VOLUME 2

ATTACHMENTS H THROUGH P TO

TECHNICAL REPORT ON THE DEMONSTRATION OF THE FEASIBILITY OF NOx EMISSIONS REDUCTION AT RIVERSIDE CEMENT COMPANY, CRESTMORE PLANT

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VOLUME 2

LIST OF ATTACHMENTS

H. G. Young, Riverside Cement Company, Process Redesign and Modifications List for Crestmore Plant, June 1984.

I. G. Young, Riverside Cement Company, Equipment Description and Function List for NOx Project, February 1984.

J. C. Phillips, JCP Associates, History of NOx Calculations and Heat Balance Equations, prepared for Riverside Cement Company, November 1, 1985.

K. G. Young, Riverside Cement Company, Crestmore NOx Project Quality Assurance Manual, July 1, 1985.

L. KVB, Inc., Audit of Current NOx Monitoring Project, prepared for Gifford-Hill & Company, Inc., Riverside Cement, September 3, 1985.

M. Riverside Cement Company, Response to KVB, Inc.'s September 3, 1985, report, January 13, 1986.

N. NOx Project Equipment Calibration Certifications, Riverside Cement Company, Crestmore Plant, 1985.

O. KVB, Inc., Short-Term Flue Gas Monitoring And Flow Rate Determinations At ID Fan Outlet, prepared for Gifford-Hill & Company, Inc., Riverside Cement, October 29, 1985.

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Process Redesign and Modifications
At
RCC's Crestmore Plant

Attached is a list of approximately 45 separate items that were redesigned and modified prior to the August 1984 restart of Number Two kiln. This list includes items associated with the four methods used by RCC to reduce NOx emissions:

1) reduce the quantity of fuel used to produce a ton of clinker;
2) reduce the quantity and temperature of the primary air;
3) achieve better control of the flame configuration; and
4) achieve better operational control of the kiln.

The process modifications made by RCC are listed below.

1) To reduce the quantity of fuel used:
    a) install redesigned kiln hood seal;
    b) enlarge the clinker cooler throat;
    c) install redesigned kiln chain system; and
    d) install new indirect firing system.
2) To reduce the quantity and temperature of the primary air:
    a) install new indirect firing system;
    b) install new primary air supply fan using ambient air;
    c) design and install new coal mill instrumentation; and
    d) install redesigned fuel burner pipe.

3) To achieve better control of the flame configuration:

   a) enlarge the clinker cooler throat;

   b) install redesigned airlocks on kiln baghouse dust system;

   c) redesign the reverse air fan on the kiln baghouse;

   d) redesign ductwork and install new dust collector at the feed end of the kiln;

   e) redesign kiln exit gas multiclones;

   f) install new instrumentation on clinker cooler fans to permit automatic air flow control;

   g) install new solenoid valves on baghouse cleaning system;

   h) install new controller on kiln baghouse reverse air fan;

   i) redesign and install new clinker cooler fan damper positioners; and

   j) install redesigned fuel burner pipe.

4) To achieve better operational control of the kiln:

   a) redesign BC1-A raw material belt conveyor;

   b) install new belt scale on raw material belt conveyor BC-3 to weigh total raw material flow rate;

   c) install new clay storage and reclaim facility;

   d) design and install instrumentation for control of raw material proportioning;

   e) redesign and install new air heater system on raw material sampling station;

   f) modify raw material stacker;

   g) modify raw material reclaimer;

   h) modify raw mill cyclones;

   i) redesign kiln feed silos filling system;

j) redesign and modify kiln feed silos aeration system;

k) redesign kiln feed silos withdrawal system;

l) install new kiln feed weighing device;

m) redesign and install new kiln dust return system;

n) install new internal thermocouple in the kiln;

o) enlarge clinker cooler throat;

p) redesign clinker cooler fan motors control instrumentation;

q) install thermocouples for kiln baghouse inlet temperature;

r) redesign clinker cooler baghouse screw conveyor system;

s) install constant head kiln feed low level alarm;

t) install kiln feed elevator low amperage alarm;

u) install new cleaning cycle timer for kiln baghouse;

v) install new solenoid valves for baghouse cleaning system;

w) install new baghouse inlet pressure sensor;

x) install motor actuated flow control gate on discharge of kiln feed elevator 707E2;

y) install new baghouse reverse air fan damper positioner;

z) redesign and install new reverse air fan controller;

aa) install new vibration analyzers for kiln ID fan and reverse air fan;

bb) install new kiln exhaust gas tempering air damper positioner;

cc) redesign clinker cooler dust discharge tipping valve sequencing;

dd) redesign instrumentation for clinker cooler baghouse fans and screw conveyors;

ee) install new pressure sensor on clinker cooler vent system multiclone;

ff) install new thermocouple on clinker cooler baghouse inlet;

gg) install new thermocouples on clinker cooler grates;

hh) install new natural gas flow meter; and

ii) install new closed circuit television monitoring system on the kiln.

In addition to the items listed above, the Crestmore NOx Research Project hardware was designed, purchased, and installed to monitor the effects on NOx emissions resulting from the modifications listed above.

EQUIPMENT DESCRIPTION AND FUNCTION

There are 45 analog input signals from the kiln system and environment that are monitored by the NOx system. These signals are supplied to a Kaye "Digilink" multiplexer which transforms the analog signals to digital signals and then transfers these signals to an IBM-PC. The IBM-PC records these signals, performs various calculations on the values supplied, and supplies selected data to three printers which generate a hard copy of the selected data.

KAYE DIGILINK

The digilink is a device which recieves analog signals from field instrumentation and converts the analog signals to digital signals. The Digilink calculates a six minute running average of the 45 field signals and, at the end of the six minute time period, multiplexes these accumulated data to an IBM-PC.

IBM-PC COMPUTER

The IBM-PC has two, double sided, double density floppy disk drives. The IBM-PC performs various calculations on the data supplied by the Digilink, records the raw data and the calculated figures on one of the floppy disks, and supplies selected data to each of three printers for a hard copy record of these selected data.

PROCESS ENGINEER'S PRINTER

This printer provides a hard copy of all of the 45 field signals and all of the calculated values from the IBM-PC. On December 19, 1984, a revision was made to the output program of the IBM-PC which resulted in the calculation of an eight hour shift average of selected field signals and calculated values. These eight hour averages are also printed out on the process engineer's printer and are available for use as a tool to aid in the diagnoses of reasons for changes in the generation of NOx in the Crestmore kiln.

SCAQMD PRINTER

This printer is dedicated to printing the NOx per ton of clinker each six minutes the kiln is operating above a predetermined range and a 24 hour average of the NOx per ton. This printer is dedicated to generating the data requested by the SCAQMD in a hard copy form.

CONTROL ROOM PRINTER

This printer is located in the kiln control room and prints selected field signals and calculated values every six minutes. The purpose of this printer is to provide information to the control room operator in the hope that this information may aid in the operation of the kiln.

FIELD INSTRUMENTATION

All of the field instruments, associated with the NOx Research Project, supply raw field data to the Kaye Digilink for six minute averaging. The following is a list of the 45 field signals supplied to the Kaye Digilink.

1. AMBIENT AIR TEMPERATURE

The ambient air temperature is measured by a thermocouple, calibrated for a range of 0 - 150 degrees F. The ambient air temperature is supplied to the Kaye Digilink for use in the calculation of several values relating to the quantity of NOx being generated in the kiln.

2. PPM OF NO AT THE I.D. FAN OUTLET

The NOx content of the kiln exit gases is measured by a Lear Siegler NOx analyzer. The analyzer is located at the outlet of the I.D. fan and can measure NOx in the range of 0 - 1500 ppm. This analyzer is an "in situ" gas analyzer.

3. PPM OF SO2 AT THE I.D. FAN OUTLET

The SOx content of the kiln exit gases is measured by a Lear Siegler SOx analyzer. The analyzer is located at the outlet of the I.D. fan and can measure SOx in the range of 0 - 1500 ppm.

4. PERCENT OXYGEN AT THE I.D. FAN OUTLET

The oxygen content of the kiln exit gases is measured by a Lear-Siegler oxygen analyzer located at the I.D. fan outlet. The oxygen analyzer can measure oxygen in the range of 0 - 25 percent.

5. TEMPERATURE AT THE I.D. FAN OUTLET

A type "J" thermocouple is used to measure the gas temperature at the I.D. fan. The thermocouple can measure temperature in a range of 0 - 1000 degrees F.

6. KILN BAGHOUSE INLET PRESSURE

The kiln baghouse inlet pressure is measured over a range of 0 - 10 inches water column by a pressure transmitter located in the inlet duct to the baghouse.

7. I.D. FAN SPEED

The I.D. fan speed is measured over a range of 0 - 750 RPM.

8. I.D. FAN AMPERAGE

The amperage of the I.D. fan drive motor is measured over a range of 0 - 200 amps.

9. KILN ROTATIONAL SPEED

The rotational speed of the kiln is measured over a range of 0 - 88 RPH.

10. KILN DRIVE MOTOR AMPERAGE

The amperage of the two kiln drive motors is measured in a range of 0 - 1500 amps. The amperage of the kiln drive motors may provide an indication of the temperature inside the kiln.

11. TEMPERATURE AT THE KILN EXIT

The temperature of the gases at the kiln exit is measured by a type "J" thermocouple calibrated for a range of 0 - 1000 degrees F.

12. KILN EXIT GAS PRESSURE

A pressure transmitter, calibrated for a range of -5 to 0 inches water column, is used to measure the kiln exit gas pressure.

13. OXYGEN CONTENT OF THE KILN EXIT GASES

The oxygen content of the kiln exit gases is measured by a Bailey oxygen analyzer calibrated for a range of 0 - 5 percent oxygen.

14. KILN RAW FEED RATE

The raw kiln feed rate is measured by a Sankyo brand impact flow meter. The Sankyo impact flow meter is calibrated for a range of 0 - 120 tons per hour.

15. PRESSURE OF THE PRIMARY SWIRL AIR

The pressure of the swirl air on the Pillard Type VR 3-

7 burner pipe is measured by a pressure transmitter, located in the swirl air supply line, calibrated for a range of -5 to +50 inches water column.

16. PRESSURE OF THE PRIMARY AXIAL AIR

The pressure of the axial air on the Pillard Type VR 3-7 burner pipe is measured by a pressure transmitter, located in the axial air supply line, calibrated for a range of -5 to +30 inches water column.

17. AMPERAGE OF THE CLINKER COOLER FANS

The amperages of the five clinker cooler fans are measured. The range of the sensing elements for fans FA 5 through FA 8 is 0 - 150 amps. The amperage of fan FA 9 is measured over a range of 0 - 200 amps.

18. UNDERGRATE PRESSURE OF THE UPPER GRATES

The air pressure in the first clinker cooler undergrate compartment is measured over a range of 0 - 20 inches water column by a pressure transmitter.

19. UNDERGRATE PRESSURE OF THE LOWER GRATES

The air pressure in the lower clinker cooler undergrate compartments is measured over a range of 0 - 20 inches water column by a pressure transmitter.

20. UPPER GRATE DRIVE MOTOR AMPERAGE

The amperage of the upper grate drive motor is measured over a range of 0 - 50 amps.

21. LOWER GRATE DRIVE MOTOR AMPERAGE

The amperage of the lower grate drive motor is measured over a range of 0 - 50 amps.

22. KILN DISCHARGE HOOD PRESSURE

The air pressure inside the kiln discharge hood is measured by a pressure transmitter calibrated for a range of -0.5 to +0.5 inches water column.

23. COAL CONVEYING AIR PRESSURE

The outlet pressure of the pulverized coal transport blower is measured by a pressure transmitter calibrated for a range of 0 - 7 PSIG.

24. COMBUSTIBLES CONTENT OF THE KILN EXIT GASES

The percent of combustibles in the kiln exit gases is measured by a Bailey combustibles analyzer calibrated for a range of 0 - 5 percent.

25. CLINKER TEMPERATURE AT THE COOLER DISCHARGE

The temperature of the clinker being discharged from the clinker cooler is measured by a thermocouple calibrated for a range of 0 - 300 degrees F.

26. TEMPERATURE OF THE SECONDARY AIR

A type "J" thermocouple, calibrated for a range of 0 - 2000 degrees F., is used to measure the temperature of the preheated combustion air supplied by the clinker cooler.

27. PRIMARY AIR BLOWER MOTOR AMPERAGE

The amperage of the motor that powers the primary air blower is measured over a range of 0 - 200 amps.

28. CLINKER COOLER DUST COLLECTOR AMPERAGE

The combined amperage of all electrical equipment associated with the clinker cooler dust collector is measured over a range of 0 - 1500 amps.

29. CLINKER COOLER VENT TEMPERATURE

The temperature of the air vented from the clinker cooler is measured by a type "J" thermocouple calibrated for a range of 0 - 1000 degrees F.

30. PRESSURE DROP ACROSS THE CLINKER COOLER VENT AIR CYCLONE

A pressure transmitter, calibrated for a range of 0 - 10 inches water column, is used to measure the pressure drop across the Barron multiclone in the clinker cooler vent air system.

31. CLINKER COOLER DUST COLLECTOR INLET TEMPERATURE

A type "J" thermocouple, calibrated for a range of 0 - 1000 degrees F., is used to measure the inlet temperature to the clinker cooler dust collector.

32. KILN DUST FEED RATE

A Sankyo impact flow meter, calibrated for a range of 0 - 50 tons per hour, is used to measure the rate that kiln dust is returned to the kiln.

33. COAL FEED RATE TO THE KILN

The rate that pulverized coal is supplied to the kiln for combustion is measured by a Sankyo impact flow meter which is calibrated for a range of 0 - 15 tons per hour.

34. TEMPERATURE OF THE BURNING ZONE

The temperature of the burning zone is measured by a two color, optical, infrared pyrometer, calibrated for a range of 1800 - 3200 degrees F.

35. OUTLET TEMPERATURE OF THE COAL MILL HOT AIR CYCLONE

The outlet temperature of the hot air cyclone between the clinker cooler and the Raymond coal mill is measured by a type "J" thermocouple, calibrated for a range of 0 - 1000 degrees F.

36. INLET TEMPERATURE OF THE RAYMOND COAL MILL

A type "J" thermocouple, with a range of 0 - 500 degrees F., is used to measure the temperature of the air stream at the inlet to the Raymond coal mill.

37. INLET PRESSURE OF THE RAYMOND COAL MILL

A pressure transmitter, with a range of -10 to 0 inches water column, is used to measure the pressure of the air stream at the inlet to the Raymond coal mill.

38. OUTLET TEMPERATURE OF THE RAYMOND COAL MILL

A thermocouple, calibrated for a range of 0 - 200 degrees F., is used to measure the temperature of the air stream at the outlet of the Raymond coal mill.

39. OUTLET PRESSURE OF THE RAYMOND COAL MILL

A pressure transmitter, calibrated for a range of 0 to 20 inches water column, is used to measure the pressure of the air stream at the outlet of the Raymond coal mill.

40. COAL FEED RATE TO THE RAYMOND COAL MILL

A load cell type belt scale, calibrated for a range of 0 - 15 tons per hour, is used to measure the raw coal feed rate to the Raymond coal mill.

41. KILN FEED END COOLING WATER SPRAY

A flow meter with a range of 0 - 100 gallons per minute is used to measure the quantity of cooling water that is sprayed into the feed end of the kiln to regulate the exit gas temperature.

