AP-42 Section 9.13.4
Reference 8
Report Sect.
Reference

FINAL TEST REPORT
FOR
FERMENTER NO. 5

SEP 5 1990

PREPARED FOR

AMERICAN YEAST
8215 BEACHWOOD ROAD
BALTIMORE, MARYLAND 21222

AUGUST 1990

GANNETT FLEMING, INC.
SUITE 200, EAST BLOCK QUADRANGLE
VILLAGE OF CROSS KEYS
BALTIMORE, MARYLAND 21210

Gannett Fleming
ENGINEERS AND PLANNERS

GANNETT FLEMING, INC.
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East Quadrangle
The Village of Cross Keys
Baltimore, MD 21210
Fax: (301) 433-6520
Office: (301) 433-8832

August 31, 1990

Mr. Brooks H. Stafford
Bureau of Air Quality Management
401 Bosley Avenue
Towson, Maryland 21204

Re: American Yeast Fermenter No. 5

Dear Mr. Stafford:

Gannett Fleming conducted an air emissions test at American Yeast on August 16 and 17. The tests were observed by Mr. S. David Ross of your staff and Mr. Pars Ramnarain of the State Air Management Administration. Enclosed are results of that test. If you have any questions, please do not hesitate to call me at 433-8832.

Very truly yours,

GANNETT FLEMING, INC.

Richard Hergenroeder, P.E.
Project Manager

RH/cr

Enclosure

cc: L. Baugh, American Yeast
M. Kindig, Gannett Fleming

GF: 26981.000

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1.0 INTRODUCTION

Gannett Fleming, Inc. conducted a field test to sample and analyze stack gas emitted from Fermenter Number 5 at the American Yeast facility in Baltimore County, Maryland on August 16, 1990. Tests were conducted to demonstrate compliance with Baltimore County and State air quality regulations. Volatile Organic Carbon (VOC) was measured with a flame ionization analyzer employing U.S. EPA Reference Method (RM) 25A. American Yeast estimates that Fermenter Number 5 emits a maximum of 15 pounds per day of VOCs which is composed of 95 per cent ethanol and 5 per cent acetaldehyde. Preliminary tests conducted by Gannett Fleming indicated that 6.5 pounds of VOC were emitted per day which included 0.8 pounds of acetaldehyde. Additional tests were run on August 16, 1990 to confirm the preliminary results.

1.1 TEST PURPOSE

The purpose of these tests was to determine regulatory compliance of the emission rates with respect to VOCs from Fermenter Number 5. Maryland air toxic regulations (COMAR 26.11.15) require American Yeast to report their emissions of acetaldehyde, a class 1 toxic air pollutants (TAPs). Maryland General Emissions Standards, Prohibitions and Restrictions (COMAR 26.11.06) also requires reports of VOCs emissions. Ethanol is not covered by the TAPs regulations.

1.2 TEST LOCATION AND PROCESS

American Yeast's facility located in Beachwood Road, Baltimore, Maryland, is an unclassified industry, thus being subject to the general air quality standards described in COMAR 26.11.06 and COMAR 26.11.15, as discussed above. Fermenter Number 5 is a state-of-the-art yeast production unit. The fermenter design results in significantly lower VOC emissions than found in more traditional designs.

Fermenter Number 5 is operated over a 14-hour batch with one fermentation per day. The unit requires approximately one hour for feeding and start-up. After approximately another hour of operation, the fermenter reaches equilibrium and operates at this level for the remaining 12 hours of the cycle. During the operation, waste gases are vented to the outside air through ductwork at approximately 5,000 cubic feet per minute (cfm).

1.3 TEST DATES

The field tests were performed by Gannett Fleming personnel on August 16 and 17, 1990.

1.4 POLLUTANTS TESTED

The field tests were performed for VOCs by a flame ionization analyzer, employing U.S. EPA RM 25A.

1.5 OBSERVER'S NAMES (INDUSTRY AND AGENCY)

Baltimore County, Bureau of Air Quality Management
S. David Ross - Engineer
State of Maryland, Air Management Administration
Pars Ramnarain - Engineer
Gannett Fleming, Inc.
Scott Furlong - Test Technician
Walter Koehler - Test Technician

2.0 SUMMARY OF RESULTS

2.1 EMISSION RESULTS

American Yeast's emissions estimates are compared to Gannett Fleming's preliminary test results and final test results in Table 2-1. Data for VOC, ethanol, acetaldehyde, and air flow are shown. The calculations and raw data forming the basis of this table are found in Section 4.0 and Appendix A, respectively. In the final field tests, the average air flow rate was 4570 cfm and the VOC emissions rate was 4.84 lbs/day.

2.2 ALLOWABLE EMISSIONS

According to the State of Maryland Air Management Administration Regulations COMAR 26.11.06B(2), emissions rate should not exceed 20 lbs/day. The emission rates from each method shown in Table 2-1 are within this range.

2.3 DESCRIPTION OF COLLECTED SAMPLES

The samples were collected under the referenced EPA field methods for VOCs.

2.4 MEASUREMENT ERRORS

The VOCs sampling was within 3.9% measurement error according to the beginning and ending of potentiometer settings.

2.5 PREVIOUS TEST RESULTS

Gannett Fleming conducted preliminary tests to estimate the mass of VOCs, ethanol and acetaldehyde. A test report was submitted to Baltimore County on March 10, 1990, that provided the following results:

- Acetaldehyde emissions were less than 3 micrograms per liter and less than 0.8 pounds per day.

TABLE 2-1

SUMMARY RESULTS OF FIELD TESTS

PLANT NAME: AMERICAN YEAST
LOCATION: FERMENTER NUMBER 5

Tests/Parameter	VOC (lbs/day)	Ethanol (lbs/day)	Acetaldehyde (lbs/day)	Air Flow (cfm)
American Yeast Estimate	15	14.25	0.75	5,000
Gannett Fleming Preliminary Test	< 6.5	--	< 0.8	--
Gannett Fleming Final Test	4.84	--	--	4,570

- VOC emissions were approximately 25 micrograms per liter or 6.5 pounds per day.
- Ethanol was measured, but results were inconclusive, since humidity interfered with sampling efficiency.

3.0 SAMPLING AND ANALYSIS PROCEDURES

3.1 SAMPLING PORT LOCATION

The air flow was measured at the inlet to Fermenter Number 5. Sample gases were extracted from fermenter outlet at the top of the fermenter.

3.2 SAMPLE TRAIN DESCRIPTION

The sampling train employed to measure VOCs in the gas stream was provided by Gannett Fleming in compliance with U.S. EPA Reference Method R 25A.

