tests, as outlined in section VIII,C,2,b. However, run these material tests at a flow rate of 40-50 percent of full scale.

2) Determine the average flow factor, w/c. Record the average flow factor. If the average flow factor is greater than the registration flow factor (calculated in section VIII,C,2,d), then positive compensation will be required. If the average flow factor is less than the registration flow factor, negative compensation will be required.

3) The Load Distribution Compensation Board may be adjusted to account for any non-linearity in the output signal by performing the following procedure:

   a) Hang a static test weight on the calibration pulley equivalent to approximately 90 percent indication of full scale flow with the Load Distribution Compensation board switch in the "NO COMP" position.

   b) Position the switch to the "+ COMP" position (if positive compensation is required) and adjust the "CROSS" (P-1) control until there is no difference in the indicated flow rate with the switch in the "NO COMP" or the "+ COMP" position.

c) Place the switch in the "NO COMP" position.

d) Change the weight on the calibration pulley to get an indicated flow rate reading of approximately 45 percent. Record the indicated flow rate.

e) Switch to the "+ COMP" position and adjust the "COMP", (P-2) control for the required amount of compensation. To determine the correct compensation, adjust the "COMP" control until the calculated indicated flow rate reading, with the switch in the "+ COMP" position, is displayed on the meter. Use the following equation to calculate the correct reading on the meter with the switch in the "+COMP" position:

$$\text{"+COMP" reading} = \frac{(\text{"NO COMP" reading})(\text{average flow factor})}{(\text{registration flow factor})}$$

"NO COMP" reading from section VIII,C,2,g,3,d.

Average flow factor from section VIII,C,2,g,2

Registration flow factor from section VIII,C,2,b

EXAMPLE:

If the "NO COMP" reading "d" above was 46 percent, the average flow factor in part 2 above was 0.0315, and the registration flow factor is 0.0306, then the "COMP" control B is adjusted to give the following indicated flow rate when the switch is in the "+ COMP" position:

$$\text{"+COMP" reading} = \frac{(46)\ (0.0315)}{(0.0306)} = 47.35$$

f) If negative compensation is required substitute "-COMP" for "+ COMP" in the preceding section "g". Load Distribution Compensation Calibration".

h) This completes the load distribution compensation calibration of a Sankyo Impact Flowmeter.

D. PRESSURE TRANSMITTER

There are two pressure transmitters that are considered to be important instruments associated with the NOx project. The two important field signals generated by pressure transmitters are the axial and swirl air pressure on the Pillard burner. These two signals may show a correlation to NOx generation.

1. Zero / Span Calibrations for Pressure Transmitters

   a. To check the zero on a pressure transmitter, first disconnect the pressure transmitter from the air line on which it is installed and be sure that both the high and low sides of the pressure transmitter are vented to the atmosphere. Connect an ammeter to the output signal wires and adjust the zero screw to get the correct milliamp output signal. This completes the zero check.

b. The span is checked by applying a known pressure, near the upper limit of the pressure transmitter's range, to the high, or positive, side of the pressure transmitter. An ammeter is connected to the output wires of the transmitter and the span adjusting screw or bolt is adjusted as required to produce the correct milliamp output signal. The correct signal is calculated according to the following equation (for a 10-50 ma signal):

$$\text{Correct ma output} = \frac{(\text{test pressure})(40)}{(\text{full scale pressure})} + 10$$

FOR EXAMPLE:

ASSUME:

*The range of a pressure transmitter is 0-50 inches of water.

**The known pressure used to span the pressure transmitter is 40 inches of water.

Then, the correct milliamp output signal would be:

$$\text{ma output} = \frac{(40)(40)}{(50)} + 10$$

$$= 42.0 \text{ ma}$$

This completes the span calibration of a pressure transmitter.

E. DYNAMIC CALIBRATION OF THE KILN EXIT WATER SPRAY TURBINE FLOWMETER

Since the gallons per minute of water that is sprayed into the kiln is a critical value that is used in the calculation of the pounds of NOx per ton of clinker, and a dynamic calibration of the kiln exit water spray turbine flowmeter is not feasible, this flowmeter should be calibrated by an independent laboratory and certified as to its precision and accuracy.

F. BAILEY OXYGEN AND COMBUSTIBLES GAS ANALYZER

The Bailey kiln exit gas oxygen and combustibles analyzer provides an important field signal to the NOx project. Although the signals from the Bailey gas analyzer are not used in the equations for calculation of pounds of NOx per ton of clinker, the oxygen content of the kiln gases may show a correlation to NOx generation.

There are some routine maintenance items that need to be done daily on the Bailey gas analyzer. There are also some routine maintenance items that must be done once every three months.

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regulating valves are floating freely; be sure the block temperature is correct (160 degrees F.), and that the pressure of the hydrogen pressure regulator is correct (25 psig).

3) Remove and clean the low pressure sample regulating valve and the low pressure air regulating valve.

4) Blow down the sample line by closing the valve above the gas pump and washer and then blowing compressed air back through

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assembly. Renew the filter cartridge if

The Bailey analyzer does not have a daily zero and span check as do most of the other instruments; however, a full multipoint calibration will be performed on this instrument once per week. The increased frequency of dynamic calibrations is not required for the NOx project, but is required for the safe and efficient operation of the rotary kiln.

1. Routine Maintenance
   a. The following routine maintenance should be performed on the Bailey oxygen and combustibles gas analyzer on a daily basis:
      1) Open the valve at the bottom of the filter and heater assembly and drain the unit of collected moisture.
      2) Make a visual inspection of the analyzer to be sure the sample and the air regulating valves are floating freely; be sure the block temperature is correct (160 degrees F.), and that the pressure of the hydrogen pressure regulator is correct (25 psig).
      3) Remove and clean the low pressure sample regulating valve and the low pressure air regulating valve.
      4) Blow down the sample line by closing the valve above the gas pump and washer and then blowing compressed air back through

the sampling tube. Do not apply compressed air to the gas pump and washer or the seperator trap.

5) Unscrew the oxygen analyzer, combustibles analyzer, and the air flow control orifice assemblies; then clean the orifices. The drill size corresponding to the size of the orifice hole is stamped on the face of the orifice assembly. A drill of that size may be used to clean the orifice. When replacing the orifice assemblies, be sure that the copper gasket is in place and seats firmly.

b. The following routine maintenance should be performed once every three months, or more often if necessary, in addition to the daily routine maintenance.

1) Examine and clean the filter and heater assembly. Renew the filter cartridge if required. To disassemble the heater and filter assembly, remove the three bolts from the top cover flange, lower and remove the casing and heater from the filter, and unscrew the gas nozzle from the filter base. Clean the stainless steel wool, and remove and replace the filter cartridge, if necessary.

2) Inspect all piping connections for leaks.

3) Remove the filament clamp and filament assemblies from the analyzer block. On each assembly, take out the pins securing the shield to the filament base and remove the shield. Examine the filament coils for equal spacing and symmetry. Reassemble the filament assemblies and replace them in the analyzer block with the screened portions of the shield facing to the left.

NOTE: The filament coils may be straightened by carefully screwing a 3-48 screw through the filament coil. This delicate operation should only be performed by an experienced technician.

2. Dynamic Calibration of the Bailey Oxygen Analyzer

a. Use the following procedure to calibrate the low range on the Bailey Oxygen Analyzer.

1) Connect an ammeter to the output signal wire of the Bailey Oxygen Analyzer.

2) Disconnect and close off the sample line at the inlet to the pump and washer assembly.

3) Connect the low range (less than 1.3 percent oxygen) standard gas cylinder,

through a suitable pressure regulator, to the gas pump and washer assembly.

4) Adjust the pressure of the standard gas sample so that the gas pressure regulating valves at the rear of the analyzer float freely.

5) The rest of the analyzer, fuel systems, measuring circuit, etc., must be functioning normally.

6) Allow the analyzer to operate on the sample from the standard gas cylinder until the milliamp reading on the ammeter stabilizes. This indicates that equilibrium has been established throughout the instrument.

7) Adjust the zero control on the analyzer to get the correct milliamp reading on the ammeter. Use the following equation to calculate the correct milliamp reading:

$$\text{Correct milliamp output} = \frac{(\text{percent 02 of sample})(40)}{(\text{full range 02})} + 10$$

FOR EXAMPLE ASSUME:

*The percent oxygen of the calibration gas is 1.2 percent.

**The full range of the analyzer is 5.0 percent oxygen.

Then:

$$\text{Correct milliamp output} = \frac{(1.2)\ (40)}{(5.0)} + 10 = 19.6$$

b. Use the following procedure to calibrate the high range on the Bailey oxygen analyzer.

1) Disconnect the low range calibration gas cylinder and connect the high range (4.4-5.0 percent oxygen) standard gas cylinder.

2) Adjust the pressure of the standard gas cylinder so that the gas pressure regulating valves at the rear of the analyzer float freely.

3) Allow the analyzer to operate on the sample from the high range calibration gas until the milliamp reading on the ammeter stabilizes.

4) Adjust the span control on the analyzer to get the correct milliamp reading on the ammeter. Use the equation in step a,7, immediately above, to calculate the correct milliamp reading expected for the high range calibration gas.

5) If the output milliamp reading on the high range gas must be adjusted more than 2.0 ma to get the correct high range milliamp reading, repeat the entire section VIII, E, 2 "Dynamic Calibration of the Bailey Oxygen Analyzer".

6) The full calibration of the Bailey oxygen analyzer is now complete and the sample line may be reconnected and opened.

G. IRCON OPTICAL INFRARED PYROMETER

This Modline, R Series, two color infrared pyrometer is a non-contact temperature sensing device. It determines temperature by measuring the infrared radiation that is emitted by hot materials. The range of this instrument is 1800-3200 degrees F. and it includes a "Peak Picker" option which holds the peak temperature observed for a set period of time.

Below, is a procedure for a zero and span calibration of the Modline, R Series, two color infrared pyrometer.

1. Zero and Span Calibration

Use the following procedure for a zero/span calibration of the optical pyrometer.

a. Turn the POWER switch off.

b. Check the indicator needle on the front panel meter to be sure that it registers zero percent of scale, (1800 degrees F.) If it does not, insert a small screwdriver into the small hole directly below the center of the meter and turn gently until the meter reads zero percent of scale.

c. Turn the POWER switch on and allow 15 minutes for the instrument to warm up.

d. Cover the objective lens with a solid, opaque object that will completely block any external radiation.

e. Switch the PEAK PICKER toggle to "Direct".

f. Depress the momentary toggle switch labled CALIBRATE and observe if the meter reads within the red "Cal. Zone".

   NOTE: Wait for the indicator to settle. This may take 15 seconds.

g. If the meter does not read in the red "Cal. Zone", continue to hold the CALIBRATE switch down and use a small screwdriver to adjust the small, slotted potentiometer next to the CALIBRATE switch. Turn the potentiometer slowly until the meter indicates the approximate center of the red zone. The instrument is now calibrated.

h. The output signal from the Modline, R Series optical pyrometer is a 0-100 mv signal which represents 1800-3200 degrees F. This signal is converted to a 10-50 ma signal for transmission to the control room. Use the following procedure to check the 10-50 ma signal.

   1) Simulate a zero millivolt output at the pyrometer and adjust the zero adjustment on the signal converter to read 10 ma.

2) Simulate a 100 millivolt output at the pyrometer and adjust the span adjustment on the signal converter to read 50 ma.

3) With the objective lens covered by a solid opaque object and the PEAK PICKER toggle switch in the "Direct" position, hold the CALIBRATE toggle switch down. This simulates an output of 55 percent of scale. Check the 10-50 ma signal for the expected value with the pyrometer at 55 percent of scale. The expected milliamp signal, for a 10-50 ma signal is 32.0 ma.

i. Switch the PEAK PICKER to the "Peaking" position.

j. The zero/span calibration is now completed.

H. THERMOCOUPLES

There are two field signals that are considered important to the NOx project that are generated by a thermocouple. They are the secondary air temperature and the chain inlet temperature. Both of these are calibrated in the same manner.

1. Zero and Span Calibration

A zero and span calibration is accomplished by applying a voltage to the output wires of the thermocouple that simulates the voltage output generated by a thermocouple at a particular temperature.

A dynamic calibration of a thermocouple would use a certified thermometer or thermocouple to independently measure the temperature of the gas stream next to, or near, the thermocouple to be calibrated. This is not possible with either of the two thermocouples in question, so the zero and span calibration outlined below will be all the calibration that is possible.

Use the following procedure to check the zero and span of the thermocouple signal to the control room.

a. Disconnect the temperature output wires of the thermocouple at the thermocouple.

b. Apply a known voltage corresponding to zero degrees F., for the type of thermocouple in use. Both of the thermocouples in question are Type K thermocouples and the output voltage at zero degrees F. for a Type K thermocouple is -0.692 millivolts.

c. Adjust the milliamp output signal to reflect zero degrees F. Both of these thermocouples have a range of 0-2000 degrees F., and both transmit data with a 10-50 ma signal. So, with a simulated zero degrees F. the zero control should be adjusted to produce a 10.0 ma output signal.

d. Apply a known voltage to the thermocouple output wires, corresponding to 2000 degrees F. With a Type K thermocouple, this voltage is 44.856 millivolts.

e. Adjust the span control to produce an output signal of 50.0 ma, with a simulated 2000 degrees F. input.

f. Reconnect the thermocouple wires.

g. The zero and span calibration is now completed.

I. AMMETERS

There are two field signals generated by ammeters that may be important to the NOx project. These signals are the amperage of the kiln drive motors and the amperage of the primary air fan. These signals may show a correlation to the generation of NOx in a rotary cement kiln.

These ammeters are calibrated by comparing their indicated amperage to the amperage of a certified ammeter.

1. Zero and Span Calibration

a. Connect an ammeter to the output signal wires of the CT. Both of these signals are 10-50 milliamp signals.

b. With the motor off, check the zero on the CT. The output signal should be 10.0 ma for both ammeters that are associated with the NOx project. Adjust the zero control to get

10.0 ma when the motor is down.

c. With the motor operating under a load, connect a certified ammeter to the motor or starter to read the motor amperage directly.

d. Connect another ammeter to the output wires of the CT and adjust the span control to get the expected milliamp signal out. Use the following equation to calculate the expected milliamp output signal:

$$\text{expected milliamps} = \frac{(\text{cert. ammeter reading})\ (40)}{(\text{full scale amps})} + 10$$

FOR EXAMPLE:

ASSUME:

*The range of the primary air fan motor ammeter is 0-200 amps.

**The certified ammeter connected to the primary air fan motor reads 150 amps.

THEN:

$$\text{expected milliamp signal} = \frac{(150\ \text{amps})(40)}{(200)} + 10$$

$$= 40.0\ \text{ma.}$$

e. The calibration of the ammeter is complete.

APPENDIX A

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE:____________ TIME :____________ NAME:____________

RANGE: SOx: 0 - 1500 ppm

NOx: 0 - 1500 ppm

TEST EQUIPMENT USED

ITEM	EQUIP. #	CAL. DUE DT.
______	______	__________
______	______	__________
______	______	__________

OUTPUT SIGNAL: 4 - 20 ma

	NOx	SOx
LOOP NUMBER:	11A	11B
DIGILINK CHANNEL	102	103
DIGISTRIP CHANNEL:	110	111

SO2 INTERNAL SPAN CELL VALUE: 890ppm

NO INTERNAL SPAN CELL VALUE: 640ppm

DIGILINK METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	________	______________
NO Zero	________	______________
SO2 Span	________	______________
NO Span	________	______________

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	________	______________
NO Zero	________	______________
SO2 Span	________	______________
NO Span	________	______________

ZERO AND SPAN CHECKLIST

LEAR SIEGLER CM-50 OXYGEN ANALYZER

DATE: ____________ TIME: ____________ NAME: ____________

RANGE: 0 - 25 percent oxygen

OUTPUT SIGNAL: 4 - 20 ma.

LOOP NUMBER: 11C

DIGILINK CHANNEL: 104

DIGISTRIP CHANNEL: 112

TEST EQUIPMENT USED

ITEM	EQUIP. #	CAL. DUE DATE

DIGILINK METER READING

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO		
OXYGEN SPAN		

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO		
OXYGEN SPAN		

ZERO AND SPAN CHECKLIST

KILN FEED SANKYO IMPACT FLOWMETER

DATE:____________ TIME:______________ NAME:_______________

RANGE: 0 - 110 tons per hour

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER: 19

DIGILINK CHANNEL: 114

DIGISTRIP CHANNEL: 204

STATIC TEST WEIGHT:____________________

EXPECTED READINGS WITH STATIC TEST WEIGHT:

____________ TPH _____________ ma

TEST EQUIPMENT USED

ITEM	EQUIPMENT #	CAL. DUE DATE
_______	_____________	_______________
_______	_____________	_______________
_______	_____________	_______________

FRONT PANEL METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	_________	____________________
WITH STATIC TEST WEIGHT	_________	____________________

MILLIAMP OUTPUT SIGNAL (10 - 50 ma)

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	_________	____________________
WITH STATIC TEST WEIGHT	_________	____________________

ZERO AND SPAN CHECKLIST

COAL FEED SANKYO IMPACT FLOWMETER

DATE:__________ TIME:__________ NAME: __________

TEST EQUIPMENT USED

ITEM	EQUIP. #	CAL. DUE DATE

RANGE: 0 - 15 tons per hour

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER: 62

DIGILINK CHANNEL: 305

DIGISTRIP CHANNEL: 112

STATIC TEST WEIGHT: ______________

EXPECTED READINGS WITH STATIC TEST WEIGHT: ______TPH ______ma

FRONT PANEL METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH		
WITH STATIC TEST WEIGHT		

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH		
WITH STATIC TEST WEIGHT		

ZERO AND SPAN CHECKLIST

PULVERIZED FUEL BIN LOAD CELL SCALES

DATE:____________ TIME:___________ NAME:______________

TEST EQUIPMENT USED

ITEM	EQUIP. #	CAL. DUE DATE
_____	__________	____________
_____	__________	____________
_____	__________	____________

RANGE: 0 - 5 Tons

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER:

DIGILINK CHANNEL:

DIGISTRIP CHANNEL:

MILLIAMP OUTPUT SIGNAL (10 - 50 ma)

TEST	AS FOUND	AFTER CALIBRATION
ZERO	________	_____________
SPAN	________	_____________

ZERO AND SPAN CHECKLIST

DIFFERENTIAL PRESSURE TRANSMITTER-KILN EXIT WATER SPRAY

DATE: ________ TIME: ________ NAME: ________

TEST EQUIPMENT USED

ITEM	EQUIPMENT NO.	CAL. DUE DATE

RANGE: 0 - 100 GPM

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER: 13

DIGILINK CHANNEL: 313

DIGISTRIP CHANNEL: 114

FLOWRATE USED FOR SPAN: ________ (from turbine meter)

EXPECTED OUTPUT SIGNAL = $\frac{(\text{flow rate})\ 40}{100} + 10$

= ________

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
ZERO		
SPAN		

ZERO AND SPAN CHECKLIST

PRESSURE TRANSMITTER

AXIAL OR SWIRL AIR ON PILLARD BURNER (Circle one)

DATE:__________ TIME:__________ NAME:__________

RANGE: - 5 to 60 inches of water

OUTPUT SIGNAL: 10 - 50 ma.

TEST PRESSURE USED FOR SPAN: __________

EXPECTED OUTPUT SIGNAL =

$$\frac{(\text{Test Pressure})\ 40}{(65)} + 10$$

= __________

TEST EQUIPMENT USED

ITEM	EQUIP #	CAL. DUE DT.

EXPECTED OUTPUT SIGNAL WHEN VENTED TO ATMOSPHERE = 13.1 ma

	SWIRL	AXIAL
LOOP NUMBER:	45A	45B
DIGILINK CHANNEL:	115	116
DIGISTRIP CHANNEL:	101	102

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
AT -5" W.C.		
VENTED TO ATMOS.		
AT SPAN TEST PRESS.		

ZERO AND SPAN CHECKLIST

BAILEY OXYGEN ANALYZER

DATE:____________ TIME:_____________ NAME:________________

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE
______	_________	_____________
______	_________	_____________
______	_________	_____________

RANGE: 0 - 5.0 Percent Oxygen

OUTPUT SIGNAL: 10 - 50 ma.

	OXYGEN	COMBUSTIBLES
LOOP NUMBER:	17	18
DIGILINK CHANNEL:	113	212
DIGISTRIP CHANNEL:	202	203

PERCENT OXYGEN OF GAS USED FOR ZERO CALIBRATION:_____________

PERCENT OXYGEN OF GAS USED FOR SPAN CALIBRATION:_____________

CALCULATION OF EXPECTED MILLIAMP OUTPUT:

$$\text{EXPECTED MILLIAMPS} = \frac{(\%\ \text{Oxygen of Test Gas})\ 40}{(5.0)} + 10$$

Low Range = _____________ High Range = _______________

	MILLIAMP OUTPUT SIGNAL	
TEST	AS FOUND	AFTER CALIBRATION
LOW RANGE TEST GAS	__________	__________
HIGH RANGE TEST GAS	__________	__________

ZERO AND SPAN CHECKLIST

KILN DRIVE MOTORS AMMETER

DATE:__________ TIME:__________ NAME:__________

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE
______	________	__________
______	________	__________
______	________	__________

RANGE: 0 - 1500 amps

OUTPUT SIGNAL: 10 - 50 ma.

LOOP NUMBER: 38

DIGILINK CHANNEL: 110

DIGISTRIP CHANNEL: 216

SPAN AMPS (FROM A CERTIFIED AMMETER): ____________

CALCULATION OF EXPECTED MILLIAMPS AT THE MEASURED SPAN AMPERAGE LOADING:

$$\text{EXPECTED MILLIAMPS} = \frac{(\text{Span Amps})\ 40}{(1500)} + 10$$

= ______________

	MILLIAMP OUTPUT SIGNAL	
TEST	AS FOUND	AFTER CALIBRATION
ZERO AMPS	________	________
SPAN AMPS	________	________

ZERO AND SPAN CHECKLIST

PRIMARY AIR FAN MOTOR AMMETER

DATE:____________ TIME:____________ NAME:________________

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE

RANGE: 0 - 200 amps

OUTPUT SIGNAL: 10 - 50 ma.

LOOP NUMBER: 46

DIGILINK CHANNEL: 215

DIGISTRIP CHANNEL: 106

SPAN AMPS (FROM A CERTIFIED AMMETER):________________

CALCULATION OF EXPECTED MILLIAMPS AT THE MEASURED SPAN AMPERAGE LOADING:

$$\text{EXPECTED MILLIAMPS} = \frac{(\text{Span Amps})\ 40}{(200)} + 10$$

	MILLIAMP OUTPUT SIGNAL	
TEST	AS FOUND	AFTER CALIBRATION
ZERO AMPS		
SPAN AMPS		

ZERO AND SPAN CHECKLIST

INFRARED OPTICAL PYROMETER

DATE: ____________ TIME: ___________ NAME: _______________

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE

RANGE: 1800 - 3200 Degrees F.

OUTPUT SIGNAL: 10 - 50 ma.

LOOP NUMBER: 48

DIGILINK CHANNEL: 306

DIGISTRIP CHANNEL: XXX

EXPECTED READING WITH CALIBRATE SWITCH ENGAGED:

1) FRONT PANEL METER: RED CALIBRATE MARK
2) OUTPUT SIGNAL : 32.0 ma

FRONT PANEL METER READING

TEST	AS FOUND	AFTER CALIBRATION
ZERO		
CALIBRATE ENGAGED		

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
ZERO		
CALIBRATE ENGAGED		

ZERO AND SPAN CHECKLIST

TYPE K THERMOCOUPLES (Circle one)
SECONDARY AIR TEMPERATURE
CHAIN INLET TEMPERATURE

DATE: ____________ TIME: ____________ NAME: _______________

RANGE: 0 - 2000 Degrees F.

OUTPUT SIGNAL: 10 - 50 ma

	SECONDARY AIR TEMP	CHAIN INLET TEMP
LOOP NUMBER:	68	35
DIGILINK CHANNEL:	214	315
DIGISTRIP CHANNEL:	109	214

SIMULATED TEMPERATURE USED FOR ZERO CALIBRATION: _______________

SIMULATED TEMPERATURE USED FOR SPAN CALIBRATION: _______________

CALCULATION OF EXPECTED MILLIAMPS AT THE SIMULATED CALIBRATION TEMPERATURE:

EXPECTED MILLIAMPS: $\frac{(\text{Simulated Temp.})\ 40}{(2000)} + 10$

EXPECTED MILLIAMPS FOR ZERO CALIBRATION: _______________

EXPECTED MILLIAMPS FOR SPAN CALIBRATION: _______________

	MILLIAMP OUTPUT SIGNAL	
TEST	AS FOUND	AFTER CALIBRATION
ZERO CALIBRATION	________	__________
SPAN CALIBRATION	________	__________

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE
______	__________	____________
______	__________	____________
______	__________	____________

FULL ELECTRONIC CALIBRATION WORKSHEET

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: ____________ TIME: ____________ NAME: ______________

	NOx	SO2
RANGE:	0 - 1500 ppm	0 - 1500 ppm
OUTPUT SIGNAL:	4 - 20 ma	4 - 20 ma
LOOP NUMBER:	11A	11B
DIGILINK CHANNEL:	102	103
DIGISTRIP CHANNEL:	110	111

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE

1. Was the UV lamp replaced prior to beginning the full calibration:

   Yes ______ No __________

2. Adjust R-5 to get 3.25 - 3.59 vdc at TP-10 on the transceiver:

   *Value at TP-10 before calibration: ____________

   **Value at TP-10 after calibration: ____________

3. Set the scanner frequency at 26 - 28 milliseconds when viewed on an oscilloscope connected to TP-3 at the

transceiver. Adjust the scanner frequency with R-2.

*Scanner frequency at TP-3 before calibration:__________

**Scanner frequency at TP-3 after calibration:__________

4. Connect an oscilloscope to TP-5 at the transceiver, and check for a symetrical S02 half waveform. Adjust R-3, as coarse adjustment, to get the best symetrical, half wave signal possible then adjust R-2 to bring both halves of the waveform to ground.