42. INDIRECT FIRING SYSTEM I.D. FAN AMPERAGE

The amperage of the indirect coal firing system induced draft fan motor is measured over a range of 0 - 300 amps.

HISTORY OF NOx CALCULATIONS AND HEAT BALANCE EQUATIONS

RIVERSIDE CEMENT COMPANY
A Gifford-Hill Company
Riverside, California

Prepared By : Craig Phillips
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Riverside CA

Date : November 1, 1985

INTRODUCTION

In an effort to obtain a reasonable means of measuring NOx and of quantifying the parameters which could effect the production of NOx emissions, a series of computer programs were developed for the IBM PC and IBM AT. The process of data collection on the DigiLink has already been well-documented and this report will attempt to summarize the computer procedures for storage and analysis after the data has been dumped from the DigiLink.

There has been considerable evolution of the data analysis and computations from the inception of the monitoring program - from the early phases of determining exactly what data would be needed for a proper analysis to the later phases of statistically analyzing the data which has been produced.

CHRONOLOGY

The following is a chronology of the development of the "NOx equations" and the present reporting formats.

01/15/82	Prepared initial list of required calculations. Developed "engineering constants" for kiln operations. These constants are actually factors which vary over long periods of time, but for a short-term basis are considered constant, e.g., the heat content of coal.
03/05/82	Began developing heat balance equations for NOx calculation using the "Latchem" equations.
03/15/82	Completed selection of monitoring system equipment.
03/31/82	Completed selection of 48 data points (raw data signals) to be collected by the DigiLink and dumped to the IBM PC for storage and analysis. Selection parameters included necessity of data for NOx calculation and siginificant representation of kiln operating conditions.
04/13/82	Completed flow diagrams for the kiln system, including location and identification of new and current instrument loops. Coordinated loops with DigiLink channels.
04/25/82	Completed development of NOx calculation (see Figure 1).
05/01/82	Programmed DigiLink for NOx calculation to be reported as an instantaneous signal, as well as a 5 minute average.
06/30/82	Completed DIGIED.MEN - used for using IBM PC to edit DigiLink equations and standards.
07/01/82	"Day 1" programmed into DigiLink. Initiated use of six(6)

	minute averages as a compromise between representative "current" data and storage capacity of the IBM PC hard disk.
07/15/82	Completed CHART1 - used for output of DigiLink raw data dumps to the CRT in tabular form.
07/31/82	Completed CHART2 - used for output of DigiLink raw data in a graphical trend plot on the CRT. Allows up to three(3) parameters to be shown point by point over a 60 minute window.
08/10/82	Completed CHART3 - used for output of DigiLink raw data as a bar chart deviation from pre-established set points of up to 22 parameters.
09/10/82	Completed CHART4 - output of DigiLink raw data in selected graphical process flow diagrams.
09/15/82	Completed design of SCR files used for compilation and storage of DigiLink raw data signals.
09/16/82	Completed NOX.MEN. Original format included only the menu portion of the program which allowed user access to DigiLink editing, CHART data editing, establishing communications links, running the data collection program, etc.
09/20/82	Completed MASTER.EDI - used for editing CHART data labels, ranges, etc.
09/30/82	Compiled CHART1 through CHART4 and SCR file compilation into one program - MASTER.RUN.
10/20/82	Completed NOX.REP which allowed the generation of hourly, daily and monthly compilations of the NOx calculation.
10/29/82	Finalized format of MASTER.NAM - CHART data.
11/15/82	Incorporated light pen on Control Room CRT for selection of screen output.
12/01/82	Completed heat balance equations of kiln and coal mill (see Figure 2).
01/15/83	Because the primary software developer was leaving Riverside Cement, it was decided to compile all data logging, CRT display and data storage into one self-running program called NOX.MEN.
01/25/82	Completed data logging format to the Production Log.
02/20/83	Completed data logging format to the Process Engineer's Log.

04/29/83	Completed NOX.MEN conversion.
11/82 - 9/84	Kiln down.
07/26/84	Completed new kiln heat balance equations using "Burgard" equations. Incorporated into NOX.MEN. Reorganized SCAQMD report to reflect six(6) minute averages.
08/31/84	Added shift summaries to Production Log and Process Engineer's Log. Refined data collection from DigiLink. Expanded Error Handling portion of NOX.MEN.
09/03/84	Began logging kiln production data.
10/24/84	Upgraded and modified Production Log to allow additional columns. Reorganized SCAQMD log to allow better reporting of 24 hour averages.
11/16/84	Modified NOX.MEN to better handle "out-of-range" readings. Adjusted calculated NOx to reflect true loss on ignition rather than a production factor for SCAQMD reporting only. Established data file for SCAQMD data so that hourly averages would not be lost during kiln downs. Streamlined printing subroutines.
12/24/84	Completed a partial statistical analysis report of selected raw and calculated data. This report attempts to bracket NOx emissions and correlate the NOx data with these selected parameters.
01/10/85	Began development of ANA.MEN, the analytical portion of the NOx project by completing a method of retrieving the SCR data and presenting it in identical format as the data log formats - PROCES.REP, PROD.REP and SCAQMD.REP.
02/02/85	Complete DSKANA.REP - used to determine the data contained in SCR files stored on consecutive floppy disks.
02/03/85	Completed revision of heat balance equations into matrix format - HTBALC.SYM (see Figure 3).
02/05/85	Completed HTBAL.REP - used to simulate DigiLink raw data signals and analyze the effect on the heat balance equations.
02/07/85	Completed ENGCON.REP - provides a method for modifying the engineering constants used in the heat balance equations.
02/10/85	Completed PLOT.REP - used for plotting data in a series of formats on an HP plotter, as well as providing linear and non-linear regression analysis.
02/25/85	Complete total reorganization of NOX.MEN, which included basic cleanup for clearer presentation; additional "time-

sharing" commands for maintaining the data base, printers, etc. without interrupting the data collection; handling out-of range readings; incorporation of HTBALC.SYM; capability for footnoting the SCAQMD report for highlighting kiln down times, etc.; allow changing of "engineering constants"; and refined error handling. Documentation for this final format is given in Figure 4.

06/05/85	Incorporated "newnox" calculation, which bypasses the bulky and sometimes inaccurate calculations in HTBALC.SYM. Calculation in Rule 1112 format (see Figure 5).
06/18/85	Developed procedure for transferring SCR data to Dallas for statistical analysis in the Burrough's main frame.
08/12/85	Completed all instrumentation corrections and began logging "good" data.
08/31/85	Incorporated KVB changes in NOx calculation which adjusts for air moisture (see Figure 6).
09/14/85	Incorporated final NOx calculation developed by Young, McMann and Phillips (see Figure 7).
09/17/85	Began development of CONVRT.MEN - a menu-driven series of programs originating in ANA.MEN. Used for converting SCR files to DAL files, i.e., a format easily read by the main frame for statistical work.
09/19/85	Completed COPY.UTI - used for transfering SCR data to IBM AT hard disk. Locates disk media errors, and bad data.
09/22/85	Completed SETRNG.UTI - used to set exception limits for pre-screening data prior to building DAL files.
09/23/85	Completed EXCEPT.REP - used to generate a hard copy of a data scan of the SCR files and highlight data which falls outside of "normal" operating ranges.
09/26/85	Completed SCAN.UTI - incorporates Lotus 1-2-3 to view and modify SCR data. Includes plotting capabilites and "erase" functions.
10/02/85	Completed DAL.UTI - used to convert SCR files which have been scanned for "reasonable" data (PRN files) to the DAL format and create floppy disks for transmittal to Dallas.
10/14/85	Completed 24AV.REP - used to display and produce hard copy of daily averages in DAL format for available SCR files.
10/30/85	Completed conversion of 72 days of "good" SCR data to DAL format.

FIGURE 1 : NOx Calculation incorporated on April 25, 1982.

NO/NOX CALCULATIONS

Constant K1: $K1 = .55/1.55 \left[\frac{2000 \times 379}{60 \times 44}\right] = 101.88$

Where .55/1.55 is 35.4% loss from kiln feed of CO_2, 2000/60 is pounds per min., 379 is a gas constant, & 44 is molecular weight of CO_2.

Constant K2: $K2 = 2000/60 \left[10.5/.97 \times .0767 \times 1.04\right] = 431.78$
Where 2000/60 is pounds per min., 10.5 is one pound of coal + 9.5 pounds of air, .97 is correction for elevation, .0767 is density of air, & 1.04 is ratio of air & combustibles.

Constant K3: $K3 = 1/21 + 1 \times 100 = 5.76$
Where 1/21 is 0% O_2 divided by 21% O_2, + 1 & x 100 is for linearizing.

Constant K4: $K4 = 30/379 \times .97 = .0767$
Where 30 is molecular weight of nitrogen (14) + that of oxygen (16), 379 is a gas constant, & .97 is correction for elevation.

Calculation ① : SCFM of CO_2 in exit gas volume = K1 x kiln feed tph.

Calculation ② : SCFM of products of combustion = K2 x dry coal feed tph.

Calculation ③ : SCFM of excess air at kiln exit = [% O_2 at analyzer/100] + ① + ② x K3

Calculation ④ : Total SCFM of dry kiln exit gases = ① + ② + ③

Calculation ⑤ : SCFM of O_2 at NOX source = [% O_2 at NOX source - % O_2 at analyzer] / [.21 - % O_2 at NOX source] + 1 x ④

Calculation ⑥ : Infiltration SCFM from kiln ID fan exit = ⑤ - ④

Calculation ⑦ : ACFM of NOX = [Temp. at NOX source + 460/520] x ⑤

Calculation ⑧ : Pounds of NO per min. = K4 x % NOX at analyzer x ⑤

Calculation ⑨ : Pounds of NO per ton of clinker = [⑧ x 60/kiln feed tph] /1.55

FIGURE 2 : Heat Balance equations as of Decemeber 1, 1982

```
1000 '
1010 '
1020 '
1030 '**************************************
1040 '*   HEAT BALANCE OF #2 GREY KILN      *
1050 '**************************************
1060 '
1070 '
1080 '
1090 DIM A(48),FANDAT(10)
1100 CLS:E1=10.5:E2=6!:E3=1!
1101 A(1)=100:A(17)=82:A(18)=90:A(19)=82:A(20)=99:A(21)=154
1102 A(33)=750:A(34)=4:A(45)=1:A(40)=150:A(14)=80*2000/60:A(28)=A(14)/1.55
1103 KCALBH=870000!:KCALPIPE=480000!
1109 STOP
1110 DEF FNC(CHAN)=A(CHAN-84*(CHAN\100)-16)
1120 DEF FNHTCON(CHAN)=.249-5.3/FNC(CHAN)
1199 GOTO 2000
1200 OPEN "B:
1210 INPUT
2000 '
2010 '
2020 '
2030 '***********************************
2040 '*   CLINKER COOLER HEAT INPUT     *
2050 '***********************************
2060 '
2070 '
2080 '
2090 FOR I=1 TO 5
2100 READ ROCAL,FULD,MOHP,MAXFLO
2110 HP=FNC(200+I)*MOHP/FULD
2120 IC=0
2130 FOR J=0 TO 10
2140 IF IC=0 THEN L1=FANDAT
2150 READ FANDAT
2160 IF (IC=0 AND HP>FANDAT) OR IC=1 THEN 2190
2170 L2=FANDAT:IC=1:JL=J-1
2190 NEXT J
2200 ACFM(I)=MAXFLO*100*(JL+(HP-L1)/(L2-L1))*ROCAL
2210 NEXT I
2220 UNGRTIN=0:FOR I=1 TO 5:UNGRTIN=UNGRTIN+ACFM(I):NEXT I
2230 TOTIN=FNC(212)*638+UNGRTIN*FNHTCON(101)
3000 '
3010 '
3020 '
3030 '**************************************
3040 '*    CLINKER COOLER HEAT OUTPUT      *
3050 '**************************************
3060 '
3070 '
3080 '
3090 CLKREX=FNC(212)*FNHTCON(213)
3100 VENSTK=KCALBH*SQR(FNC(302)/(460+FNC(301)))
3110 GOSUB 4000
3120 TOCOAL=MASFLO*FNHTCON(213)
3130 RADHT=TOTIN*.015
3140 SECHTIN=TOTIN-(CLKREX+VENSTK+TOCOAL+RADHT)
3150 SECWT=UNGRTIN-TOCOAL-VENSTK
3160 SECHTCON=SECHTIN/SECWT
3170 SECTEMP=(SECHTCON+5.3)/.249
3180 LB TON=UNGRTIN/FNC(212)
3999 STOP
4000 '
4010 '
4020 '
4030 '**************************************
4040 '* HEAT BALANCE FOR RAYMOND COAL MILL *
4050 '**************************************
4060 '
4070 '
4080 '
4090 COALDRY=FNC(312)*(1-E2/100)
4100 MOIST1=FNC(312)*E2/100
4110 MOIST2=COALDRY*((E3/100)/(1-E3/100))
4120 MOIST3=MOIST1-MOIST2
4130 MILOUTHT=FNHTCON(311):AMBHT=FNHTCON(101):MILINHT=FNHTCON(308):CYCHT=FNHTCO
(307):COOLHT=FNHTCON(306)
4140 PRIMAIR=KCALPIPE*SQR(FNC(313)/(460+FNC(308)))
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FIGURE 2 : (continued)

```
4160 'MOISTURE IN COAL CONTRIBUTES TO "PRIMAIR" BUT IS MINOR AND IS IGNORED:
4170 'TO CALCULATE=MOIST3*(379/18)*((460+FNC(311))/520)
4180 '
4190 SENSHTML=COALDRY*.3*(FNC(311)-FNC(101))
4200 SENSHTLQ=MOIST2*1.1*(FNC(311)-FNC(101))
4210 SENSHTVP=MOIST3*(212-FNC(101)+970-(212-FNC(311))*.4)
4220 SENSHTAR=PRIMAIR*MILOUTHT
4230 MILTOTHT=SENSHTML+SENSHTLQ+SENSHTVP+SENSHTAR
4240 MILLIN=((MILLOTHT/PRIMAIR)-AMBHT)/(MILINHT-AMBHT)
4250 MILLFLO=MILLIN*PRIMAIR
4260 MILLINF=1-MILLIN:IF MILLINF).2 THEN PRINT "HIHO"
4270 INFLO=MILLINF*PRIMAIR
4280 CYC=(1.1*MILINHT-AMBHT)/(CYCHT-AMBHT)
4290 CYCEXFLO=CYC*MILLFLO:TMPMIL=1-CYC
4300 COOLOUT=(1.1*CYCHT-AMBHT)/(COOLHT-AMBHT)
4310 MASFLO=COOLOUT*CYCEXFLO:TMPCYC=1-COOLOUT
4500 RETURN
10000 '
10010 '
10020 '
10030 '********************************
10040 '*       FAN CURVE DATA           *
10060 '*  CALIBRATION DENSITY,
10070 '*  MOTOR FULL LOAD AMPS,
10080 '*  MOTOR RATED HORSEPOWER,
10090 '*  FAN CURVE MAXIMUM AIR FLOW (1000 CFM),
10100 '*  HP AT 1/10 POINTS OF AIR FLOW
10110 '********************************
10120 '
10130 '
10140 '
10150 '****FAN 3-2
10160 DATA .0712,122,100,36,26,30.5,44,56.5,67.5,78,86.5,93.5,98,99,96
10170 '****FAN 13-2
10180 DATA .0675,112,100,40,21,31,46,62.5,80,96.5,112.5,127.5,142.5,157.5,174
10190 '****FAN 4-2
10200 DATA .0675,91.5,75,36,26,32,42,54,62,77,88,96,100,108,120
10210 '****FAN 5-2
10220 DATA .0674,127,100,60,28,40,52,65,78,87,92,97,98,95,87
10230 '****FAN 6-2
10240 DATA .0674,188,150,120,38,55,73,93,109,123,130,132,128,121,107
```

FIGURE 3 : Heat Balance equations and NOx calculation as of February 3, 1985