3.3 SAMPLING PROCEDURES

Air flow was determined by the existing flow meter currently in use. The meter provides a continuous digital reading at the inlet to the fermenter. It became operational in February 1990 after calibration in January 1990 by the Superior Measurement Equipment Company against American National Standard Institute Standard Number ANSI/API 2530-1985. The method for determining air flow was a change from the original test protocol because of safety concerns.

The temperature of the fermenter exhaust stream was determined using a thermocouple and readout device. The VOC content of the exhaust stream was determined by extracting a sample of gas from the duct for the duration of the 14-hour batch cycle. Zero and span gas calibrations were performed every hour.

3.4 ANALYTICAL PROCEDURES

The analytical procedures to determine the concentration of VOCs and air flow are referenced to U.S. EPA RM 25A. The exhaust stream from Fermenter Number 5 was sampled with Flame Ionization detectors (FID) following the procedures outlined in EPA Reference Method 25A (40 CFR, Part 50, App. A) (see attached copy of Reference Method 25A). JUM Model portable FIDs was calibrated for a range of 0-100 ppm. Strip chart recorders continuously recorded analyzer output. Quality assurance consisted of zero, and calibration span gas passes every hour of sampling. The primary span gases consisted of various concentrations of propane in air. In addition, the response curves were developed in a controlled laboratory environment, and after each instrument had been calibrated with a primary calibrant gas (propane in air).

4.0 RESULTS AND CALCULATIONS

4.1 TEST RESULTS

Test results of air flow rate (cfm) and VOCs concentration (ppm) in the test period were presented in Table 4-1. In the table, the generation rate of VOCs as propane was calculated by the concentration of VOCs and flow rate in each test period. From the table, the total amount of VOCs generated in each shift or over the 14-hour batch is 4.84 pounds. Since the plant has only one batch per day, the generation rate for VOCs is 4.84 lbs/day.

4.2 CALCULATION OF VOCs AS PROPANE

VOC was reported as propane the calibrant gas. An example calculation for the period 7 to 8 p.m. is shown below.

$$66.9 \text{ ppm} \times 10^{-6} \times 44.096 \frac{\text{lb-propane}}{\text{lb-mole}} \times \frac{1 \text{ lb-mole}}{385.1 \text{ ft}^3} \times 4743 \frac{\text{ft}^3}{\text{min}} \times 60 \frac{\text{min}}{\text{hr}}$$

$=$ 2.17 lb/hr VOC as propane

where 385.1 ft^3 is the standard volume for 1 lb-mole of propane at actual conditions.

4.3 CALCULATION OF THE MASS OF ACETALDEHYDE

Acetaldehyde constitutes 12 percent of the total measured VOCs according to previous results. Therefore, total amount of acetaldehyde can be estimated as:

$$4.84 \text{ lbs/day} \times 0.12 = 0.58 \text{ lbs/day}$$

Since the mass of aldehyde is 0.58 lbs/day, the ethanol and other VOCs will be the difference, approximately 4.26 lbs/day.

TABLE 4-1

RESULTS OF VOCs AND AIR FLOW ON AUGUST 21 and 22, 1990

24 hours = 1 day

Test Period	VOC (ppm)	Flow Rate (ft^3/min)	VOC (lb/hr)
1900	66.9	4743.0	2.17
2000	12.5	4743.0	0.41
2100	7.4	4714.7	0.24
2200	6.0	4681.2	0.19
2300	3.9	4682.3	0.13
2400	2.4	4647.7	0.07
0100	3.6	4609.5	0.11
0200	5.8	4575.7	0.18
0300	6.0	4575.9	0.19
0400	11.0	4532.6	0.34
0500	4.6	4481.8	0.14
0600	14.0	4426.5	0.43
0700	5.6	4331.3	0.17
0800	2.5	4240.8	0.07
0900	END TEST		

Avg = 4566 ft^3/min

4.84 lbs/day

63.

(4566 ft^3/min (0.02832 m^3/ft^3 (60 min/hr [illegible] = [illegible] 212 m^3

4.4 CALCULATION OF PER CENT ERROR

The percent error is based on the potentiometer (pot) setting and is calculated by the following formula:

$$\text{percent error} = \frac{\text{beginning pot setting} - \text{ending pot setting}}{\text{beginning pot setting}}$$

$$\text{Therefore, \% error} = \frac{333-320}{333} \times 100\% = 3.9\%$$

This percent error is equivalent to 0.19 lbs/day.

