Background Report Reference

AP-42 Section Number: 12.15

Background Chapter: 4

Reference Number: 19

Title: Stationary Source Sampling Report for Johnson Controls, Inc., Louisville, Kentucky

Trigon Engineering Consultants,Inc.

1991

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ENGINEERING CONSULTANTS, INC.

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STATIONARY SOURCE SAMPLING REPORT

FOR

JOHNSON CONTROLS, INC.

LOUISVILLE, KENTUCKY

RADCO #1 STACK
RADCO #2 STACK
RADCO #3 STACK
SOUTH APB STACK

Trigon Engineering Consultants,Inc.
Air Monitoring Division
Charlotte, North Carolina
Project #046-91-011

REPORT CERTIFICATION

The sampling and analyses performed for this report were carried out under my supervision and/or direction.

Date October 3, 1991 Signature _____

J.A. (Tony) Blanton
Senior Project Manager
Air Monitoring Division
Trigon Engineering Consultants, Inc.

I have reviewed all testing details and results in this report and hereby certify that the test report is authentic and accurate.

Date October 3, 1991 Signature _____

Richard B. McCain, III
Manager, Air Monitoring Division
Trigon Engineering Consultants, Inc.

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INTRODUCTION

Purpose:

The purpose of the sampling was to determine lead emissions for regulatory compliance purposes.

Outline of Test Program:

Source sampling was performed at the Johnson Controls, Inc. battery manufacturing facility in Louisville, Kentucky to determine concentrations and emission rates of inorganic lead from Pasting Line #1 RADCO #3 Stack, Pasting Line #2 RADCO #2 Stack, Pasting Line #3 RADCO #1 Stack and the South Auto Post Burner (APB) Stack. On September 17, 1991 three 2-hour sampling runs were conducted on RADCO #1 and #2 Stacks. On September 18, 1991 three 2-hour sampling runs were conducted on RADCO #3 Stack and the South Auto Post Burner Stack.

Test Participants:

Testing was performed by Mr. J. Anthony Blanton, Mr. Jeffery W. Kohlstedt and Mr. H. David Sides of Trigon Engineering Consultants, Inc. Testing was coordinated with Mr. David Brown, Johnson Controls, Inc. Process Engineer, and plant personnel. Mr. Paul Costangio a representative from the Air Pollution Control District of Jefferson County was present to observe the test proceedings. Testing was conducted during normal production hours.

SUMMARY OF RESULTS

Presentation:

Table 1 presents the summary of results from the Pasting Line #3 RADCO #1 Stack. The mean lead concentration was 0.000002 grains per dry standard cubic foot. The mean lead emission rate was 0.00026 pounds per hour.

Table 2 presents the summary of results from the Pasting Line #2 RADCO #2 Stack. The mean lead concentration was 0.000009 grains per dry standard cubic foot. The mean lead emission rate was 0.00114 pounds per hour.

Table 3 presents the summary of results from the Pasting Line #1 RADCO #3 Stack. The mean lead concentration was 0.000003 grains per dry standard cubic foot. The mean lead emission rate was 0.00045 pounds per hour.

Table 4 presents the summary of results from the South Auto Post Burner Stack. The mean lead concentration was 0.000017 grains per dry standard cubic foot. The mean lead emission rate was 0.000005 pounds per hour.

Detailed sampling results and example calculations are presented in Appendix A; analytical data is presented in Appendix B; and field data is presented in Appendix C.

Discussion:

Based on the results of the lead sampling, the four processes sampled at the Johnson Controls, Inc., Louisville, Kentucky battery manufacturing facility were in compliance with the New Source Performance Standards (NSPS) emission limitations. For the pasting processes the allowable lead emission rate is 0.00044 grains per dry standard cubic foot. For the Post Burner process the allowable lead emission rate is also 0.00044 grains per dry standard cubic foot.

TABLE 1

SUMMARY OF RESULTS, LEAD SAMPLING

PASTING LINE #3 RADCO #1 STACK

Run Number	1	2	3
Date	09/17/91	09/17/91	09/17/91
Percent Isokinetic	95.20	94.79	96.13
Avg. Stack Temperature, ^{O}F	88.92	94.58	97.42
Stack Gas Flow Rate, DSCFM *	14957.76	14511.20	15349.62
Stack Gas Flow Rate, ACFM	15860.33	15695.58	16615.64
Lead:			
Concentration, mg	0.0088	0.0118	0.0198
Concentration, gr/dscf	0.000001	0.000002	0.000003
Emission Rate, lbs/hour	0.000169	0.000228	0.000380

* $68^{O}F$, 29.92 inches Hg

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TABLE 2

SUMMARY OF RESULTS, LEAD SAMPLING

PASTING LINE #2 RADCO #2 STACK

Run Number	1	2	3
Date	09/17/91	09/17/91	09/17/91
Percent Isokinetic	92.40	96.10	93.92
Avg. Stack Temperature, ^{O}F	89.21	91.88	97.50
Stack Gas Flow Rate, DSCFM *	14137.69	14600.44	14088.54
Stack Gas Flow Rate, ACFM	14972.55	15675.86	15307.58
Lead:			
Concentration, mg	0.0366	0.1136	0.0178
Concentration, gr/dscf	0.000006	.000018	0.000003
Emission Rate, lbs/hour	0.000775	0.002274	0.000356

* $68^{O}F$, 29.92 inches Hg

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TABLE 3

SUMMARY OF RESULTS, LEAD SAMPLING

PASTING LINE #1 RADCO #3 STACK

Run Number	1	2	3
Date	09/18/91	09/18/91	09/18/91
Percent Isokinetic	96.62	93.93	96.41
Avg. Stack Temperature, ^{O}F	81.38	84.38	82.75
Stack Gas Flow Rate, DSCFM *	18128.79	17319.86	16761.53
Stack Gas Flow Rate, ACFM	19088.71	18407.82	17908.33
Lead:			
Concentration, mg	0.0137	0.036	0.0168
Concentration, gr/dscf	0.000002	0.000005	0.000002
Emission Rate, lbs/hour	0.000277	0.000737	0.000327

* $68^{O}F$, 29.92 inches Hg

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TABLE 4

SUMMARY OF RESULTS, LEAD SAMPLING

SOUTH AUTO POST BURNER STACK

Run Number	1	2	3
Date	09/18/91	09/18/91	09/18/91
Percent Isokinetic	95.10	94.84	98.06
Avg. Stack Temperature, ^{O}F	141.60	144.63	142.38
Stack Gas Flow Rate, DSCFM *	31.38	31.34	29.73
Stack Gas Flow Rate, ACFM	36.84	36.89	35.33
Lead:			
Concentration, mg	0.0702	0.14	0.0793
Concentration, gr/dscf	0.000012	0.000025	0.000014
Emission Rate, lbs/hour	0.000003	0.000007	0.000004

* $68^{O}F$, 29.92 inches Hg

PROCESS DESCRIPTION

The Johnson Controls, Inc., Louisville, Kentucky battery manufacturing facility operates pasting lines to produce positive and negative plates. Lead grids from the grid casting department are coated with a lead oxide/sulfuric acid paste and then flash dried and stacked. The emissions from each pasting line are collected by the corresponding RADCO vacuum filter. Pasting Line #1 is vented to RADCO #3, Pasting Line #2 is vented to RADCO #2, and Pasting Line #3 is vented to RADCO #1. Air passes through each RADCO and return air passes through the Hastings Baghouse before returning to the Pasting area. Exhaust gases pass from the Pasting area to a I.D. fan, RADCO, and stack to the atmosphere. A RADCO is a high volume, two stage HEPA filter with the capacity to continuously clean the main filter bank while operating. Figure 1 details the flow diagram for the Pasting Line/RADCO process.

In the Auto Post Burner process a small amount of molten lead is poured into a mold on the terminal tops of each battery to form a terminal post. This process is used primarily for top terminal type batteries. Emissions from the APB lines are vented uncontrolled to the atmosphere via a fan and common stack. Figure 2 details the flow diagram for the APB process.

Johnson Controls has provided information regarding production during the sampling. This data can be found in Appendix D - Process Data.

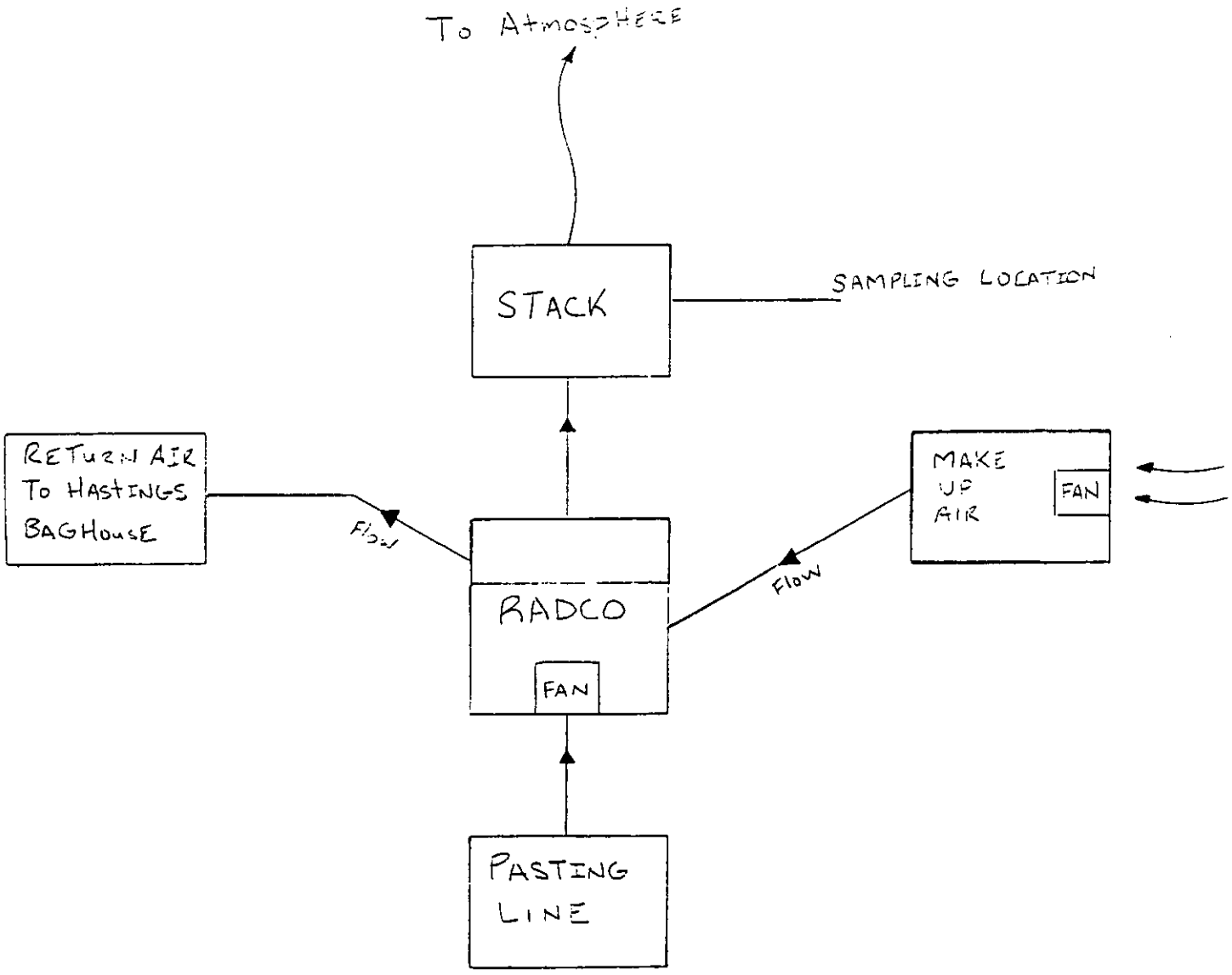

Figure 1
Flow Diagram
Pasting Lines #1, #2, and #3

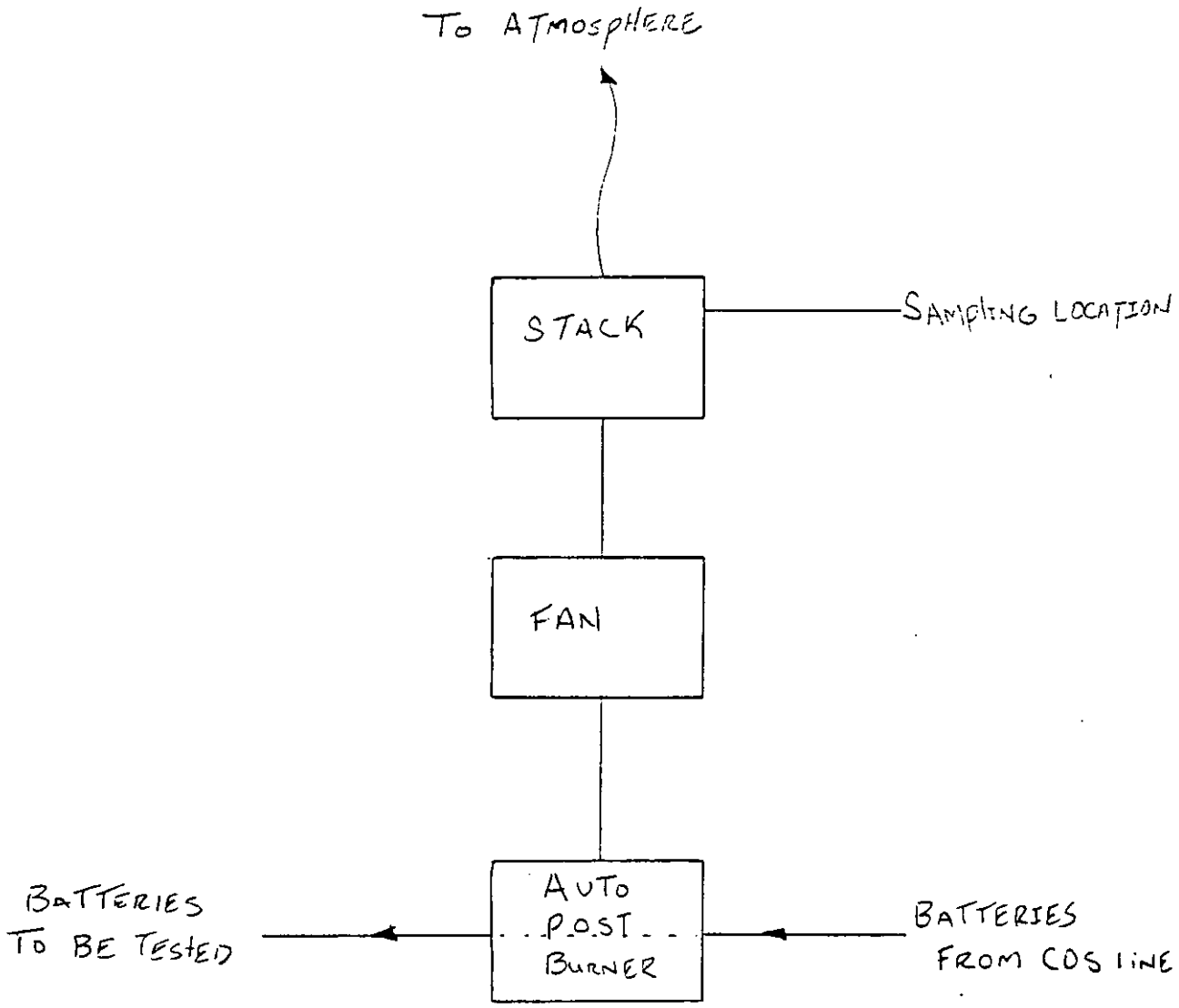

Figure 2
Flow Diagram
South Auto Post Burner (APB)

SAMPLING AND ANALYTICAL PROCEDURES

General:

Sampling and analytical procedures used were those recommended by the U.S. Environmental Protection Agency (EPA) and the Air Pollution Control District of Jefferson County. Due to the high analytical accuracy required for these lead samples, the laboratory determined total lead concentration (ug) by diluting each sample as necessary to bring it into optimum range of the calibration curve. This procedure is outlined in Reference Method 12 paragraph 5.4.1. Complete details are found in the Code of Federal Regulations, Title 40, Part 60, Appendix A, Methods 1 through 4, and Method 12.

Sampling Points:

The dimensions of the stack and the location of the sampling points are detailed in Figures 3 and 4. The stack cross section for the RADCO Lines #1, #2 and #3 were divided into 24 equal areas. The ports were labeled A and B. Each point was sampled for a period of 5.0 minutes which yielded a total test time of 120 minutes per run. The stack cross section for the South APB Line was divided into 8 equal areas. The ports were labeled A and B. Each point was sampled for a period of 7.5 minutes twice which yielded a total test time of 120 minutes per run.

The number of velocity sampling points were determined according to EPA Method 1. Velocity measurements were determined according to EPA Method 2. Gas composition was based on the emission of normal air concentrations for CO_2, O_2, CO, and N_2 which yields a dry molecular weight of 28.836 lb/lb mole basis. This was confirmed using a Fyrite gas analyzer. Moisture content was determined according to EPA Method 4. Sampling and analysis for lead was determined according to EPA Method 12.

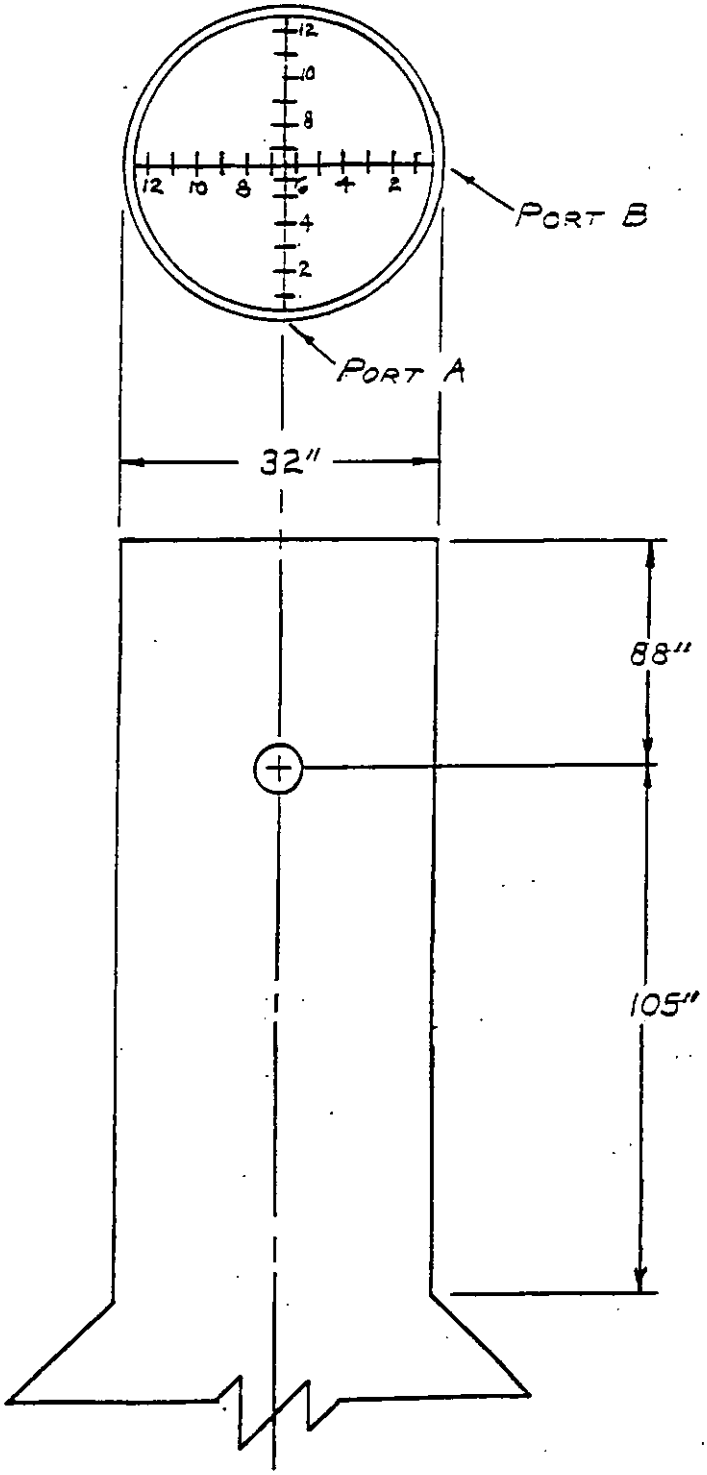

Figure 1
Location of Sampling Points and Ports
RADCO Lines

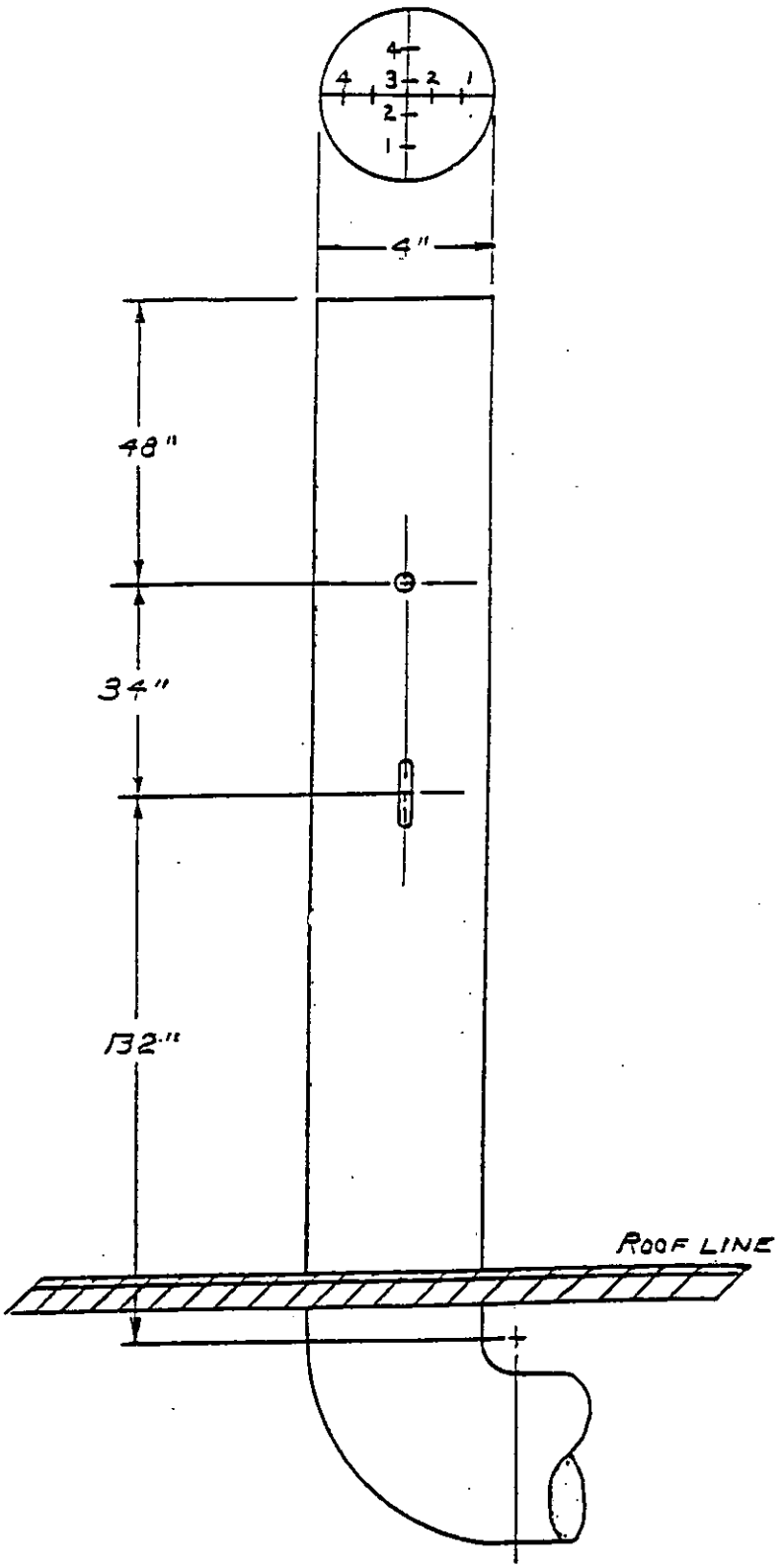

Figure 2
Location of Sampling Points and Ports
South APB Stack

APPENDICES

APPENDIX A

SAMPLING RESULTS AND EXAMPLE CALCULATIONS

SUMMARY OF RESULTS

PASTING LINE #3 RADCO #1 STACK

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #1 Stack

Run Number	1	2	3
Date:	09/17/91	09/17/91	09/17/91
TT - Net Time of Test	120	120	120
PB - Barometric Pressure, in Hg.	29.75	29.5	29.5
PS - Stack Pressure, Absolute	29.7794	29.5294	29.5294
DPS - Avg. Delta P Sqrd.	0.82	0.81	0.85
VSTD - Volume Sampled at Stand. Cond.	102.63	99.14	105.49
TM - Avg. Gas Meter Temp.Deg. F	86.20	94.40	95.02
TS - Avg. Stack Temp. Deg. F	88.92	94.58	97.42
VS - Avg. Stack Velocity, ft/s	47.37	46.88	49.63
QA - Actual Gas Volume Flow, (acfm)	15860.33	15695.58	16615.64
QS - Gas Volume Flow, Dry Std. Cond. (dscfm)	14957.76	14511.20	15349.62
QSW - Gas Volume Flow, Wet Std. Cond. (wscfm)	15184.14	14748.19	15533.17
MWD - Avg. Mole. Wt. Dry Stack Gas #/#	28.84	28.84	28.84
MW - Mole. Wt. Stack Gas #/#	28.67	28.66	28.71
PERI - Percent Isokinetic	95.20	94.79	96.13
AS - Area Stack, ft2	5.58	5.58	5.58
CP - Pitot Tube Constant	0.84	0.84	0.84

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #1 Stack

DN - Sample Nozzle Diameter	0.248	0.248	0.247
P02 - Percent 02 Dry	20.9	20.9	20.9
PC02 - Percent C02 Dry	0	0	0
PMV - Percent Moisture in Stack	1.491	1.607	1.182
VMV - Volume of Water Vapor at Std. Cond.	1.55	1.62	1.26
MD - Mole Fraction of Dry Gas	0.9845	0.9838	0.9874
FMF - Lead Concentration, Mg.	0.0088	0.0118	0.0198
CAN - Lead Concentration, gr/dscf	0.000001	0.000002	0.000003
CAT - Lead Concentration, gr/acf	0.000001	0.000002	0.000003
CAW - Lead Emission Rate, lbs/hr	0.000169	0.000228	0.000380
FMP - Net Sampling Points	24	24	24

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #1 Stack

Example Calculations Run 1

Pressure of Stack, Absolute inches Hg.
PS = PB - Static Pressure inches Hg. = 29.7794

Volume of Dry Gas Sampled at Standard Cond.

$$VSTD = \frac{17.64 * VM * (PB + PM / 13.6)}{TM + 460} = 102.6323$$

Volume of Water At Standard Cond.
VMV = 0.04709 * VW = 1.5533

Percent Moisture in Stack Gas

$$PMV = \frac{100 * VMV}{VMST + VMV} = 1.4909$$

Mole Fraction of Dry Gas

$$MD = \frac{100 - PMV}{100} = 0.9845$$

Average Molecular Weight of Dry Stack Gas
MWD = 0.44 * %C02 + 0.32 * %02 + 0.28 * (100 - %C02 - %02) = 28.8360

Molecular Weight of Stack Gas
MW = MWD * MD + [18 *(1 -MD)] = 28.6744

Stack Gas Velocity at Stack Cond.
VS = 5129.4 * CP * DPS * SQRT (TS + 460)/(PS * MW) = 47.3726

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #1 Stack

Stack Gas Volumetric Flow At Stack Cond.

$$QA = \frac{QS * (TS + 460)}{17.64 * PS * MD} =$$ 15860.33

Stack Gas Volumetric Folw at Standard Cond. Dry

$$QS = \frac{0.123 * VS * PS * MD}{TS + 460} =$$ 14957.76

Stack Gas Volumetric Flow at Standard Cond. Wet

$QSW = QS * [1/(1-(PMV / 100))]$ 15184.14

Percent Isokinetic

$$PERI = \frac{1039 * (TS + 460) * VMSTD}{VS * TT * PS MD * DN * DN} =$$ 95.1958

Lead Loading -- Probe, Impingers, and Filter
(At Standard Conditions gr/dscf)

$CAN = 0.0154 * FMF / VMSTD =$ 0.0000

Lead Loading -- Probe, Impingers, and Filter
(At Stack Conditions gr/acf)

$$CAT = \frac{17.64 * CAN * PS * MD}{TS + 460} =$$ 0.0000

Lead LB/hr -- Probe, Impingers, and Filter
(AT Standard Conditions)

$CAW = 0.00857 * CAN * QS =$ 0.0002

* Standard Conditions = 68 degrees F, 29.92 inches Hg.

TRIGON

SUMMARY OF RESULTS

PASTING LINE #2 RADCO #2 STACK

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #2 Stack

Run Number	1	2	3
Date:	09/17/91	09/17/91	09/17/91
TT - Net Time of Test	120	120	120
PB - Barometric Pressure, in Hg.	29.74	29.48	29.37
PS - Stack Pressure, Absolute	29.7694	29.5094	29.3994
DPS - Avg. Delta P Sqrd.	0.78	0.81	0.78
VSTD - Volume Sampled at Stand. Cond.	88.18	96.29	93.07
TM - Avg. Gas Meter Temp Deg. F	85.14	91.42	95.06
TS - Avg. Stack Temp. Deg. F	89.21	91.88	97.50
VS - Avg. Stack Velocity, ft/s	44.72	46.82	45.72
QA - Actual Gas Volume Flow, (acfm)	14972.55	15675.86	15307.58
QS - Gas Volume Flow, Dry Std. Cond. (dscfm)	14137.69	14600.44	14088.54
QSW - Gas Volume Flow, Wet Std. Cond. (wscfm)	14321.83	14791.71	14245.29
MWD - Avg. Mole. Wt. Dry Stack Gas #/#	28.84	28.84	28.84
MW - Mole. Wt. Stack Gas #/#	28.70	28.70	28.72
PERI - Percent Isokinetic	92.40	96.10	93.92
AS - Area Stack, ft2	5.58	5.58	5.58
CP - Pitot Tube Constant	0.84	0.84	0.84

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #2 Stack

DN - Sample Nozzle Diameter	0.24	0.242	0.245
P02 - Percent 02 Dry	20.9	20.9	20.9
PC02 - Percent C02 Dry	0	0	0
PMV - Percent Moisture in Stack	1.286	1.293	1.100
VMV - Volume of Water Vapor at Std. Cond.	1.15	1.26	1.04
MD - Mole Fraction of Dry Gas	0.9885	0.9874	0.9896
FMF - Lead Concentration, Mg.	0.0366	0.1136	0.0178
CAN - Lead Concentration, gr/dscf	0.000006	0.000018	0.000003
CAT - Lead Concentration, gr/acf	0.000006	0.000017	0.000003
CAW - Lead Emission Rate, lbs/hr	0.000775	0.002274	0.000356
FMP - Net Sampling Points	24	24	24

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #2 Stack

Example Calculations Run 1

Pressure of Stack, Absolute inches Hg.
PS = PB - Static Pressure inches Hg. = 29.7694

Volume of Dry Gas Sampled at Standard Cond.

$$VSTD = \frac{17.64 * VM * (PB + PM / 13.6)}{TM + 460} = 88.1764$$

Volume of Water At Standard Cond.
VMV = 0.04709 * VW = 1.1485

Percent Moisture in Stack Gas

$$PMV = \frac{100 * VMV}{VMST + VMV} = 1.2858$$

Mole Fraction of Dry Gas

$$MD = \frac{100 - PMV}{100} = 0.9885$$

Average Molecular Weight of Dry Stack Gas
MWD = 0.44 * %C02 + 0.32 * %02 + 0.28 * (100 - %C02 - %02) = 28.8360

Molecular Weight of Stack Gas
MW = MWD * MD + [18 *(1 -MD)] = 28.6967

Stack Gas Velocity at Stack Cond.
VS = 5129.4 * CP * DPS • SQRT (TS + 460)/(PS * MW) = 44.7209

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #2 Stack

Stack Gas Volumetric Flow At Stack Cond.

$$QA = \frac{QS * (TS + 460)}{17.64 * PS * MD} =$$ 14972.55

Stack Gas Volumetric Folw at Standard Cond. Dry

$$QS = \frac{0.123 * VS * PS * MD}{TS + 460} =$$ 14137.69

Stack Gas Volumetric Flow at Standard Cond. Wet

QSW = QS * [1/(1-(PMV / 100))] 14321.83

Percent Isokinetic

$$PERI = \frac{1039 * (TS + 460) * VMSTD}{VS * TT * PS MD * DN * DN} =$$ 92.3964

Lead Loading -- Probe, Impingers, and Filter
(At Standard Conditions gr/dscf)

CAN = 0.0154 * FMF / VMSTD = 0.0000 ov

Lead Loading -- Probe, Impingers, and Filter
(At Stack Conditions gr/acf)

$$CAT = \frac{17.64 * CAN * PS * MD}{TS + 460} =$$ 0.0000

Lead LB/hr -- Probe, Impingers, and Filter
(AT Standard Conditions)

CAW = 0.00857 * CAN * QS = 0.0008 ✓

* Standard Conditions = 68 degrees F, 29.92 inches Hg.

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SUMMARY OF RESULTS

PASTING LINE #1 RADCO #3 STACK

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #3 Stack

Run Number	1	2	3
Date:	09/18/91	09/18/91	09/18/91
TT - Net Time of Test	120	120	120
PB - Barometric Pressure, in Hg.	29.62	29.49	29.44
PS - Stack Pressure, Absolute	29.6494	29.5194	29.4694
DPS - Avg. Delta P Sqrd.	0.99	0.95	0.93
VSTD - Volume Sampled at Stand. Cond.	118.23	111.65	113.67
TM - Avg. Gas Meter Temp Deg. F	85.58	97.17	89.73
TS - Avg. Stack Temp. Deg. F	81.38	84.38	82.75
VS - Avg. Stack Velocity, ft/s	57.02	54.98	53.49
QA - Actual Gas Volume Flow, (acfm)	19088.71	18407.82	17908.33
QS - Gas Volume Flow, Dry Std. Cond. (dscfm)	18128.79	17319.86	16761.53
QSW - Gas Volume Flow, Wet Std. Cond. (wscfm)	18448.51	17614.84	17159.22
MWD - Avg. Mole. Wt. Dry Stack Gas #/#	28.84	28.84	28.84
MW - Mole. Wt. Stack Gas #/#	28.65	28.65	28.58
PERI - Percent Isokinetic	96.62	93.93	96.41
AS - Area Stack, ft2	5.58	5.58	5.58
CP - Pitot Tube Constant	0.84	0.84	0.84

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #3 Stack

DN - Sample Nozzle Diameter	0.24	0.242	0.245
P02 - Percent 02 Dry	20.9	20.9	20.9
PC02 - Percent C02 Dry	0	0	0
PMV - Percent Moisture in Stack	1.733	1.675	2.318
VMV - Volume of Water Vapor at Std. Cond.	2.09	1.90	2.70
MD - Mole Fraction of Dry Gas	0.9791	0.9810	0.9730
FMF - Lead Concentration, Mg.	0.0137	0.036	0.0168
CAN - Lead Concentration, gr/dscf	0.000002	0.000005	0.000002
CAT - Lead Concentration, gr/acf	0.000002	0.000005	0.000002
CAW - Lead Emission Rate, lbs/hr	0.000277	0.000737	0.000327
FMP - Net Sampling Points	24	24	24

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #3 Stack

Example Calculations Run 1

Pressure of Stack, Absolute inches Hg.
PS = PB - Static Pressure inches Hg. = 29.6494

Volume of Dry Gas Sampled at Standard Cond.

$$VSTD = \frac{17.64 * VM * (PB + PM / 13.6)}{TM + 460} = 118.2344$$

Volume of Water At Standard Cond.
VMV = 0.04709 * VW = 2.0852

Percent Moisture in Stack Gas

$$PMV = \frac{100 * VMV}{VMST + VMV} = 1.7331$$

Mole Fraction of Dry Gas

$$MD = \frac{100 - PMV}{100} = 0.9791$$

Average Molecular Weight of Dry Stack Gas
MWD = 0.44 * %C02 + 0.32 * %02 + 0.28 * (100 - %C02 - %02) = 28.8360

Molecular Weight of Stack Gas
MW = MWD * MD + [18 *(1 -MD)] = 28.6482

Stack Gas Velocity at Stack Cond.
VS = 5129.4 * CP * DPS * SQRT (TS + 460)/(PS * MW) = 57.0153

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SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

Radco #3 Stack

Stack Gas Volumetric Flow At Stack Cond.

$$QA = \frac{QS * (TS + 460)}{17.64 * PS * MD} =$$ 19088.71

Stack Gas Volumetric Folw at Standard Cond. Dry

$$QS = \frac{0.123 * VS * PS * MD}{TS + 460} =$$ 18128.79

Stack Gas Volumetric Flow at Standard Cond. Wet

QSW = QS * [1/(1-(PMV / 100))] 18448.51

Percent Isokinetic

$$PERI = \frac{1039 * (TS + 460) * VMSTD}{VS * TT * PS MD * DN * DN} =$$ 96.6176

Lead Loading -- Probe, Impingers, and Filter
(At Standard Conditions gr/dscf)

CAN = 0.0154 * FMF / VMSTD = 0.0000

Lead Loading -- Probe, Impingers, and Filter
(At Stack Conditions gr/acf)

$$CAT = \frac{17.64 * CAN * PS * MD}{TS + 460} =$$ 0.0000

Lead LB/hr -- Probe, Impingers, and Filter
(AT Standard Conditions)

CAW = 0.00857 * CAN * QS = 0.0003

* Standard Conditions = 68 degrees F, 29.92 inches Hg.

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SUMMARY OF RESULTS

SOUTH APB STACK

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

South APB Stack

Run Number	1	2	3
Date:	09/18/91	09/18/91	09/18/91
TT - Net Time of Test	120	120	120
PB - Barometric Pressure, in Hg.	29.61	29.49	29.44
PS - Stack Pressure, Absolute	29.6093	29.4893	29.4393
DPS - Avg. Delta P Sqrd.	0.12	0.12	0.11
VSTD - Volume Sampled at Stand. Cond.	87.33	86.96	85.30
TM - Avg. Gas Meter Temp Deg. F	81.50	88.25	80.50
TS - Avg. Stack Temp. Deg. F	141.60	144.63	142.38
VS - Avg. Stack Velocity, ft/s	7.03	7.04	6.75
QA - Actual Gas Volume Flow, (acfm)	36.84	36.89	35.33
QS - Gas Volume Flow, Dry Std. Cond. (dscfm)	31.38	31.34	29.73
QSW - Gas Volume Flow, Wet Std. Cond. (wscfm)	32.00	31.75	30.47
MWD - Avg. Mole. Wt. Dry Stack Gas #/#	28.84	28.84	28.84
MW - Mole. Wt. Stack Gas #/#	28.63	28.70	28.57
PERI - Percent Isokinetic	95.10	94.84	98.06
AS - Area Stack, ft2	0.0873	0.0873	0.0873
CP - Pitot Tube Constant	0.84	0.84	0.84

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

South APB Stack

DN - Sample Nozzle Diameter	0.625	0.625	0.625
P02 - Percent 02 Dry	20.9	20.9	20.9
PC02 - Percent C02 Dry	0	0	0
PMV - Percent Moisture in Stack	1.924	1.288	2.439
VMV - Volume of Water Vapor at Std. Cond.	1.71	1.13	2.13
MD - Mole Fraction of Dry Gas	0.9829	0.9887	0.9787
FMF - Lead Concentration, Mg.	0.0702	0.14	0.0793
CAN - Lead Concentration, gr/dscf	0.000012	0.000025	0.000014
CAT - Lead Concentration, gr/acf	0.000011	0.000021	0.000012
CAW - Lead Emission Rate, lbs/hr	0.000003	0.000007	0.000004
FMP - Net Sampling Points	16	16	16

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

South APB Stack

Example Calculations Run 1

Pressure of Stack, Absolute inches Hg.
PS = PB - Static Pressure inches Hg. = 29.6093

Volume of Dry Gas Sampled at Standard Cond.

$$VSTD = \frac{17.64 * VM * (PB + PM / 13.6)}{TM + 460} = 87.3273$$

Volume of Water At Standard Cond.
VMV = 0.04709 * VW = 1.7133

Percent Moisture in Stack Gas

$$PMV = \frac{100 * VMV}{VMST + VMV} = 1.9242$$

Mole Fraction of Dry Gas

$$MD = \frac{100 - PMV}{100} = 0.9829$$

Average Molecular Weight of Dry Stack Gas
MWD = 0.44 * %C02 + 0.32 * %02 + 0.28 * (100 - %C02 - %02) = 28.8360

Molecular Weight of Stack Gas
MW = MWD * MD + [18 *(1 -MD)] = 28.6275

Stack Gas Velocity at Stack Cond.
VS = 5129.4 * CP * DPS * SQRT (TS + 460)/(PS * MW) = 7.0335

TRIGON

SUMMARY OF RESULTS
METHOD 12 INORGANIC LEAD

Johnson Controls Inc. Louisville, Kentucky

South APB Stack

Stack Gas Volumetric Flow At Stack Cond.

$$QA = \frac{QS * (TS + 460)}{17.64 * PS * MD} =$$ 36.84

Stack Gas Volumetric Flow at Standard Cond. Dry

$$QS = \frac{0.123 * VS * PS * MD}{TS + 460} =$$ 31.38

Stack Gas Volumetric Flow at Standard Cond. Wet

QSW = QS * [1/(1-(PMV / 100))] 32.00

Percent Isokinetic

$$PERI = \frac{1039 * (TS + 460) * VMSTD}{VS * TT * PS MD * DN * DN} =$$ 95.1015

Lead Loading -- Probe, Impingers, and Filter
(At Standard Conditions gr/dscf)

CAN = 0.0154 * FMF / VMSTD = 0.0000

Lead Loading -- Probe, Impingers, and Filter
(At Stack Conditions gr/acf)

$$CAT = \frac{17.64 * CAN * PS * MD}{TS + 460} =$$ 0.0000

Lead LB/hr -- Probe, Impingers, and Filter
(AT Standard Conditions)

CAW = 0.00857 * CAN * QS = 0.0000

* Standard Conditions = 68 degrees F, 29.92 inches Hg.

TRIGON

APPENDIX B

ANALYTICAL DATA

Oxford Laboratories, Inc.
Analytical and Consulting Chemists
1316 South Fifth Street
Wilmington, N.C. 28401
(919) 763-9793

DATE RECEIVED 09-23-91
DATE REPORTED 09-30-91
91W3086

TRIGON ENGINEERING CONSULTANTS INC.
7461-B ORR ROAD
CHARLOTTE, NC 28213

P.O. # AM-5039

ATTENTION: JEFFREY KOHLSTEDT

SAMPLE DESCRIPTION: PROJECT 046-91-005

1. M12-1
2. M12-2
3. M12-3
4. M12-4
5. M12-5
6. M12-6

RESULTS

	1	2	3	4	5	6
Lead, as Pb, Total ug	8.50	10.5	20.5	32.5	112	18.0
ead, as Pb, Total ug	8.50	13.5	18.5	32.0	113	18.5
ead, as Pb, Total ug	9.50	11.5	20.5	33.5	116	17.0

Oxford Laboratories, Inc.
Analytical and Consulting Chemists
1316 South Fifth Street
Wilmington, N.C. 28401
(919) 763-9793

DATE RECEIVED 09-23-91
DATE REPORTED 09-30-91
91W3086

TRIGON ENGINEERING CONSULTANTS INC. P.O. # AM-5039
7461-B ORR ROAD
CHARLOTTE, NC 28213

ATTENTION: JEFFREY KOHLSTEDT

SAMPLE DESCRIPTION: PROJECT 046-91-005

7. M12-7
8. M12-8
9. M12-9
10. M12-10
11. M12-11
12. M12-12

RESULTS

	7	8	9	10	11	12
Lead, as Pb, Total ug	14.0	36.0	17.0	69.0	139	79.0
ead, as Pb, Total ug	13.5	35.0	15.5	71.5	138	78.5
ead, as Pb, Total ug	13.5	37.0	18.0	70.0	143	80.5

Oxford Laboratories, Inc.
Analytical and Consulting Chemists
1316 South Fifth Street
Wilmington, N.C. 28401
(919) 763-9793

DATE RECEIVED 09-23-91
DATE REPORTED 09-30-91
91W3086

TRIGON ENGINEERING CONSULTANTS INC.
7461-B ORR ROAD
CHARLOTTE, NC 28213

P.O. # AM-5039

ATTENTION: JEFFREY KOHLSTEDT

SAMPLE DESCRIPTION: PROJECT 046-91-005

13. FILTER BLANK A
14. FILTER BLANK B
15. 0.1N HN03 BLANK
16. SPIKE OF #5 % RECOVERY

RESULTS

	13	14	15	16
ead, as Pb, Total ug	<5.00	<5.00	<5.00	103%
Lead, as Pb, Total ug	<5.00	<5.00	<5.00	107%
ead, as Pb, Total ug	<5.00	<5.00	<5.00	110%

OTE: SEE ATTACHED NOTE REGARDING METHOD 12 PROCEDURES.