```
100 '
101 '**************  HEAT BALANCE OF KILN/COAL MILL  ***************
102 '
110 'E(1)=.01
120 C(1)=(VM(37)*2000/60)*(1-E(1))
130 'E(2)=.7305
140 'E(3)=.0543
150 'E(4)=.0095
160 'E(5)=.1057
170 'E(6)=.0933
180 C(2)=E(3)-(E(5)/7.937001)
190 'E(7)=.0065
191 'E(12)=14093*E(2)+51623!*C(2)+3983*E(7)
192 CMW=12.011:H2MW=2.016:H2OMW=18.016:O2MW=32:N2MW=28.016:SMW=32.066
193 INRTMW=28.163:AIRMW=28.965:AIRO2=.209
194 'E(16)=.00347
196 RTO2=(1-AIRO2)/AIRO2
197 INERT=RTO2*INRTMW/O2MW
200 '
201 '****************  REQ. FOR COMB. AT 0% EXCESS O2  ***************
202 '
210 C(3)=O2MW*(E(2)/CMW+E(3)/(2*H2MW)-E(5)/O2MW+E(7)/SMW)*C(1)
211 'C(3)=(2.664*E(2)+7.936001*C(2)+1.142*E(4)+.998*E(7))*C(1)
220 C(4)=INERT*C(3)+E(4)*C(1)
221 'C(4)=3.2543*C(3)
230 'C(3)=952.8313
240 C(5)=0
241 'C(5)=.0579*C(3)
250 C(6)=E(16)*(1+INERT)*C(3)+VM(37)*E(1)*2000/60+(E(5)*H2OMW/(O2MW/2))*C(1)
251 'c(6)=.01495*c(3)+vm(37)*e(1)*2000/60+(e(5)*8.936001/7.937001)*c(1)
260 C(7)=C(1)*E(6)
270 C(8)=(1+E(16))*(1+INERT)*C(3)
271 'C(8]=4.3271*C(3)
280 C(9)=C(6)+8.936001*C(2)*C(1)
290 C(10)=(CMW+O2MW)/CMW*E(2)*C(1)+VM(14)*(1-E(11))*(1-1/E(13))*2000/60
291 'C(10)=3.664*E(2)*C(1)+VM(14)*(1-E(11))*(1-1/E(13))*100/3
300 C(11)=C(8)*10.73*520/(14.696*28.9)
310 C(12)=VM(13)*(C(4)/INRTMW+C(10)/(CMW+O2MW))
311 'C(12)=VM(13)*(C(4)/28.013+C(10)/44.01+C(5)/39.675)/(100/32-VM(13)*.14888)
312 C(12)=C(12)/(100/O2MW-VM(13)*(1+INERT)/AIRMW)
320 IF VM(13)>20 THEN C(12)=1000
330 C(13)=(1+E(16))*(1+INERT)*(C(3)+C(12))
331 'C(13)=4.3271*(C(3)+C(12))
340 C(14)=1000:IF C(1)<1 THEN 2360
350 C(14)=C(13)/C(1)
360 C(15)=1000:IF C(3)<1 THEN 2380
370 C(15)=C(12)*100/C(3)
380 C(16)=C(12)/O2MW+(C(4)+INERT*C(12))/INRTMW+C(10)/(CMW+O2MW)+C(9)/H2OMW
381 '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)
390 C(17)=C(16)*385.3
391 'C(17)=C(16)*379.48
400 C(18)=21:IF C(16)<1 THEN 2420
410 C(18)=(C(12)/O2MW)*100/C(16)
411 'C(18)=(C(12)/32!)*100/C(16)
420 C=AIRO2/(1+E(16)*AIRMW/H2OMW)
421 'C(19)=.20874*((C(16)+(VM(45)*8.3453/18.015))*(VM(4)/100)-(C(16)*C(18)*.01)
/(.20874-VM(4)/100)
422 C(19)=C*((C(16)+(VM(45)*8.3453/H2OMW))*(VM(4)/100)-(C(16)*C(18)/100))/(C-VM
```

FIGURE 3 : (continued)

```
(4)/100)
2430 IF C(19)>1000 THEN C(19)=1000
2440 C(20)=C(12)+C(19)*O2MW
2441 'C(20)=C(12)+C(19)*32!
2450 C(21)=C(16)-(C(9)/H2OMW)+C(19)*(1+RTO2)
2451 'C(21)=C(16)-(C(9)/18.015)+C(19)*(1+(.77598+9.739999E-03)/.20874)
2460 C(22)=C(21)+(VM(45)*8.3453+C(9))/H2OMW
2461 'C(22)=C(21)+(VM(45)*8.3453+C(9))/18.015
2470 C(23)=C(22)*385.3
2471 'C(23)=C(22)*379.48
2480 C(24)=VM(2)*.000001*30*C(22)
2481 'C(24)=((VM(2)*14.696*32.4/(10.73*520))*.000001)*C(21)*379.48
2490 C(25)=C(24)*46/30
2491 'C(25)=VM(2)*C(21)*46:'C(25)=C(24)*46/30.01
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)))
2503 'C(26)=C(25)/(VM(14)*(1-E(11))*(1/E(13))/60)
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)))*1000000!
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 '
2591 '***************  COAL MILL BALANCE  *****************
2592 '
2600 C(31)=VM(44)*100/3
2610 C(32)=(VM(44)-VM(37))*100/3
2620 C(33)=10.4*VM(48)-295.9
2630 C(34)=C(33)-C(32)-6.7124
2640 C=VM(40)
2650 C(35)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3+6.951E-13*C^4-7.6193
2660 C=VM(42)
2670 C(36)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2680 C(37)=.4421*C+2.434E-05*C^2+1.0636E-08*C^3-2.043E-12*C^4-14.172
2690 C(38)=VM(1)+30
2700 C=C(38)
2710 C(39)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2720 C=VM(38)
2730 C(40)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2740 C(41)=C(1)*(C(38)-32)*.3
2750 C(42)=C(31)*.0795873
760 C(43)=C(42)*(C(38)-32)
770 C(44)=C(41)+C(43)
780 C(45)=C(1)*(140-32)*.3
790 'E(8)=454
800 C(46)=C(34)*C(36)
810 C(47)=C(32)*971.3
820 C(48)=C(32)*C(37)
830 C(49)=C(45)+E(8)+C(46)+C(47)+C(48)
840 C(50)=100:IF C(39)=C(35) OR C(34)<1 THEN 2860
850 C(50)=(C(49)-C(44)-C(34)*C(35))*100/(C(34)*(C(39)-C(35)))
860 C(51)=1000:IF C(40)=C(39) THEN 2880
870 C(51)=C(34)*(C(35)-C(39))/(C(40)-C(39))
880 C(52)=100:IF C(42)<1 THEN 2900
890 C(52)=C(32)*100/C(42)
900 '
901 '*****************  CLINKER COOLER BALANCE  ********************
```

FIGURE 3 : (continued)

```
2902 '
2910 C(53)=VM(17)*100/122
2920 C(54)=VM(18)*100/112
2930 C(55)=VM(19)*100/91.5
2940 C(56)=VM(20)*100/127
2950 C(57)=VM(21)*100/188
2960 C(58)=.07:IF VM(1)>400 THEN 2980
2970 C(58)=38.396/(460+VM(1))
2980 C(59)=0:IF C(53)<2 THEN 3000
2990 C(59)=VM(17)*1.8868E-05*(460+VM(1))*(7.49*LOG(C(53))+57.66)*(.0002*C(53)+.8
3)
3000 C(60)=0:IF C(54)<2 THEN 3020
3010 C(60)=VM(18)*1.9153E-05*(460+VM(1))*(7.49*LOG(C(54))+57.66)*(.0002*C(54)+.8
3)
3020 C(61)=0:IF C(55)<2 THEN 3040
3030 C(61)=VM(19)*1.7537E-05*(460+VM(1))*(6.15*LOG(C(55))+63.1)*(.0002*C(55)+.87
50001)
3040 C(62)=0:IF C(56)<2 THEN 3060
3050 C(62)=VM(20)*1.6622E-05*(460+VM(1))*(7.49*LOG(C(56))+57.66)*(.0002*C(56)+.8
3)
3060 C(63)=0:IF C(57)<2 THEN 3080
3070 C(63)=VM(21)*1.6608E-05*(460+VM(1))*(7.39*LOG(C(57))+58.39)*(.0003*C(57)+.8
3)
3080 C(64)=476*C(59)-19620:IF C(59)>75 THEN 3100
3090 C(64)=305*C(59)+1.3*((C(59)-62.5)^2)-6671
3100 C(65)=235.3*C(60)-2824
3110 C(66)=312.9*C(61)-6033
3120 C(67)=632*C(62)+10.8*((C(62)-83)^2)-25690:IF C(62)>75 THEN 3140
3130 C(67)=447.4*C(62)-11281
3140 C(68)=966*C(63)+12.5*((C(63)-117.5)^2)-58460!:IF C(63)>110 THEN 3160
3150 C(68)=652.3*C(63)+3.1*((C(63)-90)^2)-24716
3160 C(69)=0:IF VM(34)<1.5 THEN 3180
3170 C(69)=EXP(LOG(VM(34)/.000005)/1.75)
3180 C(70)=VM(14)*(1-E(11))*(1/E(13))*100/3
3190 C(71)=(C(64)+C(65)+C(66)+C(67)+C(68))*C(58)
3200 C(72)=C(71)-C(51)-C(69)
3210 'E(9)=638.0741
3220 C(73)=.2057*VM(29)+.0000217*((VM(29)-340)^2)-9.82
3230 C(74)=C(70)*E(9)
3240 C(75)=C(71)*C(39)
 250 C(76)=C(70)*C(73)
 260 C(77)=.1*(C(74)+C(75))
 270 C(78)=C(51)*C(40)
 280 C(79)=C(69)*C(36)
 290 C(80)=1000:IF C(72)<10 THEN 3310
 300 C(80)=(C(74)+C(75)-C(76)-C(77)-C(78)-C(79))/C(72)
 310 C(81)=0:IF C(80)<-1000 THEN 3330
 320 C(81)=(-.2383+SQR((.2383^2)+4*4.979E-06*C(80)))/(2*4.979E-06)
 330 C(82)=0:IF C(74)+C(75)<1000 THEN 3350
 340 C(82)=(C(78)+C(72)*C(80))*100/(C(74)+C(75))
 350 C(83)=0:C(84)=0:C(85)=0:C(86)=0:C(87)=0:IF C(70)<10 THEN 3410
 360 C(83)=C(71)/C(70)
 370 C(84)=C(72)/C(70)
 380 C(85)=C(51)/C(70)
 390 C(86)=C(69)/C(70)
 400 C(87)=C(83)+C(84)+C(85)+C(86)
 410 '
 411 '*******************  KILN BALANCE  ************************
 412 '
 420 C(88)=4.75*VM(31)-61.1
```

FIGURE 3 : (continued)

```
3430 C(89)=-2.31*VM(27)+158.1
3440 C(90)=C(13)-C(72)-C(88)-C(89)
3450 C(91)=0:IF C(72)<10 THEN 3470
3460 C(91)=C(88)/C(72)
3470 C(92)=0:C(93)=0:C(94)=0:IF C(13)=<10 THEN 3510
3480 C(92)=C(88)*100/C(13)
3490 C(93)=C(72)*100/C(13)
3500 C(94)=C(90)*100/C(13)
3510 C(95)=C(88)/.0763
3520 C(96)=C(72)/.0763
3530 C(97)=C(90)/.0763
3540 C(98)=C(89)/.0763
3550 C(99)=C(95)+C(96)+C(97)+C(98)
3560 C(100)=VM(1)+70
3570 C(101)=.2383*C(100)+4.979E-06*(C(100)^2)-7.619001
3580 C(102)=(.21*C(100)-6.72)*.9000001+(.24*C(100)-7.68)*.1
3590 C(103)=.3*(VM(1)+50)-9.600001
3600 C(104)=VM(1)+50
3610 C(105)=.4421*C(104)+2.4339E-05*(C(104)^2)-14.17
3620 'E(10)=19.1
3630 C(106)=.4421*C(100)+2.4339E-05*(C(100)^2)-14.17
3640 C=VM(11)
3650 C(107)=.2315*C+3.262E-05*C^2-6.0393E-09*C^3+5.6E-13*C^4-7.44
3660 C(108)=(.21*C-6.72)*.9000001+(.24*C-7.68)*.1
3670 C(109)=C(88)*C(39)
3680 C(110)=C(89)*C(39)
3690 C(111)=C(90)*C(101)
3700 C(112)=C(72)*C(80)
3710 C(113)=C(1)*E(12)
3720 C(114)=C(1)*C(103)
3730 C(115)=VM(14)*(1-E(11))*C(102)*100/3
3740 C(116)=VM(14)*E(11)*C(106)*100/3
3750 C(117)=VM(45)*8.3453*E(10)
3760 C(118)=C(109)+C(110)+C(111)+C(112)+C(113)+BH+C(114)+C(115)+C(116)+C(117)
3770 C(119)=1000:IF C(113)+C(112)<1000 THEN C(23)=0:GOTO 3790
3780 C(119)=C(112)*100/(C(113)+C(112))
3790 C(120)=C(16)*31.73665
3800 C(121)=C(120)*C(107)
3810 C(122)=C(120)*C(108)*.3
3820 C(123)=VM(45)*8.3453*971.3
3830 C(124)=C(70)*E(9)
3840 C(125)=C(70)*1124
3850 C(126)=C(121)+C(122)+C(123)+C(124)+C(125)
3860 C(127)=C(118)-C(126)
3870 C(128)=100:IF C(118)<1000 THEN 3890
3880 C(128)=C(127)*100/C(118)
3890 C(129)=0:IF VM(14)<1 THEN 3910
3900 C(129)=(VM(37)*(1-E(1))*2000*E(12)*E(13))/(VM(14)*(1-E(11)))
3910 '
3920 'E(14)=.35968
3922 'E(15)=.35
3930 C(130)=E(1)*2000/18.016
3932 C(131)=(1-E(1))*2000*E(14)
3934 C(132)=(C(130)+C(131))*VM(37)/60
3940 C(133)=E(11)*2000/18.016
3942 C(134)=(1-E(11))*2000*E(15)/44.01
3944 C(135)=(C(133)+C(134))*VM(14)/60
3950 C(136)=VM(45)*8.34/18.016
3960 C(137)=C(132)+C(135)+C(136)
3970 C(138)=VM(4)*C(137)/(20.88-VM(4))
```

FIGURE 3 : (continued)