   *Was the waveform symetrical before calibration? YES NO

   **Was the waveform symetrical after calibration? YES NO

5. Connect the oscilloscope to TP-6 at the transceiver and observe the scanner drive signal. This signal should be a 0.35 - 0.85 volt triangular waveform with slightly rounded peaks.

   *Was the shape of the waveform proper: YES NO

   **Record the observed voltage of the waveform:__________

6. Connect the oscilloscope to TP-5, at the transceiver, and check for a symetrical NO half waveform. Adjust R-88 to achieve a symetrical half wave signal.

   *Was the waveform symetrical before calibration: YES NO

   **Was the waveform symetrical after calibration: YES NO

7. Connect the oscilloscope to TP-7, at the transceiver and observe the scanner feedback signal. This signal should be -8 to -6 volts which does not go above ground.

*Are there any irregularities in this signal: YES NO

**Record the voltage of this signal:____________

8. Connect the oscilloscope to TP-12 at the transceiver to check the scanner level detect signal. This signal should be -50 to 50 mvdc and may be adjusted with R-4.

*Voltage of signal before calibration:_____________

**Voltage of signal after calibration:_____________

9. Output drive signal adjustment.

With the zero mirror in and the front panel selector switch in the INPUT position:

*Does the front panel meter read approximately zero:
YES NO

Compute the expected voltage, with a high SO2 span cell inserted, by using the following equation:

$$\text{Expected Voltage} = \frac{(\text{Span cell value})(7)}{750}$$

The voltage may also be checked at TP-5 at the transceiver. Use R-15 to adjust the voltage.

**Expected voltage at TP-5:____________

***Voltage at TP-5 before calibration:______________

****Voltage at TP-5 after calibration:______________

10. Temperature Compensation Calibration.

Check the voltage at TP-4 on the Integrator, Sample, and Hold board. It should read zero volts and can be adjusted with R-4.

*Voltage at TP-4 before calibration:____________

**Voltage at TP-4 after calibration:____________

11. Check the amperage with an ammeter in series with the temperature output wires. Use the following equation to calculate the expected amperage.

$$\text{Expected amps} = \frac{(\text{Actual Temperature})\ \ 20.0\ \text{ma}}{(800)}$$

This amperage can be adjusted with R-72 at the transceiver.

*Expected amperage:____________

**Amperage before calibration:____________

***Amperage after calibration:____________

12. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board. Use the following equation to calculate the expected voltage:

$$\text{Expected volts} = \frac{(\text{Actual Temperature})\ 10.0\ \text{volts}}{(800)}$$

This voltage may be adjusted with R-5.

*Expected voltage at TP-4:____________

**Voltage at TP-4 before calibration:____________

***Voltage at TP-4 after calibration:____________

13. Connect a voltmeter to TP-2 on the Temperature Compensation board. The average voltage over several SO2 sample periods should be 0.0 volts. This voltage may be adjusted with R-30.

*Voltage at TP-2 before calibration:____________

**Voltage at TP-2 after calibration:____________

14. During an NO sample period, adjust R-32 for 0.0 volts at TP-2.

*Voltage at TP-2 before calibration:____________

**Voltage at TP-2 after calibration:____________

15. Connect a voltmeter to TP-4 on the Integrator, Sample and Hold board and adjust R-4 to get 0.9375 volts:

    *Voltage at TP-4 after adjusting R-4:____________

16. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 1.0 volts and may be adjusted with R-29 on the Temperature Compensation board.

    *Voltage at TP-2 before calibration:____________

    **Voltage at TP-2 after calibration:____________

17. Adjust R-4 on the Temperature Compensation board so there is no change in the voltage at TP-2 with the switch S-2 in the "up" or "down" position.

18. Adjust R-4 on the Integrator, Sample, and Hold board to get 10.0 volts at TP-4.

    *Voltage at TP-4 after adjusting R-4:____________

19. Connect a voltmeter to TP-2 on the Temperature Compensation board. The voltage should be 3.65 volts and may be adjusted with R-2 on the Temperature Compensation board.

    *Voltage at TP-2 before calibration:____________

    **Voltage at TP-2 after calibration:____________

20. Connect a voltmeter to TP-4 on the Integrator, Sample, and Hold board and adjust R-4 to get 0.9375 volts.

    *Voltage at TP-4 after adjusting R-4:____________

21. Connect a voltmeter to TP-3 on the Integrator, Sample, and Hold board and record the voltage during an SO2 sample period with switch S-2 in the "up" position.

*Voltage at TP-3:____________

22. Place switch S-2 in the down position and record the voltage. Use the following equation to calculate the expected voltage:

Expected voltage = (Voltage at TP-3, from #21 above) (1.075)

Use R-64 on the Integrator, Sample, and Hold board to adjust this voltage. (R-64 is the top, grey potentiometer located near the center of the board.)

*Expected voltage at TP-3:____________

**Voltage at TP-3 before calibration:____________

***Voltage at TP-3 after calibration:____________

23. Connect a voltmeter to TP-4 on the Integrator, Sample and Hold board and adjust R-4 to get 10.0 volts.

*Voltage at TP-4 after adjusting R-4: ____________

24. Connect a voltmeter to TP-3 on the Integrator, Sample, and Hold board and record the voltage during an SO2 sample period with switch S-2 in the "up" position.

*Voltage at TP-3: ____________

25. Place switch S-2 in the "down" position and record the voltage. Use the following equation to calculate the expected voltage:

Expected voltage = (Voltage at TP-3,from #24)(2.74)

Use R-65 on the Integrator, Sample and Hold board to adjust this voltage. (R-65 is the lower, blue potentiometer located near the center of the board.)

*Expected voltage at TP-3: ____________

**Voltage at TP-3 before calibration: __________

***Voltage at TP-3 after calibration: __________

26. Connect a voltmeter to TP-4 on the IS/H board and adjust R-4 to get 0.0 volts. Remove all jumpers that have been connected. Place switch S-2 in the down position.

27. The full electronic calibration is now completed.

FULL ELECTRONIC CALIBRATION WORKSHEET

LEAR SIEGLER CM-50 OXYGEN GAS ANALYZER

DATE:____________ TIME:____________ NAME:______________

RANGE: 0 - 25 percent oxygen

OUTPUT SIGNAL: 4 - 20 ma

LOOP NUMBER: 11C

DIGILINK CHANNEL: 104

DIGISTRIP CHANNEL: 112

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE

HEATER CONTROLLER BOARD

1. The pressure regulator should be set at 18 - 22 psi.

   *As found pressure on the regulator:____________

   **Pressure after adjustment:____________

2. Verify the reference flow printed on top of the meter and adjust the flowmeter, if required.

   *Reference flow printed on top of flowmeter:__________

   **Flowrate before adjusting flowmeter:__________

   ***Flowrate after adjusting flowmeter:__________

3. With the calibration switch in the "HIGH" position, verify that the flowmeter indicates the flowrate printed on top of the meter.

*Reference flow printed on top of the flowmeter:_______

**Flowrate before adjusting flowmeter:__________

***Flowrate after adjusting flowmeter:__________

4. With the calibration switch in the "LOW" position, verify that the flowmeter indicates the flowrate printed on top of the meter.

*Reference flow printed on top of the flowmeter:_________

**Flowrate before adjusting flowmeter:__________

***Flowrate after adjusting flowmeter:__________

5. Verify that the power supply voltage and the ambient temperature are within specificiation.

*Power supply voltage:__________

**Ambient temperature:__________

6. Connect a voltmeter to TP-8 on the Heater Controller board. The voltage should be within the -50 to 50 mv range and can be adjusted with R-2.

*Voltage at TP-8 before calibration:__________

**Voltage at TP-8 after calibration:__________

7. Connect a voltmeter to TP-2 on the Heater Controller board. The voltage should be -374 mv and may be adjusted with R-3.

*Voltage at TP-2 before calibration:__________

**Voltage at TP-2 after calibration:__________

8. Approximately 30 minutes after installing the heater fuse, depress the TEMPERATURE FAULT push button. The front panel meter should indicate a stable reading in the green zone. The meter indication may be adjusted with R-4 on the Heater Controller board. Wait 5 minutes after adjusting R-4 for the meter to stabilize.

   *Did the meter indicate the green zone before adjusting R-4?

   YES NO

   **Did the meter indicate the green zone after adjusting R-4?

   YES NO

9. Calculate the compensated thermocouple output by using the following equation:

   Compensated Thermocouple output =

   $$\{(-34.07) - (\text{card cage temp} - 77)\}(-0.022)$$

   Expected compensated thermocouple output:__________

10. Connect a voltmeter to TP-3 on the Heater Controller board. This reading should be the expected compensated thermocouple output calculated in step 9, above. Use R-3 to adjust this voltage.

    *Voltage at TP-3 before calibration:__________

    **Voltage at TP-3 after calibration:__________

11. This completes the Heater Controller board calibration.

PERCENT OXYGEN BOARD

12. Verify the thermocouple output as explained above in step 10.

TO VERIFY THE CELL CONSTANT

13. Disconnect the wire at TB2-2 on the Percent Oxygen board and connect a voltmeter to this wire. Connect the voltmeter return to TB2-1. With the calibration switch in the HIGH position and the range switch in the 25% position, read the cell constant on the voltmeter.

*Record the cell constant:__________

TO VERIFY THE ZERO:

14. Connect a voltmeter to TP-4. The reading should be 300 - 500 mv and may be ajusted with R-4.

*Voltage at TP-4 before calibration:__________

**Voltage at TP-4 after calibration:__________

15. Connect a voltmeter to TP-1. The reading should be 0.00 volts dc, plus or minus 10 mv.

*Voltage at TP-1:__________

16. Connect an ammeter to TB1-11. The reading should be 3.99 - 4.01 ma, and may be adjusted with R-1.

*Amperage at TB1-11 before calibration:__________

**Amperage at TB1-11 after calibration:__________

17. Connect a voltmeter to TP-2 on the Percent Oxygen board. The reading should be 0.00 vdc plus or minus 1.0 mv and may be adjusted with R-68.

*Voltage at TP-2 before calibration:__________

**Voltage at TP-2 after calibration:__________

18. Connect a voltmeter to TP-1 on the Percent Oxygen board. The expected output is Item 6 on the probe data sheet and may be adjusted with R-7.

*Voltage at TP-1 before calibration:__________

**Voltage at TP-1 after calibration:__________

25 PERCENT RANGE CALIBRATION:

19. Connect a voltmeter to TP-1 on the Heater Controller board. The value should be the specified cell constant (Item 4 on the probe data sheet) and may be adjusted with R-1.

*Voltage at TP-1 before calibration:__________

**Voltage at TP-1 after calibration:__________

20. Connect a voltmeter to TP-1 on the Percent Oxygen board. Adjust R-3 to get 8.38 volts dc plus or minus 0.01 volts.

21. The front panel meter should read the green calibration dot. If it does not read the calibration dot, the meter may be adjusted with R-52 on the Percent Oxygen board.

*Did the meter read the calibration dot without adjusting R-52? YES NO

**Did the meter read the calibration dot after adjusting R-52? YES NO

10 PERCENT RANGE CALIBRATION:

22. Refer to Item 3 (10 Percent Calibration) on the probe data sheet.

Record the value for Item 3:_____________

23. If the value for item 3 is positive, do step 24 and skip step 25. If the value for item 3 is negative, skip step 24 and do step 25.

24. Connect a voltmeter to TP-4 on the Percent Oxygen board. The reading should be equal to the value of item 3 and may be adjusted with R-4 on the Percent Oxygen board.

*Voltage at TP-4 before calibration:__________

**Voltage at TP-4 after calibration:__________

25. Connect a voltmeter to TP-1 on the Heater Controller board The reading should be equal to the value of item 3 and may be adjusted with R-1 on the Heater Controller board.

*Voltage at TP-1 before calibration:__________

**Voltage at TP-1 after calibration:__________

26. Connect a voltmeter to TP-1 on the Percent Oxygen board. The reading should be 10.00 volts dc plus or minus 10 mv and may be adjusted with R-6.

*Voltage at TP-1 before calibration:__________

**Voltage at TP-1 after calibration:__________

27. Connect an ammeter to TB1-11. The reading should be 20.00 ma plus or minus 0.01 ma and may be adjusted with R-2 on the Percent Oxygen board.

*Amperage at TB1-11 before calibration:__________

**Amperage at TB1-11 after calibration:__________

2.5 PERCENT RANGE CALIBRATION:

28. Connect a voltmeter to TP-4 on the Percent Oxygen board. The reading should be item 5 (2.095 calibration voltage) on the probe data sheet and may be adjusted with R-4 on the Percent Oxygen board.

*Voltage at TP-4 after adjusting R-4:__________

29. Connect a voltmeter to TP-1 on the Percent Oxygen board. The reading should be 8.38 volts dc plus or minus 1.0 mv and may be adjusted with R-5 on this board.

*Voltage at TP-1 before calibration:__________

**Voltage at TP-1 after calibration:__________

CALCULATING THE OXYGEN PROBE CALIBRATION

30. Verify the proper probe heater temperature as outlined above, in steps 9, 10, and 11.

*Expected calculated thermocouple output:__________

**Thermocouple output before calibration:__________

***Thermocouple output after calibration:__________

31. Connect a voltmeter to TP-3 on the Percent Oxygen board. Place the calibration switch on the front panel in the HIGH position and read the cell constant (cc) on the voltmeter.

*Record the value of the cell constant: cc = __________

32. With the voltmeter connected to TP-3, place the calibration switch in the LOW position and read the cell output (E).

*Record the value of the cell output: E = __________

33. Calculate the MV Decade using the following equation:

$$\text{MV/Dec} = \frac{E - CC}{\text{Log} \dfrac{(20.95)}{(\%\ 02\ \text{of low cal gas})}}$$

*Record the value of the MV Decade; MV/Dec = ___________

34. Calculate the 10 percent calibration using the following equation:

$$10\%\ \text{Cal} = (\text{MV/Dec})(0.3212) + CC$$

*Record the 10 percent calibration; 10% Cal = ___________

35. Calculate the 2.095 percent calibration using the following equation:

$$2.095\%\ \text{Cal} = \text{MV/Dec} + CC$$

*Record the 2.095 percent calibration;
2.095% Cal = ___________

36. Calculate the output for zero input using the following equation:

$$\text{Output for zero input} = 8.38 \times 10^{\frac{CC}{\text{MV/Dec}}}$$

*Record the output for zero input = ________________

DYNAMIC CALIBRATION WORKSHEET

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE:_______________ TIME:______________ NAME:__________________

NAME:__________________

NAME:__________________

1. Temperature Verification

   a. Disconnect the temperature wires TB 1-29 and TB 1-15 in the control unit and short these wires together. Adjust R-4 to get 0.0 volts at TP-4 on the Integrator, Sample, and Hold board.

      *Voltage at TP-4 before calibration: _____________

      **Voltage at TP-4 after calibration:_______________

   b. Connect the temperature wires to a transmation and record the indicated temperature. Then reconnect the temperature wires at TB 1-29 and TB 1-15.

      *Temperature reading:_________________

   c. Calculate the voltage that represents the temperature recorded in part b. above, according to the following formula:

      $$\text{Voltage} = \frac{(\text{Part b actual temp.}) \times 10}{800}$$

      *Voltage = ____________

   d. Adjust the span on the thermocouple get the calculated voltage (from part c., above) at TP-4 on the Integrator, Sample, and Hold board.

      *Voltage at TP-4 before calibration:___________

      **Voltage at TP-4 after calibration:___________

2. Flow pure N2 zero gas at 2.0 to 2.3 liters per minute. Observe Digilink channels 102, for NO, and 103 for SO2. Adjust the NO and SO2 zero potentiometers on the Integrator, Sample, and Hold board to get zero (0) ppm plus or minus 15 ppm.

   *NO zero reading before calibration:__________

   **NO zero reading after calibration:__________

   ***SO2 zero reading before calibration:__________

   ****SO2 zero reading after calibration:__________

3. Flow standard NO span gas at a rate of 2.0 to 2.3 liters per minute. Record the observed value.

   *Certified value of NO span gas:__________

   **Observed reading of NO span gas:__________

4. Calculate the error of the observed reading versus the certified value.

$$\text{Error} = \frac{\text{Certified NO value}}{\text{Observed NO value}}$$

$$\text{Error} = \frac{(\qquad\qquad)}{(\qquad\qquad)} = \underline{\qquad\qquad\qquad}$$

5. Flow standard SO2 span gas at a rate of 2.0 to 2.3 liters per minute. Record the observed value.

   *Certified value of SO2 span gas:__________

   **Observed reading of SO2 span gas:__________

6. Calculate the error of the observed reading versus the certified value.

$$\text{Error} = \frac{\text{Certified SO2 value}}{\text{Observed SO2 value}}$$

$$\text{Error} = \frac{(\qquad\qquad)}{(\qquad\qquad)} = \underline{\qquad\qquad\qquad}$$

7. Average the errors calculated in step 4 and step 6.

$$\text{Average error} = \frac{\text{Error from step 4 + error from step 6}}{2}$$

$$\text{Average error} = \frac{(\qquad) + (\qquad)}{2} = \underline{\qquad\qquad}$$

8. If both observed span gas values are in error by less than 2.5 percent of the certified span gas values, no adjustments are required and the dynamic calibration is complete.

9. If either, or both, of the observed values for the span gases are in error by more than 2.5 percent of the appropriate span gas certified value, adjustment is required.

10. Flow NO standard gas and record the observed value.

*Observed value of NO span gas:__________

11. Correct the observed NO span gas value from step 10 by the average error calculated in step 7.

Corrected NO value = (NO value step 10)x(Avg. error step 7)

Corrected No value = __________x__________ = __________

12. Adjust R-2 on the Temperature Compensation board so that the observed NO value is equal to the corrected NO value calculated in step 11.

*Observed NO value before calibration:__________

**Observed NO value after calibration:__________

13. Flow N2 zero gas to be sure that the observed NO and SO2 values return to zero, plus or minus 15 ppm, within three sample periods.

*Observed NO value:__________

**Observed SO2 value:__________

14. The dynamic calibration is complete.

DYNAMIC CALIBRATION WORKSHEET

LEAR SIEGLER CM-50 OXYGEN ANALYZER

NAME:________________

DATE:____________ TIME:________________

NAME:________________

1. Select channel number 104 on the Kaye Digilink.
2. Turn the CM-50 control unit front panel "Calibration" switch to the "Low" position. (This allows the low value oxygen standard gas to flow into the analyzer).
3. Record the certified value of the low oxygen standard gas.

   *Certified value of low range oxygen standard:__________
4. Record the observed value from channel 104 on the Kaye Digilink. Correct the observed value to the certified value of the standard gas by adjusting R-3 zero potentiometer on the Percent Oxygen board.

   *Observed low range value before calibration:__________

   **Observed low range value after calibration:__________
5. Turn the CM-50 control unit front panel "Calibration" switch to the "High" position. (This allows outside air, with an oxygen content of 20.9 percent to enter the analyzer.)
6. Allow the reading on the Kaye Digilink to stabilize. Record the observed value. Adjust the R-2 span potentiometer, on the Percent Oxygen board, to produce a 20.9 percent reading as observed on channel 104 of the Kaye Digilink.

   *Observed high range value before calibration:__________

   **Observed high range value after calibration:__________
7. Turn the CM-50 control unit front panel "Calibration" switch to the "Operate" position.
8. The dynamic calibration is now complete.

---

of the test period

control room printer.

*Final reading of Sankyo totalizer:__________

6. Load the clinker collected during the test period into a previously tared, empty truck. Weight all of the collected clinker on a certified scale.

---

11. Compare the actual clinker collected to the computed clinker from the kiln feed used.

*$\frac{\text{Computed clinker, from totalizer}}{\text{Actual clinker}}$ = ______________

**$\frac{\text{Computed clinker, from NOx printer}}{\text{Actual clinker}}$ = ______________

12. If the computed clinker values are more than 5 percent in error, adjust the kiln feed Sankyo Impact Flowmeter at the earliest possible time to correct the error.

13. The dynamic calibration is now complete.

DYNAMIC CALIBRATION WORKSHEET

KILN FEED SANKYO IMPACT FLOWMETER

DATE:__________ TIME:__________ NAME:____________

RANGE: 0 - 110 TPH

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER: 19

DIGILINK CHANNEL: 114

DIGISTRIP CHANNEL: 204

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE

ZERO CALIBRATION:

1. With no material flowing over the Sankyo, establish the scale zero.

   *Were both zero indicating lights illuminated to equal intensity before calibration: YES NO

   **Were both zero indicating lights illuminated to equal intensity after calibration: YES NO

SPAN CALIBRATION:

2. Weigh an empty truck and then move it into position to catch the kiln feed used for the material test.

   Run #1: Tare weight of the empty truck:__________

   Run #2: Tare weight of the empty truck:__________

   Run #3: Tare weight of the empty truck:__________

3. Record the initial reading on the Sankyo totalizer.

Run #1: Initial reading on the Sankyo totalizer:__________

Run #2: Initial reading on the Sankyo totalizer:__________

Run #3: Initial reading on the Sankyo totalizer:__________

4. Run kiln feed over the Sankyo flowmeter at a rate of 75 - 100 percent of full scale for at least 3 minutes.

5. Catch the kiln feed in the truck provided and weight the loaded truck.

Run #1: Weight of the loaded truck:__________

Run #2: Weight of the loaded truck:__________

Run #3: Weight of the loaded truck:__________

6. Record the final reading on the Sankyo totalizer.

Run #1: Final reading on the Sankyo totalizer:__________

Run #2: Final reading on the Sankyo totalizer:__________

Run #3: Final reading on the Sankyo totalizer:__________

7. Repeat steps 2 - 6 three times.

8. Calculate the amount of material that was used in each test run.

	LOADED TRUCK WEIGHT	-	TARE WEIGHT	=	TEST WEIGHT
RUN #1	__________	-	__________	=	__________
RUN #2	__________	-	__________	=	__________
RUN #3	__________	-	__________	=	__________

9. Calculate the number of counts recorded on the Sankyo totalizer for each run.

	FINAL READING	-	INITIAL READING	=	COUNTS
RUN #1	________	-	________	=	______
RUN #2	________	-	________	=	______
RUN #3	________	-	________	=	______

10. Calculate the flow factor (w/c) for each run. The flow factor is the weight of the test material divided by the number of counts recorded on the totalizer.

	TEST WEIGHT	/	COUNTS	=	FLOW FACTOR
RUN #1	______	/	______	=	__________
RUN #2	______	/	______	=	__________
RUN #3	______	/	______	=	__________

11. Calculate the average flow factor.

$$\frac{\text{W/C Run \#1} + \text{W/C Run \#2} + \text{W/C Run \#3}}{3} = \text{Average Flow Factor}$$

(__________+__________+__________)/3 = ____________

12. Suspend a static test weight (about 15 pounds) over the calibration pulley. Record the exact weight of the static test weight to the nearest 0.01 pounds.

*Weight of static test weight = __________

13. Record the initial indicated flow rate created by the static test weight.

*Initial indicated flow rate: __________

14. Calculate the registration flow factor using the following equation:

$$\text{Reg. flow factor} = \frac{\text{Full scale flow}}{3600}$$

For the kiln feed Sankyo, the registration flow factor is currently 0.0306 tons per count.

15. Calculate the correct indicated flow rate with the static test weight attached using the following equation:

$$\text{Correct indicated flow rate} = \frac{\text{(Avg. flow fctr)}}{\text{(Reg. flow fctr)}} \text{(Init. indicated flow rate)}$$

*Record the correct indicated flow rate: __________

16. Adjust the span control to achieve the correct indicated flow rate with the static test weight attached.

*Indicated flow rate after calibration:__________

17. If the span adjustment required was more than 5 percent of the full range of the scale, repeat steps 1 - 16.

LOAD DISTRIBUTION COMPENSATION CALIBRATION:

18. Perform the load distribution compensation calibration after completing steps 1 - 17.

19. Weigh an empty truck to be used to catch the kiln feed used for the material test.

RUN #1 Weight of empty truck:__________

RUN #2 Weight of empty truck:__________

RUN #3 Weight of empty truck:__________

20. Record the initial reading on the Sankyo totalizer.

RUN #1 Initial reading on the Sankyo totalizer:__________

RUN #2 Initial reading on the Sankyo totalizer:__________

RUN #3 Initial reading on the Sankyo totalizer:__________

21. Run kiln feed over the Sankyo flowmeter at a rate of 40 - 50 percent of full scale flow for at least 3 minutes.

22. Catch the kiln feed in the truck provided and weigh the loaded truck.

RUN #1 Weight of the loaded truck:__________
RUN #2 Weight of the loaded truck:__________
RUN #3 Weight of the loaded truck:__________

23. Record the final reading on the Sankyo totalizer.

RUN #1 Final reading on the Sankyo totalizer:__________
RUN #2 Final reading on the Sankyo totalizer:__________
RUN #3 Final reading on the Sankyo totalizer:__________

24. Repeat steps 2 - 6 three times.

25. Calculate the amount of material that was used in each test run.

	LOADED TRUCK WEIGHT	-	TARE WEIGHT	=	TEST WEIGHT
RUN #1	__________	-	__________	=	__________
RUN #2	__________	-	__________	=	__________
RUN #3	__________	-	__________	=	__________

26. Calculate the number of counts recorded on the Sankyo totalizer for each run.

	FINAL READING	-	INITIAL READING	=	COUNTS
RUN #1	__________	-	__________	=	__________
RUN #2	__________	-	__________	=	__________
RUN #3	__________	-	__________	=	__________

27. Calculate the flow factor (w/c) for each test run. The flow factor is the weight of the test material divided by the number of counts recorded on the totalizer.