APPENDIX A

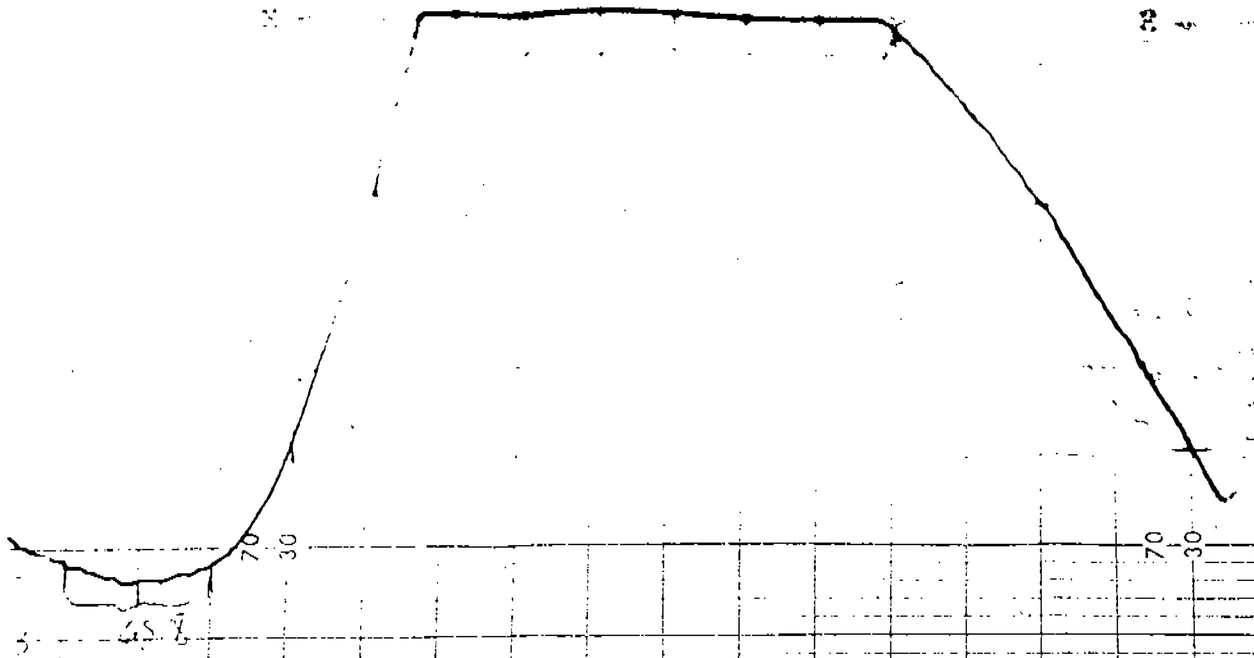
SUMMARY OF FIELD DATA

```
atch# E-930
et on : Thu Aug 16  1990

ime                 AIR(MCM)             Temp(DegC)

 0.1                 133.0                  30.00
10.5                 134.4                  30.51
20.1                 135.1                  30.47
30.3                 135.6                  30.37
40.3                 135.0                  30.24
50.3                 132.5                  30.03
60.1                 134.9                  29.86
70.0                 135.1                  29.83
80.5                 132.2                  29.80
90.1                 133.5                  29.80
00.1                 134.1                  29.86
10.2                 133.8                  30.00
20.4                 135.6                  30.07
30.4                 133.3                  30.34
40.6                 134.0                  30.88
50.4                 133.1                  31.32
60.5                 134.1                  31.49
70.0                 132.9                  31.42
80.1                 134.0                  31.15
90.2                 134.0                  31.02
00.5                 131.6                  30.92
10.1                 133.1                  30.81
20.1                 132.7                  30.71
30.1                 131.0                  30.78
40.3                 133.5                  30.68
50.2                 133.7                  30.61
60.1                 132.4                  30.54
70.6                 132.8                  30.64
80.5                 131.6                  30.68
90.1                 131.6                  30.75
00.1                 132.0                  30.95
10.3                 132.2                  31.22
20.3                 130.4                  31.66
30.0                 130.0                  32.31
40.4                 132.8                  32.41
50.5                 132.8                  32.34
60.4                 130.7                  32.10
70.5                 129.9                  32.10
80.5                 130.4                  32.07
90.5                 130.8                  31.90
00.1                 130.3                  31.83
10.1                 131.9                  31.70
20.1                 130.4                  31.63
30.1                 129.8                  31.66
40.1                 131.0                  31.76
50.0                 128.8                  31.93
60.5                 129.3                  32.27
70.0                 129.6                  32.48
80.5                 129.5                  32.68
90.0                 128.6                  32.64
00.0                 129.0                  32.41
10.1                 127.8                  32.31
20.1                 128.4                  31.56
30.6                 128.4                  30.95
40.1                 127.6                  30.51
50.0                 125.7                  30.03
60.5                 127.1                  29.63
70.4                 126.1                  29.59
80.0                 127.1                  30.24
90.2                 126.6                  31.59
00.1                 125.0                  32.54
10.2                 125.9                  33.12
20.5                 127.1                  33.63
30.2                 125.9                  33.83
40.3                 126.6                  34.07
50.3                 123.4                  34.14
60.3                 127.3                  34.10
```

```
70.5          125.1          34.24
80.5          124.9          34.10
90.1          125.5          34.04
00.2          125.9          33.97
10.3          123.9          33.87
20.1          121.2          33.83
30.2          123.9          33.76
40.5          122.3          33.70
50.5          123.5          33.19
60.4          122.8          32.85
70.4          122.7          32.71
80.0          117.4          32.64
90.5          120.3          32.54
00.2          121.5          32.54
10.4          120.5          32.54
20.3          120.5          32.51
30.5          120.2          32.51
40.1          120.8          32.58
```