```
3972 C(139)=C(137)+C(138)
3980 C(140)=(C(139)*VM(2)*46*60*E(13))/(VM(14)*(1-E(11))*1000000!)
3999 RETURN
```

FIGURE 4 : Documentation of NOX.MEN

Appendix III : NOX.MEN Internal Documentation

The following internal documentation is broken down by line number ranges with a brief description od what is accomplished in this area of the program. Every attempt was made to maintain the original variable names set up by Rob Burgard. Where a new variable is added, it is shown in brackets [].

The GOSUBs listed within the range are routines called from this line range. In some cases there is a description of how the program is setup, so that the program can be more easily modified if required.

Line Numbers	Description
1- 10	Documentation note. All internal documentation of the program is handled with a similar heading.
11- 42	Formats for the various reports. The column label is found immediately below the numeric format. Proper aligning when new columns are added can be accomplished by modifying these pairs of format lines concurrently. A further description of these lines are shown in Appendix IV.
1000- 1012	Set up of variables, arrays and user defined functions. GOSUB 9000: Sets up printers GOSUB 7000: Reads screen labels for raw data signals
1020- 1042	Establishes communications link and time/date handshake with DigiLink. GOSUB 8300: Clears communication buffer GOSUB 8400: Opens SCR file

This area also adds in a 10 second delay between the DigiLink and IBM PC for easier coordination and checking of the communications buffer.

Line 1040 - Programmer aid for checking output at various times. This line should normally be "REMed" out.

1100 Will not allow inappropriate entry into the program.

1130- 1199 Waits for keyboard input, report times or a full communications buffer. Prints time while waiting.

Line 1142 - Opens new SCR at 2 minutes past midnight.
Line 1146 - Prints Production Log Shift Summary and Statistical Report at Shift breaks.

GOSUB 4100: Update and print summaries

Line 1150 - Set up new production day by zeroing NOX.REP - GOSUB 7300
Line 1154 - Prints SCAQMD hourly report - GOSUB 6000

1164- 1199 CHECK FOR KEYBOARD INPUT - See Appendix II

Line 1168 - Return to system
Line 1170 - Change disks - GOSUB 7800
* Line 1172 - Print new screen - GOSUB 7100
Line 1174 - List SCR files - GOSUB 7200
* Line 1176 - Change printer formats - GOSUB 7700
* Line 1178 - Stats only On/Off - GOSUB 8500
* Line 1180 - Change Engineering Constants - GOSUB 8700
* Line 1182 - Check printer status - GOSUB 8600
* Line 1184 - Zero cumulative statistics data file GOSUB 8800

* New additions

2000- 2060 Reads communications buffer and checks for bad data input and out-of-range readings (so that the Heat Balance equations won't give screwy results).

Note: If a bad data signal is being put out by the DigiLink you should either

1) Put the DigiLink into "Simulate" mode for that channel, or

2) Adjust the reading in Lines 2030-2050. [VM(xx)] is the raw data signal.

Line 2060 - updates the screen:runs heat balance equations:prints production log:prints process engineer's log.

2100-	3910	HEAT BALANCE EQUATIONS. The equations have been converted to three(3) matrixed arrays: [C(xxx)] - One of the calculated variables. Refer to the attached listings of the Key. The line numbers for the [C] value is identical to the line number for the keyed variable name. The variable names are identical to those assigned by Rob in the original program. [E(xxx)] - An engineering constant. The "REMed" values are the original values used in the equations. These are updated with ANA.MEN [VM(xx)] - The raw data signals - unchanged from the original.
4000-	4500	PRODUCTION LOG
4000-	4030	Production Log output calculations. The [P] matrix is the [P]rintout matrix and works similarly in all the logs. The [P] value is assigned either a [C], [VM] or other calculated value and then printed out. GOSUB 8200: Production Log print format output
4040-	4054	Updates NOX.REP (daily shift report data) and SC.DAT (SCAQMD hourly data and cumulatives).
4100-	4240	Reads NOX.REP for the appropriate shift data and prints the report. GOSUB 8200: Production Log print format output Line 4190 - accumulates for average Line 4192 - calculates shift tonnage [TON]
4250-	4290	Prints averages and production total for shift GOSUB 8200: Production Log print format output
4300-	4392	At the appropriate time, the averages for the day are printed along with the daily tonnage. Line 4352 - accumulates for average Line 4354 - accumulates daily tonnage [TON]
4400-	4442	Prints averages for the day and total tonnage
4470-	4500	Prints new heading for Production Log.

5000-	5999	PROCESS ENGINEER'S LOG AND STATISTICAL REPORT
5000-	5036	Establishes [P] matrix - see previous description. In some cases, the [P] values from the Production Log are reassigned to the PEL [P] matrix. The [P] values established here are in the same format found in the SCR files. Line 5032 - This is where the "Stats Only" print option is detected. GOSUB 8000: PEL print format output
5040-	5052	Updates the SCR file.
5060-	5078	Reads the statistical data for the cumulative shift summary, STAT.NOX, and accumulates new input. Line 5065 - This is where the cutoff ranges for the stored data NOx values is determined.
5080-	5098	Establishes [P] matrix for the statistical report - see previous description.
5100-	5126	Assigns data to the appropriate range of NOx and updates STAT.NOX Line 5123 - cutoff range for the data which will be used in the statistical averages.
5500-	5532	Prints header for the statistical report.
5535-	5564	Prints shift averages for [P] matrix GOSUB 8000: PEL print format output.
5581-	5609	NOx range statistical shift printout. The averages within the range use all points which meet the cutoff criteria. The cumulative totals and sums of squares are also updated. Line 5605 - if the NOx level is less than 3.00 #/tn or greater than 10.00 #/tn, then the values are not included in the statistics. The number printed in parentheses is the total number of points collected. Line 5609 - [N8] refers to the above value. GOSUB 8100: Statistical Report print format output
5610-	5618	Prints the shift averages and standard deviations in PEL format. RPH and feedrate must be greater than 40 for the data to be included.
5620-	5639	Identical to Lines 5581-5618, except that the to-date cumulative values are used.

5640- 5648	Identical to Lines 5610-5618, except that the to-date cumulative values are used.
5660- 5666	Calculates and prints the correlation coefficients between [NOLB] and the different parameters. GOSUB 8150: Correlation Coefficient print format output
5680- 5999	Zeroes the shift cumulator in STAT.NOX and prints a new PEL heading.
6000- 6140	SCAQMD LOG Line 6130 - Updates daily accumulator - SC.DAT
7000- 9999	SUBROUTINES
GOSUB 7000	Reads screen raw data signal labels and formats from CHART.NAM Called only at Start Up.
GOSUB 7100	Prints above labels to screen. GOSUB 7400: Print raw data signals to screen. Called at any time screen needs to be updated, i.e. after data update or after the screen has been cleared in another subroutine.
GOSUB 7200	Lists SCR files found on B:drive. Called with - $ - only (see Appendix II).
GOSUB 7300	Zeroes shift data, NOX.REP Called at Start Up (on request - see Appendix I) and at the beginning of A-shift (see Line 1152 above).
GOSUB 7400	Updates the raw data signals to the screen. Called after data dumps from the DigiLink and from GOSUB 7300.
GOSUB 7500	Answers "Yes/No"-type questions and converts numeric answers to the appropriate format for processing. Called by GOSUB 7700 and GOSUB 7900.
GOSUB 7600	Tests communications buffer for good data. If the first data in the buffer is not in a "date:time:status" format sent by the DigiLink, then the buffer is emptied until this format is present.

	[Qx] - these are status flags to insure that these routines are not repeated interminably. These flags are used in other routines as well. Called at Start Up and at any time the buffer needs to be cleared before the next data signal arrives.
GOSUB 7700	Changes printer formats. Depending on the printer selected, this routine will input the appropriate control characters and send them to the printer along with a test pattern. Called at Start Up or - % - (see Appendix I and II for details).
GOSUB 7800	Allows replacement of the disk in B:drive without leaving the program. Properly closes the old disk and establishes the SCR file on the new disk. Called only with - ! -
GOSUB 7900	If a printer is found to be inoperative during Start Up or during a printer status check, this routine allows you to either restart the printer in question or permanently remove it from the printer queue. [PR] - used throughout the program to determine the status of a printer. This flag can be set automatically (see lines 20020, 20030 and 20040 below). Called at Start Up and - & -
GOSUB 8000	Process Engineer's Log print format output. This way of doing the format appears to be rather cumbersome, but is, in fact, very flexible for adding new columns (see Lines 11-42). Called from PEL processing.
GOSUB 8100	Statistical Report print format output. See previous comments.
GOSUB 8150	Correlation Coefficient print format output. See previous comments.
GOSUB 8200	Production Log print format output. See previous comments.
GOSUB 8300	Clears communication buffer whenever inappropriate data has been detected. Called during Start Up and GOSUB 7600. **Note:** The IBM PC is set up to buffer communications whether you are in NOX.MEN or not.

GOSUB 8400	Open SCR file at two(2) minutes past midnight, after a disk is changed or during Start Up. **Note:** When you find a SCR file with a strange day number, e.g. "00000", on a disk, it is because you called this routine without proper communications linkage with the DigiLink and IBM PC.
GOSUB 8500	Initiates the PEL option to either print all data signals in the PEL format or the Statistical Shift Reports only. [PRX] - Flag is set to "Stats Only" at Start Up. Called with - ^ - only.
GOSUB 8600	This routine closes all communications lines, reopens them and sends a test pattern. If a printer or the DigiLink is found to be faulty, you will be given an opportunity to change the status or remove it from the printer queue. GOSUB 9060: Initiate communication links Called during Start Up and with - & -
GOSUB 8700	Loads updated engineering constants prepared with ANA.MEN. Creates new ENG.CON file on A:Drive. Called only with - * -
GOSUB 8800	Zeroes or initiates all files for a new cumulative data base.
8830- 8858	Zero STAT.NOX
8860- 8876	Zero NOX.REP
8880- 8888	Zero SC.DAT Called only with - (-
GOSUB 9000	Initiates system and sets up screen.
9000- 9032	Selects Monochrome(green) or Auxilary screen. Selecting the latter will send a duplicate screen to the control panel. Line 9012 - Waits for approximately 30 seconds for input for this question. If there is no response, continues through Start Up with default values to the initial questions.
9040- 9044	Gets system date.
9050- 9054	Allows a zeroing of NOX.REP GOSUB 7500: Answer question GOSUB 7300: Zero NOX.REP

9060- 9064	Opens comm line to DigiLink [COM1:]
9065- 9069	Opens comm line to PEL [LPT1:] GOSUB 5702: Printers header test pattern
9070- 9075	Opens comm line to Production Log [COM2:] GOSUB 4480: Prints header test pattern
9075- 9079	Opens comm line to SCAQMD Log [LPT2:]
9082- 9999	Checks for correct printer format. GOSUB 7500: Answers question GOSUB 7700: Change printer format Line 9100 - Get NOx range labels.
10000- 10040	DATA for NOx range labels.
10100- 10150	A programmer aid for debugging the program is to use simulated data without the benefit of the DigiLink. Access to these DATA statements has been "REMed" out.
20000- 20900	ERROR HANDLING Line 20010 - Faulty DigiLink communications line Line 20020 - Faulty PEL communications line. Line 20030 - Faulty Production Log communication line. Line 20040 - Faulty SCAQMD communications line.
20050- 20054	Detects a faulty printer and automatically removes the printer from the print queue. Line 20060 - No ENG.CON file to update. Line 20070 - Bad date format. Line 20080 - Finds empty SC.DAT file. Line 20090 - Finds empty communications buffer. Line 20100 - Finds partially full SC.DAT file. Line 20900 - General error handling - Error number and line it occured on printed on screen.

FIGURE 5 : "newnox" calculation - used concurrently with previous calculation, as of June 6, 1985.

```
3900 '
3930 N(30)=E(1)*2000/18.016
3932 N(31)=(1-E(1))*2000*E(14)
3934 N(32)=(N(30)+N(31))*VM(37)/60
3940 N(33)=E(11)*2000/18.016
3942 N(34)=(1-E(11))*2000*E(15)/44.01
3944 N(35)=(N(33)+N(34))*VM(14)/60
3950 N(36)=VM(45)*8.34/18.016
3960 N(37)=N(32)+N(35)+N(36)
3970 N(38)=VM(4)*N(37)/(20.88-VM(4))
3972 N(39)=N(37)+N(38)
3980 N(26)=(N(39)*VM(2)*46*60*E(13))/(VM(14)*(1-E(11))*1000000!)
```

FIGURE 6 : KVB NOx calculation, as of August 31, 1985

```
.000 DIM C(200),MM(100),E(100),VM(50),R(50),K(50),N(50)
.100 VM(37)=11.34:VM(14)=90.9:VM(45)=26:VM(4)=5.5:VM(2)=318:VM(13)=1.3
.110 E(1)=.0454:E(2)=.713:E(3)=.0497:E(4)=.0126:E(5)=.1235:E(6)=.0961
.120 E(7)=.0051:E(11)=.0032:E(12)=12437:E(16)=.0035
.130 E(13)=.3499:E(15)=.35
000 '
001 '**************                 Constants                 **************
002 '
010 CMW=12.01
012 H2MW=2.016
014 H2OMW=18.016
016 O2MW=32
018 N2MW=28.016
020 SMW=32.066
022 INRTMW=28.163
024 AIRMW=28.965
026 AIRO2=.209
028 CO2MW=44.01
030 RTO2=(1-AIRO2)/AIRO2
040 INERT=RTO2*INRTMW/O2MW

000 '
120 K(1)=(VM(37)*2000/60)*(1-E(1))
180 K(2)=E(3)-(E(5)/7.937001)
210 K(3)=O2MW*(E(2)/CMW+E(3)/(2*H2MW)-E(5)/O2MW+E(7)/SMW)*K(1)
220 K(4)=INERT*K(3)+E(4)*K(1)
240 K(5)=0
250 K(6)=E(16)*(1+INERT)*K(3)+VM(37)*E(1)*2000/60+(E(5)*H2OMW/(O2MW/2))*K(1)
260 K(7)=K(1)*E(6)
270 K(8)=(1+E(16))*(1+INERT)*K(3)
280 K(9)=K(6)+8.936001*K(2)*K(1)
290 K(10)=(CMW+O2MW)/CMW*E(2)*K(1)+VM(14)*(1-E(11))*(1-1/E(13))*2000/60
300 K(11)=K(8)*10.73*520/(14.696*28.9)
310 K(12)=VM(13)*(K(4)/INRTMW+K(10)/(CMW+O2MW))
312 K(12)=K(12)/(100/O2MW-VM(13)*(1+INERT)/AIRMW)
320 IF VM(13)>20 THEN K(12)=1000
330 K(13)=(1+E(16))*(1+INERT)*(K(3)+K(12))
340 K(14)=1000:IF K(1)<1 THEN 5360
350 K(14)=K(13)/K(1)
360 K(15)=1000:IF K(3)<1 THEN 5380
370 K(15)=K(12)*100/K(3)
380 K(16)=K(12)/O2MW+(K(4)+INERT*K(12))/INRTMW+K(10)/(CMW+O2MW)+K(9)/H2OMW
390 K(17)=K(16)*385.3
400 K(18)=21:IF K(16)<1 THEN 5420
410 K(18)=(K(12)/O2MW)*100/K(16)
420 C=AIRO2/(1+E(16)*AIRMW/H2OMW)
422 K(19)=C*((K(16)+(VM(45)*8.3453/H2OMW))*(VM(4)/100)-(K(16)*K(18)/100))/(C-VM
4)/100)
430 IF K(19)>1000 THEN K(19)=1000
440 K(20)=K(12)+K(19)*O2MW
450 K(21)=K(16)-(K(9)/H2OMW)+K(19)*(1+RTO2)
460 K(22)=K(21)+(VM(45)*8.3453+K(9))/H2OMW
470 K(23)=K(22)*385.3
480 K(24)=VM(2)*.000001*30*K(22)
490 K(25)=K(24)*46/30
500 K(26)=0:IF VM(14)=0 THEN 5510
502 K(26)=VM(2)*46*1.56E-07*C(23)/(VM(14)*(1-E(11))*(1/E(13)))
510 IF K(26)<0 THEN K(26)=0
```

FIGURE 7 : Final NOx calculation developed by Young, McMann and Phillips as of September 14, 1985