	TEST WEIGHT	/	COUNTS	=	FLOW FACTOR
RUN #1	__________	/	_______	=	_________
RUN #2	__________	/	_______	=	_________
RUN #3	__________	/	_______	=	_________

28. Calculate the average flow factor.

$$\frac{\text{W/C RUN \#1 + W/C RUN \#2 + W/C RUN \#3}}{3} = \text{Average Flow Factor}$$

(_________+__________+__________) / 3 = ___________

29. If the average flow factor is greater than the registration flow factor (0.0306 tons per count), then positive compensation will be required. If it is less than the registration value, negative compensation will be required.

30. With the Load Distribution Compensation board switch in the NO COMP position, hang a static test weight which will produce an indicated flow rate of approximately 90 percent of full scale.

31. Change the switch to the "+ COMP" position (if positive compensation is required) or the "- COMP" position. Adjust the CROSS control until there is no change in the indicated flow rate when the switch is in the NO COMP or the "+ or - COMP" position.

32. Change the static test weight to get an indicated flow rate of about 45 percent.

*Record the indicated flow rate:__________

33. Calculate the correct indicated flow rate with the switch in the "+ or - COMP" position expected when the static test weight is attached by using the following equation:

$$\text{+ or - COMP reading} = \frac{\text{(NO COMP reading)(Avg. flow factor)}}{\text{Registration flow factor}}$$

NO COMP reading from step 32.

Average flow factor from step 28.

Registration flow factor is 0.0306.

*Calculated "+ or - COMP" reading :______________

34. Turn the switch to the "+ COMP" position (for positive compensation) or the "- COMP" position and adjust the "COMP" control to get the calculated "+ or - COMP" reading.

* " + or - COMP" reading before adjusting the COMP control:

____

** "+ or - COMP" reading after adjusting the COMP control:

____

35. This completes the dynamic calibration worksheet.

FULL CALIBRATION WORKSHEET

PULVERIZED FUEL BIN LOAD CELLS AND COAL FEED TO THE KILN SANKYO IMPACT FLOWMETER

DATE:____________ TIME:___________ NAME:______________

	LOAD CELLS	COAL SANKYO
RANGE:	0 - 5 Tons	0 - 15 TPH
OUTPUT SIGNAL:	10 - 50 ma	10 - 50 ma
LOOP NUMBER:	104	62
DIGILINK CHANNEL:	None	305
DIGISTRIP CHANNEL:	204	112

TEST EQUIPMENT USED

ITEM	EQUIP. NO.	CAL. DUE DATE
______	__________	___________
______	__________	___________
______	__________	___________
______	__________	___________

The coal Sankyo and the pulverized fuel bin load cells will be treated as a unit since the fuel bin load cells provide the means to pass a known weight of material over the Sankyo during the calibration of the Sankyo.

PULVERIZED FUEL BIN LOAD CELLS CALIBRATION:

1. Empty the pulverized fuel bin completely of material.

2. Connect an ammeter to the output signal wires of the load cells. Adjust the zero to get a 10.0 ma output.

   *Signal output of empty bin before calibration:_________

   **Signal output of empty bin after calibration:_________

3. Suspend certified weights from the empty bin. (These weights may be provided by Accurate Scale Co. or a similar company.)

4. Adjust the span control to give the expected output signal. The correct output signal for the span calibration may be calculated by using the following equation. (For a 10 - 50 ma signal.)

$$\text{Expected Signal} = \frac{(\text{Test weight})\ 40}{(\text{Full scale range})} + 10$$

*Expected output signal for test weights:__________

**Output signal before calibration:__________

***Output signal after calibration:__________

5. This completes the calibration of the pulverized fuel bin load cells.

COAL SANKYO IMPACT FLOWMETER CALIBRATION:

6. With no material flowing over the Sankyo, establish the scale zero.

*Were both zero indicating lights illuminated to equal intensity before calibration: YES NO

**Were both zero indicating lights illuminated to equal intensity after calibration: YES NO

7. Fill the pulverized fuel bin with about three (3) tons of material and record the exact weight of the material.

RUN #1 Initial weight of material in the bin:__________

RUN #2 Initial weight of material in the bin:__________

RUN #3 Initial weight of material in the bin:__________

RUN #1 Final reading on the Sankyo totalizer:__________

RUN #2 Final reading on the Sankyo totalizer:__________

RUN #3 Final reading on the Sankyo totalizer:__________

12. Repeat steps 7 - 11 three times.

13. Calculate the amount of material that was used in each test run.

	INITIAL BIN WEIGHT	-	FINAL BIN WEIGHT	=	TEST WEIGHT
RUN #1	________	-	________	=	________
RUN #2	________	-	________	=	________
RUN #3	________	-	________	=	________

14. Calculate the number of counts recorded on the Sankyo totalizer for each run.

	FINAL READING	-	INITIAL READING	=	COUNTS
RUN #1	________	-	__________	=	______
RUN #2	________	-	__________	=	______
RUN #3	________	-	__________	=	______

15. Calculate the flow factor (w/c) for each run. The flow factor is the weight of the test material divided by the number of counts recorded on the totalizer.

	TEST WEIGHT	/	COUNTS	=	FLOW FACTOR
RUN #1	_________	/	______	=	_________
RUN #2	_________	/	______	=	_________
RUN #3	_________	/	______	=	_________

16. Calculate the average flow factor.

$$\text{Avg. flow factor} = \frac{\text{W/C Run \#1} + \text{W/C Run \#2} + \text{W/C Run \#3}}{3}$$

(__________+__________+__________) / 3 = __________

17. Suspend a static test weight (about 2 pounds) over the calibration pulley. Record the exact weight of the static test weight to the nearest 0.01 pounds.

*Weight of the static test weight = _________

18. Record the initial indicated flow rate created by the static test weight.

*Initial indicated flow rate:__________

19. Calculate the registration flow factor using the following equation:

$$\text{Registration flow factor} = \frac{\text{Full scale flow}}{3600}$$

For the pulverized coal Sankyo, the registration flow factor is currently 0.00417 tons per count.

20. Calculate the correct indicated flow rate with the static test weight attached using the following equation:

$$\text{Correct indicated flow rate} = \frac{(\text{Avg. flow factor})(\text{Init.ind. flow rate})}{(\text{Reg. flow factor})}$$

*Record the correct indicated flow rate:_____________

21. Adjust the span control to achieve the correct indicated flow rate with the static test weight attached.

*Indicated flow rate after calibration:__________

22. If the span adjustment required was more than 5 percent of the full range of the scale, repeat steps 6 - 21.

COAL SANKYO LOAD DISTRIBUTION COMPENSATION CALIBRATION:

23. Perform the load distribution compensation calibration after completing steps 6 - 22.

24. Fill the pulverized fuel bin with about 3 tons of material and record the exact weight of the material.

RUN #1 Initial weight of the material in the bin:_______

RUN #2 Initial weight of the material in the bin:_______

RUN #3 Initial weight of the material in the bin:_______

25. Record the initial reading on the Sankyo totalizer.

RUN #1 Initial reading on the Sankyo totalizer:_________

RUN #2 Initial reading on the Sankyo totalizer:_________

RUN #3 Initial reading on the Sankyo totalizer:_________

26. Run the material from the bin over the Sankyo flowmeter at a rate of 40 - 50 percent of full scale flow for at least 3 minutes. (5 - 8 minutes is preferred.)

27. Record the final weight reading of the material remaining in the pulverized fuel bin.

RUN #1 Final weight of material in the bin:__________
RUN #2 Final weight of material in the bin:__________
RUN #3 Final weight of material in the bin:__________

28. Record the final reading on the Sankyo totalizer.

RUN #1 Final reading on the Sankyo totalizer:__________
RUN #2 Final reading on the Sankyo totalizer:__________
RUN #3 Final reading on the Sankyo totalizer:__________

29. Repeat steps 7 - 11 three times.

30. Calculate the amount of material that was used in each test run.

	INITIAL BIN WEIGHT	-	FINAL BIN WEIGHT	=	TEST WEIGHT
RUN #1	__________	-	__________	=	__________
RUN #2	__________	-	__________	=	__________
RUN #3	__________	-	__________	=	__________

31. Calculate the number of counts recorded on the Sankyo totalizer for each run.

	FINAL READING	-	INITIAL READING	=	COUNTS
RUN #1	__________	-	__________	=	__________
RUN #2	__________	-	__________	=	__________
RUN #3	__________	-	__________	=	__________

32. Calculate the flow factor (w/c) for each run. The flow factor is the weight of the test material divided by the number of counts recorded on the totalizer.

	TEST WEIGHT	/	COUNTS	=	FLOW FACTOR
RUN #1	________	/	______	=	________
RUN #2	________	/	______	=	________
RUN #3	________	/	______	=	________

33. Calculate the average flow factor.

$$\text{Avg. flow factor} = \frac{\text{W/C Run \#1} + \text{W/C Run \#2} + \text{W/C Run \#3}}{3}$$

(________+________+________) / 3 = ________

34. If the average flow factor is greater than the registration flow factor (0.00417 tons per count), then positive compensation will be required. If it is less than the registration value, negative compensation will be required.

35. With the Load Distribution Compensation board switch in the NO COMP position, hang a static test weight which will produce an indicated flow rate of approximately 90 percent of full scale.

36. Change the switch to the "+ COMP" position (if positive compensation is required) or the "- COMP" position. Adjust the CROSS control until there is no change in the indicated flow rate when the switch is in the NO COMP or the "+ or - COMP" position.

37. Change the static test weight to get an indicated flow rate of about 45 percent.

*Record the indicated flow rate:________

38. Calculate the correct indicated flow rate with the switch in the "+ or - COMP" position expected when the static test weight is attached by using the following equation:

$$\text{+ or - COMP reading} = \frac{\text{(NO COMP reading)(Avg. flow factor)}}{\text{Registration flow factor}}$$

NO COMP reading from step 37.

Average flow factor from step 33.

Registration flow factor is 0.00417

*Calculated "+ or - COMP" reading :______________

39. Turn the switch to the "+ COMP" position (for positive compensation) or the "- COMP" position and adjust the "COMP" control to get the calculated "+ or - COMP" reading.

* " + or - COMP" reading before adjusting the COMP control:

____

** "+ or - COMP" reading after adjusting the COMP control:

____

40. This completes the full calibration worksheet.

DATA VALIDATION WORKSHEET

NAME	DATE	FROM TIME	TO TIME	REASON FOR QUESTIONABLE DATA

SAMPLE CUSTODY WORKSHEET

SAMPLE

COAL: _______

KILN FEED: _______

DATE: _______

TIME: _______

TAKEN BY: _______

TYPE OF ANALYSIS

MOISTURE: _______

L.O.I.: _______

DATE: _______

ANALYST: _______

RESULTS: _______

SAMPLE

COAL: _______

KILN FEED: _______

DATE: _______

TIME: _______

TAKEN BY: _______

TYPE OF ANALYSIS

MOISTURE: _______

L.O.I.: _______

DATE: _______

ANALYST: _______

RESULTS: _______

SAMPLE

COAL: _______

KILN FEED: _______

DATE: _______

TIME: _______

TAKEN BY: _______

TYPE OF ANALYSIS

MOISTURE: _______

L.O.I.: _______

DATE: _______

ANALYST: _______

RESULTS: _______

SAMPLE

COAL: _______

KILN FEED: _______

DATE: _______

TIME: _______

TAKEN BY: _______

TYPE OF ANALYSIS

MOISTURE: _______

L.O.I.: _______

DATE: _______

ANALYST: _______

RESULTS: _______

ZERO / SPAN SUMMARY SHEET

LSI SM-810 NOx/SOx ANALYZER AND LSI CM-50 OXYGEN ANALYZER

	CM-50		SM-810			
	Oxygen		NO		SO2	
DATE	Low (2.0%)	High (20.9%)	Zero 0 ppm	Span 640 ppm	Zero 0 ppm	Span 890 ppm

ATTACHMENT C

VARIATION OF ENGINEERING CONSTANTS

DATE	COAL BTU(dry)	DATE	COAL MOISTURE	KILNFEED MOISTURE	KILN FEED LOI X-RAY	KILN FEED LOI WET
6-03-85	12619	8-25-85	3.70	0.29	34.51	34.44
6-07-85	12729	8-26-85	5.00	0.23	35.10	34.90
6-13-85	12526	8-27-85	4.70			
6-13-85	12251	7-29-85	4.40		33.82	
6-20-85	12667	7-30-85	3.80	0.33	33.42	34.96
6-27-85	12605	7-31-85	3.40	0.46	35.16	34.96
6-27-85	12329	8-01-85	3.70	0.48	33.14	35.18
7-16-85	12270	8-02-85	3.40	0.36	33.99	35.15
7-22-85	12701	8-03-85		0.27	34.29	34.99
		8-04-85		0.27	34.43	35.67
		8-05-85		0.31	35.20	35.77
		8-06-85		0.42	35.00	35.80
		8-07-85		0.33	35.21	35.92
		8-08-85		0.24	34.85	35.38
		8-09-85			34.23	
		8-10-85	4.00		34.30	
		8-11-85	4.60		34.40	
		8-12-85	6.00	0.39	34.62	35.94
		8-13-85	5.90		34.60	
		8-14-85	5.50		34.55	34.82
		8-15-85	4.75	0.35	34.60	34.79
		8-16-85	4.70	0.35	34.65	34.67
		8-17-85	5.00	0.25	34.03	34.61
		8-18-85	3.70	0.23	33.91	34.40
		8-19-85		0.23	34.06	34.48
		8-20-85	6.40	0.36	33.66	34.67
		8-21-85	6.00	0.29	33.26	34.46
		8-22-85	2.80	0.32	33.87	34.85
		8-23-85	3.80	0.32	35.26	34.53
		8-24-85	4.70	0.31		34.50

xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx

AVERAGE	12522	4.54	0.32	34.36	34.99
STD.DIV.	178.4	0.96	0.07	0.58	0.49
COEF VAR	1.42	21.09	21.31	1.70	1.40

COAL ULTIMATE ANALYSIS

	ASH	CARBON	H	N	S	O
AVERAGE	9.55	71.30	4.97	1.26	0.51	12.35
STD.DIV.	0.88	1.04	0.22	0.14	0.10	0.96
COEF VAR	9.26	1.46	4.38	11.37	19.02	7.81

COAL ANALYSIS

LAB	I.D. NO.	DATE	ASH	CARBON	H	N	S	O
CT&E	19174	7-18-85	9.00	72.40	5.20	1.40	0.60	11.10
CT&E	18866	5-23-85	9.70	72.31	5.47	1.66	0.77	10.05
CT&E	19447	8-28-85	10.45	70.72	4.70	1.22	0.52	12.35
CT&E	19448	8-28-85	9.33	72.03	4.93	1.26	0.41	12.00
CT&E	19449	8-28-85	9.05	71.74	4.99	1.17	0.52	12.48
CT&E	19450	8-28-85	9.53	71.08	4.90	1.23	0.50	12.72
CT&E	19451	8-28-85	11.34	68.98	4.74	1.14	0.53	13.23
CT&E	19452	8-28-85	8.62	71.50	5.04	1.27	0.42	13.10
CT&E	19453	8-28-85	9.10	71.70	5.03	1.18	0.46	12.48
CT&E	19454	8-28-85	10.85	69.81	4.82	1.19	0.45	12.85
CT&E	19455	8-28-85	8.92	71.10	4.76	1.16	0.45	13.57
CT&E	19456	8-28-85	8.65	72.19	5.08	1.25	0.51	12.28

ATTACHMENT D

```
11000 '
11001 '*************** NOx Calculation (lbs/ton of clinker) **************
11002 '
11003 '
11004 '***************      Calculation of "TOTGAS"       **************
11005 '
11006 '***************   Contribution of COMBUSTION AIR    **************
11007 '
11010 MM(1)=VM(37)*(2000/60)*(1-E(1))
11030 MM(3)=MM(1)*(E(2)/CMW+E(3)*.5/H2MW+E(7)/SMW-E(5)/O2MW)
11040 MM(4)=MM(3)*((1-AIRO2)/AIRO2)
11050 MM(5)=(E(16)*AIRMW/H2OMW)*(MM(3)+MM(4))
11051 '
11052 '***************       Contribution of COAL         **************
11053 '
11060 MM(6)=MM(1)*(E(2)/CMW+E(3)/H2MW+E(4)/N2MW+E(7)/SMW)
11070 MM(7)=VM(37)*E(1)*(2000/60)/H2OMW
11080 MM(8)=MM(4)+MM(5)+MM(6)+MM(7)
11090 MM(9)=VM(14)*(2000/60)*E(11)/H2OMW
11091 '
11092 '***************      Contribution of KILN FEED     **************
11093 '
11100 MM(10)=VM(14)*(2000/60)*(1-E(11))*(E(15)-E(11))/CO2MW
11110 MM(11)=MM(9)+MM(10)
11111 '
11112 '***************     Contribution of WATER SPRAY    **************
11113 '
11120 MM(12)=VM(45)*8.350001/H2OMW
11121 '
11122 '***************     Contribution of EXCESS AIR     **************
11123 '
11130 MM(13)=MM(8)+MM(11)+MM(12)
11140 MM(14)=AIRO2/(1+E(16)*AIRMW/H2OMW)
11150 MM(15)=MM(13)*VM(4)*.01/(MM(14)-VM(4)/100)
11151 '
11152 '***************      Final TOTGAS Calculation      **************
11153 '
11160 MM(16)=MM(13)+MM(15)
11170 MM(17)=385.3*MM(16)
11171 '
11172 '***************          CLINKER PRODUCTION        **************
11173 '
11180 MM(18)=VM(14)*(1-E(15))
11181 '
11182 '***************       Final NOx Calculation        **************
11183 '
11185 IF MM(18)<=0 THEN MM(19)=0:RETURN
11190 MM(19)=VM(2)*46*1.56E-07*MM(17)/MM(18)
11200 RETURN
```

KAYE
INSTRUMENTS

CERTIFICATE OF CALIBRATION

Issued to: Riverside Cement
Riverside, CA

Kaye Instrument Model DR3-3C
Serial Number 12843

This document certifies that the equipment described above has been calibrated on this 1st day of November in the year of 1985.

The accuracy of the General Resistance DAS-45 Calibrator, Serial Number 119, used during the calibration of this equipment is certified to be better than 0.015 percent of output.

Kaye Instruments, Inc. certifies that the accuracy and calibration of this equipment are traceable to the U.S. National Bureau of Standards via NBS Test Number 230660.

Quality Control Manager

Kaye Job# ______

This certificate expires one year from date of issue.

KAYE INSTRUMENTS INC. 15 DE ANGELO DR., BEDFORD, MASS. 01730 TEL 617-275-0300

KAYE
INSTRUMENTS

CERTIFICATE OF CALIBRATION

Issued to: Riverside Cement
Riverside, CA

Kaye Instrument Model Digi-Link
Serial Number 10105

This document certifies that the equipment described above has been calibrated on this 1st day of November in the year of 1985.

The accuracy of the General Resistance DAS-45 Calibrator, Serial Number 119, used during the calibration of this equipment is certified to be better than 0.015 percent of output.

Kaye Instruments, Inc. certifies that the accuracy and calibration of this equipment are traceable to the U.S. National Bureau of Standards via NBS Test Number 230660.

Quality Control Manager

Kaye Job# ________

This certificate expires one year from date of issue.

KAYE INSTRUMENTS INC. 15 DE ANGELO DR., BEDFORD, MASS. 01730 TEL 617-275-0300

KAYE
INSTRUMENTS

CERTIFICATE OF CALIBRATION

Issued to: Riverside Cement
Riverside, CA

Kaye Instrument Model DR3-3C
Serial Number 15031

This document certifies that the equipment described above has been calibrated on this 1st day of November in the year of 1985.

The accuracy of the General Resistance DAS-45 Calibrator, Serial Number 119, used during the calibration of this equipment is certified to be better than 0.015 percent of output.

Kaye Instruments, Inc. certifies that the accuracy and calibration of this equipment are traceable to the U.S. National Bureau of Standards via NBS Test Number 230660.

Newell Tillman
Quality Control Manager

Kaye Job# ________

This certificate expires one year from date of issue.

KAYE INSTRUMENTS INC. 15 DE ANGELO DR., BEDFORD, MASS. 01730 TEL 617-275-0300

KAYE
INSTRUMENTS

CERTIFICATE OF CALIBRATION

Issued to: Riverside Cement
Riverside, CA

Kaye Instrument Model DR3-3C
Serial Number 14404

This document certifies that the equipment described above has been calibrated on this 1st day of November in the year of 1985.

The accuracy of the General Resistance DAS-45 Calibrator, Serial Number 119, used during the calibration of this equipment is certified to be better than 0.015 percent of output.

Kaye Instruments, Inc. certifies that the accuracy and calibration of this equipment are traceable to the U.S. National Bureau of Standards via NBS Test Number 230660.

Quality Control Manager

Kaye Job#__________

This certificate expires one year from date of issue.

KAYE INSTRUMENTS INC. 15 DE ANGELO DR., BEDFORD, MASS. 01730 TEL 617-275-0300

IRCON, INC. 7301 NORTH CALDWELL AVENUE NILES, ILLINOIS 60648 TELEPHONE (312) 967-5151 TELEX 72-[illegible]

August 16, 1985

Mr. Paul Fogg
Riverside Cement
1500 Rubidaux Street
Riverside, CA 92509

Ref: No. RD75131-3570-44

Dear Paul:

As per your work order number D-22835, we have calibrated a ribbon-filament lamp through the temperature range of 1800°F - 3200°F traceable to the National Bureau of Standards and have assigned the serial number RC#1.

Enclosed is the Certificate of Calibration.

If you may have any questions regarding the calibration service, please contact me by using our toll-free telephone number 800-323-7660.

We look forward to serving you in the very near future.

Sincerely,

IRCON, INC.

DT Murphy

D. T. Murphy
Field Service Engineer

DTM:gg
Encl.

SQUARE D COMPANY

PYROMETER SERVICE CENTER

SQUARE D COMPANY

CERTIFICATE OF CALIBRATION
FOR
TUNGSTEN RIBBON LAMP

Test Report No. 3570-44

Serial No. RC #1

Date 8-16-85

R Series Indicated Temperature and True Brightness Temperature (at 0.655 microns) versus DC Lamp Current

R Series Temperature (°F)	Brightness Temperature (°F)	Lamp Current (Amps DC)	R Series Temperature (°F)	Brightness Temperature (°F)	Lamp Current (Amps DC)
1800	1588	12.253	2600	2255	17.043
1900	1675	12.724	2700	2335	17.797
2000	1760	13.220	2800	2415	18.604
2100	1845	13.758	2900	2495	19.447
2200	1927	14.323	3000	2575	20.325
2300	2010	14.941	3100	2650	21.158
2400	2093	15.592	3200	2730	22.059
2500	2175	16.316			

NOTE: The NBS calibration is for 0.655 micron brightness temperature vs. current. "R" series temperature vs. current was calculated.

1. This lamp was calibrated against a Standard Lamp calibrated by the National Bureau of Standards.
2. Maximum uncertainty of the temperature values reported is estimated to be ±5°C (±9°F).
3. The reported values apply when the lamp is operated base down and the portion of the filament at the notch is made vertical. The center contact should be at a positive dc potential. The room temperature should be 25°C (77°F).
4. Sighting should be about 15 degrees normal to the filament at the very small notch with the lamp label opposite the observer.

D. T. Murphy
Field Service Engineer

David M. Williams
National Service Manager

IRCON, INC. • 7301 NORTH CALDWELL AVENUE • NILES, ILLINOIS 60648 • PHONE (312) 967-5151 • TELEX 72-4412
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R CC

WYLE #	INSTRUMENT	RANGE	ACCURACY	MANUFACTURER	MODEL #	RECORD #
101	CALIBRATOR	0-50MA	1%	FOXBORO	8121	1
102	DMM	MULTIPLE	DATA	BECKMAN	HD110	2
103	THERMO REF	DATA	5.2 F	THERMO ELECTRIC	DIGIMITE	3
104	DMM	MULTIPLE	DATA	FLUKE	8062A	4
105	SHUNT	50A/50MV	1%	NA	NA	5
106	CALIBRATOR	-100 +850"H20	.5%	W&T	6120	6
107	CALIBRATOR	150"LB	.5%	W&T	6120	7
108	COUNTER	5-50MHZ	.003%	SIMPSON	7026	8
109	DMM	MULT	.25%DC	BECKMAN	HD100	9
110	DMM	MULT	.5%DC	KEITHLEY	128	10
111	DMM	MULT	.1%DC	SIMPSON	465	11
112	DIFFERENTIAL VM	1000VDC	.01%	CSC	DC200B	12
113	CALIBRATOR	DATA	.05%	PROMAC	DHT720	13
114	MICROMITE	DUAL	1.0 F	THERMO ELECTRIC	31152JK100	14
115	STOPWATCH	60MIN	.2SEC	MEYLAN	224	15
116	TACHOMETER	3000 RPM	.25%	HASLER BERN	TYPE B	16
117	TACHOMETER	30000RPM	.25%	HASLER BERN	TYPEA	17
118	DIG.AMMETER	333 A	DATA	TIF	333A	18
119	DMM	DATA	DATA	BECKMAN	HD100	19
120	CALIBRATOR	0-50MA	.25%NULL	FOXBORO	8121	20

FLW

1A1

11-1-85

SOLD TO
Riverside Cement
1500 Rubidoux Blvd
Riverside, CA 92507
Paul Fog (714) 683-3660

SHIP TO

SHIP DATE | TAXABLE | PURCHASE ORDER

ITEM NO. | QTY ORDERED | QTY SHIPPED | QTY BACK ORDER | DESCRIPTION | UNIT PRICE | DISC | EXTENSION

Kaye Service Call:
Maintenance Contract 6120-1012
Calibration.
1) DR3-3C SN 12843 Calibrated
2) DR3-3C SN 14404 "
3) DR3-3C SN 15031 "
4) Digi-Link SN 10105 "

Item 1 - Replaced Bad Analog Board U0920.