Roger Oxford

ROGER C. OXFORD, CHEMIST

Oxford Laboratories, Inc.

Analytical and Consulting Chemists
1316 South Fifth Street
Wilmington, N.C. 28401
(919) 763-9793

DATE RECEIVED
DATE REPORTED

NOTE: ALL OF THESE RESULTS WERE GENERATED BY METHOD 12. THE ONLY MODIFICATION TO THE METHOD IS THE FINAL VOLUME OF 50ml IN PLACE OF A 250ml F.V. BY EVAPORATING THE FINAL FILTRATE TO DRYNESS AND RECONSTITUTING IN 10% HN03 ACID. WE ARE CONTROLLING THE ACID MATRIX BETWEEN SAMPLES AND STANDARDS. METHOD 12 IS VERY LAX ON THIS POINT.

APPENDIX C

FIELD DATA

FIELD DATA

PASTING LINE #3 RADCO #1 STACK

TRIGON

Preliminary Field Data

PLANT NAME Johnson Controls Inc

LOCATION Louisville KY

SAMPLING LOCATION LADCO #1 STACK

DATE 9/16/01

DUCT DEPTH

FROM INSIDE FAR WALL TO OUTSIDE OF PORT 32

NIPPLE LENGTH 0

DEPTH OF DUCT 32

WIDTH (RECTANGULAR DUCT) N/A

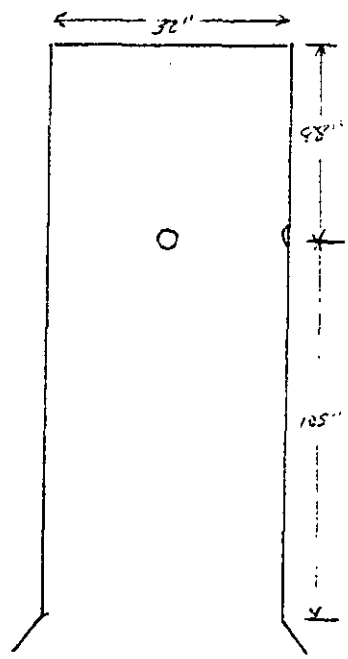
EQUIVALENT DIAMETER:

$$D_E = \frac{2 \times \text{DEPTH} \times \text{WIDTH}}{\text{DEPTH} + \text{WIDTH}} = \frac{2(\ \ )(\ \ )}{(\ \ +\ \ )} = N/A$$

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE	UPSTREAM	DOWNSTREAM
	94"	105"
DIAMETERS	2.75	3.29

STACK AREA = 804.25 IN² 5.584 FT²

CALCULATED BY JWK



SCHEMATIC OF SAMPLING LOCATION

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.5	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5		85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6		95.6	80.6	65.8	35.6	28.9	22.0	18.8	16.5	14.6	13.2
7			89.5	77.4	64.4	36.6	28.3	22.6	20.4	16.0	16.1
8			96.8	85.4	75.0	63.4	37.5	29.5	25.0	21.8	19.4
9				91.8	82.3	73.1	62.5	38.2	30.8	28.2	22.0
10				97.4	88.2	79.9	71.7	61.8	38.6	31.5	27.2
11					93.3	85.4	78.0	70.4	61.2	39.3	32.3
12					97.9	90.1	82.1	76.4	69.4	60.7	39.8
13						94.3	87.5	81.2	73.0	65.5	60.2
14						96.2	91.5	85.4	79.6	73.6	67.7
15							95.1	88.1	83.5	78.2	72.6
16							98.4	92.5	87.1	83.0	77.0
17								95.6	90.3	85.4	80.6
18								98.8	93.3	88.4	83.9
19									96.1	91.2	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.6
24											98.8

LOCATION OF TRAVERSE PINTS IN RECTANGULAR STACKS

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	18.8	16.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.8
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.8	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	86.4	79.2
11										95.5	87.5
12											96.6

POINT	% OF STACK I.D.	STACK I.D.	DISTANCE FROM INSIDE WALL	NIPPLE LENGTH	DISTANCE FROM OUTSIDE OF PORT
1	2.1	32	0.67	0	0.67
2	6.7	32	2.14	0	2.14
3	11.8	32	4.03	0	4.03
4	17.7	32	5.66	0	5.66
5	25.0	32	8.0	0	8.0
6	35.6	32	11.39	0	11.39
7	64.4	32	20.61	0	20.61
8	75.0	32	24.0	0	24.0
9	82.3	32	26.34	0	26.34
10	88.2	32	28.22	0	28.22
11	93.3	32	29.86	0	29.86
12	97.9	32	31.33	0	31.33

EPA REFERENCE METHOD 2

DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE

DETERMINATION OF CYCLONIC FLOW

Plant JOHNSON CONTROLS INC City LOUISVILLE KY
Sampling Location PAINT # 1 STACK
Run Date 6/16/91 Time 10:48
Operators JAB/JWK/HDS Ambient Temp, °F 87

Bar. Press., in. Hg 29.75 Pitot Tube I.D. No. 200.003
Stack Press., in. Hg 29.779 Pitot Tube Coefficient, Cp 0.84
Static Press., in. H_2O +0.39 Date Calibrated 05/09/91
Static Press., in. Hg 0.029 Leak Check <0.1 @ 3.7 in. H_2O

Stack Dimension, in., diameter/side 1 32 side 2 —

FIELD DATA

Traverse Point Number	Velocity Head Inches H_2O		Stack Temperature °F		Cyclonic Flow Determination Δp_s at 0° reference		Angle which yields a null Δp	
1	0.86	0.90	86	85	0.35	0.39	10	14
2	1.1	0.91	85	85	0.33	0.40	12	16
3	1.05	0.91	84	85	0.31	0.37	10	13
4	1.03	0.85	85	85	0.31	0.30	11	10
5	0.95	0.76	85	85	0.27	0.25	9	9
6	0.75	0.65	85	85	0.17	0.15	8	7
7	0.53	0.59	85	85	0.15	0.14	8	8
8	0.57	0.69	85	85	0.11	0.10	7	8
9	0.57	0.80	85	86	0.17	0.15	10	9
10	0.52	0.84	86	88	0.25	0.24	13	10
11	0.45	0.82	87	86	0.23	0.20	11	10
12	0.69	0.71	85	85	0.19	0.17	10	9
Average	0.74		85				10.0	

< 20°? yes

Stack Temp., Dry, °F (A) 83 Stack Temp., Wet, °F (B) 69

Difference (A - B) 14 Percent Moisture 4%

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME Johnson Controls Inc RUN NUMBER 1

CITY/STATE Louisville KY DATE 9/2/91

SAMPLING LOCATION [illegible] # 1 Stack OPERATORS JAB / JWK / [illegible]

Ambient Temperature, °F 68	NOMOGRAPH SET-UP	LEAK CHECKS	
Barometric Pressure, in. Hg 29.75	ΔH @ 1.91 Gamma = 1.00	Pre-test 0.001 @ 15 In. Hg	
Static Pressure, in. H_2O + 0.40	Meter Temp. 35 °F	Post-test 0.001 @ 6 In. Hg	
Meter Box Number 300.045	Stack Temp. [illegible] °F	Pre-test Pitot <0.1 @ [illegible] In. Hg	
Sample Box Number 1	Assumed % Moisture 4%	Post-test Pitot <0.1 @ [illegible] In. Hg	
Probe Number 1	C Factor 1.10	Orsat System [illegible]	
Filter Number [illegible]	Avg ΔP 0.74	Tedlar Bag # NA	
Nozzle Number [illegible]	Ref. ΔP [illegible]	Tedlar Bag Leakcheck NA	
Nozzle Diameter 0.245	Noz. Dia. Desired [illegible]	Probe Temp. Setting [illegible] °F	

Start Time 0939 Finish Time 1156 Observer [illegible] Paul [illegible] [illegible]

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING ΔP IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ACTUAL	DRY GAS METER TEMP. °F INLET (6)	OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A-1	0	338.48	0.75	3.20	3.20	70	70	3.9	86	243	45
2	5	343.12	0.81	3.30	3.30	73	72	4.1	85	245	45
3	10	347.80	0.78	3.20	3.20	80	72	4.1	86	242	50
4	15	352.60	0.71	2.89	2.89	86	74	4.0	88	244	59
5	20	357.00	0.61	2.50	2.50	91	76	3.5	88	242	55
6	25	361.53	0.67	2.70	2.70	93	78	4.0	89	242	59
7	30	365.60	0.57	2.30	2.30	91	79	3.2	88	240	61
8	35	370.14	0.62	2.55	2.55	90	81	3.5	89	242	61
9	40	373.77	0.72	2.95	2.95	90	81	[illegible]	89	241	62
10	45	378.28	0.82	3.32	3.32	90	82	4.6	89	242	61
11	50	383.10	0.78	3.20	3.20	91	82	4.0	82	243	61
12	55	388.00	0.73	3.00	3.00	92	83	4.2	88	242	61
B-1	60/0	392.43	0.85	3.50	3.50	83	82	4.9	89	246	65
2	5	397.41	0.95	3.85	3.85	85	83	4.9	84	243	52
3	10	402.61	0.95	3.85	3.85	91	83	5.0	90	244	58
4	15	407.78	0.92	3.80	3.80	93	83	5.0	90	245	60
5	20	412.90	0.84	3.42	3.42	96	85	4.9	91	244	62
6	25	417.72	0.71	2.90	2.90	98	86	4.0	91	245	63
7	30	422.49	0.47	1.95	1.95	96	86	3.1	91	242	61
8	35	426.24	0.44	1.83	1.83	96	87	3.0	91	243	61
9	40	429.94	0.46	1.91	1.91	90	87	3.0	91	243	59
10	45	433.65	0.46	1.91	1.91	93	86	3.0	91	241	59
11	50	437.32	0.43	1.78	1.78	90	87	2.9	92	242	59
12	55	440.92	0.43	1.78	1.78	95	87	3.0	92	240	57
	60	444.56									
		106.02	0.69		2.82		86.2		88.92		

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME JOHNSON CONTROLS INC RUN NUMBER 2

CITY/STATE LOUISVILLE KY DATE 9/17/91

SAMPLING LOCATION RADIO #1 STACK OPERATORS JAB MDS TWK

Ambient Temperature, °F 83
Barometric Pressure, in. Hg 29.50
Static Pressure, in. H_2O 0.40
Meter Box Number 3.00.046
Sample Box Number 2
Probe Number 2
Filter Number MH2-2
Nozzle Number 2.00-028
Nozzle Diameter 0.248

NOMOGRAPH SET-UP

ΔH @ 1.91 Gamma = 1.00
Meter Temp. 90 °F
Stack Temp. 93 °F
Assumed % Moisture 4
C Factor 1.10
Avg ΔP 0.74
Ref. ΔP 0.45
Noz. Dia. Desired 0.27

LEAK CHECKS

Pre-test 0.007 @ 15 In. Hg
Post-test 0.006 @ 5 In. Hg
Pre-test Pitot <0.1 @ 7.2 In. Hg
Post-test Pitot <0.1 @ 7 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 105 °F

Start Time 1219 Finish Time 1426 Observer Paul Costanzo, MACE, Air Pollution Control Dist. of Jefferson Co.

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A1	0	440.971	0.61	2.40	2.40	87	86	2.0	93	250	63
2	5	445.25	0.67	2.80	2.80	90	87	2.5	94	250	53
3	10	453.30	0.75	3.10	3.10	94	91	3.0	94	251	53
4	15	463.09	0.64	2.65	2.65	96	93	2.4	94	251	55
5	20	462.29	0.61	2.60	2.60	95	97	2.5	93	249	56
6	25	466.43	0.55	2.30	2.30	96	97	2.0	94	250	59
7	30	470.98	0.56	2.35	2.35	93	89	2.0	94	245	61
8	35	474.53	0.61	2.40	2.40	98	89	2.0	94	245	62
9	40	478.67	0.67	2.54	2.54	95	89	2.5	90	247	63
10	45	482.92	0.66	2.70	2.70	99	90	2.6	90	245	63
11	50	487.36	0.64	2.65	2.65	97	89	2.5	94	243	63
12	55	491.73	0.55	2.27	2.27	99	90	2.4	94	245	64
A1	6010	495.86	0.62	2.51	2.51	98	91	2.5	95	246	62
2	5	500.15	0.70	2.80	2.80	99	91	2.3	96	243	59
3	10	504.80	0.72	2.91	2.91	99	93	2.3	94	242	56
4	15	509.21	0.67	2.74	2.74	100	93	2.6	95	244	56
5	20	513.71	0.64	2.65	2.65	102	94	2.5	96	245	57
6	25	518.09	0.57	2.33	2.33	101	93	2.4	96	245	55
7	30	522.16	0.57	2.40	2.40	102	94	2.5	96	245	53
8	35	526.23	0.64	2.66	2.66	103	95	2.5	96	246	54
9	40	530.67	0.68	2.80	2.80	103	95	2.3	96	246	56
10	45	535.10	0.71	2.90	2.90	102	95	2.6	96	248	53
11	50	539.74	0.83	3.40	3.40	101	95	3.0	95	243	53
12	55	544.16	0.81	3.30	3.32	100	95	3.0	95	244	54
	60	549.54									
		104.87	0.65		2.66		94.4		94.58		

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME Johnson Controls Inc — RUN NUMBER 3

CITY/STATE Louisville KY — DATE 9/17/96

SAMPLING LOCATION Baghouse #1 Stack — OPERATORS JAB, MDS Jack

Ambient Temperature, °F 93
Barometric Pressure, in. Hg 29.50
Static Pressure, in. H_2O -1.0
Meter Box Number 3Q-005
Sample Box Number 2
Probe Number 3
Filter Number M123
Nozzle Number 290 - 0.26
Nozzle Diameter 0.247

NOMOGRAPH SET-UP
ΔH @ 1.91 Gamma = 1.00
Meter Temp. 80 °F
Stack Temp. 40 °F
Assumed % Moisture 4
C Factor 1.10
Avg ΔP 0.72
Ref. ΔP 0.45
Noz. Dia. Desired 0.27

LEAK CHECKS
Pre-test 0.002 @ 15 In. Hg
Post-test 0.001 @ 5 In. Hg
Pre-test Pitot <0.1 @ 5 In. Hg
Post-test Pitot <0.1 @ 4 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 165 °F

Start Time 1444 — Finish Time 1644 — Observer Paul Costanzo (Clayton Environmental Consultants, Inc.)

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A1	0	552.90	0.97	1.0	1.0	97	93	4.5	96	251	60
2	5	556.01	0.92	3.1	3.1	95	93	4.5	97	250	59
3	10	559.71	0.90	3.60	3.60	98	93	4.0	97	250	59
4	15	563.54	0.74	3.00	3.00	98	92	3.5	97	250	59
5	20	567.16	0.65	2.50	2.50	99	92	4.0	97	243	62
6	25	570.80	0.60	2.44	2.44	99	92	4.0	97	243	61
7	30	574.91	0.52	2.105	2.105	99	92	4.0	98	243	62
8	35	578.10	0.68	2.80	2.80	100	94	4.0	98	244	61
9	40	582.65	0.74	3.20	3.20	103	95	4.0	98	246	54
10	45	586.27	0.75	3.20	3.20	104	95	4.0	98	243	53
11	50	590.06	0.71	2.90	2.90	104	95	4.0	97	246	54
12	55	594.82	0.65	2.70	2.70	103	95	3.5	98	246	53
B1	60	599.21	0.80	3.26	3.26	101	96	4.0	97	248	52
2	5	603.04	0.78	3.20	3.20	101	96	4.0	98	245	55
3	10	606.88	0.81	3.36	3.36	101	95	4.2	97	247	55
4	15	610.77	0.75	3.08	3.08	101	96	3.9	98	248	56
5	20	614.51	0.64	2.62	2.62	100	95	3.5	98	247	57
6	25	618.90	0.57	2.35	2.35	99	94	3.3	98	246	58
7	30	623.06	0.62	2.52	2.52	99	95	3.4	98	246	59
8	35	627.34	0.73	2.98	2.99	101	95	3.9	99	245	59
9	40	631.96	0.80	3.26	3.26	102	95	4.0	99	245	59
10	45	636.37	0.86	3.26	3.26	102	95	4.0	98	247	58
11	50	640.66	0.75	3.03	3.08	102	95	3.9	97	247	60
12	55	644.34	0.56	2.32	2.32	102	95	3.5	97	245	61
	60	647.52									
		111.62	0.73		2.99		95.02		97.42		

TRIGON

EPA METHOD 12 - INORGANIC LEAD DETERMINATION - DATA ANALYSIS

CLIENT/CITY Johnson Controls INC/Louisville PROJECT NUMBER 046-91-005

SAMPLING LOCATION Cupro #1 STACK SAMPLE DATE 9-17-91

CLEAN-UP BOX NUMBER #1 RECOVERY DATE 9-17-91

LABORATORY CUSTODY: DATE REC'D 9/19/91 REC'D BY DWK LOCKED? ✓

Run Number	1	2	3	
Sample Box Number	1	2	3	1
Probe Number	1	2	3	
Filter Number	M12 - 1	M12 - 2	M12 - 3	M12 -

ANALYSIS OF MOISTURE RECOVERY

Reagent Recovery Container #	M12 - 1 A	M12 - 2 A	M12 - 3 A	M12 - A
Description of Reagent	Clear	Clear	Clear	
Reagent Level Marked	✓	✓	✓	
Final Volume, ml	213	211	206	
Initial Volume, ml	200	200	200	
Net Condensed Volume, ml	13	11	6	
Silica Gel Recovery Cont. #	M12 - 1 B	M12 - 2 B	M12 - 3 B	M12 - B
% Silica Gel Spent	50 %	60 %	50 %	
Final Weight, g	220	223.4	220.8	
Initial Weight, g	200	200	200	
Net Adsorbed Water, g	20	23.4	20.8	
TOTAL REAGENT COLLECTED, ml	33.0	34.4	26.8	

ANALYSIS OF INORGANIC LEAD RECOVERY

Filter Recovery Container #	M12 - 1 C	M12 - 2 C	M12 - 3 C	M12 - C
Particulate Description	None Visible	None Visible	None Visible	
Filter Container Sealed?	✓	✓	✓	
Probe Rinse Container #	M12 - 1 D	M12 - 2 D	M12 - 3 D	M12 - D
Liquid Level Marked?	✓	✓	✓	

For final lead determination see the Appendix for Laboratory Data.

Remarks/Comments: NONE

FIELD DATA

PASTING LINE #2 RADCO #2 STACK

TRIGON

Preliminary Field Data

PLANT NAME Johnson Controls Inc.

LOCATION Louisville KY.

SAMPLING LOCATION Rack Stack #2

DATE 9/4/91

DUCT DEPTH
FROM INSIDE FAR WALL TO OUTSIDE OF PORT 32"

NIPPLE LENGTH 0

DEPTH OF DUCT 32"

WIDTH (RECTANGULAR DUCT) N/A

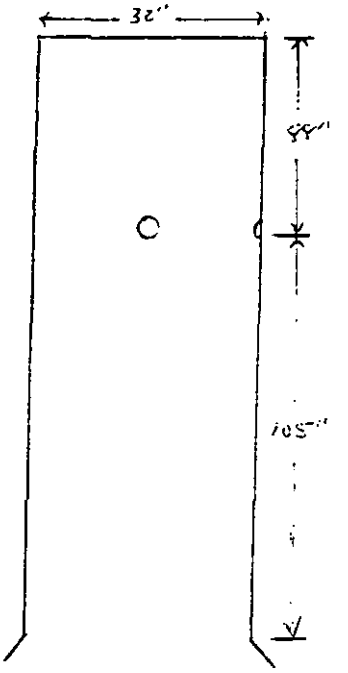
EQUIVALENT DIAMETER:

$D_E = \frac{2 \times \text{DEPTH} \times \text{WIDTH}}{\text{DEPTH} + \text{WIDTH}} = \frac{2(\ \ )(\ \ )}{(\ \ +\ \ )} = N/A$

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE	UPSTREAM	DOWNSTREAM
	88"	105"
DIAMETERS	2.75	3.28

STACK AREA = 804.25 IN² 5.58 ft²

CALCULATED BY JNK



SCHEMATIC OF SAMPLING LOCATION

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	(12)	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.6	17.7	14.8	12.5	10.9	9.7	8.7	7.9
5		85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6		93.6	80.6	65.8	35.6	28.9	22.0	18.8	16.5	14.8	13.2
7			89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8			96.8	85.4	75.0	63.4	37.5	29.8	25.0	21.8	19.4
9				91.8	82.3	73.1	62.5	38.2	30.8	26.2	23.0
10				97.4	88.2	79.9	71.7	61.8	38.6	31.5	27.2
11					93.3	85.4	78.0	70.4	61.2	39.3	32.3
12					97.9	90.1	83.1	78.4	69.4	60.7	39.6
13						94.3	87.5	81.2	75.0	68.5	60.2
14						98.2	91.5	85.4	79.8	73.8	67.7
15							95.1	88.1	83.5	78.2	72.8
16							98.4	92.5	87.1	82.0	77.0
17								95.8	90.3	85.4	80.8
18								98.8	93.3	88.4	83.9
19									96.1	91.3	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.8
24											98.9

LOCATION OF TRAVERSE PINTS IN RECTANGULAR STACKS

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	18.8	16.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.8
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.8	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	86.4	79.2
11										86.5	87.5
12											96.8

POINT	% OF STACK I.D.	STACK I.D.	DISTANCE FROM INSIDE WALL	NIPPLE LENGTH	DISTANCE FROM OUTSIDE OF PORT
1	2.1	32	0.67	0	0.67
2	6.7	32	2.14	0	2.14
3	11.8	32	4.13	0	4.13
4	17.7	32	5.66	0	5.66
5	25.0	32	8.0	0	8.0
6	35.6	32	11.39	0	11.39
7	64.4	32	20.61	0	20.61
8	75.0	32	24.0	0	24.0
9	82.3	32	26.34	0	26.34
10	88.2	32	28.22	0	28.22
11	93.3	32	29.86	0	29.86
12	97.9	32	31.33	0	31.33

EPA REFERENCE METHOD 2

DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE

DETERMINATION OF CYCLONIC FLOW

Plant JOHNSON CONTROLS INC City LOUISVILLE KY
Sampling Location CANCO #2 STACK
Run Date 9/14/01 Time 1623
Operators [illegible] Ambient Temp, °F 88

Bar. Press., in. Hg 29.73 Pitot Tube I.D. No. [illegible]
Stack Press., in. Hg 29.759 Pitot Tube Coefficient, Cp 0.84
Static Press., in. H_2O +0.8 Date Calibrated [illegible]
Static Press., in. Hg +0.059 Leak Check <0.1 @ 3.8 in. H_2O

Stack Dimension, in., diameter/side 1 32 side 2 —

FIELD DATA

Traverse Point Number	Velocity Head Inches H_2O A	Velocity Head Inches H_2O B	Stack Temperature °F		Cyclonic Flow Determination: Δp_s at 0° reference		Cyclonic Flow Determination: Angle which yields a null Δp	
1	0.64	0.52	101	105	0.45	0.34	11	13
2	0.69	0.54	[illegible]	[illegible]	0.42	0.34	15	12
3	0.71	0.52	[illegible]	99	0.39	0.25	13	11
4	0.68	0.50	[illegible]	[illegible]	0.32	0.32	10	10
5	0.59	0.48	[illegible]	[illegible]	0.29	0.25	12	12
6	0.56	0.48	[illegible]	[illegible]	0.16	0.16	13	10
7	0.55	0.59	[illegible]	[illegible]	0.15	0.19	8	9
8	0.83	0.71	[illegible]	[illegible]	0.20	0.15	10	10
9	0.76	0.72	[illegible]	[illegible]	0.19	0.17	12	11
10	0.78	0.84	[illegible]	[illegible]	0.17	0.16	14	12
11	0.75	0.83	[illegible]	99	0.19	0.15	13	10
12	0.65	0.72	[illegible]	99	0.16	0.22	9	15
~~13~~								
Average	0.65		101				11.42	

<20° ? yes

Stack Temp., Dry, °F (A) 102 Stack Temp., Wet, °F (B) 77

Difference (A - B) 25 Percent Moisture 4%

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME Johnson Controls Inc — RUN NUMBER 1

CITY/STATE Louisville KY — DATE 9/17/81

SAMPLING LOCATION Range #2 Stack — OPERATORS TAC/TWC/WTS

Ambient Temperature, °F 70
Barometric Pressure, in. Hg 29.74
Static Pressure, in. H_2O +0.4
Meter Box Number 300 007
Sample Box Number 4
Probe Number 4
Filter Number M12-4
Nozzle Number 300-057
Nozzle Diameter 0.240

NOMOGRAPH SET-UP
ΔH @ 1.95 Gamma = 1.00
Meter Temp. 55 °F
Stack Temp. 85 °F
Assumed % Moisture 4%
C Factor 1.1
Avg ΔP 0.65
Ref. ΔP 0.44
Noz. Dia. Desired 0.232

LEAK CHECKS
Pre-test 0.007 @ 15 In. Hg
Post-test 0.006 @ 5 In. Hg
Pre-test Pitot <0.1 @ 3.0 In. Hg
Post-test Pitot <0.1 @ 3.7 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 115 °F

Start Time 0954 — Finish Time 1235 — Observer Larry Maze / Paul Costanzo, Air pollution Control District of Jefferson County

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A1	0	411.90	0.45	1.72	1.72	76	71	3.0	85	257	85
2	5	414.16	0.46	1.73	1.75	75	71	3.0	86	240	41
3	10	417.63	0.46	1.78	1.78	78	73	3.0	87	247	42
4	15	420.57	0.44	1.70	1.70	83	75	3.0	87	250	45
5	20	423.43	0.43	1.65	1.65	86	76	3.0	87	251	47
6	25	426.39	0.43	1.65	1.65	88	78	3.0	88	250	48
7	30	429.27	0.60	2.29	2.29	87	78	3.2	87	246	44
8	35	432.62	0.69	2.68	2.68	87	79	3.5	87	244	52
9	40	436.32	0.77	2.91	2.91	86	80	3.8	87	245	54
10	45	440.27	0.81	3.10	3.10	89	81	3.9	88	248	57
11	50	444.22	0.78	2.95	2.95	90	82	4.0	88	248	58
12	55	448.21	0.72	2.74	2.74	91	83	3.8	88	250	59
B1	60	452.08	0.60	2.30	2.30	82	82	4.0	88	250	46
2	5	456.69	0.64	2.45	2.45	85	83	4.0	90	246	46
3	10	460.65	0.68	2.60	2.60	89	84	4.1	91	249	47
4	15	465.02	0.61	2.32	2.32	93	85	4.0	91	250	48
5	20	469.15	0.59	2.23	2.23	92	84	3.5	91	250	49
6	25	473.19	0.53	2.00	2.00	94	85	3.5	91	249	49
7	30	477.00	0.55	2.10	2.10	94	85	3.9	91	249	52
8	35	481.01	0.62	2.38	2.38	95	86	4.0	92	249	50
9	40	485.23	0.68	2.60	2.60	98	88	4.0	93	249	52
10	45	489.56	0.62	2.35	2.35	99	88	4.0	93	249	52
11	50	493.77	0.74	2.84	2.84	99	89	4.3	92	249	53
12	55	498.35	0.72	2.78	2.78	100	89	4.2	92	247	54
	60	502.99									
		91.85	0.61		2.33	85.14			89.21		

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME JOHNSON CONTROLS INC RUN NUMBER 2

CITY/STATE LOUISVILLE KY DATE 9-17-91

SAMPLING LOCATION CADCC #2 STACK OPERATORS JAB HDS JNC

Ambient Temperature, °F 70
Barometric Pressure, in. Hg ~~29.24~~ 29.48
Static Pressure, in. H_2O 0.4
Meter Box Number 300.067
Sample Box Number 5
Probe Number 5
Filter Number M1-85 (Am)
Nozzle Number 300.055
Nozzle Diameter 0.247

NOMOGRAPH SET-UP
ΔH @ 1.95 Gamma = 1.00
Meter Temp. 90 °F
Stack Temp. 55 °F
Assumed % Moisture 4%
C Factor 1.11
Avg ΔP 0.65
Ref. ΔP 1.65
Noz. Dia. Desired 0.222

LEAK CHECKS
Pre-test 0.006 @ 15 In. Hg
Post-test 0.003 @ 5 In. Hg
Pre-test Pitot <0.1 @ 3.7 In. Hg
Post-test Pitot <0.1 @ 3.5 In. Hg
Orsat System FYRITE
Tedlar Bag # N/A
Tedlar Bag Leakcheck N/A
Probe Temp. Setting 135 °F

Start Time 1250 Finish Time 1457 Observer LARRY MAZE / Paul Costango Air Pollution Control District of Jefferson County

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PILOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A	0	503.10	0.71	2.90	2.80	89	57	4.0	90	247	64
1	5	507.01	0.69	2.60	2.60	93	89	4.0	91	239	63
2	10	511.96	0.60	2.27	2.27	96	89	3.8	92	247	66
3	15	516.87	0.56	2.14	2.14	95	89	3.8	92	249	60
4	20	521.98	0.54	2.05	2.08	96	89	3.9	93	245	61
5	25	523.97	0.56	2.10	2.10	97	90	3.8	92	249	59
6	30	527.75	0.62	2.32	2.32	95	90	4.0	92	249	55
7	35	530.99	0.55	2.10	2.10	99	91	3.8	91	249	54
8	40	535.77	0.65	2.49	2.49	98	92	4.0	90	250	53
9	45	540.89	0.65	2.49	2.49	100	92	4.0	92	252	54
10	50	544.24	0.67	2.55	2.55	98	93	4.0	92	251	54
11	55	549.50	0.65	2.49	2.49	100	93	3.5	93	251	55
12	60/0	552.73	0.74	2.82	2.82	98	100	3.5	93	251	54
1	5	557.45	0.75	2.90	2.90	100	94	4.0	92	251	55
2	10	561.21	0.73	2.80	2.80	100	94	4.0	93	247	55
3	15	566.31	0.65	2.50	2.50	100	94	4.0	92	246	55
4	20	570.57	0.63	2.40	2.40	100	94	4.0	92	245	56
5	25	574.73	0.57	2.19	2.19	99	95	3.8	91	246	56
6	30	578.72	0.56	2.12	2.12	97	93	3.8	90	248	55
7	35	582.13	0.67	2.55	2.55	98	94	3.9	92	243	56
8	40	586.70	0.65	2.50	2.50	92	90	4.0	93	244	56
9	45	591.00	0.70	2.60	2.60	99	94	4.0	93	245	58
10	50	595.30	0.77	2.98	2.98	100	95	4.2	93	250	58
11	55	599.90	0.76	2.92	2.92	100	96	4.2	92	249	58
	60	604.52									
		101.42	0.65		2.49		91.42		91.88		

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME JOHNSON CONTROLS INC — RUN NUMBER 3

CITY/STATE LOUISVILLE KY — DATE 9/[illegible]/91

SAMPLING LOCATION RADCO #2 STACK — OPERATORS [illegible]

Ambient Temperature, °F 90
Barometric Pressure, in. Hg 29.37
Static Pressure, in. H_2O +0.4
Meter Box Number 3000.007
Sample Box Number #5
Probe Number #0
Filter Number M12-6
Nozzle Number 300.059
Nozzle Diameter .245

NOMOGRAPH SET-UP

ΔH @ 1.84 Gamma = 1.00
Meter Temp. 96 °F
Stack Temp. 85 °F
Assumed % Moisture 10%
C Factor 1.11
Avg ΔP 0.65
Ref. ΔP 0.49
Noz. Dia. Desired 0.245

LEAK CHECKS

Pre-test 0.002 @ 15 In. Hg
Post-test 0.001 @ 5 In. Hg
Pre-test Pitot <0.1 @ 5 In. Hg
Post-test Pitot <0.1 @ 5 In. Hg
Orsat System Lodge
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 115 °F
Carley Maze / Particostango

Start Time 1513 — Finish Time 1729 — Observer Air Pollution Control District of Jefferson County

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
1	0	604.80	0.71	2.30	2.30	96	85	3.9	96	248	58
2	5	609.20	0.51	2.00	2.00	92	89	3.4	97	245	61
3	10	613.89	0.47	1.86	1.86	90	92	3.7	97	250	52
4	15	618.40	0.46	1.79	1.79	97	92	3.7	97	254	51
5	20	623.27	0.46	1.79	1.79	97	93	3.6	97	249	52
6	25	623.86	0.47	1.80	1.80	97	92	3.7	98	249	53
7	30	627.49	0.57	2.21	2.21	96	93	4.0	98	250	53
8	35	631.49	0.70	2.69	2.69	98	90	4.2	98	250	53
9	40	635.65	0.76	2.90	2.90	98	93	4.3	98	249	55
10	45	640.45	0.77	3.00	3.00	99	93	4.3	98	248	56
11	50	645.14	0.87	3.31	3.31	97	92	4.7	97	247	56
12	55	649.59	0.88	3.33	3.33	101	93	4.8	99	246	58
A1	60	654.77	0.53	2.00	2.00	96	93	3.8	98	251	63
2	5	657.50	0.50	1.91	1.91	96	93	3.8	98	251	59
3	10	662.31	0.49	1.88	1.88	98	93	3.9	98	249	58
4	15	665.98	0.47	1.86	1.85	99	93	3.7	98	248	55
5	20	669.64	0.45	1.72	1.72	98	93	3.6	98	249	56
6	25	673.23	0.55	2.10	2.10	99	93	3.9	98	249	57
7	30	677.09	0.66	2.53	2.53	99	93	4.0	98	249	58
8	35	681.26	0.74	2.83	2.83	100	93	4.2	97	249	58
9	40	685.75	0.74	2.83	2.83	100	93	4.2	97	248	57
10	45	690.27	0.77	2.92	2.92	101	93	4.2	97	248	57
11	50	694.86	0.83	3.16	3.16	99	92	4.0	97	248	56
12	55	699.07	0.72	2.74	2.74	99	92	4.2	96	247	56
	60	703.87									
		99.07	0.62		2.38		95.06		97.5		

TRIGON

EPA METHOD 12 - INORGANIC LEAD DETERMINATION - DATA ANALYSIS

CLIENT/CITY Johnson Controls Inc/Louisville PROJECT NUMBER 046-91-005

SAMPLING LOCATION Lab's #2 STACK SAMPLE DATE 9/17/91

CLEAN-UP BOX NUMBER #1 RECOVERY DATE 9/17/91

LABORATORY CUSTODY: DATE REC'D 9/19/91 REC'D BY Clerk LOCKED? ✓

Run Number	1	2	3	
Sample Box Number	4	5	6	
Probe Number	4	5	6	
Filter Number	M12 -4	M12 -5	M12 -6	M12 -

ANALYSIS OF MOISTURE RECOVERY

Reagent Recovery Container #	M12 -4 A	M12 -5 A	M12 -6 A	M12 - A
Description of Reagent	clear	clear	clear	
Reagent Level Marked	YES	YES	YES	
Final Volume, ml	211	207	206	
Initial Volume, ml	200	200	200	
Net Condensed Volume, ml	11	7	6	
Silica Gel Recovery Cont. #	M12 -4 B	M12 -5 B	M12 -6 B	M12 - B
% Silica Gel Spent	55	55	55	
Final Weight, g	213.4	219.3	216.0	
Initial Weight, g	200	200	200	
Net Adsorbed Water, g	13.4	19.3	16.0	
TOTAL REAGENT COLLECTED, ml	24.4	26.3	22.0	

ANALYSIS OF INORGANIC LEAD RECOVERY

Filter Recovery Container #	M12 -4 C	M12 -5 C	M12 -6 C	M12 - C
Particulate Description	None Visible	None Visible	None Visible	
Filter Container Sealed?	✓	✓	✓	
Probe Rinse Container #	M12 -4 D	M12 -5 D	M12 -6 D	M12 - D
Liquid Level Marked?	✓	✓	✓	

For final lead determination see the Appendix for Laboratory Data.

Remarks/Comments: None

FIELD DATA

PASTING LINE #1 RADCO #3 STACK

TRIGON

Preliminary Field Data

PLANT NAME Johnson Controls Inc

LOCATION Louisville KY

SAMPLING LOCATION Rayco #3 Stack

DATE 9/11/91

DUCT DEPTH
FROM INSIDE FAR WALL TO OUTSIDE OF PORT 32"

NIPPLE LENGTH 0

DEPTH OF DUCT 32"

WIDTH (RECTANGULAR DUCT) NA

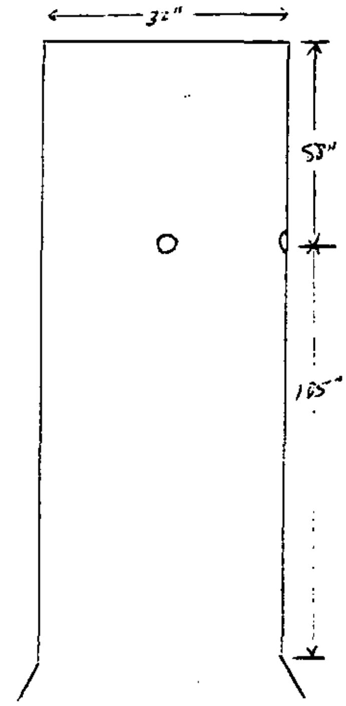
EQUIVALENT DIAMETER:

$$D_E = \frac{2 \times \text{DEPTH} \times \text{WIDTH}}{\text{DEPTH} + \text{WIDTH}} = \frac{2(\ -\ )(\ -\ )}{(\ -\ +\ -\ )} = NA$$

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE	UPSTREAM	DOWNSTREAM
	88"	105"
DIAMETERS	2.75	3.28

STACK AREA = 804.25 IN2 5.55 ft

CALCULATED BY TWK



SCHEMATIC OF SAMPLING LOCATION

POINT	% OF STACK I.D.	STACK I.D.	DISTANCE FROM INSIDE WALL	NIPPLE LENGTH	DISTANCE FROM OUTSIDE OF PORT
1	2.1	32	0.67	0	0.67
2	6.7	32	2.14	0	2.14
3	11.8	32	4.03	0	4.03
4	17.7	32	5.66	0	5.66
5	25.0	32	8.0	0	8.0
6	35.6	32	11.39	0	11.39
7	64.4	32	20.61	0	20.61
8	75.0	32	24.0	0	24.0
9	82.3	32	26.34	0	26.34
10	88.2	32	28.22	0	28.22
11	93.3	32	29.86	0	29.86
12	97.9	32	31.33	0	31.33

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.5	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5		85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6		95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7			89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8			96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9				91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10				97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11					93.3	85.4	78.0	70.4	61.2	39.3	32.3
12					97.9	90.1	83.1	76.4	69.4	60.7	39.8
13						94.3	87.5	81.2	75.0	68.5	60.2
14						98.2	91.5	85.4	79.6	73.8	67.7
15							95.1	89.1	83.5	78.2	72.8
16							98.4	92.5	87.1	82.0	77.0
17								95.6	90.3	85.4	80.6
18								98.6	93.3	88.4	83.9
19									96.1	91.3	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.8
24											98.9

LOCATION OF TRAVERSE PINTS IN RECTANGULAR STACKS

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	18.8	16.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.8
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.8	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	86.4	79.2
11										95.5	87.5
12											95.8

TRIGON

EPA REFERENCE METHOD 2

DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE

DETERMINATION OF CYCLONIC FLOW

Plant JOHNSON Controls INC City LOUISVILLE KY
Sampling Location [illegible] STACK
Run Date 9/16/91 Time 17:19
Operators [illegible] Ambient Temp, °F 84

Bar. Press., in. Hg 29.25 Pitot Tube I.D. No. 20.83
Stack Press., in. Hg 29.27 Pitot Tube Coefficient, Cp 0.84
Static Press., in. H_2O +0.35 Date Calibrated 05/10/91
Static Press., in. Hg +0.026 Leak Check <0.1 @ 3.4 in. H_2O

Stack Dimension, in., diameter/side 1 30 side 2 —

FIELD DATA

Traverse Point Number	Velocity Head Inches H_2O		Stack Temperature °F		Cyclonic Flow Determination			
					Δp_s at 0° reference		Angle which yields a null Δp	
1	0.87	0.95	79	82	0.42	0.48	14	13
2	0.96	0.92	82	84	0.41	0.39	13	12
3	1.00	1.05	81	83	0.37	0.37	13	11
4	1.05	1.00	81	81	0.33	0.31	11	10
5	1.05	1.00	83	80	0.30	0.29	10	10
6	1.05	1.05	81	80	0.21	0.19	7	9
7	1.10	1.05	80	79	0.16	0.15	6	7
8	1.10	1.05	80	79	0.14	0.16	5	7
9	1.15	1.10	86	79	0.17	0.15	6	7
10	1.10	1.15	81	80	0.19	0.17	7	8
11	1.05	1.00	80	78	0.20	0.22	9	9
12	0.92	0.94	79	79	0.24	0.23	10	12
Average	1.03		80.46				9.38	

<20°? yes

Stack Temp., Dry, °F (A) 83 Stack Temp., Wet, °F (B) 69

Difference (A - B) 11 Percent Moisture 4%

TRIGON

EPA METHOD 12 – DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME JOHNSON CONTROLS INC RUN NUMBER 1

CITY/STATE LOUISVILLE KY DATE 9/13/91

SAMPLING LOCATION EAFDC #3 STACK OPERATORS JWL/HDS

Ambient Temperature, °F 72
Barometric Pressure, in. Hg 29.62
Static Pressure, in. H_2O -0.29
Meter Box Number 3000667
Sample Box Number 1
Probe Number 1
Filter Number #1-7
Nozzle Number 3000557
Nozzle Diameter 0.240

NOMOGRAPH SET-UP

ΔH @ 1.95 Gamma = 1.00
Meter Temp. 85 °F
Stack Temp. 85 °F
Assumed % Moisture 0%
C Factor 1.11
Avg ΔP 1.63
Ref. ΔP 0.49
Noz. Dia. Desired 0.197

LEAK CHECKS

Pre-test 0.003 @ 15 In. Hg
Post-test 0.001 @ 7 In. Hg
Pre-test Pitot <0.1 @ 25 In. Hg
Post-test Pitot <0.1 @ 35 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck N/A
Probe Temp. Setting 165 °F