```
11000 '
11001 '************** NOx Calculation (lbs/ton of clinker) **************
1002 '
1003 '
1004 '**************        Calculation of "TOTGAS"         **************
1005 '
1006 '**************   Contribution of COMBUSTION AIR       **************
1007 '
1010 MM(1)=VM(37)*(2000/60)*(1-E(1))
1030 MM(3)=MM(1)*(E(2)/CMW+E(3)*.5/H2MW+E(7)/SMW-E(5)/O2MW)
1040 MM(4)=MM(3)*((1-AIRO2)/AIRO2)
1050 MM(5)=(E(16)*AIRMW/H2OMW)*(MM(3)+MM(4))
1051 '
1052 '**************        Contribution of COAL            **************
1053 '
1060 MM(6)=MM(1)*(E(2)/CMW+E(3)/H2MW+E(4)/N2MW+E(7)/SMW)
1070 MM(7)=VM(37)*E(1)*(2000/60)/H2OMW
1080 MM(8)=MM(4)+MM(5)+MM(6)+MM(7)
1090 MM(9)=VM(14)*(2000/60)*E(11)/H2OMW
1091 '
1092 '**************        Contribution of KILN FEED       **************
1093 '
1100 MM(10)=VM(14)*(2000/60)*(1-E(11))*(E(15)-E(11))/CO2MW
1110 MM(11)=MM(9)+MM(10)
1111 '
1112 '**************      Contribution of WATER SPRAY       **************
1113 '
1120 MM(12)=VM(45)*8.350001/H2OMW
1121 '
1122 '**************      Contribution of EXCESS AIR        **************
1123 '
1130 MM(13)=MM(8)+MM(11)+MM(12)
1140 MM(14)=AIRO2/(1+E(16)*AIRMW/H2OMW)
1150 MM(15)=MM(13)*VM(4)*.01/(MM(14)-VM(4)/100)
1151 '
1152 '**************        Final TOTGAS Calculation        **************
1153 '
1160 MM(16)=MM(13)+MM(15)
1170 MM(17)=385.3*MM(16)
1171 '
1172 '**************           CLINKER PRODUCTION           **************
1173 '
1180 MM(18)=VM(14)*(1-E(15))
1181 '
1182 '**************         Final NOx Calculation          **************
1183 '
1185 IF MM(18)<=0 THEN MM(19)=0:RETURN
1190 MM(19)=VM(2)*46*1.56E-07*MM(17)/MM(18)
1200 RETURN
```

CRESTMORE NOx PROJECT
QUALITY ASSURANCE MANUAL

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

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APPENDIX A

Zero and Span Checklists

Full Electronic Calibration Worksheets

Dynamic Calibration Worksheets

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 reestablished 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:

$$\text{Amperage} = \frac{(\text{Simulated or actual temperature})\ (20\text{ma})}{(800)}$$

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:

$$\text{Volts} = \frac{(10)\ (\text{Simulated or actual temperature})\ (1.0\text{ volts})}{(800)}$$

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 S02 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.

1) 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

$$\text{MV/DEC} = \frac{E - cc}{\text{Log}\ \dfrac{(20.95)}{(\%\ O2\ \text{of low cal gas})}}$$

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

$$\text{Output for zero input} = 8.38 \times 10^{\frac{(cc)}{(MV/DEC)}}$$

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,

$$\text{corrected indicated flow rate} = \frac{(\text{average flow factor})}{(\text{reg. flow factor})} \; (\text{present indicated})(\text{flow rate})$$

$$\text{correct indicated flow rate (for static test wt)} = \frac{(0.0284)(70\%)}{(0.0306)}$$

$$= 65\%$$

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.

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:

$$\text{Correct milliamp output} = \frac{(\text{percent } O_2 \text{ of sample})(40)}{(\text{full range } O_2)} + 10$$

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:

$$\text{Correct milliamp output} = \frac{(1.2)\ (40)}{(5.0)} + 10 = 19.6$$

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:

$$\text{Correct milliamp output} = \frac{(\text{percent } O_2 \text{ of sample})(40)}{(\text{full range } O_2)} + 10$$

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)

$$\text{EXPECTED OUTPUT SIGNAL} = \frac{(\text{flow rate})\ 40}{100} + 10$$

$$= \underline{\hspace{4cm}}$$

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:

$$\text{EXPECTED MILLIAMPS} = \frac{(\text{Span Amps})\ 40}{(1500)} + 10$$

$$= \underline{\qquad\qquad\qquad}$$

	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) - (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:

$$\text{MV/Dec} = \frac{E - CC}{\text{Log} \dfrac{(20.95)}{(\text{\% 02 of low cal gas})}}$$

*Record the value of the MV Decade; MV/Dec = ___________

34. Calculate the 10 percent calibration using the following equation:

10% Cal = (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% Cal = 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.

$$\text{Error} = \frac{\text{Certified NO value}}{\text{Observed NO value}}$$

$$\text{Error} = \frac{(\qquad\qquad\qquad)}{(\qquad\qquad\qquad)} = \underline{\hspace{6cm}}$$

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.

$$\text{Error} = \frac{\text{Certified SO2 value}}{\text{Observed SO2 value}}$$

$$\text{Error} = \frac{(\qquad\qquad\qquad)}{(\qquad\qquad\qquad)} = \underline{\hspace{6cm}}$$

7. Average the errors calculated in step 4 and step 6.

$$\text{Average error} = \frac{\text{Error from step 4 + error from step 6}}{2}$$

$$\text{Average error} = \frac{(\qquad\quad) + (\qquad\qquad)}{2} = \underline{\qquad\qquad}$$

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.

---

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.

DYNAMIC CALIBRATION WORKSHEET

KILN FEED SANKYO IMPACT FLOWMETER

(Actual clinker weight versus kiln feed Sankyo)

DATE:_____________ FROM TIME:____________ TO TIME:_____________

1. Begin taking hourly kiln feed samples from BC-2 four hours prior to beginning the test and send them to the lab for an LOI determination.

2. Clean the "dump" area of clinker conveyor BC-25 of all material prior to the start of the clinker weight check.

3. Switch clinker conveyor BC-25 to the "dump" area and simultaneously record an initial reading on the kiln feed Sankyo totalizer. Also, indicate on the NOx control room printer the beginning of the test.

   *Initial reading of Sankyo totalizer:__________

4. Collect clinker in the "dump" area for four to six hours.

5. At the completion of the clinker collection period, switch clinker conveyor BC-25 out of the "dump" area and simultaneously record a final reading on the kiln feed Sankyo totalizer. Also, indicate the end of the test period on the NOx project 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.

Truck Number	Loaded Weight	Empty Weight	Weight of Clinker
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
TOTAL			

7. Calculate the weight of kiln feed used to produce the clinker during the test period.

*Final Sankyo totalizer reading - Initial Sankyo totalizer reading = Total Kiln Feed used

____________________ - __________________ = ______________

**Total the values in the "Feed" column on the NOx project control room printer for the time period covered during the collection of clinker and divide this value by ten.

$$\frac{\text{Total of "Feed" column values}}{10} = \underline{\hspace{4cm}}$$

8. Record the kiln feed LOI's determined by the laboratory and determine the average LOI.

Sample	LOI
1	______
2	______
3	______
4	______
5	______
6	______
7	______
8	______
9	______
Average	______

9. Determine the clinker to kiln feed factor

Factor = 1 - (Average LOI from step 8) = __________

Factor = 1 - ______________ = ______________

10. Calculate the clinker anticipated from the kiln feed used.

*(Kiln feed used, from totalizer) x (Kiln feed factor) = ________________

**(Kiln feed used, from NOx printer) x (Kiln feed factor) = _____________

______________ x ________________ = __________________

______________ x _______________ = __________________

11. Compare the actual clinker collected to the computed clinker from the kiln feed used.

$$*\frac{\text{Computed clinker, from totalizer}}{\text{Actual clinker}} = \underline{\hspace{4cm}}$$

$$**\frac{\text{Computed clinker, from NOx printer}}{\text{Actual clinker}} = \underline{\hspace{4cm}}$$

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	__________	-	__________	=	______

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:_________

8. 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:________

9. Run the material from the bin over the Sankyo flowmeter at a rate of 75 - 100 percent of full scale flow for at least 3 minutes. (5 - 8 minutes is preferred.)

10. 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:_________

11. 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:________

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.

Avg. flow factor = $\frac{\text{W/C Run \#1 + W/C Run \#2 + W/C Run \#3}}{3}$

(__________+__________+__________) / 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:

$$+ \text{ or } - \text{ COMP reading} = \frac{(\text{NO COMP reading})(\text{Avg. flow factor})}{\text{Registration flow factor}}$$

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

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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APPENDICES:

FIGURES

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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
<u>Lear Siegler SM-810</u>						
• 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
<u>Lear Sigler CM-50</u>						
• 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			---	
<u>Coal Feed Sankyo Flowmeter</u>						
• Zero and Span Check		X			7/18, 7/23, 7/24	Appendix J
• Full Calibration		X		Kiln not offline		
<u>Kiln Feed Sankyo Flowmeter</u>						
• Zero and Span Check		X			7/18	Appendix K
• Full Calibration		X		Kiln not offline	---	
• Certified Weights for Calibration		X				Appendix L
<u>Differential Pressure Water Spray Flowmeter</u>						
• 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.

computer program with the supporting calculations and assumptions for determining pounds NO_x per ton of clinker and a copy of the quality assurance plan. The pounds NO_x per ton of clinker calculations and assumptions and the quality assurance plan are reviewed and discussed in this report.

DATA HANDLING

The equipment selected to generate the pounds NO_x per ton of clinker values consists of the following components: a Lear-Siegler SM810 Dual component stack gas monitor to measure exit levels of NO and SO_2; a Baily and a Lear Siegler oxygen analyzer for combustion efficiency and infiltration across the I.D. fan; a Kaye Instruments Digilink analog/digital microprocessor for accepting, converting, processing, averaging and transmitting raw and converted data; a Chessel six point recorder for process control of various key inputs and an IBM Personal Computer for system control. The calculated pounds NO_x per ton clinker is printed every six minutes with hourly averages for each shift including an eight-hour (shift) average and a daily average. Since the Lear Siegler SM 810 is a time share system between NO_x and SO_2, the NO_x ppm and pounds per ton of clinker data point printed every six minutes represents three one-minute averages where the one-minute average is a continuous integration of gathered data. The Lear Siegler alternates between the NO_x and the SO_2 every other minute (e.g. NO_x measurements at $t = 1, 3, 5$ minutes, etc. and SO_2 measurements at $t = 0, 2, 4, 6$ minutes, etc.) The other data used in the pounds NO_x per ton clinker calculation is based on a continuous integration of input signals over the six minute time period.

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 deflection	Second derivative Spectroscopic measurement	impact flowmeter with a strain gauge to measure arm deflection	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	$\bar{x}$	s	CI95	Current Sampling Analysis Frequency	Measurement Uncertainty	Reference Method Measurement Uncertainty	Analysis by
<u>Coal (As Fired)</u>								
% C	2	70.55	-	-	represents monthly	± 0.3%	ASTM	Commercial
% H	2	5.20	-	-	composite for April	± 0.07%	ASTM	Testing
% N	2	1.49	-	-	and May of 1985	± 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	-	-		-		
<u>Raw Feed (Type II)</u>								
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: $\bar{x}$: 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 NO_x/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

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			
	Yes	No	Partially	Notes/Recommendations
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.

*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.

- 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		
<u>Three-Month Basis</u>				
• Full Calibration Lear Siegler SM810				
• UV Lamp Replacement Lear Siegler				
<u>Kiln Off Line</u>				
• 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    [C]    06-05-1985     ****
*************************************************


.01  ***************  HEAT BALANCE OF KILN/COAL MILL  ***************
102 '
110 'E(1)=.01
120 C(1)=(VM(37)*2000/60)*(1-E(1))
130 'E(2)=.7305
140 'E(3)=.0543
150 'E(4)=.0095
160 'E(5)=.1057
170 'E(6)=.0933
180 C(2)=E(3)-(E(5)/7.937001)
190 'E(7)=.0065
200 '
201 '*****************  REQ. FOR COMB. AT 0% EXCESS O2  ***************
202 '
210 C(3)=(2.664*E(2)+7.936001*C(2)+1.142*E(4)+.998*E(7))*C(1)
220 C(4)=3.2543*C(3)
230 'C(3)=952.8313
240 C(5)=.0579*C(3)
250 C(6)=.01495*C(3)+VM(37)*E(1)*2000/60+(E(5)*8.936001/7.937001)*C(1)
260 C(7)=C(1)*E(6)
270 C(8)=4.3271*C(3)
280 C(9)=C(6)+8.936001*C(2)*C(1)
290 C(10)=3.664*E(2)*C(1)+VM(14)*(1-E(11))*(1-1/E(13))*100/3
300 C(11)=C(8)*10.73*520/(14.696*28.9)
31(  12)=VM(13)*(C(4)/28.013+C(10)/44.01+C(5)/39.675)/(100/32-VM(13)*.14838)
 0 IF VM(13)>20 THEN C(12)=1000
330 C(13)=4.3271*(C(3)+C(12))
340 C(14)=1000:IF C(1)<1 THEN 2360
350 C(14)=C(13)/C(1)
360 C(15)=1000:IF C(3)<1 THEN 2380
370 C(15)=C(12)*100/C(3)
380 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)
390 C(17)=C(16)*379.48
400 C(18)=21:IF C(16)<1 THEN 2420
410 C(18)=(C(12)/32!)*100/C(16)
420 C(19)=.20874*((C(15)+(VM(45)*8.3453/18.015))*(VM(4)/100)-(C(16)*C(18)*.01))/(.20874-VM(4)/100)
430 IF C(19)>1000 THEN C(19)=1000
440 C(20)=C(12)+C(19)*32!
450 C(21)=C(16)-(C(9)/18.015)+C(19)*(1+(.77559+9.739999E-03)/.20874)
460 C(22)=C(21)+(VM(45)*8.3453+C(9))/18.015
470 C(23)=C(22)*379.48
480 C(24)=((VM(3)*14.696*32.4/(10.73*520))*.000001)*C(21)*379.48
490 C(25)=C(24)*46/30.01
500 C(26)=0:IF VM(14)=0 THEN 2510
502 C(26)=C(25)/(VM(14)*(1-E(11))*(1/E(13))/60)
510 IF C(26)<0 THEN C(26)=0
520 C(27)=1000:IF VM(37)<1 THEN 2540
530 C(27)=C(25)/((VM(37)*(1-E(1))*(2000/60)*E(12)))*.000001
540 C(28)=21:C(29)=0:IF C(21)<1 THEN 2570
550 C(28)=(C(20)/32)*100/C(21)
     29)=VM(2)*(13/(21-C(28)))
570 C(30)=100:IF C(16)<1 THEN 2590
580 C(30)=((C(19)/.20874)*28.9/(C(16)*31.74))*100
590 '
```

```
2591  ***************  COAL MILL BALANCE  ******************
2592
2600 C(31)=VM(44)*100/3
2610 C(32)=(VM(44)-VM(37))*100/3
2620 C(33)=10.4*VM(48)-295.9
     C(34)=C(33)-C(32)-6.7124
2640 C=VM(40)
2650 C(35)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3+6.951E-13*C^4-7.6193
2660 C=VM(42)
2670 C(36)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2680 C(37)=.4421*C+2.434E-05*C^2+1.0636E-08*C^3-2.043E-12*C^4-14.172
2690 C(38)=VM(1)+30
2700 C=C(38)
2710 C(39)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2720 C=VM(38)
2730 C(40)=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2740 C(41)=C(1)*(C(38)-32)*.3
2750 C(42)=C(31)*.0795873
2760 C(43)=C(42)*(C(38)-32)
2770 C(44)=C(41)+C(43)
2780 C(45)=C(1)*(140-32)*.3
2790 'E(8)=454
2800 C(46)=C(34)*C(36)
2810 C(47)=C(32)*971.3
2820 C(48)=C(32)*C(37)
2830 C(49)=C(45)+E(8)+C(46)-C(47)+C(48)
2840 C(50)=100:IF C(39)=C(35) OR C(34)<1 THEN 2860
2850 C(50)=(C(49)-C(44)-C(34)*C(35))*100/(C(34)*(C(39)-C(35)))
2860 C(51)=1000:IF C(40)=C(39) THEN 2880
2870 C(51)=C(34)*(C(35)-C(39))/(C(40)-C(39))
     C(52)=100:IF C(42)<1 THEN 2900
2890 C(52)=C(32)*100/C(42)
2900 '
2901 '******************  CLINKER COOLER BALANCE  *********************
2902 '
2910 C(53)=VM(17)*100/122
2920 C(54)=VM(18)*100/112
2930 C(55)=VM(19)*100/91.5
2940 C(56)=VM(20)*100/127
2950 C(57)=VM(21)*100/128
2960 C(58)=.07:IF VM(1)>400 THEN 2980
2970 C(58)=38.396/(460+VM(1))
2980 C(59)=0:IF C(53)<2 THEN 3000
2990 C(59)=VM(17)*1.8868E-05*(460+VM(1))*(7.49*LOG(C(53))+57.66)*(.0002*C(53)+.88)
3000 C(60)=0:IF C(54)<2 THEN 3020
3010 C(60)=VM(18)*1.9153E-05*(460+VM(1))*(7.49*LOG(C(54))+57.66)*(.0002*C(54)+.88)
3020 C(61)=0:IF C(55)<2 THEN 3040
3030 C(61)=VM(19)*1.7537E-05*(460+VM(1))*(6.15*LOG(C(55))+63.1)*(.0002*C(55)+.8750001)
3040 C(62)=0:IF C(56)<2 THEN 3060
3050 C(62)=VM(20)*1.6622E-05*(460+VM(1))*(7.49*LOG(C(56))+57.66)*(.0002*C(56)+.88)
3060 C(63)=0:IF C(57)<2 THEN 3080
3070 C(63)=VM(21)*1.6608E-05*(460+VM(1))*(7.39*LOG(C(57))+58.39)*(.0003*C(57)+.88)
3080 C(64)=476*C(59)-19620:IF C(59)>75 THEN 3100
3090 C(64)=305*C(59)+1.3*((C(59)-62.5)^2)-6671
3100 C(65)=235.3*C(60)-2824
        (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
3130 C(67)=447.4*C(62)-11281
3140 C(68)=965*C(63)+12.5*((C(63)-117.5)^2)-58460!:IF C(63)>110 THEN 3160
3150 C(68)=652.3*C(63)+3.1*((C(63)-90)^2)-24716
```

```
3160 C(69)=0:IF VM(34)<1.5 THEN 3180
3170 C(69)=EXP(LOG(VM(34)/.0065)/1.75)
3180 C(70)=VM(14)*(1-E(11))*(1/E(13))*100/3
3190 C(71)=(C(64)+C(65)+C(66)+C(67)+C(68))*C(58)
3200 C(72)=C(71)-C(51)-C(69)
     'E(9)=638.0741
3220 C(73)=.2057*VM(29)+.0000217*((VM(29)-340)^2)-9.82
3230 C(74)=C(70)*E(9)
3240 C(75)=C(71)*C(39)
3250 C(76)=C(70)*C(73)
3260 C(77)=.1*(C(74)+C(75))
3270 C(78)=C(51)*C(40)
3280 C(79)=C(69)*C(36)
3290 C(80)=1000:IF C(72)<10 THEN 3310
3300 C(80)=(C(74)+C(75)-C(76)-C(77)-C(78)-C(79))/C(72)
3310 C(81)=0:IF C(80)<-1000 THEN 3330
3320 C(81)=(-.2363+SQR((.2383^2)+4*4.979E-06*C(80)))/(2*4.979E-06)
3330 C(82)=0:IF C(74)+C(75)<1000 THEN 3350
3340 C(82)=(C(78)+C(72)*C(80))*100/(C(74)+C(75))
3350 C(83)=0:C(84)=0:C(85)=0:C(86)=0:C(87)=0:IF C(70)<10 THEN 3410
3360 C(83)=C(71)/C(70)
3370 C(84)=C(72)/C(70)
3380 C(85)=C(51)/C(70)
3390 C(86)=C(69)/C(70)
3400 C(87)=C(83)+C(84)+C(85)+C(86)
3410 '
3411 '*******************  KILN BALANCE  **********************
3412 '
3420 C(88)=4.75*VM(31)-61.1
3430 C(89)=-2.31*VM(27)+158.1
     C(90)=C(13)-C(72)-C(88)-C(89)
3450 C(91)=0:IF C(72)<10 THEN 3470
3460 C(91)=C(88)/C(72)
3470 C(92)=0:C(93)=0:C(94)=0:IF C(13)=<10 THEN 3510
3480 C(92)=C(88)*100/C(13)
3490 C(93)=C(72)*100/C(13)
3500 C(94)=C(90)*100/C(13)
3510 C(95)=C(88)/.0763
3520 C(96)=C(72)/.0763
3530 C(97)=C(90)/.0763
3540 C(98)=C(89)/.0763
3550 C(99)=C(95)+C(96)+C(97)+C(98)
3560 C(100)=VM(1)+70
3570 C(101)=.2383*C(100)+4.979E-06*(C(100)^2)-7.619001
3580 C(102)=(.21*C(100)-6.72)*.9000001+(.24*C(100)-7.68)*.1
3590 C(103)=.3*(VM(1)+50)-9.600001
3600 C(104)=VM(1)+50
3610 C(105)=.4421*C(104)+2.4339E-05*(C(104)^2)-14.17
3620 'E(10)=19.1
3630 C(106)=.4421*C(100)+2.4339E-05*(C(100)^2)-14.17
3640 C=VM(11)
3650 C(107)=.2315*C+3.2625E-05*C^2-6.0393E-09*C^3+5.6E-13*C^4-7.44
3660 C(108)=(.21*C-6.72)*.9000001+(.24*C-7.68)*.1
3670 C(109)=C(88)*C(39)
3680 C(110)=C(89)*C(39)
3690 C(111)=C(90)*C(101)
     (112)=C(72)*C(80)
3710 C(113)=C(1)*E(12)
3720 C(114)=C(1)*C(103)
3730 C(115)=VM(14)*(1-E(11))*C(102)*100/3
```