11-1-85

Dale O. Henderson 11-1-85

SALE AMOUNT
MISC CHARGES
SALES TAX

Thank You for Your Order

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 10-18-85
Due 4-20-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Calibrator MFG. Ronan
M/N X 85 W/N OR GOVT. NO. RCC 122 RANGE
TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ____ POOR ____

CALIBRATION 100Ω ±.07%
Others ±.05%

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Input						
100 mv	100.00	100.00		±.05		
1 v	1.0000	1.0000		.0005		
10 v	10.000	10.001		.005		
100 ma	100.00	100.02		.05		
100 Ω	100.00	100.04		.07		
1 KΩ	1.0000	.9998		.5		
Output						
100 mv	100.00	100.02		±.05		
1 v	1.0000	.9999		.0005		
10 v	10.000	9.9937		.005		
100 ma	100.00	~~99.85~~	99.90	.05	✓	
		[illegible]				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DMM	Data Pro	3500	7884	2-16-85	±.015%
DC Std	Valhalla	2701C	10501	11-24-85	±.002%
I Std	Valhalla	2500E	9320	8-17-86	±.03%
R Std	Valhalla	2724A	9691	4-6-86	±.01%

REMARKS Cal OK except for 100ma output. Requires replacement of factory selected value.

Calibration Technician: Hayworth. ㉝

W-757A Q.C. Form Approval: N/A

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

Page 2 of 2

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 10-18-85

Due

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE ____ MFG. ____

M/N ____ W/N OR GOVT. NO. RCC 121 RANGE ____

TEMP. 68 to 75.2°F HUMIDITY < 60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ____ POOR ____

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Output						
V	10.000	10.0003		±.0030		
mV	100.000	100.015		±.030		
mA	100.00	100.00		±.03		
	L/4	4.002		±.030		
	L/12	12.002				
	L/20	19.99				
Type "T"	32°	29.4	32.4	±1.0°	✓	✓
	700°	698.4	700.6	"	✓	✓
Probe	18.4	OK	19.1	±1.0		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy

REMARKS See Page 1 of 2

Calibration Technician:

W-757A Q.C. Form Approval:

Page 1 of 2

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 10-18-85

Due 4-20-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Calibrator MFG. Promac

M/N DHT820 W/N OR GOVT. NO. RCC121 RANGE

TEMP. 68 to 75.2°F HUMIDITY ≤60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. POOR

CALIBRATION Mv, V, mA, KHz ± .03% of Range
Temp ±1.0°F ±1 digit

Function Tested	Nominal Value	Measured Value First	Measured Value Second	Allowable Tolerance	Tolerance Out	Tolerance In
Input						
MV	100.00	99.98		±.03		
V	10.000	10.000		±.003		
	1.000	1.000		±.003		
mA	100.00	99.99	100.00	±.03		
f	9.999	9.999		±.003		
Ω	100.00	99.97		±.03		
		Auto	Manual			
J	-350	344	-301	±2°F	✓	✓
	32°	34	32			
	1000	1002	1000			
	2190	2192	2190			
K	-300	-294	302			
	32	35	32			
	2400	2403	2400			
T	-300	-295	-301			
	32	35	32		✓	
	700	701	699			
E	-300	293	300		✓	
	32	36	32			
	1800	1803	1800			
RTD	32°F	35°F			✓	

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±.002%
I Std	Valhalla	2500E	9320	8-17-86	±.03%
R Std	Valhalla	2724A	9691	4-6-86	±.01%
AC Std	Valhalla	2703	9667	6-29-86	±.03%
32° Ref	Omega	TRC J	10503	12-3-85	±.1°C
DC Std	EDC	5100E	7568	5-11-86	±.01%

REMARKS Thermocouple input and output out of tolerance as much as 6° at some points. CJ Comp in Manual Mode

Calibration Technician:

W-757A Q.C. Form Approval:

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-17-85

Due 1-19-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE CALIBRATOR MFG. FOXBORO

M/N 8121 W/N OR GOVT. NO. RCC101 RANGE

TEMP. 68 to 75.2°F HUMIDITY ≤60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. ____ POOR ____

± 1.0% METER

± .25% NULL & MV OUT

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
OUTPUT CURRENT	METER Rdg	MV OUT	CURRENT OUT			
@ NULL						
2.0 MA	2.0	2.002	1.997 MA	±.005 MA		
10.0	10.0	10.02	10.004	±.125		
30.0	30.0	30.06	29.99			
50.0	50.0	50.08	49.98			
INPUT CURRENT						
@ NULL						
2.0 MA	2.0	2.002 MV	1.998 MA	±.005		
10.0	10.0	10.025	9.98	±.125		
30.0	30.0	30.07	29.92			
50.0	50.0	50.09	49.90			

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC STD	EDC	1030	7974	6-8-86	±.005%
DMM	DATA P.	3500	7884	10-13-85	±.015% DC
DECADE RES.	GR	1432T	3173	7-6-86	±0.1%

REMARKS CALIB

Calibration Technician: C Babcock

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH "STANDARDS" TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-25-85

Due 1-26-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE TACHOMETER MFG. HASLER BERN

M/N ______ W/N OR GOVT. NO. RCC 116 RANGE ______

TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. ______ POOR ______

CALIBRATION

± 0.25% Rdg

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	
RPM	1720	1722.7		± 6.3RPM		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
COUNTER	HP	5302A	8520	6-8-86	±.001%

REMARKS CALIB

Calibration Technician:

W-757A Q.C. Form Approval: NH

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

Riverside Cement Co

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-9-85

Due 7-13-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE DMM MFG. Beckman

M/N HD110 W/N OR GOVT. NO. RCC 102 RANGE

TEMP. 68 to 75.2°F HUMIDITY ≤60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. POOR

CALIBRATION Data

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
DC Voltage						
200mv rng	190.0	189.9		± 0.6		
2v	1.900	1,899		± .006		
20v	19.00	18,99		± .06		
200v	190.0	189.9		± .6		
1500v	1000	999		± 4		
AC Voltage @ 400Hz						
200mv	190.0	190.1		± 1.7		
2v	1.900	1,902		± .017		
20v	19.00	19.02		± .17		
200v	190.0	190.2		± 1.7		
1000v	1000	1000		± 11		
DC Current						
200µa	100,0	99.9		± 0.9		
2 ma.	1.000	.998		± .009		
20 ma	10.00	10.00		± .09		
200 ma	100.0	100.1		± .9		
2000 ma	1000	.999		± 9		
10 a	10.00	9.97		± .16		
Resistance						
200Ω	190.0	189.9		± 1.1		
2kΩ	1.000	.999		± .006		
20kΩ	10.00	10.00		± .06		
200kΩ	100.0	100.0		± .6		
2MΩ	1.000	1,000		± .006		
20MΩ	19.00	18,99		± .30		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	± .002%
AC Std.	Valhalla	2703	9667	6-29-86	± .03%
Resistance Std	Valhalla	2724A	9691	4-6-86	± .012%
Current Std	Valhalla	2500E	9320	8-11-85	± .03%

REMARKS Calibrated To Manufacturers specifications.

Calibration Technician:

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

Riverside Cement Co.

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-10-85
Due 1-12-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Digimite MFG. Thermo Electric
M/N ______ W/N OR COVT. NO. RCC 103 RANGE ______
TEMP. 68 to 75.2°F HUMIDITY < 60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ____ POOR ____

± 3.2 °F

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Output	Deg F					
Type J	-300	-0299		± 3.2		
	0	0001				
	500	0502				
	1000	1002				
	1500	1502				
Type K	0	0001				
	500	0502				
	1000	1001				
	1500	1500				
	2400	2400				
EM						
Type J	-300	-0298				
	0	0001				
	500	0501				
	1000	1002				
	1500	1502				
Type K	0	0002				
	500	0501				
	1000	1001				
	1500	1500				
	2400	2400				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
32° Ref	Omega	TRC 3	10503	6-8-86	±.1°C
DC Std	EDC	E100E	7568	5-11-86	±.01%
DVM	Data	3500	7999	8-11-85	±.015%

REMARKS Charge batteries. Calibration OK

Calibration Technician: Jerwood. (83)

W-757A Q.C. Form Approval: ______

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement Co

Date 7-9-85

Due 7-13-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE DMM MFG. Fluke

M/N 8062 W/N OR GOVT. NO. RCC 104 RANGE

TEMP. 68 To 75.2°F HUMIDITY ≤60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. ____ POOR ____

CALIBRATION Data

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	[illegible]
DC Voltage						
200 mv range	190,00	189,99		± ,12		
2 v "	1,9000	1,9000		±,0012		
20 v "	19,000	19,001		±,015		
200 v "	190,00	190,04		±,15		
1000 v "	1000,0	999,9		±,4		
AC Voltage @400 Hz						
200 mv	190,00	190,13		± ,30		
2 v	1,9000	1,8977		± ,0030		
20 v	19,000	19,006		± ,030		
200 v	190,00	190,22		± ,30		
750 v	750,0	753,0		± 16,0		
DC Current						
200 ua	100,00	100,00		±,32		
2 ma	1,0000	,9999		± ,0032		
20 ma	10,000	10,002		± ,032		
200 ma	100,00	100,01		± ,72		
2000 ma	1000,0	1001,5		± 7,2		
Resistance						
200 Ω	190,00	189,92		± ,23		
2 kΩ	1,0000	,9990		± ,0012		
20 kΩ	10,000	9,991		±,012		
200 kΩ	100,00	99,93		±,11		
2 MΩ	1,0000	,9999		±,0022		
20 MΩ	10,000	10,00		±,029		
100 MΩ	90,0	90,6		± 1,2		
300 MΩ	290MΩ	292		± 9		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±,002%
AC Std	Valhalla	2703	4667	5-29-86	±,03%
Resistance Std	Valhalla	2724A	9691	4-5-86	±,15%
Current Std	Valhalla	2500E	9320	8-11-85	±,03%

REMARKS Calibrated To manufactures specifications.

Calibration Technician: H Yarwood

W-757A Q.C. Form Approval: RH

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

Riverside Cement Co.

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-9-85
Due 7-13-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Shunt MFG. SECO
M/N — 6709 W/N OR GOVT. NO. RCC 105 RANGE 50a/50mv
TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD____ AVE.____ POOR____

± 1.0 %

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
10 Amps	10.00 mv	10.06 mv	10.04	±.10 mv		
5 Amps	mv	mv		mv		
1 Amps	mv	mv		mv		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	EDC	1030	7974	—	±.003%
I Std	Valhalla	2500E	9320	9-11-85	±.05%
DMM	DATA	3500	7999	8-11-85	±.015%
"	"	"	7334	—	±.015%
DC Std	Valhalla	2701C	10501	11-24-85	±.002%

REMARKS Calebration accuracy better than ±1%

Calibration Technician: H Heywood.

W-757A Q.C. Form Approval: VH

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND [illegible]

TEST EQUIPMENT RECORD

ITEM CALIBRATED

[illegible] PRESSURE GAUGE [illegible] PSI

SECTION A

1. ACTIVITY PERFORMING CALIBRATION
GAUGE REPAIR SERVICE

2. ACTIVITY REQUESTING CALIBRATION
[illegible] LABS

3. INVENTORY NUMBER

4. MANUFACTURER
WALLACE & TIERNAN

5. MODEL NUMBER
FA-233

6. SERIAL NUMBER
YY15873

7. METROLOGY NUMBER
RCC1[illegible]

8. CALIBRATION PROCEDURE USED
MFGS SPECS.

9. DATE OF LAST CALIBRATION
—

10. RESUBMISSION DATE
B[illegible]

11. REASON FOR PERFORMING CALIBRATION
- ☒ CERTIFICATION
- ☒ CALIBRATION (PERIODIC)
- ☐ CROSSCHECK
- ☐ OPERATIONAL FAILURE
- ☐ FUNCTIONAL TEST
- ☐ NONE OF THE ABOVE (SEE REMARKS)

SECTION B

1. CALIBRATED BY
TH

2. TEST DATE
[illegible] MAY 85

3. NUMBER OF MONTHS SINCE LAST CALIBRATION
—

4. AMBIENT TEMPERATURE

4A. TIME ☐ A.M. ☐ P.M

5. HUMIDITY
45 %

5A. BAROMETRIC IN Hg

6. DID ITEM SHOW EVIDENCE OF
- ☐ SEVERE ENVIRONMENT
- ☐ PHYSICAL MISHANDLING
- ☐ AGE AND LONG SERVICE
- ☐ OVERLOAD
- ☒ NONE OF THE ABOVE SEE REMARKS

7. WAS ADJUSTMENT OR PARTS REQUIRED
- ☒ YES
- ☐ NO

8. CERT OR LABEL ☒ YES ☐ NO

9. REPORT ISSUED ☒ YES ☐ NO

10. MFGS LISTED ACCURACY
± .1 % UP FULL SCALE
± — % HYSTERESIS

11. MANHOURS
CALIBRATION
REPAIR

LIST ALL EQUIPMENT USED IN THIS CALIBRATION

SECTION C

MFGR	MODEL NO.	SERIAL NO	ACCURACY	TEST #	TEST DATE	RECALL DATE	NBS TEST #
[illegible]	350 B	[illegible]	.005%	P-555	7 MAY 85	[illegible] MAY 8[illegible]	3577

REMARKS

ADJUSTED TO .1% ACCURACY
CLEANED OUT LINES, TESTED REGULATORS

GRS FORM G-102

Lab Phone: (213) 649-5330

Gauge Repair Service

10410 La Cienega Blvd.
Inglewood, Calif. 90304

TEST NO. 30558-1

Customer's P.O. No. 3-9921

Customer's Name: WYLE LABS.

Description: WALLACE + TIERNAN PNEUMATIC CALIBRATOR -3/0/+30 PS.

Gauge No.: RCC109

Standard: M+G DEAD WT. TESTER

Date: 10 JULY 85 DUE 1-26-86

Calib. By: TED HAGGSTROM

Temp. During Test: 70°F

Our Invoice No.: 30558

ACTUAL PRESSURE APPLIED	INCOMING READING		OUTGOING READING	
PSI	UP SCALE	~~DOWN SCALE~~	UP SCALE	~~DOWN SCALE~~
-3.000	-2.980		-3.010	
0.000	+.015		+.005	
3.000	3.005		2.990	
6.000	5.995		5.975	
9.000	9.000		7.980	
12.000	12.005		11.990	
15.000	15.025		15.005	
18.000	18.030		18.010	
21.000	21.035 *		21.010	
24.000	24.045 *		24.025	
27.000	27.050 *		27.025	
30.000	30.040 *		30.015	

* OUT OF TOLERANCE, ADJUSTED
CALIBRATED WITH GN2

CERTIFIED TRACEABLE TEST
THIS TEST WAS PERFORMED ON OUR
LABORATORY PRIMARY PRESSURE
STANDARD RUSKA DEAD WEIGHT GAGE
OR STANDARDS TRACEABLE THROUGH
N.B.S. TEST NO. [illegible]
TECHNICIAN PERFORMING TEST

Calibration System Conforms to MIL-STD-45662 - Documents are on file and may be reviewed by Authorized Personnel or a Government Representative

GRS FORM G-101

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-23-85

Due 1-26-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Counter MFG. Simpson

M/N 7026 W/N OR GOVT. NO. RCC 108 RANGE 5 - 50MHz

TEMP. 68 to 75.2°F HUMIDITY < 60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. ____ POOR ____

CALIBRATION Time Base ± .003%

Function Tested	Nominal Value	Measured Value First	Measured Value Second	Allowable Tolerance	Tolerance Out	Tolerance In
Sens @	50MHz	200mvpp				
	50KHz	40mvpp				
Time Base						
10MHz @ 1sec	000 000	000014		± 300		
Self Test		ok				
Period		ok				
Ratio		ok				
Time Int		ok				
Totalize		ok				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
Amp Std	Tek	191	1552	10-27-85	± 3%
Time Mark	Tek	184	7807	8-18-85	± .001%

REMARKS Calibration OK

Calibration Technician:

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-23-85

Due 7-27-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE DMM MFG. Beckman

M/N HD100 W/N OR GOVT. NO. RCC109 RANGE

TEMP. 68 to 75.2°F HUMIDITY ≤60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. POOR

± .25% dev basic dc Accuracy

CALIBRATION Data

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
DC Voltage						
200mv	190.0	190.0		± 0.6		
2v	1.900	1.900		± .006		
20v	19.00	19.00		± .06		
200v	190.0	190.0		± .6		
1500v	1000	999		± 4		
AC Voltage @ 400Hz						
200mv	190.0	190.0		± 1.7		
2V	1.900	1.902		± .017		
20v	19.00	19.01		± .17		
200v	190.0	189.9		± 1.7		
1000v	1000	1001		± 11		
DC Current						
200μa	100.0	99.9		± 0.9		
2ma	1.000	1.000		± .009		
20ma	10.00	10.00		± .09		
200ma	100.0	100.0		± .9		
2000ma	1000	.999		± 9		
10a	10.00	NA		± .16		
Resistance						
200Ω	190.0	190.0		± 1.1		
2kΩ	1.000	1.000		± .006		
20kΩ	10.00	9.99		± .06		
200kΩ	100.0	99.9		± .6		
2MΩ	1.000	.999		± .006		
20MΩ	19.00	18.99		± .30		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	1-24-85	± .002%
AC Std.	Valhalla	2703	9657	6-29-86	± .03%
Resistance Std.	Valhalla	2724A	9691	4-6-86	± .012%
Current Std	Valhalla	2500E	9320	8-11-85	± .03%

REMARKS Calibration OK Replaced battery.

Calibration Technician:

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-23-85

Riverside Cement

Due 7-27-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE DMM MFG. Keithley

M/N 128 W/N OR GOVT. NO. RCC 110 RANGE

TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. POOR

DATA CALIBRATION .5% dc, 1.0% ac, 2% current, Ohms N.A

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Voltage						
2 v dc	1,900	1,903		±.010		
20 v	19.00	19,02		±.10		
200 v	190.0	190,3		± 1,0		
1000 v	1000	1002		± 5		
2 v ac @ 400Hz	1,900	1,898		± .020		
20 v	19.00	19,05		± ,20		
200 v	190.0	190,7		± 2.0		
750 v	750.	755		± 8		
Ohms						
200 Ω	190.0	190,5		Data		
20 K	19.00	19,01				
2 MΩ	1,000	1,000				
20 MΩ	19.00	18.95				
Current						
10A dc	10.00	10,01		±.20		
10 A ac @ 400Hz	10.00	10,02		±.20		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±.002%
AC Std	Valhalla	2703	9667	6-29-86	±.03%
Res. Std	Valhalla	2724A	9691	4-6-86	±.012%
I Std	Valhalla	2500E	9320	8-11-85	±.03%

REMARKS Cal OK Resistance tolerance not available

Calibration Technician: A. Sherwood.

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-24-85
Due 7-27-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE DMM MFG. Simpson
M/N 465 W/N OR GOVT. NO. RCC 111 RANGE
TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. POOR

CALIBRATION Data

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Volts dc						
.2v	.1900	.1898		±.0003		
2v	1.900	1.898		±.003		
20	19.00	18.98		±.03		
200	190.0	189.8		±.3		
1000	1000	998		± 2		
ac @ 400Hz						
.2v	.1900	.1899		±.0012		
2v	1.900	1.899		±.012		
20	19.00	18.98		±.12		
200	190.0	190.0		±1.2		
600	600	600		± 5		
Resistance						
2KΩ	1.900	1.903		±.010		
20	19.00	19.02		±.10		
200	190.0	190.1		±1.0		
2000	1000	1000		± 5		
20MΩ	10.00	10.00		±.11		
Current						
.2ma	.1000	.1000		±.0004		
2ma	1.000	.999		±.004		
20	10.00	10.00		±.04		
200	.100.0	.0999		±.4		
2a	1.000	.999		±.004		
10a	10.00	9.97		±.12		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±.002%
AC Std	Valhalla	2703	9667	6-29-86	±.03%
Res Std	Valhalla	2724A	9691	4-6-86	±.012%
I Std	Valhalla	2500E	9320	8-11-85	±.03%

REMARKS Calibration OK

Calibration Technician: A Isewood.

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH "STANDARDS" TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-29-85
Due 2-2-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Differential VM MFG. Calibration Standards
M/N DC 200B W/N OR GOVT. NO. RCC 112 RANGE 0-1/1000 vdc
TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ✓ POOR ____

CALIBRATION TVM ± 4%
Differential ±.01

Function Tested	Nominal Value	Measured Value First	Measured Value Second	Allowable Tolerance	Tolerance Out	Tolerance In
Differential						
10v rng	0.00000	0.00000				
	1.11111	1.11090	1.11113	±.00011	✓	✓
	2.22222	2.22201	2.22220	.00022	✓	
	3.33333	3.33280	3.33333	.00033	✓	
	4.44444	4.44390	4.44444	.000.44	✓	
	5.55555	5.55489	5.55556	.00055	✓	
	6.66606	6.66570	6.66664	.00067	✓	
	7.77777	7.77670	7.77777	.00077	✓	
	8.88888	8.88766	8.88883	.00089	✓	
	9.99999	9.99860	10.00001	.00100	✓	
1 v	.999999	.999888	1.000007	.00010	✓	✓
100v	99.9999	99.9936	100.0003	.0100		
1000v	999.999	999.748	1000.000	.100	✓	✓
TVM	1.00	1.04		±.04		
	10.0	10.2		±.4		
	100	102		±4		
	1000	950		±40	✓	

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±.002%

REMARKS Adjusted differential ranges. TVM not adjustable. Limit to ±5%

Calibration Technician: A. Jerwood

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH "STANDARDS" TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

0-100ma	100.00	100.0		±.05		
0-10KHz	0.010	0.011				
	0.100	0.101				
	1.000	1.001				
	10.000	9.997				
Output						
0-11v	1.000	.9993		±.006		
	11.000	11.0035				
0-110mv	10.00	10.015		±.06		
	110.00	110.033				
0-100ma	04.00	3.996		±.05		
	12.00	11.999				
	20.00	20.000				
	50.00	50.006				
	100.00	100.029				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±.002%
AC Std	Valhalla	2703	9667	6-29-86	±.01% freq.
I Std	Valhalla	2500E	9320	8-11-85	±.03%

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-24-85

Due 1-26-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Calibrator MFG. Promac

M/N DHT 720 W/N OR GOVT. NO. RCC 113 RANGE

TEMP. 68 to 75.2°F HUMIDITY ≤60% VISUAL INSP.: CONDITION: GOOD ___ AVE. ✓ POOR ___

All functions: ±.05% of Range

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Input						
0-11v	1.000	.999		±,006		
	11.000	10,997				
0-110mv	110.00	109,99		±,06		
0-100ma	100.00	100,02		±,05		
0-10KHz	0.010	0.011				
	0,100	0,101				
	1,000	1,001				
	10.000	9,997				
Output						
0-11v	1,000	,9993		±,006		
	11,000	11,0035				
0-110mv	10.00	10.015		±,06		
	110.00	110,033				
0-100ma	04.00	3,996		±.05		
	12.00	11,999				
	20.00	20,000				
	50.00	50,006				
	100.00	100,029				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±,002%
AC Std	Valhalla	2703	9667	6-29-96	±,01% freq.
I Std	Valhalla	2500E	9320	8-11-55	±,03%

REMARKS Calibration OK

Calibration Technician: H. Gerwood. (37)

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-24-85

Due 1-26-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE MicroMite MFG. Thero Electric

M/N 31152JK100 W/N OR GOVT. NO. RCC114 RANGE ______

TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ____ POOR ____

Data ±1.0°F

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
Input						
Type "K"	-300	-299.6		±1.0		
	32	32.1				
	+1100	1099.9				
	2400	2400.2				
Type "J"	-300	-300.5				
	32	31.7				
	800	799.7				
	1600	1599.8				
Out Put						
Type K						
Lo	-300	299.8				
	+1800	1099.7				
Hi	+1200	1200.1				
	2400	2400.0				
Type "J"						
Lo	-300	300.3				
	+800	799.5				
	+900	899.4				
	+1600	1599.6				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
32°F Ref	Omega	TRC-3	10503	12-8-85	±.1°C
DC STd	ED&C	E100E	7568	5-11-86	±.01%

REMARKS Calibration uncertainty 1.0°F

Calibration Technician: Harwood

W-757A Q.C. Form Approval: ______

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Riverside Cement

Date 7-25-85

Due 1-26-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Stop Watch MFG. Mey Lan

M/N 224 W/N OR GOVT. NO. RCC 115 RANGE 60min

TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ___ AVE. ___ POOR ___

± .2 sec

CALIBRATION

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
	60 sec	60.0				

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
Receiver	Specific	SR7R	6587	System	NBS

REMARKS Calibration OK

Calibration Technician: A. Greenwood, (01 ua)

W-757A Q.C. Form Approval: NH

THIS CALIBRATION WAS PERFORMED WITH "STANDARDS" TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 7-25-85

Due 1-26-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE TACHOMETER MFG. HASLER BERN

M/N ______ W/N OR GOVT. NO. RCC 116 RANGE ______

TEMP. 68 To 75.2°F HUMIDITY < 60% VISUAL INSP.: CONDITION: GOOD ✓ AVE. ____ POOR ____

CALIBRATION

± 0.25% Rdg

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
RPM	1720	1722.7		± 6.3 rpm		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
COUNTER	HP	5302A	8520	6-8-85	±.001%

REMARKS CALIB

Calibration Technician: C. Hancock

W-757A Q.C. Form Approval: KH

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 8-23-85

Due 2-23-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Clamp-on Ammeter MFG. TIF

M/N —— W/N OR GOVT. NO. RCC118 RANGE

TEMP. 68 To 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ____ POOR ____

CALIBRATION Data

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
AC Amps	10.0	10.4	11.8			
	30.0	34.2				
	100	106				
	320	328	333			

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
AC Std	Valhalla	2703	9667	6-29-86	±.05%
Current Std	Valhalla	2500E	9320	8-17-86	±.05%

REMARKS An error of 15% or more may be present. Instrument is not reliable.

Calibration Technician: A Greenwood.