analysis exceeds scale
for 6.5 minutes
recording made as
follows

1

2

3

4

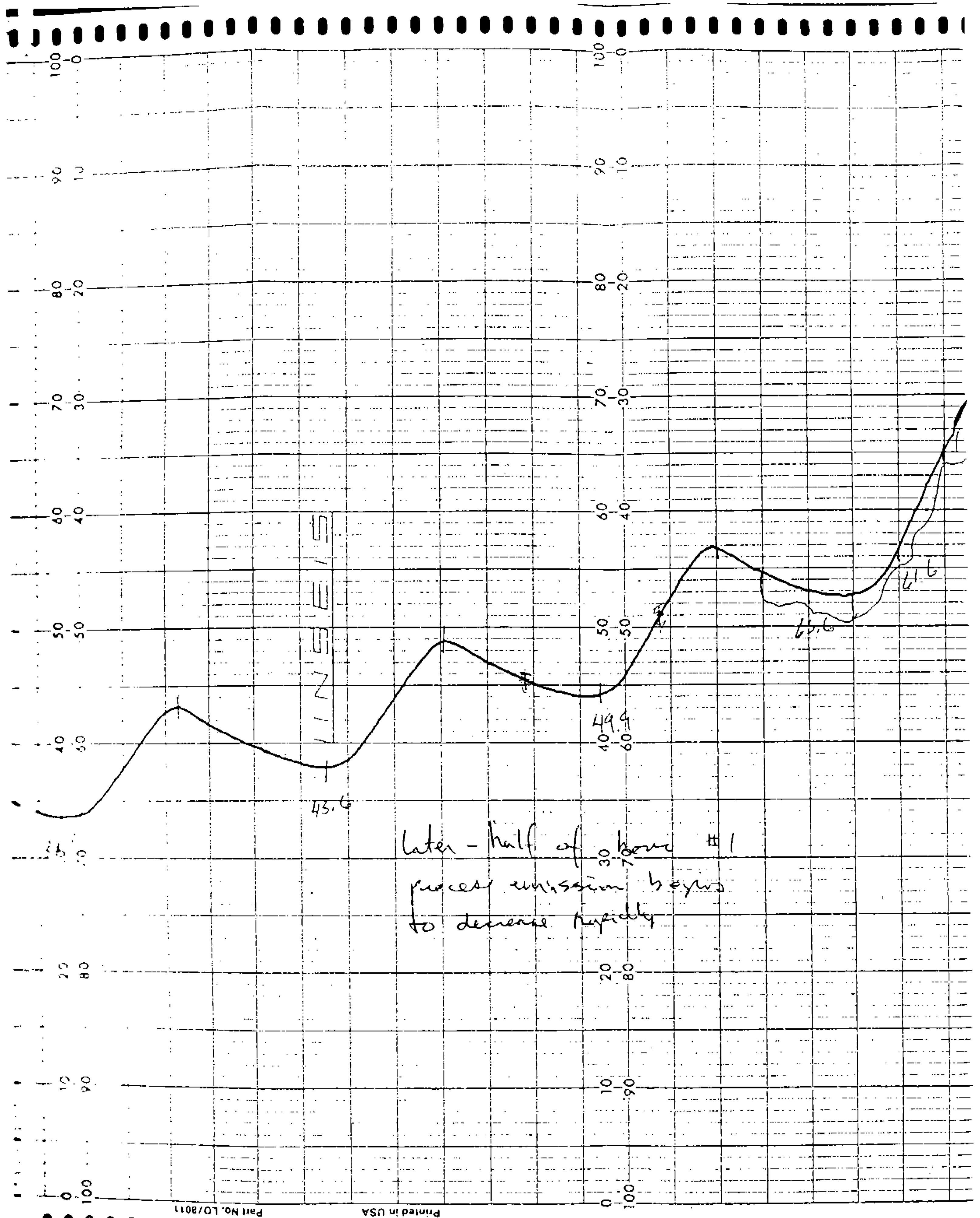
5

6

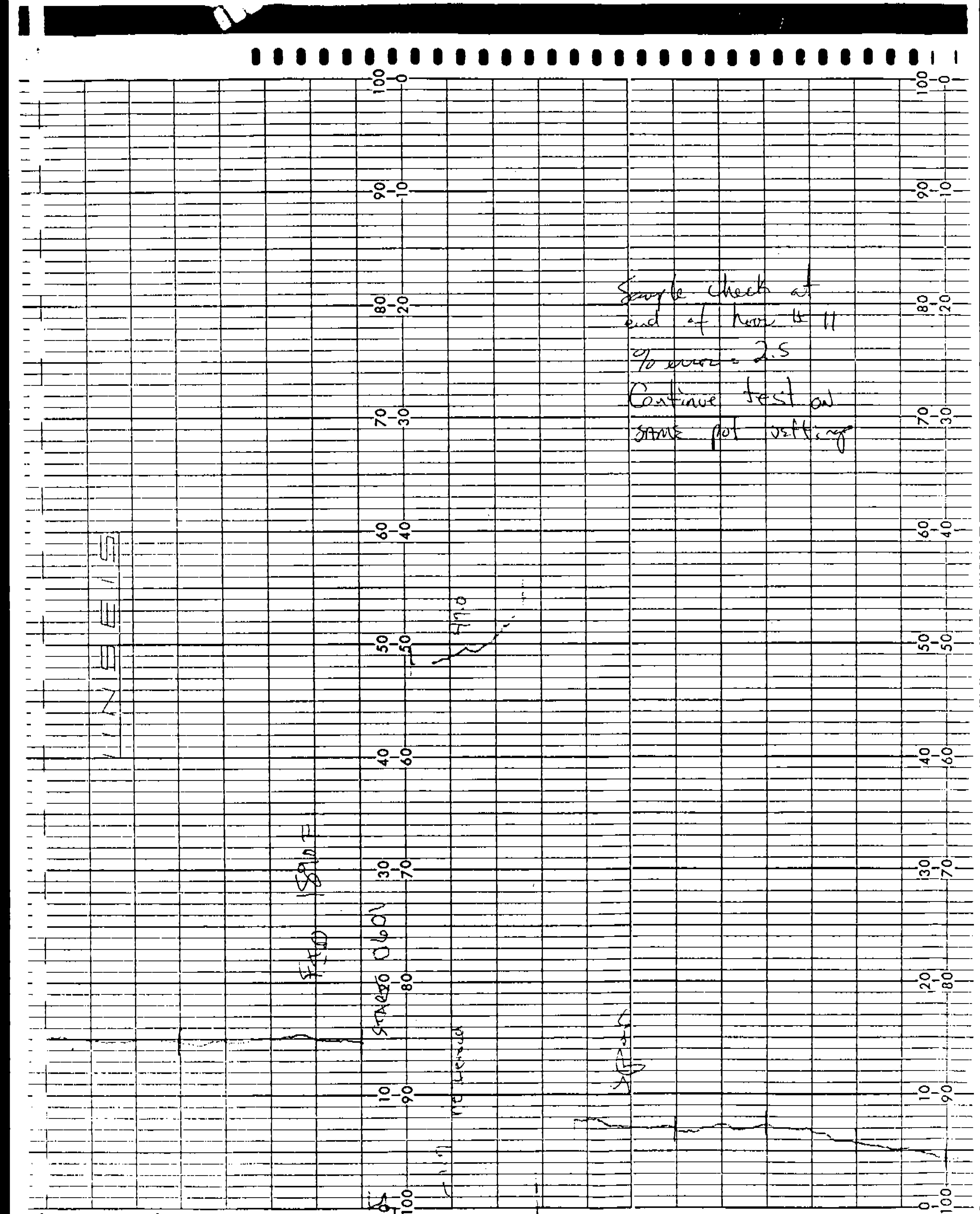
TEST DATA

1900–2400 16 AUG 90

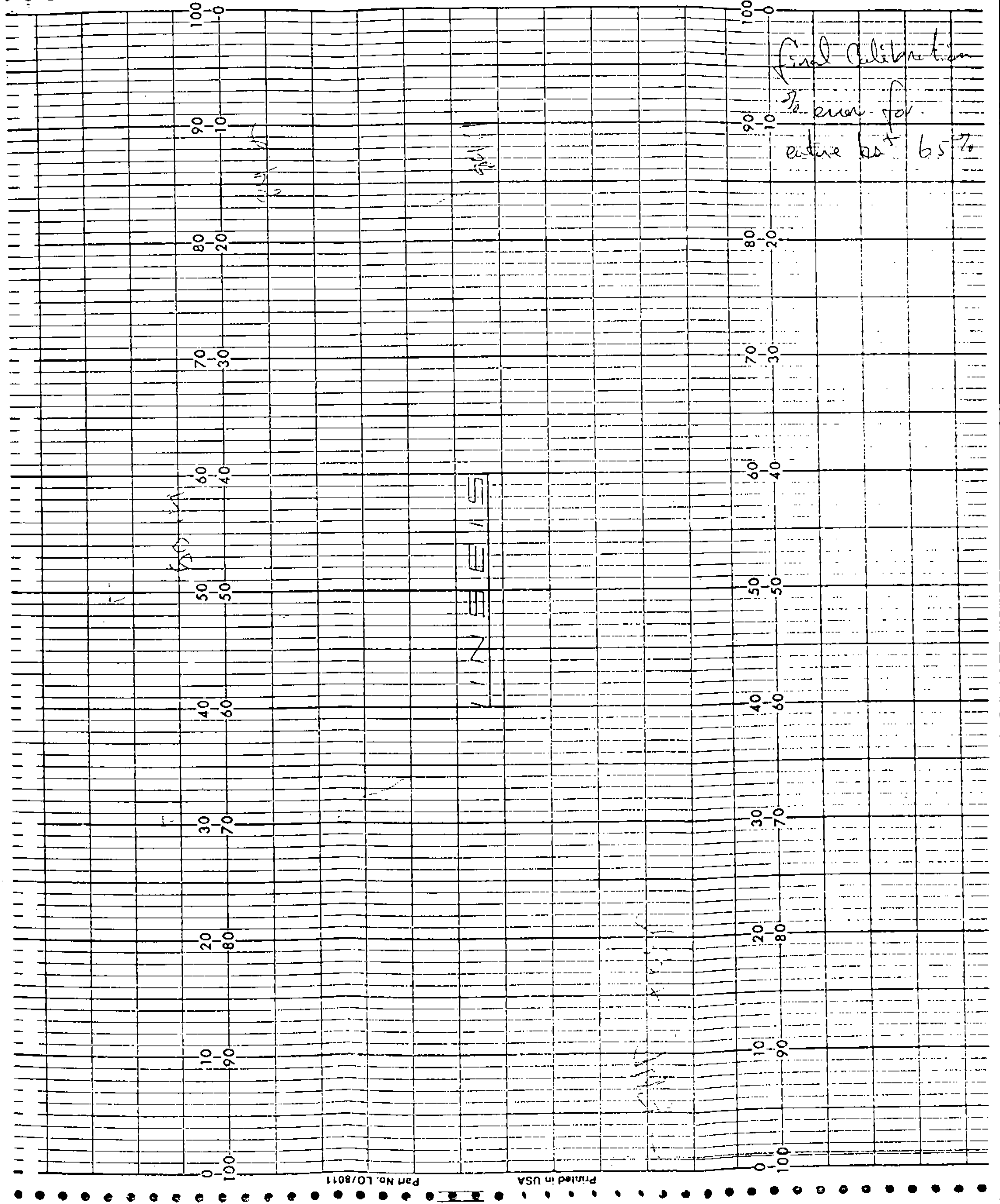
Job # 26181.000 Ametek



later - half of hour #1
process emission begins
to decrease rapidly



Sample check at
end of hour # 11
% error = 2.5
Continue test on
same pot setting



Final Calibration
% error for
entire test 65%

Method 25A
V.O.C. Sampling

Operator : [illegible]
Date : 15 AUG 95
Job No. : 2034.003
F.I.D. No.: 1432

Visual Checks

1.) F.I.D. Temp. 157 °F
2.) Sample Pressure 3 psi
3.) Recorder ✓
4.) Sampling line temperature _____ °F
5.) Barometric Pressure _____
6. Ambient Temperature _____

Tanks:

Gas Nomenclature	Gas Concentration	Tank* Pressure	Tank* Outlet Pressure	Comments
	0	275	—	
	30.4		—	
	60.3		—	
	~~84~~ 89.7		—	
	—			

Stack Parameters
At Sampling Point

Stack Number	Velocity (fpm)	Temp.	Static Pressure	Stack dia.	Stack Description
	Obtained	From	[illegible] at	0900	17 Aug 95

*Note: Span gas should be @ 15 psi
Fuel gas should be @ 43 psi

APPENDIX B

CALIBRATION PROCEDURES AND RESULTS

Koegel [illegible] STATE [illegible] PROCESS

Multicalibration Points

	Zero (<.1%)* Span	Low (25-35%)* Level Span	Mid (45-55%)* Level Span	High (80-90%)* Level Span	Pot Setting Zero	Pot Setting Span	Range Selection	Time Start	Time Finish
Pre-Test	0.00	30.4	50.8	80.8	[illegible]	393	2	1000	[illegible]
Post-Test	0.01	30.4	49.5		335	304	2	0800	0805

Span Checks

~~Test~~ Stack No.	Zero Span**	Mid Level Span**	Time Start	Time Finish	Pot Setting Zero	Pot Setting Span	Range Selection
1	13.3	66.3	2000		[illegible]	388	2
1			2100		330	340	2
1	-0.15	54.1	2200		300	320	2
1	-0.14	54.5	2300		334	304	2
	0.01	45.9	2400		334	304	2