Start Time 0501 Finish Time 1006 Observer C

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A 1	0	764.66	0.79	2.55	2.85	69	67	5.0	79	247	68
2	5	767.51	0.96	3.54	3.54	72	69	5.9	80	245	64
3	10	773.41	0.98	3.62	3.62	77	69	5.9	82	249	63
4	15	778.40	1.00	3.79	3.79	81	70	6.1	81	249	64
5	20	783.49	0.98	3.62	3.62	84	71	5.9	81	248	62
6	25	788.51	1.05	3.95	3.95	83	73	6.1	81	257	63
7	30	793.72	1.05	3.95	3.95	88	74	6.1	81	256	64
8	35	799.95	1.10	4.11	4.11	91	76	6.2	81	249	64
9	40	744.79	1.10	4.11	4.11	92	77	6.2	81	252	65
10	45	749.65	1.10	4.11	4.11	94	78	6.2	81	251	65
11	50	755.62	0.90	3.42	3.42	95	79	5.4	79	253	65
12	55	759.95	0.89	3.36	3.36	95	81	5.3	80	250	64
B 1	60/0	764.79	0.85	3.22	3.22	91	81	5.1	81	255	64
2	5	769.62	0.93	3.51	3.51	94	81	5.3	81	251	56
3	10	774.55	0.99	3.70	3.70	95	82	5.9	82	249	54
4	15	779.64	0.97	3.69	3.68	96	83	5.9	82	251	53
5	20	784.75	0.98	3.62	3.62	97	84	5.8	82	251	53
6	25	789.84	0.97	3.68	3.68	98	84	5.8	82	251	54
7	30	794.96	0.99	3.70	3.70	99	85	5.8	83	251	55
8	35	800.05	1.05	3.95	3.95	100	87	6.0	83	252	55
9	40	805.34	1.10	4.11	4.11	101	88	6.1	83	251	54
10	45	810.62	1.10	4.11	4.11	102	88	6.1	83	251	54
11	50	816.02	1.10	4.11	4.11	103	89	6.1	83	252	54
12	55	821.19	0.89	3.34	3.34	104	90	5.4	83	250	54
	60	826.37									
		122.31	0.99		3.55		9558		81.38		

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME JOHNSON CONTROLS INC RUN NUMBER 2

CITY/STATE LOUISVILLE KY DATE 9/12/91

SAMPLING LOCATION Eanr. #3 STACK OPERATORS JCK/UDS

Ambient Temperature, °F 76
Barometric Pressure, in. Hg 29.49
Static Pressure, in. H_2O -0.23
Meter Box Number 300 247
Sample Box Number 2
Probe Number 2
Filter Number M17-8
Nozzle Number 300.058
Nozzle Diameter 0.242

NOMOGRAPH SET-UP
ΔH @ 1.95 Gamma = 1.00
Meter Temp. 90 °F
Stack Temp. 85 °F
Assumed % Moisture 4.3
C Factor 1.11
Avg ΔP 1.03
Ref. ΔP 0.49
Noz. Dia. Desired 0.197

LEAK CHECKS
Pre-test 0.004 @ 15 In. Hg
Post-test 0.002 @ 5 In. Hg
Pre-test Pitot <0.1 @ 35 In. Hg
Post-test Pitot <0.1 @ 35 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 265 °F

Start Time 1044 Finish Time 1153 Observer —

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A 1	0	827.13	0.74	2.50	2.50	85	85	3.5	54	253	67
2	5	831.64	0.88	3.32	3.32	90	85	3.2	84	252	64
3	10	836.46	0.91	3.42	3.42	95	86	3.9	85	251	65
4	15	841.39	0.91	3.41	3.42	99	87	3.9	86	251	63
5	20	846.31	0.93	3.47	3.47	102	88	4.0	86	252	63
6	25	851.29	0.91	3.42	3.42	103	89	4.0	86	251	63
7	30	856.24	0.94	3.51	3.51	104	91	4.0	85	250	64
8	35	861.24	0.99	3.70	3.70	105	91	4.0	85	250	63
9	40	866.36	1.05	3.95	3.95	105	92	4.1	85	250	63
10	45	871.64	0.98	3.62	3.62	105	92	4.0	84	251	61
11	50	876.73	0.84	3.28	3.28	102	91	3.8	84	249	60
12	55	881.54	0.72	2.71	2.71	101	90	3.5	85	245	60
B 1	60/0	886.01	0.86	3.25	3.25	97	89	3.7	84	252	60
2	5	890.84	0.94	3.51	3.51	99	89	3.9	85	249	58
3	10	895.82	0.89	3.35	3.35	100	89	4.0	85	248	59
4	15	900.51	0.90	3.42	3.42	101	90	3.9	85	249	59
5	20	905.77	0.90	3.42	3.42	103	90	3.9	86	248	59
6	25	910.65	0.91	3.43	3.43	104	91	4.0	86	250	59
7	30	915.60	0.92	3.45	3.45	103	91	4.0	85	248	59
8	35	920.55	0.95	3.50	3.50	103	91	3.9	85	247	59
9	40	925.53	0.98	3.62	3.62	104	91	4.0	84	250	59
10	45	930.61	0.99	3.70	3.70	104	91	4.1	80	249	60
11	50	935.72	0.93	3.47	3.47	104	91	4.0	81	249	61
12	55	940.64	0.93	3.47	3.47	105	91	4.0	82	249	61
	60	945.64									
		118.51	0.91		3.42		97.17		84.38		

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET

COMPANY NAME JOHNSON CONTROLS INC — RUN NUMBER 3

CITY/STATE LOUISVILLE KY — DATE 9/18/91

SAMPLING LOCATION [illegible] # 3 STACK — OPERATORS JUK LINES

Ambient Temperature, °F 84
Barometric Pressure, in. Hg 29.00
Static Pressure, in. H_2O -0.25
Meter Box Number [illegible]
Sample Box Number 3
Probe Number 3
Filter Number M12-9
Nozzle Number [illegible]
Nozzle Diameter .205

NOMOGRAPH SET-UP
ΔH @ 1.85 Gamma = 1.00
Meter Temp. 95 °F
Stack Temp. 97 °F
Assumed % Moisture 4%
C Factor 1.14
Avg ΔP .03
Ref. ΔP 0.04
Noz. Dia. Desired .197

LEAK CHECKS
Pre-test 0.006 @ 15 In. Hg
Post-test 0.002 @ 6 In. Hg
Pre-test Pitot <0.1 @ 3.7 In. Hg
Post-test Pitot <0.1 @ 3.7 In. Hg
Orsat System FYRITE
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 165 °F

Start Time 1307 — Finish Time 1512 — Observer Paul Costagnolo / John Bartles Air Pollution Control Distric of Jefferson County

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING P IN. H_2O	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A 1	0	945.87	0.79	3.24	3.24	89	87	4.4	85	243	67
2	5	950.03	0.91	3.80	3.80	92	87	4.9	86	244	64
3	10	955.53	0.91	3.80	3.80	95	87	4.8	85	246	64
4	15	960.87	0.90	3.68	3.68	95	88	4.9	85	249	62
5	20	965.92	0.88	3.66	3.62	96	87	4.9	85	248	59
6	25	970.53	0.94	3.95	3.95	98	87	5.0	84	246	59
7	30	975.82	0.97	3.98	3.98	99	87	5.0	84	250	58
8	35	980.11	1.05	4.30	4.30	98	86	5.2	83	247	59
9	40	984.56	1.05	4.30	4.30	98	86	5.2	83	247	56
10	45	989.03	1.16	4.50	4.50	97	86	5.5	83	250	57
11	50	993.62	0.99	4.05	4.05	95	87	5.2	83	249	58
12	55	1002.92	0.82	3.42	3.42	98	87	6.7	1.82	249	58
A 1	60/0	1007.59	0.82	3.42	3.42	82	81	4.6	81	246	62
2	5	1012.52	0.89	3.60	3.60	86	81	4.8	81	245	52
3	10	1017.51	0.87	3.58	3.58	89	81	4.8	82	245	55
4	15	1022.52	0.84	3.48	3.48	92	91	4.8	82	249	57
5	20	1027.49	0.84	3.48	3.48	95	83	4.9	82	249	57
6	25	1032.44	0.86	3.56	3.56	96	83	4.9	82	249	57
7	30	1037.45	0.76	3.14	3.14	97	83	4.5	82	250	58
8	35	1042.19	0.70	2.90	2.90	97	84	4.1	82	[illegible]	57
9	40	1046.79	.73	3.0	3.0	15	84	4.2	81	249	61
10	45	1051.36	.70	2.9[illegible]	2.90	95	84	4.1	81	247	56
11	50	1055.86	0.70	2.90	2.90	94	84	4.1	82	249	56
12	55	1060.51	.72	3.05	3.05	95	84	[illegible]	82	256	56
	60	1065.01									
		119.20	0.87		3.57		84.73		82.75		

TRIGON

EPA METHOD 12 - INORGANIC LEAD DETERMINATION - DATA ANALYSIS

CLIENT/CITY Johnson Controls Inc / Louisville | PROJECT NUMBER 046-91-005

SAMPLING LOCATION Edco #3 Stack | SAMPLE DATE 9/17/91

CLEAN-UP BOX NUMBER #1 | RECOVERY DATE 9/18/91

LABORATORY CUSTODY: DATE REC'D 9/19/91 | REC'D BY AWL | LOCKED? ✓

Run Number	1	2	3	
Sample Box Number	1	2	3	
Probe Number	1	2	3	
Filter Number	M12 - 7	M12 - 8	M12 - 9	M12 -

ANALYSIS OF MOISTURE RECOVERY

Reagent Recovery Container #	M12 - 7 A	M12 - 8 A	M12 - 9 A	M12 - A
Description of Reagent	clear	clear	clear	
Reagent Level Marked	✓	✓	✓	
Final Volume, ml	218	218	233	
Initial Volume, ml	200	200	200	
Net Condensed Volume, ml	18	18	33	
Silica Gel Recovery Cont. #	M12 - 7 B	M12 - 8 B	M12 - 9 B	M12 - B
% Silica Gel Spent	90%	50%	80%	
Final Weight, g	226.3	222.4	224.3	
Initial Weight, g	200	200.0	200	
Net Adsorbed Water, g	26.3	22.4	24.3	
TOTAL REAGENT COLLECTED, ml	44.3	40.4	57.3	

ANALYSIS OF INORGANIC LEAD RECOVERY

Filter Recovery Container #	M12 - 7 C	M12 - 8 C	M12 - 9 C	M12 - C
Particulate Description	None visible	None visible	None visible	
Filter Container Sealed?	✓	✓	✓	
Probe Rinse Container #	M12 - 7 D	M12 - 8 D	M12 - 9 D	M12 - D
Liquid Level Marked?	✓	✓		

For final lead determination see the Appendix for Laboratory Data.

Remarks/Comments: None

FIELD DATA

SOUTH APB STACK

Preliminary Field Data

PLANT NAME Johnson Controls Inc

LOCATION Louisville KY

SAMPLING LOCATION South APB Stack

DATE 9/13/91

DUCT DEPTH
FROM INSIDE FAR WALL TO OUTSIDE OF PORT 4"

NIPPLE LENGTH 0"

DEPTH OF DUCT 4"

WIDTH (RECTANGULAR DUCT) NA

EQUIVALENT DIAMETER:

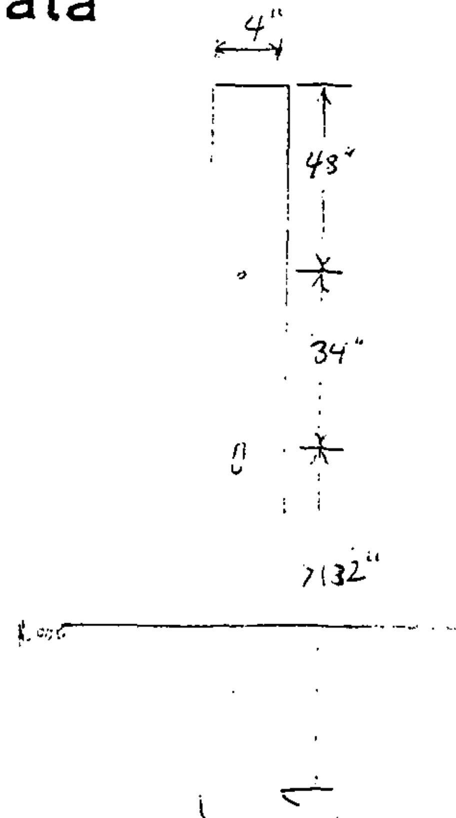
$$D_E = \frac{2 \times DEPTH \times WIDTH}{DEPTH + WIDTH} = \frac{2(\ -\ )(\ -\ )}{(\ -\ +\ -\ )} = NA$$

DISTANCE FROM PORTS TO NEAREST FLOW DISTURBANCE	UPSTREAM	DOWNSTREAM
	48"	34"
DIAMETERS	12	8.5

>132"

STACK AREA = 12.567 in² 0.0873 ft²

CALCULATED BY JEB



SCHEMATIC OF SAMPLING LOCATION

POINT	% OF STACK I.D.	STACK I.D.	DISTANCE FROM INSIDE WALL	NIPPLE LENGTH	DISTANCE FROM OUTSIDE OF PORT
1	6.7	4"	0.268 →	0"	0.500"
2	25.0	4"	1.00"	0"	1.00"
3	75.0	4"	3.00"	0"	3.00"
4	93.3	4"	3.732	0"	3.500"

LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

	4	6	8	10	12	14	16	18	20	22	24
1	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3	75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4	93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5		85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6		95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7			89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8			96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9				91.8	82.3	73.1	62.5	38.2	30.6	26.2	23.0
10				97.4	88.2	79.9	71.7	61.8	38.8	31.5	27.2
11					93.3	85.4	78.0	70.4	61.2	39.3	32.3
12					97.9	90.1	83.1	76.4	69.4	60.7	39.8
13						94.3	87.5	81.2	75.0	68.5	60.2
14						98.2	91.5	85.4	79.6	73.8	67.7
15							95.1	89.1	83.5	78.2	72.8
16							98.4	92.5	87.1	82.0	77.0
17								95.6	90.3	85.4	80.6
18								98.6	93.3	88.4	83.9
19									96.1	91.3	86.8
20									98.7	94.0	89.5
21										96.5	92.1
22										98.9	94.5
23											96.8
24											98.9

LOCATION OF TRAVERSE PINTS IN RECTANGULAR STACKS

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	18.8	16.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.8
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.8	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	86.4	79.2
11										95.5	87.5
12											95.8

TRIGON

EPA REFERENCE METHOD 2

DETERMINATION OF STACK GAS VELOCITY AND VOLUMETRIC FLOW RATE

DETERMINATION OF CYCLONIC FLOW

Plant JOHNSON CONTROLS INC City LOUISVILLE KY
Sampling Location SOUTH END STACK
Run Date 9/ /91 Time 0722
Operators JMD Ambient Temp, °F 72

Bar. Press., in. Hg 29.61 Pitot Tube I.D. No. 200-001
Stack Press., in. Hg 27.609 Pitot Tube Coefficient, Cp .77
Static Press., in. H_2O -0.01 Date Calibrated 05/09/91
Static Press., in. Hg -0.0007 Leak Check <0.1 @ 3.7 in. H_2O

Stack Dimension, in., diameter/side 1 4" side 2 —

FIELD DATA

Traverse Point Number	Velocity Head Inches H_2O A	Velocity Head Inches H_2O B	Stack Temperature °F		Cyclonic Flow Determination: Δp_s at 0° reference		Cyclonic Flow Determination: Angle which yields a null Δp	
1	0.005	0.006	135	132	0	0	0	0
2	0.004	0.01	135	120	0	0	0	0
3	0.009	0.009	131	135	0	0	0	0
4	0.01	0.005	135	136	0	0	0	0
Average	0.0015		134				0	
	0.009							

Stack Temp., Dry, °F (A) 141 Stack Temp., Wet, °F (B) 81

Difference (A - B) 60 Percent Moisture 7.5%

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET - Ducts 4" to 12" Diameter

COMPANY NAME JOHNSON CONTROLS INC RUN NUMBER #1

CITY/STATE Louisville KY DATE 9/15/91

SAMPLING LOCATION SOUTH APB STACK OPERATORS JAB

Ambient Temperature, °F 70
Barometric Pressure, in. Hg 29.61
Static Pressure, in. H_2O -0.01
Meter Box Number [illegible]
Sample Box Number 4
Probe Number 4 200.015
Filter Number M 2-11
Nozzle Number 200.010
Nozzle Diameter 0.125

NOMOGRAPH SET-UP

ΔH @ 1.91 Gamma = 1.00
Meter Temp. 80 °F
Stack Temp. 134 °F
Assumed % Moisture 2.5%
C Factor 1.09
Avg ΔP 0.0051 @ 0.94 Cp
Ref. ΔP 0.0125
Noz. Dia. Desired 0.680

LEAK CHECKS

Pre-test 0.005 @ 15 In. Hg
Post-test 0.007 @ 5 In. Hg
Pre-test Pitot <0.1 @ 3.5 In. Hg
Post-test Pitot <0.1 @ 5.6 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 145 °F

Start Time 0830 Finish Time 1048 Observer

1.1786

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING ΔP IN. H_2O 0.99	PITOT READING ΔP IN. H_2O 0.84	ORIFICE SETTING ΔH IN. H_2O IDEAL	ORIFICE SETTING ΔH IN. H_2O ACTUAL	DRY GAS METER TEMP. °F INLET (6)	DRY GAS METER TEMP. °F OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A1	0	665.00	0.014	0.0165	2.41	2.41	71	70	3.01	139	249	62
1	7.5	671.46	0.015	0.0177	2.58	2.54	77	70	3.0	140	249	63
2	15	677.70	0.0145	0.0171	2.13	2.13	83	72	2.8	143	246	62
2	22.5	683.50	0.0125	0.0147	2.13	2.13	82	73	2.3	143	246	62
3	30	689.25	0.0125	0.0147	2.13	2.13	83	76	2.8	130	248	59
3	37.5	695.00	0.013	0.015	2.20	2.20	85	78	2.9	131	250	58
4	45	700.96	0.010	0.012	1.75	1.75	86	79	2.2	140	250	58
4	52.5	706.23	0.010	0.012	1.75	1.75	87	80	2.2	140	247	53
B1	60	711.42	0.010	0.012	1.75	1.75	83	81	2.0	104	251	61
1	7.5	716.78	0.011	0.013	1.90	1.90	85	82	2.0	148	251	52
2	15	722.96	0.009	0.011	1.61	1.61	89	83	2.0	149	251	54
2	22.5	728.14	0.010	0.012	1.75	1.75	85	83	2.1	146	248	53
3	30	733.41	0.013	0.015	2.20	2.20	86	83	2.2	145	247	52
3	37.5	739.22	0.010	0.012	1.75	1.75	88	83	2.0	141	247	52
4	45	744.63	0.010	0.012	1.75	1.75	87	83	2.1	142	246	53
4	52.5	749.78	0.011	0.013	1.90	1.90	88	83	2.0	143	248	54
	60	755.04										
		90.04			1.98		8.5			141.6		

TRIGON

EPA METHOD 12 – DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET – Ducts 4" to 12" Diameter

COMPANY NAME Johnson Controls Inc RUN NUMBER 2

CITY/STATE Louisville KY DATE 9/18/91

SAMPLING LOCATION South APO STACK OPERATORS JAR

Ambient Temperature, °F 80
Barometric Pressure, in. Hg 29.49
Static Pressure, in. H_2O -0.01
Meter Box Number 300-045
Sample Box Number 5
Probe Number 200-010
Filter Number [illegible]
Nozzle Number 300-010
Nozzle Diameter [illegible]

NOMOGRAPH SET-UP
ΔH @ 1.91 Gamma = 1.00
Meter Temp. 88 °F
Stack Temp. 140 °F
Assumed % Moisture 3.5
C Factor 1.10
Avg ΔP 0.01 @ 0.84 Cp
Ref. ΔP 0.0122
Noz. Dia. Desired 0.630

LEAK CHECKS
Pre-test 0.004 @ 15 In. Hg
Post-test 0.002 @ 5.0 In. Hg
Pre-test Pitot <0.1 @ 33 In. Hg
Post-test Pitot <0.1 @ 39 In. Hg
Orsat System Fyrite
Tedlar Bag # NA
Tedlar Bag Leakcheck NA
Probe Temp. Setting 185 °F

Start Time 1057 Finish Time 1342 Observer

1.1786

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING ΔP IN. H_2O 0.99	0.84	ORIFICE SETTING ΔH IN. H_2O IDEAL	ACTUAL	DRY GAS METER TEMP. °F INLET (6)	OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A1	0	755.16	0.010	0.012	1.32	1.32	84	83	2.5	144	245	66
1	7.5	760.82	0.014	0.017	2.55	2.55	89	85	3.2	142	245	56
2	15	766.41	0.012	0.013	1.98	1.99	93	86	2.5	145	243	54
2	22.5	772.59	0.015	0.018	2.70	2.70	93	86	2.8	144	242	53
3	30	778.2	0.012	0.013	1.98	1.98	90	85	3.4	143	240	54
3	37.5	784.25	0.012	0.013	1.98	1.98	89	83	3.0	144	243	55
4	45	790.49	0.0125	0.0147	2.21	2.21	89	83	3.0	145	243	55
4	52.5	796.44	0.010	0.012	1.82	1.82	88	82	3.0	144	243	56
B1	60/0	801.79	0.009	0.011	1.69	1.69	75	78	2.4	145	245	62
1	7.5	806.95	0.014	0.017	2.55	2.55	82	80	3.2	140	243	52
2	15	812.98	0.014	0.017	2.55	2.55	89	82	3.2	144	243	51
2	22.5	819.56	0.012	0.013	1.98	1.98	90	82	3.2	148	244	59
3	30	825.15	0.0125	0.0147	2.20	2.21	91	83	3.0	144	244	58
3	37.5	831.12	0.010	0.012	1.82	1.82	90	83	2.9	146	244	58
4	45	836.42	0.007	0.008	1.20	1.20	88	83	2.2	148	244	58
4	52.5	840.99	0.010	0.012	1.82	1.82	86	83	2.8	148	245	59
	60	841.37										
		91.16				1.93	88.25			144.63		

Break 1200-1240

TRIGON

EPA METHOD 12 - DETERMINATION OF INORGANIC LEAD EMISSIONS
FIELD DATA SHEET - Ducts 4" to 12" Diameter

COMPANY NAME Johnson Controls Inc RUN NUMBER 3

CITY/STATE Louisville KY DATE 4/3/91

SAMPLING LOCATION South APB Stack OPERATORS JAB

Ambient Temperature, °F 82	**NOMOGRAPH SET-UP**	**LEAK CHECKS**
Barometric Pressure, in. Hg 29.44	Δ H @ 1.91 Gamma = 1.00	Pre-test 0.004 @ 15 In. Hg
Static Pressure, in. H_2O -0.01	Meter Temp. 88 °F	Post-test 0.004 @ 5 In. Hg
Meter Box Number 3?? 045	Stack Temp. 140 °F	Pre-test Pitot <0.1 @ 3.5 In. Hg
Sample Box Number 10	Assumed % Moisture 3.5	Post-test Pitot <0.1 @ 3.5 In. Hg
Probe Number ? 200-017	C Factor 1.10	Orsat System Fyrite
Filter Number M-?-17	Avg Δ P 0.024 @ 0.84 ??	Tedlar Bag # NA
Nozzle Number 300.011	Ref. Δ P 0.0125	Tedlar Bag Leakcheck NA
Nozzle Diameter 0.625	Noz. Dia. Desired 0.650	Probe Temp. Setting 1?? °F

Start Time @ 1029 Finish Time 1634 Observer —

1.1736

SAMPLE POINT	CLOCK TIME	DRY GAS METER Cu.Ft.	PITOT READING Δ P IN. H_2O 0.99	0.84	ORIFICE SETTING Δ H IN. H_2O IDEAL	ACTUAL	DRY GAS METER TEMP. °F INLET (6)	OUTLET (7)	PUMP VACUUM IN. HG GAUGE	STACK TEMP. °F (1)	FILTER BOX °F (3)	IMP. TEMP °F (4)
A1	0	846.55	0.010	0.012	1.85	1.85	75	75	2.1	148	249	63
1	7.5	851.99	0.008	0.009	1.38	1.38	75	75	2.0	143	2??	56
2	15	858.64	0.010	0.012	1.85	1.85	80	76	2.0	142	242	58
2	22.5	862.00	0.008	0.009	1.38	1.38	82	75	2.0	140	241	48
3	30	866.61	0.015	0.015	2.71	2.71	80	75	3.0	138	245	46
3	37.5	[illegible]	0.019	0.022	1.85	1.85	81	76	3.0	14?	2??	45
4	45	878.73	0.015	0.018	2.71	2.71	84	76	3.0	144	245	49
4	52.5	88?.??	0.0125	0.0147	2.20	2.20	88	77	3.0	146	245	49
B1	60	891.19	0.009	0.011	1.63	1.63	81	77	2.2	140	24?	59
1	7.5	896.81	0.010	0.012	1.85	1.85	87	78	2.3	142	242	51
2	15	901.89	0.010	0.012	1.85	1.85	89	78	2.3	144	240	53
2	22.5	907.10	0.009	0.011	1.63	1.63	89	79	2.1	144	240	54
3	30	912.44	0.010	0.012	1.85	1.85	89	78	2.1	142	238	53
3	37.5	915.39	0.013	0.015	2.71	2.71	89	78	3.0	141	238	54
4	45	924.07	0.010	0.012	1.85	1.85	86	78	2.2	140	237	54
4	52.5	929.47	0.010	0.012	1.85	1.86	87	77	2.2	142	237	53
	60	934.85										

Totals				
88.30	0.0124	1.95	80.5	142.38

TRIGON

EPA METHOD 12 - INORGANIC LEAD DETERMINATION - DATA ANALYSIS

CLIENT/CITY Johnson Controls Inc / Louisville | PROJECT NUMBER 046-91-005

SAMPLING LOCATION South APB STACK | SAMPLE DATE 9/14/91

CLEAN-UP BOX NUMBER #1 | RECOVERY DATE 9/18/91

LABORATORY CUSTODY: DATE REC'D 9/19/91 | REC'D BY D.K | LOCKED? ✓

Run Number	1	2	3	
Sample Box Number	1	1	1	
Probe Number	4	5	6	
Filter Number	M12 -10	M12 -11	M12 -12	M12 -

ANALYSIS OF MOISTURE RECOVERY

Reagent Recovery Container #	M12 -10 A	M12 -11 A	M12 -12 A	M12 - A
Description of Reagent	Clear	Clear	Clear	
Reagent Level Marked	✓	✓	✓	
Final Volume, ml	218.0	209.0	229.0	
Initial Volume, ml	200	200	200	
Net Condensed Volume, ml	18.0	9.0	29.0	
Silica Gel Recovery Cont. #	M12 -10 B	M12 -11 B	M12 -12 B	M12 - B
% Silica Gel Spent	65%	70%	65	
Final Weight, g	215.4	215.1	216.3	
Initial Weight, g	200	200	200	
Net Adsorbed Water, g	15.4	15.1	16.3	
TOTAL REAGENT COLLECTED, ml	36.4	24.1	45.3	

ANALYSIS OF INORGANIC LEAD RECOVERY

Filter Recovery Container #	M12 -10 C	M12 -11 C	M12 -12 C	M12 - C
Particulate Description	None Visible	None Visible	None Visible	
Filter Container Sealed?	✓	✓	✓	
Probe Rinse Container #	M12 -10 D	M12 -11 D	M12 -12 D	M12 - D
Liquid Level Marked?	✓	✓	✓	

For final lead determination see the Appendix for Laboratory Data.

Remarks/Comments: _____

APPENDIX D

PROCESS DATA

TRIGON

PASTING LINE PRODUCTION (IN THOUSANDS OF PLATE

TUES		WED
9-17		9-18
MACH 1		
1ST	71.4	23.7
2ND	71.8	42.9
3RD	76.8	65.3
MACH 2		
1ST	68.8	75.4
2ND	83.2	98.1
3RD	86.2	48.7
MACH 3		
1ST	93.7	85.7
2ND	66.5	81.8
3RD	92.8	62.0
	711.6	583.6

NOTE: PASTING LINE #1 IS VENTILATED BY RADCO #3 [redacted].
PASTING LINE #2 IS VENTILATED BY RADCO #2
PASTING LINE #3 IS VENTILATED BY RADCO #1

REFERENCE #18

9/18/91 - Johnson Controls, Inc., Louisville KY
by: Trigon Engineering Consultants, Inc.

Automatic Post Burner (APB) (a small amount of molten lead is poured into a mold on the terminal tops of each battery to form a terminal post - this process is used primarily for top-terminal type batteries); emissions are vented uncontrolled, via a fan and stack, to the atmosphere

Sampling / Analytical: Methods 1-4, 12; all field data, calculations, and calibrations complete and included

Results:

Run	Isokinetic	Lead, $\frac{lb}{HR}$
1	95.19 %	3×10^{-6}
2	94.84 %	7×10^{-6}
3	98.06 %	4×10^{-6}

} $5 \times 10^{-6} \frac{lb}{HR}$

field data: all tests during 2nd shift (8 AM - 4 PM)

Appendix D: C.O.S. line #4 to APB, 2nd shift 9/18/91 654 batteries

$$5 \times 10^{-6} \frac{lb}{HR} \Big/ \frac{654 \text{ batteries}}{8 \text{ hrs.}} = \boxed{61.2 \times 10^{-6} \frac{lb}{1000 \text{ batteries}}}$$

standard deviation = 45 % RATING = B

9/17-18/91 Johnson Controls, Inc., Louisville KY

by: Trigon Engineering Consultants, Inc.

Reference #18

Pasting Lines (lead grids, from the grid casting department, are coated with a lead oxide/sulfuric acid paste and then flash dried and stacked); emissions from each pasting line collected by individual RADCO vacuum filter (line #1 - RADCO #3; #2 - #2; line #3 - RADCO #1); air passes through each RADCO and return air passes through a Hastings Baghouse before returning to the pasting area. A RADCO is a high-volume, 2-stage HEPA filter w/ the capacity to continuously clean the main filter bank while operating.

Sampling/Analytical: Methods 1-4, 12; all field data, calculation, and calibration complete and included.

Results:

Run	Stack/Run	Isokinetic	Lead, $\frac{lb}{HR}$	
9/17	1/1	95.20%	169×10^{-6}	198×10^{-6}
	1/2	94.79%	228×10^{-6}	
	1/3	97.42%	360×10^{-6}	
	2/1	92.40%	775×10^{-6}	1524×10^{-6}
	2/2	96.10%	$2,274 \times 10^{-6}$	
	2/3	93.92%	356×10^{-6}	
9/18	3/1	96.62%	277×10^{-6}	447×10^{-6}
	3/2	93.93%	737×10^{-6}	
	3/3	96.41%	327×10^{-6}	

Field Data Sheets indicate Runs 1/1 - 1/3 and 2/1 - 2/3 ran almost concurrently (9:30 - 11:30, 12:30 - 2:30, and 3:00 - 5:00) → 3/1 8-10, 3/2 10:30 - noon, 3-3

Appendix D, "Process Data," indicates

stack #1 (line #3) 9/17 - 1st shift - 93,700 plates
2nd - 66,900
3rd - 92,800

stack #2 (line #2) 9/17 1st shift - 65,800 plates
2nd - 83,200
3rd - 86,200

~~[redacted]~~

ASSUMPTION: test runs 1-2 2nd shift, run 3 3rd shift:

stack #1: $198 \times 10^{-6} \frac{LB}{HR} \Big/ \left(\frac{66,900 \text{ plates}}{8 \text{ hrs.}}\right) = 23.7 \times 10^{-9}$ (two runs)

$390 \times 10^{-6} \Big/ \left(\frac{92,800}{8}\right) = 32.8 \times 10^{-9}$ (one run)

average = 26.7×10^{-6} LB/1000 plates

stack #2: $152 \times 10^{-6} \frac{LB}{HR} \Big/ \frac{83,200 \text{ plates}}{8 \text{ hrs.}} = 146.6 \times 10^{-9}$ (two runs)

$356 \times 10^{-6} \Big/ \frac{86,200}{8} = 33.0 \times 10^{-9}$ (one run)

average = 108.7×10^{-6} LB/1000 plates

stack #3 (line #1) 9/18 2nd shift 42,900 plates

$447 \times 10^{-6} \frac{LB}{HR} \Big/ \frac{42,900 \text{ plates}}{8 \text{ hrs.}} = 83.4 \times 10^{-6} \frac{LB}{1000 \text{ plates}}$

note that standard deviation for stack #1 = 20% #2: 60%

⇒ RATING = B #3: 56%

E.P-91

Cos # 3 APB Production

Line 1st 77830 - 628 Not APB's

3

2nd 77830 - 510 Not APB's

Cos # 4

Line 1st 52742 - (689) APB

4

2nd 52742 - (654) APB

APPENDIX E

CALIBRATION DATA

QUALITY ASSURANCE AND EQUIPMENT CALIBRATION PROCEDURES

General. Each item of field or laboratory test equipment purchased or constructed by Trigon Engineering Consultants is assigned a unique, permanent identification number. New items for which calibration is required are calibrated before initial field use. Equipment whose calibration status may change with use or with time is inspected in the field before testing begins, and again upon return from each field use. When an item of equipment is found to be out of calibration, it is adjusted and recalibrated or retired from service. All equipment is periodically recalibrated in full, regardless of the outcome of these regular inspections.

Calibrations are conducted in accordance with U.S. EPA specifications. Trigon follows the calibration procedures outlined in EPA Reference Methods, and those recommended in the Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III. When the Reference Methods are inapplicable, Trigon uses methods such as those prescribed by the American Society for Testing and Materials (ASTM).

Data obtained during calibrations are recorded on standardized forms, which are verified for completeness and accuracy by the Quality Assurance Director. Data reduction and subsequent calculations are performed using Trigon's in-house computer facilities. Calculations are generally performed at least twice as a check for accuracy. Copies of calibration data are included in each test or project report.

Inspection and Maintenance. An effective preventative maintenance program is necessary for equipment to ensure quality prior to, during, and following every test. Each item of equipment returning from the field is inspected before it is returned to storage. During the course of these inspections, items are cleaned, repaired, reconditioned, and recalibrated where necessary.

Each item of equipment transported to the field for a test project is inspected again prior to being packed. Trigon performs these quality assurance checks prior to departure for the project site to detect equipment problems which may occur during periods of storage. Trigon transports adequate back-up equipment to each project so as to avoid any unforeseen circumstances.

Calibration. Source sampling equipment that require calibration include nozzles, pitot tubes, thermometers, flow meters, dry gas meters, and barometers. The following sections detail the calibration procedures followed by Trigon for each item. Calibration data for the specific items of equipment used for this project follow.

Nozzles. Each probe nozzle is uniquely and permanently identified at the time of purchase or fabrication, and it is calibrated before initial field use and prior to each test. The inside diameter of the nozzle is measured to the nearest 0.001 inch using a digital micrometer. Five measurements are made using different diameters each time. If the difference between the high and the low numbers does not exceed 0.004 inch, the average of the five measurements is used. If the difference exceeds this amount, or when the nozzle becomes nicked, dented, or corroded, the nozzle is reshaped, sharpened, and recalibrated. Regardless of usage, all nozzles are inspected and recalibrated on a yearly basis.

TRIGON

Pitot Tubes. All Type S pitot tubes are constructed and calibrated in strict accordance with the procedures contained in EPA Reference Method 2. A Type S pitot tube will have a coefficient of 0.84 $\pm$0.02. A standard pitot tube will have a coefficient of 0.99. Each pitot tube is visually inspected prior to any field use. If the inspection indicates damage, it is recalibrated. Regardless of usage, all pitot tubes are inspected and recalibrated on a yearly basis.

Dry Gas Meter and Orifice. Each metering system receives a full calibration at the time of purchase and annually, thereafter. Post-test calibrations are performed after each source test. If the calibration factor, Y (gamma), deviates by less than five percent from the initial value, the test data are acceptable. If Y deviates by more than five percent, the meter is recalibrated and the meter coefficient (initial or recalibrated) that yields the lowest sample volume for the test runs is used. Standard practice at Trigon is to recalibrate the dry gas meter anytime Y is found to be outside the range of $0.98 \leq Y \leq 1.02$.

Barometer. Each field barometer is calibrated to agree within $\pm$0.1 inches Hg of a reference aneroid barometer. The barometric pressure is corrected for pressure and temperature. Prior to and following each field test the field barometer is verified.

Thermometers. Each new thermometer, pryometer and thermocouple purchased or fabricated by Trigon is calibrated in strict accordance with U.S. EPA Protocol. Calibration tolerance limits are as follows:

Impinger Thermometers	$\pm 1^{o}C$
Dry Gas Meter Thermometers	$\pm 3^{o}C$
Stack Thermocouples	$\pm$1.5% of absolute temperature

All thermometers and thermocouples are inspected and calibrated prior to and following each field test. Regardless of usage, all thermometers and thermocouples are inspected and recalibrated on a yearly basis.

Laboratory Equipment. Trigon Engineering Consultants has a written quality assurance document that covers calibration and maintenance of laboratory equipment. This includes calibration of each analytical balance against Class S weights. Calibration of thermometers, barometers, and wet test meters are traceable to N.B.S. A copy of our quality assurance document may be obtained by written request.

TRIGON

PRETEST - POSTEST CALIBRATION CHECKS
Thermometers, Thermocouples, & Barometer

Client/City: JOHNSON CONTROLS INC / LOUISVILLE

Calibrator: JWK Pretest Date: 9/10/91 Postest Date: 9/20/91

Reference Thermometer # 100-006 Reference Barometer # 600-003

	Pretest		Postest	
	Temp., °F	Ref. Temp., °F	Temp., °F	Ref. Temp., °F
Omega 880 DB	81	81	76	77
Omega 880 WB	81	81	76	77
Omega 880 HT	———	———	———	———
Dial DB #	———	———	———	———
Dial WB #	———	———	———	———
DGM In/Out #005	81	81	77	77
DGM In/Out #005	81	81	76	77
Impinger #1	80	81	76	77
Impinger #2	80	81	76	77
Impinger #3	80	81	76	77
Impinger #4	80	81	77	77
Impinger #5	80	81	76	77
Impinger #6	80	81	76	77
Filter Box #1	80	81	76	77
Filter Box #2	81	81	76	77
Filter Box #3	81	81	76	77
Filter Box #4	81	81	77	77
Filter Box #5	81	81	76	77
Filter Box #6	81	81	76	77
Probe # 200-004 (S)	81	81	75	77
Probe # 200-005 (S)	80	81	76	77
Probe # 200-006 (S)	81	81	77	77
Probe # 200-015 (S)	80	81	76	77
Probe # 200-016 (S)	81	81	77	77
Probe # 200-017 (S)	81	81	77	77
Pitot # 100-010	81	81	77	77
Pitot #	———	———	———	———
DGM In/Out # 067	81	81	77	77
DGM In/Out # 067	81	81	77	77

	Pretest		Postest	
Reference Barometer	29.31	in. Hg	29.34	in. Hg
Field Barometer	29.30	in. Hg	29.33	in. Hg
Difference	.01	in. Hg	0.01	in. Hg

Was the pretest field barometer reading correct? (within ± 0.1 in. Hg) Yes ✓ No ___
Was the postest field barometer reading correct? (within ± 0.1 in. Hg) Yes ✓ No ___
Was recalibration required? Yes ___ No ✓ If yes, no correction necessary for calculations when the field barometer has a lower reading; if the reference barometer is lower, subtract the difference from the field data readings for the calculations.

TRIGON

POSTTEST DRY GAS METER CALIBRATION DATA FORM (English units)

Test number 1 Date 9/20/91 Meter box number 300.045 Plant Johnson Controls Inc. Louisville, KY

Barometric pressure, P_b = 29.329 in. Hg Dry gas meter number 300.045 Pretest Y 1.00

Orifice manometer setting, (ΔH), in. H_2O	Gas volume: Wet test meter (V_w), ft^3	Gas volume: Dry gas meter (V_d), ft^3	Temperature: Wet test meter (t_w), °F	Temperature: Dry gas meter: Inlet (t_{d_i}), °F	Temperature: Dry gas meter: Outlet (t_{d_o}), °F	Temperature: Dry gas meter: Average[a] (t_d), °F	Time (θ), min	Vacuum setting, in. Hg	Y_i	$Y_i \frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$
2.82	10	10.14	73.1	96.5	85.	90.75	11.30	5.0	1.011	$1.0\left(\frac{29.329(90.75+460)}{10.14(29.329+\frac{2.82}{13.6})(73.1+460)}\right)$
2.82	10	10.15	73.0	97	85.5	91.25	11.32	5.0	1.011	$1.0\left(\frac{29.329(91.25+460)}{10.15(29.329+\frac{2.82}{13.6})(73.0+460)}\right)$
2.82	10							5.0	1.009	
									Y = 1.01	

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d

where

V_w = Gas volume passing through the wet test meter, ft^3.

V_d = Gas volume passing through the dry gas meter, ft^3.

t_w = Temperature of the gas in the wet test meter, °F.

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F.

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F.

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F.

ΔH = Pressure differential across orifice, in. H_2O.

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run.

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ±0.05Y.

P_b = Barometric pressure, in. Hg.

θ = Time of calibration run, min.

TRIGON

POSTTEST DRY GAS METER CALIBRATION DATA FORM (English units)

Johnson Controls Inc.

Test number 2 Date 9/26/91 Meter box number 300.045 Plant Louisville, Ky

Barometric pressure, P_b = 29.329 in. Hg Dry gas meter number 300 045 Pretest Y 1.00

Orifice manometer setting, (ΔH), in. H_2O	Gas volume: Wet test meter (V_w), ft^3	Gas volume: Dry gas meter (V_d), ft^3	Temperature: Wet test meter (t_w), °F	Temperature: Dry gas meter: Inlet (t_{d_i}), °F	Temperature: Dry gas meter: Outlet (t_{d_o}), °F	Temperature: Dry gas meter: Average[a] (t_d), °F	Time (θ), min	Vacuum setting, in. Hg	Y_i	$Y_i = \frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$
1.95	10	10.21	72.5	95.5	86.	90.25	13.63	3.2	1.007	$\frac{10(29.329)(90.25+460)}{10.21(29.329+\frac{1.95}{13.6})(72.5+460)}$
1.95	10	10.22	72.25	95.5	86.5	91	13.72	3.2	1.008	$\frac{10(29.329)(91+460)}{10.22(29.329+\frac{1.95}{13.6})(72.25+460)}$
1.95	10	10.23	72.0	95	86.5	90.75	13.71	3.2	1.007	$\frac{10(29.329)(90.75+460)}{10.23(29.329+\frac{1.95}{13.6})(72+460)}$
									Y = 1.007	

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d

where

V_w = Gas volume passing through the wet test meter, ft^3.

V_d = Gas volume passing through the dry gas meter, ft^3.

t_w = Temperature of the gas in the wet test meter, °F.

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F.

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F.

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F.

ΔH = Pressure differential across orifice, in. H_2O.

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run.

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y $\pm$0.05Y.

P_b = Barometric pressure, in. Hg.

θ = Time of calibration run, min.

TRIGON

POSTTEST DRY GAS METER CALIBRATION DATA FORM (English units)

Test number 3 Date 9/20/91 Meter box number 300.067 Plant Johnson Controls, Inc. Louisville KY

Barometric pressure, P_b = 29.329 in. Hg Dry gas meter number 300.067 Pretest Y 1.00

Orifice manometer setting, (ΔH), in. H_2O	Gas volume: Wet test meter (V_w), ft^3	Gas volume: Dry gas meter (V_d), ft^3	Temperature: Wet test meter (t_w), °F	Temperature: Dry gas meter: Inlet (t_{d_i}), °F	Temperature: Dry gas meter: Outlet (t_{d_o}), °F	Temperature: Dry gas meter: Average[a] (t_d), °F	Time (θ), min	Vacuum setting, in. Hg	Y_i	Y_i $\frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$
3.51	10	10.14	72.5	98	83.5	90.75	10.10	6.2	1.007	$\frac{10(29.329)(90.75+460)}{10.14(29.329+\frac{3.51}{13.6})(72.5+460)}$
3.51	10	10.22	72.0	97.5	83.5	90.50	10.13	6.2	1.004	$\frac{10(29.329)(90.5+460)}{10.22(29.329+\frac{3.51}{13.6})(72.0+460)}$
3.51	10	10.23	72.0	97.5	84	90.75	10.18	6.2	1.003	$\frac{10(29.329)(90.75+460)}{10.23(29.329+\frac{3.51}{13.6})(72.0+460)}$
									Y = 1.005	

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d

where

V_w = Gas volume passing through the wet test meter, ft^3.

V_d = Gas volume passing through the dry gas meter, ft^3.

t_w = Temperature of the gas in the wet test meter, °F.

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F.

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F.