W-757A Q.C. Form Approval:

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 8-29-85
Due 8-31-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE DMM MFG. Beckman
M/N HD100 W/N OR GOVT. NO. RCC 119 RANGE
TEMP. 68 to 75.2°F HUMIDITY <60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ✓ POOR ____

CALIBRATION Data

Function Tested	Nominal Value	Measured Value		Allowable Tolerance	Tolerance	
		First	Second		Out	In
DC Voltage.						
200mv fnc	190.0	190.1		± 0.6		
2v	1.900	1.901		± .006		
20v	19.00	1.901		± .06		
200v	190.0	190.2		± .6		
1500v	1000	1000		± 4		
AC Voltage @ 400Hz						
200mv	190.0	190.1		± 1.7		
2v	1.900	1.902		± .017		
20v	19.00	19.02		± .17		
200v	190.0	190.1		± 1.7		
1000v	1000	1000		± 11		
DC Current						
200μa	100.0	99.9		± 0.9		
2ma	1.000	.999		± .009		
20 ma	10.00	10.00		± .09		
200 ma	100.0	100.1		± .9		
2000 ma	1.000	.997		± 9		
10 a	10.00	NA		± .16		
Resistance						
200Ω	190.0	190.2		± 1.1		
2kΩ	1.000	1.000		± .006		
20kΩ	10.00	10.00		± .06		
200kΩ	100.0	100.0		± .6		
2MΩ	1.000	1.000		± .006		
20MΩ	19.00	19.02		± .30		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	± .002%
AC Std.	Valhalla	2703	9667	6-29-86	± .03%
Resistance Std.	Valhalla	2724A	9691	4-6-86	± .012%
Current Std	Valhalla	2500E	9330	8-17-86	± .03%

REMARKS Decimal point occasionally appears in wrong position. Calibration ok.

Calibration Technician: ____

W-757A Q.C. Form Approval: ____

THIS CALIBRATION WAS PERFORMED WITH STANDARDS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D.C. AND BOULDER, COLORADO

WYLE LABORATORIES CALIBRATION LABORATORY REPORT

Date 8-29-85
Due 3-2-86

DESCRIPTION OF UNIT CALIBRATED

NOMENCLATURE Calibrator MFG. Foxboro
M/N 8121 W/N OR GOVT. NO. RCC 120 RANGE 0 - 50ma
TEMP. 68 to 75.2°F HUMIDITY < 60% VISUAL INSP.: CONDITION: GOOD ____ AVE. ✓ POOR ____

CALIBRATION Meter ± 1% FS
Null ± .25% FS

Function Tested	Nominal Value	Measured Value First	Measured Value Second	Allowable Tolerance	Tolerance Out	Tolerance In
MA OUT						
Null	2ma	2,007		±,005		
	10	10,04		±,125		
	20	20.04				
	30	30,04				
	40	40,02				
	50	50,02				
Meter	2ma	1,992		±.02		
	50 ma	49,82		±,5		
MA IN						
Null	2	1,999		±,005		
	10	10,00		±,125		
	20	20,02				
	30	30,03				
	40	70,03				
	50	50,02				
Meter	2	1,99		±,02		
	50	50.01		±,5		

CALIBRATION EQUIPMENT USED

Nomenclature	Mfg.	M/N	W/N	Due Date	Accuracy
DC Std	Valhalla	2701C	10501	11-24-85	±,002%
Current Std	Valhalla	2500E	9320	8-17-86	±,03%
DVM	Fluke	8040A	8900	5-4-86	± .1%

REMARKS Repaired power connector, Cleaned & Lubed switches.

Calibration Technician: A Garwood (FS)

W-757A Q.C. Form Approval: NH

THIS CALIBRATION WAS PERFORMED WITH "STANDARDS" TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS OF THE DEPARTMENT OF COMMERCE, WASHINGTON, D. C. AND BOULDER, COLORADO

Matheson
8800 Utica Avenue
Cucamonga, California 91730
Phone: (714) 987-4611

LABORATORY REPORT ON GAS ANALYSIS

Riverside Cement
Riverside, Ca.

DATE 7-19-8[illegible]

OUR INVOICE NO. 106-65[illegible]

YOUR P.O. NO. RD [illegible]

LOT NO. 10-7-44, P544, P54

GENTLEMEN:

Below are the results of the analysis you requested, as reported by our laboratory. Results are in volume percent, unless otherwise indicated.

COMPONENT	Cyl. No. SV 11790 Requested	Cyl. No. SV 11790 Actual	Cyl. No. 7539P Requested	Cyl. No. 7539P Actual	Cyl. No. RA015668 Requested	Cyl. No. RA015668 Actual
CARBON DIOXIDE						
OXYGEN			2.0	2.00%		
HYDROGEN						
CARBON MONOXIDE						
NITROGEN	BALANCE					
ARGON						
AIR						
METHANE						
HELIUM						
SULFUR DIOXIDE	50ppm	52ppm				
NITRIC OXIDE					100ppm	1019ppm

PRIMARY STANDARD

PRIMARY STANDARD

COMPONENT	Cyl. No. Requested	Cyl. No. Actual	Cyl. No. Requested	Cyl. No. Actual	Cyl. No. Requested	Cyl. No. Actual
CARBON DIOXIDE						
OXYGEN						
HYDROGEN						
CARBON MONOXIDE						
NITROGEN						
ARGON						
AIR						
METHANE						
HELIUM						

ANALYST Bill [illegible]
MATHESON GAS PRODUCTS

The only liability of this company for gas which fails to comply with the analysis shall be replacement thereof by the Company without extra cost.

COUNTY OF LOS ANGELES
DEPARTMENT OF WEIGHTS AND MEASURES
DIVISION OF METROLOGICAL SERVICES

PAUL B. ENGLER
DIRECTOR

CERTIFICATE M.S. 7387

Certificate of Accuracy

ON WRITTEN REQUEST BY AMERICAN SCALE COMPANY

THIS CERTIFIES THAT THE DEVICES DESIGNATED BELOW HAVE BEEN TESTED TO SPECIFICATIONS AND TOLERANCES OF: THE NATIONAL BUREAU OF STANDARDS XX THE MANUFACTURER ☐ THE OWNER ☐.
THE STANDARDS USED IN THE CALIBRATIONS ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS THROUGH TEST NUMBER: MAP 737/202491 213.09/0656

DESIGNATION		CALIBRATION DATA			
ITEM	DESCRIPTION	NOMINAL	MEASURED		TOLERANCE
1.	6 Each Fairbanks-Morse				
	Cast Iron Test Weights	1000 Lbs.	ADJUSTED TO CONFORM		CLASS "F"
	S/N T102 Thru T107				0.10 Lbs.
2.	1 Each Cast Iron		ADJUSTED TO CONFORM		CLASS "F"
	Test Weight	1000 Lbs.			0.10 Lbs.
	S/N T 3003				
3.	1 Each Fairbanks-Morse				
	Cast Iron Test Weight	1000 Lbs.	NOT CERTIFIABLE		
	S/N T 101		WATER IN ADJUSTMENT CAVITY		

AMBIENT TEMPERATURE 22.2°C
RELATIVE HUMIDITY 31%
BAROMETRIC PRESSURE 759.3 mm Hg

William D. Moore
METROLOGIST

April 2, 1985
DATE

COUNTY OF LOS ANGELES
DEPARTMENT OF WEIGHTS AND MEASURES
DIVISION OF METROLOGICAL SERVICES

PAUL B. ENGLER
DIRECTOR

CERTIFICATE M.S. 8022

Certificate of Accuracy

ON WRITTEN REQUEST BY AMERICAN SCALE CO., INCORPORATED

THIS CERTIFIES THAT THE DEVICES DESIGNATED BELOW HAVE BEEN TESTED TO SPECIFICATIONS AND TOLERANCES OF: THE NATIONAL BUREAU OF STANDARDS ☒ THE MANUFACTURER ☐ THE OWNER ☐.
THE STANDARDS USED IN THE CALIBRATIONS ARE TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS THROUGH TEST NUMBER: MAP 737/202491, 213.09/0656

DESIGNATION		CALIBRATION DATA			
ITEM	DESCRIPTION	NOMINAL	MEASURED		TOLERANCE
			APPARENT MASS VS:	BRASS	
1.	3 Each Cast Iron Weights		ADJUSTED TO CONFORM		CLASS "F"
	S/N TI-01, TI-005, TI-08	1000 Lbs.			0.10 Lbs.

AMBIENT TEMPERATURE 22.2 °C
RELATIVE HUMIDITY 40%
BAROMETRIC PRESSURE 757.3 mm Hg

William D. Moore
METROLOGIST

APRIL 26, 1985
DATE

Scott Specialty Gases
a division of Scott Environmental Technology, Inc.
PLUMSTEADVILLE, PA. 18949 PHONE: (215) 766 8861 TWX: 510-665-9344

Date: AUGUST 7, 1985
Our Project No.: 49298
Your P.O. No.: D23279

RIVERSIDE CEMENT
1500 RUBIDOUX
RIVERSIDE, CA 92509
ATTN: DEBBIE

Gentlemen:

Thank you for choosing Scott for your Specialty Gas needs. The analyses for the gases ordered, as reported by our laboratory, are listed below. Results are in volume percent, unless otherwise indicated.

ANALYTICAL REPORT

Cyl. No. BAL3355 Analytical Accuracy ±1%

Component	Concentration
NITRIC OXIDE	495.5PPM
NOX	498.1PPM
*GRAVIMETRIC MASTER	
NITROGEN	BALANCE

Cyl. No. BAL3276 Analytical Accuracy ±1%

Component	Concentration
SULFUR DIOXIDE	995.9PPM
*GRAVIMETRIC MASTER	
NITROGEN	BALANCE

Cyl. No. Analytical Accuracy

Component	Concentration

Cyl. No. Analytical Accuracy

Component	Concentration

*CERTIFIED TO HAVE BEEN BLENDED AGINST NBS CERTIFIED WEIGHTS AND VERIFIED CORRECT BY INDEPENDENT ANALYSIS.

Analyst

Approved By

HOMER R. DULIN CO.

729 EAST WILLOW STREET
LONG BEACH, CALIFORNIA 90806
(213) 424-8533 (213) 636-4096

CALIBRATION CERTIFICATION

SUBMITTED BY: DATACRAFT

FLOWMETER SERIAL No.

MANUFACTURER F&P MFG. SERIAL No.

~~TUBE No~~. Model 10C1515 FLOAT No.

REMARKS: Hz Vs GPM H_2O @ 75°F

Accuracy ±1% Rate

INDICATED		ACTUAL	
Hz		GPM	$\overline{K}$
474.0		91.729	310.0
451.5		87.372	310.0
400.4		77.488	310.0
351.7		68.006	310.2
299.4		57.813	310.7
250.2		48.180	311.5
203.0		39.057	311.8
149.6		28.813	311.6
104.2		20.074	311.4
51.6		9.950	311.1
26.3		5.101	310.0

Flowmeter Certified with HOMER R. DULIN CO.

Equipment No. 11601 Accuracy 0.05% Calib. Due 8-85

NBS No. Cert. No. MAP 737/202491

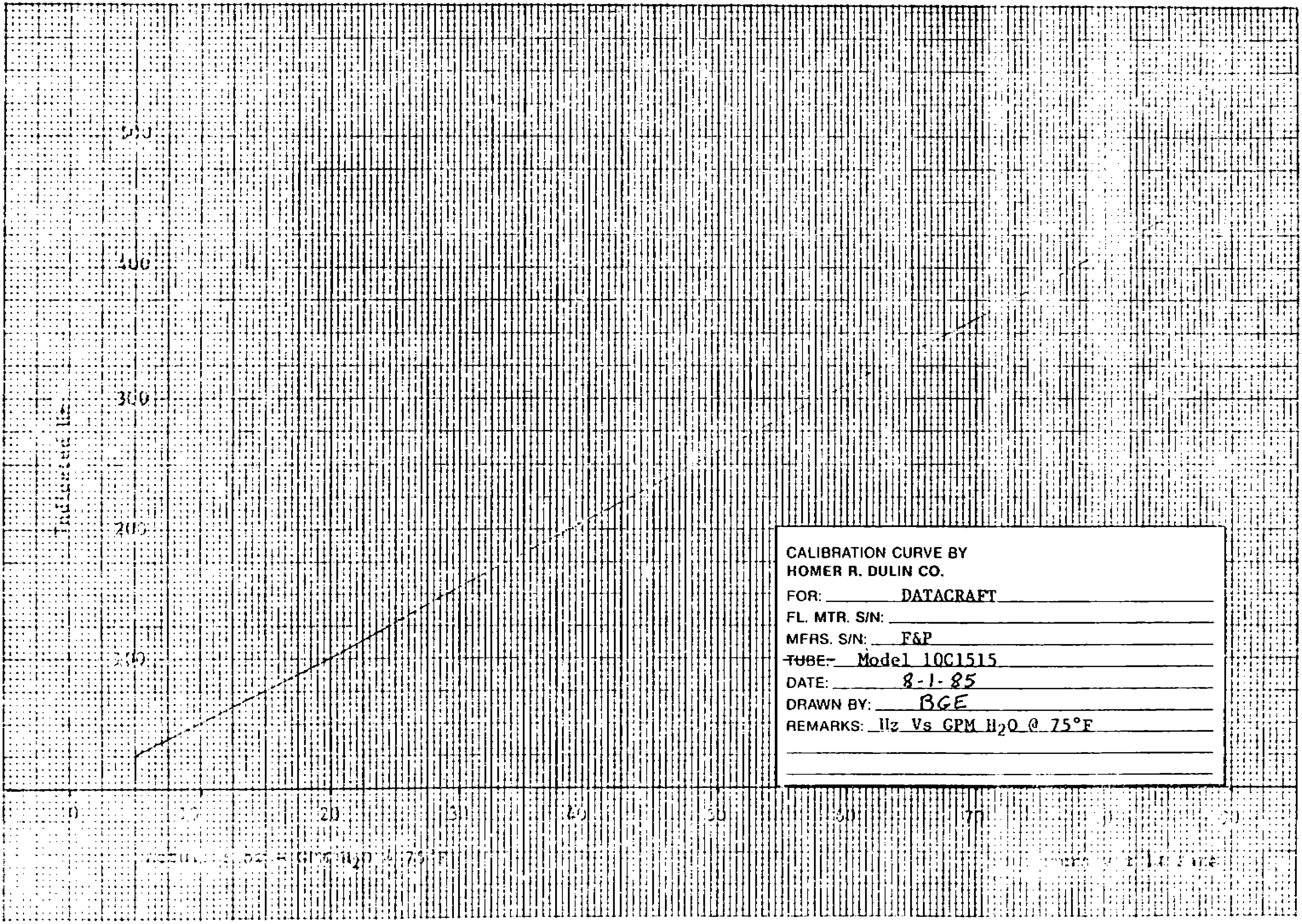
Our standards are certified by or are traceable to the National Bureau of Standards and comply with MIL-STD 45662

P.O. No. Verbal, C. Campbell Shipper No. 18787

8-1-85
CALIBRATION DATE

8-1-86
RECALIBRATION DATE

T.Davis
CALIBRATION TECHNICIAN



CALIBRATION CURVE BY
HOMER R. DULIN CO.

FOR: DATACRAFT
FL. MTR. S/N:
MFRS. S/N: F&P
~~TUBE~~- Model 10C1515
DATE: 8-1-85
DRAWN BY: BGE
REMARKS: Hz Vs GPM H_2O @ 75°F

Scott Specialty Gases a division of Scott Environmental Technology, Inc.
2600 CAJON BLVD. SAN BERNARDINO, CA 92411 PHONE (714) 887-2571

Date Shipped AUGUST 23, 1985
Our Project No 49299
Your P.O. No: D23279
Page 1 of 1

RIVERSIDE CEMENT
1500 RUBIDOUX
RIVERSIDE, CA 92509
ATTN: DEBBIE

CERTIFICATE OF ANALYSIS – EPA PROTOCOL GASES*

(Concentrations are in mole % or ppm)

Cylinder Number BAL1312 Certified Accuracy ±1 % NBS Traceable Analysis Dates: First 8-12-85 Last 8-20-85

COMPONENTS	CERTIFIED CONC	EXPIRATION DATE	ANALYTICAL PRINCIPLE	PRIMARY STANDARD NBS/SRM's	REPLICATE CONCENTRATIONS FIRST	REPLICATE CONCENTRATIONS SECOND
SULFUR DIOXIDE	995.9PPM	2-20-86	ULTRAVIOLET	SRM1663	995.9PPM	995.9PPM
NITROGEN	BALANCE					

Cylinder Number BAL1057 Certified Accuracy ±1% % NBS Traceable Analysis Dates: First 8-15-85 Last 8-22-85

COMPONENTS	CERTIFIED CONC	EXPIRATION DATE	ANALYTICAL PRINCIPLE	PRIMARY STANDARD NBS/SRM's	REPLICATE CONCENTRATIONS FIRST	REPLICATE CONCENTRATIONS SECOND
NITRIC OXIDE	1020PPM	2-22-86	CHEMI.	SRM1687B	1020PPM	1020PPM
NOX	1022PPM				1022PPM	1022PPM
NITROGEN	BALANCE					

*We hereby certify the cylinder gas has been analyzed according to EPA Protocol No: I

Analyst ______________________ Approved By Wayne McGowan

The only liability of this Company for gas which fails to comply with this analysis shall be replacement thereof by the Company without extra cost.

CALIBRATION DATA

In Service 9/24/85
3/24/86

08/29/85 SERIES 1500 DIAL INSTRUMENT
SERIAL # AR0175 0.0 - 125.00 IN. WATER, 20 C

TEST PRESSURE IN. WATER, 20 C	GAUGE READING IN. WATER, 20 C	ERROR IN. WATER, 20 C	ERROR %
0.0	-0.04	-0.04	-0.03
13.86	13.84	-0.02	-0.02
27.72	27.76	0.04	0.03
41.60	41.68	0.08	0.06
55.46	55.50	0.04	0.03
69.32	69.32	0.0	0.0
83.18	83.18	0.0	0.0
97.06	96.98	-0.08	-0.06
110.92	110.94	0.02	0.02
122.00	121.96	-0.04	-0.03

THIS IS TO CERTIFY THAT MATERIALS AND PROCESSES INVOLVED IN THE MANUFACTURE AND VERIFICATION OF THE PRODUCT(S) INCLUDED IN THIS SHIPMENT COMPLY WITH THE CATALOG, DRAWING OR SPECIFICATION REFERENCED IN THE ORDER.

IT IS CERTIFIED FURTHER THAT THE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

WALLACE & TIERNAN DIVISION
PENNWALT CORPORATION
25 MAIN STREET
BELLEVILLE, NEW JERSEY 07109

WALLACE & TIERNAN
PENNWALT
EQUIPMENT ■ CHEMICALS
HEALTH PRODUCTS

Form 3650

SHORT-TERM FLUE GAS MONITORING AND FLOW RATE DETERMINATIONS AT ID FAN OUTLET

PREPARED FOR:

GIFFORD-HILL & COMPANY, INC.
RIVERSIDE CEMENT
1500 RUBIDOUX BOULEVARD
RIVERSIDE, CALIFORNIA 92502

PREPARED BY:

KVB, INC.
18006 SKYPARK BOULEVARD
IRVINE, CALIFORNIA 92714

OCTOBER 29, 1985

KVB71-71901-1-2037

CONTENTS

FIGURES

TABLES

INTRODUCTION

KVB was retained by Riverside Cement to perform a velocity traverse of the ID fan exhaust duct. Originally, traverses were to be conducted using the existing sample ports in the duct. Discussions between the plant personnel and KVB resulted in the addition of five sample ports on the side of the duct and four sample ports on the top of the duct. The traverse data would then be used to determine the gas flow through the duct and compare the measured gas flow with the flow calculated from the fuel flow, gas analysis and kiln feed mass balance. The results of the tests are presented with recommendations relative to the SCAQMD Rule 1112 requirement that NO_x emissions be based on measured exhaust flow as compared to a calculated flow.

In addition to the velocity traverses, one gaseous emissions traverse was completed along with three flue gas moisture content determinations. The multipoint gaseous emissions traverse provided data to compare with the single point NO_x/O_2 measurements of the Lear Siegler SM-810 and Lear Siegler CM-50 analyzers, respectively. Flue gas moisture content was used as a check to see how well the calculated gas flow on a wet and dry basis compared with the measured flue gas moisture.

TEST LOCATION AND PROCEDURES

Testing was conducted on Kiln #2 at the ID fan outlet, upstream of the baghouse. The cross-sectional area of the rectangular duct is 38.9 ft^2 (83 inches x 67.5 inches). Original plans were to use the three existing ports for the traverse. The three ports are located on the opposite side of the duct from the Lear Siegler SM-810. The lower port is located such that a dust layer may impede measurement. The middle port is located opposite the Lear Siegler. The pitot tube readings may be bias because of the Lear Siegler probe interference. Also, there was concern that the pitot may strike or chip the Lear Siegler ceramic probe. In view of these facts, new ports were installed for the testing. The newly installed ports used for the testing were approximately 11 feet from the ID fan outlet. The Lear Siegler SM-810 is located approximately 4.5 feet downstream of the new ports and the Lear

Siegler CM-50 is approximately 2 feet downstream of the new ports. There are five ports on the side of the duct and four ports on the top of the duct. The centerline to centerline distance between adjacent ports on the side of the duct is eleven inches. The ports on the side of the duct were used for the velocity traverses, gas traverse and flue gas moisture determinations. The ports on the top of the duct were utilized for determining if any dust was at the bottom of the duct. If any dust had settled at the duct bottom, the effective flue gas duct area would be adjusted accordingly.

EPA Method One calls for a sampling site that is at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, contraction or visible flame. The equivalent diameter of the rectangular duct is 74 inches (6.2 feet). The distance from the ID fan to the sample ports is approximately 134 inches (11 feet). The ports should have been located approximately fifty feet downstream of the ID fan outlet. However, the ID fan outlet duct splits into two ducts approximately 25 feet downstream of the fan. The distance from each duct to the baghouse is only 20 feet. Once the flue gas has passed through the baghouse, it is vented to the atmosphere (no stack). The location of ports satisfying the EPA Method One protocol is prohibitive with the current constraints.

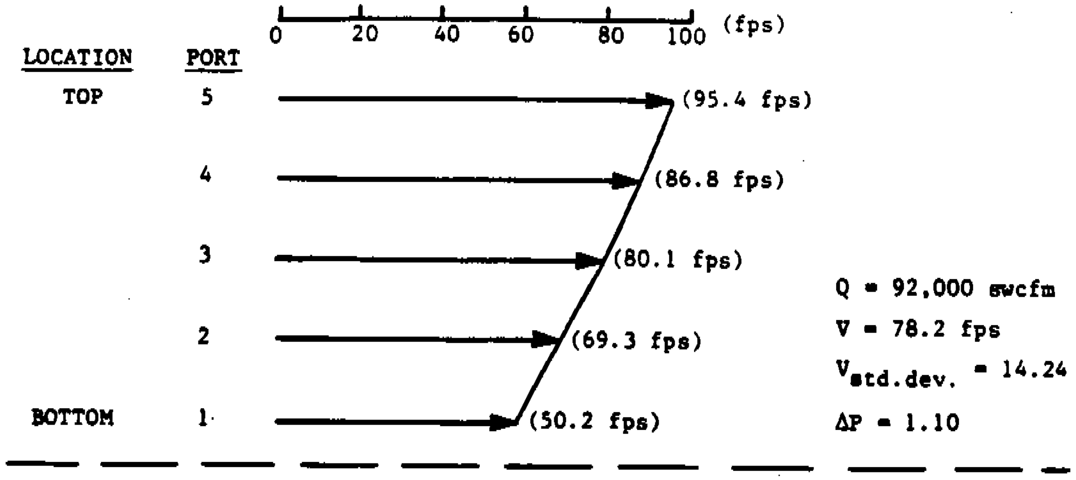
The gaseous emissions and velocity traverse consisted of sampling in one foot increments at each of the five ports. The total number of traverse points is thirty five (seven test points for each of the five ports).

Velocity head (inches water) was measured with an "S" type calibrated pitot tube and inclined manometer. Flue gas temperature was measured with a Type K chromel alumel thermocouple. Frequent backpurging of the pitot tube and sample lines with compressed air was necessary to dislodge dust in the lines.