			[illegible]		341	272	2
	-0.0[illegible]	44.5	[illegible]		~~334~~ 335	~~35[illegible]~~ 304	2

[illegible]

Excessive fluctuations - [illegible]
[illegible]
[illegible]
Cal. 200 - 0.02% = [illegible]

* - Calibration Error <±5% of Span gas concentration.
** - Drift <±3% of Span value.

Multicalibration Points

	Zero (<.1%)* Span	Low (25-35%)* Level Span	Mid (45-55%)* Level Span	High (80-90%)* Level Span	Pot Setting Zero	Pot Setting Span	Range Selection	Time Start	Time Finish
Pre-Test	0.00	30.7	50.3	[illegible]	343 3[illegible]	280 33[illegible]	2	0800	0805
Post-Test	0.00	30.5	50.4	84.7	370	3[illegible]	2	0900	0905

[illegible]

Span Checks

~~Test~~ Start No.	Zero Span**	Mid Level Span**	Time Start	Time Finish	Pot Setting Zero	Pot Setting Span	Range Selection
1	+3.1	4[illegible]	08[illegible]	[illegible]	343	[illegible]	2
1	-1.1	50.3	[illegible]	[illegible]	343	280	2
	-1.1	5[illegible]	[illegible]	[illegible]	360	280	2
	-1.7	49.0	[illegible]	[illegible]	373	280	2
	-0.9	49.[illegible]	[illegible]	[illegible]	351	280	2
	+0.[illegible]	4[illegible]	0800	0805	370	283	2
	0.00		0900		370		2

Fermentor [illegible] process unit at [illegible]
Caused by peak of 21.4 ppm – FID accurate to
± .2% at time of [illegible]

* - Calibration Error <±5% of Span gas concentration.
** - Drift <±3% of Span value.

APPENDIX C

U.S. EPA REFERENCE METHOD (RM) 25A

Method 25A—Determination of Total Gaseous Organic Concentration Using a Flame Ionization Analyzer

1. *Applicability and Principle*

1.1 Applicability. This method applies to the measurement of total gaseous organic concentration of vapors consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons). The concentration is expressed in terms of propane (or other appropriate organic calibration gas) or in terms of carbon.