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F.

ΔH = Pressure differential across orifice, in. H_2O.

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run.

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ±0.05Y.

P_b = Barometric pressure, in. Hg.

θ = Time of calibration run, min.

TRIGON

POSTTEST DRY GAS METER CALIBRATION DATA FORM (English units)

Test number 4 Date 9/20/91 Meter box number 300.067 Plant Johnson Controls Inc Louisville, KY

Barometric pressure, P_b = 29.329 in. Hg Dry gas meter number 300.61 Pretest Y 1.00

Orifice manometer setting, (ΔH), in. H_2O	Gas volume: Wet test meter (V_w), ft^3	Gas volume: Dry gas meter (V_d), ft^3	Temperature: Wet test meter (t_w), °F	Temperature: Dry gas meter: Inlet (t_{d_i}), °F	Temperature: Dry gas meter: Outlet (t_{d_o}), °F	Temperature: Dry gas meter: Average[a] (t_d), °F	Time (θ), min	Vacuum setting, in. Hg	Y_i	$Y_i = \frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$
2.40	10	10.41	73.75	102.5	92	97.25	12.48	4.8	0.997	10(29.329)(97.25+460) / 10.41(29.329+2.40/13.6)(73.75+460)
2.40	10	10.43	74.25	103	92.5	97.75	12.45	4.8	0.995	10(29.329)(97.75+460) / 10.43(29.329+2.40/13.6)(74.25+460)
2.40	10	10.41	74.75	103	93	98	12.46	4.8	0.996	10(29.329)(98+460) / 10.41(29.329+2.40/13.6)(74.75+460)
									Y = 0.996	

[a] If there is only one thermometer on the dry gas meter, record the temperature under t_d

where

V_w = Gas volume passing through the wet test meter, ft^3.

V_d = Gas volume passing through the dry gas meter, ft^3.

t_w = Temperature of the gas in the wet test meter, °F.

t_{d_i} = Temperature of the inlet gas of the dry gas meter, °F.

t_{d_o} = Temperature of the outlet gas of the dry gas meter, °F.

t_d = Average temperature of the gas in the dry gas meter, obtained by the average of t_{d_i} and t_{d_o}, °F.

ΔH = Pressure differential across orifice, in. H_2O.

Y_i = Ratio of accuracy of wet test meter to dry gas meter for each run.

Y = Average ratio of accuracy of wet test meter to dry gas meter for all three runs; tolerance = pretest Y ±0.05Y.

P_b = Barometric pressure, in. Hg.

θ = Time of calibration run, min.

TRIGON

CONTROL CONSOLE CALIBRATION

Console Number: 300-045 Date: 07/22/91 Barometric Pressure: 29.328 Calibrated by: JWK

Orifice Setting ΔH	Gas Volume: Wet Test Meter V_w	Gas Volume: Dry Gas Meter V_d	Temperatures: Wet Test Meter t_w	Temperatures: Dry Gas Meter Inlet t_{di}	Temperatures: Dry Gas Meter Outlet t_{do}	Temperatures: Dry Gas Meter Average t_d	Time θ	Y	$\Delta H_@$
in. H_2O	ft^3	ft^3	°F	°F	°F	°F	minutes		in. H_2O
0.5	5	5.11	81.35	100.5	94.5	97.5	12.9	1.006	1.820
1.0	5	5.09	81.35	97.5	93.0	95.25	9.30	1.005	1.912
1.5	10	10.25	81.4	104.5	96.5	100.50	15.46	1.006	1.943
2.0	10	10.27	81.5	108.0	97.5	102.75	13.47	1.007	1.956
3.0	10	10.29	81.5	111.5	98.5	105.0	10.95	1.006	1.928
4.0	10	10.32	81.5	115.0	99.5	107.25	9.47	1.005	1.908
Tolerances	Y = 1.00 +/- 0.05	$\Delta H_@$ = 1.84 +/- 0.25					**Average**	1.006	1.911

Y and $\Delta H_@$ are calculated as follows:

$$Y = \frac{V_w P_b (t_d + 460)}{V_d (P_b + \Delta H/13.6)(t_w + 460)} = 1.00$$

$$\Delta H_@ = \frac{0.0317\ H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)\ \theta}{V_w}\right]^2 = 1.911$$

0.5 $Y = \dfrac{5\ (29.328)\ (97.5 + 460)}{5.11\ (29.328 + 0.0368)\ (81.35 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (0.5)}{29.328\ (97.5 + 460)} \left[\dfrac{(81.35 + 460)\ 12.9}{5}\right]^2$

1.0 $Y = \dfrac{5\ (29.328)\ (95.25 + 460)}{5.09\ (29.328 + 0.0737)\ (81.35 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (1.0)}{29.328\ (95.25 + 460)} \left[\dfrac{(81.35 + 460)\ 9.3}{5}\right]^2$

1.5 $Y = \dfrac{10\ (29.328)\ (100.5 + 460)}{10.25\ (29.328 + 0.110)\ (81.4 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (1.5)}{29.328\ (100.5 + 460)} \left[\dfrac{(81.4 + 460)\ 15.46}{10}\right]^2$

2.0 $Y = \dfrac{10\ (29.328)\ (102.75 + 460)}{10.27\ (29.328 + 0.147)\ (81.5 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (2.0)}{29.328\ (102.75 + 460)} \left[\dfrac{(81.5 + 460)\ 13.47}{10}\right]^2$

3.0 $Y = \dfrac{10\ (29.328)\ (105.00 + 460)}{10.29\ (29.328 + 0.221)\ (81.5 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (3.0)}{29.328\ (105.00 + 460)} \left[\dfrac{(81.5 + 460)\ 10.95}{10}\right]^2$

4.0 $Y = \dfrac{10\ (29.328)\ (107.25 + 460)}{10.32\ (29.328 + 0.294)\ (81.5 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (4.0)}{29.328\ (107.25 + 460)} \left[\dfrac{(81.5 + 460)\ 9.47}{10}\right]^2$

TRIGON

CONTROL CONSOLE CALIBRATION

Console Number: 300-067 Date: 08/08/91 Barometric Pressure: 29.275 Calibrated by: JWK

	Gas Volume		Temperatures				Time		
Orifice Setting	Wet Test Meter	Dry Gas Meter	Wet Test Meter	Dry Gas Meter Inlet	Dry Gas Meter Outlet	Dry Gas Meter Average	Θ	Y	$\Delta H_@$
ΔH	V_w	V_d	t_w	t_{di}	t_{do}	t_d			
in. H_2O	ft^3	ft^3	°F	°F	°F	°F	minutes		in. H_2O
0.5	5	5.10	79.5	92.5	87.5	90.0	12.88	0.998	1.901
1.0	5	5.11	80.0	97.5	90.5	94.00	9.30	1.001	1.972
1.5	10	10.26	80.0	99.5	91.5	95.50	15.41	0.999	2.025
2.0	10	10.29	80.0	104.0	94.0	99.0	13.22	1.001	1.974
3.0	10	10.31	80.0	107.0	95.5	101.25	10.56	1.001	1.882
4.0	10	10.30	80.0	109.0	96.0	102.5	9.31	1.001	1.946
Tolerances	Y = 1.00 +/- 0.05		$\Delta H_@$ = 1.84 +/- 0.25				Average	1.000	1.950

Y and $\Delta H_@$ are calculated as follows:

$$Y = \frac{V_w P_b (t_d + 460)}{V_d (P_b + \Delta H/13.6)(t_w + 460)} = 1.00 \qquad \Delta H_@ = \frac{0.0317\ H}{P_b (t_d + 460)} \left[\frac{(t_w + 460)\ \Theta}{V_w}\right]^2 = 1.950$$

0.5 $Y = \dfrac{5\ (29.275)\ (90.0\ + 460)}{5.10\ (29.275 + 0.0368)\ (79.5 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (0.5)}{29.275\ (90.0\ + 460)} \left[\dfrac{(79.5 + 460)\ 12.88}{5}\right]^2$

1.0 $Y = \dfrac{5\ (29.275)\ (94.0\ + 460)}{5.11\ (29.275 + 0.0737)\ (80.0 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (1.0)}{29.275\ (94.0\ + 460)} \left[\dfrac{(80.0 + 460)\ 9.3}{5}\right]^2$

1.5 $Y = \dfrac{10\ (29.275)\ (95.5\ + 460)}{10.26\ (29.275 + 0.110)\ (80.0 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (1.5)}{29.275\ (95.5\ + 460)} \left[\dfrac{(80.0 + 460)\ 15.41}{10}\right]^2$

2.0 $Y = \dfrac{10\ (29.275)\ (99.0\ + 460)}{10.29\ (29.275 + 0.147)\ (80.0 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (2.0)}{29.275\ (99.0\ + 460)} \left[\dfrac{(80.0 + 460)\ 13.22}{10}\right]^2$

3.0 $Y = \dfrac{10\ (29.275)\ (101.25\ + 460)}{10.31\ (29.275 + 0.221)\ (80.0\ + 460)}$ $\Delta H@ = \dfrac{0.0317\ (3.0)}{29.275\ (101.25 + 460)} \left[\dfrac{(80.0\ + 460)\ 10.56}{10}\right]^2$

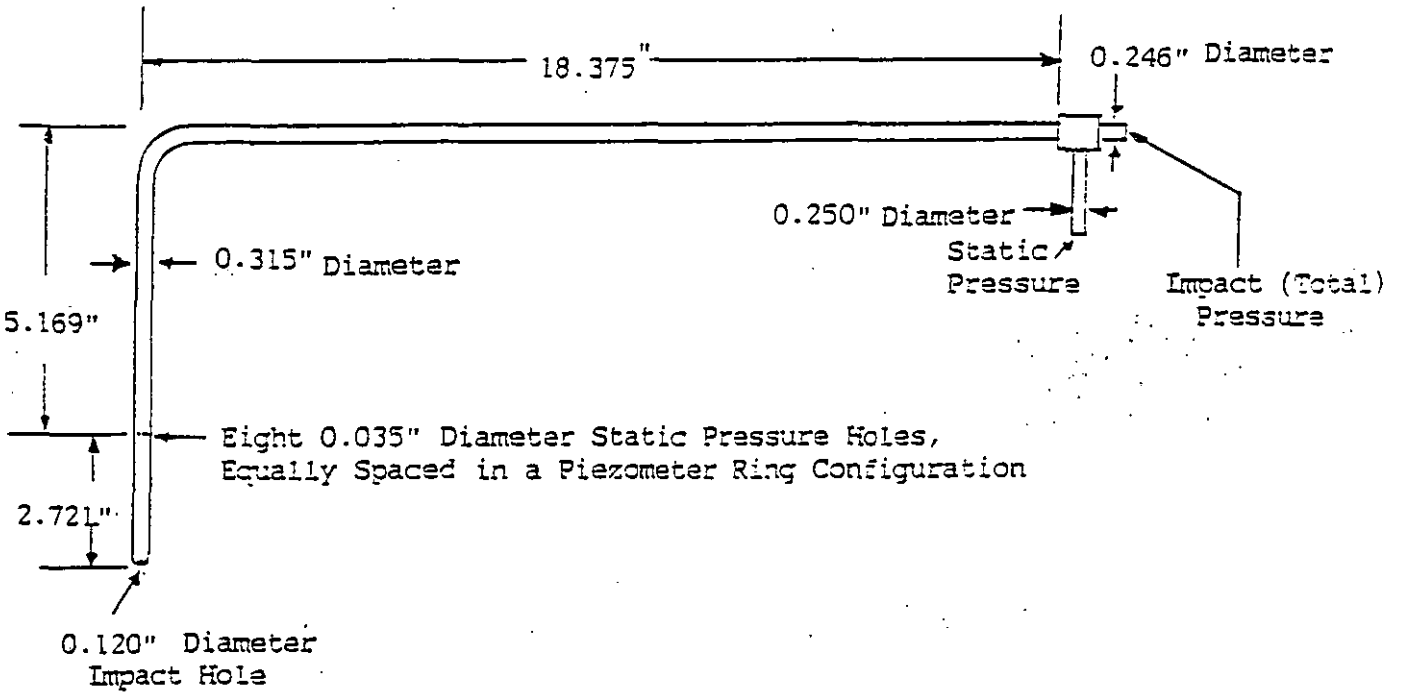
4.0 $Y = \dfrac{10\ (29.275)\ (102.5\ + 460)}{10.30\ (29.275 + 0.294)\ (80.0 + 460)}$ $\Delta H@ = \dfrac{0.0317\ (4.0)}{29.275\ (102.5\ + 460)} \left[\dfrac{(80.0 + 460)\ 9.31}{10}\right]^2$

TRIGON

STANDARD PITOT TUBE CALIBRATION

Date: 05/09/91 I.D. Number: 200-001 Model Number: 160-18

Calibrator: JAB



The calibration of standard pitot tubes is in accordance with EPA Reference Method 2, Section 2.7. This pitot tube has been calibrated as outlined in Section 2.7 and the specifications are listed below.

2.7.1	Hemispherical Tip
2.7.2	8.6 diameters (A minimum of six diameters straight run between the tip and static pressure holes.)
2.7.3	16.3 diameters (A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, following the 90 degrees bend.)
2.7.4	0.035" (This is the diameter of the eight static pressure holes, equally spaced in a piezometer ring configuration.)
2.7.5	90°curve bend

TRIGON

TYPE S PITOT TUBE CALIBRATION FORM

Date: 05/09/91 Calibrator: JAB

Specifications:
A.) Pitot tube assembly must be level.
B.) If pitot tube is damaged explain under comments section.
C.) $z = A \sin T$ and $w = A \sin O$ (<0.03125)
D.) $a < 10^{o}$ and $B < 5^{o}$

I.D. No.	Length	$a_1{}^{o}$	$a_2{}^{o}$	$B_1{}^{o}$	$B_2{}^{o}$	Y^{o}	O^{o}	A, in.	z, in.	w, in.	P_A, in.	P_B, in.	D_t, in
200.019	2'	0.5	0.5	0.5	0.5	1.0	0.5	0.937	0.0164	0.0082	0.468	0.469	0.375
200.002	4'	0.5	0.5	0.0	1.5	1.5	1.0	0.953	0.0250	0.0166	0.476	0.476	0.375
200.003	6'	1.5	0.5	1.0	0.5	0.5	0.5	0.947	0.0008	0.0008	0.473	0.473	0.375
200.004	3'	0.5	1.5	1.0	0.0	0.05	0.5	0.938	0.0008	0.0082	0.468	0.468	0.375
200.005	3'	0.0	0.5	0.0	0.5	0.5	0.5	0.947	0.0083	0.0083	0.473	0.473	0.375
200.006	3'	1.0	0.0	0.0	1.5	0.5	1.2	0.944	0.0080	0.0200	0.472	0.472	0.368
200.015	3'	1.0	1.0	2.0	1.5	0.5	0.5	0.940	0.0080	0.0080	0.469	0.470	0.369
200.016	3'	1.0	2.0	1.0	1.0	1.8	1.4	0.940	0.0300	0.0230	0.469	0.469	0.372
200.017	3'	2.0	2.5	2.0	3.0	1.5	1.0	0.943	0.0250	0.0165	0.471	0.470	0.369
200.007	5'	1.5	0.0	0.5	1.0	0.4	1.1	0.935	0.0070	0.0180	0.467	0.467	0.367
200.008	5'	1.2	1.0	0.8	0.5	2.5	1.0	0.929	0.0410	0.0308	0.465	0.464	0.369
200.009	5'	0.5	0.5	1.5	0.5	1.0	0.5	0.929	0.0160	0.0082	0.469	0.469	0.375
200.010	7'	1.5	0.5	0.5	0.5	1.0	1.0	0.941	0.0160	0.0164	0.470	0.470	0.367
200.011	7'	1.0	0.5	0.5	1.0	0.05	1.7	0.937	0.0008	0.0278	0.468	0.468	0.360
200.012	7'	1.5	2.0	0.0	1.0	1.5	1.0	0.942	0.0247	0.0164	0.471	0.471	0.368
200.013	10'	1.0	0.5	1.5	0.0	0.5	1.8	0.950	0.0080	0.0298	0.475	0.475	0.360
200.014	10'	1.0	0.5	1.5	1.0	2.0	1.8	0.947	0.0330	0.0296	0.473	0.474	0.375

Comments: Pitot tubes were purchased new from Nutech Corporation.

Pitot tubes requiring calibration: None

TRIGON

NOZZLE CALIBRATION
SET ONE

DATE CALIBRATED: 05/09/91 CALIBRATED BY: JAB

NOZZLE I.D. NUMBER	NOZZLE DIAMETER(a) D1 (in.)	D2 (in.)	D3 (in.)	D4 (in.)	D5 (in.)	Diff (b)	Davg(c) (in.)
			3/4" NOZZLES				
300.010	0.749	0.750	0.750	0.750	0.750	0.002	0.750
			5/8" NOZZLES				
300.011	0.625	0.624	0.625	0.625	0.624	0.001	0.625
			1/2" NOZZLES				
300.012 (1)	0.498	0.497	0.497	0.498	0.497	0.001	0.497
300.013 (2)	0.499	0.498	0.500	0.499	0.500	0.002	0.499
300.014 (3)	0.497	0.498	0.499	0.497	0.498	0.002	0.498
			7/16" NOZZLES				
300.015 (1)	0.441	0.440	0.440	0.439	0.440	0.001	0.440
300.016 (2)	0.441	0.441	0.439	0.439	0.440	0.002	0.440
300.017 (3)	0.432	0.433	0.431	0.430	0.430	0.002	0.431
			3/8" NOZZLES				
300.018 (1)	0.375	0.375	0.374	0.375	0.375	0.001	0.375
300.019 (2)	0.376	0.376	0.375	0.375	0.376	0.001	0.376
300.020 (3)	0.374	0.374	0.373	0.374	0.375	0.002	0.374
			5/16" NOZZLES				
300.021 (1)	0.313	0.311	0.313	0.312	0.312	0.002	0.312
300.022 (2)	0.310	0.308	0.308	0.310	0.310	0.002	0.309
300.023 (3)	0.310	0.311	0.310	0.309	0.310	0.002	0.310
			1/4" NOZZLES				
300.024 (1)	0.248	0.248	0.249	0.248	0.249	0.001	0.248
300.025 (2)	0.248	0.247	0.248	0.248	0.249	0.002	0.248
300.026 (3)	0.247	0.247	0.248	0.248	0.247	0.001	0.247
			3/16" NOZZLES				
300.027 (1)	0.188	0.188	0.186	0.187	0.186	0.002	0.187
300.028 (2)	0.187	0.186	0.185	0.187	0.185	0.002	0.186
300.029 (3)	0.187	0.187	0.188	0.185	0.185	0.003	0.186

where:

(a) $D_{1,2,3,4,5}$ = five different nozzle diameters, (in.); each diameter must be within 0.001 in.

(b) D = maximum difference between any two diameters, (in.) $D < 0.004$ in.

(c) D_{avg} = average of D_1, D_2, D_3, D_4, and D_5

TRIGON

NOZZLE CALIBRATION
SET TWO

DATE CALIBRATED: 05/09/91 CALIBRATED BY: JAB

NOZZLE I.D. NUMBER	NOZZLE DIAMETER(a) D1 (in.)	D2 (in.)	D3 (in.)	D4 (in.)	D5 (in.)	Diff (b)	Davg (c) (in.)
			1/2" NOZZLES				
300.051 (1)	0.493	0.495	0.493	0.494	0.493	0.002	0.494
300.052 (2)	0.495	0.497	0.495	0.497	0.497	0.002	0.496
300.053 (3)	0.497	0.499	0.498	0.498	0.498	0.002	0.498
			3/8" NOZZLES				
300.054 (1)	0.369	0.369	0.370	0.370	0.369	0.001	0.369
300.055 (2)	0.371	0.372	0.371	0.370	0.371	0.002	0.371
300.056 (3)	0.369	0.370	0.370	0.369	0.370	0.001	0.370
			1/4" NOZZLES				
300.057 (1)	0.240	0.240	0.240	0.239	0.239	0.001	0.240
300.058 (2)	0.241	0.242	0.242	0.242	0.241	0.001	0.242
300.059 (3)	0.246	0.244	0.245	0.244	0.246	0.002	0.245
			3/16" NOZZLES				
300.060 (1)	0.180	0.181	0.180	0.180	0.180	0.001	0.180
300.061 (2)	0.179	0.179	0.179	0.179	0.179	0.000	0.179
300.062 (3)	0.180	0.181	0.180	0.181	0.180	0.001	0.180

where:

(a) $D_{1,2,3,4,5}$ = five different nozzle diameters, (in.); each diameter must be within 0.001 in.

(b) D = maximum difference between any two diameters, (in.) $D < 0.004$ in.

(c) D_{avg} = average of D_1, D_2, D_3, D_4, and D_5

TRIGON

TEMPERATURE SENSOR CALIBRATION FORM

STACK THERMOMETERS

Tolerance: ±1.5% of Absolute Temperature

Date: 06/27/91
Ambient Temperature °C: 27.3
Calibrator: JWK

Barometric Pressure, In. Hg.: 29.53
Reference Thermometer Number: ITS-90

Thermocouple/ Thermometer I.D. #	Reference Point #	Source[a]	Reference Thermometer Temperature °C	Thermocouple Potentiometer Temperature °C	Temperature Difference[b] %
2' Pitot Tube					
200.019	1	Ice Water	1.8	1.5	0.15
	2	Water Bath	95.7	96.0	-0.08
	3	Oil Bath	180.0	178.0	0.44
4' Pitot Tube					
200.002	1	Ice Water	1.2	1.4	-0.07
	2	Water Bath	86.5	86.9	-0.11
	3	Oil Bath	194.0	192.9	0.24
6' Pitot Tube					
200.003	1	Ice Water	1.7	1.5	0.07
	2	Water Bath	88.0	87.7	0.08
	3	Oil Bath	179.0	178.6	0.08

[a] Type of calibration system used.
[b] Temperature Difference Calculation:

$$\frac{(\text{Ref. Temp.}^{\circ}\text{C} + 273) - (\text{Test Temp.}^{\circ}\text{C} + 273)}{\text{Ref. Temp.}^{\circ}\text{C} + 273} \times 100 \leq 1.5\%$$

TRIGON

TEMPERATURE SENSOR CALIBRATION FORM

STACK THERMOMETERS

Tolerance: ±1.5% of Absolute Temperature

Date: 06/27/91
Ambient Temperature °C: 27.3
Calibrator: JWK

Barometric Pressure, In. Hg.: 29.53
Reference Thermometer Number: ITS-90

Thermocouple/ Thermometer I.D. #	Reference Point #	Source[a]	Reference Thermometer Temperature °C	Thermocouple Potentiometer Temperature °C	Temperature Difference[b] %
DGM Thermocouple - In					
300.035	1	Ice Water	0.9	1.1	-0.07
	2	Water Bath	97.7	98.1	-0.12
	3	Oil Bath	184.7	184.9	-0.04
DGM Thermocouple - Out					
300.035	1	Ice Water	0.7	0.6	0.04
	2	Water Bath	198.5	98.2	0.08
	3	Oil Bath	184.3	184.9	-0.13
DGM Thermocouple - In					
300.045	1	Ice Water	0.7	0.4	0.11
	2	Water Bath	104.0	104.7	-0.19
	3	Oil Bath	163.5	164.2	-0.16
DGM Thermocouple - Out					
300.045	1	Ice Water	0.7	0.5	0.07
	2	Water Bath	104.0	105.1	-0.30
	3	Oil Bath	165.3	166.2	-0.21
DGM Thermocouple - In					
300.067	1	Ice Water	1.6	2.0	-0.15
	2	Water Bath	99.4	99.0	0.11
	3	Oil Bath	164.8	165.7	-0.21
DGM Thermocouple - Out					
300.067	1	Ice Water	1.7	2.0	-0.11
	2	Water Bath	99.6	100.0	-0.11
	3	Oil Bath	165.8	166.5	0.16

[a] Type of calibration system used.
[b] Temperature Difference Calculation:

$$\frac{(\text{Ref. Temp.}^{\circ}\text{C} + 273) - (\text{Test Temp.}^{\circ}\text{C} + 273)}{\text{Ref. Temp.}^{\circ}\text{C} + 273} \times 100 \leq 1.5\%$$

TRIGON

TEMPERATURE SENSOR CALIBRATION FORM

STACK THERMOMETERS

Tolerance: ±1.5% of Absolute Temperature

Date: 06/27/91
Ambient Temperature °C: 27.3
Calibrator: JWK

Barometric Pressure, In. Hg.: 29.53
Reference Thermometer Number: ITS-90

Thermocouple/ Thermometer I.D. #	Reference Point #	Source[a]	Reference Thermometer Temperature °C	Thermocouple Potentiometer Temperature °C	Temperature Difference[b] %
Omega HH-82 Dry Bulb					
100.002	1	Ice Water	4.8	6.1	-0.47
	2	Water Bath	90.0	91.3	-0.36
	3	Oil Bath	182.0	181.4	-0.13
Omega HH-82 Wet Bulb					
100.003	1	Ice Water	4.2	5.0	0.29
	2	Water Bath	90.0	91.7	-0.36
	3	Oil Bath	182.0	181.1	0.20
Bimetallic Dial Dry Bulb					
100.004	1	Ice Water	16.0	16.3	-0.10
	2	Water Bath	90.0	90.5	-0.14
	3	Oil Bath	180.8	181.3	-0.11
Bimetallic Dial Wet Bulb					
100.005	1	Ice Water	0.4	0.6	-0.07
	2	Water Bath	90.0	90.4	-0.11
	3	Oil Bath	181.9	182.5	-0.13
Bimetallic Dial Wet Bulb					
100.006	1	Ice Water	0.5	0.6	-0.03
	2	Water Bath	90.0	90.4	-0.11
	3	Oil Bath	184.4	183.2	0.26
Bimetallic Dial Dry Bulb					
100.007	1	Ice Water	16.0	16.2	-0.07
	2	Water Bath	90.0	90.5	-0.14
	3	Oil Bath	184.0	182.7	0.28
Omega HH-82 High Temp					
100.008	1	Oil Bath	194.0	192.9	0.24
	2	Furnace	1015.3	1014.2	0.09
	3	Furnace	1750.4	1748.7	0.08

[a] Type of calibration system used.
[b] Temperature Difference Calculation:

$$\frac{(\text{Ref. Temp.}^{\circ}\text{C} + 273) - (\text{Test Temp.}^{\circ}\text{C} + 273)}{\text{Ref. Temp.}^{\circ}\text{C} + 273} \times 100 \leq 1.5\%$$

TRIGON

TEMPERATURE SENSOR CALIBRATION FORM

STACK THERMOMETERS

Tolerance: ±1.5% of Absolute Temperature

Date: 06/27/91
Ambient Temperature °C: 27.3
Calibrator: JWK

Barometric Pressure, In. Hg.: 29.53
Reference Thermometer Number: ITS-90

Thermocouple/ Thermometer I.D. #	Reference Point #	Source[a]	Reference Thermometer Temperature °C	Thermocouple Potentiometer Temperature °C	Temperature Difference[b] %
Umbilical Adaptor 300.030 (1)	1	Ice Water	0.5	0.4	0.04
	2	Water Bath	89.0	89.7	-0.19
	3	Oil Bath	180.0	178.2	0.40
Umbilical Adaptor 300.031 (2)	1	Ice Water	0.9	1.0	-0.04
	2	Water Bath	89.0	90.0	-0.28
	3	Oil Bath	180.0	178.1	0.42
Umbilical Adaptor 300.032 (3)	1	Ice Water	1.1	1.2	-0.04
	2	Water Bath	89.0	89.9	-0.25
	3	Oil Bath	180.0	178.2	0.40
Umbilical Adaptor 300.042 (4)	1	Ice Water	2.3	2.4	-0.04
	2	Water Bath	90.0	90.4	-0.11
	3	Oil Bath	162.0	159.3	0.62
Umbilical Adaptor 300.043 (5)	1	Ice Water	2.4	2.7	-0.11
	2	Water Bath	90.0	90.7	-0.19
	3	Oil Bath	162.0	160.8	0.28
Umbilical Adaptor 300.044 (6)	1	Ice Water	1.5	1.8	-0.11
	2	Water Bath	90.0	90.7	-0.19
	3	Oil Bath	162.0	162.8	-0.18

[a] Type of calibration system used.
[b] Temperature Difference Calculation:

$$\frac{(\text{Ref. Temp.}^{\circ}\text{C} + 273) - (\text{Test Temp.}^{\circ}\text{C} + 273)}{\text{Ref. Temp.}^{\circ}\text{C} + 273} \times 100 \leq 1.5\%$$

TRIGON

TEMPERATURE SENSOR CALIBRATION FORM

STACK THERMOMETERS

Tolerance: ±1.5% of Absolute Temperature

Date: 06/27/91
Ambient Temperature °C: 27.3
Calibrator: JWK

Barometric Pressure, In. Hg.: 29.53
Reference Thermometer Number: ITS-90

Thermocouple/ Thermometer I.D. #	Reference Point #	Source[a]	Reference Thermometer Temperature °C	Thermocouple Potentiometer Temperature °C	Temperature Difference[b] %
3' Probe (1)					
200.004	1	Ice Water	1.0	1.2	0.07
	2	Water Bath	85.0	85.4	0.11
	3	Oil Bath	174.0	173.4	0.13
3' Probe (2)					
200.005	1	Ice Water	1.0	1.1	0.04
	2	Water Bath	86.0	85.7	0.08
	3	Oil Bath	189.0	188.2	0.17
3' Probe (3)					
200.006	1	Ice Water	1.1	1.4	-0.11
	2	Water Bath	82.0	81.7	0.06
	3	Oil Bath	194.0	192.9	0.24
3' Probe (4)					
200.015	1	Ice Water	1.5	1.8	0.11
	2	Water Bath	87.0	87.7	-0.19
	3	Oil Bath	194.0	192.9	0.24
3' Probe (5)					
200.016	1	Ice Water	1.5	1.7	-0.07
	2	Water Bath	87.0	87.4	-0.11
	3	Oil Bath	185.0	184.6	0.09
3' Probe (6)					
200.017	1	Ice Water	1.5	1.8	0.11
	2	Water Bath	85.0	85.2	-0.05
	3	Oil Bath	194.0	193.6	0.09

[a] Type of calibration system used.
[b] Temperature Difference Calculation:

$$\frac{(\text{Ref. Temp.}^{\circ}\text{C} + 273) - (\text{Test Temp.}^{\circ}\text{C} + 273)}{\text{Ref. Temp.}^{\circ}\text{C} + 273} \times 100 \leq 1.5\%$$

TRIGON

EVER READY THERMOMETER CO., New York, N.Y. 10157

LABORATORY TEST CERTIFICATE

Liquid-in-Glass Thermometer
ITS-90

Marked – ERTCO

Instrument No. 1019

Thermometer Scale Range – 1 *to* 51°C *in* 0.1° *divisions*

Tested for
ERTCO
RESULTS OF TEST

Thermometer Reading	Correction
0.00°C	0.00°C
10.00	+ .06
20.00	.00
30.00	- .03
37.00	- .01
40.00	- .01
50.00	- .01

If the correction is preceded by a + sign, it should be added to the thermometer reading; if it is preceded by a – sign, it should be subtracted from the thermometer reading to obtain the temperature. To use the corrections properly, reference should be made to the notes on the reverse side of this sheet.

Test No. 140098

Date 1-30-90

EVER READY THERMOMETER CO.

Certified by Shirley Windenhaven

Measurement Controls, Inc.

Gas Meter Remanufacturing and Sales

August 13, 1990

Lamb Industrial Consultants, Inc.
7561 B Orr Road
Charlotte, North Carolina 28213

Dear Mr. Blanton,

This is to certify that your AL-20 Wet Test Meter, Serial # 11088, has been calibrated with an American five foot bell prover, Serial # 2260. It is traceable to the National Bureau of Standards, reference no. 106870, PI- Tape.

The registered proof at a flow rate of 60 cubic feet per minute is 1.002 .

Sincerely,

Larry B. Lane
Measurement Controls, Inc.

102 S. Main Street • P.O. Box 997 • Huntersville, NC 28078 • (704) 875-2034

453

NATIONAL WEATHER SERVICE TYPE MERCURIAL BAROMETERS

Usable up to 900 metres (3,000 feet)

The National Weather Service type barometer is PRINCO's highest grade mercurial barometer. It is used by weather services and airports the world over. The glass tube has a uniform inside diameter of 7 mm for constant capillary depression throughout the length of the scale. Scales are set at the factory by comparison with a barometer certified by the National Bureau of Standards, and read the local pressure without the necessity of correcting for capillary depression. The vernier can be smoothly and precisely set by means of a rack and pinion drive, controlled by a knurled adjusting knob. White plastic backgrounds on the mounting panel facilitate observation of the Fortin type cistern and mercury column. The vernier has a sighting edge, front and rear, to avoid parallax. A suspension bracket and an adjustable ring clamp for the cistern hold the barometer firmly in the vertical position on the mounting panel. A dual scale Celsius/Fahrenheit thermometer with a −25 to 50 °C/−10 to 120 °F range indicates the proper temperature to be used for temperature corrections. An instruction booklet with information for understanding and proper use of the barometer is supplied with each instrument. Complete correction tables for temperature and gravity are included.

This barometer is accurate to ±0.3 mb, 0.2 mm, or 0.01 inch of mercury when carefully set and read, and after temperature and gravity corrections have been applied. For greatest accuracy a Certificate of Calibration may be obtained and the correction contained therein also applied. Each National Weather Service barometer has a serial number.

The rugged construction of the National Weather Service type barometer is such that it can be shipped safely by United Parcel Service or express. The kidskin bag, in the Fortin type reservoir, dampens mercury column oscillations during shipment. The lower part of the glass tube is narrowed down to minimize mercury weight, and is protected by foam cushions, thus offering added resistance to damage during shipment. The cistern may be opened in the field for cleaning of the cistern glass and cistern mercury. The barometer contains approximately 680 grams (1.5 pounds) of mercury total. It is shipped completely assembled, filled with mercury and ready to use. Mounting panel dimensions are 19 x 76 x 1072 mm (3/4 x 3 x 42 inches). The shipping weight is 5 kg (11 pounds) and box dimensions are 235 x 250 x 1197 mm (9 x 10 x 47 inches).

Catalog Number	Scales
→ 453	inch and millimetre
4538I	inch and millibar
453MB	millibar and millimetre

OHAUS

Certificate of Accuracy

Weight Values 50g To 1mg Certificate No. № 6640

Adjustment Tolerance Class NIST "P" Date 10-31-1990

This is to certify that the mass values for the weights of the set indicated above do not deviate from the nominal values in excess of the adjustment tolerances for the appropriate class. Compliance with the allowed tolerances has been established by comparison with suitable standards which in turn have been compared with standards calibrated by the National Institute of Standards Technology under Test Set No. 737/224785.

Adjustment is made on the basis of the Apparent Mass versus Stainless Steel.

OHAUS CORPORATION
29 Hanover Road
Florham Park, New Jersey 07932

Authorized Signature

Weights adjusted in accordance with the following specifications:

International Organization of Legal Metrology Recommendations

ANSI/ASTM E617

National Bureau of Standards, Circular 547, Handbook 105-1, Handbook 44 & Circular 3

Whatman

Whatman

Laboratory Division

Whatman Inc
9 Bridewell Place,
Clifton, New Jersey 07014
Telephone: 201-773-5800
Fax: 201-472-6949 Telex: 133426
Cable: WHATMAN

March 26, 1991

MR. TONY BLANTON
LAMB INDUSTRIAL CONSULT., INC.
7561-B ORR ROAD
CHARLOTTE, NC 28213

Dear Mr. Blanton,

Per our conversation earlier today, I am enclosing a copy of the Technical Information Sheet for Whatman Grade 934-AH glass microfibre paper.

I trust this will be satisfactory. Should you require any additional information, please contact me at any time.

Sincerely,

Elaine Heilweil

Elaine Heilweil
Divisional Technical Services Manager
North America

EH/em
Enclosure

Whatman
Specialty Products Division

Whatman Paper Limited
Springfield Mill,
Maidstone, Kent ME14 2LE
Telephone: (0622) 692022
Fax: (0622) 691425 Telex: 96113

CERTIFICATE OF ANALYSIS

CUSTOMER	:	Lamb Industrial Consult
GRADE	:	934-AH
BATCH No	:	087057A

PROPERTY	MEAN
Basis Weight, lbs /24 x 36ins ream	40
Thickness, ins	0.0139
Wet Tensile, g/inch	400
Gurley, sec/300cm³/1sq inch	16

J A Gilbert
QC Inspector

M C Lacey
Divisional Quality Manager - Europe

20th March 1991

APPENDIX F

SAMPLING AND ANALYTICAL PROCEDURES

METHOD 1—SAMPLE AND VELOCITY TRAVERSES FOR STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Principle. To aid in the representative measurement of pollutant emissions and/or total volumetric flow rate from a stationary source, a measurement site where the effluent stream is flowing in a known direction is selected, and the cross-section of the stack is divided into a number of equal areas. A traverse point is then located within each of these equal areas.

1.2 Applicability. This method is applicable to flowing gas streams in ducts, stacks, and flues. The method cannot be used when: (1) flow is cyclonic or swirling (see Section 2.4), (2) a stack is smaller than about 0.30 meter (12 in.) in diameter, or 0.071 m^2 (113 $in.^2$) cross-sectional area, or (3) the measurement site is less than two stack or duct diameters downstream or less than a half diameter upstream from a flow disturbance.

The requirements of this method must be considered before construction of a new facility from which emissions will be measured; failure to do so may require subsequent alterations to the stack or deviation from the standard procedure. Cases involving variants are subject to approval by the Administrator, U.S. Environmental Protection Agency.

2. *Procedure*

2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected, at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (D_e) shall be calculated from the following equation, to determine the upstream and downstream distances:

$$D_e = \frac{2LW}{(L+W)}$$

where L=length and W=width.

An alternative procedure is available for determining the acceptability of a measurement location not meeting the criteria above. This procedure, determination of gas flow angles at the sampling points and comparing the results with acceptability criteria, is described in Section 2.5.

[2.1 amended by 51 FR 20288, June 4, 1986]

2.2 Determining the Number of Traverse Points.

[Appendix A, Method 1]

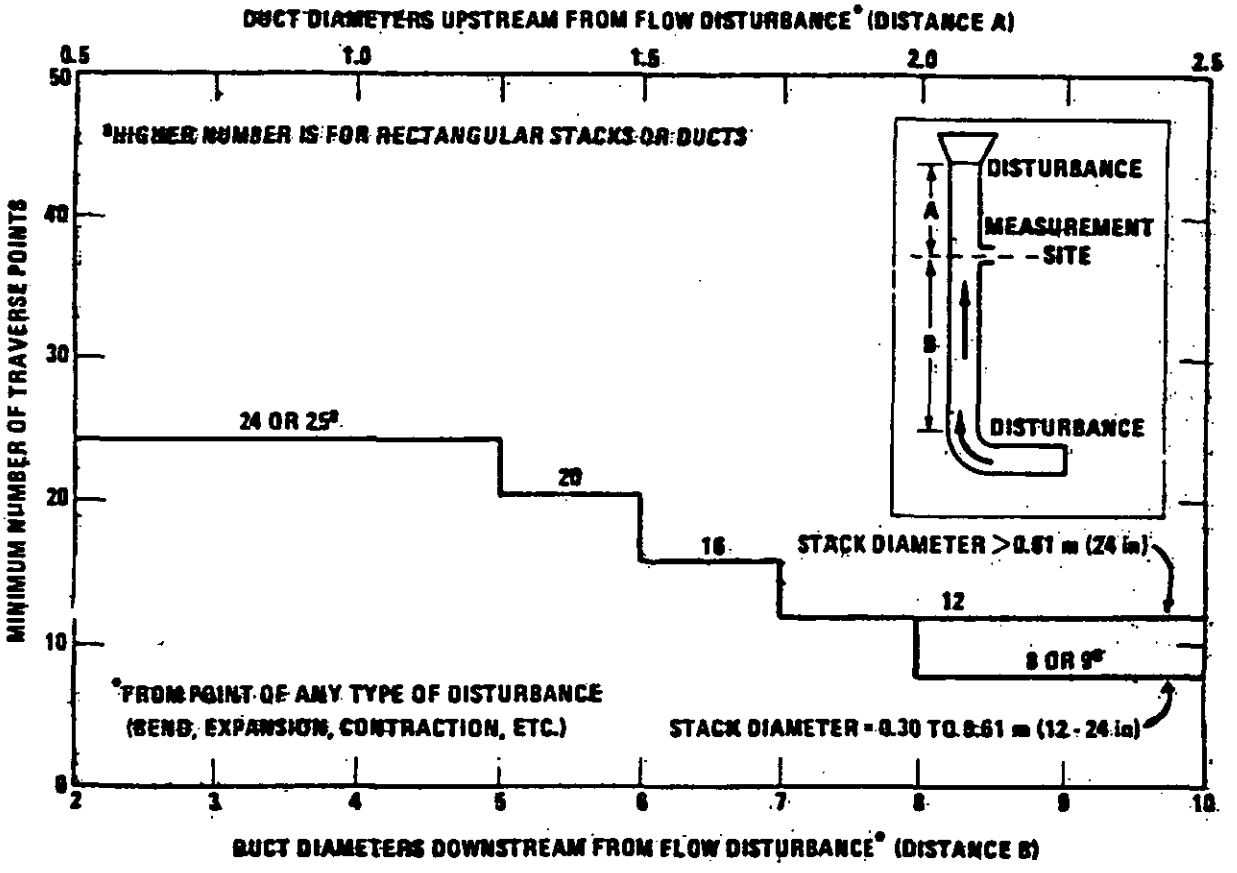


Figure 1-1. Minimum number of traverse points for particulate traverses.

[Method 1—Figure 1-1 revised by 52 FR 34639, September 14, 1987]

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.); (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-1 the minimum number of traverse points that corresponds: (1) to the number of duct diameters upstream; and (2) to the number of diameters downstream. Select the higher of the two minimum numbers of traverse points, or a greater value, so that for circular stacks the number is a multiple of 4, and for rectangular stacks, the number is one of those shown in Table 1-1.

TABLE 1-1. CROSS-SECTION LAYOUT FOR RECTANGULAR STACKS

Number of traverse points	Matrix layout
9	3x3
12	4x3
16	4x4
20	5x4
25	5x5
30	6x5
36	6x6
42	7x6
49	7x7

[Appendix A, Method 1]

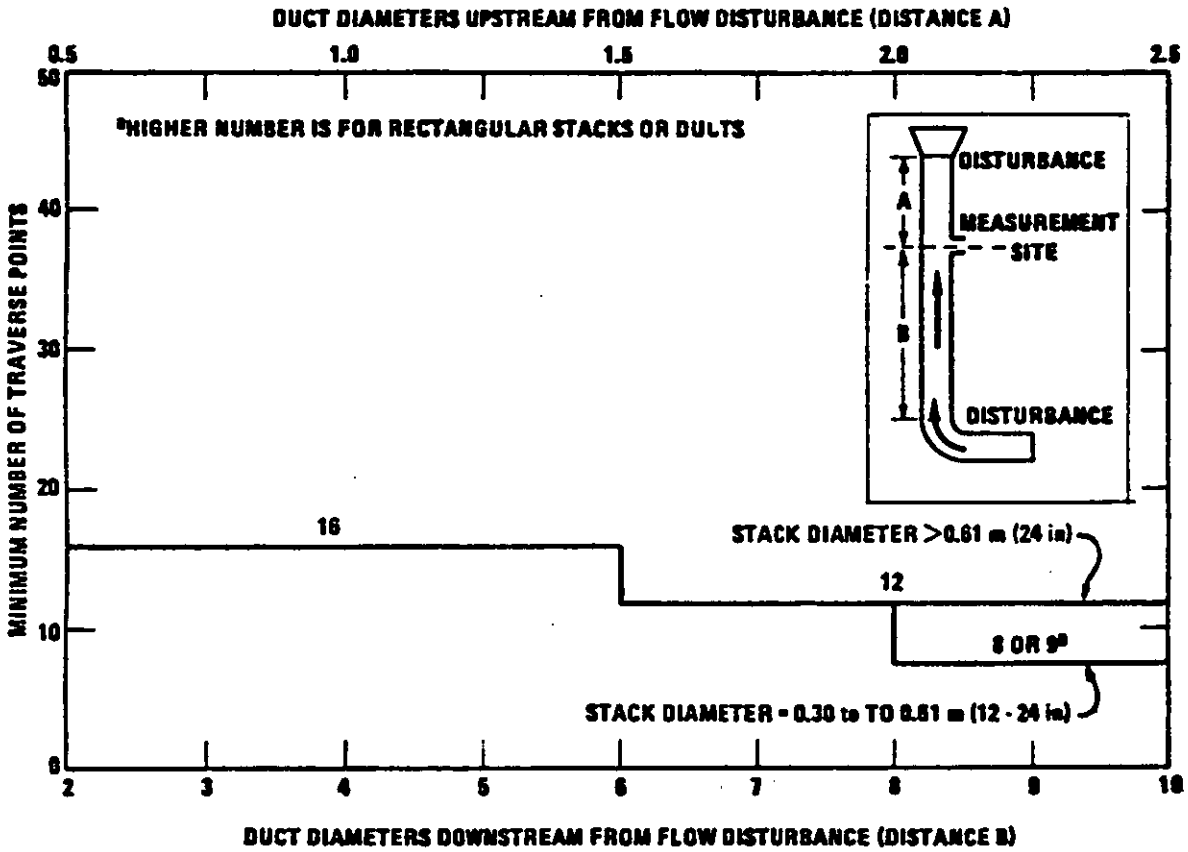


Figure 1-2. Minimum number of traverse points for velocity (nonparticulate) traverses.