[C] Matrix   3/4

```
3740 C(116)=VM(14)*E(11)*C(108)*1.0[illegible]
3750 C(117)=VM(45)*8.3453*E(10)
3760 C(118)=C(109)+C(110)+C(111)+C(112)+C(113)+BH+C(114)+C(115)+C(116)+C(117)
3770 C(119)=1000:IF C(113)+C(112)<1000 THEN C(23)=0:GOTO 3790
3780 C(119)=C(112)*100/(C(113)+C(112))
     120)=C(16)*31.73655
3800 C(121)=C(120)*C(107)
3810 C(122)=C(120)*C(108)*.3
3820 C(123)=VM(45)*8.3453*971.3
3830 C(124)=C(70)*E(9)
3840 C(125)=C(70)*1124
3850 C(126)=C(121)+C(122)+C(123)+C(124)+C(125)
3860 C(127)=C(118)-C(126)
3870 C(128)=100:IF C(118)<1000 THEN 3890
3880 C(128)=C(127)*100/C(118)
3890 C(129)=0:IF VM(14)<1 THEN 3910
3900 C(129)=(VM(37)*(1-E(1))*2000*E(12)*E(13))/(VM(14)*(1-E(11)))
3920 'E(14)=.35968
3922 'E(15)=.35
3930 C(130)=E(1)*2000/18.016
3932 C(131)=(1-E(1))*2000*E(14)
3934 C(132)=(C(130)+C(131))*VM(37)/60
3940 C(133)=E(11)*2000/18.016
3942 C(134)=(1-E(11))*2000*E(15)/44.01
3944 C(135)=(C(133)+C(134))*VM(14)/60
3950 C(136)=VM(45)*8.34/18.016
3960 C(137)=C(132)+C(135)+C(136)
3970 C(138)=VM(4)*C(137)/(20.88-VM(4))
3972 C(139)=C(137)+C(138)
3980 C(140)=(C(139)*VM(2)*46*60*E(13))/(VM(14)*(1-E(11))*1000000))
     .TURN
```

[illegible] JC

New NOx

?

Kiln raw feed,

Kiln Feed moisture

4/3/97 JCT

? 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

```
2650 AENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3+6.951E-13*C^4-7.6193
2660 C=VM(42)
2670 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
2690 AMB=VM(1)+30
2700 C=AMB
2710 DENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2720 C=VM(38)
2730 EENT=.2383*C+4.979E-06*C^2+2.7958E-09*C^3-6.951E-13*C^4-7.6193
2740 AAA=DCOAL*(AMB-32)*.3
2750 COALWAT=WCOAL*.0795873
2760 BBB=COALWAT*(AMB-32)
2770 J=AAA+BBB
2780 CCC=DCOAL*(140-32)*.3
2790 DDD=454
2800 EEE=DAIR*BENT
2810 FFF=WATER*971.3
2820 GGG=WATER*CENT
2830 ZZZ=CCC+DDD+EEE+FFF+GGG
2840 CINF=100:IF DENT=AENT OR DAIR<1 THEN 2860
2850 CINF=(ZZZ-J-DAIR*AENT)*100/(DAIR*(DENT-AENT))
2860 CCAIR=1000:IF EENT=DENT THEN 2880
2870 CCAIR=DAIR*(AENT-DENT)/(EENT-DENT)
2880 MILLEFF=100:IF COALWAT<1 THEN 2900
2890 MILLEFF=WATER*100/COALWAT
2900 '************ CLINKER COOLER BALANCE**************
2910 LLA=VM(17)*100/122
2920 LLB=VM(18)*100/112
      LC=VM(19)*100/91.5
2940 LLD=VM(20)*100/127.
2950 LLE=VM(21)*100/168
2960 DENS=.07:IF VM(1)>400 THEN 2980
2970 DENS=38.396/(460+VM(1))
2980 BHPA=0:IF LLA<2 THEN 3000
2990 BHPA=VM(17)*1.8868E-05*(460+VM(1))*(7.49*LOG(LLA)+57.66)*(.0002*LLA+.88)
3000 BHPB=0:IF LLB<2 THEN 3020
3010 BHPB=VM(18)*1.9153E-05*(460+VM(1))*(7.49*LOG(LLB)+57.66)*(.0002*LLB+.88)
3020 BHPC=0:IF LLC<2 THEN 3040
3030 BHPC=VM(19)*1.7537E-05*(460+VM(1))*(6.15*LOG(LLC)+63.1)*(.0002*LLC+.875)
3040 BHPD=0:IF LLD<2 THEN 3060
3050 BHPD=VM(20)*1.6622E-05*(460+VM(1))*(7.49*LOG(LLD)+57.66)*(.0002*LLD+.88)
3060 BHPE=0:IF LLE<2 THEN 3090
3070 BHPE=VM(21)*1.6608E-05*(460+VM(1))*(7.39*LOG(LLE)+58.39)*(.0003*LLE+.86)
3080 CFMA=476*BHPA-19620:IF BHPA>75 THEN 3100
3090 CFMA=305*BHPA+1.3*((BHPA-62.5)^2)-6671
3100 CFMB=235.3*BHPB-2824
3110 CFMC=312.9*BHPC-6033
3120 CFMD=632*BHPD+10.8*((BHPD-83)^2)-25690:IF BHPD>75 THEN 3140
3130 CFMD=447.4*BHPD-11281
3140 CFME=966*BHPE+12.5*((BHPE-117.5)^2)-58460!:IF BHPE>110 THEN 3160
3150 CFME=652.3*BHPE+3.1*((BHPE-70)^2)-24716
3160 CYCFLO=0:IF VM(34)<1.5 THEN 3180
3170 CYCFLO=EXP(LOG(VM(34)/.000005)/1.75)
      LINN=VM(14)*(1-.004)*(1/1.6)*100/3
      FANFLOW=(CFMA+CFMB+CFMC+CFMD+CFME)*DENS
3200 SECFLO=FANFLOW-CCAIR-CYCFLO
3210 ENTA=638.0741
3220 ENTB=.2057*VM(29)+.0000217*((VM(29)-340)^2)-9.62
3230 AAAA=CLINN*ENTA
```

KEY 2/4

```
3250 CCCC=CLINN*ENTS
3260 DDDD=.1*(AAAA+BBBB)
3270 EEEE=CCAIR*EENT
     FFFF=CYCFLO*BENT
3290 ENTHSEC=1000:IF SECFLO<10 THEN 3310
3300 ENTHSEC=(AAAA+BBBB-CCCC-DDDD-EEEE-FFFF)/SECFLO
3310 SECTEM=0:IF ENTHSEC<-1000 THEN 3330
3320 SECTEM=(-.2383+SQR((.2383^2)+4*4.979E-06*ENTHSEC))/(2*4.979E-06)
3330 CDOEFF=0:IF AAAA+BBBB<1000 THEN 3380
3340 CDOEFF=(EEEE+SECFLO*ENTHSEC)*100/(AAAA+BBBB)
3350 ARA=0:ARB=0:ARC=0:ARD=0:TOTAR=0:IF CLINN<10 THEN 3410
3360 ARA=FANFLOW/CLINN
3370 ARB=SECFLO/CLINN
3380 ARC=CCAIR/CLINN
3390 ARD=CYCFLO/CLINN
3400 TOTAR=ARA+ARB+ARC+ARD
3410 '*************KILN BALANCE********************
3420 PAIRA=4.75*VM(34)-61.1
3430 TAIRP=-2.31*VM(27)+158.1
3440 KILNINF=TAIR-SECFLO-PAIRA-TAIRP
3450 HHH=0:IF SECFLO<10 THEN 3470
3460 HHH=PAIRA/SECFLO
3470 III=0:JJJ=0:KKK=0:IF TAIR=<10 THEN 3510
3480 III=PAIRA*100/TAIR
3490 JJJ=SECFLO*100/TAIR
3500 KKK=KILNINF*100/TAIR
3510 LLL=PAIRA/.0763
3520 MMM=SECFLO/.0763
     NNN=KILNINF/.0763
3540 OOO=TAIRP/.0763
3550 PPP=LLL+MMM+NNN+OOO
3560 AMBB=VM(1)+70
3570 AF=.2383*AMBB+4.979E-06*(AMBB^2)-7.619001
3580 AS=(.21*AMBB-6.72)*.9000001+(.24*AMBB-7.68)*.1
3590 AI=.3*(VM(1)+50)-9.600001
3600 AAMBB=VM(1)+50
3610 AJ=.4421*AAMBB+2.4339E-05*(AAMBB^2)-14.17
3620 AK=19.1
3630 AL=.4421*AMBB+2.4339E-05*(AMBB^2)-14.17
3640 C=VM(11)
3650 AM=.2315*C+3.262E-05*C^2-6.0393E-09*C^3+5.6E-13*C^4-7.44
3660 AN=(.21*C-6.72)*.9+(.24*C-7.68)*.1
3670 BC=PAIRA*CENT
3680 BD=TAIRP*DENT
3690 BE=KILNINF*AF
3700 BF=SECFLO*ENTHSEC
3710 BG=DCOAL*12437
3720 BI=DCOAL*AI
3730 BJ=VM(14)*(1-.004)*AJ*100/3
3740 BK=VM(14)*.004*AL*100/3
3750 BL=VM(45)*8.3453*AK
3760 BM=BC+BD+BE+BF+BG+BH+BI+BJ+BK+BL
3770 KILNHET=1000:IF BG+BF<1000 THEN EESCFM=0:GOTO 3790
     KILNHET=BF*100/(BG+BF)
     ENT=MOLEW*31.73665
3800 CB=ENT*AM
3810 CC=ENT*AN*.3
3820 CD=VM(45)*8.3453*971.3
```