1.2 Principle. A gas sample is extracted from the source through a heated sample line, if necessary, and glass fiber filter to a flame ionization analyzer (FIA). Results are reported as volume concentration equivalents of the calibration gas or as carbon equivalents.

2. *Definitions*

2.1 Measurement System. The total equipment required for the determination of the gas concentration. The system consists of the following major subsystems:

2.1.1 Sample Interface. That portion of the system that is used for one or more of the following: sample acquisition, sample transportation, sample conditioning, or protection of the analyzer from the effects of the stack effluent.

2.1.2 Organic Analyzer. That portion of the system that senses organic concentration and generates an output proportional to the gas concentration.

2.2 Span Value. The upper limit of a gas concentration measurement range that is specified for affected source categories in the applicable part of the regulations. The span value is established in the applicable regulation and is usually 1.5 to 2.5 times the applicable emission limit. If no span value is provided, use a span value equivalent to 1.5 to 2.5 times the expected concentration. For convenience, the span value should correspond to 100 percent of the recorder scale.

2.3 Calibration Gas. A known concentration of a gas in an appropriate diluent gas.

2.4 Zero Drift. The difference in the measurement system response to a zero level calibration gas before and after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

2.5 Calibration Drift. The difference in the measurement system response to a mid-level calibration gas before and after a stated period of operation during which no unscheduled maintenance, repair or adjustment took place.

2.6 Response Time. The time interval from a step change in pollutant concentration at the inlet to the emission measurement system to the time at which 95 percent of the corresponding final value is reached as displayed on the recorder.

2.7 Calibration Error. The difference between the gas concentration indicated by the measurement system and the known concentration of the calibration gas.

3. *Apparatus*

A schematic of an acceptable measurement system is shown in Figure 25A-1. The essential components of the measurement system are described below:

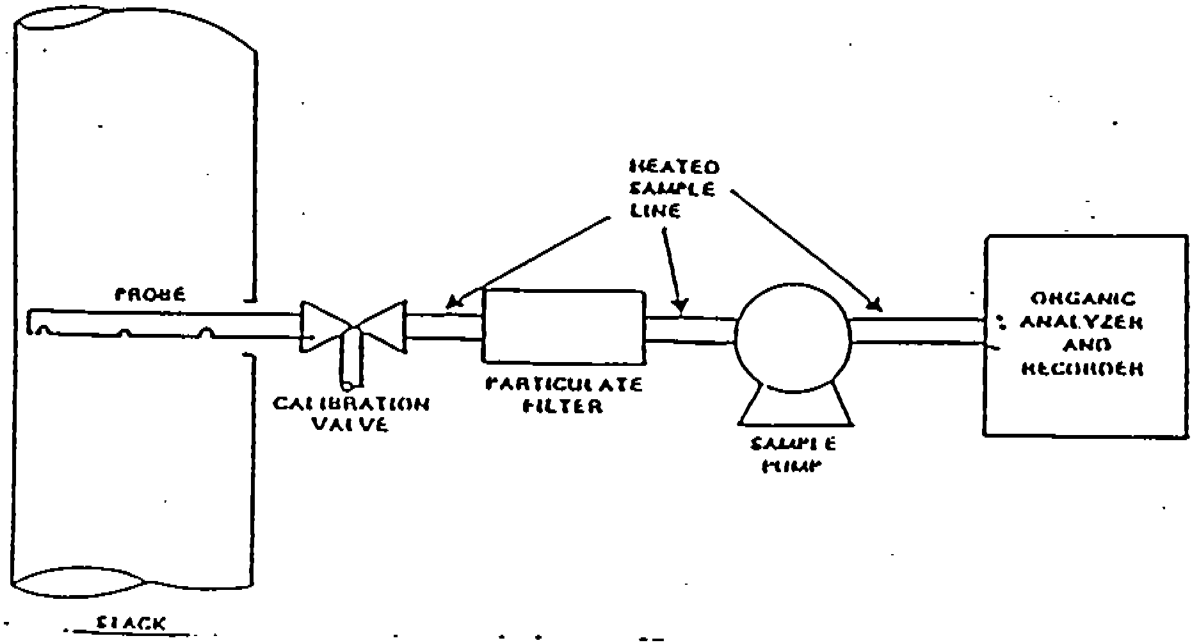


Figure 25A-1. Organic Concentration Measurement System.

3.1 Organic Concentration Analyzer. A flame ionization analyzer (FIA) capable of meeting or exceeding the specifications in this method.

3.2 Sample Probe. Stainless steel, or equivalent, three-hole rake type. Sample holes shall be 4 mm in diameter or smaller and located at 16.7, 50, and 83.3 percent of the equivalent stack diameter. Alternatively, a single opening probe may be used so that a gas sample is collected from the centrally located 10 percent area of the stack cross-section.

3.3 Sample Line. Stainless steel or Teflon* tubing to transport the sample gas to the analyzer. The sample line should be heated, if necessary, to prevent condensation in the line.

3.4 Calibration Valve Assembly. A three-way valve assembly to direct the zero and calibration gases to the analyzers is recommended. Other methods, such as quick-connect lines, to route calibration gas to the analyzers are applicable.

3.5 Particulate Filter. An in-stack or an out-of-stack glass fiber filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter should be heated to prevent any condensation.

3.6 Recorder. A strip-chart recorder, analog computer, or digital recorder for recording measurement data. The minimum data recording requirement is one measurement value per minute. Note: This method is often applied in highly explosive areas. Caution and care should be exercised in choice of equipment and installation.

4. *Calibration and Other Gases*

Gases used for calibrations, fuel, and combustion air (if required) are contained in compressed gas cylinders. Preparation of calibration gases shall be done according to the procedure in Protocol No. 1, listed in Reference 9.2. Additionally, the manufacturer of the cylinder should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change more than ±2 percent from the certified value. For calibration gas values not generally available (i.e., organics between 1 and 10 percent by volume), alternative methods for preparing calibration gas mixtures, such as dilution systems, may be used with prior approval of the Administrator.

Calibration gases usually consist of propane in air or nitrogen and are determined in terms of the span value. Organic compounds other than propane can be used following the above guidelines and making the appropriate corrections for response factor.

4.1 Fuel. A 40 percent H_2/60 percent He or 40 percent H_2/60 percent N_2 gas mixture is recommended to avoid an oxygen synergism effect that reportedly occurs when oxygen concentration varies significantly from a mean value.

4.2 Zero Gas. High purity air with less than 0.1 parts per million by volume (ppmv) of organic material (propane or carbon equivalent) or less than 0.1 percent of the span value, whichever is greater.