[Method 1—Figure 1-2 revised by 52 FR 34639, September 14, 1987]

2.2.2 Velocity (Non-Particulate) Traverses. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1-2 may be used instead of Figure 1-1.

2.3 Cross-sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (for examples, see Citations 2 and 3 in the Bibliography) that gives the same values as those in Table 1-2 may be used in lieu of Table 1-2.

For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation, e.g., after bends, one diameter shall be in the plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls; and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls. To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.). When any of the traverse points as located in Section 2.3.1 fall within 2.5 cm (1.00 in.) of the stack walls, relocate them away from the stack walls to: (1) a distance of 2.5 cm (1.00 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

Whenever two successive traverse points are combined to form a single adjusted traverse point, treat the adjusted point as two separate traverse points, both in the sampling (or velocity measurement) procedure, and in recording the data.

[Appendix A, Method 1]

TRAVERSE POINT	DISTANCE, % of diameter
1	4.4
2	14.6
3	29.6
4	70.4
5	85.4
6	95.6

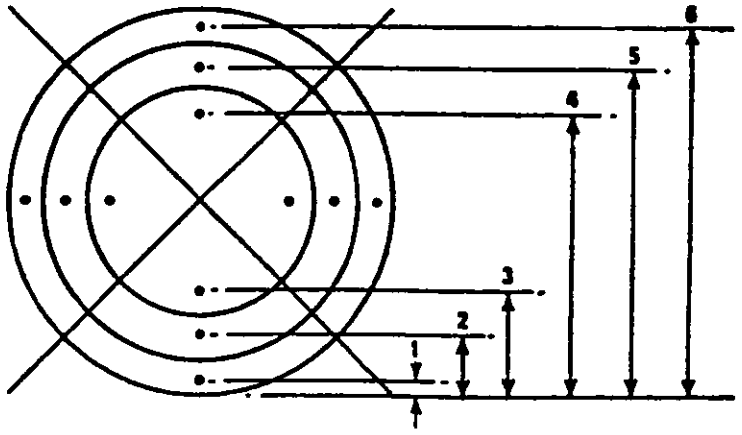


Figure 1-3. Example showing circular stack cross section divided into 12 equal areas, with location of traverse points indicated.

[Method 1—Figure 1-3 revised by 52 FR 34639, September 14, 1987]

TABLE 1-2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

[Percent of stack diameter from inside wall to traverse point]

Traverse point number on a diameter	Number of traverse points on a diameter—											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9	11.6	10.5
6			95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.4	36.6	28.3	23.6	20.4	18.0	16.1
8				96.8	85.4	75.0	63.4	37.5	29.6	25.0	21.8	19.4
9					91.8	82.3	73.1	62.5	36.2	30.6	26.2	23.0
10					97.4	88.2	78.9	71.7	61.8	38.8	31.5	27.2
11						93.3	85.4	78.0	70.4	61.2	38.3	32.3
12						97.9	90.1	83.1	76.4	68.4	60.7	38.8
13							94.3	87.5	81.2	75.0	68.5	60.2
14							98.2	91.5	85.4	79.6	73.8	67.7
15								95.1	89.1	83.5	78.2	72.8
16								98.4	92.5	87.1	82.0	77.0
17									95.6	90.3	85.4	80.6
18									98.6	93.3	88.4	83.9
19										96.1	91.3	86.8
20										98.7	94.0	89.5
21											96.5	92.1
22											98.9	94.5
23												96.8
24												98.9

2.3.1.2 Stack With Diameters Equal to or Less Than 0.61 m (24 in.). Follow the procedure in Section 2.3.1.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3.2 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point to the centroid of each equal area according to the example in Figure 1-4.

If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one or the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4X3 "minimum number of points" matrix were expanded to 36 points, the final matrix could be 9X4 or 12X3, and would not necessarily have to be 6X6. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.4 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essential parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination.

[Appendix A, Method 1]

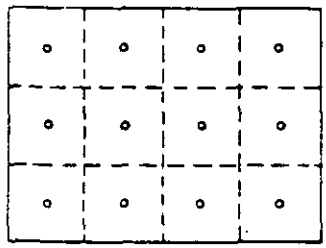


Figure 1-4. Example showing rectangular stack cross section divided into 12 equal areas, with a traverse point at centroid of each area.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Δp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to ±90° yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (a) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of a; assign a values of 0° to those points for which no rotation was required and include these in the overall average. If the average value of a is greater than 20°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

The alternative procedure described in Section 2.5 may be used to determine the rotation angles in lieu of the procedure described above.

[2.4 amended by 51 FR 20288, June 4, 1986; 52 FR 34639, September 14, 1987]

3. Bibliography

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2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District. Los Angeles, CA. November 1963.

3. Methods for Determination of Velocity, Volume, Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co. Los Angeles, CA. Bulletin WP-50. 1968.

4. Standard Method for Sampling Stacks for Particulate Matter. In: 1971 Book of ASTM Standards, Part 23. ASTM Designation D-2928-71. Philadelphia, Pa. 1971.

5. Hanson, H. A., et al. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. USEPA, ORD, ESRL, Research Triangle Park, N.C. EPA-600/2-76-170, June 1976.

6. Entropy Environmentalists, Inc. Determination of the Optimum Number of Sampling Points: An Analysis of Method 1 Criteria. Environmental Protection Agency, Research Triangle Park, N.C. EPA Contract No. 68-01-3172, Task 7.

[Citations 7—12 added by 48 FR 45035, September 30, 1983]

7. Hanson, H.A., R.J. Davini, J.K. Morgan, and A.A. Iversen. Particulate Sampling Strategies for Large Power Plants Including Nonuniform Flow. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-600/2-76-170. June 1976. 350 p.

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12. Knapp, K.T. The Number of Sampling Points Needed for Representative Source Sampling. In: Proceedings of the Fourth National Conference on Energy and the Environment, Theodore, L., et al. (ed.). Dayton, Dayton Section of the American Institute of Chemical Engineers. October 3-7, 1976. p. 563-568.

[13. — 15. added by 51 FR 20288, June 4, 1986]

13. Smith, W.S. and D.J. Grove. A Proposed Extension of EPA Method 1 Criteria. "Pollution Engineering." *XV* (8):36-37. August 1983.

14. Gerhart, P.M. and M.J. Dorsey. Investigation of Field Test Procedures for Large Fans. University of Akron, Akron, Ohio. (EPRI Contract CS-1651). Final Report (RP-1649-5) December 1980.

15. Smith, W.S. and D.J. Grove. A New Look at Isokinetic Sampling—Theory and Applications. "Source Evaluation Society Newsletter." *VIII* (3):19-24. August 1983.

Method 1A—Sample and Velocity Traverses for Stationary Sources with Small Stacks or Ducts

[Added by 54 FR 12622, March 28, 1989]

1. Applicability and Principle

1.1 The applicability and principle of this method are identical to Method 1, except this method's applicability is limited to stacks or ducts less than about 0.30 meter (12 in.) in diameter or 0.071 m^2 (113 $in.^2$) in cross-sectional area, but equal to or greater than about 0.10 meter (4 in.) in diameter or 0.0081 m^2 (12.57 $in.^2$) in cross-sectional area.

1.2 In these small diameter stacks or ducts, the conventional Method 5 stack assembly (consisting of a Type S pitot tube attached to a sampling probe, equipped with a nozzle and thermocouple) blocks a significant portion of the cross section of the duct and causes inaccurate measurements. Therefore, for particulate matter (PM) sampling in small stacks or ducts, the gas velocity is measured using a standard pitot tube downstream of the actual emission sampling site. The straight run of duct between the PM sampling and velocity measurement sites allows the flow profile, temporarily disturbed by the presence of the sampling probe, to redevelop and stabilize.

1.3 The cross-sectional layout and location of traverse points and the verification of the absence of cyclonic flow are the same as in Method 1, Sections 2.3 and 2.4, respectively. Differences from Method 1, except as noted, are given below.

2. Procedure

2.1 Selection of Sampling and Measurement Sites.

2.1.1 PM Measurements. Select a PM sampling site located preferably at least 8 equivalent stack or duct diameters downstream and 10 equivalent diameters upstream from any flow disturbances such as bends, expansions, or contractions in the stack, or from a visible flame. Next, locate the velocity measurement site 8 equivalent diameters downstream of the PM sampling site. See Figure 1A-1. If such locations are not available, select an alternative PM sampling site that is at least 2 equivalent stack or duct diameters downstream and 2½ diameters upstream from any flow disturbance. Then, locate the velocity measurement site 2 equivalent diameters downstream from the PM sampling site. Follow Section 2.1 of Method 1 for calculating equivalent diameters for a rectangular cross section.

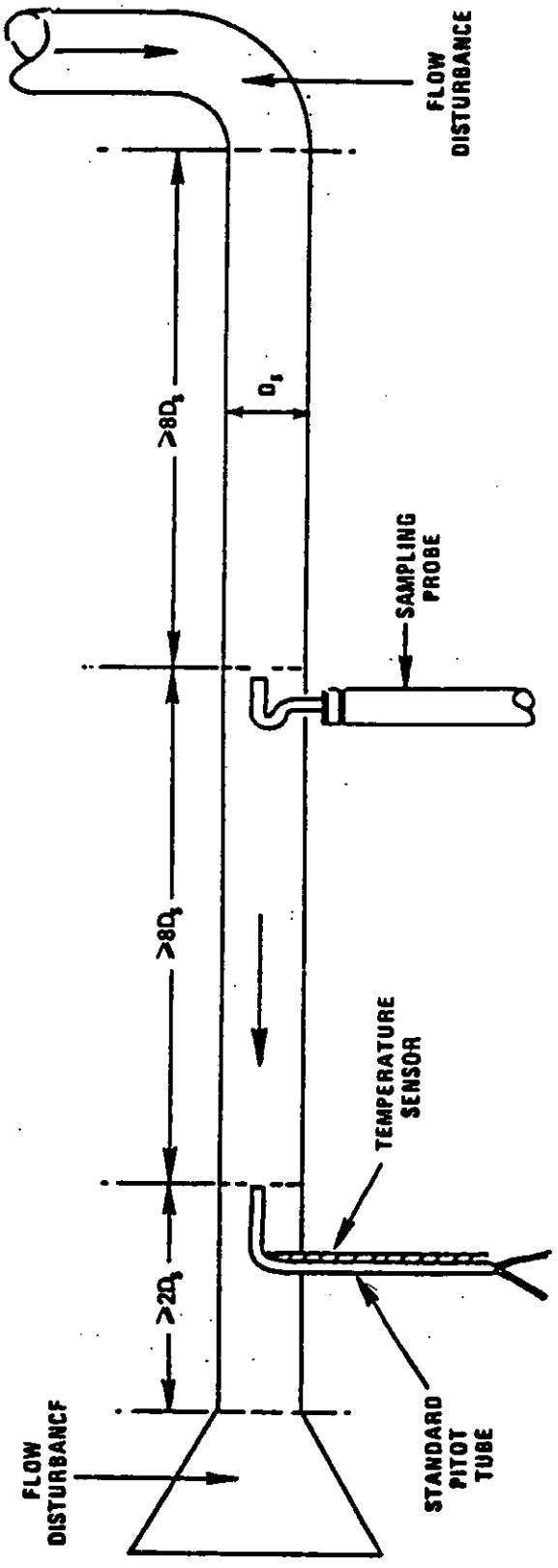


Figure 1A-1. Recommended sampling arrangement for small ducts.

[Appendix A, Method 1A]

2.1.2 PM Sampling (Steady Flow) or only Velocity Measurements. For PM sampling when the volumetric flow rate in a duct is constant with respect to time, Section 2.1 of Method 1 may be followed, with the PM sampling and velocity measurement performed at one location. To demonstrate that the flow rate is constant (within 10 percent) when PM measurements are made, perform complete velocity traverses before and after the PM sampling run, and calculate the deviation of the flow rate derived after the PM sampling run from the one derived before the PM sampling run. The PM sampling run is acceptable if the deviation does not exceed 10 percent.

2.2 Determining the Number of Traverse Points.

2.2.1 PM Sampling. Use Figure 1–1 of Method 1 to determine the number of traverse points to use at both the velocity measurement and PM sampling locations. Before referring to the figure, however, determine the distances between both the velocity measurement and PM sampling sites to the nearest upstream and downstream disturbances. Then divide each distance by the stack diameter or equivalent diameter to express the distances in terms of the number of duct diameters. Next, determine the number of traverse points from Figure 1–1 of Method 1 corresponding to each of these four distances. Choose the highest of the four numbers of traverse points (or a greater number) so that, for circular ducts, the number is a multiple of four, and for rectangular ducts, the number is one of those shown in Table 1–1 of Method 1. When the optimum duct diameter location criteria can be satisfied, the minimum number of traverse points required is eight for circular ducts and nine for rectangular ducts.

2.2.2 PM Sampling (Steady Flow) or Velocity Measurements. Use Figure 1–2 of Method 1 to determine the number of traverse points, following the same procedure used for PM sampling traverses as described in Section 2.2.1 of Method 1. When the optimum duct diameter location criteria can be satisfied, the minimum number of traverse points required is eight for circular ducts and nine for rectangular ducts.

3. Bibliography

1. Same as in Method 1, Section 3, Citations 1 through 6.

2. Vollaro, Robert F. Recommended Procedure for Sample Traverses in Ducts Smaller Than 12 Inches in Diameter. U.S. Environmental Protection Agency, Emission Measurement Branch, Research Triangle Park, North Carolina. January 1977.

Method 2—Determination of Stack Gas Velocity and Volumetric Flow Rate (Type S Pitot Tube)

1. Principle and Applicability

1.1 Principle. The average gas velocity in a stack is determined from the gas density and from measurement of the average velocity head with a Type S (Stausscheibe or reverse type) pitot tube.

1.2 Applicability. This method is applicable for measurement of the average velocity of a gas stream and for quantifying gas flow.

This procedure is not applicable at measurement sites which fail to meet the criteria of Method 1, Section 2.1. Also, the method cannot be used for direct measurement in cyclonic or swirling gas streams; Section 2.4 of Method 1 shows how to determine cyclonic or swirling flow conditions. When unacceptable conditions exist, alternative procedures, subject to the approval of the Administrator, U.S. Environmental Protection Agency, must be employed to make accurate flow rate determinations; examples of such alternative procedures are: (1) to install straightening vanes; (2) to calculate the total volumetric flow rate stoichiometrically, or (3) to move to another measurement site at which the flow is acceptable.

2. Apparatus

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

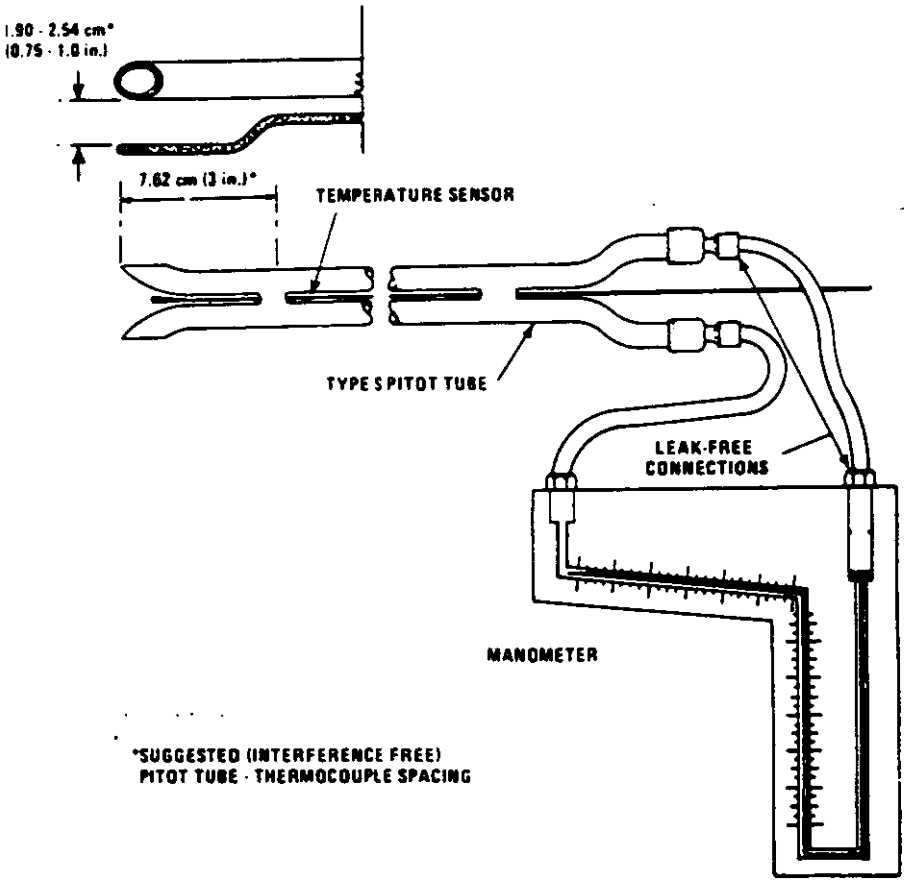
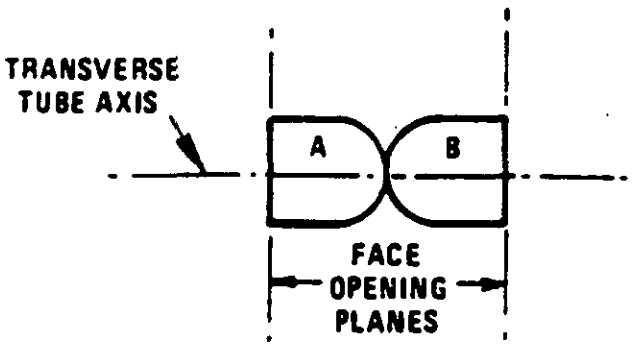


Figure 2-1. Type S pitot tube manometer assembly.

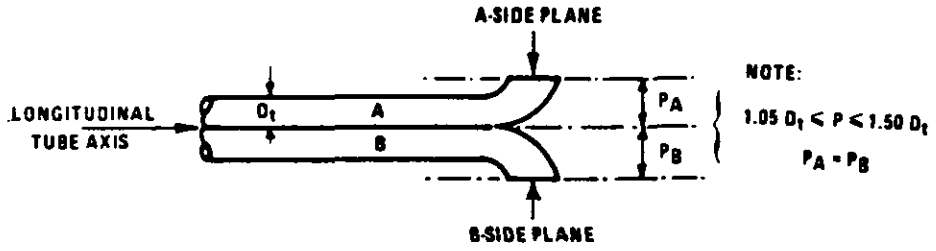
2.1 Type S Pitot Tube. The Type S pitot tube (Figure 2-1) shall be made of metal tubing (e.g. stainless steel). It is recommended that the external tubing diameter (dimension D_t, Figure 2-2b) be between 0.48 and 0.95 centimeters (3/16 and 3/8 inch). There shall be an equal distance from the base of each leg of the pitot tube to its face-opening plane (dimensions P_A and P_B, Figure 2-2b); it is recommended that this distance be between 1.05 and 1.50 times the external tubing diameter. The face openings of the pitot tube shall, preferably, be aligned as shown in Figure 2-2; however, slight misalignments of the openings are permissible (see Figure 2-3).

The Type S pitot tube shall have a known coefficient, determined as outlined in Section 4, an identification number shall be assigned to the pitot tube; this number shall be permanently marked or engraved on the body of the tube.

[Appendix A, Method 2]



(a)



(b)

(c)

Figure 2-2. Properly constructed Type S pitot tube, shown in: (a) end view; face opening planes perpendicular to transverse axis; (b) top view; face opening planes parallel to longitudinal axis; (c) side view; both legs of equal length and centerlines coincident, when viewed from both sides. Baseline coefficient values of 0.84 may be assigned to pitot tubes constructed this way.

[Appendix A, Method 2]

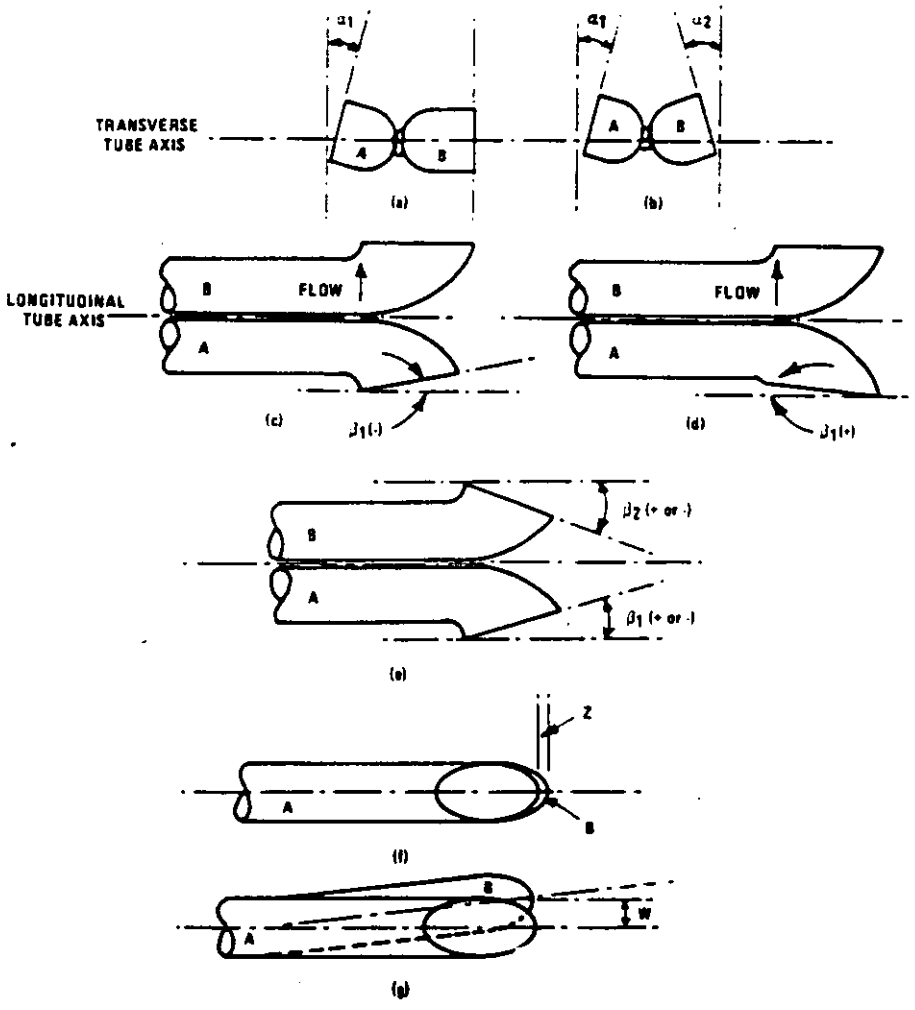


Figure 2-3. Types of face-opening misalignment that can result from field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as $\alpha 1$ and $\alpha 2$ 10°, $\beta 1$ and $\beta 2$ 5°, z 0.32 cm (1/8 in.) and w 0.08 cm (1/32 in.) (citation 11 in Section 6).

A standard pitot tube may be used instead of a Type S, provided that it meets the specifications of Sections 2.7 and 4.2; note, however, that the static and impact pressure holes of standard pitot tubes are susceptible to plugging in particulate-laden gas streams. Therefore, whenever a standard pitot tube is used to perform a traverse, adequate proof must be furnished that the openings of the pitot tube have not plugged up during the traverse period; this can be done by taking a velocity head (Δp) reading at the final traverse point, cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and then taking another Δp reading. If the Δp readings made before and after the air purge are the same (±5 percent), the traverse is acceptable. Otherwise, reject the run. Note that if Δp at the final traverse point is unsuitably low, another point may be selected. If "back-purging" at regular intervals is part of the procedure, then comparative Δp readings shall be taken, as above, for the last two back purges at which suitably high Δp readings are observed.

2.2 Differential Pressure Gauge. An inclined manometer or equivalent device is used. Most sampling trains are equipped with a 10-in. (water column) inclined-vertical manometer, having 0.01-in. H_2O divisions on the 0-to 1-in. inclined scale, and 0.1-in. H_2O divisions on the 1- to 10-in. vertical scale. This type of manometer (or other gauge of equivalent sensitivity) is satisfactory for the measurement of Δp values as low as 1.3 mm (0.05 in.) H_2O. However, a differential pressure gauge of greater sensitivity shall be used (subject to the approval of the Administrator), if any of the following is found to be true: (1) the arithmetic average of all Δp readings at the traverse points in the stack is less than 1.3 mm (0.05 in.) H_2O; (2) for traverses of 12 or more points, more than 10 percent of the individual Δp readings are below 1.3 mm (0.05 in.) H_2O; (3) for traverses of fewer than 12 points, more than one Δp reading is below 1.3 mm (0.05 in.) H_2O. Citation 18 in Section 6 describes commercially available instrumentation for the measurement of low-range gas velocities.

As an alternative to criteria (1) through (3) above, the following calculation may be performed to determine the necessity of using a more sensitive differential pressure gauge:

$$T = \frac{\sum_{i=1}^{n} \sqrt{\Delta p_i} + K}{\sum_{i=1}^{n} \sqrt{\Delta p_i}}$$

where:

Δp_i = Individual velocity head reading at a traverse point, mm H_2O (in. H_2O).

n = Total number of traverse points.

K = 0.13 mm H_2O when metric units are used and 0.005 in H_2O when English units are used.

If T is greater than 1.05, the velocity head data are unacceptable and a more sensitive differential pressure gauge must be used.

NOTE: If differential pressure gauges other than inclined manometers are used (e.g., magnehelic gauges), their calibration must be checked after each test series. To check the calibration of a differential pressure gauge, compare Δp readings of the gauge with those of a gauge-oil manometer at a minimum of three points, approximately representing the range of Δp values in the stack. If, at each point, the values of Δp as read by the differential pressure gauge and gauge-oil manometer agree to within 5 percent, the differential pressure gauge shall be considered to be in proper calibration. Otherwise, the test series shall either be voided, or procedures to adjust the measured Δp values and final results shall be used subject to the approval of the Administrator.

2.3 Temperature Gauge. A thermocouple, liquid-filled bulb thermometer, bimetallic thermometer, mercury-in-glass thermometer, or other gauge, capable of measuring temperature to within 1.5 percent of the minimum absolute stack temperature shall be used. The temperature gauge shall be attached to the pitot tube such that the sensor tip does not touch any metal; the gauge shall be in an interference-free arrangement with respect to the pitot tube face openings (see Figure 2-1 and also Figure 2-7 in Section 4). Alternate positions may be used if the pitot tube-temperature gauge system is calibrated according to the procedure of Section 4. Provided that a difference of not more than 1 percent in the average velocity measurement is introduced, the temperature gauge need not be attached to the pitot tube; this alternative is subject to the approval of the Administrator.

2.4 Pressure Probe and Gauge. A piezometer tube and mercury- or water-filled U-tube manometer capable of measuring stack pressure to within 2.5 mm (0.1 in.) Hg is used. The static tap of a standard type pitot tube or one leg of a Type S pitot tube with the face opening planes positioned parallel to the gas flow may also be used as the pressure probe.

[Appendix A, Method 2]

2.5 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm (0.1 in.) Hg per 30-meter (100 foot) elevation increase or vice-versa for elevation decrease.

[The second 2.5 was added by 51 FR 20288, June 4, 1986]

2.5 Alternative Measurement Site Selection Procedure. This alternative applies to sources where measurement locations are less than 2 equivalent stack or duct diameters downstream or less than ½ duct diameter upstream from a flow disturbance. The alternative should be limited to ducts larger than 24 in. in diameter where blockage and wall effects are minimal. A directional flow-sensing probe is used to measure pitch and yaw angles of the gas flow at 40 or more traverse points; the resultant angle is calculated and compared with acceptable criteria for mean and standard deviation.

Note.—Both the pitch and yaw angles are measured from a line passing through the traverse point and parallel to the stack axis. The pitch angle is the angle of the gas flow component in the plane that INCLUDES the traverse line and is parallel to the stack axis. The yaw angle is the angle of the gas flow component in the plane PERPENDICULAR to the traverse line at the traverse point and is measured from the line passing through the traverse point and parallel to the stack axis.

2.5.1 Apparatus.

2.5.1.1 Directional Probe. Any directional probe, such as United Sensor Type DA Three-Dimensional Directional Probe, capable of measuring both the pitch and yaw angles of gas flows is acceptable. (Note: Mention of trade name or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.) Assign an identification number to the directional probe, and permanently mark or engrave the number on the body of the probe. The pressure holes of directional probes are susceptible to plugging when used in particulate-laden gas streams. Therefore, a system for cleaning the pressure holes by "back-purging" with pressurized air is required.

2.5.1.2 Differential Pressure Gauges. Inclined manometers, U-tube manometers, or other differential pressure gauges (e.g., magnehelic gauges) that meet the specifications described in Method 2, § 2.2.

Note.—If the differential pressure gauge produces both negative and positive readings, then both negative and positive pressure readings shall be calibrated at a minimum of three points as specified in Method 2, § 2.2.

2.5.2 Traverse Points. Use a minimum of 40 traverse points for circular ducts and 42 points for rectangular ducts for the gas flow angle determinations. Follow § 2.3 and Table 1–1 or 1–2 for the location and layout of the traverse points. If the measurement location is determined to be acceptable according to the criteria in this alternative procedure, use the same traverse point number and locations for sampling and velocity measurements.

2.5.3 Measurement Procedure.

2.5.3.1 Prepare the directional probe and differential pressure gauges as recommended by the manufacturer. Capillary tubing or surge tanks may be used to dampen pressure fluctuations. It is recommended, but not required, that a pretest leak check be conducted. To perform a leak check, pressurize or use suction on the impact opening until a reading of at least 7.6-cm (3 in.) H_2O registers on the differential pressure gauge, then plug the impact opening. The pressure of a leak-free system will remain stable for at least 15 seconds.

2.5.3.2 Level and zero the manometers. Since the manometer level and zero may drift because of vibrations and temperature changes, periodically check the level and zero during the traverse.

2.5.3.3 Position the probe at the appropriate locations in the gas stream, and rotate until zero deflection is indicated for the yaw angle pressure gauge. Determine and record the yaw angle. Record the pressure gauge readings for the pitch angle, and determine the pitch angle from the calibration curve. Repeat this procedure for each traverse point. Complete a "back-purge" of the pressure lines and the impact openings prior to measurements of each traverse point.

A post-test check as described in § 2.5.3.1 is required. If the criteria for a leak-free system are not met, repair the equipment, and repeat the flow angle measurements.

2.5.4 Calculate the resultant angle at each traverse point, the average resultant angle, and the standard deviation using the following equations. Complete the calculations retaining at least one extra significant figure beyond that of the acquired data. Round the values after the final calculations.

2.5.4.1 Calculate the resultant angle at each traverse point:

R_i = arc cosine [(cosine Y_i)(cosine P_i)] Eq. 1–2

Where:

R_i = Resultant angle at traverse point i, degree.

Y_i = Yaw angle at traverse point i, degree.

P_i = Pitch angle at traverse point i, degree.

2.5.4.2 Calculate the average resultant for the measurements:

$$\bar{R} = \frac{\Sigma R_i}{n} \qquad \text{Eq. 1–3}$$

where:

$\bar{R}$ = Average resultant angle, degree.

n = Total number of traverse points.

[2.5.4.2 corrected by 51 FR 29104, August 14, 1986]

2.5.4.3 Calculate the standard deviations:

$$S_d = \sqrt{\frac{\sum_{i=1}^{n} (R_i - \bar{R})^2}{(n-1)}} \qquad \text{Eq. 1-4}$$

[2.5.4.3. Eq. 1-4 corrected by 51 FR 29104, August 14, 1986]

Where:

S_d = Standard deviation, degree.

2.5.5 The measurement location is acceptable if $\bar{R} \leq 20°$ and $S_d \leq 10°$.

2.5.6 Calibration. Use a flow system as described in Sections 4.1.2.1 and 4.1.2.2 of Method 2. In addition, the flow system shall have the capacity to generate two test-section velocities: one between 365 and 730 m/min (1200 and 2400 ft/min) and one between 730 and 1280 m/min (2400 and 3900 ft/min).

2.5.6.1 Cut two entry ports in the test section. The axes through the entry ports shall be perpendicular to each other and intersect in the centroid of the test section. The ports should be elongated slots parallel to the axis of the test section and of sufficient length to allow measurement of pitch angles while maintaining the pitot head position at the test-section centroid. To facilitate alignment of the directional probe during calibration, the test section should be constructed of plexiglass of some other transparent material. All calibration measurements should be made at the same point in the test section, preferably at the centroid of the test-section.

[Appendix A, Method 2]

2.5.6.2 To ensure that the gas flow is parallel to the central axis of the test section, follow the procedure in Section 2.4 for cyclonic flow determination to measure the gas flow angles at the centroid of the test section from two test ports located at 90° apart. The gas flow angle measured in each port must be ±2° of 0°. Straightening vanes should be installed, if necessary, to meet this criterion.

2.5.6.3 Pitch Angle Calibration. Perform a calibration traverse according to the manufacturer's recommended protocol in 5° increments for angles from −60° to +60° at one velocity in each of the two ranges specified above. Average the pressure-ratio values obtained for each angle in the two flow ranges, and plot a calibration curve with the average values of the pressure ratio (or other suitable measurement factor as recommended by the manufacturer) versus the pitch angle. Draw a smooth line through the data points. Plot also the data values for each traverse point. Determine the differences between the measured data values and the angle from the calibration curve at the same pressure ratio. The difference at each comparison must be within 2° for angles between 0° and 40° and within 3° for angles between 40° and 60°.

2.5.6.4 Yaw Angle Calibration. Mark the three-dimensional probe to allow the determination of the yaw position of the probe. This is usually a line extending the length of the probe and aligned with the impact opening. To determine the accuracy of measurements of the yaw angle, only the zero or null position need be calibrated as follows. Place the directional probe in the test section, and rotate the probe until the zero position is found. With a protractor or other angle measuring device, measure the angle, indicated by the yaw angle indicator on the three-dimensional probe. This should be within 2° of 0°. Repeat this measurement for any other points along the length of the pitot where yaw angle measurements could be read in order to account for variations in the pitot markings used to indicate pitot head positions.

2.6 Gas Density Determination Equipment. Method 3 equipment, if needed (see Section 3.6), to determine the stack gas dry molecular weight, and Reference Method 4 or Method 5 equipment for moisture content determination; other methods may be used subject to approval of the Administrator.

2.7 Calibration Pitot Tube. When calibration of the Type S pitot tube is necessary (see Section 4), a standard pitot tube is used as a reference. The standard pitot tube shall, preferably, have a known coefficient, obtained either (1) directly from the National Bureau of Standards, Route 270, Quince Orchard Road, Gaithersburg, Maryland, or (2) by calibration against another standard pitot tube with an NBS-traceable coefficient. Alternatively, a standard pitot tube designed according to the criteria given in 2.7.1 through 2.7.5 below and illustrated in Figure 2-4 (see also Citations 7, 8, and 17 in Section 6) may be used. Pitot tubes designed according to these specifications will have baseline coefficients of about 0.99±0.01.

2.7.1 Hemispherical (shown in Figure 2-4), ellipsoidal, or conical tip.

2.7.2 A minimum of six diameters straight run (based upon D, the external diameter of the tube) between the tip and the static pressure holes.

2.7.3 A minimum of eight diameters straight run between the static pressure holes and the centerline of the external tube, following the 90 degree bend.

2.7.4 Static pressure holes of equal size (approximately 0.1 D), equally spaced in a piezometer ring configuration.

2.7.5 Ninety degree bend, with curved or mitered junction.

2.8 Differential Pressure Gauge for Type S Pitot Tube Calibration. An inclined manometer or equivalent is used. If the single-velocity calibration technique is employed (see Section 4.1.2.3), the calibration differential pressure gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in. H_2O). For multivelocity calibrations, the gauge shall be readable to the nearest 0.13 mm H_2O (0.005 in H_2O) for Δp values between 1.3 and 25 mm H_2O (0.05 and 1.0 in. H_2O), and to the nearest 1.3 mm H_2O (0.05 in. H_2O) for Δp values above 25 mm H_2O (1.0 in. H_2O). A special, more sensitive gauge will be required to read Δp values below 1.3 mm H_2O (0.05 in. H_2O) (see Citation 18 in Section 6).

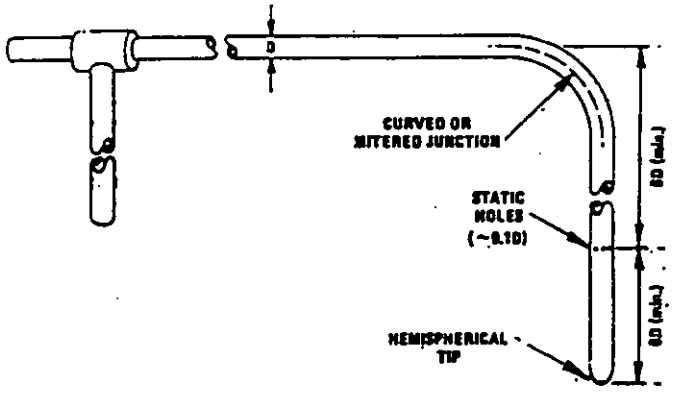


Figure 2-4. Standard pitot tube design specifications.

3. Procedure

3.1 Set up the apparatus as shown in Figure 2-1. Capillary tubing or surge tanks installed between the manometer and pitot tube may be used to dampen Δp fluctuations. It is recommended, but not required, that a pretest leak-check be conducted, as follows: (1) blow through the pitot impact opening until at least 7.6 cm (3 in.) H_2O velocity pressure registers on the manometer; then, close off the impact opening. The pressure shall remain stable for at least 15 seconds; (2) do the same for the static pressure side, except using suction to obtain the minimum of 7.6 cm (3 in.) H_2O. Other leak-check procedures, subject to the approval of the Administrator may be used.

3.2 Level and zero the manometer. Because the manometer level and zero may drift due to vibrations and temperature changes, make periodic checks during the traverse. Record all necessary data as shown in the example data sheet (Figure 2-5).

3.3 Measure the velocity head and temperature at the traverse points specified by Method 1. Ensure that the proper differential pressure gauge is being used for the range of Δp values encountered (see Section 2.2). If it is necessary to change to a more sensitive gauge, do so, and remeasure the Δp and temperature readings at each traverse point. Conduct a post-test leak-check (mandatory), as described in Section 3.1 above, to validate the traverse run.

3.4 Measure the static pressure in the stack. One reading is usually adequate.

3.5 Determine the atmospheric pressure.

[Appendix A, Method 2]

PLANT _____

DATE _____ RUN NO. _____

STACK DIAMETER OR DIMENSIONS, m(in.) _____

BAROMETRIC PRESSURE, mm Hg (in. Hg) _____

CROSS SECTIONAL AREA, m^2(ft^2) _____

OPERATORS _____

PITOT TUBE I.D. NO. _____

AVG. COEFFICIENT, C_p = _____

LAST DATE CALIBRATED _____

SCHEMATIC OF STACK CROSS SECTION

Traverse Pt. No.	Vel. Hd., Δp mm (in.) H_2O	Stack Temperature		P_s mm Hg (in. Hg)	$\sqrt{\Delta p}$
		t_s, °C (°F)	T_s, °K (°R)		
		Average			

Figure 2-5. Velocity traverse data.

3.6 Determine the stack gas dry molecular weight. For combustion processes or processes that emit essentially CO_2, O_2, CO, and N_2, use Method 3. For processes emitting essentially air, an analysis need not be conducted; use a dry molecular weight of 29.0. For other processes, other methods, subject to the approval of the Administrator, must be used.

3.7 Obtain the moisture content from Reference Method 4 (or equivalent) or from Method 5.

3.8 Determine the cross-sectional area of the stack or duct at the sampling location. Whenever possible, physically measure the stack dimmensions rather than using blueprints.

4. *Calibration*

4.1 Type S Pitot Tube. Before its initial use, carefully examine the Type S pitot tube in top, side, and end views to verify that the face openings of the tube are aligned within the specifications illustrated in Figure 2-2 or 2-3. The pitot tube shall not be used if it fails to meet these alignment specifications.

After verifying the face opening alignment, measure and record the following dimensions of the pitot tube: (a) the external tubing diameter (dimension D_t, Figure 2-2b); and (b) the base-to-opening plane distances (dimensions P_A and P_B, Figure 2-2b). If D_t is between 0.48 and 0.95 cm (3/16 and 3/8 in.) and if P_A and P_B are equal and between 1.05 and 1.50 D_t, there are two possible options: (1) the pitot tube may be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, or (2) a baseline (isolated tube) coefficient value of 0.84 may be assigned to the pitot tube. Note, however, that if the pitot tube is part of an assembly, calibration may still be required, despite knowledge of the baseline coefficient value (see Section 4.1.1).

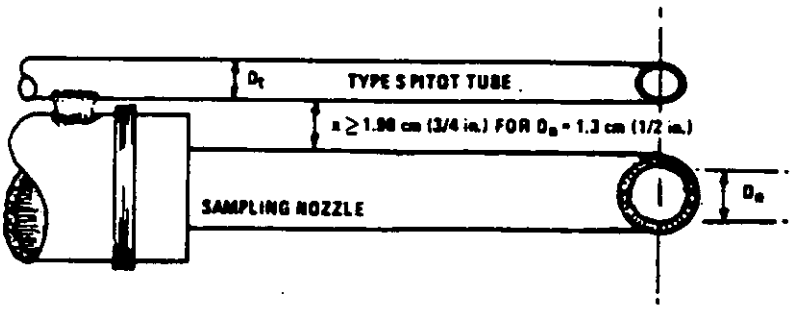
If D_t, P_A, and P_B are outside the specified limits, the pitot tube must be calibrated as outlined in 4.1.2 through 4.1.5 below.

4.1.1 Type S Pitot Tube Assemblies. During sample and velocity traverses, the isolated Type S pitot tube is not always used; in many instances, the pitot tube is used in combination with other source-sampling components (thermocouple, sampling probe, nozzle) as part of an "assembly." The presence of other sampling components can sometimes affect the baseline value of the Type S pitot tube coefficient (Citation 9 in Section 6); therefore an assigned (or otherwise known) baseline coefficient value may or may not be valid for a given assembly. The baseline and assembly coefficient values will be identical only when the relative placement of the components in the assembly is such that aerodynamic interference effects are eliminated. Figures 2-6 through 2-8 illustrate interference-free component arrangements for Type S pitot tubes having external tubing diameters between 0.48 and 0.95 cm (3/16 and 3/8 in.). Type S pitot tube assemblies that fail to meet any or all of the specifications of Figures 2-6 through 2-8 shall be calibrated according to the procedure outlined in Sections 4.1.2 through 4.1.5 below, and prior to calibration, the values of the intercomponent spacings (pitot-nozzle, pitot-thermocouple, pitot-probe sheath) shall be measured and recorded.