KEY 3/4

PROJECT TITLE: M & E Balance

PLANT: ______ DATE: 4-29-84

PREPARED BY: ______ DISTRIBUTION: ______

Excess Oxygen: O_2% (dry)

Use if O_2 % (wet) — Most Absorbed

$$\frac{\text{lbs } O_2 \text{ Excess}}{\text{Min}} = \frac{-\%\ \text{stack}\,O_2\left(\frac{\text{lb } N_2}{28.013} + \frac{\text{lb } CO_2}{44.01} + \frac{\text{lb } Ar}{39.675} + \left(\frac{\text{lb } H_2O}{18.015}\right) + \frac{\text{lb } NO}{30.01} + \frac{\text{lb } SO_2}{64.06}\right)}{-\frac{1}{3200} + \%\ \text{Stack } O_2\underbrace{\left(\frac{1}{32.00} + \frac{3.2543}{28.013} + \frac{.0579}{39.675} + \left(\frac{.01495}{18.015}\right)_{(\cong O_2\%,\ \text{wet})}\right)}_{.14888\ (\text{dry}),\ \cong .14971\ (\text{wet})}}$$

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

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

EXOTWO

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

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

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 = 3,475.38

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 = 220.9961

└ No water spray yet — neglect

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

TAIR lb/M Air = 4,621.06655

LBLB lb Air/lb fuel = 4,621.0655/416.3346 = 11.0994 dry coal, wet air @ 2% (dry)

$$\frac{\text{Moles Flue (dry)}}{\text{Min}} = \left(\frac{\text{lb } O_2}{32.00} + \frac{\text{lb } N_2}{28.013} + \frac{\text{lb } CO_2}{44.01} + \frac{\text{lb } Ar}{39.675} + \frac{\text{lb } NO}{30.01}\right) = \frac{115.10486}{32.00} + \frac{3,475.3847}{28.013} + \frac{2,214.3438}{44.01} + \frac{61.83347}{39.675} + \frac{9}{3}$$

= 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

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:

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

$$\text{Vol }\%O_2\text{ (dry)} = \frac{(115.10496/32.00)100}{179.85139} = 1.999999486 \sim 2\%$$ Checks

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

(100 moles)

Species	mol WT	Vol % D	Vol % W	lbs D	lbs W
O_2	32.000	2.000	1.97229	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

WOTWO

Ar

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 lbs

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

Mol WT (dry) = Σ lbs Dry / 100

Mol WT (WET) = Σ lbs WET / 100

$$\text{VPPM NO (dry)} = \frac{\text{moles NO}}{\text{Total moles}}\times 10^6 = \frac{(9.54382/30.01)}{179.95139}\times 10^6 = 1768 \text{ PPM (dry)}$$ If No Reduction

$$\text{VPPM No (dry) }3\%O_2 = 1768\left(\frac{19}{21-2}\right) = 1675 \text{ PPM}$$ If No Reduction

XAIR

% Excess Air (r2):

$$\% = \frac{O_2\text{ IN} - O_2\text{ req}}{O_2\text{ req}}\times 100 = \frac{952.9136 + 115.10486 - 952.933}{952.9213} = \frac{115.10496}{952.5512}\times 100 = 12.08$$

0 2?5

GIFFORD-HILL

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M+E Balance

PLANT: DATE: 4-29-84

PREPARED BY: DISTRIBUTION:

O₂ AT Burner:

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

$$\%O_2 (dry) = 2.3228$$

EXIT GAS FLOW: (WET) (ACTUAL) (not Inc. water Spray)

ESCFM

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

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

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

← Assume const for Comp. lb/m

EWT

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

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).

$$wet\ Air = 28.904 \frac{lb}{lb\ mol}$$

Total Air = 4,621.06655 lb/M

P(10)

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

$$\text{or}\quad SCFM = \frac{lb/M}{\rho} = \frac{4,621.06655}{\frac{(14.696)(28.904)}{(10.73)(459.7+60)}} = 60,670.6$$

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M+F 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
‡ 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. UGP - 10" w.c
Upper cc. drive Amp - ~~50~~ 25
Lower cc. drive Amp - 50 25
Hood Pressure - -.03" w.c
‡ Conv. Air Press - 7.4 PSIG

Clinker Disch Temp - 200°F
Conv Air Amps - Need
‡ Primary Air Amps - ~~72~~ 4
Kiln Dust Return - 0 TPH
Cooler Vent Temp - 180°F
‡ ΔP on Cyclone - 9.44
Cooler BGHSE Inlet T - 170°
Cooler BGHSE Outlet T - 140°
Coal To Kiln - 12.467 (1
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
GPM To Kiln Exit - 15.0
‡ Coal Mill Amps - ~~200~~
Chain Zone Temp - ~~1150~~
Coal Mill System FAN Amp - 9

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 -

% 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 -

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

GIFFORD-HILL CEMENT COMPANY
PROJECT DATA SHEET

PROJECT TITLE: M+E BALANCE

PLANT: DATE: 4-28-84

PREPARED BY: DISTRIBUTION:

1A FLUE GAS ANALYSIS:

A KILN EXIT:

Fr's

Coal Feed - 12.6162 TPH (wet)

WMCOAL Coal H_2O - 1% (Computer (1.5)

CCOAL Coal C - 73.05% (dry)

HCOAL Coal H - 5.43% (dry)

NCOAL Coal N - 0.95% (dry)

OCOAL Coal O - 10.57% (dry)

ASHCOAL Coal Ash - 9.33% (dry) Coal S - 0.65% (dry)

SCOAL Coal S_2 - .65% (dry)

DCOAL Dry Coal = 12.6162 (1 - .01 [.015]) = 12.49 TPH $12.49 \frac{2000}{60}$ = 416.3346 #/M

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

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

✓ Fr on Computer

$\therefore \frac{10.57}{7.937}$ = 1.33 %H AS H_2O.

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

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

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

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

NTWOR Org N_2: lb/M Org N_2 = 12.49 (Fr N) $\frac{2000}{60}$ = 12.49 (.0095) $\frac{2000}{60}$ = 3.95517 lb/M

NOT USED S: lb/M S = 12.49 (.0065) $\frac{2000}{60}$ = 2.70617 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) × (1 - $\frac{1}{1.55}$) × $\frac{2000}{60}$ = 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

H OUT H_2O: 66.8055 lb/M + 8.936 (% avg 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) (1 - $\frac{1}{1.55}$) $\frac{2000}{60}$ = 1,114.3378 + 1,100.006
-1.60

2,214.3438

[illegible] 10 ₵ => 1 ton

Verify NO: 2.143 (org N) = 2.143 (3.95517) = 9.54382 lb/M — 60-70% reduced

Verify SO2: 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

.076

— Program Variable Identification — [illegible]

— Mass Balance — Page [illegible]

			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 multicyclones).	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

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		Page	Line #
LBLB – Calc. (= 1000 IF DCOAL < 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 vm(4) > 19)	moles/Min Air Added by infiltration between Kiln Exit and I.D FAN	8	2140
OOUT – Calc.	LB/Min O_2 add by infiltration @ 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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			Form	L
NOTHR - Calc. (=0 IF DMOLE<1)		VPPM NO at 3% Stack O_2 at I.D Fan Exit.	10	21
INF - Calc. (=100 IF MOLEW<1)		% Air Infiltration Between Kiln Exit and I.D Fan. (Excludes water Spray)	〃	216
WCOAL -	measured	LB/Min Wet Coal Feed To Coal Mill	12	221
WATER -	Measured.	LB/Min Water Evaporated in Coal Mill	〃	〃
Pounds -	Calc.	LB/Min Air from System Fan. (Includes water Evaporated and False 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)	〃	222
CENT -	Calc.	Enthalpy of water vapor out Coal mill	〃	〃
AMB -	measured.	Ambient Temperature + 30°F. Used as Temperature for Coal mill feed.	〃	〃
DENT -	Calc.	Enthalpy of "AMB" Air.	〃	223
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:

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

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:

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

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.)
$28.965 = 0.209 * 32 + 0.791 * MW_{\text{inerts}}$

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

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

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

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

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

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

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

This term is essentially the NTWO term in the IBM program

NTWO = C(4) = 3.3309 * OTWO + 0.0095 * 374.22
= 3.3309 * 852.4563 + 3.555
= 2842.9857 lb / min

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.

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

= HUMID * 28.965 / 18.016 = 0.00563 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 %)

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

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

$$O_2\ \text{wet} = \frac{\text{moles } O_{2EA}\ /\text{min}}{(\text{moles } O_{2EA} + \text{moles inert}_{EA} + \text{moles water}_{EA} + \text{moles of other})/\text{min}}$$

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

This equation has the form:

$$O_2\ \text{wet} = \frac{\text{moles } O_{2EA}\ /\text{min}}{\text{moles } O_{2EA}\ /\text{min} * A + B}$$

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

$$\text{moles } O_{2EA}\ /\text{min} = \frac{O_2\ \text{wet} * B}{1 - O_2\ \text{wet} * A}$$

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

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):

$$B = \left(\frac{\mathrm{CCCOAL}}{12.011} + \frac{\mathrm{NCOAL}}{28.016} + \frac{\mathrm{SCOAL}}{32.066}\right) * \mathrm{DCOAL} \qquad [\text{ kiln coal dry gas }] \; (\ CO_2,\ N_2,\ \&\ SO_2\ )$$

$$+ \left(\frac{\mathrm{WATCOAL}}{1 - \mathrm{WATCOAL}} * \frac{1}{18.016} + \frac{\mathrm{HCOAL}}{2.016}\right) * \mathrm{DCOAL} \qquad [\text{ kiln coal water }]$$

$$+ \frac{1 - 0.209}{0.209} * \frac{\mathrm{OTWO}}{32} \qquad [\text{ comb air inerts }]$$

$$+ \frac{\mathrm{HUMID} * 28.965}{0.209 * 18.016} * \frac{\mathrm{OTWO}}{32} \qquad [\text{ comb air water }]$$

$$+ \frac{\mathrm{VM}(14) * (1 - \mathrm{E}(11)) * (1 - 1/\mathrm{E}(13)) * 2000}{44.011 * 60} \qquad [\text{ feed } CO_2\ ]$$

$$+ \frac{\mathrm{VM}(14) * \mathrm{E}(11) * 2000}{18.016 * 60} \qquad [\text{ feed } H_2O\ ]$$

$$+ \frac{\mathrm{VM}(45) * 8.3453}{18.016} \qquad [\text{ spray } H_2O\ ]$$

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

NO, ppm_v, dry = VM(2) / (SDCFM/SWCFM)

= 318 / (0.89781)