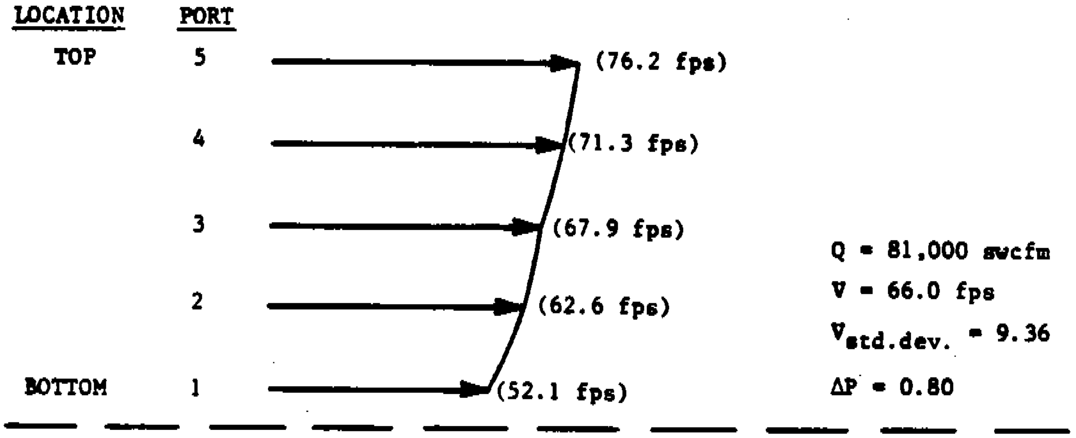
VELOCITY TRAVERSE

The flow rate calculations for the three velocity traverses are based on the data sheets in Appendix A. Figure 1 summarizes the velocity profile by port and test. The first velocity traverse was conducted on August 29, 1985

VELOCITY TRAVERSE - AUGUST 29, 1985



VELOCITY TRAVERSE - OCTOBER 8, 1985



VELOCITY TRAVERSE - OCTOBER 17, 1985

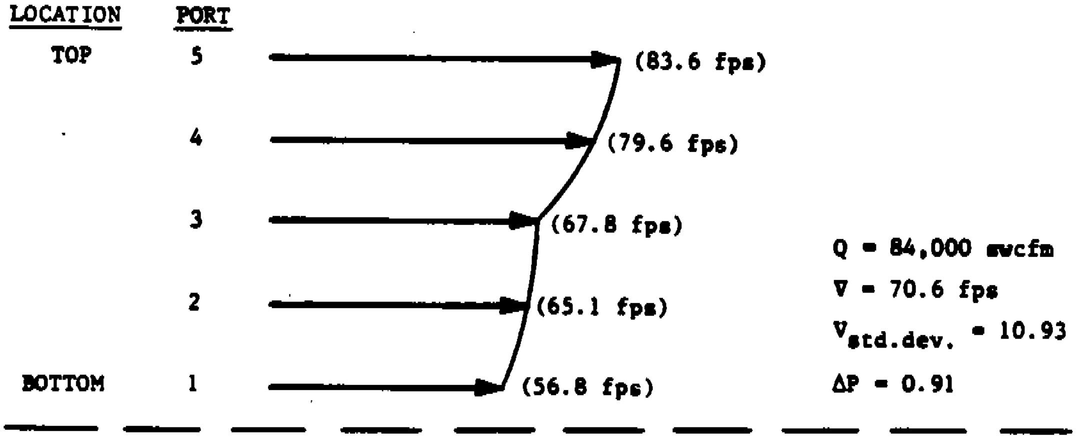


Figure 1. Velocity Traverses

between 1400 and 1600 hours (twenty-four hour time basis). The data show a definite air flow stratification. At the bottom of the duct, the average velocity was 60 feet per second and at the top of the duct the average velocity was 95 feet per second. Overall, the average flow rate based on the velocity traverse was approximately 92,000 swcfm (standard wet cubic feet per minute). This flow rate is approximately 13 to 14 percent higher than the calculated flow rate based on the nine engineering constants, kiln feed, rate, coal rate and kiln exit water spray and ID fan outlet oxygen. The results were not unexpected because the velocity traverse does not "see" the boundary layer effect in the duct. The kiln was operating in a fairly steady mode during the time of the testing (i.e., very few changes to fuel rates, kiln speed and ID fan speed).

The second velocity traverse was conducted on October 8, 1985 between 0940 and 1202 hours (twenty-four hour time basis). The trend in terms of higher velocities and flow rates in the upper portions of the duct was again observed. The kiln was not operating in a steady mode. Several changes to the fuel rate, kiln speed and ID fan speed were made during the test. The average volumetric flow rate based on the velocity traverse was approximately 81,000 swcfm compared to the calculated volumetric flow rate of 66,000 swcfm. Evidence of cyclonic flow was evident in the top port (negative delta P reading).

The third velocity traverse was conducted on October 17, 1985 between 0835 and 1020 hours (twenty-four hour time basis). The kiln was operating in a very steady mode during the course of the testing. The test data corroborated the observations of the previous two velocity traverses (i.e., higher velocities and flow rates in the upper portion of the duct). The average volumetric flow rate based on the velocity traverse was approximately 84,600 swcfm compared to the calculated volumetric flow rate of 71,000 swcfm.

During the second velocity traverse, the pitot tube was rotated ±90 degrees from the horizontal position. The list of negative values on the velocity traverse data sheets show that the flow is indeed cyclonic and swirling.

The two inside ports on the top of the duct were used for the dust layer determination. The delta P velocity head did decrease at approximately three inches from the bottom of the duct. The drop in pressure at the bottom of the duct is most likely due to the boundary layer effect rather than a dust layer.

GAS TRAVERSE

The gaseous traverse was conducted on August 29, 1985. The objective of the gaseous traverse was to determine if gaseous emissions varied significantly from sample point to sample point. A comparison can be made with the single point wet NO_x measurements (Lear Siegler SM-810) and the gaseous traverse data on both a dry and wet basis. KVB-measured NO values are on a dry basis but were corrected for approximately 19 percent moisture in the flue gas. The moisture correction factor is based on the results from EPA Method 4 testing and a moisture content derived from field signals and engineering constants. Figure 2 is a time trace of KVB-measured NO (dry basis) versus the Riverside Cement-measured NO (wet basis). Figure 3 is a time trace of KVB-measured NO corrected to a wet basis versus the Riverside Cement-measured NO (wet basis). When the KVB-measured NO values are corrected to a wet basis, the variation between the Riverside Cement-measured NO and KVB-measured NO is very small. The calculations are shown in Appendix B. The average Riverside Cement NO value for the testing period was 538 ppm, wet (uncorrected for oxygen content in the flue gas). The average KVB-measured NO value for the testing period was 544 ppm, wet.

During the gaseous traverse, the oxygen content of the flue gas was also measured. The flue gas oxygen measurements (dry basis corrected to a wet basis) also agree well with that of the Riverside Cement-measured oxygen content. The average Riverside Cement oxygen value for the testing was 3.5 percent. The average KVB-measured oxygen value (corrected from a dry to a wet basis) was 3.65 percent.

MOISTURE CONTENT

The objective of measuring flue gas moisture was to corroborate the calculated flue gas moisture content based on fuel input, kiln feed input, air

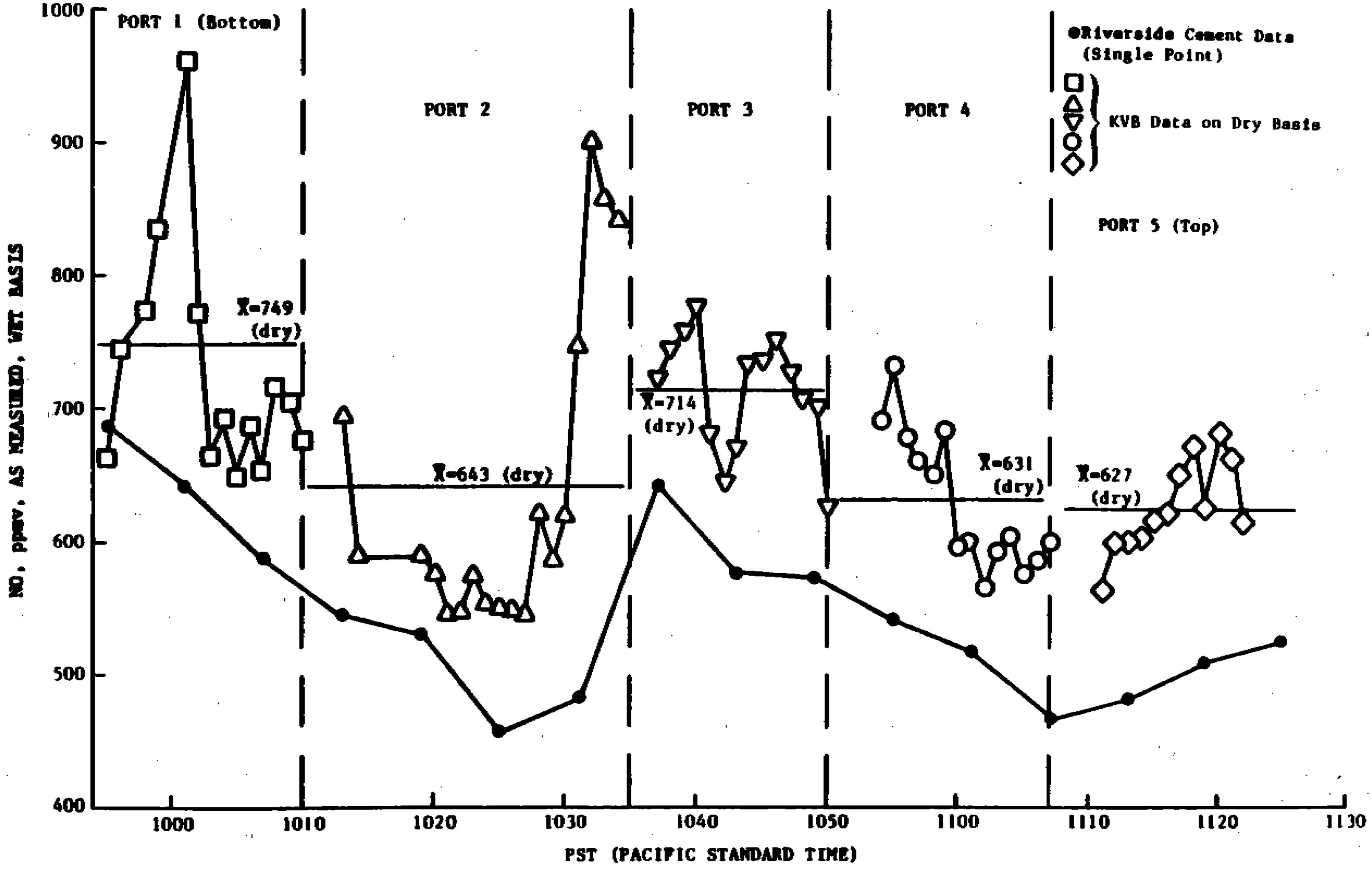


Figure 2. Riverside Cement - KVB Gas Traverse (8/29/85), 1055 to 1222 hours

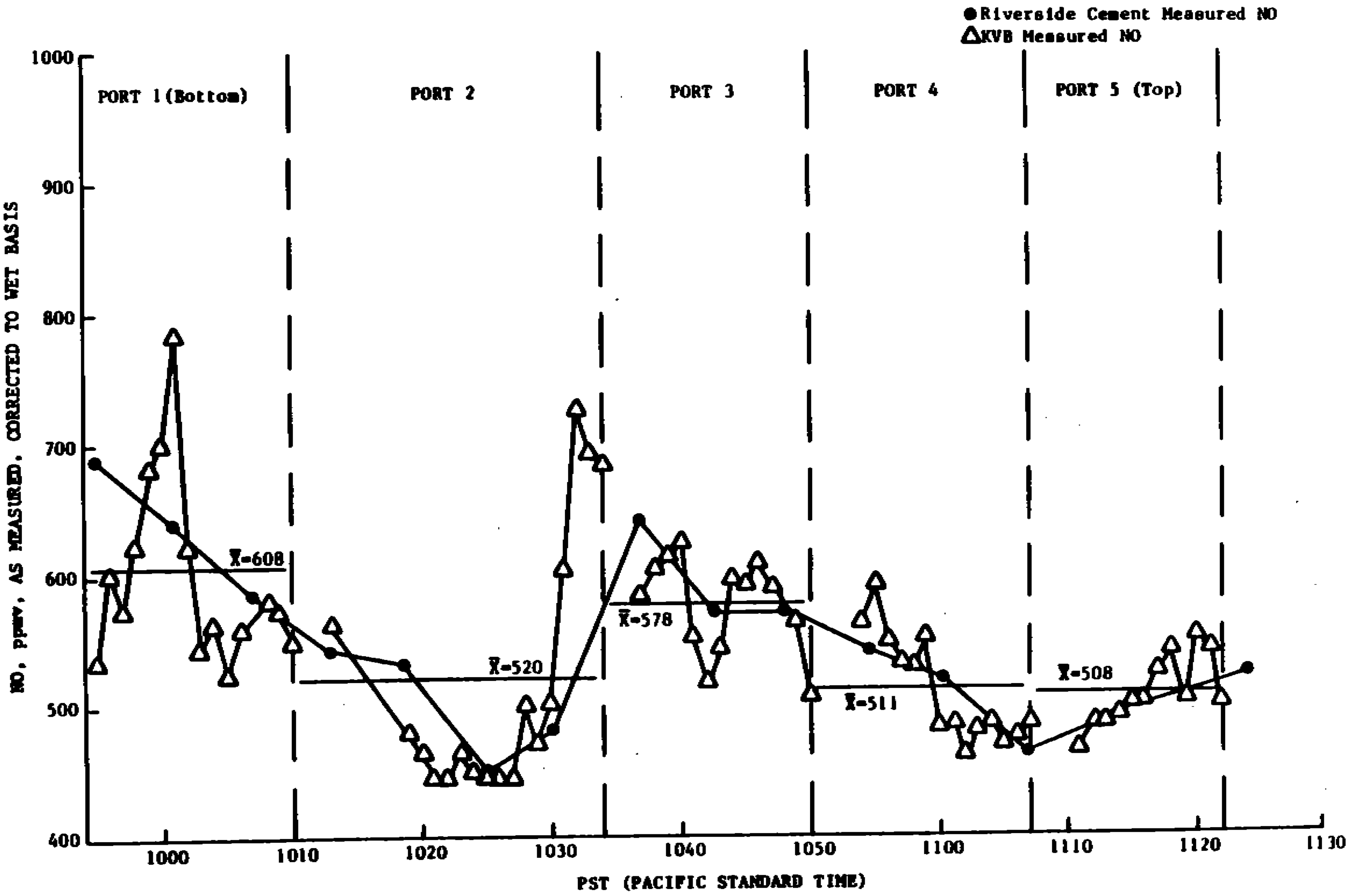


Figure 3. Riverside Cement - KVB Gas Traverse (8/29/85), Kiln #2

input and kiln exit water spray input. The moisture content of the flue gas at the ID fan outlet is determined by using EPA Method 4. Three tests were conducted at or around the same time as the velocity traverse was conducted. Table 1 summarizes the measured moisture content compared to the calculated moisture content. The percentage difference ranged from approximately from a low 1.5 (Test 2) to a high of 16.3 (Test 1). The average percentage difference between the two methods is 8.3. For each test, the probe was located in the center of the middle port (#3) on the side of the duct. The measured and calculated moisture content level seem to agree fairly well.

DISCUSSION OF RESULTS

The measured flow rate downstream of the ID fan was approximately 14 to 20 percent higher than the calculated flow rate (Table 1). As mentioned earlier, the location for measuring the flow rate was constrained by the short distance between the ID fan and baghouse and the split of the ID fan outlet duct into two ducts approximately 20 feet upstream of the baghouse. If there were a stack downstream of the baghouse, the sampling environment (cooler flue gas temperature and essentially dust free) would be suitable for a continuous in-situ flow measurement device. Also, the port locations in the stack would need to be far enough downstream of the baghouse to avoid any disturbances. Although a measured flow rate would be more desirable in a disturbance free/dust free environment, rather than a calculated flow rate, the disturbance free/dust free environment is unavailable at Riverside Cement.

The measured flow rate is a more attractive approach for generating pounds NO_x per ton of clinker than the calculated flow rate from the standpoint of input values. Table 2 lists the inputs needed for both methods. The measured flow rate (with the pitot tube) requires eight measured values while the calculated flow rate required four field signals and eight engineering constants. Of the eight measured values, molecular weight of the flue gases is the most difficult to accurately determine. Continuous measurement of at least O_2, CO_2, and H_2O (N_2 by difference) would be necessary to calculate the molecular weight.

If a continuous in-situ air flow measurement device were to be located in the duct where the traverses were conducted, the sample point

TABLE 1. DATA SUMMARY

	Test 1		Test 2		Test 3	
	IBM Program	Measured	IBM Program	Measured	IBM Program	Measured
Stack Gas Flow Rate (scfm)	82,000	92,000	66,053	81,175	70,500	84,600
Moisture Content (%)	19.0	15.9	19.6	19.3	13.8	14.9

TABLE 2. INPUTS FOR DETERMINING FLUE GAS FLOW RATES

INPUTS (CALCULATED FLOW RATE)

Field Signals

- Coal Flow Rate, tph
- Kiln Feed Rate, tph
- Kiln Exit Water Spray, gpm
- % O_2 at ID Fan Outlet

Engineering Constants

- % C coal as fired
- % H coal as fired
- % N coal as fired
- % S coal as fired
- % O coal as fired
- Coal Moisture, %
- Kiln Feed Moisture, %
- Kiln Feed Ignition Loss

INPUTS (MEASURED FLOW RATE)

- Velocity Head, inches H_2O
- Static Head, inches H_2O
- Duct Temperature, °F
- Molecular Wt Flue Gas
  (based on % H_2O, % CO_2, % O_2, % N_2 by difference)
- Barometric Pressure
- Duct Area

representative of the average flow rate would be the middle port approximately 45 inches into the duct. The single point measurement would not reflect the stratification and swirling effects in the duct.

Table 3 summarizes the advantages and disadvantages of each of the two methods. The calculated flow rate is a more reliable number although the engineering constants are not real time values and the field signals may be slightly in error. Also, the accuracy of the calculated flow rate value is better because flow stratification and cyclonic flow does not affect the value as does the measured value.

CONCLUSIONS/RECOMMENDATIONS

1. Cyclonic flow exists at the current sample port locations. Flow is biased toward the upper portions of the duct.
2. The single point in-situ Lear Siegler NO and O_2 measurements agreed quite well with the average multipoint extractive NO and O_2 measurements conducted by KVB.
3. The measured moisture content of the flue gas corroborates the IBM calculated moisture content based on the difference between standard wet cubic per minute and standard dry cubic feet per minute.
4. Installation of a permanent flow measuring device at the current location is not recommended. No suitable location between the ID fan and baghouse for a continuous flow monitor is available.

TABLE 3. ADVANTAGES/DISADVANTAGES OF CALCULATED FLOW RATE VERSUS MEASURED FLOW RATE

CALCULATED FLOW RATE	
Advantages	**Disadvantages**
• No downtime associated with probe/sensor out-of-service	• More Inputs
• Better accuracy when field signals in calibration and engineering constants up-to-date	• Engineering constants may not reflect kiln feed and coal feed properties on a real time basis
MEASURED FLOW RATE	
Advantages	**Disadvantages**
• Fewer Inputs	• No suitable location for flow measurement from a disturbance standpoint between ID fan outlet and baghouse
• Real Time	• High dust loading (possible problems with erosion and/or dust accumulation and pluggage)
	• Single point in-situ measurement non-representative of flow conditions in the dust
	• Accuracy not as good

APPENDIX A

VELOCITY TRAVERSES OF ID FAN OUTLET

C = 83+67.5 × 2 = 301 inches
= 25 ft
[illegible] = [illegible] ft = [illegible]

11" between ₵ of each port

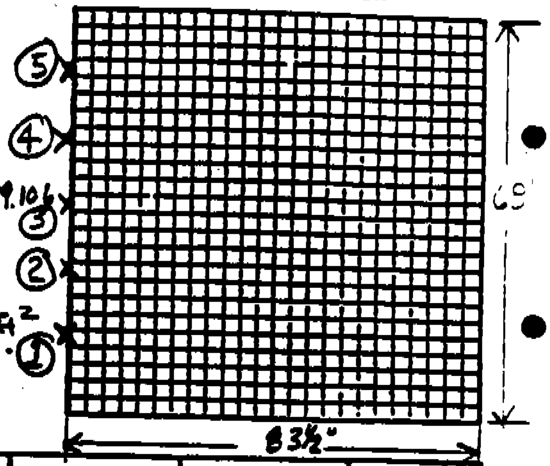
VELOCITY TRAVERSE

Project: Riverside Cement
Test Description: As Found
Date: 8/21/85
Location: Riverside Cement
Unit: 2
Test: Velocity Traverse
Personnel: Benson, Markee
Fuel: Coal
Barometric Press. (in. Hg): 28.9
Absolute Static Press. in Stack (in. Hg): $28.9 + \frac{2.3}{13.6}$ $(P_s) = 29.106$
Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\ C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

$$A = \frac{83'' \times 67\tfrac{1}{2}''}{144''^2/ft^2} = 38.91\ ft^2$$

Stack Cross Section



static pressure at 1452 hrs 2.3" H_2O.

Time	Traverse Port	Point Depth	Velocity Head (in. H_2O) ΔP	Gas Temp. (°F)	Gas Temp. (°R) T_s	Molecular Wt. M_s	Velocity (ft/sec) V_s	O_2 Conc. (% Dry)
1515	1	6"	0.48	536	996			
	Bottom	18"	0.54	539	999			
		30"	0.68	539	999			
		42"	0.70	545	1005			
		54"	0.68	540	1000			
		66"	0.65	540	1000			
		78"	0.60	535	995			
	Avg $\overline{X}$		0.618	539	999	30.5	59.24	
	2	6"	0.60-0.65	531	991			
		18"	0.70-0.75	535	995			
		30"	0.92-0.98	539	999			
1500		42"	1.0	548	1008			
		54"	0.95-1.00	548	1008			
		66"	0.85-0.95	549	1009			
		78"	0.75	540	1000			
	Avg $\overline{X}$		0.844	541	1001	30.5	69.27	

6002-13

VELOCITY TRAVERSE

Project: Riverside Cement **Test Description:** As Found
Date: 8/29/85
Location: Riverside Cement
Unit: 2
Test: Velocity Traverse **Personnel:** Bryan Markee
Fuel: Coal
Barometric Press. (in. Hg): 2893
Absolute Static Press. in Stack (in. Hg): 29106 (P_s)
Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\, C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

Stack Cross Section

Time	Traverse Point Port	Depth	Velocity Head (in. H_2O)	Gas Temp. (°F)	Gas Temp. (°R)	Molecular Wt.	Velocity (ft/sec)	O_2 Conc. (% Dry)
			ΔP		T_s	M_s	V_s	
	3	6"	0.65-0.75	536	996			
		18"	0.8-0.85	537	997			
		30"	1.2	536	996			
		42"	1.0	535	995			
		54"	1.1-1.4	545	1005			
		66"	1.6	542	1007			
		78"	1.2-1.4	547	1007			
	Avg $\bar{X}$		1.13	540	1000	30.5	80.14	
	4	6"	.65-.75	528	988			
		18"	.95-1.3	536	996			
		30"	1.2-1.5	541	1001			
		42"	1.3-1.7	545	1005			
		54"	1.4-1.8	548	1008			
		66"	1.6	552	1012			
1417		78"	1.4	551	1011			
	Avg $\bar{X}$		1.32	543	1003	30.5	86.75	

6002-13

VELOCITY TRAVERSE

Project: Riverside Cement
Date: 8/29/85
Location: Riverside Cement
Unit: 2
Test: Velocity Traverse
Fuel: Coal
Barometric Press. (in. Hg): 28 98
Absolute Static Press. in Stack (in. Hg): 29.06 (P_s)
Pitot Tube Coefficient: .83 (C_p)

Test Description: As Found

Personnel: Benson, Markee

$$V_s = 85.48\, C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

2.8" H_2O

Stack Cross Section

Time	Traverse Port	Point Depth	Velocity Head (in. H_2O)	Gas Temp. (°F)	Gas Temp. (°R)	Molecular Wt.	Velocity (ft/sec)	O_2 Conc. (% Dry)
			ΔP		T_s	M_s	V_s	
1415	5	6"	1.90	545	1005			
		18"	1.7	545	1005			
		30"	1.30-1.70	548	1008			
		42"	1.70	548	1008			
		54"	1.90	548	1008			
		66"	1.40	548	1008			
1400		78"	1.05	547	1007			
	Avg $\bar{x}$		1.59	547	1007	30.5	95.4	

Top PORT(s) 1" from bottom .33" H_2O 0" from bottom 0" H_2O
6" from bottom .35" H_2O

6002-23

MOBILE LABORATORY DATA

Test No. M-1

Test No. _____ Date 8/30 Location Riverside Cement Engr. Benson

Unit No. 2 Fuel Coal Capacity _____

Unit Type Long Dry Kiln Burner Type Pillard

Zero and Span Instruments

1. Test No.					
2. Date	8/30	8/30	8/30		
3. Time	0910	0940 30	1049 30		
4. Load		start of moisture test	post check		
5. Process Rate					
6. Flue Diam. or Size, ft					
7. Probe Position					
8. Oxygen (%)	0 4.1		0 40		
9. NOx (hot) read/3% O_2 (ppm)*					
10. NO (hot) read/3% O_2 (ppm)*					
11. NO_2 (hot) read/3% O_2 (ppm)*					
12. NO (cold) read/3% O_2 (ppm)*	0 603		0 590		
13. Carbon Dioxide (%)	0 10.1		0 10.2		
14. Carbon Monoxide (ppm) uncor/cor*	0 305		8 304		
15. Hydrocarbon (ppm) uncor/cor*					
16. Sulfur Dioxide (ppm) uncor/cor*	0 99		5 195		
17. Smoke Spot (Bacharach)					
18. Atmos. Temp. (°F/°C)					
19. Dew Point Temp. (°F/°C)					
20. Atmos. Pressure (in. Hg)					
21. Relative Humidity (%)					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

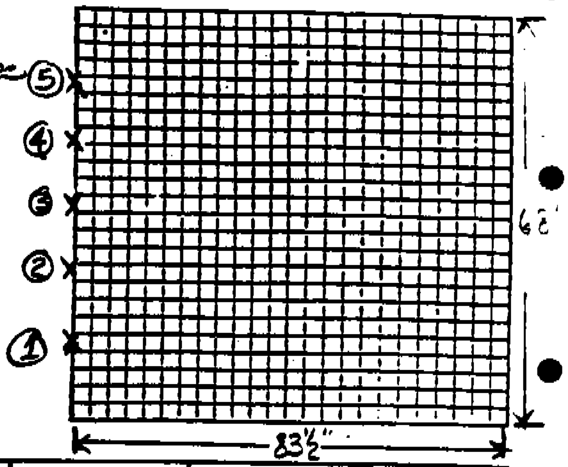
VELOCITY TRAVERSE

Project: Riverside Cement
Test Description: As Found
Date: 10/8/85
Location: Riverside Cement Crestmore Plant
Unit: 2
Test: Velocity Traverse
Personnel: Olsen, Podlenski, Markee
Fuel: Coal
Barometric Press. (in. Hg): 28.9
Absolute Static Press. in Stack (in. Hg): ________ (P_s)
Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\, C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