4.3 Low-level Calibration Gas. An organic calibration gas with a concentration equivalent to 25 to 35 percent of the applicable span value.

4.4 Mid-level Calibration Gas. An organic calibration gas with a concentration equivalent to 45 to 55 percent of the applicable span value.

4.5 High-level Calibration Gas. An organic calibration gas with a concentration equivalent to 80 to 90 percent of the applicable span value.

5. *Measurement System Performance Specifications*

5.1 Zero Drift. Less than ±3 percent of the span value.

5.2 Calibration Drift. Less than ±3 percent of span value.

5.3 Calibration Error. Less than ±5 percent of the calibration gas value.

6. *Pretest Preparations*

6.1 Selection of Sampling Site. The location of the sampling site is generally specified by the applicable regulation or purpose of the test; i.e., exhaust stack, inlet line, etc. The sample port shall be located at least 1.5 meters or 2 equivalent diameters upstream of the gas discharge to the atmosphere.

6.2 Location of Sample Probe. Install the sample probe so that the probe is centrally located in the stack, pipe, or duct and is sealed tightly at the stack port connection.

6.3 Measurement System Preparation. Prior to the emission test, assemble the measurement system following the manufacturer's written instructions in preparing the sample interface and the organic analyzer. Make the system operable.

FIA equipment can be calibrated for almost any range of total organics concentrations. For high concentrations of organics (>1.0 percent by volume as propane) modifications to most commonly available analyzers are necessary. One accepted method of equipment modification is to decrease the size of the sample to the analyzer through the use of a smaller diameter sample capillary. Direct and continuous measurement of organic concentration is a necessary consideration when determining any modification design.

6.4 Calibration Error Test. Immediately prior to the test series, (within 2 hours of the start of the test) introduce zero gas and

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* Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

high-level calibration gas at the calibration valve assembly. Adjust the analyzer output to the appropriate levels, if necessary. Calculate the predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level responses. Then introduce low-level and mid-level calibration gases successively to the measurement system. Record the analyzer responses for low-level and mid-level calibration gases and determine the differences between the measurement system responses and the predicted responses. These differences must be less than 5 percent of the respective calibration gas value. If not, the measurement system is not acceptable and must be replaced or repaired prior to testing. No adjustments to the measurement system shall be conducted after the calibration and before the drift check (Section 7.3). If adjustments are necessary before the completion of the test series, perform the drift checks prior to the required adjustments and repeat the calibration following the adjustments. If multiple electronic ranges are to be used, each additional range must be checked with a mid-level calibration gas to verify the multiplication factor.

6.5 Response Time Test. Introduce zero gas into the measurement system at the calibration valve assembly. When the system output has stabilized, switch quickly to the high-level calibration gas. Record the time from the concentration change to the measurement system response equivalent to 95 percent of the step change. Repeat the test three times and average the results.

7. *Emission Measurement Test Procedure*

7.1 Organic Measurement. Begin sampling at the start of the test period, recording time and any required process information as appropriate. In particular, note on the recording chart periods of process interruption or cyclic operation.

7.2 Drift Determination. Immediately following the completion of the test period and hourly during the test period, reintroduce the zero and mid-level calibration gases, one at a time, to the measurement system at the calibration valve assembly. (Make no adjustments to the measurement system until after both the zero and calibration drift checks are made.) Record the analyzer response. If the drift values exceed the specified limits, invalidate the test results preceding the check and repeat the test following corrections to the measurement system. Alternatively, recalibrate the test measurement system as in Section 6.4 and report the results using both sets of calibration data (i.e., data determined prior to the test period and data determined following the test period).

8. *Organic Concentration Calculations*

Determine the average organic concentration in terms of ppmv as propane or other calibration gas. The average shall be determined by the integration of the output recording over the period specified in the applicable regulation.

If results are required in terms of ppmv as carbon, adjust measured concentrations using Equation 25A-1.

$$C_c = K\, C_{meas} \qquad \text{Eq. 25A-1}$$

Where:

C_c=Organic concentration as carbon, ppmv.
C_{meas}=Organic concentration as measured, ppmv.
K=Carbon equivalent correction factor,
  K=2 for ethane.
  K=3 for propane.
  K=4 for butane.
  K=Appropriate response factor for other organic calibration gases.

9. *Bibliography*

9.1 Measurement of Volatile Organic Compounds—Guideline Series. U.S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA-450/2-78-041. June 1978. p. 46-54.

9.2 Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol No. 1). U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory. Research Triangle Park, NC. June 1978.

9.3 Gasoline Vapor Emission Laboratory Evaluation—Part 2. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC. EMB Report No. 75-GAS-6. August 1975.

APPENDIX D

CORRESPONDENCE

Gannett Fleming
ENGINEERS AND PLANNERS

GANNETT FLEMING, INC.
Suite 200
East Quadrangle
The Village of Cross Keys
Baltimore, MD 21210
Fax: (301) 433-6520
Office: (301) 433-8832

June 26, 1990

Mr. Brooks H. Stafford
Bureau of Air Quality Management
401 Bosley Avenue
Towson, Maryland 21204

RE: American Yeast Fermenter No. 5

Dear Mr. Stafford:

On behalf of American Yeast, we request a change from the test protocol for Fermenter No. 5. We request that air flow be determined by the existing flow meter currently in use. The reasons for this request are as follows;

- Outlet stack gas flow measurements can only be taken on the facility's roof. The roof is steeply pitched and is only accessible through use of a crane. The stack's inaccessibility and its height (75 feet) pose safety concerns.
- Inlet air to the fermenter is accessible. However, tapping a port into the inlet would introduce filings and other foreign matter into the fermenter. This is undesirable since 1) a food product is being fermented and 2) valves could get damaged.
- The existing flow meter provides a continuous digital reading at the inlet to the fermenter. This meter became operational in February 1990 after calibration in January 1990. The meter was calibrated by the Superior Measurement Equipment Company. The calibration standard was American National Standard Institute Standard No. ANSI/API 2530-1985. This standard and its specifications apply to orifice meters with circular orifices located concentrically in the meter tube.

Because of safety concerns and because the existing flow meter was recently calibrated against an ANSI standard, we believe that this request is justified.

We look forward to conducting the test on behalf of American Yeast. If you have any questions, do not hesitate to call me.

Very truly yours,

GANNETT FLEMING, INC.