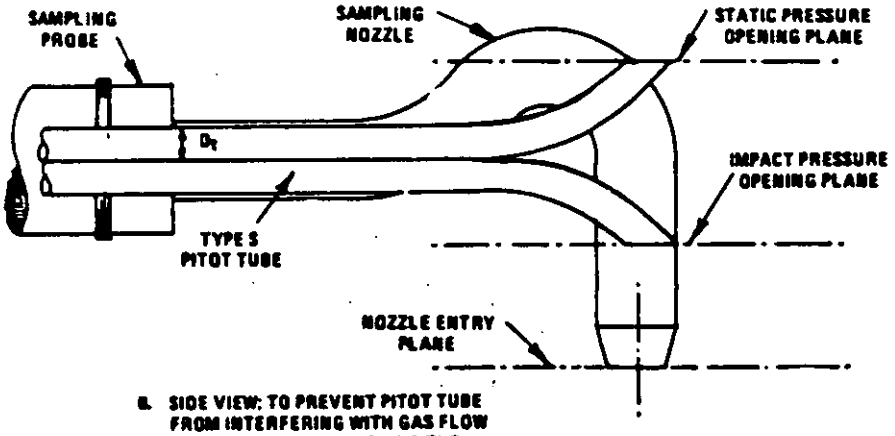
NOTE.—Do not use any Type S pitot tube assembly which is constructed such that the impact pressure opening plane of the pitot tube is below the entry plane of the nozzle (see Figure 2-6b).

4.1.2 Calibration Setup. If the Type S pitot tube is to be calibrated, one leg of the tube shall be permanently marked A, and the other, B. Calibration shall be done in a flow system having the following essential design features:

[Appendix A, Method 2]



A. BOTTOM VIEW: SHOWING MINIMUM PITOT-NOZZLE SEPARATION.



B. SIDE VIEW: TO PREVENT PITOT TUBE FROM INTERFERING WITH GAS FLOW STREAMLINES APPROACHING THE NOZZLE, THE IMPACT PRESSURE OPENING PLANE OF THE PITOT TUBE SHALL BE EVEN WITH OR ABOVE THE NOZZLE ENTRY PLANE.

Figure 2-6. Proper pitot tube-sampling nozzle configuration to prevent aerodynamic interference; buttonhook-type nozzle; centers of nozzle and pitot opening aligned; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

[Figure 2-6 amended by 52 FR 34639, September 14, 1987]

[Appendix A, Method 2]

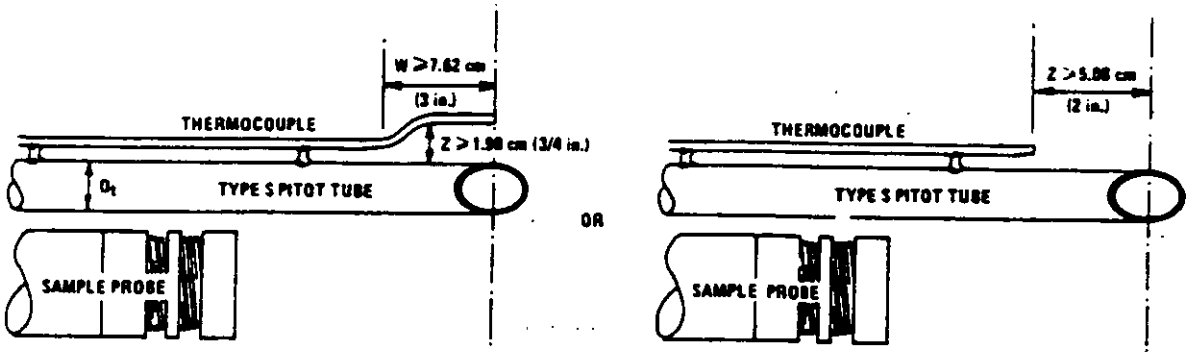


Figure 2-7. Proper thermocouple placement to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

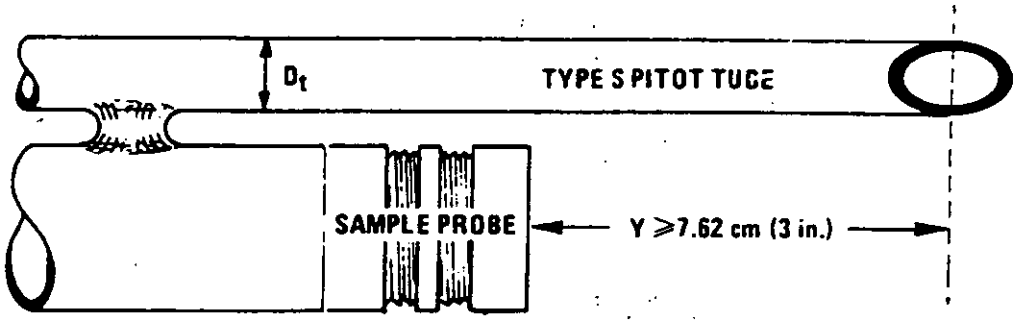


Figure 2-8. Minimum pitot-sample probe separation needed to prevent interference; D_t between 0.48 and 0.95 cm (3/16 and 3/8 in.).

4.1.2.1 The flowing gas stream must be confined to a duct of definite cross-sectional area, either circular or rectangular. For circular cross-sections, the minimum duct diameter shall be 30.5 cm (12 in.); for rectangular cross-sections, the width (shorter side) shall be at least 25.4 cm (10 in.).

4.1.2.2 The cross-sectional area of the calibration duct must be constant over a distance of 10 or more duct diameters. For a rectangular cross-section, use an equivalent diameter, calculated from the following equation, to determine the number of duct diameters:

$$D = \frac{2LW}{(L+W)} \qquad \text{Equation 2-1}$$

where:
D = Equivalent diameter
L = Length
W = Width

To ensure the presence of stable, fully developed flow patterns at the calibration site, or "test section," the site must be located at least eight diameters downstream and two diameters upstream from the nearest disturbances.

NOTE: The eight- and two-diameter criteria are not absolute; other test section locations may be used (subject to approval of the Administrator), provided that the flow at the test site is stable and demonstrably parallel to the duct axis.

4.1.2.3 The flow system shall have the capacity to generate a test-section velocity around 915 m/min (3,000 ft/min). This velocity must be constant with time to guarantee steady flow during calibration. Note that Type S pitot tube coefficients obtained by single-velocity calibration at 915 m/min (3,000 ft/min) will generally be valid to within ±3 percent for the measurement of velocities above 305 m/min (1,000 ft/min) and to within ±5 to 6 percent for the measurement of velocities between 180 and 305 m/min (600 and 1,000 ft/min). If a more precise correlation between C_p and velocity is desired, the flow system shall have the capacity to generate at least four distinct, time-invariant test-section velocities covering the velocity range from 180 to 1,525 m/min (600 to 5,000 ft/min), and calibration data shall be taken at regular velocity intervals over this range (see Citations 9 and 14 in Section 6 for details).

4.1.2.4 Two entry ports, one each for the standard and Type S pitot tubes, shall be cut in the test section; the standard pitot entry port shall be located slightly downstream of the Type S port, so that the standard and Type S impact openings will

[Appendix A, Method 2]

lie in the same cross-sectional plane during calibration. To facilitate alignment of the pitot tubes during calibration, it is advisable that the test section be constructed of plexiglas or some other transparent material.

4.1.3 Calibration Procedure. Note that this procedure is a general one and must not be used without first referring to the special considerations presented in Section 4.1.5. Note also that this procedure applies only to single-velocity calibration. To obtain calibration data for the A and B sides of the Type S pitot tube, proceed as follows:

4.1.3.1 Make sure that the manometer is properly filled and that the oil is free from contamination and is of the proper density. Inspect and leak-check all pitot lines; repair or replace if necessary.

4.1.3.2 Level and zero the manometer. Turn on the fan and allow the flow to stabilize. Seal the Type S entry port.

4.1.3.3 Ensure that the manometer is level and zeroed. Position the standard pitot tube at the calibration point (determined as outlined in Section 4.1.5.1), and align the tube so that its tip is pointed directly into the flow. Particular car should be taken in aligning the tube to avoid yaw and pitch angles. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.4 Read Δp_{std} and record its value in a data table similar to the one shown in Figure 2-9. Remove the standard pitot tube from the duct and disconnect it from the manometer. Seal the standard entry port.

4.1.3.5 Connect the Type S pitot tube to the manometer. Open the Type S entry port. Check the manometer level and zero. Insert and align the Type S pitot tube so that its A side impact opening is at the same point as was the standard pitot tube and is pointed directly into the flow. Make sure that the entry port surrounding the tube is properly sealed.

4.1.3.6 Read Δp_s and enter its value in the data table. Remove the Type S pitot tube from the duct and disconnect it from the manometer.

4.1.3.7 Repeat steps 4.1.3.3 through 4.1.3.6 above until three pairs of Δp readings have been obtained.

4.1.3.8 Repeat steps 4.1.3.3 through 4.1.3.7 above for the B side of the Type S pitot tube.

4.1.3.9 Perform calculations, as described in Section 4.1.4 below.

4.1.4 Calculations.

4.1.4.1 For each of the six pairs of Δp readings (i.e., three from side A and three from side B) obtained in Section 4.1.3 above, calculate the value of the Type S pitot tube coeffficient as follows:

PITOT TUBE IDENTIFICATION NUMBER: _____ DATE: _____

CALIBRATED BY: _____

	"A" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(A)$
1				
2				
3				
		$\bar{C}_p$ (SIDE A)		

	"B" SIDE CALIBRATION			
RUN NO.	Δp_{std} cm H_2O (in. H_2O)	$\Delta p_{(s)}$ cm H_2O (in. H_2O)	$C_{p(s)}$	DEVIATION $C_{p(s)} - \bar{C}_p(B)$
1				
2				
3				
		$\bar{C}_p$ (SIDE B)		

$$\text{AVERAGE DEVIATION} = \sigma\,(\text{A OR B}) = \frac{\sum_{1}^{3} \left| C_{p(s)} - \bar{C}_p(\text{A OR B}) \right|}{3} \leftarrow \text{MUST BE} \leq 0.01$$

$$\left| \bar{C}_p\,(\text{SIDE A}) - \bar{C}_p\,(\text{SIDE B}) \right| \leftarrow \text{MUST BE} \leq 0.01$$

Figure 2-9. Pitot tube calibration data.

[Appendix A, Method 2]

$$C_{p(s)} = C_{p(std)} \sqrt{\frac{\overline{\Delta p_{std}}}{\Delta p_s}}$$

Equation 2-2

where:

$C_{p(s)}$ = Type S pitot tube coefficient

$C_{p(std)}$ = Standard pitot tube coefficient; use 0.99 if the coefficient is unknown and the tube is designed according to the criteria of Sections 2.7.1 to 2.7.5 of this method.

Δp_{std} = Velocity head measured by the standard pitot tube, cm H_2O (in. H_2O)

Δp_s = Velocity head measured by the Type S pitot tube, cm H_2O (in H_2O)

4.1.4.2 Calculate $\overline{C_p}$ (side A), the mean A-side coefficient, and $\overline{C_p}$ (side B), the mean B-side coefficient; calculate the difference between these two average values.

[4.1.4.2 amended by 52 FR 34639, September 14, 1987; corrected by 52 FR 42061, November 2, 1987]

4.1.4.3 Calculate the deviation of each of the three A-side values of $C_{p(s)}$ from $\overline{C_p}$ (side A), and the deviation of each B-side value of $C_{p(s)}$ from $\overline{C_p}$ (side B). Use the following equation:

$$\text{Deviation} = C_{p(s)} - \overline{C_p}(\text{A or B})$$

Equation 2-3

[4.1.4.3 amended by 52 FR 34639, September 14, 1987; corrected by 52 FR 42061, November 2, 1987]

4.1.4.4 Calculate σ, the average deviation from the mean, for both the A and B sides of the pitot tube. Use the following equation:

$$\sigma\,(\text{side A or B}) = \frac{\sum_{1}^{3} |C_{p(s)} - \overline{C_p}(A \text{ or } B)|}{3}$$

Equation 2-4

[4.1.4.4 amended by 52 FR 34639, September 14, 1987]

4.1.4.5 Use the Type S pitot tube only if the values of σ (side A) and σ (side B) are less than or equal to 0.01 and if the absolute value of the difference between $\overline{C_p}$ (A) and $\overline{C_p}$ (B) is 0.01 or less.

[4.1.4.5 amended by 52 FR 34639, September 14, 1987; corrected by 52 FR 42061, November 2, 1987]

4.1.5 Special considerations.

4.1.5.1 Selection of calibration point.

4.1.5.1.1 When an isolated Type S pitot tube is calibrated, select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The Type S pitot coefficients so obtained, i.e., $\overline{C_p}$ (side A) and $\overline{C_p}$ (side B), will be valid, so long as either: (1) the isolated pitot tube is used; or (2) the pitot tube is used with other components (nozzle, thermocouple, sample probe) in an arrangement that is free from aerodynamic interference effects (see Figures 2-6 through 2-8).

[4.1.5.1.1 amended by 52 FR 34639, September 14, 1987; corrected by 52 FR 42061, November 2, 1987]

4.1.5.1.2 For Type S pitot tube-thermocouple combinations (without sample probe), select a calibration point at or near the center of the duct, and follow the procedures outlined in Sections 4.1.3 and 4.1.4 above. The coefficients so obtained will be valid so long as the pitot tube-thermocouple combination is used by itself or with other components in an interference-free arrangement (Figures 2-6, and 2-8).

4.1.5.1.3 For assemblies with sample probes, the calibration point should be located at or near the center of the duct; however, insertion of a probe sheath into a small duct may cause significant cross-sectional area blockage and yield incorrect coefficient values (Citation 9 in Section 6). Therefore, to minimize the blockage effect, the calibration point may be a few inches off-center if necessary. The actual blockage effect will be negligible when the theoretical blockage, as determined by a projected-area model of the probe sheath, is 2 percent or less of the duct cross-sectional area for assemblies without external sheaths (Figure 2-10a), and 3 percent or less for assemblies with external sheaths (Figure 2-10b).

4.1.5.2 For those probe assemblies in which pitot tube-nozzle interference is a factor (i.e., those in which the pitot-nozzle separation distance fails to meet the specification illustrated in Figure 2-6a), the value of $C_{p(s)}$ depends upon the amount of free-space between the tube and nozzle, and therefore is a function of nozzle size. In these instances, separate calibrations shall be performed with each of the commonly used nozzle sizes in place. Note that the single-velocity calibration technique is acceptable for this purpose, even though the larger nozzle sizes (>0.635 cm or ¼ in.) are not ordinarily used for isokinetic sampling at velocities around 915 m/min (3,000 ft/min), which is the calibration velocity; note also that it is not necessary to draw an isokinetic sample during calibration (see Citation 19 in Section 6).

4.1.5.3 For a probe assembly constructed such that its pitot tube is always used in the same orientation, only one side of the pitot tube need be calibrated (the side which will face the flow). The pitot tube must still meet the alignment specifications of Figure 2-2 or 2-3, however, and must have an average deviation (σ) value of 0.01 or less (see Section 4.1.4.4).

[4.1.5.3 amended by 52 FR 34639, September 14, 1987]

[Appendix A, Method 2]

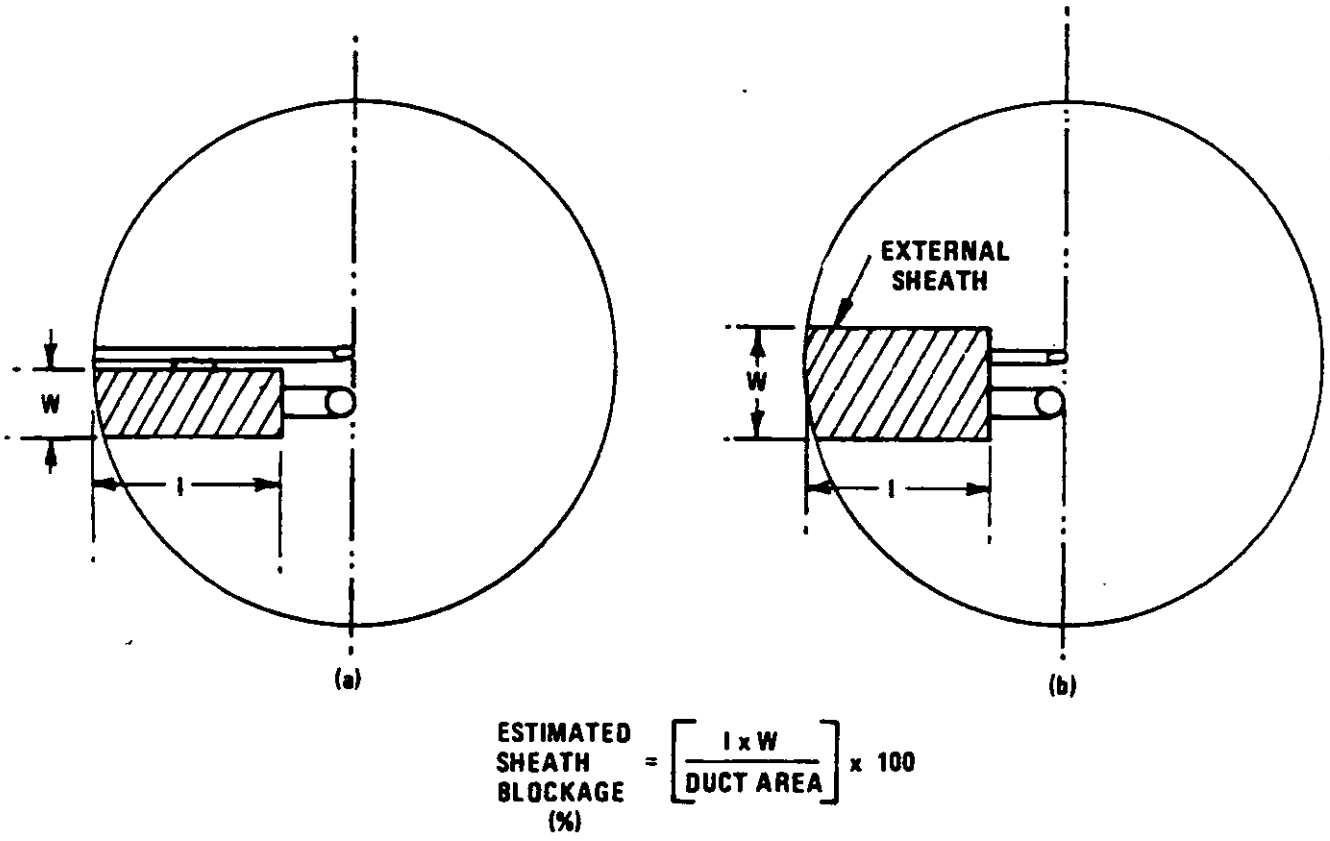


Figure 2-10. Projected-area models for typical pitot tube assemblies.

4.1.6 Field Use and Recalibration.

4.1.6.1 Field Use.

4.1.6.1.1 When a Type S pitot tube (isolated tube or assembly) is used in the field, the appropriate coefficient value (whether assigned or obtained by calibration) shall be used to perform velocity calculations. For calibrated Type S pitot tubes, the A side coefficient shall be used when the A side of the tube faces the flow, and the B side coefficient shall be used when the B side faces the flow; alternatively, the arithmetic average of the A and B side coefficient values may be used, irrespective of which side faces the flow.

4.1.6.1.2 When a probe assembly is used to sample a small duct (12 to 36 in. in diameter), the probe sheath sometimes blocks a significant part of the duct cross-section, causing a reduction in the effective value of $C_{p(s)}$. Consult Citation 9 in Section 6 for details. Conventional pitot-sampling probe assemblies are not recommended for use in ducts having inside diameters smaller than 12 inches (Citation 16 in Section 6).

4.1.6.2 Recalibration.

4.1.6.2.1 Isolated Pitot Tubes. After each field use, the pitot tube shall be carefully reexamined in top, side, and end views. If the pitot face openings are still aligned within the specifications illustrated in Figure 2-2 or 2-3, it can be assumed that the baseline coefficient of the pitot tube has not changed. If, however, the tube has been damaged to the extent that it no longer meets the specifications of Figure 2-2 or 2-3, the damage shall either be repaired to restore proper alignment of the face openings or the tube shall be discarded.

4.1.6.2.2 Pitot Tube Assemblies. After each field use, check the face opening alignment of the pitot tube, as in Section 4.1.6.2.1; also, remeasure the intercomponent spacings of the assembly. If the intercomponent spacings have not changed and the face opening alignment is acceptable, it can be assumed that the coefficient of the assembly has not changed. If the face opening alignment is no longer within the specifications of Figures 2-2 or 2-3, either repair the damage or replace the pitot tube (calibrating the new assembly, if necessary). If the intercomponent spacings have changed, restore the original spacings or recalibrate the assembly.

4.2 Standard pitot tube (if applicable). If a standard pitot tube is used for the velocity traverse, the tube shall be constructed according to the criteria of Section 2.7 and shall be assigned a baseline coefficient value of 0.99. If the standard pitot tube is used as part of an assembly, the tube shall be in an interference-free arrangement (subject to the approval of the Administrator).

4.3 Temperature Gauges. After each field use, calibrate dial thermometers, liquid-filled bulb thermometers, thermocouple-potentiometer systems, and other gauges at a temperature within 10 percent of the average absolute stack temperature. For temperatures up to 405° C (761° F), use an ASTM mercury-in-glass reference thermometer, or equivalent, as a reference; alternatively, either a reference thermocouple and potentiometer (calibrated by NBS) or

[Appendix A, Method 2]

thermometric fixed points, e.g., ice bath and boiling water (corrected for barometric pressure) may be used. For temperatures above 405° C (761° F), use an NBS-calibrated reference thermocouple-potentiometer system or an alternate reference, subject to the approval of the Administrator.

If, during calibration, the absolute temperatures measured with the gauge being calibrated and the reference gauge agree within 1.5 percent, the temperature data taken in the field shall be considered valid. Otherwise, the pollutant emission test shall either be considered invalid or adjustments (if appropriate) of the test results shall be made, subject to the approval of the Administrator.

4.4 Barometer. Calibrate the barometer used against a mercury barometer.

5. *Calculations*

Carry out calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

5.1 Nomenclature.

A = Cross-sectional area of stack, m^2 (ft^2).

B_{ws} = Water vapor in the gas stream (from Method 5 or Reference Method 4), proportion by volume.

C_p = Pitot tube coefficient, dimensionless.

K_p = Pitot tube constant,

$$34.97 \frac{m}{sec}\left[\frac{(g/g\text{-mole})(mm\ Hg)}{(°K)(mm\ H_2O)}\right]^{1/2}$$

for the metric system and

$$85.49 \frac{ft}{sec}\left[\frac{(lb/lb\text{-mole})(in.\ Hg)}{(°R)(in.\ H_2O)}\right]^{1/2}$$

for the English system.

M_d = Molecular weight of stack gas, dry basis (see Section 3.6) g/g-mole (lb/lb-mole).

M_s = Molecular weight of stack gas, wet basis, g/g-mole (lb/lb-mole).

$= M_d(1 - B_{ws}) + 18.0\ B_{ws}$

Eq. 2-5

P_{bar} = Barometric pressure at measurement site, mm Hg (in. Hg).

P_g = Stack static pressure, mm Hg (in. Hg).

P_s = Absolute stack gas pressure, mm Hg (in. Hg).

$= P_{bar} + P_g$

Equation 2-6

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

Q_{sd} = Dry volumetric stack gas flow rate corrected to standard conditions, dscm/hr (dscf/hr).

t_s = Stack temperature, °C (°F).

T_s = Absolute stack temperature, °K, (°R).

$= 273 + t_s$ for metric

Equation 2-7

$= 460 + t_s$ for English

Equation 2-8

T_{std} = Standard absolute temperature, 293 °K (528° R)

v_s = Average stack gas velocity, m/sec (ft/sec).

Δ_p = Velocity head of stack gas, mm H_2O (in. H_2O).

3,600 = Conversion factor, sec/hr.

18.0 = Molecular weight of water, g/g-mole (lb/lb-mole).

5.2 Average stack gas velocity.

$$v_s = K_p C_p (\sqrt{\Delta p})_{avg} \sqrt{\frac{T_{s(avg)}}{P_s M_s}}$$

Equation 2-9

5.3 Average stack gas dry volumetric flow rate.

$$Q_{sd} = 3{,}600(1 - B_{ws}) v_s A \frac{T_{std}}{T_{s\ (avg)}} \frac{P_s}{P_{std}}$$

Equation 2-10

To convert Q_{sd} from dscm/hr (dscf/hr) to dscm/min (dscf/min), divide Q_{sd} by 60.

[5.3 amended by 52 FR 34639, September 14, 1987]

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Method 2A—Direct Measurement of Gas Volume Through Pipes and Small Ducts

1. *Applicability and Principle.*

1.1 Applicability. This method applies to the measurement of gas flow rates in pipes and small ducts, either in-line or at exhaust positions, within the temperature range of 0 to 50°C.

[Appendix A, Method 2A]

1.2 Principle. A gas volume meter is used to measure gas volume directly. Temperature and pressure measurements are made to correct the volume to standard conditions.

2. *Apparatus.*

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

2.1 Gas Volume Meter. A positive displacement meter, turbine meter, or other direct volume measuring device capable of measuring volume to within 2 percent. The meter shall be equipped with a temperature gauge (± 2percent of the minimum absolute temperature) and a pressure gauge (±2.5 mm Hg). The manufacturer's recommended capacity of the meter shall be sufficient for the expected maximum and minimum flow rates at the sampling conditions. Temperature, pressure, corrosive characteristics, and pipe size are factors necessary to consider in choosing a suitable gas meter.

[2.1 amended by 52 FR 34639, September 14, 1987]

2.2 Barometer. A mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested, and an adjustment for elevation differences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm Hg per 30-meter elevation increase, or vice-versa for elevation decrease.

2.3 Stopwatch. Capable of measurement to within 1 second.

3. *Procedure.*

3.1 Installation. As there are numerous types of pipes and small ducts that may be subject to volume measurement, it would be difficult to describe all possible installation schemes. In general, flange fittings should be used for all connections wherever possible. Gaskets or other seal materials should be used to assure leak-tight connections. The volume meter should be located so as to avoid severe vibrations and other factors that may affect the meter calibration.

3.2 Leak Test. A volume meter installed at a location under positive pressure may be leak-checked at the meter connections by using a liquid leak detector solution containing a surfactant. Apply a small amount of the solution to the connections. If a leak exists, bubbles will form, and the leak must be corrected.

A volume meter installed at a location under negative pressure is very difficult to test for leaks without blocking flow at the inlet of the line and watching for meter movement. If this procedure is not possible, visually check all connections and assure tight seals.

3.3 Volume Measurement.

3.3.1 For sources with continuous, steady emission flow rates, record the initial meter volume reading, meter temperature(s), meter pressure, and start the stopwatch. Throughout the test period, record the meter temperature(s) and pressure so that average values can be determined. At the end of the test, stop the timer and record the elapsed time, the final volume reading, meter temperature(s), and pressure. Record the barometric pressure at the beginning and end of the test run. Record the data on a table similar to Figure 2A-1.

[Appendix A, Method 2A]

Plant _____

Date _____ Run Number _____

Sample Location _____

Barometric Pressure mm Hg Start _____ Finish _____

Operators _____

Meter Number _____ Meter Calibration Coefficient _____

Last Date Calibrated _____

Time	Volume	Static pressure	Temperature	
Run/clock	Meter reading	mm Hg	°C	°K
Average				

Figure 2A-1. Volume flow rate measurement data.

[Appendix A, Method 2A]

3.3.2 For sources with noncontinuous, non-steady emission flow rates, use the procedure in 3.3.1 with the addition of the following: Record all the meter parameters and the start and stop times corresponding to each process cyclical or noncontinuous event.

4. *Calibration.*

4.1 Volume Meter. The volume meter is calibrated against a standard reference meter prior to its initial use in the field. The reference meter is a spirometer or liquid displacement meter with a capacity consistent with that of the test meter.

Alternately, a calibrated, standard pitot may be used as the reference meter in conjunction with a wind tunnel assembly. Attach the test meter to the wind tunnel so that the total flow passes through the test meter. For each calibration run, conduct a 4-point traverse along one stack diameter at a position at least eight diameters of straight tunnel downstream and two diameters upstream of any bend, inlet, or air mover. Determine the traverse point locations as specified in Method 1. Calculate the reference volume using the velocity values following the procedure in Method 2, the wind tunnel cross-sectional area, and the run time.

Set up the test meter in a configuration similar to that used in the field installation (i.e., in relation to the flow moving device). Connect the temperature and pressure gauges as they are to be used in the field. Conncet the reference meter at the inlet of the flow line, if appropriate for the meter, and begin gas flow through the system to condition the meters. During this conditioning operation, check the system for leaks.

The calibration shall be run over at least three different flow rates. The calibration flow rates shall be about 0.3, 0.6, and 0.9 times the test meter's rated maximum flow rate.

For each calibration run, the data to be collected include: reference meter initial and final volume readings, the test meter initial and final volume reading, meter average temperature and pressure, barometric pressure, and run time. Repeat the runs at each flow rate at least three times.

Calculate the test meter calibration coefficient, Y_m, for each run as follows:

$$Y_m = \frac{(V_f - V_i)(t_r + 273)}{(V_{mf} - V_{mi})(t_m + 273)} \cdot \frac{P_b}{(P_b + P_g)}$$

Eq. 2A-1

Where:

Y_m = Test volume meter calibration coefficient, dimensionless.

V_r = Reference meter volume reading, m^3.

V_m = Test meter volume reading, m^3.

t_r = Reference meter average temperature, °C.

t_m = Test meter average temperature, °C.

P_b = Barometric pressure, mm Hg.

P_g = Test meter average static pressure, mm Hg.

f = Final reading for run.

i = Initial reading for run.

Compare the three Y_m values at each of the flow rates tested and determine the maximum and minimum values. The difference between the maximum and minimum values at each flow rate should be no greater than 0.030. Extra runs may be required to complete this requirement. If this specification cannot be met in six successive runs, the test meter it not suitable for use. In addition, the meter coefficients should be between 0.95 and 1.05. If these specifications are met at all the flow rates, average all the Y_m values from runs meeting the specifications to obtain an average meter calibration coefficient, Y_m.

The procedure above shall be performed at least once for each volume meter. Thereafter, an abbreviated calibration check shall be completed following each field test. The calibration of the volume meter shall be checked by performing three calibration runs at a single, intermediate flow rate (based on the previous field test) with the meter pressure set at the average value encountered in the field test. Calculate the average value of the calibration factor. If the calibration has changed by more than 5 percent, recalibrate the meter over the full range of flow as described above.

NOTE.—If the volume meter calibration coefficient values obtained before and after a test series differ by more than 5 percent, the test series shall either be voided, or calculations for the test series shall be performed using whichever meter coefficient value (i.e., before or after) gives the greater value of pollutant emission rate.

4.2 Temperature Gauge. After each test series, check the temperature gauge at ambient temperature. Use an American Society for Testing and Materials (ASTM) mercury-in-glass reference thermometer, or equivalent, as a reference. If the gauge being checked agrees within 2 percent (absolute temperature) of the reference, the temperature data collected in the field shall be considered valid. Otherwise, the test data shall be considered invalid or adjustments of the test results shall be made, subject to the approval of the Administrator.

4.3 Barometer. Calibrate the barometer used against a mercury barometer prior to the field test.

5. *Calculations.*

Carry out the calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation.

5.1 Nomenclature

P_b = Barometric pressure, mm Hg.

P_g = Average static pressure in volume meter, mm Hg.

Q_s = Gas flow rate, m^3/min, standard conditions.

T_m = Average absolute meter temperature, °K.

V_m = Meter volume reading, m^3.

Y_m = Average meter calibration coefficient, dimensionless.

f = Final reading for test period.

i = Initial reading for test period.

s = Standard conditions, 20° C and 760 mm Hg.

θ = Elapsed test period time, min.

5.2 Volume.

$$V_{ms} = 0.3853\ Y_m\ (V_{mf} - V_{mi}) \frac{(P_b + P_g)}{T_m}$$

Eq. 2A-2

5.3 Gas Flow Rate.

$$Q_s = \frac{V_{ms}}{\theta}$$

Eq. 2A-3

6. *Bibliography.*

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METHOD 2B—DETERMINATION OF EXHAUST GAS VOLUME FLOW RATE FROM GASOLINE VAPOR INCINERATORS

1. *Applicability and principle*

1.1 Applicability. This method applies to the measurement of exhaust volume flow rate from incinerators that process gasoline vapors consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons). It is assumed that the amount of auxiliary fuel is negligible.

1.2 Principle. The incinerator exhaust flow rate is determined by carbon balance. Organic carbon concentration and volume flow rate are measured at the incinerator inlet. Organic carbon, carbon dioxide (CO_2), and carbon monoxide (CO) concentrations are measured at the outlet. Then the ratio of total carbon at the incinerator inlet and outlet is multiplied by the inlet volume to determine the exhaust volume and volume flow rate.

2. *Apparatus.*

2.1 Volume Meter. Equipment described in Method 2A.

2.2 Organic Analyzers (2). Equipment described in Method 25A or 25B.

2.3 CO Analyzer. Equipment described in Method 10.

[Appendix A, Method 2B]

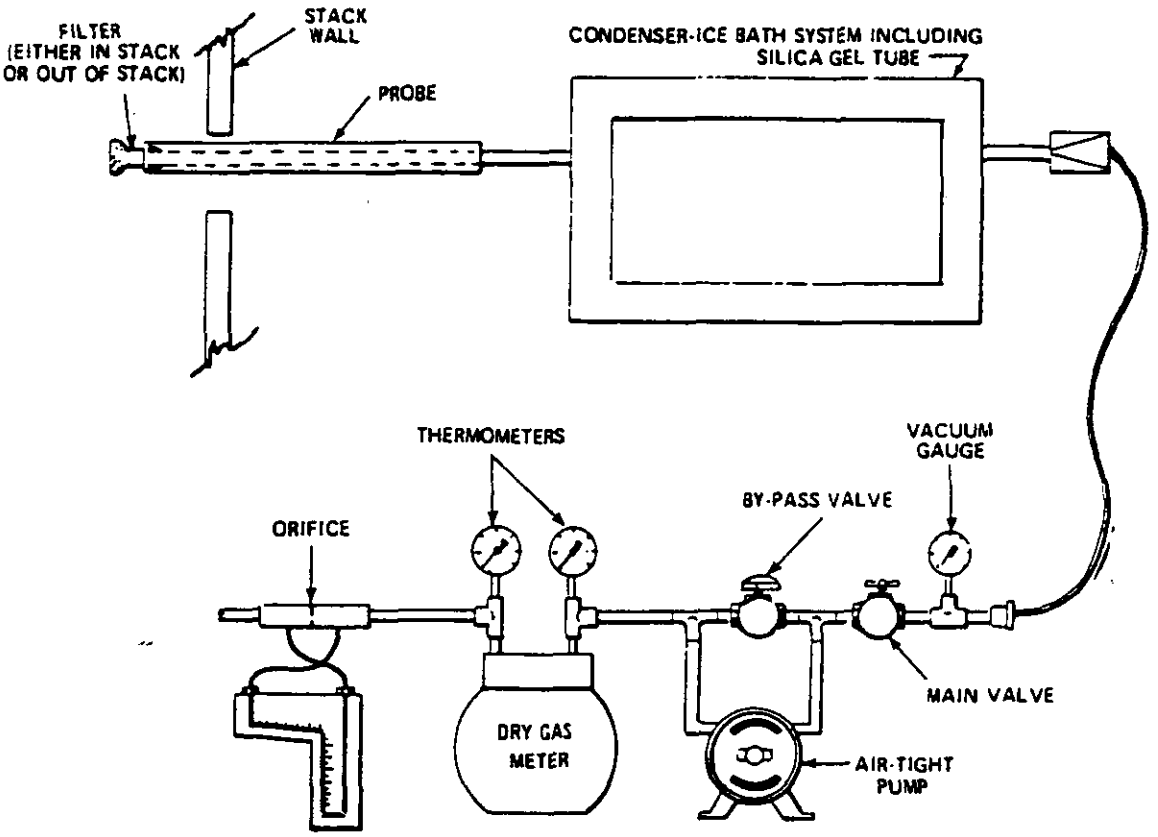

Figure 4-1. Moisture sampling train-reference method.

2.1.1 Probe. The probe is constructed of stainless steel or glass tubing, sufficiently heated to prevent water condensation, and is equipped with a filter, either in-stack (e.g., a plug of glass wool inserted into the end of the probe) or heated out-stack (e.g., as described in Method 5), to remove particular matter.

When stack conditions permit, other metals or plastic tubing may be used for the probe, subject to the approval of the Administrator.

2.1.2 Condenser. The condenser consists of four impingers connected in series with ground glass, leak-free fittings or any similarly leak-free non-contaminating fittings. The first, third, and fourth impingers shall be of the Greenburg-Smith design, modified by replacing the tip with a 1.3 centimeter (½ inch) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. The second impinger shall be of the Greenburg-Smith design with the standard tip. Modifications (e.g., using flexible connections between the impingers, using materials other than glass, or using flexible vacuum lines to connect the filter holder to the condenser) may be used, subject to the approval of the Administrator.

The first two impingers shall contain known volumes of water, the third shall be empty, and the fourth shall contain a known weight of 6- to 16-mesh indicating type silica gel, or equivalent desiccant. If the silica gel has been previously used, dry at 175° C (350° F) for 2 hours. New silica gel may be used as received. A thermometer, capable of measuring temperature to within 1° C (2° F), shall be placed at the outlet of the fourth impinger, for monitoring purposes.

Alternatively, any system may be used (subject to the approval of the Administrator) that cools the sample gas stream and allows measurement of both the water that has been condensed and the moisture leaving the condenser, each to within 1 ml or 1 g. Acceptable means are to measure the condensed water, either gravimetrically or volumetrically, and to measure the moisture leaving the condenser by: (1) monitoring the temperature and pressure at the exit of the condenser and using Dalton's law of partial pressures, or (2) passing the sample gas stream through a tared silica gel (or equivalent desiccant) trap, with exit gases kept below 20° C (68° F), and determining the weight gain.

If means other than silica gel are used to determine the amount of moisture leaving the condenser, it is recommended that silica gel (or equivalent) still be used between the condenser system and pump, to prevent moisture condensation in the pump and metering devices and to avoid the need to make corrections for moisture in the metered volume.

2.1.3 Cooling System. An ice bath container and crushed ice (or equivalent) are used to aid in condensing moisture.

2.1.4 Metering System. This system includes a vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 3° C (5.4° F), dry gas meter capable of measuring volume to within 2 percent, and related equipment as shown in Figure 4-1. Other metering systems, capable of maintaining a constant sampling rate and determining sample gas volume, may be used, subject to the approval of the Administrator.

2.1.5 Barometer. Mercury, aneroid, or other barometer capable of measuring atmospheric pressure to within 2.5 mm Hg (0.1 in. Hg) may be used. In many cases, the barometric reading may be obtained from a nearby national weather service station, in which case the station value (which is the absolute barometric pressure) shall be requested and an adjustment for elevation dif-

[Appendix A, Method 4]

2.4 CO_2 Analyzer. A nondispersive infrared (NDIR) CO_2 analyzer and supporting equipment with comparable specifications as CO analyzer described in Method 10.

3. *Procedure.*

3.1 Inlet Installation. Install a volume meter in the vapor line to incinerator inlet according to the procedure in Method 2A. At the volume meter inlet, install a sample probe as described in Method 25A. Connect to the probe a leak-tight, heated (if necessary to prevent condensation) sample line (stainless steel or equivalent) and an organic analyzer system as described in Method 25A or 25B.

3.2 Exhaust Installation. Three sample analyzers are required for the incinerator exhaust: CO_2, CO, and organic analyzers. A sample manifold with a single sample probe may be used. Install a sample probe as described Method 25A. Connect a leak-tight heated sample line to the sample probe. Heat the sample line sufficiently to prevent any condensation.

3.3 Recording Requirements. The output of each analyzer must be permanently recorded on an analog strip chart, digital recorder, or other recording device. The chart speed or number of readings per time unit must be similar for all analyzers so that data can be correlated. The minimum data recording requirement for each analyzer is one measurement value per minute.

3.4 Preparation. Prepare and calibrate all equipment and analyzers according to the procedures in the respective methods. For the CO_2 analyzer, follow the procedures described in Method 10 for CO analysis substituting CO_2 calibration gas where the method calls for CO calibration gas. The span value for the CO_2 analyzer shall be 15 percent by volume. All calibration gases must be introduced at the connection between the probe and the sample line. If a manifold system is used for the exhaust analyzers, all the analyzers and sample pumps must be operating when the calibrations are done. Note: For the purposes of this test, methane should not be used as an organic calibration gas.

3.5 Sampling. At the beginning of the test period, record the initial parameters for the inlet volume meter according to the procedures in Method 2A and mark all of the recorder strip charts to indicate the start of the test. Continue recording inlet organic and exhaust CO_2, CO, and organic concentrations throughout the test. During periods of process interruption and halting of gas flow, stop the timer and mark the recorder strip charts so that data from this interruption are not included in the calculations. At the end of the test period, record the final parameters for the inlet volume meter and mark the end on all of the recorder strip charts.

3.6 Post Test Calibrations. At the conclusion of the sampling period, introduce the calibration gases as specified in the respective reference methods. If an analyzer output does not meet the specifications of the method, invalidate the test data for the period. Alternatively, calculate the volume results using initial calibration data and using final calibration data and report both resulting volumes. Then, for emissions calculations, use the volume measurement resulting in the greatest emission rate or concentration.

4. *Calculations.*

Carry out the calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after the final calculation.

4.1 Nomenclature.

CO_c = Mean carbon monoxide concentration in system exhaust, ppmv.

CO_{2c} = Mean carbon dioxide concentration in system exhaust, ppmv.

HC_c = Mean organic concentration in system exhaust as defined by the calibration gas, ppmv.

HC_i = Mean organic concentration in system inlet as defined by the calibration gas, ppmv.

K = Calibration gas factor
- = 2 for ethane calibration gas.
- = 3 for propane calibration gas.
- = 4 for butane calibration gas.
- = Appropriate response factor for other calibration gas.

V_m = Exhaust gas volume, M^3.

V_s = Inlet gas volume, M^3.

Q_{cs} = Exhaust gas volume flow rate, m^3/min.

Q_s = Inlet gas volume flow rate, m^3/min.

θ = Sample run time, min.

s = Standard Conditions: 20°C, 760 mm Hg.

300 = Estimated concentration of ambient CO_2, ppmv. (CO_2 concentration in the ambient air may be measured during the test period using an NDIR).

4.2 Concentrations. Determine mean concentrations of inlet organics, outlet CO_2, outlet CO, and outlet organics according to the procedures in the respective methods and the analyzers' calibration curves, and for the time intervals specified in the applicable regulations. Concentrations should be determined on a parts per million by volume (ppmv) basis.

4.3 Exhaust Gas Volume. Calculate the exhaust gas volume as follows:

$$V_m = V_s \frac{K(HC_i)}{K(HC_c)+CO_{2c}+CO_c-300}$$

Eq. 2B-1

4.4 Exhaust Gas Volume Flow Rate. Calculate the exhaust gas volume flow rate as follows:

$$Q_{cs} V_{cs}/\theta$$

Eq. 2B-2

[4.4 Eq. 2 B-2 amended by 52 FR 34639, September 14, 1987]

5. *Bibliography.*

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Method 2C—Determination of Stack Gas Velocity and Volumetric Flow Rate in Small Stacks or Ducts (Standard Pitot Tube)

[Added by 54 FR 12622, March 28, 1989]

1. Applicability and Principle

1.1 Applicability.

1.1.1 The applicability of this method is identical to Method 2, except this method is limited to stationery source stacks or ducts less than about 0.30 meter (12 in.) in diameter or 0.071 m^2 (113 $in.^2$) in cross-sectional area, but equal to or greater than about 0.10 meter (4 in.) in diameter or 0.0081 m^2 (12.57 $in.^2$) in cross-sectional area.