11" between ℄ of each port

Stack Cross Section



90°L	Time	Traverse Point Port	Depth	Velocity Head (in. H_2O)	Gas Temp. (°F)/°R	STATIC P ~~Gas Temp. (°R)~~	90°L ~~Molecular Wt.~~	Velocity (ft/sec)	O_2 Conc. (% Dry)
				ΔP		~~T_s~~ "H_2O	~~M_s~~	V_s	
-.34-.3?	0940	5	78"	1.25	565/1025	1.95	-.34-.30		
1.95	948		66"	.44 & .80 (.62)	556/1016		1.95		
C	0952		54"	-1.35 & .82 (1.09)	553/1013	1.5			
.8 .1	0957		42"	1.4 & 1.55 (1.48)	550/1010	1.4	-.8 to -1.1		
84 & .95	1002		30"	1.2	532/992	1.5	-.84 to -.95		
03			18"	.82 & .89 (.86)	525/985	1.3	-.03		
	1008		6"	.67 & .75 (.71)	518/978				
		Avg $\bar{x}$		1.03	542/1002	1.53		76.62	
03 & .24	1017	4	78"	1.1 & 1.2 (1.15)	535/995	2.0	-.03 to .24		4.7
.2 & .5			66"	1.2 & 1.3 (1.25)	529/989		-.20 to -.50		
.47	1028		54"	.74 & .77 (.755)	523/983		-.47		
.3 & -.5	1040		42"	.77 & .83 (.80)	501/961		-.3 to -.5		
.03 & .14	1044		30"	.84 & .89 (.865)	494/954		-.03 to -.14		
.18 & .3			18"	.88 & .94 (.91)	495/955	.9	-.18 to -.30		
.3			6"	.73	496/956	.5 & .65	-.30		
		Avg $\bar{x}$		0.92	510/970	1.2		71.28	

60.75" down to dust level
7.25" of dust on bottom

} the static pressure started to change at this elevation but this static pressure change may be due to operational changes or the boundary layer effect

KVB-TP-1111

KVB

VELOCITY TRAVERSE

Project: Riverside Cement NOx Program
Test Description: As Found
Date: 10/8/85
Location: Riverside Cement, Crestmore Plant
Unit: 2
Test: Velocity Traverse
Personnel: Olsen, Bdlnski, Markee
Fuel: Coal
Barometric Press. (in. Hg): 28.9
Absolute Static Press. in Stack (in. Hg): 28.9 + $\frac{\text{stat. pressure}}{13.6}$ (P_s)
Pitot Tube Coefficient: .83 (C_p)

$$V_S = 85.48\, C_p \left[\frac{T_S \Delta P}{P_S M_S}\right]^{1/2}$$

Stack Cross Section

cyclone

	Time	Traverse Port	Point Depth	Velocity Head (in. H_2O)	Gas Temp. (°F)/°R	STATIC ~~Gas Temp.~~ (~~°R~~) in. H_2O	90°L ~~Molecular Wt.~~	Velocity (ft/sec)	O_2 Conc. (% Dry)
				ΔP		~~T_S~~	~~M_S~~	V_S	
[illegible].32	1100	3	78"	.54 & .6 (.57)	497/957	.94	+.09 to .32		
.32&+.02	1103		66"	.77 & .80 (.785)	506/966	.99	-.02 to +.02		
.01&-.03	1105		54"	.82 & .96 (.89)	506/966	.81	-.01 to -.03		
.2&-.3	1107		42"	.95 & 1.0 (1.0)	501/961	.7	-.2 to -.3		
.38&-.43	1110		30"	.89 & 1.1 (.995)	506/966	.85	-.38 to -.43		
.57&-.64	1113		18"	.86 & .73 (.80)	499/959	.73	-.57 to -.64		
.7&.78	1116		6"		506/966	1.2	-.70 to -.78		
		Avg $\bar{X}$		0.84	503/963	0.89		67.9	
[illegible]	1120	2	78"	.5 & .53 (.515)	518/978	1.3	0 to .08		
.28&.37	1123		66"	.81 & .86 (.835)	524/984	1.0	.28 to .37		
13	1127		54"	.76	520/980	.97	-.13		5.1
.1&-.3	1130		42"	.61 & .73 (.665)	508/968	.86	-.1 to -.3		
.1&-.15	1133		30"	.73 & .76 (.745)	497/957	1.4	-.1 to -.15		
.54&-.61	1136		18"	.67 & .72 (.695)	495/955	1.1	-.54 to -.61		
.21&-.26	1139		6"	.68 & .76 (.71)	495/955	1.1 & 1.4 (1.25)	-.21 to -.26		
		Avg $\bar{X}$		0.71	508/968	1.13		626	

KVB-TP-1111

VELOCITY TRAVERSE

Project: Riverside Cem^t NO_x Project **Test Description:** As Found

Date: 10/8/85

Location: Riverside Cem^t Crestmore Plant

Unit: 2

Test: Velocity Traverse **Personnel:** Olsen, Podlaski, Markee

Fuel: Coal

Barometric Press. (in. Hg): 289

Absolute Static Press. in Stack (in. Hg): 28.9 + $\frac{\text{Static pressure}}{13.6}$ (P_s)

Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\, C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

Stack Cross Section

cyclonic flow	Time	Traverse Point Port	Traverse Point Depth	Velocity Head (in. H_2O) ΔP	Gas Temp. (°F)	STATIC P ~~Gas Temp. (°R)~~ ~~T_s~~	90°L Molecular Wt. M_s	Velocity (ft/sec) V_s	O_2 Conc. (% Dry)
0	1192	1	78"	.21	485/945	1.7 & 1.8	0		
17 & .18	1146		66"	(.54) .51 & .57	499/959	1.1	.14 to .18		
.08	1149		54"	(.48) .44 & .52	500/960	1.45	.08		
.01 & -.03	1153		42"	(.55) .52 & .58	498/958	1.3	-.01 to -.03		
17 & .21	1156		30"	(.49) .46 & .52	488/948	1.35	+.17 to .21		4.95
.07 & -.07	1159		18"	(.615) .57 & .66	488/948	1.40	-.04 to -.07		
.22 & .25	1202		6"	(.60) .57 & .63	489/949	1.40	-.22 to -.25		
				0.50	492/952	1.39		52.04	

KVB-TP-1111

Flowrate ⊥ to paper (coming out

11" between ℄ of each port.

VELOCITY TRAVERSE

Project: Riverside Gen. NO, [illegible]

Test Description: ____

Date: 10/[illegible]/85

Location: Riverside Gen. Cressman

Unit: 2

Test: Velocity Traverse

Personnel: [illegible]

Fuel: Coal

Barometric Press. (in. Hg): 28.9

Absolute Static Press. in Stack (in. Hg): 28.7[illegible] (P_s)

Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\, C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

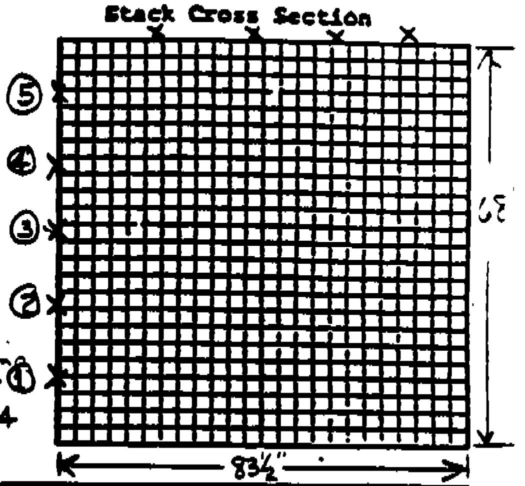
983 .4[illegible]

.83

29.06 30.5

70.54 fps × 38.91 ft² × 60 s/min × 528/983 × 29.0[illegible]/29.92 = 54614

Stack Cross Section



Rotate [illegible] 90°

Time	Traverse Point Port	Depth	Velocity Head (in. H_2O)	Static [illegible] Gas Temp. (°F)	Gas Temp. °F/(°R)	Molecular Wt.	Velocity (ft/sec)	O_2 Conc. (% Dry)
			ΔP		T_s	M_s	V_s	
0833	5	7	.85-1.0	2.3	526 986			
		6	1.15	2.6	528 988			
		5	1.4	2.2	524/984			
		4	1.4	2.6	526/986			
		3	1.50	2.5	525/985			
		2	1.40	2.4	522/982			
0850		1	.9-1.0	2.1	515/975			
			1.25	2.38	524/984		83.55	
0853	4	7	.75-.85	2.4	540/1000			
0857		6	1.2	2.3	540/1000			
0859		5	1.2-1.3	2.2	538/998			
0901		4	1.2	2.5	530 990			
0903		3	.85-.95	2.3	522/982			
0905		2	.75-.85	2.1	515 975			
0907		1	.6-.75	2.3	507/967			
			1.13	2.3	527/987		79.57	

1.3

1.2

6002-13

VELOCITY TRAVERSE

Project: Riverside Cement NOx Program **Test Description:**
Date: 10/17/85
Location: Riverside Cement Crestmore Plant
Unit: 2
Test: Velocity Traverse **Personnel:** Benson, Markee
Fuel: Coal
Barometric Press. (in. Hg): 28.9
Absolute Static Press. in Stack (in. Hg): $28.9 + \frac{\text{static press}}{13.6}$ (P_s)
Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\, C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

Stack Cross Section

	Time	Traverse Port	Point Depth	Velocity Head (in. H_2O)	Static Press Gas Temp. (°F)	Gas Temp. °F/(°R)	Molecular Wt.	Velocity (ft/sec)	O_2 Conc. (% Dry)
				ΔP		T_s	M_s	V_s	
		3	7	.52-.68$^{(.6)}$	2.2	536/996			
			6	.75-.80^{78}	2.3	537/997			
1.4			✓ 5	.90-1.0$^{.95}$	2.3	537/997			
	0929		4	1.0-1.1^{105}	2.3	526/986			
			3	.95-1.0$^{.98}$	2.3	523/983			5.1
			2	.75-.85$^{.8}$	2.5	513/973			
.60			1	.55	2.1	512/972			
			$\bar{x}$	.82	2.28	526/986		67.75	
	0948	2	7	.45-.50	2.2	531/991			
			6	.75-.86	2.2	531/991			
			5	.86-.92	2.4	528/988			
			4	.82-.90	2.4	523/983			
.90			3	.85-.90	2.4	516/976			
			2	.75-.80	2.4	513/973			
			1	.6[illegible]-.70	2.4	508/968			
			$\bar{x}$	.76	2.34	521/981		65.05	

6002-13

VELOCITY TRAVERSE

Project: Riverside Cement NO$_x$ Program **Test Description:**
Date: 12/7,85
Location: Riverside Cement Crestmore Plant
Unit: 2
Test: Velocity Traverse **Personnel:** Benson, Markee
Fuel: Coal
Barometric Press. (in. Hg): 28.94 $\frac{\text{static pressure}}{13.6}$
Absolute Static Press. in Stack (in. Hg): .83 (P_s)
Pitot Tube Coefficient: .83 (C_p)

$$V_s = 85.48\ C_p \left[\frac{T_s \Delta P}{P_s M_s}\right]^{1/2}$$

Stack Cross Section

Time	Traverse Port	Point Depth	Velocity Head (in. H_2O)	Static Pressure ~~Gas~~ Temp. (°F)	Gas Temp. °F/(°R)	Molecular Wt.	Velocity (ft/sec)	O_2 Conc. (% Dry)
			ΔP		T_s	M_s	V_s	
	A	7	.52	2.2	523/983			
		6	.54-.58	2.2	527/987			
		5	.62-.68	2.2	528/988			
1010		4	.60-.65	2.2	522/982			
		3	.60-.65	2.2	517/977			
		2	.53-.55	2.0	509/969			
		1	.47-.52	2.1	507/967			
	$\overline{X}$		.58	2.15	519/979		56.79	
	TOP PORT	1'	.6					
		6"	.25					
		3"	.15					
		0"	0					

90° ap 0.2

6002-13

APPENDIX B

GAS TRAVERSE EMISSIONS MONITORING

RCB
9-5-85
KVB 71901-1

RIVERSIDE CEMENT DATA

Time (PST)*		NO, ppm as measured+		O_2, %+		Kiln Feed, tph		Coal Feed, tph		Kiln Exit Water Spray, gpm		Fan Speed, rpm	
		$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
8/29	1001 to 1125	538	57	3.51	0.26	83.5	2.1	10.49	0.03	67	0	3230	2.5
8/29	1301 to 1455	378	61	3.88	0.15	85.7	0.9	10.50	0.02	689	0.9	331.6	2.2
8/30	0849 to 0949	1043	96	3.58	0.16	74.0	0.9	10.20	0.14	64.1	0.3	322.3	6.5

* Pacific Standard Time
+ wet basis

COMPARISON OF RIVERSIDE CEMENT EMISSIONS DATA (WET BASIS) TO KVB-MEASURED EMISSIONS DATA (DRY BASIS)

8/29 AM

KVB $\overline{NO}$: 672 ppm, dry $* \left(1 - \frac{\% H_2O}{100}\right)$ = 565 ppm, wet (assuming % H_2O = 15.9 from 8/30 EPA Method 4 Test)

672 pm, dry $* \left(1 - \frac{\% H_2O}{100}\right)$ = 544 ppm, wet (assuming % H_2O = 19.0 based on calculat

RIVERSIDE CEMENT $\overline{NO}$ = 538 ppm wet

- - - -

KVB $\overline{O_2}$: 4.5 %, dry $* \left(1 - \frac{\% H_2O}{100}\right)$ = 3.78 %, wet (assuming % H_2O = 15.9 from 8/30 EPA Method 4 Test)

4.5 %, dry $* \left(1 - \frac{\% H_2O}{100}\right)$ = 3.65 %, wet (assuming % H_2O = 19.0 based on calculations

RIVERSIDE CEMENT $\overline{O_2}$ = 3.5 %, wet

COMPARISON OF RIVERSIDE CEMENT EMISSIONS DATA (WET BASIS)
TO KVB-MEASURED EMISSIONS DATA (DRY BASIS)

8/30 AM

KVB $\overline{NO}$: 1198 ppm, dry * $\left(\frac{1-\%H_2O}{100}\right)$ = 1008 ppm, wet (assuming $\%H_2O$=15.9 from 8/30 EPA Method 4 Test)

: 1198 ppm, dry × $\left(\frac{1-\%H_2O}{100}\right)$ = 970 ppm, wet (assuming $\%H_2O$= 19 from calculations

RIVERSIDE CEMENT $\overline{NO}$: 1043 ppm, wet

- - - - - -

KVB $\overline{O_2}$: 4.6% dry, × $\left(1-\frac{\%H_2O}{100}\right)$ = 3.86%, wet (assuming $\%H_2O$=15.9 from 8/30 EPA Method 4 Test)

: 4.6% dry × $\left(1-\frac{\%H_2O}{100}\right)$ = 3.72%, wet (assuming $\%H_2O$=190 from 8/30 EPA Method 4 Test)

RIVERSIDE CEMENT $\overline{O_2}$ = 3 58%, wet

ONLINE EMISSIONS MONITOR

LOCATION RIVERSIDE CEMENT
UNIT NUMBER KILN 2
DESCRIPTION EMISSION MONITORING ID FAN FLOW
LOAD AS FOUND
TEST NUMBER 1
TEST DATE 8-29-1985

	ID # DST	computer TIME	POINT	MODE	O2 %	CO PPM	NO 3% PPM	CO2 %	SO2 PPM	SO2 3% PPM	NO PPM
	1	0828	ID OUT	AUTO	5.2	1	1069	27.4	0	0	935
0:55	2	0842	ID OUT 7' in	AUTO	3.7	400	689	31.9	0	0	662
	3	0843	ID OUT	AUTO	4	400	788	30.1	0	0	744
	4	0844	ID OUT 6' in	AUTO	3.7	376	735	28.6	0	0	707
	5	0845	ID OUT	AUTO	3.7	400	806	28	0	0	772
	6	0846	ID OUT 5' in	AUTO	4.3	125	905	27	0	0	839
1:00	7	0847	ID OUT	AUTO	4.2	123	928	26.5	0	0	864
	8	0848	ID OUT 4' in	AUTO	5.4	147	1122	24.9	0	0	972
	9	0849	ID OUT	AUTO	5.4	89	889	24.1	0	0	771
	10	0850	ID OUT 3' in	AUTO	5.5	89	774	24.4	0	0	668
	11	0851	ID OUT	AUTO	4.7	89	767	24.6	0	0	694
1:05	12	0852	ID OUT 2' in	AUTO	4.7	291	716	24.4	0	0	649
	13	0853	ID OUT	AUTO	4.7	89	761	24.4	0	0	690
	14	0854	ID OUT 1' in	AUTO	4.8	95	729	24.2	0	0	656
	15	0855	ID OUT	AUTO	4.8	90	802	24.5	0	0	719
	16	0856	ID OUT	AUTO	4.8	92	785	23.8	0	0	707
1:10	17	0857	ID OUT	AUTO	5.1	92	766	25.5	0	0	678
				$\bar{x}$	4.6		825	26.1			749
				S	.6		121	2.4			99

NOTE- PORT 1 DATA ABOVE (Bottom Port)

NOTE- PORT 2 DATA BELOW

1:13	18	0900	ID OUT 7' in	AUTO	4	104	737	27.4	0	0	695

Comp[illegible] time

1119	2	0906	ID QUIT	7' in	AUTO	4.2	133	634	27.8	0	0	591
1120	3	0907	ID QUIT		AUTO	3.9	157	606	28.1	0	0	573
	4	0908	ID QUIT		AUTO	4	329	580	30.1	0	0	543
	5	0909	ID QUIT	6' in	AUTO	3.9	400	578	30	0	0	550
	6	0910	ID QUIT		AUTO	3.9	143	606	28.3	0	0	573
	7	0911	ID QUIT	5' in	AUTO	3.9	155	586	28.1	0	0	555
	8	0912	ID QUIT		AUTO	3.8	248	576	28.1	0	0	551
	9	0913	ID QUIT	4' in	AUTO	3.9	377	579	28.2	0	0	551
	10	0914	ID QUIT		AUTO	4	186	583	26.6	0	0	549
	11	0915	ID QUIT	3' in	AUTO	4.3	127	672	27.3	0	0	624
	12	0916	ID QUIT		AUTO	4.3	213	634	27.9	0	0	589
	13	0917	ID QUIT	2' in	AUTO	4.5	164	676	27.9	0	0	620
	14	0918	ID QUIT		AUTO	4.7	98	825	26.4	0	0	748
	15	0919	ID QUIT	1' in	AUTO	4.8	99	1001	25.2	0	0	900
1:33	16	0920	ID QUIT		AUTO	4.6	224	945	27.4	0	0	859
:34	17	0921	ID QUIT		AUTO	4.4	113	913	25.9	0	0	842
					X̄	4.2		640	27.7			643
		NOTE- PORT 3			S	.3		143	1.3			120
1:37	18	0924	ID OUT	7' in	AUTO	4.7	112	801	25.7	0	0	723
11:38	19	0925	ID OUT		AUTO	4.4	97	808	26.8	0	0	747

ONLINE EMISSIONS MONITOR

LOCATION	RIVERSIDE CEMENT
UNIT NUMBER	KILN 2
DESCRIPTION	EMISSION MONITORING ID FAN FLOW
LOAD	AS FOUND
TEST NUMBER	1
TEST DATE	8-29-1985

ID #	Computer TIME	POINT	MODE	O2 %	CO PPM	NO 3% PPM	CO2 %	SO2 PPM	SO2 3% PPM	NO PPM
1	0926	ID OUT 6' in	AUTO	4.4	131	824	29	0	0	760
2	0927	ID OUT	AUTO	4.3	299	836	29.3	0	0	777
3	0928	ID OUT 5' in	AUTO	4.1	307	723	29.2	0	0	680
4	0929	ID OUT	AUTO	4.5	249	697	27.9	0	0	640
5	0930	ID OUT 4' in	AUTO	3.9	366	709	27.9	0	0	672
6	0931	ID OUT	AUTO	4.3	151	795	26.4	0	0	738
11:45 7	0932	ID OUT 3' in	AUTO	4.1	370	783	26.8	0	0	736
8	0933	ID OUT	AUTO	4.3	142	809	26.2	0	0	753
9	0934	ID OUT 2' in	AUTO	4.4	123	789	26.1	0	0	728
10	0935	ID OUT	AUTO	4.6	108	775	25.9	0	0	707
11	0936	ID OUT 1' in	AUTO	4.6	143	769	26.3	0	0	702
11:50 12	0937	ID OUT	AUTO	4.3	387	675	26.9	0	0	627
			$\bar{x}$	4.35		771	27.3			714
	NOTE- PORT 4		S	.22		50	1.3			45
11:54 13	0941	ID OUT 7' in	AUTO	4.4	106	751	26.3	0	0	694
14	0942	ID OUT	AUTO	4.5	103	801	25.9	0	0	732
15	0943	ID OUT 6' in	AUTO	4.8	98	753	26.5	0	0	678
16	0944	ID OUT	AUTO	4.4	157	718	26	0	0	661
17	0945	ID OUT 5' in	AUTO	4.5	104	714	27.2	0	0	654
18	0946	ID OUT	AUTO	4.4	120	739	26.7	0	0	683
2:00 19	0947	ID OUT 4' in	AUTO	4.6	105	655	26.9	0	0	598

ONLINE EMISSIONS MONITOR

LOCATION RIVERSIDE CEMENT
UNIT NUMBER KILN 1
DESCRIPTION EMISSION MONITORING ID FAN FLOW
LOAD AS FOUND
TEST NUMBER 1
TEST DATE 8-29-1985

	ID #	Computer TIME	POINT		MODE	O2 %	CO PPM	NO 3% PPM	CO2 %	SO2 PPM	SO2 3% PPM	NO PPM
	1	0948	ID OUT	4' in	AUTO	4.2	142	646	27.6	0	0	602
	2	0949	ID OUT	3' in	AUTO	4.3	227	613	26.6	0	0	568
	3	0950	ID OUT		AUTO	4.3	175	640	27.2	0	0	592
	4	0951	ID OUT	2' in	AUTO	4.3	128	653	27	0	0	604
2:05	5	0952	ID OUT		AUTO	4.5	165	629	27	0	0	576
	6	0953	ID OUT	1' in	AUTO	4.6	169	643	27.5	0	0	587
	7	0954	ID OUT		AUTO	4.9	105	673	26.6	0	0	600
					$\bar{x}$	4.5		688	26.8			631
		NOTE- PORT 5			S	.2		57	.5			52
2[illegible]	8	0958	ID OUT	7' in	AUTO	4.5	114	618	27.7	0	0	565
	9	0959	ID OUT		AUTO	4.7	100	665	26.6	0	0	600
	10	1000	ID OUT	6' in	AUTO	4.6	121	657	26.2	0	0	600
	11	1001	ID OUT		AUTO	5.1	100	688	24.5	0	0	606
	12	1002	ID OUT	5' in	AUTO	5.4	98	717	24.1	0	0	619
	13	1003	ID OUT		AUTO	5.4	98	717	24.3	0	0	622
	14	1004	ID OUT	4' in	AUTO	4.8	99	726	25.3	0	0	652
	15	1005	ID OUT		AUTO	5	98	757	23.8	0	0	671
	16	1006	ID OUT	3' in	AUTO	5.3	96	717	24.7	0	0	625
	17	1007	ID OUT		AUTO	5	95	772	24.5	0	0	684
	18	1008	ID OUT	2' in	AUTO	5.2	90	760	24.8	0	0	668
2:22	19	1009	ID OUT		AUTO	4.7	95	681	25.3	0	0	617
					$\bar{x}$	4.98		706	25.2			627
					S	.31		46	1.2			35

APPENDIX C

MOISTURE CONTENT

FCE
9-9-85
KVB 71901-1

MOISTURE CONTENT OF FLUE GAS, TEST #1

Data Input

Start Time. 0940 30 > 66 minutes
Stop Time: 1046. 30

Flue Gas Volume Collected: 41.0256 ft^3
H_2O Volume Collected: 151 ml

T_m : 77°F
P_{bar} · 28.88 " Hg

Probe was 49 ¼" into the duct (middle port)

Calculations

$$V_{wc} = .0474 \frac{ft^3}{ml} * (V_f - V_i)$$

$$= .0474 \frac{ft^3}{\cancel{ml}} * (151 - 0)\cancel{ml}$$

$$= 7.1574 \ ft^3$$

$$V_{mc} = V_m \times \frac{P_m}{P_{std}} \times \frac{T_{std}}{T_m}$$

$$= 41.026 \ ft^3 \times \frac{28.88}{29.92} \times \frac{530}{537}$$ 2144

$$= 37.81 \ ft^3 \text{ (standard conditions)}$$

MOISTURE CONTENT OF FLUE GAS, TEST #1

$$B_{wo} = \frac{7.1574}{37.81 + 7.1574} \times 100\%$$

$$= \underline{\underline{15.9}}\ \%$$

RCB
10-18-85
KVB 71901-1

MOISTURE CONTENT TEST #2

Coal Feed Rate: 10.1 tph
Kiln Exit Water Spray Rate: 67.5 gpm
TOTGAS 80605 wscfm
O_2 (ID FAN OUTLET): 4.18 %
Kiln Feed Rate: 91

WATCOAL: .0454
CC COAL: .7130
HCOAL: .0497
NCOAL: .0126
OCOAL: .1235
S COAL: .0051
KFH2O: .0029
KFLOI:

EQUATIONS FROM APPENDIX B OF "AUDIT OF CURRENT NO_x MONITORING PROJECT"

$$\text{YNERT} = \left(\frac{1-.209}{.209}\right) \times \frac{28.163}{32.} = \underline{\underline{33309}}$$

$$\text{DTWO} = 32 \times \left(\frac{.7130}{12.011} + \frac{.0497}{2 \times 2.016} - \frac{.1235}{32} + \frac{.0051}{32066}\right) \times 32138 = \underline{\underline{699.2}}$$

$$\text{AVAH} = .0497 - \frac{.1235}{7.937} = \underline{\underline{.0341}}$$

$$\text{DCOAL} = (10.1) \times \frac{2000}{60} \times (1 - .0454) = \underline{\underline{32138}}$$

$$\text{HTWOO} = \underbrace{(.0035 \times (1 + 3.3309) \times 2.294)}_{.0348} + \underbrace{(10.1 \times .0454 \times 2000/60)}_{15.2847} + \underbrace{\left(\frac{.1235 \times 18.011}{16}\right) \times 321.38}_{44.679}$$

$$= \underline{\underline{6}}$$

MOISTURE CONTENT TEST #2

$$NTWO = \underbrace{(3.3309 * 699.2)}_{2328.96} + \underbrace{(.0126 * 321.38)}_{4.0494} = \underline{\underline{2333.01}}$$

$$COTWO = \underbrace{\left(\frac{44.011}{12} * .7130 * 321.38\right)}_{840.4} + \underbrace{\frac{91 * (1 - .0029) * (.344) * 2000}{60}}_{1040.44} = \underline{\underline{188\ldots}}$$

$$HOUT = \left[60 + \left(\frac{18.011}{2.011} * .0341 * 321.38\right)\right] = \underline{\underline{158.15}}$$

$$MKDG = \frac{2333.01}{28.163} + \frac{1880.8}{44.011} = \underline{\underline{125.57}}$$

$$MKW = \underbrace{\frac{158.15}{18.011}}_{8.78} + \underbrace{\frac{67.5 * 8.3453}{18.011}}_{31.28} = \underline{\underline{40.06}}$$

$$MKWG = 165.63$$

$$MIDO2 = \frac{.0418 * 165.63}{1 - (.0418 * \underbrace{(1 + 3.7847 + .02693)}_{4.8114})} = \underline{\underline{8.6676}}$$

$$MIDXSDA = 8.6676 * (1 + (1 - .209)/.209) = \underline{\underline{41.47}}$$

$$MIDXSW = \frac{(41.47 * (.00347) * 28.95)}{18.011} = \underline{\underline{.2313}}$$

MOISTURE CONTENT TEST #2

$$SDCFM = (125.57 + 40.06) * 385.3 = \underline{\underline{63817.23}}$$

$$SWCFM = 63817.23 + \underbrace{(40.06 + .2313) * 385.3}_{15524} = \underline{\underline{79341}}$$

$$\%\ moisture = \frac{15524}{79341} = \underline{\underline{19.6}}\ \%$$

H_2O

LOCATION GIFFORD HILL
UNIT ______ FUEL ______
OPERATORS OLSON MARKEE

TEST NUMBER	1
DATE	10/8/85
AMBIENT TEMPERATURE, °F	
METER VOL. (START/END)	1105.40 /

Page ______
Of ______

System Checks

	Initial	Final
Pitot		
Thermometer		
Leak Rate, CFM		
VAC, "Hg		
Initials		
Test for		

System Data

Meter Box # ______ ΔH@= ______
Date last Cal. ______
Probe # ______
Liner Material ______
Nozzle # ______
Diameter (in) ______
Thermometer # ______
Date last Cal. ______

Imp.	Vol. (End)		Vol. (Start)		ΔVol. (ml)
#1	150	−	100	=	50
#2	104	−	100	=	4
#3	0	−	0	=	0
			Total		54
	g (End)		g (Start)		Δ grams
#4 (Silica Gel)	295.4	−	289.1	=	6.3
			Total Vol. H_2O		60.3 ml

Filter# ______

Particulate Wts

Filter ______ mg
Front Half
Acetone ______ mg
EPA-5
Total ______ mg

Sampling Time Per Point, Min.	Particulate Wt., mg	Condensate Vol., ml	Fuel Flow gal/hr	Load MW	C_{pitot}	Stack Press. In. Hg-Gauge	Barometric Pressure

Sample Point	Time	METER CONDITIONS			TEMPERATURES, °F							O_2, %	Vac.
		ΔP_s	ΔH	Meter Reading	Stack	Probe	Oven	Impingers In	Impingers Out	Meter In	Meter Out		
	1235			1105.40						62	62		
	1238		.8	1107.38						65	62		8
	1243		.8	1109.2						65	62		8
	1248		.8	1111.3						65	62		8
	1253		.8	1113.3						65	62		8
	1259		.8	1115.4						65	62		8
	1303			1117.52									
Average													

TEST RESULTS

Test Averages:
ΔP_s = ______ T_{stack} = ______ °F
ΔH = ______ T_{meter} = ______ °F
Sample Vol.= ______ ft^3 (meter)
Percent O_2 = ______
$MW_{stack\ gas}$ = ______ (~28)
Velocity = ______ ft/sec
Total Sample Time = ______ min.

Comments:

19.35%
H_2O

Note: $\overline{\Delta P} = \left(\frac{\sum_{i}^{M} \sqrt{\Delta P_i}}{\ldots} \right)^2$

RJB
10-18-85
KVB 71901-1

MOISTURE CONTENT OF FLUE GAS, TEST #3

10/17/85

Data Input

Flue Gas Volume Collected: 22.51 ft^3
H_2O Volume Collected: 81 ml

T_m = 70°F
P_{bar} = 28.9"Hg

Calculations

$$V_{wc} = .0474 \frac{ft^3}{ml} * (V_f - V_i)$$

$$= .0474 \frac{ft^3}{ml} * (81 - 0)\ ml$$

$$= 3.84\ ft^3$$

$$V_{mc} = V_m * \frac{P_m}{P_{std}} * \frac{T_{std}}{T_m}$$

$$= 22.51\ ft^3 * \frac{28.9}{29.92} * \frac{530}{523.5}$$

$$= 22.01\ ft^3 \text{ (standard conditions)}$$

$$B_{wo} = \frac{3.84}{22.01 + 3.84} * 100\%$$

$$= 14.9\ \%$$

10/17/85 Moisture Content Determination, TEST #3

MM(1) = 299.16

MM(3) = 20.34

MM(4) = 76.986

MM(5) = .5477 *

MM(6) = 25.3155

MM(7) = .7861 *

✓ MM(8) = 103635

MM(9) = .4561 *

MM(10) = 21.98

✓ MM(11) = 2244

✓ MM(12) = 22.25 *

MM(13) = 148.33 moles/min Kiln gas at 0% O_2

$\frac{24.03}{148.33 + 27.48}$ = 13.70 moisture content

(148.33 * 385.3) = 57,151

+ (x * 385.3) = 10,589

67,740

PARTICULATE CALCULATION SHEET

Test No. ______ Date 10/17/85 Test Crew Benner McKee
Location Riverside Cement - Crestmore
Box No. EN-538 Sample Probe Position Center Port
Test Description

Dry Gas Meter Vol. (ft^3) 3.84
Final 1152.06
Initial 1129.55
Total 22.51

Impinger Water Vol (ml)

	1	2	3	S. Gel	Total
Final	180	100	1	—	
Initial	100	100	0	—	
Δ Vol	80	0	1	—	81

Beaker No.						Filter No.	Blank No.
Date Weighed							
Tare Wt. 1							
2							
3							
4							
5							
6							
Avg							
Bottle No.							
Content	Impinger (Water)	Probe (Acetone)	Probe (Water)	Cyclone (Acetone)	Flask (Dry)		
Rinse (ml)							
Date Weighed or 250 Bake							
Final Wt. 250 1							
2							
3							
4							
5							
6							
Avg							
Residue wt Final 250-Tare							
Date Weighed or 650 Bake							
Final Wt. 650 1							
2							
3							
4							
5							
6							
Avg							
Residue Wt Final 650-Tare							

Comments:

Data Sheet 6002-3

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18006 Skypark Blvd., P.O. Box 19518, Irvine, California 92714 (714) 250-6200

September 27, 1985
KVB72-71901-3 LD#19/3

Dr. Mallory May
Gifford-Hill & Company, Inc.
P. O. Box 47127
Dallas, TX 75247

SUBJECT: Periodic Audit of NO_x Monitoring Procedures
at Riverside Cement, Task 3

Dear Mallory:

The first KVB audit for reviewing conformance to the quality assurance plan at Riverside Cement was completed on Thursday, September 19. The results of the audit are summarized on a one page checklist (Attachment 1). Daily zero/span checks for the Lear Siegler SM 810 and CM 50 show minimal drift (Attachment 2). Drift calculations were performed by KVB for the Lear Siegler SM 810 NO analyzer. The zero drift was calculated to be 5.33 ppm while the span drift was calculated to be 12.5 ppm. Both values are well within the 37.5 ppm drift limit specified by EPA Performance Specification 2 for NO analyzers (EPA-340/1-83-013)

A dynamic calibration of the Lear Siegler SM 810 and CM 50 was performed during the audit to validate the zero/span checks (Attachment C). The flue gas NO_x values were within 2.5 percent of the gas cylinder values. Thus, the NO_x ppm values being recorded by the computer were valid. Dynamic calibrations are occurring on a weekly basis at the plant.

The kiln feed Sankyo impact flowmeter setting was being checked with a six hour clinker production determination and a kiln feed loss on ignition based on several kiln feed samples. These samples are collected prior to and during the course of clinker weighings to calculate an up-to-date ignition loss. The percent difference between the clinker rate measured and clinker rate calculated from the kiln feedrate and loss on ignition is noted in the logbook of daily activities. Any adjustments to the Sankyo kiln feed are noted in the log book.

Kiln exit water spray flowmeter will be calibrated during the October outage. The coal feed Sankyo flowmeter will also be calibrated during the October outage.

The engineering constants for the computer program are being updated weekly. Kiln feed samples are collected daily and analyzed for loss-on-ignition and moisture. Coal samples are also being analyzed periodically.

The NO_x project at Riverside Cement is very well documented and organized regarding instrument checks, certification sheets, and daily activities associated with the program. Attachment D lists the notebooks and data sheets inspected during the audit. The documentation recommendations in KVB's audit report (Task 2) are being implemented. Formal dynamic calibration data sheets with weekly test results were not available but will be completed by the next audit.

A new computer program to calculate the pounds NO_x per ton of clinker was being implemented during the first audit. During the next audit, current engineering constants and field signal input will be substituted into the equations for calculating pounds NO_x per ton of clinker.

Overall, the NO_x project at Riverside Cement is proceeding satisfactorily. If there are any questions regarding the audit, please do not hesitate to call me at 714/250-6286.

Sincerely,

KVB, INC.
Engineering & Research Division

FOR R BENSON

Ron C. Benson

RCB:jk

Attachments: As Noted

cy: [redacted]Riverside Cement
S. C. Hunter, KVB
J. Podlenski, KVB

ATTACHMENT 1
RIVERSIDE CEMENT - NO_x PROJECT WEEKLY AUDIT BY KVB

Date: 9/19/85
Audit by: Ron Benson
John Podlenski

	Completed		
	Yes	No	Comments/Review
1. Daily Summary sheet of daily zero/span checks on Lear Siegler NO_x/O_2 Analyzer		X	A summary sheet will be implemented by the next audit. The daily zero/span checks are reviewed by Paul Fogg. If the daily zero/span checks show any anomalies, a dynamic calibration is performed. To date, such a dynamic calibration has not been needed. Zero and drift calcs by KVB show that the NO_x monitor is well within P.S.T.* drift specifications.
2. Summary sheet of any adjustments/ maintenance to Sankyo kiln feed, coal feed, NO_x, O_2, kiln exit water spray equipment and any adjustments to engineering constants (daily basis).		X	This information is kept in Jerry Young's logbook of daily activities associated with the program.
3. Dynamic calibration (zero, 500 ppm, 1000 ppm) of NO_x analyzer (linearity check).	X		Dynamic calibration satisfactory; no adjustments made since measured and actual span values were less than 2.5% difference. Linearity checks OK.
4. Dynamic calibration of O_2 analyzer	X		OK at low span (1.9% measured, 2.0% actual) OK at high span (20.5% measured, 20.9% actual)
5. Data validation (relate data to normal operation, startup, shutdown, etc.).	X		OK
6. Administrative - logbook inspection, documentation of equipment checks, full and dynamic calibration, etc.	X		OK Jerry Young will have formal dynamic calibration data sheets completed by the next audit.

*P.S.T. - Performance Specification Tests used for certifying continuous emissions monitors

ATTACHMENT 3

24-HOUR ZERO AND CALIBRATION DRIFT

Analyzer:	Lear Siegler SM 810
Location:	Riverside Cement
Serial No.:	
Measurement Range:	0-1500 ppm NO

Data Set No.	Date	Time Begin	Time End	Zero Rdg Init. A	Zero Rdg Fin. B	Zero Drift X_L C=B−A	Hi-Range Rdg Init. D	Hi-Range Rdg Fin. E	Span Drift F=E−D	Calib. Drift X_L G=F−C
1	8/26	0750	0730	−12	−8	4	610	625	15	11
2	8/27	0730	0730	−8	−6	2	625	639	14	12
3	8/30	0730	0730	−6	−8	−2	639	624	−15	−13
4	8/31	0730	0830	−8	−10	−12	624	620	−4	−2
5	9/1	0830	1015	−10	0	10	620	650	30	20
6	9/2	1015	0727	0	0	0	650	640	−10	−10
7	9/3	0727	0740	0	0	0	640	634	−6	−6

Arithmetic Mean	$\bar{X}$	1.71	$\bar{X}$	1.71
Confidence Interval	CI_{95}	3.62	CI_{95}	10.79
	Zero drift	5.33	Calibraton drift	12.50
PST 2 Drift Specification		37.50		37.50

$$CI_{95} = \tau_{0.975} \frac{\sigma}{\sqrt{n}}$$

ATTACHMENT 3

DYNAMIC CALIBRATION

ZERO/SPAN VALUES

Zero Gas: N_2
[NO]: 498 ppm, EPA Protocol 1
[NO]: 1019 ppm, EPA Protocol 1
[SO_2]: 995 ppm
[O]: 2.0%
[O_2]: Ambient air, 21%

	Zero		Span		Span	
	Before Calib	After Calib	Before Calib	After Calib	Before Calib	After Calib
NO ppm	4 to 11	4 to -6	997 to 1010	-	497	-
SO_2 ppm	3	-	962 to 976	991		
O_2, %	-	-	1.9	-	20.5	-
Internal Zero/ Span Check						
NO ppm	-12	-	601	-	-	-

*If the NO_x span value is less/more than 2.5 percent the certified bottle value, an adjustment is made. Otherwise, no adjustment is made.

ATTACHMENT 4

DOCUMENTATION FOR NO_x PROJECT

Documentation	Description
Computer Instrumentation Notebook	Includes Baghouse Inlet Temp.
Daily Notebook	Zero and Span NO_x, O_2 analyzers
Kiln-Down Notebook	Kiln feed Sankyo flowmeter, kiln backend water spray flowmeter
Quarterly Notebook	Full electric calibration worksheet for Lear Siegler SM 810
Weekly Notebook	Bailey O_2
Log Book	Kept by Jerry Young - Daily activities associated with the NO_x program; includes telephone conversations, meetings, changes/updates to engineering constants; clinker production check versus kiln feed rate, etc.
Data Validation Sheets	Any kiln upsets, downtime are noted with day/time/length of outage (Jerry Young showed us data validation sheets from August 7 on).
Variation of Engineering Constants	Daily coal moisture, kiln feed moisture, L.O.I. x-ray, L.O.I. wet
Zero/Span Gases Certification	Supplied by Matheson
Weights Certificaton	
Turbine water flowmeter	Calibration of indicating Hz versus actual flow
Digital Multimeter Calibration/ Certifications by Wylie Labs	Multimeters used to verify field signal inputs/outputs

KVB®
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18006 Skypark Blvd., P.O. Box 19518, Irvine, California 92714 (714) 250-6200

October 11, 1985
KVB71-71901-3/8

Dr. Mallory May
Gifford-Hill & Company, Inc.
P.O. Box 47127
Dallas, TX 75247

SUBJECT: Periodic Audit of NO_x Monitoring Procedures at Riverside Cement, Task 3

Dear Mallory:

The second KVB audit to review conformance to the quality assurance plan at Riverside Cement was completed on Tuesday, October 8. The results of the audit are summarized on a one page checklist (Attachment 1). Based on the audit, the NO_x project is proceeding satisfactorily.

If there are any questions regarding the audit, please do not hesitate to call me at (714) 250-6286.

Sincerely,

KVB, Inc.
Engineering & Research Division

R. C. Benson
Senior Engineer

RCB:mr

cy: [redacted]
S. Hunter, KVB
J. Podlenski, KVB

Date: 10/8/85
Audit By: John Podlenski

RIVERSIDE CEMENT - WEEKLY NOx PROJECT AUDIT BY KVB

	Completed		
	Yes	No	Comments/Review
1) Daily summary sheet of zero/span checks on Lear Siegler NO_x/O_2 Analyzer	X		Filled out to date
2) Daily summary sheet of adjustments/maintenance to Sankyo kiln feed, coal feed, NO_x, O_2, kiln exit water spray equipment and any adjustments to engineering constants	X		10/1/85 - Full electronic calibration of LS, and UV lamp change Sanko scheduled in approximately 2 weeks
3) Dynamic calibration (zero, 500 ppm, 1000 ppm) of NO_x analyzer (linearity check)	X		Dynamic calibrations conducted on 10/2/85 on $NO/SO_2/O_2$ analyzers
4) Dynamic calibration of O_2 analyzer	X		
5) Data validation (relate data to normal operation, startup, shutdown, etc.)	X		Covered 9/18 - 10/5, noted calibrations, unit availability, etc.
6) Administrative - log book inspection, documentation of equipment checks, full and dynamic calibrations, etc.	X		Filled out to date
7) Calibration Summary Sheet	X		Zero/span summary from 7/17/85 to 9/30/85
8) General QC Check	X		All instruments, printers, etc. functional and and in order

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18006 Skypark Blvd., P.O. Box 19518, Irvine California 92714 (714) 250-6200

October 21, 1985
KVB71-71901-3/9

Dr. Mallory May
Gifford-Hill & Company, Inc.
P.O. Box 47127
Dallas, TX 75247

SUBJECT: Periodic Audit of NO_x Monitoring Procedures at Riverside Cement, Task 3

Dear Mallory:

The third audit of Riverside Cement's NO_x quality assurance program was completed on October 16, 1985. The results of the audit are summarized on a one page checklist (Attachment 1). The NO zero was slightly in error based on dynamic calibrations of 10/9 and 10/16/85. The zero/span summary sheets (10/10-10/15/85) show that the NO zero was approximately 40 ppm low and the NO span was approximately 30 ppm low (Attachment 2). A dynamic calibration of the Lear Siegler SM 810 NO analyzer was performed on 10/9/85 and the NO zero before and after calibration was 70 ppm. The NO zero was not adjusted pending discussions with Lear Siegler. The NO span gas reading was 1110 ppm prior to calibration and was 1039 ppm after calibration. The previous week's dynamic calibration was satisfactory indicating that at some time between October 2nd and October 9th, the NO measured values were bias high. Another dynamic calibration was performed during the day of the audit. The NO zero prior to calibration was 190 ppm but was adjusted back to zero with nitrogen gas. After the zero check was made, the NO span gas reading was between 994 ppm and 1006 ppm, which satisfied the dynamic calibration criteria.

The NO data collected sometime after October 2nd until October 16th will be noted in the data validation report as being bias. Jerry Young/Paul Fogg contacted Lear Siegler regarding the problem with the zero/span mirror of the Lear Siegler SM 810. Evidently, the problem is related to interference with ozone generated by the UV lamp. During the next kiln outage, the Lear Siegler probe will be examined by the instrumentation technicians. Until the situation with the calibrated span cells is resolved, the dynamic calibration is the only reliable means of assuring data quality.

The data validation worksheet format shows the date, time interval of questionable data and the reason for questionable data. The documentation

for data validation has been completed to date with the exception of the NO_x data from the previous two weeks.

The latest updates to the engineering constants were reviewed. The review included the eight engineering constants used in the calculation of pounds NO_x per ton of clinker calculation. These updated constants are shown in Attachments 3 and 4. For a particular set of field signal inputs (specifically from 0756 to 0801 hours, October 16) and the current engineering inputs, the total flow rate and pounds NO_x per ton was calculated from the set of eighteen equations developed concurrently by KVB and Gifford-Hill. The calculations were then compared with the computer printout values. The calculated flow rate is 80851 wscfm compared to the computer printout value of 80817 wscfm (listed as TOTGAS on the computer printout). The calculated pounds NO_x per ton of clinker is 7.704 compared to the computer printout value of 7.7 pounds NO_x per ton of clinker. The calculations verify that the field signal input and the latest engineering inputs are yielding the expected values as printed by the computer and stored on disk.

No further checks on the kiln feed Sankyo flowmeter were conducted. The kiln exit water spray flowmeter and coal feed Sankyo flowmeter are scheduled for calibration during the scheduled October outage.

In summary, the NO_x project is proceeding satisfactorily. If there are any questions regarding the audit, please do not hesitate to call me at (714) 250-6286.

Sincerely,

KVB, Inc.
Engineering & Research Division

Ron Benson

R. C. Benson
Senior Engineer

RCB:mr

Attachments: As Noted

cy: Jerry Young, Riverside Cement
S. Hunter, KVB
J. Podlenski, KVB

Date: 10/16/85

Audit By: R. Benson

ATTACHMENT 1

RIVERSIDE CEMENT - WEEKLY NOx PROJECT AUDIT BY KVB

	Completed		Comments/Review
	Yes	No	
1) Daily summary sheet of zero/span checks on Lear Siegler NO_x/O_2 Analyzer	X		NO zero approximately -40 ppm from 10/10/85 to 10/15/85. Lear Siegler suggests problem with zero span cell (i.e., interference with ozone generated by the U.V. lamp)
2) Daily summary sheet of adjustments/ maintenance to Sankyo kiln feed, coal feed, NO_x, O_2, kiln exit water spray equipment and any adjustments to engineering constants	X		O.K.
3) Dynamic calibration (zero, 500 ppm, 1000 ppm) of NO_x analyzer (linearity check)	X		Dynamic calibrations O.K. 8/20, 8/29, 9/19, 10/2; last two dynamic calibrations show NO zero in error. Adjustment to NO zero not made 10/9/85 but was made 10/16/85
4) Dynamic calibration of O_2 analyzer	X		O.K.
5) Data validation (relate data to normal operation, startup, shutdown, etc.)	X		O.K.
6) Administrative - log book inspection, documentation of equipment checks, full and dynamic calibrations, etc.	X		O.K.

ATTACHMENT 2

ZERO/SPAN SUMMARY SHEET
LSI SM-810 NO_x/SO_x ANALYZER AND LSI CM-50 OXYGEN ANALYZER

	CM-50		SM-810			
	Oxygen		NO		SO2	
DATE	Low (2.0%)	High (20.9%)	Zero 0 ppm	Span 640 ppm	Zero 0 ppm	Span 890 ppm
9/22/85	2.24	20.5	-6	600	0	890
9/23/85	2.0	21.4	-12	592	-4	888
9/29/85	2.25	21	0	650	0	980
9/30/85	2.0	21.0	-15	623	-9	963
10/3/85	2.0	21.0	-2	646	4	936
10/4/85	2.0	21.0	-5	665	-3	927
10/5/85	2.0	20.5	4	650	-1	930
10/6/85	2.1	20.1	X	640	0	x
10/7/85	1.9	20.6	-9	657	0	944
10/8/85	1.9	20.5	0	663	3	908
10/9/85	1.9	20.8	-1	658	1	931
10/12/85	1.9	20.6	-42	612	0	938
10/11/85	1.9	20.5	-46	626	0	913
10/13/85	1.9	20.5	-4	600	0	850
10/14/85	1.9	20.7	-43	606	1	927
10/15/85	1.9	20.7	-46	605	3	913

ATTACHMENT 3

VARIATION OF ENGINEERING CONSTANTS

	Coal Moisture		Kiln Feed Moisture		Kiln Feed			
					LOI Wet		LOI Dry	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
7/26-8/12	4.05	0.72	0.34	0.07	34.23	0.75	35.35	0.39
7/26-8/18	4.36	0.82	0.33	0.07	34.28	0.65	35.16	0.46
7/26-8/24	4.43	1.00	0.32	0.07	34.33	0.60	35.02	0.48
8/2-8/31	4.66	0.95	0.30	0.05	34.42	0.39	34.99	0.51
8/9-9/7	4.63	0.84	0.29	0.05	34.25	0.35	34.71	0.36
8/16-9/20	4.57	0.74	0.29	0.04	34.27	0.49	34.60	0.21
8/21-9/30	4.52	0.64	0.29	0.05	34.24	0.56	34.56	0.29

$\bar{X}$ = Mean

S = Standard Deviation

ATTACHMENT 4

COAL ULTIMATE ANALYSIS

	ASH	CARBON	H	N	S	O
AVERAGE	9.55	71.30	4.97	1.26	0.51	12.35
STD.DIV.	0.88	1.04	0.22	0.14	0.10	0.96
COEF VAR	9.26	1.46	4.38	11.37	19.02	7.81

			COAL ANALYSIS					
LAB	I.D. NO.	DATE	ASH	CARBON	H	N	S	O
CT&E	19174	7-18-85	9.00	72.40	5.20	1.40	0.60	11.10
CT&E	18866	5-23-85	9.70	72.31	5.47	1.66	0.77	10.05
CT&E	19447	8-28-85	10.45	70.72	4.70	1.22	0.52	12.35
CT&E	19448	8-28-85	9.33	72.03	4.93	1.26	0.41	12.00
CT&E	19449	8-28-85	9.05	71.74	4.99	1.17	0.52	12.48
CT&E	19450	8-28-85	9.53	71.08	4.90	1.23	0.50	12.72
CT&E	19451	8-28-85	11.34	68.98	4.74	1.14	0.53	13.23
CT&E	19452	8-28-85	8.62	71.50	5.04	1.27	0.42	13.10
CT&E	19453	8-28-85	9.10	71.70	5.03	1.18	0.46	12.48
CT&E	19454	8-28-85	10.85	69.81	4.82	1.19	0.45	12.85
CT&E	19455	8-28-85	8.92	71.10	4.76	1.16	0.45	13.57
CT&E	19456	8-28-85	8.65	72.19	5.08	1.25	0.51	12.28