= 354.1952 ppm_v, dry

CALCULATION OF LB NO_x / TON

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

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

= <u>3.6605 lbs NO_x / ton of clinker</u>

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

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

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

= <u>3.6605 lbs NO_x / ton of clinker</u>

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 <u>WMOLE</u> INSTEAD OF <u>DMOLE</u> <u>AND</u> 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 <u>dry</u> gas/min, use WMOLE instead

```
NO =    VM(2)  * .000001    *    WMOLE
           moles NO          moles wet gas         moles NO
        ---------------      -------------    =   ----------
         moles wet gas            min                 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)

FACTOR	NOM. VALUE	---ORIGINAL CALCULATION---			---MODIFIED CALCULATION---		
		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
  DDTWO= 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 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  O    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 O2% VM(4) =","(16)ID NO PPM VM(2 =","(17)EXIT O2 % VM(13)="
360 FOR I = 1 TO 17 : READ SH$(I) :NEXT
400 D$ =  CHR$ (4)
420  DATA   " DCOAL= "," AVAH= "," OTMO= "," NTMO= ","  ARG= "," HTMOO= "," ASHC= ","  AIR= ",
     "  HOUT= "," COTMO= ","  SCFM= ","EXOTMO= ","  TAIR= "," LBLB= "," EXAIR= "," MOLEW= "," ESCFM= ",
     " WOTMO= ","IDOMOL= ","  OOUT= "," DMOLE= "
421  DATA    " WMOLE= ","EESCFM= ","    NO= "," NOTMO= ","  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 O2 %
1030 VM(45) = 26!: REM    BACK END H20 SPRAY GPM
1040 VM(4) = 5.5: REM    O2% 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$(14)
1360  HTAB 1: VTAB 17: PRINT "(15)WT ID O2% VM(4) =";VM(4);: HTAB 33: PRINT VA$(15)
1370  HTAB 1: VTAB 18: PRINT "(16)ID NO PPM VM(2) =";VM(2);: HTAB 33: PRINT VA$(16)
1375  HTAB 1: VTAB 19: PRINT "(17)EXIT O2 % VM(13)=";VM(13);: HTAB 33: PRINT VA$(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) * 0.3453 / 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) * 0.3453 + 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
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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+O2MW) : C(28)=MKDG
2604 MKW = C(9)/H2OMW + VM(45)*8.3453/H2OMW : C(29)= MKW
2606 MKWG = MKDG + MKW : C(30) = MKWG
2608 MIDO2 = VM(4)*MKWG/(100-VM(4)/AIRO2*(1+HUMID*AIRMW/H2OMW)) : C(31) = MIDO2
2610 MIDXSDA = MIDO2*(1+(1-AIRO2)/AIRO2) : C(32) = MIDXSDA
2612 MIDXSW = MIDXSDA * HUMID * AIRMW/H2OMW : 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)
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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$(14)
31360 LPRINT "(15)WT ID O2% VM(4) =";VM(4); TAB(33); VA$(15)
31370 LPRINT "(16)ID NO PPM VM(2) =";VM(2); TAB(33); VA$(16)
31375 LPRINT "(17)EXIT O2 % VM(13)=";VM(13); TAB(33); VA$(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 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)=  .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 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)=  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 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)=  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 H2O    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 KFH2O  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 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)=  10.8235         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  0      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 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)=    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  %
   UOUT= 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 02%  VM(4)  = 5.55501      1 %
          (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)=   10.9995         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  %
```

```
                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) = 321.18      1 %
(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)=  10.8235        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)=  2.2563         1  %
 NOTWO= C( 25)=  3.4596         1  %
  NOLB= C( 26)=  3.6749         1  %
 NOBTU= C( 27)=  .7433          1  %

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=              3.6806     1  %
```

```
              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)= 1.313       1 %

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)=  66.9897        1.0674  %
  TAIR= C( 13)=  3995.83        .077  %
  LBLB= C( 14)=  10.6778        .077  %
 EXAIR= C( 15)=  7.8584         1.0674  %
 MOLEW= C( 16)=  170.438        .0621  %
 ESCFM= C( 17)=  65669.7        .0621  %
 WOTWO= C( 18)=  1.2283         1.0047  %
IDOMOL= C( 19)=  10.8014       -.2047  %
  OOUT= C( 20)=  412.634       -.0003  %
 DMOLE= C( 21)=  211.119       -.0001  %
 WMOLE= C( 22)=  234.163       -.0001  %
EESCFM= C( 23)=  90222.9       -.0001  %
    NO= C( 24)=  2.2339        -.0001  %
 NOTWO= C( 25)=  3.4253        -.0001  %
  NOLB= C( 26)=  3.6385        -.0001  %
 NOBTU= C( 27)=  .736          -.0001  %

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)= .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  0    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 02% VM(4) = 5.55501      1 %
(16)ID NO PPM VM(2) = 321.18       1 %
(17)EXIT 02 % 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  %
 MID02=            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

Ray Dienes 1/4

Mine Operator:	Utah Fuel Company
Mine Owner:	Getty Mining Company/Coastal States Energy C 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 Loadou
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	2.99
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

3,

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

[illegible]

UTAH FUEL COMPANY
P O Box 719
Helper, Utah 84526

PLEASE ADDRESS ALL CORRESPONDENCE TO:
224 S. CARBON AVE. [illegible]

July 16, 1985

Sample identification
by Utah Fuel Co.

Monthly Composite
May 1985

Kind of sample reported to us	Coal
Sample taken at	Skyline
Sample 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

Moisture, Ash-free Btu = 14149

ULTIMATE ANALYSIS

	As Received
% Moisture	9.84
% Carbon	65.32✓
% Hydrogen	4.76
% Nitrogen	1.27
% Chlorine	0.02
% Sulfur	0.61
% Ash	8.12
% Oxygen (diff)	10.06
	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		
Initial Deformation	2155	°F	xxx
Softening (H = W)	2255	°F	xxx
Softening (H = ½W)	2390	°F	xxx
Fluid	2450	°F	xxx

HARDGROVE GRINDABILITY INDEX = 46 at 3.97 % Moisture

[illegible] = [illegible]

Sisneros 2/4

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES [illegible]

VE SELDON
[illegible]
EST DIVISION

PLEASE ADDRESS ALL CORRESPONDENCE
224 S CARBON AVE [illegible]
OFFICE TEL (801) 63

UTAH FUEL COMPANY
P O Box 719
Helper, Utah 84526

May 23, 1985

Sample identification
by

Utah Fuel Co.

Monthly Composite of April 19
18706
18776
18777
18865

nd of sample ported to us	Coal
mple taken at	Skyline
ple taken by	Utah Fuel Co.
ate sampled	April 1985
ate 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

isture, Ash-free Btu = 14297

ULTIMATE ANALYSIS

	As Received	Dry Ba
% Moisture	8.67	xxx
% Carbon	66.04	72.
% Hydrogen	5.00	5.
% Nitrogen	1.52	1.
% Chlorine	0.04	0
% Sulfur	0.70	0.
% Ash	8.86	9.
% Oxygen (diff)	9.17	10.
	100.00	100.

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	Oxidi
Initial Deformation	2180 °F	22
Softening (H = W)	2300 °F	241
Softening (H = ½W)	2360 °F	246
Fluid	2400 °F	25

DGROVE GRINDABILITY INDEX = 50.0 at 3.32 % Moisture

[illegible]

WELLING INDEX = xxxx

DB/ap

Watermarked
Protection

COMMERCIAL TESTING & ENGINEERING CO.

Jeff [illegible]

Manager, Price Laboratory

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

Riverside Cement Company

GIFFORD-HILL

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	Sm810	SO2	4	740 P
"	"	"	NO	0	460 P
9:38 Am	"	Cm50	O2	1%	22%
8:34 Am	6-27-85	Sm810	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	O2	1%	20.5%
"	"	SM810	SO2	0	719
"	"	SM810	No	0	482
0712	7-17-85	SM810	[illegible]	[illegible]	714
"	"	"	No	[illegible]	475
	"	CM50	[illegible]	2.0	20.3
9:38	7-21-85	Sm810	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: [illegible]800 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
SO2 Zero	0	0
NO Zero	0	0
SO2 Span	850	781
NO Span	510	51[illegible]

2.33

12.25*

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	12.33
NO Span	12.[illegible]	12.25

[illegible]

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-25-85 TIME : 0723 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 781 12.33 MA 3.08 VDC

NO INTERNAL SPAN CELL VALUE 516 652 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	781	919-922)	
NO Span	516	642	

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

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

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-31-85 TIME : 11:47 NAME: WJF LT

EQUIP. USED
BECK METER
RCC 109

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	DID NOT CHANGE
NO Zero	0	BECAUSE OF
SO2 Span	930	KUB DRIFT STUDY.
NO Span	645	

MILLIAMP OUTPUT SIGNAL 1-5 VDC (~~4~~ - ~~20~~ ma)

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	1.005	
NO Zero	.985 AND STILL DROPPING	
SO2 Span	3.47	
NO Span	3.59	

ZERO AND SPAN CHECKLIST

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 8-1-85 TIME : 2:05 NAME: WALT

EQUIP USED
BECK RCC109

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	0+	
SO2 Span	880	
NO Span	640	

VOLT ~~MILLIAMP~~ OUTPUT SIGNAL 1-5 VDC ~~(4 - 20 ma)~~

TEST	AS FOUND	AFTER CALIBRATION
SO2 Zero	1.014	
NO Zero	1.023	
SO2 Span	3.34	
NO Span	3.57	

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

STOP TIME 10:45 AM

RESTART TIME - 1:18 PM

NAME: Jerry Young, Charlie Floyd, Wayne, Paul Fogg

7/26/85

Audit Team: Ryn Benson, Adam Froh[illegible], KV

	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 an

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:

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

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:

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

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 hou

*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 (3.69391) 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:

1.693

Expected voltage = (Voltage at TP-3, from #21 above) 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 (365 x 2.74)

*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:

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

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

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.

jumper TP5 to TP3

*Voltage at TP-2 before calibration: 10

**Voltage at TP-2 after calibration: 1.0001 (use Pronek 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	RCC103	Digimite
multimeter	RCC104	Fluke
Multimeter	RCC102	Beckman

FULL CALIBRATION WORKSHEETF

LEAR SIEGLER SM-810 NOx/SOx GAS ANALYZER

DATE: 7-25/26-85 TIME: 0910 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 SO2 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 wv ″ ″ 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.

2

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

**Voltage of signal after calibration: [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:

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

6.05

$$\frac{[illegible] \times 7}{750}$$

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

**Expected voltage at TP-5: 6.05

***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:

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

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

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

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

***mA ~~Voltage~~ at J1 21 ~~TP-16~~ after calibration: ~~.625~~ 12.5mA

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.

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

Matheson
8800 Utica Avenue
Cucamonga, California 91730
Phone: (714) 987-4611

LABORATORY REPORT ON GAS ANALYSIS

Riverside Cement
Riverside, Ca.

DATE 7-19-85
OUR INVOICE NO. 106-65205
YOUR P.O. NO. RD233220
LOT NO. 10-7-44, P544 PS

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. SV11790 Requested	Cyl. No. SV11790 Actual	Cyl. No. 7539P Requested	Cyl. No. 7539P Actual	Cyl. No. RA0156 Requested	Cyl. No. RA0156 Actual
CARBON DIOXIDE						
OXYGEN			2.0	2.00%		
HYDROGEN						
CARBON MONOXIDE						
NITROGEN	BALANCE	→	→	→	→	→
ARGON						
AIR						
METHANE						
HELIUM						
SULFUR DIOXIDE	50ppm	52ppm				
NITRIC OXIDE					1000ppm	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
MATHESON GAS PRODUCT

The only liability of this company for gas which fails to comply with the analysis shal be replacement thereof by the Company without extra cost.

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.

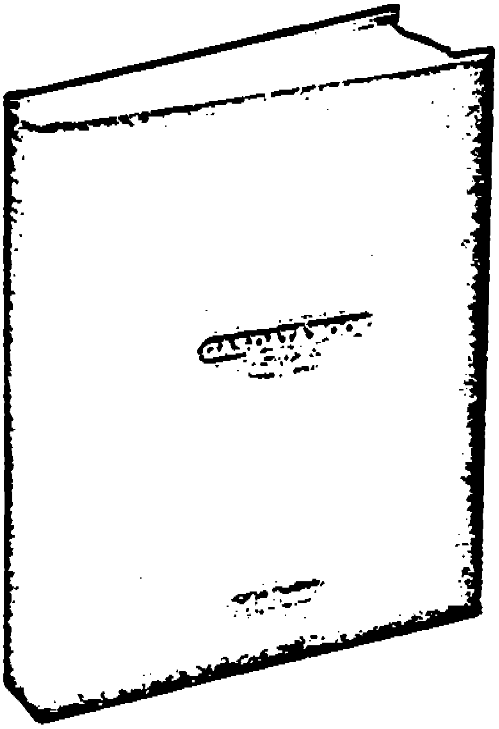
**Accuracies for Hydrogen and Helium components may vary from those stated due to their low molecular weight.

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 certificate. With these thoughts in mind Matheson has developed a *dynamic blending system* that delivers mixtures with tighter preparation tolerance 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: 7-17-85 TIME: 9:38 pm NAME: C Longberry

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	20.5%	

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO		
OXYGEN SPAN		

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	17.27	

BECKMAN
RCC 102

ZERO AND SPAN CALIBRATION

BAILEY OXYGEN ANALYZER #2

DATE: 7-24-85 TIME: 1500 NAME: [illegible]

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: 1.27

PERCENT OXYGEN OF GAS USED FOR SPAN CALIBRATION: 4.56

CALCULATION OF EXPECTED MILLIAMP OUTPUT: 20.16/46.48

$$\text{EXPECTED MILLIAMPS} = \frac{\text{(\% Oxygen of Test Gas)}}{(5.0)}\ 40 + 10$$

TEST	MILLIAMP OUTPUT SIGNAL AS FOUND	AFTER CALIBRATION
LOW RANGE TEST GAS	21.7	20.1
HIGH RANGE TEST GAS	45.7	46.4

ZERO AND SPAN CHECKLIST

LEAR SIEGLER CM-50 OXYGEN ANALYZER

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

[illegible] 102

RANGE: 0 - 25 percent oxygen

OUTPUT SIGNAL: 4 - 20 ma.

LOOP NUMBER: 11C

DIGITAL CHANNEL: 104

DIGISTRIP CHANNEL: 112

FRONT PANEL METER READING

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO		
OXYGEN SPAN	217%	

MILLIAMP OUTPUT SIGNAL (4 - 20 ma)

TEST	AS FOUND	AFTER CALIBRATION
OXYGEN ZERO	5.25	
OXYGEN SPAN	1750	

ZERO AND SPAN CALIBRATION

BAILEY OXYGEN ANALYZER #1 GRAY

DATE: 7-24-85 TIME: 10:30 NAME: CHARLIE

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: 1.22%

PERCENT OXYGEN OF GAS USED FOR SPAN CALIBRATION: 4.61%

CALCULATION OF EXPECTED MILLIAMP OUTPUT: 19.76 / 46.88

$$\text{EXPECTED MILLIAMPS} = \frac{(\%\ \text{Oxygen of Test Gas})}{(5.0)}\ 40 + 10$$

TEST	MILLIAMP OUTPUT SIGNAL AS FOUND	AFTER CALIBRATION
LOW RANGE TEST GAS	17.29	19.75
HIGH RANGE TEST GAS	42.50	46.9

RCC 10% Limit on

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

7-18-85 12:00 APPROX W.R. - ALLOCK

COAL FEED BIN

START	FINISH
ZERO OK	ZERO OK
SPAN 4.177	SPAN 4.003
0% =10 MA	SAME
4 TONS = 42 MA	SAME

0 TONS	0.002
1 TON	.998
2 TONS	2.000
3 TONS	3.000
4 TONS	4.003

EQUP USED (BECKMAN RCC 102
DUE 7-13-86)

LO SET POINT SET FOR 1.000
HI SET POINT SET FOR 3.000
FULL BIN SET FOR 4.000

ZERO AND SPAN CHECKLIST

COAL FEED SANKYO IMPACT FLOWMETER

DATE: 7-23-95 TIME: AM NAME: [illegible]

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
START	9.2	6.2
FINISH	9.2	5.0

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

ZERO AND SPAN CHECKLIST

COAL FEED SANKYO IMPACT FLOWMETER

DATE: 7-24-85 TIME: A M 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: 2,000 TONS COAL BIN

WITH D.C. SCE
OFF

ZERO POT
START 0 %
FINISH 2 %

SPAN PO
540
552

EXPECTED READINGS WITH STATIC TEST WEIGHT:

2000' TONS ~~TPH~~ — ma

FRONT PANEL METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	—	
WITH STATIC TEST WEIGHT	1956	2,012

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	—	
WITH 69 % ~~STATIC~~ ~~TEST~~ WEIGHT	37.2	37.2

APPENDIX K

ZERO AND SPAN CHECKLIST
KILN FEED SANKYO IMPACT FLOWMETER

ZERO AND SPAN CHECKLIST

~~[illegible]~~ KILN FEED SANKYO IMPACT FLOWMETER

DATE: 7-18-85 TIME: ALLDAY NAME: W. HALLOCK

RANGE: 0 - ~~[illegible]~~ 110 tons per hour

OUTPUT SIGNAL: 10 - 50 ma

LOOP NUMBER: ~~[illegible]~~ 19

DIGILINK CHANNEL: ~~[illegible]~~ 114

DIGISTRIP CHANNEL: ~~[illegible]~~ 204

STATIC TEST WEIGHT: 15.37 ± (60%)

NEW TEST WEIGHTS

MARKING ON WEIGHT	WEIGHT IN GRAMS	% SCAL
26	3008.5	28
52	3000.0	56
78	3005.1	83
103	2995.1	110

EXPECTED READINGS WITH STATIC TEST WEIGHT:

66 TPH 34 ma ? ?

31.82

USED RCC102 METER DUE 7-13-8

FRONT PANEL METER READINGS

TEST	AS FOUND	AFTER CALIBRATION
ZERO ~~TPH~~ %	-001	000
WITH STATIC TEST WEIGHT	60%	65%

MILLIAMP OUTPUT SIGNAL

TEST	AS FOUND	AFTER CALIBRATION
ZERO TPH	9.7	10.0
WITH STATIC TEST WEIGHT	34.0	34.0

10ma corresponds to 0 tons/hr
50 ma corresponds to 110 tons/hr

10ma + [illegible]

.3636 ma

APPENDIX L

CERTIFIED TEST WEIGHTS

PAUL B. ENGLER
DIRECTOR

COUNTY OF LOS ANGELES
DEPARTMENT OF WEIGHTS AND MEASURES
DIVISION OF METROLOGICAL SERVICES

CERTIFICATE M.S. 7987

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