1.1.2 The apparatus, procedure, calibration, calculations, and bibliography are the same as in Method 2, Sections 2, 3, 4, 5, and 6, except as noted in the following sections.

1.2 Principle. The average gas velocity in a stack or duct is determined from the gas density and from measurement of velocity heads with a standard pitot tube.

2. Apparatus

2.1 Standard Pitot Tube (instead of Type S). Use a standard pitot tube that meets the specifications of Section 2.7 of Method 2. Use a coefficient value of 0.99 unless it is calibrated against another standard pitot tube with an NBS-traceable coefficient.

2.2 Alternative Pitot Tube. A modified hemispherical-nosed pitot tube (see Figure 2C-1), which features a shortened stem and enlarged impact and static pressure holes, may be used. This pitot tube is useful in liquid drop-laden gas streams when a pitot "back purge" is ineffective. Use a coefficient value of 0.99 unless the pitot is calibrated as mentioned in Section 2.1 above.

[Appendix A, Method 2C]

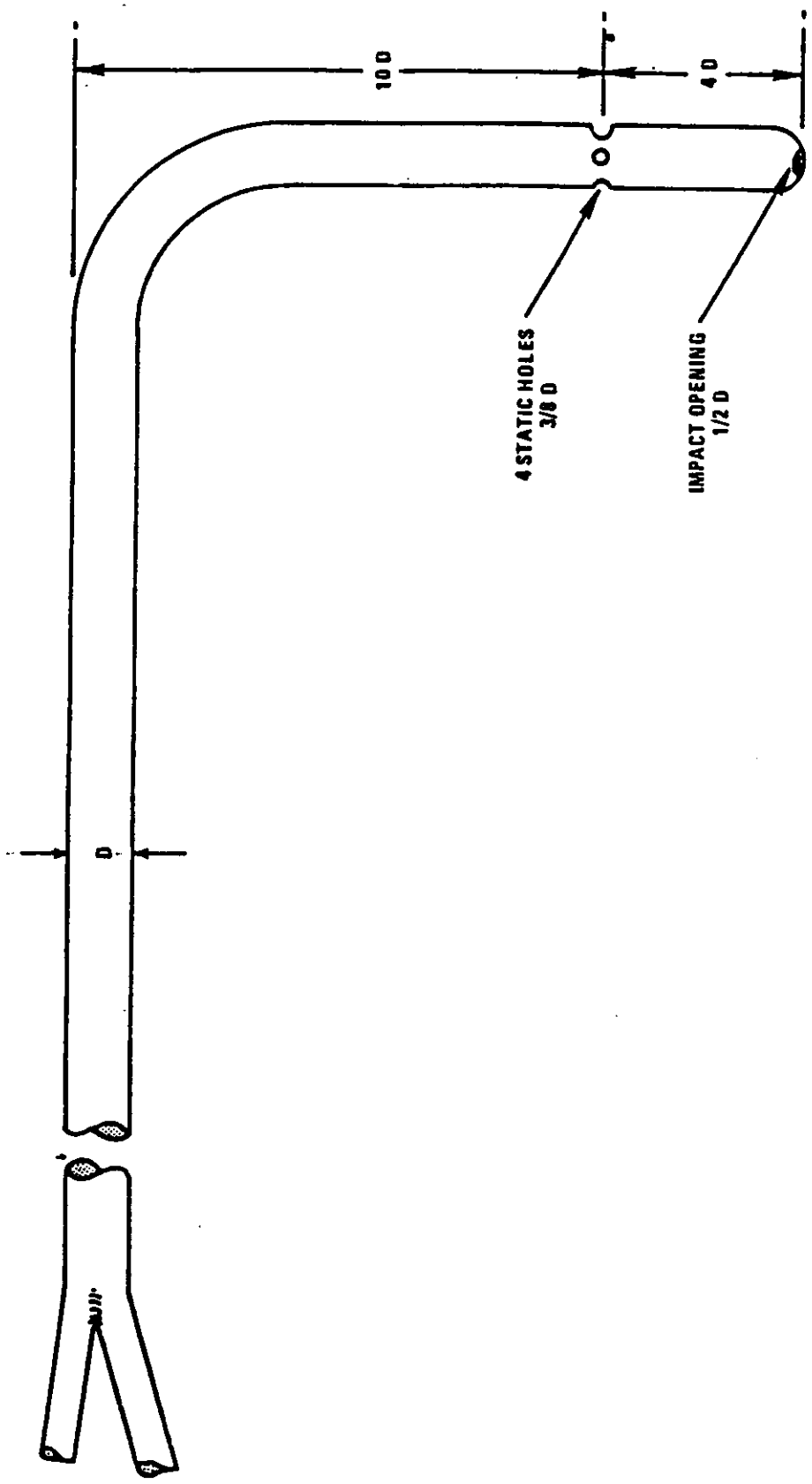

Figure 2C-1. Modified hemispherical-nosed pitot tube.

[Appendix A, Method 2C]

3. Procedure

Follow the general procedures in Section 3 of Method 2, except conduct the measurements at the traverse points specified in Method 1A. The static and impact pressure holes of standard pitot tubes are susceptible to plugging in PM-laden gas streams. Therefore, the tester must furnish adequate proof that the openings of the pitot tube have not plugged during the traverse period; this proof can be obained by first recording the velocity head (Δp) reading at the final traverse point, then cleaning out the impact and static holes of the standard pitot tube by "back-purging" with pressurized air, and finally by recording another Δp reading at the final traverse point. If the Δp reading made after the air purge is within 5 percent of the reading during the traverse, then the traverse is acceptable. Otherwise, reject the run. Note that if the Δp at the final traverse point is so low as to make this determination too difficult, then another traverse point may be selected. If "back purging" at regular intervals is part of the procedure, then take comparative Δp readings, as above, for the last two back purges at which suitable high Δp readings are observed.

Method 2D—Measurement of Gas Volumetric Flow Rates in Small Pipes and Ducts

[Added by 54 FR 12622, March 28, 1989]

1. Applicability and Principle

1.1 Applicability. This method applies to the measurement of gas flow rates in small pipes and ducts, either before or after emission control devices.

1.2 Principle. To measure flow rate or pressure drop, all the stack gas is directed through a rotameter, orifice plate or similar flow rate measuring device. The measuring device has been previously calibrated in a manner that insures its proper calibration for the gas or gas mixture being measured. Absolute temperature and pressure measurements are also made to calculate volumetric flow rates at standard conditions.

2. Apparatus

Specifications for the apparatus are given below. Any other apparatus that has been demonstrated (subject to approval of the Administrator) to be capable of meeting the specifications will be considered acceptable.

2.1 Flow Rate Measuring Device. A rotameter, orifice plate, or other flow rate measuring device capable of measuring all the stack flow rate to within 5 percent of its true value. The measuring device shall be equipped with a temperature gauge accurate to within 2 percent of the minimum absolute stack temperature and a pressure gauge accurate to within 5 mm Hg. The capacity of the measuring device shall be sufficient for the expected maximum and minimum flow rates at the stack gas conditions. The magnitude and variability of stack gas flow rate, molecular weight, temperature, pressure, compressibility, dew point, corrosiveness, and pipe or duct size are all factors to consider in choosing a suitable measuring device.

2.2 Barometer. Same as in Method 2, Section 2.5.

2.3 Stopwatch. Capable of incremental time measurement to within 1 second.

3. Procedure

3.1 Installation. Use the procedure in Method 2A, Section 3.1.

3.2 Leak Check. Use the procedure in Method 2A, Section 3.2.

3.3 Flow Rate Measurement.

3.3.1 Continuous, Steady Flow. At least once an hour, record the measuring device flow rate reading, and the measuring device temperature and pressure. Make a minimum of twelve equally spaced readings of each parameter during the test period. Record the barometric pressure at the beginning and end of the test period. Record the data on a table similar to Figure 2D-1.

Plant_____
Date_____ Run number_____
Sample location_____
Barometric pressure, mm (in.) Hg
Start_____ Finish_____
Operators _____
Measuring device number_____
Calibration coefficient_____
Calibration gas_____
Last date calibrated_____

Time	Flow rate reading	Static pressure mm (in.) Hg	Temperature	
			°C (°F)	°K (°R)
	Average			

Figure 2D-1. Flow rate measurement data.

3.3.2 Noncontinuous and Nonsteady Flows. Use flow rate measuring devices with particular caution. Calibration will be affected by variation in stack gas temperature, pressure, compressibility, and molecular weight. Use the procedure in Section 3.3.1. Record all the measuring device parameters on a time interval frequency sufficient to adequately profile each process cyclical or noncontinuous event. A multichannel continuous recorder may be used.

4. Calibration

4.1 Flow Rate Measuring Device. Use the procedure in Method 2A, Section 4, and apply the same performance standards. Calibrate the measuring device with the principal stack gas to be measured (e.g., air, nitrogen) against a standard reference meter. A calibrated dry gas meter is an acceptable reference meter. Ideally, calibrate the measuring device in the field with the actual gas to be measured. For measuring devices that have a volume rate readout, calculate the measuring device calibration coefficient, Y_m, for each run as follows:

$$Y_m = \frac{(Q_r)\,(T_r)\,P_{bar}}{(Q_m)\,(T_m)\,(P_{bar} + P_s)} \qquad \text{Eq. 2D-1}$$

where:

Q_r = reference meter flow rate reading, m^3/min (ft^3/min).

Q_m = measuring device flow rate reading, m^3/min (ft^3/min).

T_r = reference meter average absolute temperature, °K (°R).

T_m = measuring device average absolute temperature, °K (°R).

P_{bar} = barometric pressure, mm Hg (in. Hg).

P_s = measuring device average static pressure, mm Hg (in. Hg).

For measuring devices that do not have a readout as flow rate, refer to the manufacturer's instructions to calculate the Q_m corresponding to each Q_r.

4.2 Temperature Gauge. Use the procedure and specifications in Method 2A, Section 4.2. Perform the calibration at a temperature that approximates field test conditions.

4.3 Barometer. Calibrate the barometer to be used in the field test with a mercury barometer prior to the field test.

[Appendix A, Method 2D]

5. Gas Flow Rate Calculation

Calculate the stack gas flow rate, Q_s, as follows:

$$Q_s = K_1 Y_m Q_m \frac{(P_{bar} + P_g)}{T_m} \quad \text{Eq. 2D-2}$$

where:

$K_1 = 0.3858$ for international system of units (SI); 17.64 for English units.

6. Bibliography

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Method 3—Gas Analysis for the Determination of Dry Molecular Weight

[Method 3 revised by 55 FR 5212, February 14, 1990]

1. Applicability and Principle

1.1 Applicability.

1.1.1 This method is applicable for determining carbon dioxide (CO_2) and oxygen (O_2) concentrations and dry molecular weight of a sample from a gas stream of a fossil-fuel combustion process. The method may also be applicable to other processes where it has been determined that compounds other than CO_2, O_2, carbon monoxide (CO), and nitrogen (N_2) are not present in concentrations sufficient to affect the results.

1.1.2 Other methods, as well as modifications to the procedure described herein, are also applicable for some or all of the above determinations. Examples of specific methods and modifications include: (1) A multi-point sampling method using an Orsat analyzer to analyze individual grab samples obtained at each point; (2) a method using CO_2 or O_2 and stoichiometric calculations to determine dry molecular weight; and (3) assigning a value of 30.0 for dry molecular weight, in lieu of actual measurements, for processes burning natural gas, coal, or oil. These methods and modifications may be used, but are subject to the approval of the Administrator, U.S. Environmental Protection Agency (EPA).

1.1.3 Note. Mention of trade names or specific products does not constitute endorsements by EPA.

1.2 Principle. A gas sample is extracted from a stack by one of the following methods: (1) Single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for percent CO_2, percent O_2, and if necessary, for percent CO. For dry molecular weight determination, either an Orsat or a Fyrite analyzer may be used for the analysis.

2. Apparatus

As an alternative to the sampling apparatus and systems described herein, other sampling systems [e.g., liquid displacement] may be used, provided such systems are capable of obtaining a representative sample and maintaining a constant sampling rate, and are, otherwise, capable of yielding acceptable results. Use of such systems is subject to the approval of the Administrator.

2.1 Grab Sampling (Figure 3–1).

2.1.1 Probe. Stainless steel or borosilicate glass tubing equipped with an in-stack or out-stack filter to remove particulate matter (a plug of glass wool is satisfactory for this purpose). Any other materials, inert to O_2, CO_2, CO, and N_2 and resistant to temperature at sampling conditions, may be used for the probe. Examples of such materials are aluminum, copper, quartz glass, and Teflon.

2.1.2 Pump. A one-way squeeze bulb, or equivalent, to transport the gas sample to the analyzer.

2.2 Integrated Sampling (Figure 3–2).

2.2.1 Probe. Same as in Section 2.1.1.

2.2.2 Condenser. An air-cooled or water-cooled condenser, or other condenser no greater than 250 ml that will not remove O_2, CO_2, CO, and N_2, to remove excess moisture which would interfere with the operation of the pump and flowmeter.

2.2.3 Valve. A needle valve, to adjust sample gas flow rate.

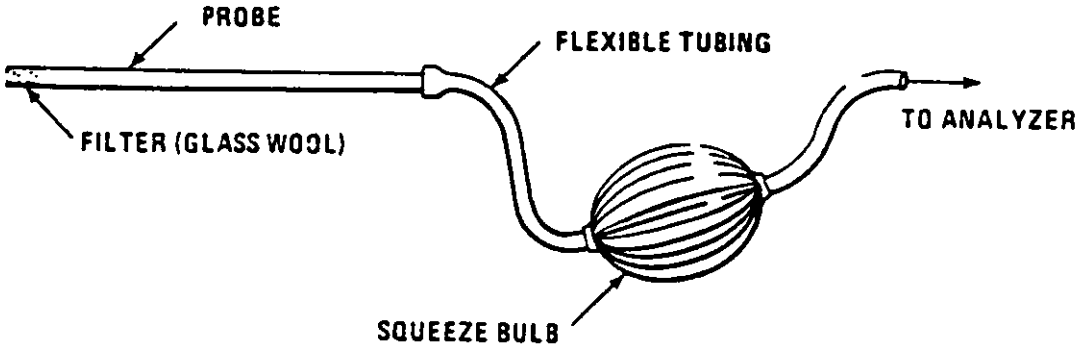

Figure 3-1. Grab-sampling train.

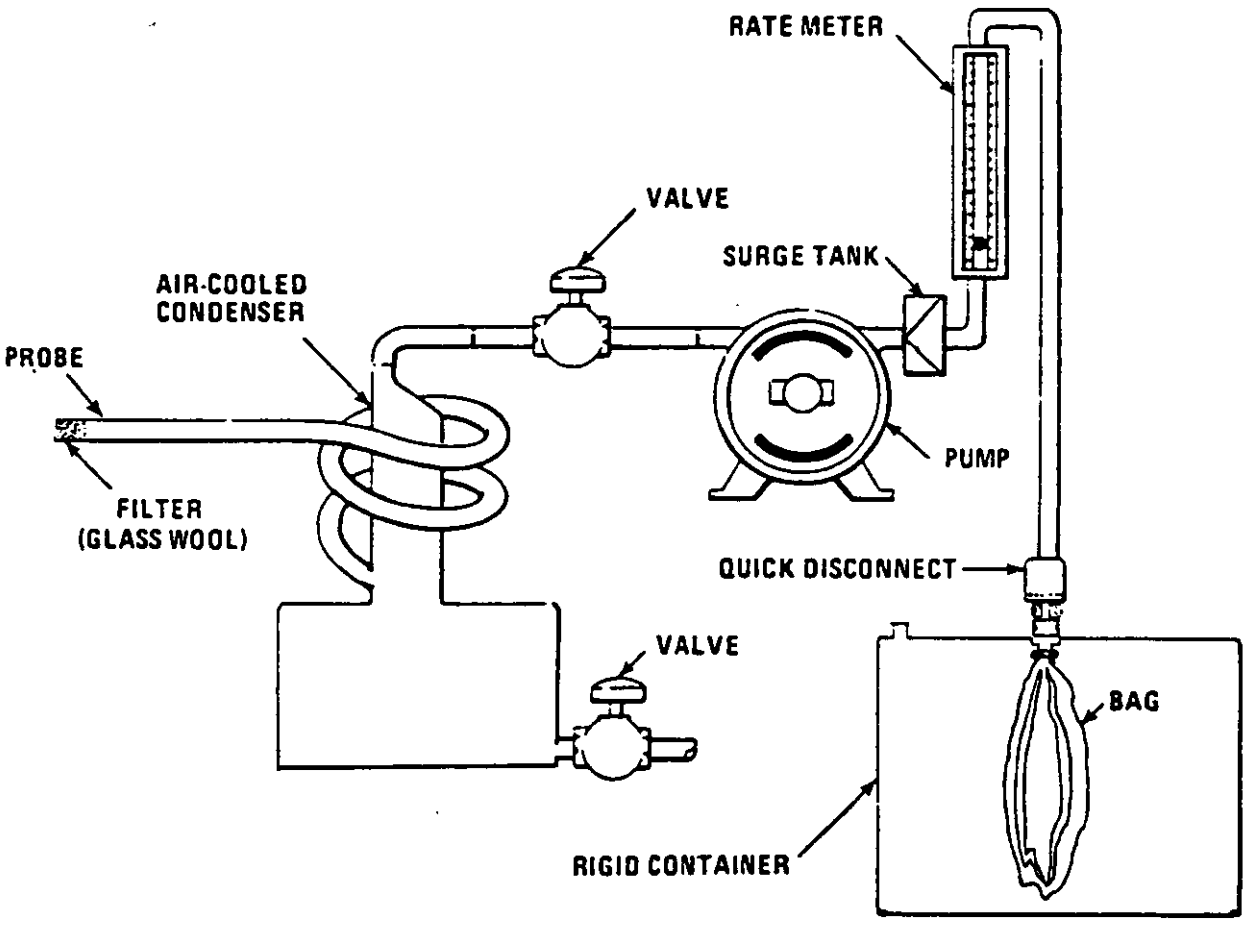

Figure 3-2. Integrated gas-sampling train.

[Appendix A, Method 3]

2.2.4 Pump. A leaf-free, diaphragm-type pump, or equivalent, to transport sample gas to the flexible bag. Install a small surge tank between the pump and rate meter to eliminate the pulsation effect of the diaphragm pump on the rotameter.

2.2.5 Rate Meter. A rotameter, or equivulent rate meter, capable of measuring flow rate to within 2 percent of the selected flow rate. A flow rate range of 500 to 1000 cc/min is suggested.

2.2.6 Flexible Bag. Any leak-free plastic (e.g., Tedlar, Mylar, Teflon) or plastic-coated aluminum (e.g., aluminized Mylar) bag, or equivalent, having a capacity consistent with the selected flow rate and time length of the test run. A capacity in the range of 55 to 90 liters is suggested. To leak check the bag, connect it to a water manometer, and pressurize the bag to 5 to 10 cm H_2O (2 to 4 in. H_2O). Allow to stand for 10 minutes. Any displacement in the water manometer indicates a leak. An alternative leak-check method is to pressurize the bag to 5 to 10 cm (2 to 4 in.) H_2O and allow to stand overnight. A deflated bag indicates a leak.

2.2.7 Pressure Gauge. A water-filled U-tube manometer, or equivalent, of about 30 cm (12 in.), for the flexible bag leak check.

2.2.8 Vacuum Gauge. A mercury manometer, or equivalent, of at least 760 mm (30 in.) Hg, for the sampling train leak check.

2.3 Analysis. An Orsat or Fyrite type combustion gas analyzer. For Orsat and Fyrite analyzer maintenance and operation procedures, follow the instructions recommended by the manufacturer, unless otherwise specified herein.

3. Single-Point, Grab Sampling and Analytical Procedure

3.1 The sampling point in the duct shall either be at the centroid of the cross section or at a point no closer to the walls than 1.00 m (3.3 ft), unless otherwise specified by the Administrator.

3.2 Set up the equipment as shown in Figure 3-1, making sure all connections ahead of the analyzer are tight. If an Orsat analyzer is used, it is recommended that the analyzer be leak checked by following the procedure in Section 6; however, the leak check is optional.

3.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line long enough to allow at least five exchanges. Draw a sample into the analyzer, and immediately analyze it for percent CO_2 and percent O_2. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 7.2.

3.4 Repeat the sampling, analysis, and calculation procedures until the dry molecular weights of any three grab samples differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (0.1 lb/lb-mole).

4. Single-Point, Integrated Sampling and Analytical Procedure

4.1 The sampling point in the duct shall be located as specified in Section 3.1.

4.2 Leak check (optional) the flexible bag as in Section 2.2.6. Set up the equipment as shown in Figure 3-2. Just before sampling, leak check (optional) the train by placing a vacuum gauge at the condenser inlet, pulling a vacuum of at least 250 mm Hg (10 in. Hg), plugging the outlet at the quick disconnect, and then turning off the pump. The vacuum should remain stable for at least 0.5 minute. Evacuate the flexible bag. Connect the probe, and place it in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line. Next, connect the bag, and make sure that all connections are tight.

4.3 Sample at a constant rate. The sampling run should be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collection of at least 30 liters (1.00 ft^3) of sample gas is recommended; however, smaller volumes may be collected, if desired.

4.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. Within 8 hours after the sample is taken, analyze it for percent CO_2 and percent O_2 using either an Orsat analyzer or a Fyrite type combustion gas analyzer. If an Orsat analyzer is used, it is recommended that Orsat leak check described in Section 6, be performed before this determination; however, the check is optional. Determine the percentage of the gas that is N_2 and CO by subtracting the sum of the percent CO_2 and percent O_2 from 100 percent. Calculate the dry molecular weight as indicated in Section 7.2.

4.5 Repeat the analysis and calculation procedures until the individual dry molecular weights for any three analyses differ from their mean by no more than 0.3 g/g-mole (0.3 lb/lb-mole). Average these three molecular weights, and report the results to the nearest 0.1 g/g-mole (0.1 lb/lb-mole).

5. Multi-Point, Integrated Sampling and Analytical Procedure

5.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of 12 traverse points shall be used for all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to approval of the Administrator.

5.2 Follow the procedures outlined in Sections 4.2 through 4.5, except for the following: Traverse all sampling points, and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3.

Time	Traverse pt.	Q, liter/min	% dev.*
Average			

* % dev. = $(Q - Q_{avg})/Q_{avg}$ X 100 (Must be < [10%])

Figure 3-3. Sampling rate data.

6. Leak-Check Procedure for Orsat Analyzer

Moving an Orsat analyzer frequently causes it to leak. Therefore, an Orsat analyzer should be thoroughly leak checked on site before the flue gas sample is introduced into it. The procedure for leak checking an Orsat analyzer is as follows:

6.1 Bring the liquid level in each pipette up to the reference mark on the capillary tubing, and then close the pipette stopcock.

6.2 Raise the leveling bulb sufficiently to bring the confining liquid meniscus onto the graduated portion of the burette, and then close the manifold stopcock.

6.3 Record the menisus position.

6.4 Observe the menisus in the burette and the liquid level in the pipette for movement over the next 4 minutes.

6.5 For the Orsat analyzer to pass the leak check, two conditions must be met:

6.5.1 The liquid level in each pipette must not fall below the botton of the capillary tubing during this 4-minute interval.

6.5.2 The menisus in the burette must not change by more than 0.2 ml during this 4-minute interval.

6.6 If the anlyzer fails the leak-check procedure, check all rubber connections and stopcocks to determine whether they might be the cause of the leak. Disassemble, clean, and regrease leaking stopcocks. Replace leaking rubber connections. After the analyzer is reassembled, repeat the lead-check procedure.

7. Calculations

7.1 Nomenclature

M_d = Dry molecular weight, g/g-mole (1b/1b-mole).

$\%CO_2$ = Percent CO_2 by volume, dry basis.

$\%O_2$ = Percent O_2 by volume, dry basis.

%CO = Percent CO by volume, dry basis.

$\%N_2$ = Percent N_2 by volume, dry basis.

0.280 = Molecular weight of N_2 or CO, divided by 100.

0.320 = Molecular wight of O_2 divided by 100.

[Appendix A, Method 3]

0.440 = Molecular weight of CO_2 divided by 100.

7.2 Dry Molecular Weight. Use Equation 3-1 to calculate the dry molecular weight of the stack gas.

$$M_d = 0.440(\%CO_2) + 0.320(\%O_2) + 0.280(\%N_2 + \%CO) \quad \text{Eq. 3-1}$$

Note. The above equation does not consider argon in air (about 0.9 percent, molecular weight of 39.9). A negative error of about 0.4 percent is introduced. The tester may choose to include argon in the analysis using procedures subject to approval of the Administrator.

8. Bibliography

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Method 3A—Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedure)

[Method 3A added by 51 FR 21165, June 11, 1986]

1. *Applicability and Principle*

1.1 Applicability. This method is applicable to the determination of oxygen (O_2) and carbon dioxide (CO_2) concentrations in emissions from stationary sources only when specified within the regulations.

1.2 Principle. A sample is continuously extracted from the effluent stream; a portion of the sample stream is conveyed to an instrumental analyzer(s) for determination of O_2 and CO_2 concentration(s). Performance specifications and test procedures are provided to ensure reliable data.

2. *Range and Sensitivity*

Same as Method 6C, Sections 2.1 and 2.2, except that the span of the monitoring system shall be selected such that the average O_2 or CO_2 concentration is not less than 20 percent of the span.

3. *Definitions*

3.1 Measurement System. The total equipment required for the determination of the O_2 or CO_2 concentration. The measurement system consists of the same major subsystems as defined in Method 6C, Sections 3.1.1, 3.1.2, and 3.1.3.

3.2 Span, Calibration Gas, Analyzer Calibration Error, Sampling System Bias, Zero Drift, Calibration Drift, Response Time, and Calibration Curve. Same as Method 6C, Sections 3.2 through 3.8, and 3.10.

3.3 Interference Response. The output response of the measurement system to a component in the sample gas, other than the gas component being measured.

4. *Measurement System Performance Specifications*

Same as Method 6C, Sections 4.1 through 4.4.

5. *Apparatus and Reagents*

5.1 Measurement System. Any measurement system for O_2 or CO_2 that meets the specifications of this method. A schematic of an acceptable measurement system is shown in Figure 6C-1 of Method 6C. The essential components of the measurement system are described below:

5.1.1 Sample Probe. A leak-free probe, of sufficient length to traverse the sample points.

5.1.2 Sample Line. Tubing, to transport the sample gas from the probe to the moisture removal system. A heated sample line is not required for systems that measure the O_2 or CO_2 concentration on a dry basis, or transport dry gases.

5.1.3 Sample Transport Line, Calibration Value Assembly, Moisture Removal System, Particulate Filter, Sample Pump, Sample Flow Rate Control, Sample Gas Manifold, and Data Recorder. Same as Method 6C, Sections 5.1.3 through 5.1.9, and 5.1.11, except that the requirements to use stainless steel, Teflon, and nonreactive glass filters do not apply.

5.1.4 Gas Analyzer. An analyzer to determine continuously the O_2 or CO_2 concentration in the sample gas stream. The analyzer shall meet the applicable performance specifications of Section 4. A means of controlling the analyzer flow rate and a device for determining proper sample flow rate (e.g., precision rotameter, pressure gauge downstream of all flow controls, etc.) shall be provided at the analyzer. The requirements for measuring and controlling the analyzer flow rate are not applicable if data are presented that demonstrate the analyzer is insensitive to flow variations over the range encountered during the test.

5.2 Calibration Gases. The calibration gases for CO_2 analyzers shall be CO_2 in N_2 or CO_2 in air. Alternatively, CO_2/SO_2, O_2/SO_2, or $O_2/CO_2/SO_2$ gas mixtures in N_2 may be used. Three calibration gases, as specified Section 5.3.1 through 5.3.3 of Method 6C, shall be used. For O_2 monitors that cannot analyze zero gas, a calibration gas concentration equivalent to less than 10 percent of the span may be used in place of zero gas.

6. *Measurement System Performance Test Procedures*

Perform the following procedures before measurement of emissions (Section 7).

6.1 Calibration Concentration Verification. Follow Section 6.1 of Method 6C, except if calibration gas analysis is required, use Method 3 and change the acceptance criteria for agreement among Method 3 results to 5 percent (or 0.2 percent by volume, whichever is greater).

6.2 Interference Response. Conduct an interference response test of the analyzer prior to its initial use in the field. Thereafter, recheck the measurement system if changes are made in the instrumentation that could alter the interference response (e.g., changes in the type of gas detector). Conduct the interference response in accordance with Section 5.4 of Method 20.

6.3 Measurement System Preparation, Analyzer Calibration Error, and Sampling System Bias Check. Follow Sections 6.2 through 6.4 of Method 6C.

7. *Emission Test Procedure*

7.1 Selection of Sampling Site and Sampling Points. Select a measurement site and sampling points using the same criteria that are applicable to tests performed using Method 3.

7.2 Sample Collection. Position the sampling probe at the first measurement point, and begin sampling at the same rate as used during the sampling system bias check. Maintain constant rate sampling (i.e., ±10 percent) during the entire run. The sampling time per run shall be the same as for tests conducted using Method 3 plus twice the system response time. For each run, use only those measurements obtained after twice the response time of the measurement system has elapsed to determine the average effluent concentration.

7.3 Zero and Calibration Drift Test. Follow Section 7.4 of Method 6C.

8. *Quality Control Procedures*

The following quality control procedures are recommended when the results of this method are used for an emission rate correction factor, or excess air determination. The tester should select one of the following options for validating measurement results:

8.1 If both O_2 and CO_2 are measured using Method 3A, the procedures described in Section 4.4 of Method 3 should be followed to validate the O_2 and CO_2 measurement results.

8.2 If only O_2 is measured using Method 3A, measurements of the sample stream CO_2 concentration should be obtained at the sample by-pass vent discharge using an Orsat or Fyrite analyzer, or equivalent. Duplicate samples should be obtained concurrent with at least one run. Average the duplicate Orsat or Fyrite analysis results for each run. Use the average CO_2 values for comparison with the O_2 measurements in accordance with the procedures described in Section 4.4 of Method 3.

8.3 If only CO_2 is measured using Method 3A, concurrent measurements of the sample stream CO_2 concentration should be obtained using an Orsat or Fyrite analyzer as described in Section 8.2. For each run, differences greater than 0.5 percent between the Method 3A results and the average of the duplicate Fyrite analysis should be investigated.

9. *Emission Calculation*

For all CO_2 analyzers, and for O_2 analyzers that can be calibrated with zero gas, follow Section 8 of Method 6C, except express all concentrations as percent, rather than ppm.

For O_2 analyzers that use a low-level calibration gas in place of a zero gas, calculate the effluent gas concentration using Equation 3A-1.

$$C_{ma} = \frac{C_{ma} - C_{ao}}{C_{ma} - C_{o}} (C - C_{o}) + C_{ma} \qquad \text{Eq. 3A-1}$$

Where:

C_{ma} = Effluent gas concentration, dry basis, percent.

C_{ma} = Actual concentration of the upscale calibration gas, percent.

C_{ao} = Actual concentration of the low-level calibration gas, percent.

C_{o} = Average of initial and final system calibration bias check responses for the upscale calibration gas, percent.

C_{o} = Average of initial and final system calibration bias check responses for the low-level gas, percent.

C = Average gas concentration indicated by the gas analyzer, dry basis, percent.

10. *Bibliography*

Same as bibliography of Method 6C.

Method 3B—Gas Analysis for the Determination of Emission Rate Correction Factor or Excess Air

[Method 3B added by 55 FR 5212, February 14, 1990]

1. Applicability and Principle

1.1 Applicability

1.1.1 This method is applicable for determining carbon dioxide (CO_2), oxygen (O_2), and carbon monoxide (CO) concentrations of a sample from a gas stream of a fossil-fuel combustion process for excess air or emission rate correction factor calculations.

1.1.2 Other methods, as well as modifications to the procedure described herein, are also applicable for all of the above determinations. Examples of specific methods and modifications include: (1) A multi-point sampling method using an Orsat analyzer to analyze individual grab samples obtained at each point, and (2) a method using CO_2 or O_2 and stoichiometric calculations to determine excess air. These methods and modifications may be used, but are subject to the approval of the Administrator, U.S. Environmental Protection Agency (EPA).

1.1.3 Note. Mention of trade names or specific products does not constitute endorsement by EPA.

1.2 Principle. A gas sample is extracted from a stack by one of the following methods: (1) Single-point, grab sampling; (2) single-point, integrated sampling; or (3) multi-point, integrated sampling. The gas sample is analyzed for percent CO_2, percent O_2, and, if necessary, percent CO. An Orsat analyzer must be used for excess air or emission rate correction factor determinations.

2. Apparatus

The alternative sampling systems are the same as those mentioned in Section 2 of Method 3.

2.1 Grab Sampling and Integrated Sampling. Same as in Sections 2.1 and 2.2, respectively, of Method 3.

2.2 Analysis. An Orsat analyzer only. For low CO_2 (less than 4.0 percent) or high O_2 (greater than 15.0 percent) concentrations, the measuring burette of the Orsat must have at least 0.1 percent subdivisions. For Orsat maintenance and operation procedures, follow the instructions recommended by the manufacturer, unless otherwise specified herein.

3. Procedures

Each of the three procedures below shall be used only when specified in an applicable subpart of the standards. The use of these procedures for other purposes must have specific prior approval of the Adminsitrator.

Note.—A Fyrite-type combustion gas analyzer is not acceptable for excess air or emission rate correction factor determinations, unless approved by the Administrator. If both percent CO_2 and percent O_2 are measured, the analytical results of any of the three procedures given below may be used for calculating the dry molecular weight (see Method 3).

3.1 Single-Point, Grab Sampling and Analytical Procedure.

3.1.1 The sampling point in the duct shall be as described in Section 3.1 of Method 3.

3.1.2 Set up the equipment as shown in Figure 3-1 of Method 3, making sure all connections ahead of the analyzer are tight. Leak check the Orsat analyzer according to the procedure described in Section 6 of Method 3. This leak check is mandatory.

3.1.3 Place the probe in the stack, with the tip of the probe positioned at the sampling point; purge the sampling line long enough to allow at least five exchanges. Draw a sample into the analyzer. For emission rate correction factor determinations, immediately analyze the sample, as outlined in Sections 3.1.4 and 3.1.5, for percent CO_2 or percent O_2. If excess air is desired, proceed as follows: (1) immediately analyze the sample, as in Sections 3.1.4 and 3.1.5, for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by subtracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air as outlined in Section 4.2.

3.1.4 To ensure complete absorption of the CO_2, O_2, or if applicable, CO, make repeated passes through each absorbing solution until two consecutive readings are the same. Several passes (three or four) should be made between readings. (If constant readings cannot be obtained after three consecutive readings, replace the absorbing solution.)

Note.—Since this single-point, grab sampling and analytical procedure is normally conducted in conjunction with a single-point, grab sampling and analytical procedure for a pollutant, only one analysis is ordinarily conducted. Therefore, great care must be taken to obtain a valid sample and analysis. Although in most cases, only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 3.4 be used to validate the analytical data.

3.1.5 After the analysis is completed, leak check (mandatory) the Orsat analyzer once again, as described in Section 6 of Method 3. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis.

3.2 Single-Point, Integrated Sampling and Analytical Procedure.

3.2.1 The sampling point in the duct shall be located as specified in Section 3.1.1.

3.2.2 Leak check (mandatory) the flexible bag as in Section 2.2.6 of Method 3. Set up the equipment as shown in Figure 3-2 of Method 3. Just before sampling, leak check (mandatory) the train as described in Section 4.2 of Method 3.

3.2.3 Sample at a constant rate, or as specified by the Administrator. The sampling run must be simultaneous with, and for the same total length of time as, the pollutant emission rate determination. Collect at least 30 liters (1.00 ft^3) of sample gas. Smaller volumes may be collected, subject to approval of the Administrator.

3.2.4 Obtain one integrated flue gas sample during each pollutant emission rate determination. For emission rate correction factor determination, analyze the sample within 4 hours after it is taken for percent CO_2 or percent O_2 (as outlined in Sections 3.2.5 through 3.2.7), the Orsat analyzer must be leak checked (see Section 6 of Method 3) before the analysis. If excess air is desired, proceded as follows: (1) within 4 hours after the sample is taken, analyze it (as in Sections 3.2.5 through 3.2.7) for percent CO_2, O_2, and CO; (2) determine the percentage of the gas that is N_2 by substracting the sum of the percent CO_2, percent O_2, and percent CO from 100 percent; and (3) calculate percent excess air, as outlined in Section 4.2.

3.2.5 To ensure complete absorption of the CO_2, O_2, or if applicable, CO, follow the procedure described in Section 3.1.4.

Note.—Although in most instances only CO_2 or O_2 is required, it is recommended that both CO_2 and O_2 be measured, and that Section 3.4.1 be used to validate the analytical data.

3.2.6 Repeat the analysis until the following criteria are met:

3.2.6.1 For percent CO_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when CO_2 is greater than 4.0 percent or (b) 0.2 percent by volume when CO_2 is less than or equal to 4.0 percent. Average three acceptable values of percent CO_2, and report the results to the nearest 0.2 percent.

3.2.6.2 For percent O_2, repeat the analytical procedure until the results of any three analyses differ by no more than (a) 0.3 percent by volume when O_2 is less than 15.0 percent or (b) 0.2 percent by volume when O_2 is greater than or equal to 15.0 percent. Average the three acceptable values of percent O_2, and report the results to the nearest 0.1 percent.

3.2.6.3 For percent CO, repeat the analytical procedure until the results of any three analyses differ by no more than 0.3 percent. Average the three acceptable values of percent CO, and report the results to the nearest 0.1 percent.

3.2.7 After the analysis is completed, leak check (mandatory) the Orsat analyzer once again, as described in Section 6 of Method 3. For the results of the analysis to be valid, the Orsat analyzer must pass this leak test before and after the analysis.

3.3 Multi-Point, Integrated Sampling and Analytical Procedure.

3.3.1 The sampling points shall be determined as specified in Section 5.3 of Method 3.

3.3.2 Follow the procedures outlined in Sections 3.2.2. through 3.2.7, except for the following: Traverse all sampling points, and sample at each point for an equal length of time. Record sampling data as shown in Figure 3-3 of Method 3.

3.4 Quality Control Procedures.

3.4.1 Data Validation When Both CO_2 and O_2 Are Measured. Although in most instances, only CO_2 or O_2 measurement is required, it is recommended that both CO_2 and O_2 be measured to provide a check on the quality of the data. The following quality control procedure is suggested.

Note.—Since the method for validating he CO_2 and O_2 analyses is based on combustion of organic and fossil fuels and dilution of the gas stream with air, this method does not apply to sources that (1) remove CO_2 or O_2 through processes other than combustion, (2) add O_2 (e.g., oxygen enrichment) and N_2 in proportions different from that of air, (3) add CO_2 (e.g., cement or lime kilns), or (4) have no fuel factor, F_o, values obtainable (e.g., extremely variable waste mixtures). This method validates the measured proportions of CO_2 and O_2 for fuel type, but the method does not detect sample dilution resulting from leaks during or after sample collection. The method is applicable for samples collected downstream of most lime or limestone flue-gas desulfurization units as the CO_2 added or removed from the gas stream is not significant in relation to the total CO_2 concentration. The CO_2 concentrations from other types of scrubbers using only water or basic slurry can be significantly affected and would render the F_o check minimally useful.

3.4.1.1 Calculate a fuel factor, F_o, using the following equation:

$$F_o = \frac{20.9 - \%O_2}{\%CO_2} \qquad \text{Eq. 3B-1}$$

where:

$\%O_2$ = Percent O_2 by volume, dry basis.
$\%CO_2$ = Percent CO_2 by volume, dry basis.
20.9 = Percent O_2 by volume in ambient air.

If CO present in quantities measurable by this method, adjust the O_2 and CO_2 values before performing the calculation for F_o as follows:

$\%CO_2$ (adj) = $\%CO_2$ + %CO
$\%O_2$ (adj) = $\%O_2$ − 0.5 %CO
where:

%CO = Percent CO by volume, dry basis.

3.4.1.2 Compare the calculated F_o factor with the expected F_o values. The following table may be used in establishing acceptable ranges for the expected F_o if the fuel being burned is known. When fuels are burned in combinations, calculate the combined fuel F_d and F_c factors (as defined in Method 19) according to the procedure in Method 19, Section 5.2.3. Then calculate the F_o factor as follows:

$$F_o = \frac{0.209\ F_d}{F_c} \qquad \text{Eq. 3B-2}$$

Fuel type	F_o range
Coal:	
Anthracite and lignite	1.016–1.130
Bituminous	1.083–1.230
Oil:	
Distillate	1.260–1.413
Residual	1.210–1.370
Gas:	
Natural	1.600–1.836
Propane	1.434–1.586
Butane	1.405–1.553
Wood	1.000–1.120
Wood bark	1.003–1.130

3.4.1.3 Calculated F_o values, beyond the acceptable ranges shown in this table, should be investigated before accepting the test results. For example, the strength of the solutions in the gas analyzer and the analyzing technique should be checked by sampling and analyzing a known concentration, such as air; the fuel factor should be reviewed and verified. An acceptability range of ±12 percent is appropriate for the F_o factor of mixed fuels with variable fuel ratios. The level of the emission rate relative to the compliance level should be considered in determining if a retest is appropriate, i.e.; if the measured emissions are much lower or much greater than the compliance limit, repetition of the test would not significantly change the compliance status of the source and would be unnecessarily time consuming and costly.

4. Calculations

4.1 Nomenclature. Same as Section 5 of Method 3 with the addition of the following:

%EA = Percent excess air.
0.264 = Ratio of O_2 to N_2 in air, v/v.

4.2 Percent Excess Air. Calculate the percent excess air (if applicable) by substituting the appropriate values of percent O_2, CO, and N_2 (obtained from Section 3.1.3 or 3.2.4) into Equation 3B-3.

[Appendix A, Method 3B]

$$\%EA = \frac{\%O_2 - 0.5\ \%CO}{0.264\ \%N_2 - (\%O_2 - 0.5\ \%CO)} \times 100 \qquad \text{Eq. 3B-3}$$

Note.—The equation above assumes that ambient air is used as the source of O_2 and that the fuel does not contain appreciable amounts of N_2 (as do coke oven or blast furnace gases). For those cases when appreciable amounts of N_2 are present (coal, oil and natural gas do not contain appreciable amounts of N_2) or when oxygen enrichment is used, alternative methods, subject to approval of the Administrator, are required.

5. BIBLIOGRAPHY

Same as Method 3.

METHOD 4—DETERMINATION OF MOISTURE CONTENT IN STACK GASES

1. *Principle and Applicability*

1.1 Principle. A gas sample is extracted at a constant rate from the source; moisture is removed from the sample stream and determined either volumetrically or gravimetrically.

1.2 Applicability. This method is applicable for determining the moisture content of stack gas.

Two procedures are given. The first is a reference method, for accurate determinations of moisture content (such as are needed to calculate emission data). The second is an approximation method, which provides estimates of percent moisture to aid in setting isokinetic sampling rates prior to a pollutant emission measurement run. The approximation method described herein is only a suggested approach; alternative means for approximating the moisture content, e.g., drying tubes, wet bulb-dry bulb techniques, condensation techniques, stoichiometric calculations, previous experience, etc., are also acceptable.

The reference method is often conducted simultaneously with a pollutant emission measurement run; when it is, calculation of percent isokinetic, pollutant emission rate, etc., for the run shall be based upon the results of the reference method or its equivalent; these calculations shall not be based upon the results of the approximation method, unless the approximation method is shown, to the satisfaction of the Administrator, U.S. Environmental Protection Agency, to be capable of yielding results within 1 percent H_2O of the reference method.

NOTE: The reference method may yield questionable results when applied to saturated gas streams or to streams that contain water droplets. Therefore, when these conditions exist or are suspected, a second determination of the moisture content shall be made simultaneously with the reference method, as follows: Assume that the gas stream is saturated. Attach a temperature sensor [capable of measuring to ±1° C (2° F)] to the reference method probe. Measure the stack gas temperature at each traverse point (see Section 2.2.1) during the reference method traverse; calculate the average stack gas temperature. Next, determine the moisture percentage, either by: (1) using a psychrometric chart and making appropriate corrections if stack pressure is different from that of the chart, or (2) using saturation vapor pressure tables. In cases where the pyschrometric chart or the saturation vapor pressure tables are not applicable (based on evaluation of the process), alternate methods, subject to the approval of the Administrator, shall be used.

2. *Reference Method*

The procedure described in Method 5 for determining moisture content is acceptable as a reference method.

2.1 Apparatus. A schematic of the sampling train used in this reference method is shown in Figure 4-1. All components shall be maintained and calibrated according to the procedure outlined in Method 5.

ferences between the weather station and the sampling point shall be applied at a rate of minus 2.5 mm Hg (0.1 in. Hg) per 30 m (100 ft) elevation increase or vice versa for elevation decrease.

2.1.6 Graduated Cylinder and/or Balance. These items are used to measure condensed water and moisture caught in the silica gel to within 1 ml or 0.5 g. Graduated cylinders shall have subdivisions no greater than 2 ml. Most laboratory balances are capable of weighing to the nearest 0.5 g or less. These balances are suitable for use here.

2.2 Procedure. The following procedure is written for a condenser system (such as the impinger system described in Section 2.1.2) incorporating volumetric analysis to measure the condensed moisture, and silica gel and gravimetric analysis to measure the moisture leaving the condenser.

2.2.1 Unless otherwise specified by the Administrator, a minimum of eight traverse points shall be used for circular stacks having diameters less than 0.61 m (24 in.), a minimum of nine points shall be used for rectangular stacks having equivalent diameters less than 0.61 m (24 in.), and a minimum of twelve traverse points shall be used in all other cases. The traverse points shall be located according to Method 1. The use of fewer points is subject to the approval of the Administrator. Select a suitable probe and probe length such that all traverse points can be sampled. Consider sampling from opposite sides of the stack (four total sampling ports) for large stacks, to permit use of shorter probe lengths. Mark the probe with heat resistant tape or by some other method to denote the proper distance into the stack or duct for each sampling point. Place known volumes of water in the first two impingers. Weigh and record the weight of the silica gel to the nearest 0.5 g, and transfer the silica gel to the fourth impinger; alternatively, the silica gel may first be transferred to the impinger, and the weight of the silica gel plus impinger recorded.

2.2.2 Select a total sampling time such that a minimum total gas volume of 0.60 scm (21 scf) will be collected, at a rate no greater than 0.021 m^3/min (0.75 cfm). When both moisture content and pollutant emission rate are to be determined, the moisture determination shall be simultaneous with, and for the same total length of time as, the pollutant emission rate run, unless otherwise specified in an applicable subpart of the standards.

2.2.3 Set up the sampling train as shown in Figure 4-1. Turn on the probe heater and (if applicable) the filter heating system to temperatures of about 120° C (248° F), to prevent water condensation ahead of the condenser; allow time for the temperatures to stabilize. Place crushed ice in the ice bath container. It is recommended, but not required, that a leak check be done, as follows: Disconnect the probe from the first impinger or (if applicable) from the filter holder. Plug the inlet to the first impinger (or filter holder) and pull a 380 mm (15 in.) Hg vacuum; a lower vacuum may be used, provided that it is not exceeded during the test. A leakage rate in excess of 4 percent of the average sampling rate or 0.00057 m^3/min (0.02 cfm), whichever is less, is unacceptable. Following the leak check, reconnect the probe to the sampling train.

2.2.4 During the sampling run, maintain a sampling rate within 10 percent of constant rate, or as specified by the Administrator. For each run, record the data required on the example data sheet shown in Figure 4-2. Be sure to record the dry gas meter reading at the beginning and end of each sampling time increment and whenever sampling is halted. Take other appropriate readings at each sample point, at least once during each time increment.

2.2.5 To begin sampling, position the probe tip at the first traverse point. Immediately start the pump and adjust the flow to the desired rate. Traverse the cross section, sampling at each traverse point for an equal length of time. Add more ice and, if necessary, salt to maintain a temperature of less 20° C (68° F) at the silica gel outlet.

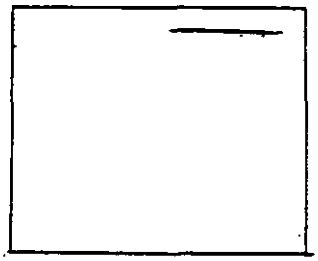
2.2.6 After collecting the sample, disconnect the probe from the filter holder (or from the first impinger) and conduct a leak check (mandatory) as described in Section 2.2.3. Record the leak rate. If the leakage rate exceeds the allowable rate, the tester shall either reject the test results or shall correct the sample volume as in Section 6.3 of Method 5. Next, measure the volume of the moisture condensed to the nearest ml. Determine the increase in weight of the silica gel (or silica gel plus impinger) to the nearest 0.5 g. Record this information (see example data sheet, Figure 4-3) and calculate the moisture percentage, as described in 2.3 below.

2.2.7 A quality control check of the volume metering system at the field site is suggested before collecting the sample following the procedure in Method 5, Section 4.4.

[2.2.7 added by 48 FR 55671, December 14, 1983]

2.3 Calculations. Carry out the following calculations, retaining at least one extra decimal figure beyond that of the acquired data. Round off figures after final calculation.

PLANT _____
LOCATION _____
OPERATOR _____
DATE _____
RUN NO. _____
AMBIENT TEMPERATURE _____
BAROMETRIC PRESSURE _____
PROBE LENGTH m(ft) _____



SCHEMATIC OF STACK CROSS SECTION

TRAVERSE POINT NUMBER	SAMPLING TIME (θ), min.	STACK TEMPERATURE °C (°F)	PRESSURE DIFFERENTIAL ACROSS ORIFICE METER (ΔH), mm(in.) H_2O	METER READING GAS SAMPLE VOLUME m^3 (ft^3)	ΔV_m m^3 (ft^3)	GAS SAMPLE TEMPERATURE AT DRY GAS METER		TEMPERATURE OF GAS LEAVING CONDENSER OR LAST IMPINGER, °C (°F)
						INLET ($T_{m_{in}}$), °C (°F)	OUTLET ($T_{m_{out}}$), °C (°F)	
TOTAL						Avg.	Avg.	
AVERAGE						Avg.		

Figure 4-2. Field moisture determination-reference method.

[Appendix A, Method 4]

	IMPINGER VOLUME, ml	SILICA GEL WEIGHT, g
FINAL		
INITIAL		
DIFFERENCE		

Figure 4-3. Analytical data - reference method.

2.3.1 Nomenclature.

B_{ws} = Proportion of water vapor, by volume, in the gas stream.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m^3)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft^3)/(lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528°R).

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

ΔV_m = Incremental dry gas volume measured by dry gas meter at each traverse point, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by the dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{wc(std)}$ = Volume of water vapor condensed corrected to standard conditions, scm (scf).

$V_{wsg(std)}$ = Volume of water vapor collected in silica gel corrected to standard conditions, scm (scf).

V_f = Final volume of condenser water, ml.

V_i = Initial volume, if any, of condenser water, ml.

W_f = Final weight of silica gel or silica gel plus impinger, g.

W_i = Initial weight of silica gel or silica gel plus impinger, g.

Y = Dry gas meter calibration factor.

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

2.3.2 Volume of water vapor condensed.

$$V_{wc(std)} = \frac{(V_f - V_i)\rho_w R T_{std}}{P_{std} M_w} = K_1 (V_f - V_i)$$

Equation 4-1

where:

K_1 = 0.001333 m^3/ml for metric units
= 0.04707 ft^3/ml for English units

2.3.3 Volume of water vapor collected in silica gel.

$$V_{wsg(std)} = \frac{(W_f - W_i) R T_{std}}{P_{std} M_w} = K_2 (W_f - W_i)$$

Equation 4-2

where:

K_2 = 0.001335 m^3/g for metric units
= 0.04715 ft^3/g for English units

2.3.4 Sample gas volume.

$$V_{m(std)} = V_m Y \frac{(P_m)(T_{std})}{(P_{std})(T_m)} = K_3 Y \frac{V_m P_m}{T_m}$$

Equation 4-3

where:

K_3 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units

NOTE: If the post-test lead rate (Section 2.2.6) exceeds the allowable rate, correct the value of V_m in Equation 4-3, as described in Section 6.3 of Method 5.

2.3.5 Moisture Content.

$$B_{ws} = \frac{V_{wc(std)} + V_{wsg(std)}}{V_{wc(std)} + V_{wsg(std)} + V_{m(std)}}$$

Equation 4-4

NOTE: In saturated or moisture droplet-laden gas streams, two calculations of the moisture content of the stack gas shall be made, one using a value based upon the saturated conditions (see Section 1.2), and another based upon the results of the impinger analysis. The lower of these two values of B_{ws} shall be considered correct.

2.3.6 Verification of constant sampling rate. For each time increment, determine the ΔV_m. Calculate the average. If the value for any time increment differs from the average by more than 10 percent, reject the results and repeat the run.

3. *Approximation Method*

The approximation method described below is presente ' only as a suggested method (see Section 1.2).

3.1 Apparatus.

3.1.1 Probe. Stainless steel glass tubing, sufficiently heated to prevent water condensation and equipped with a filter (either in-stack or heated out-stack) to remove particulate matter. A plug of glass wool, inserted into the end of the probe, is a satisfactory filter.

3.1.2 Impingers. Two midget impingers, each with 30 ml capacity, or equivalent.

3.1.3 Ice Bath. Container and ice, to aid in condensing moisture in impingers.

3.1.4 Drying Tube. Tube packed with new or regenerated 6- to 16-mesh indicating-type silica gel (or equivalent desiccant), to dry the sample gas and to protect the meter and pump.

3.1.5 Valve. Needle valve, to regulate the sample gas flow rate.

3.1.6 Pump. Leak-free, diaphragm type, or equivalent, to pull the gas sample through the train.

3.1.7 Volume Meter. Dry gas meter, sufficiently accurate to measure the sample volume within 2%, and calibrated over the range of flow rates and conditions actually encountered during sampling.

3.1.8 Rate Meter. Rotameter, to measure the flow range from 0 to 3 lpm (0 to 0.11 cfm).

3.1.9 Graduated Cylinder. 25 ml.

3.1.10 Barometer. Mercury, aneroid, or other barometer, as described in Section 2.1.5 above.

3.1.11 Vacuum Gauge. At least 760 mm Hg (30 in. Hg) gauge, to be used for the sampling leak check.

3.2 Procedure.

3.2.1 Place exactly 5 ml distilled water in each impinger.

Leak check the sampling train as follows: Temporarily insert a vacuum gauge at or near the probe inlet; then, plug the probe inlet and pull a vacuum of at least 250 mm Hg (10 in. Hg). Note, the time rate of change of the dry gas meter dial; alternatively, a rotameter (0-40 cc/min) may be temporarily attached to the dry gas meter outlet to determine the leakage rate. A leak rate not in excess of 2 percent of the average sampling rate is acceptable.

NOTE: Carefully release the probe inlet plug before turning off the pump.

[Appendix A, Method 4]

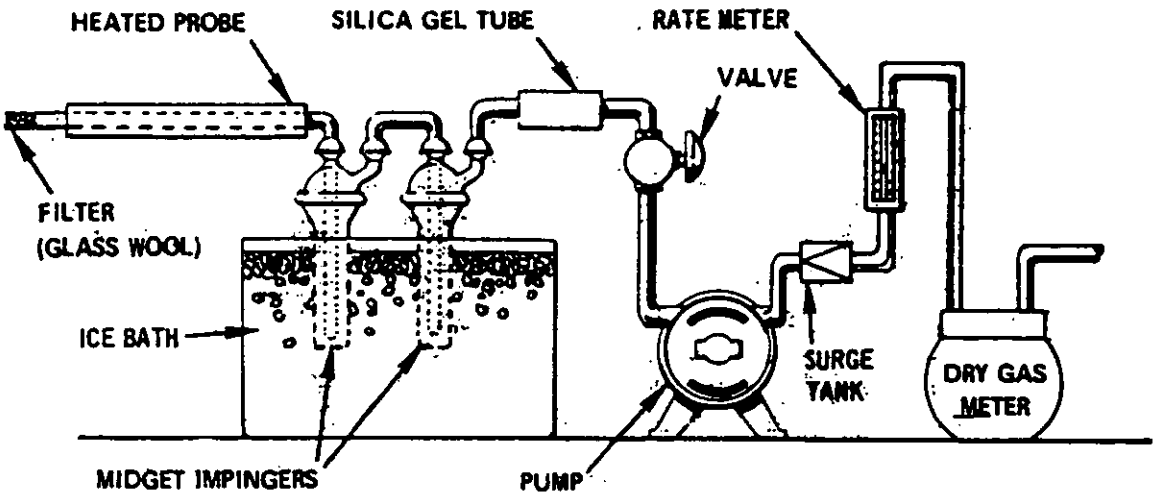


Figure 4-4. Moisture-sampling train - approximation method.

LOCATION _____ COMMENTS

TEST _____

DATE _____

OPERATOR _____

BAROMETRIC PRESSURE _____

CLOCK TIME	GAS VOLUME THROUGH METER, (Vm), m^3 (ft^3)	RATE METER SETTING m^3/min. (ft^3/min.)	METER TEMPERATURE, °C (°F)

Figure 4-5. Field moisture determination - approximation method.

[Appendix A, Method 4]

3.2.2 Connect the probe, insert it into the stack, and sample at a constant rate of 2 lpm (0.071 cfm). Continue sampling until the dry gas meter registers about 30 liters (1.1 ft³) or until visible liquid droplets are carried over from the first impinger to the second. Record temperature, pressure, and dry gas meter readings as required by Figure 4-5.

3.2.3 After collecting the sample, combine the contents of the two impingers and measure the volume to the nearest 0.5 ml.

3.3 Calculations. The calculation method presented is designed to estimate the moisture in the stack gas; therefore, other data, which are only necessary for accurate moisture determinations, are not collected. The following equations adequately estimate the moisture content, for the purpose of determining isokinetic sampling rate settings.

3.3.1 Nomenclature.

B_{ws} = Approximate proportion, by volume, of water vapor in the gas stream leaving the second impinger, 0.025.

B_{wo} = Water vapor in the gas stream, proportion by volume.

M_w = Molecular weight of water, 18.0 g/g-mole (18.0 lb/lb-mole).

P_m = Absolute pressure (for this method, same as barometric pressure) at the dry gas meter.

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

R = Ideal gas constant, 0.06236 (mm Hg) (m³)/(g-mole) (°K) for metric units and 21.85 (in. Hg) (ft³)/(lb-mole) (°R) for English units.

T_m = Absolute temperature at meter, °K (°R).

T_{std} = Standard absolute temperature, 293° K (528° R).

V_f = Final volume of impinger contents, ml.

V_i = Initial volume of impinger contents, ml.

V_m = Dry gas volume measured by dry gas meter, dcm (dcf).

$V_{m(std)}$ = Dry gas volume measured by dry gas meter, corrected to standard conditions, dscm (dscf).

$V_{w(std)}$ = Volume of water vapor condensed, corrected to standard conditions, scm (scf).

ρ_w = Density of water, 0.9982 g/ml (0.002201 lb/ml).

Y = Dry gas meter calibration factor.

3.3.2 Volume of water vapor collected.

where:

$$V_{w(std)} = \frac{(V_f - V_i)\rho_w RT_{std}}{P_{std} M_w} = K_1(V_f - V_i)$$

Equation 4-6

K_1 = 0.001333 m³/ml for metric units
= 0.04707 ft³/ml for English units.

3.3.3 Gas volume.

$$V_{m(std)} = V_m\left(\frac{P_m}{P_{std}}\right)\left(\frac{T_{std}}{T_m}\right) = K_2\frac{V_m P_m}{T_m}$$

Equation 4-6

where:

K_2 = 0.3858 °K/mm Hg for metric units
= 17.64 °R/in. Hg for English units.

3.3.4 Approximate moisture content.

$$B_{ws} = \frac{V_{ws}}{V_{ws} + V_{m(std)}} + B_{wo} = \frac{V_{ws}}{V_{ws} + V_{m(std)}} + (0.025)$$

Equation 4-7

4. *Calibration*

4.1 For the reference method, calibrate equipment as specified in the following sections of Method 5: Section 5.3 (metering system); Section 5.5 (temperature gauges); and Section 5.7 (barometer). The recommended leak check of the metering system (Section 5.6 of Method 5) also applies to the reference method. For the approximation method, use the procedures outlined in Section 5.1.1 of Method 6 to calibrate the metering system, and the procedure of Method 5, Section 5.7 to calibrate the barometer.

5. *Bibliography*

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2. Devorkin, Howard, et al. Air Pollution Source Testing Manual. Air Pollution Control District, Los Angeles, Calif. November, 1963.

3. Methods for Determination of Velocity, Volume Dust and Mist Content of Gases. Western Precipitation Division of Joy Manufacturing Co., Los Angeles, Calif. Bulletin WP-50. 1968.

METHOD 12—DETERMINATION OF INORGANIC LEAD EMISSIONS FROM STATIONARY SOURCES

1. *Principle and Applicability*

1.1 Applicability. This method applies to the determination of inorganic lead (Pb) emissions from specified stationary sources only.

1.2 Principle. Particulate and gaseous Pb emissions are withdrawn isokinetically from the source and collected on a filter and in dilute nitric acid. The collected samples are digested in acid solution and analyzed by atomic absorption spectrometry using an air acetylene flame.

2. *Range, Sensitivity, Precision, and Interferences.*

2.1 Range. For a minimum analytical accuracy of ±10 percent, the lower limit of the range is 100 μg. The upper limit can be considerably extended by dilution.

2.2 Analytical Sensitivity. Typical sensitivities for a 1-percent change in absorption (0.0044 absorbance units) are 0.2 and 0.5 μg Pb/ml for the 217.0 and 283.3 nm lines, respectively.

2.3 Precision. The within-laboratory precision, as measured by the coefficient of variation ranges from 0.2 to 9.5 percent relative to a run-mean concentration. These values were based on tests conducted at a gray iron foundry, a lead storage battery manufacturing plant, a secondary lead smelter, and a lead recovery furnace of an alkyl lead manufacturing plant. The concentrations encountered during these tests ranged from 0.61 to 123.3 mg Pb/m³.

2.4 Interferences. Sample matrix effects may interfere with the analysis for Pb by flame atomic absorption. If this interference is suspected, the analyst may confirm the presence of these matrix effects and frequently eliminate the interference by using the Method of Standard Additions.

High concentrations of copper may interfere with the analysis of Pb at 217.0 nm. This interference can be avoided by analyzing the samples at 283.3 nm.

3. *Apparatus.*

3.1 Sampling Train. A schematic of the sampling train is shown in Figure 12-1; it is similar to the Method 5 train. The sampling train consists of the following components:

3.1.1 Probe Nozzle, Probe Liner, Pitot Tube, Differential Pressure Gauge, Filter Holder, Filter Heating System, Metering System, Barometer, and Gas Density Determination Equipment. Same as Method 5, Sections 2.1.1 to 2.1.6 and 2.1.8 to 2.1.10, respectively.

3.1.2 Impingers. Four impingers connected in series with leak-free ground glass fittings or any similar leak-free noncontaminating fittings. For the first, third, and fourth impingers, use the Greenburg-Smith design, modified by replacing the tip with a 1.3 cm (½ in.) ID glass tube extending to about 1.3 cm (½ in.) from the bottom of the flask. For the second impinger, use the Greenburg-Smith design with the standard tip. Place a thermometer, capable of measuring temperature to within 1°C (2°F) at the outlet of the fourth impinger for monitoring purposes.

[Appendix A, Method 12]

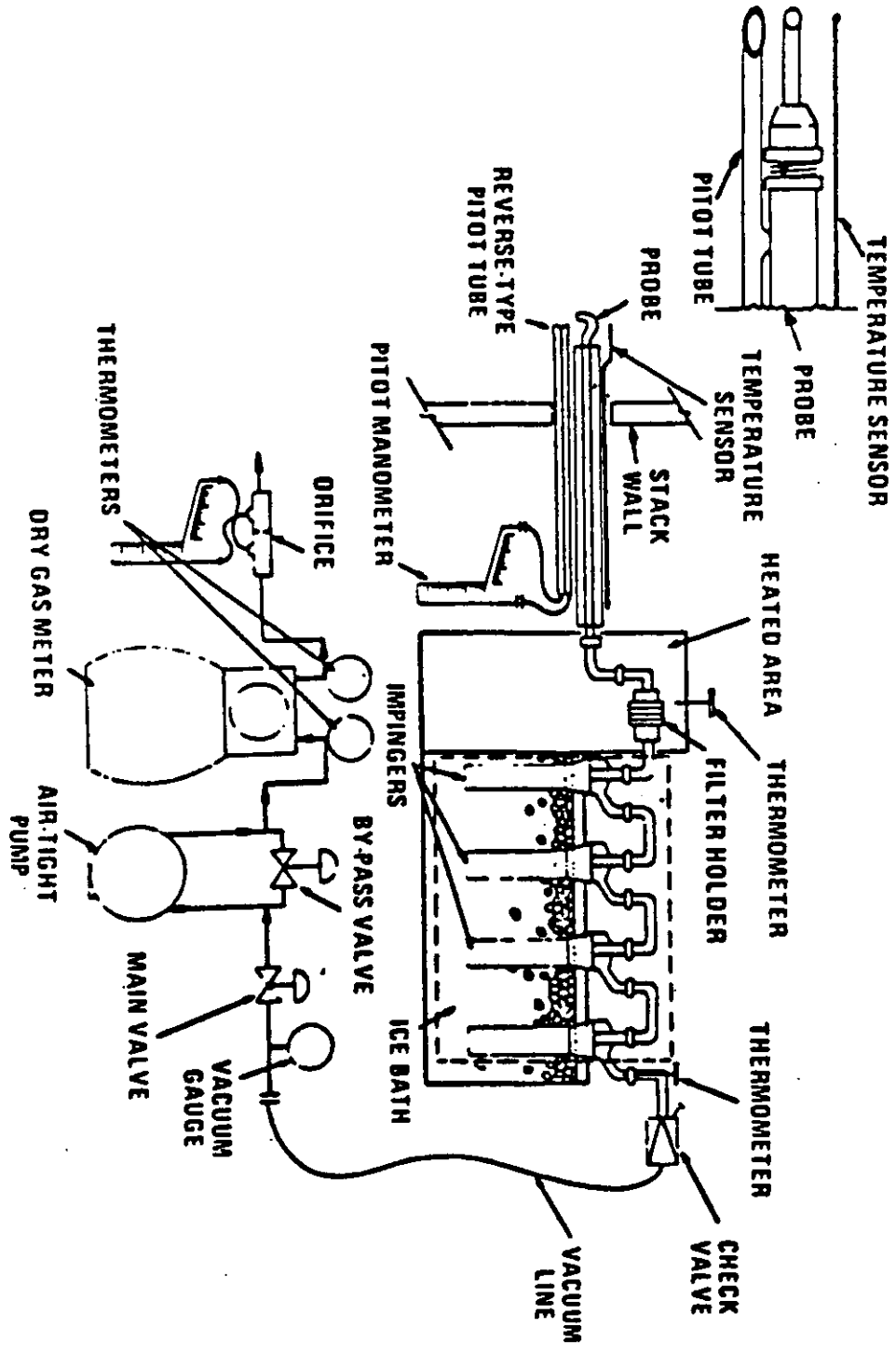

Figure 12-1. Inorganic lead sampling train.

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3.2 Sample Recovery. The following items are needed:

3.2.1 Probe-Liner and Probe-Nozzle Brushes, Petri Dishes, Plastic Storage Containers, and Funnel and Rubber Policeman. Same as Method 5, Sections 2.2.1, 2.2.4, 2.2.6, and 2.2.7, respectively.

3.2.2 Wash Bottles, Glass (2).

3.2.3 Sample Storage Containers. Chemically resistant, borosilicate glass bottles, for 0.1 nitric acid (HNO_3) impinger and probe solutions and washes, 1000-ml. Use screw-cap liners that are either rubber-backed Teflon* or leak-free and resistant to chemical attack by 0.1 N HNO_3. (Narrow mouth glass bottles have been found to be less prone to leakage.)

3.2.4 Graduated Cylinder and/or Balance. To measure condensed water to within 2 ml or 1 g. Use a graduated cylinder that has a minimum capacity of 500 ml, and subdivisions no greater than 5 ml. (Most laboratory balances are capable of weighing to the nearest 0.5 g or less.)

3.2.5 Funnel. Glass, to aid in sample recovery.

3.3 Analysis. The following equipment is needed:

3.3.1 Atomic Absorption Spectrophotometer. With lead hollow cathode lamp and burner for air/acetylene flame.

3.3.2 Hot Plate.

3.3.3 Erlenmeyer Flasks, 125-ml, 24/40 $.

3.3.4 Membrane Filters. Millipore SCWPO 4700 or equivalent.

3.3.5 Filtration Apparatus. Millipore vacuum filtration unit, or equivalent, for use with the above membrane filter.

3.3.6 Volumetric Flasks. 100-ml, 250-ml, and 1000-ml.

4. *Reagents.*

4.1 Sampling. The reagents used in sampling are as follows:

4.1.1 Filter. Gelman Spectro Grade, Reeve Angel 934 AH, MSA 1106 BH, all with lot assay for Pb, or other high-purity glass fiber filters, without organic binder, exhibiting at least 99.95 percent efficiency (<0.05 percent penetration) on 0.3 micron dioctyl phthalate smoke particles. Conduct the filter efficiency test using ASTM Standard Method D2986-71 (incorporated by reference—see § 60.17) or use test data from the supplier's quality control program.

4.1.2 Silica Gel, Crushed Ice, and Stopcock Grease. Same as Method 5, Section 3.1.2, 3.1.4, and 3.1.5, respectively.

4.1.3 Water. Deionized distilled, to conform to ASTM Specification D1193-77 (incorporated by reference—see § 60.17), Type 3. If high concentrations of organic matter are not expected to be present, the analyst may delete the potassium permanganate test for oxidizable organic matter.

4.1.4 Nitric Acid, 0.1 N. Dilute 6.5 ml of concentrated HNO_3 to 1 liter with deionized distilled water. (It may be desirable to run blanks before field use to eliminate a high blank on test samples.)

4.2 Pretest Preparation. 6 N HNO_3 is needed. Dilute 390 ml of concentrated HNO_3 to 1 liter with deionized distilled water.

4.3 Sample Recovery. 0.1 N HNO_3 (same as 4.1.4 above) is needed for sample recovery.

4.4 Analysis. The following reagents are needed for analysis (use ACS reagent grade chemicals or equivalent, unless otherwise specified):

4.4.1 Water. Same as 4.1.3 above.

4.4.2 Nitric Acid. Concentrated.

4.4.3 Nitric Acid, 50 percent (V/V). Dilute 500 ml of concentrated HNO_3 to 1 liter with deionized distilled water.

4.4.4 Stock Lead Standard Solution, 1000 μg Pb/ml. Dissolve 0.1598 g of lead nitrate [$Pb(NO_3)_2$] in about 60 ml of deionized distilled water, add 2 ml concentrated HNO_3, and dilute to 100 ml with deionized distilled water.

4.4.5 Working Lead Standards. Pipet 0.0, 1.0, 2.0, 3.0, 4.0, and 5.0 ml of the stock lead standard solution (4.4.4) into 250-ml volumetric flasks. Add 5 ml of concentrated HNO_3 to each flask and dilute to volume with deionized distilled water. These working standards contain 0.0, 4.0, 8.0, 12.0, 16.0, and 20.0 μg Pb/ml, respectively. Prepare, as needed, additional standards at other concentrations in a similar manner.

4.4.6 Air. Suitable quality for atomic absorption analysis.

4.4.7 Acetylene. Suitable quality for atomic absorption analysis.

4.4.8 Hydrogen Peroxide, 3 percent (V/V). Dilute 10 ml of 30 percent H_2O_2 to 100 ml with deionized distilled water.

5. *Procedure.*

5.1 Sampling. The complexity of this method is such that, in order to obtain reliable results, testers should be trained and experienced with the test procedures.

5.1.1 Pretest Preparation. Follow the same general procedure given in Method 5, Section 4.1.1, except the filter need not be weighed.

5.1.2 Preliminary Determinations. Follow the same general procedure given in Method 5, Section 4.1.2.

5.1.3 Preparation of Collection Train. Follow the same general procedure given in Method 5, Section 4.1.3, except place 100 ml of 0.1 HNO_3 in each of the first two impingers, leave the third impinger empty, and transfer approximately 200 to 300 g of preweighed silica gel from its container to the fourth impinger. Set up the train as shown in Figure 12-1.

5.1.4 Leak-Check Procedures. Follow the general leak-check procedures given in Method 5, Sections 4.1.4.1. (Pretest Leak-Check), 4.1.4.2 (Leak-Checks During the Sample Run), and 4.1.4.3 (Post-Test Leak-Check).

5.1.5 Sampling Train Operation. Follow the same general procedure given in Method 5, Section 4.1.5. For each run, record the data required on a data sheet such as the one shown in EPA Method 5, Figure 5-2.

5.1.6 Calculation of Percent Isokinetic. Same as Method 5, Section 4.1.6.

5.2 *Sample Recovery.* Begin proper cleanup procedure as soon as the probe is removed from the stack at the end of the sampling period.

Allow the probe to cool. When it can be safely handled, wipe off all external particulate matter near the tip of the probe nozzle and place a cap over it. Do not cap off the probe tip tightly while the sampling train is cooling down as this would create a vacuum in the filter holder, thus drawing liquid from the impingers into the filter.

Before moving the sampling train to the cleanup site, remove the probe from the sapling train, wipe off the silicone grease, and cap the open outlet of the probe. Be careful not to lose any condensate that might be present. Wipe off the silicone grease from the glassware inlet where the probe was fastened and cap the inlet. Remove the umbilical cord from the last impinger and cap the impinger. The tester may use ground-glass stoppers, plastic caps, or serum caps to close these openings.

Tranafer the probe and filter-impinger assembly to a cleanup area, which is clean and protected from the wind so that the chances of contaminating or losing the sample are minimized.

Inspect the train prior to and during disassembly and note any abnormal conditions. Treat the samples as follows:

5.2.1 *Container No. 1* (Filter). Carefully remove the filter from the filter holder and place it in its identified petri dish container. If it is necessary to fold the filter, do so such that the sample-exposed side is inside the fold. Carefully transfer to the petri dish any visible sample matter and/or filter fibers that adhere to the filter holder gasket by using a dry Nylon bristle brush and/or a sharp-edged blade. Seal the container.

5.2.2 *Container No. 2* (Probe). Taking care that dust on the outside of the probe or other exterior surfaces does not get into the sample, quantitatively recover sample matter or any condensate from the probe nozzle, probe fitting, probe liner, and front half of the filter holder by washing these components with 0.1 N HNO_3 and placing

*Mention of trade names or specific products does not constitute endorsement by the U.S. Environmental Protection Agency.

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the wash into a glass sample storage container. Measure and record (to the nearest 2-ml) the total amount of 0.1 N HNO_3 used for each rinse. Perform the 0.1 N HNO_3 rinses as follows:

Carefully remove the probe nozzle and rinse the inside surfaces with 0.1 N HNO_3 from a wash bottle while brushing with a stainless steel, Nylon-bristle brush. Brush until the 0.1 N HNO_3 rinse shows no visible particles, then make a final rinse of the inside surface.

Brush and rinse with 0.1 N HNO_3 the inside parts of the Swagelok fitting in a similar way until no visible particles remain.

Rinse the probe liner with 0.1 N HNO_3. While rotating the probe so that all inside surfaces will be rinsed with 0.1 N HNO_3, tilt the probe and squirt 0.1 N HNO_3 into its upper end. Let the 0.1 N HNO_3 drain from the lower end into the sample container. The tester may use a glass funnel to aid in transferring liquid washes to the container. Follow the rinse with a probe brush. Hold the probe in an inclined position, squirt 0.1 N HNO_3 into the upper end of the probe as the probe brush is being pushed with a twisting action through the probe; hold the sample container underneath the lower end of the probe and catch any 0.1 N HNO_3 and sample matter that is brushed from the probe. Run the brush through the probe three times or more until no visible sample matter is carried out with the 0.1 N HNO_3 and none remains on the probe liner on visual inspection. With stainless steel or other metal probes, run the brush through in the above prescribed manner at least six times, since metal probes have small crevices in which sample matter can be entrapped. Rinse the brush with 0.1 N HNO_3 and quantitatively collect these washings in the sample container. After the brushing make a final rinse of the probe as described above.

It is recommended that two people clean the probe to minimize loss of sample. Between sampling runs, keep brushes clean and protected from contamination.

After insuring that all joints are wiped clean of silicone grease, brush and rinse with 0.1 N HNO_3 the inside of the front half of the filter holder. Brush and rinse each suface three times or more, if needed, to remove visible sample matter. Make a final rinse of the brush and filter holder. After all 0.1 N HNO_3 washings and sample matter are collected in the sample container, tighten the lid on the sample container so that the fluid will not leak out when it is shipped to the laboratory. Mark the height of the fluid level to determine whether leakage occurs during transport. Label the container to clearly identify its contents.

5.2.3 *Container No. 3* (Silica Gel). Check the color of the indicating silica gel to determine if it has been completely spent and make a notation of its condition. Transfer the silica gel from the fourth impinger to the original container and seal. The tester may use a funnel to pour the silica gel and a rubber policeman to remove the silica gel from the impinger. It is not necessary to remove the small amount of particles that may adhere to the walls and are difficult to remove. Since the gain in weight is to be used for moisture calculations, do not use any water or other liquids to transfer the silica gel. If a balance is available in the field, the tester may follow procedure for Container No. 3 under Section 5.4 (Analysis).

5.2.4 *Container No. 4* (Impingers). Due to the large quantity of liquid involved, the tester may place the impinger solutions in several containers. Clean each of the first three impingers and connecting glassware in the following manner:

1. Wipe the impinger ball joints free of silicone grease and cap the joints.

2. Rotate and agitate each impinger, so that the impinger contents might serve as a rinse solution.

3. Transfer the contents of the impingers to a 500-ml graduated cylinder. Remove the outlet ball joint cap and drain the contents through this opening. Do not separate the impinger parts (inner and outer tubes) while transferring their contents to the cylinder. Measure the liquid volume to within ±2 ml. Alternatively, determine the weight of the liquid to within ±0.5 g. Record in the log the volume or weight of the liquid present, along with a notation of any color or film observed in the impinger catch. The liquid volume or weight is needed, along with the silica gel data, to calculate the stack gas moisture content (see Method 5, Figure 5-3).

4. Transfer the contents to Container No. 4.

5. Note: In steps 5 and 6 below, measure and record the total amount of 0.1 N HNO_3 used for rinsing. Pour approximately 30 ml of 0.1 N HNO_3 into each of the first three impingers and agitate the impingers. Drain the 0.1 N HNO_3 through the outlet arm of each impinger into Container No. 4. Repeat this operation a second time; inspect the impingers for any abnormal conditions.

6. Wipe the ball joints of the glassware connecting the impingers free of silicone grease and rinse each piece of glassware twice with 0.1 N HNO_3; transfer this rinse into Container No. 4. (*Do not rinse or brush the glass-fritted filter support.*) Mark the height of the fluid level to determine whether leakage occurs during transport. Label the container to clearly identify its contents.

5.2.5 Blanks. Save 200 ml of the 0.1 N HNO_3 used for sampling and cleanup as a blank. Take the solution directly from the bottle being used and place into a glass sample container labeled "0.1 N HNO_3 blank."

5.3 Sample Preparation.

5.3.1 *Container No. 1* (Filter). Cut the filter into strips and transfer the strips and all loose particulate matter into a 125-ml Erlenmeyer flask. Rinse the petri dish with 10 ml of 50 percent HNO_3 to insure a quantitative transfer and add to the flask. (Note: If the total volume required in Section 5.3.3 is expected to exceed 80 ml, use a 250-ml Erlenmeyer flask in place of the 125-ml flask.)

5.3.2 *Containers No. 2 and No. 4* (Probe and Impingers). (Check the liquid level in Containers No. 2 and/or No. 4 and confirm as to whether or not leakage occurred during transport; note observation on the analysis sheet. If a noticeable amount of leakage had occurred, either void the sample or take steps, subject to the approval of the Administrator, to adjust the final results.) Combine the contents of Containers No. 2 and No. 4 and take to dryness on a hot plate.

5.3.3 Sample Extraction for lead. Based on the approximate stack gas particulate concentration and the total volume of stack gas sampled, estimate the total weight of particulate sample collected. Then transfer the residue from Containers No. 2 and No. 4 to the 125-ml Erlenmeyer flask that contains the filter using rubber policeman and 10 ml of 50 percent HNO_3 for every 100 mg of sample collected in the train or a minimum of 30 ml of 50 percent HNO_3, whichever is larger.

Place the Erlenmeyer flask on a hot plate and heat with periodic stirring for 30 min at a temperature just below boiling. If the sample volume falls below 15 ml, add more 50 percent HNO_3. Add 10 ml of 3 percent H_2O_2 and continue heating for 10 min. Add 50 ml of hot (80°C) deionized distilled water and heat for 20 min. Remove the flask from the hot plate and allow to cool. Filter the sample through a Millipore membrane filter or equivalent and transfer the filtrate to a 250-ml volumetric flask. Dilute to volume with deionized distilled water.

5.3.4 Filter Blank. Determine a filter blank using two filters from each lot of filters used in the sampling train. Cut each filter into strips and place each filter in a separate 125-ml Erlenmeyer flask. Add 15 ml of 50 percent HNO_3, and treat as described in Section 5.3.3 using 10 ml of 3 percent H_2O_2 and 50 ml of hot, deionized distilled water. Filter and dilute to a toal volume of 100 ml using deionized, distilled water.

5.3.5 0.1 N HNO_3 Blank. Take the entire 200 ml of 0.1 N HNO_3 to dryness on a steam bath, add 15 ml of 50 percent HNO_3, and treat as described in Section 5.3.3 using 10 ml of 3 percent H_2O_2 and 50 ml of hot,

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deionized distilled water. Dilute to a total volume of 100 ml using deionized distilled water.

5.4 Analysis.

5.4.1 Lead Determination. Calibrate the spectrophotometer as described in Section 6.2 and determine the absorbance for each source sample, the filter blank, and 0.1 N HNO_3 blank. Analyze each sample three times in this manner. Make appropriate dilutions, as required, to bring all sample Pb concentrations into the linear absorbance range of the spectrophotometer.

If the Pb concentration of a sample is at the low end of the calibration curve and high accuracy is required, the sample can be taken to dryness on a hot plate and the residue dissolved in the appropriate volume of water to bring it into the optimum range of the calibration curve.

5.4.2 Check for Matrix Effects on the Lead Results. Since the analysis for Pb by atomic absorption is sensitive to the chemical composition and to the physical properties (viscosity, pH) of the sample (matrix effects), the analyst shall check at least one sample from each source using the method of additions as follows:

Add or spike an equal volume of standard solution to an aliquot of the sample solution, then measure the absorbance of the resulting solution and the absorbance of an aliquot of unspiked sample.

Next, calculate the Pb concentration C, in $\mu g/ml$ of the sample solution by using the following equation:

$$C_s = C_a \frac{A_s}{A_t - A_s} \qquad \text{Eq. 12-1}$$

Where:

C_s = Pb concentration of the standard solution, $\mu g/ml$.

A_s = Absorbance of the sample solution.

A_t = Absorbance of the spiked sample solution.

Volume corrections will not be required if the solutions as analyzed have been made to the same final volume. Therefore, C_s and C_a represent Pb concentration before dilutions.

Method of additions procedures described on pages 9-4 and 9-5 of the section entitled "General Information" of the Perkin Elmer Corporation Atomic Absorption Spectrophotometry Manual, Number 303-0152 (see Section 9.1) may also be used. In any event, if the results of the method of additions procedure used on the single source sample do not agree to within 5 percent of the value obtained by the routine atomic absorption analysis, then reanalyze all samples from the source using a method of additions procedure.

5.4.3 *Container No. 3* (Silica Gel). The tester may conduct this step in the field. Weigh the spent silica gel (or silica gel plus impinger) to the nearest 0.5 g; record this weight.

6. *Calibration.*

Maintain a laboratory log of all calibrations.

6.1 Sampling Train Calibration. Calibrate the sampling train components according to the indicated sections of Method 5: Probe Nozzle (Section 5.1); Pitot Tube (Section 5.2); Metering System (Section 5.3); Probe Heater (Section 5.4); Temperature Gauges (Section 5.5); Leak-Check of the Metering System (Section 5.6); and Barometer (Section 5.7).

6.2 Spectrophotometer. Measure the absorbance of the standard solutions using the instrument settings recommended by the spectrophotometer manufacturer. Repeat until good agreement (±3 percent) is obtained between two consecutive readings. Plot the absorbance (y-axis) versus concentration in μg Pb/ml (x-axis). Draw or compute a straight line through the linear portion of the curve. Do not force the calibration curve through zero, but if the curve does not pass through the origin or at least lie closer to the origin than ±0.003 absorbance units, check for incorrectly prepared standards and for curvature in the calibration curve.

To determine stability of the calibration curve, run a blank and a standard after every five samples and recalibrate, as necessary.

7. *Calculations.*

7.1 Dry Gas Volume. Using the data from this test, calculate $V_{m(std)}$, the total volume of dry gas metered corrected to standard conditions (20°C and 760 mm Hg), by using Equation 5-1 of Method 5. If necessary, adjust $V_{m(std)}$ for leakages as outlined in Section 6.3 of Method 5. See the field data sheet for the average dry gas meter temperature and average orifice pressure drop.

7.2 Volume of Water Vapor and Moisture Content. Using data obtained in this test and Equations 5-2 and 5-3 of Method 5, calculate the volume of water vapor $V_{w(std)}$ and the moisture content B_{ws} of the stack gas.

7.3 Total Lead in Source Sample. For each source sample correct the average absorbance for the contribution of the filter blank and the 0.1 N HNO_3 blank. Use the calibration curve and this corrected absorbance to determine the μg Pb concentration in the sample aspirated into the spectrophotometer. Calculate the total Pb content C'_{Pb} (in μg) in the original source sample; correct for all the dilutions that were made to bring the Pb concentration of the sample into the linear range of the spectrophotometer.

7.4 Lead Concentration. Calculate the stack gas Pb concentration C_{Pb} in mg/dscm as follows:

$$C_{Pb} = K \frac{C'_{Pb}}{V_{m(std)}} \qquad \text{Eq. 12-2}$$

Where:

K = 0.001 mg/μg for metric units.

= 2.205 lb/$\mu g \times 10^{-9}$ for English units.

7.5 Isokinetic Variation and Acceptable Results. Same as Method 5, Sections 6.11 and 6.12, respectively. To calculate v_s, the average stack gas velocity, use Equation 2-9 of Method 2 and the data from this field test.

8. *Alternative Test Methods for Inorganic Lead.*

8.1 Simultaneous Determination of Particulate and Lead Emissions. The tester may use Method 5 to simultaneously determine Pb provided that (1) he uses acetone to remove particulate from the probe and inside of the filter holder as specified by Method 5, (2) he uses 0.1 N HNO_3 in the impingers, (3) he uses a glass fiber filter with a low Pb background, and (4) he treats and analyzes the entire train contents, including the impingers, for Pb as described in Section 5 of this method.

8.2 Filter Location. The tester may use a filter between the third and fourth impinger provided that he includes the filter in the analysis for Pb.

8.3 In-stack Filter. The tester may use an in-stack filter provided that (1) he uses a glass-lined probe and at least two impingers, each containing 100 ml of 0.1 N HNO_3, after the in-stack filter and (2) he recovers and analyzes the probe and impinger contents for Pb. Recover sample from the nozzle with acetone if a particulate analysis is to be made.

9. Bibliography

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9.4 Mitchell, W.J. and M.R. Midgett. Determining Inorganic and Alkyl Lead Emissions from Stationary Sources. U.S. Environmental Protection Agency, Emission Monitoring and Support Laboratory. Research Triangle Park, N.C. (Presented at National APCA Meeting, Houston. June 26, 1978).

9.5 Same as Method 5, Citations 2 to 5 and 7 of Section 7.