Richard Hergenroeder

Richard Hergenroeder, P.E.
Project Manager

RH/ag

GF: 26981.000

cc: Mr. Ramnarain, MD Air Management Admin.
Mr. Franzoni, Baltimore County
Dr. Baugh, American Yeast

Test Protocol for Fermenter No. 5 for American Yeast, Baltimore, MD, Gannett Fleming, Inc., Baltimore, MD, June 1990.

This is just a proposal for the testing documented in Final Test Report for Fermenter No. 5. It details the procedures that will be used as well as giving an estimate for emissions.

TEST PROTOCOL
FOR
FERMENTER NO. 5

PREPARED FOR

AMERICAN YEAST
8215 BEACHWOOD ROAD
BALTIMORE, MARYLAND 21222

JUNE, 1990

GANNETT FLEMING, INC.
SUITE 200, EAST BLOCK QUADRANGLE
VILLAGE OF CROSS KEYS
BALTIMORE, MARYLAND 21210

TABLE OF CONTENTS

Attachments

1.0 INTRODUCTION

Gannet Fleming, Inc. proposes to determine the concentration of volatile organic compounds (VOCs) emitted from Fermenter Number 5 at the American Yeast facility in Baltimore County, Maryland. American Yeast estimates that Fermenter Number 5 emits 15 pounds per day of VOCs which is composed of ethanol (95 per cent) and acetaldehyde (5 per cent). Maryland air toxic regulations (COMAR 26.11.15) require American Yeast to estimate their emissions of acetaldehyde, a Class 1 toxic air pollutant (TAPs). Ethanol is not covered by the TAPs regulations. Maryland General Emissions Standards, Prohibitions and Restrictions (COMAR 26.11.06) require American Yeast to estimate their emissions of VOC from Fermenter Number 5.

Gannett Fleming conducted preliminary tests to estimate the mass of VOCs, ethanol and acetaldehyde. A test report was submitted to Baltimore County on March 10, 1990, that provided the following results:

- Acetaldehyde emissions were less than 3 micrograms per liter and less than 0.8 pounds per day.
- VOC emissions were approximately 25 micrograms per liter or 6.5 pounds per day.
- Ethanol was measured, but results were inconclusive , since humidity interfered with sampling efficiency.

Gannett Fleming will measure the mass of VOCs emitted and will estimate the mass of acetaldehyde emitted. This assumption is consistent with American Yeast's theoretical estimates and test data that show acetaldehyde to be a small fraction of the total VOC discarged.

2.0 LOCATION AND DESCRIPTION

American Yeast's Beachwood Road, Baltimore, Maryland, facility is an unclassified industry and is subject to the general air quality standards described in COMAR 26.11.06, General Emission Standards, Prohibitions and Restrictions and COMAR 26.11.15, Toxic Air Pollutants. Fermenter Number 5 operates on a 13-hour cycle. Approximately one hour is required for feeding and startup of the unit. After approximately one hour, the fermenter has reached equilibrium and operates at this level for the remaining 12 hours of the cycle. Waste gases are vented to the outside air through ductwork at approximately 5,000 cubic feet per minute (cfm).

3.0 TEST PROTOCOL

Gannett Fleming is prepared to conduct field tests employing U.S. EPA Reference Method (RM) 25A, Determination of Total Gaseous Organic Concentration Using A Flame Ionization Analyzer. A summary of the proposed test methods is presented in Table 1, Sampling and Analyses Strategies. The field test methods include the use of the State of Maryland, Air Management Administrations's "Stack Test Methods 1001 and 1002. These methods are published in the Air Management Administration Technical Memorandum No. 83-05, "Stack Test Methods for Stationary Sources." Methods 1001 and 1002 provide procedures for determining air velocity and volumetric air flow. Sampling ports will be established in accordance with AMA regulations.

The air velocity will be determined each hour from velocity pressure measurements taken across the exhaust duct leaving Fermenter Number 5. Velocity traverses will be taken across the duct on two directions, each direction positioned 90 degrees from the other.

The temperature of the Fermenter exhaust stream will be determined during each air velocity measurement using a thermocouple and readout device. The VOC content of the exhaust stream will be determined by extracting a sample of gas from the duct for the duration of the 13-hour batch cycle. Zero and span gas calibrations performed every hour.

TABLE 1

SAMPLING AND ANALYSES STRATEGIES

Parameter/Pollutant	EPA Reference Method* AMA Method	Sampling Type/ Duration	Analyses
Location of Test Points and Velocity/Sample Area	1--Pilot Traverse (AMA-1001)	Grab	Location Pressure drop/ diameter
Velocity/Volumetric Flow	2--Pilot Traverse Duct Measurement (AMA-1002)	Continuous	Field Calculation
Volatile Organic Compounds	25A	Continuous	Field GC-FID Volumetric

4.0 FIELD DATA

Sample data sheets for flow measurement are attached. Exhibit 1 contains a data sheet relating to RM2, the gas velocity and volumetric flow rate determination. Copies of all field data sheets and calculations will be included in the final report.

The exhaust stream from Fermenter Number 5 will be sampled with Flame Ionization detectors (FID) following the procedures outlined in EPA Reference Method 25A (40CFR, Part 50, App. A) (see attached copy of Reference Method 25A). JUM Model portable FIDs will be used which are equipped with ranges of 0-10, 0-100, 0-1000, 0-10,000, and 0-1000,000 ppm. Strip chart recorders will continuously record analyzer output. Quality assurance will consist of zero, and calibration span gas passes every hour of sampling. The primary span gases will consist of various concentrations of propane in air. Secondary standards, representing typical compounds in the exhaust stream, will be used to generate relative response curves for a more accurate estimate of VOC concentrations in the gas streams. In addition, the response curves will be developed in a controlled laboratory environment, and after each instrument has been calibrated with a primary calibrant gas (propane in air).

5.0 FINAL REPORT

The Final Report will consist of an executive summary, a discussion of results, schematic drawing of the system with test configuration, all calculations, and copy of the field data and notes. This data compilation is consistent with the recommendations outlined in AMA TM83-05.

ATTACHMENTS

EXHIBIT 1

Client: ________________

Job No.: ________________

AIR FLOW TESTING

Location: ________________

Date: ____________

Time: ____________

Operators: ________________

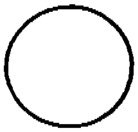
Pitot
Identification: ________ (Cp = ____)

Static, Ps (in. wg.)

Port A
Port B __________
Average

Barometric (in. Hg.)

____



ID – ________ in.

A – ________ ft.^{2}

Distance to Upstream Disturbance
– ________" – ________ x ID

Distance to Downstream Disturbance
– ________" – ________ x ID

Port	Point	X (in.)	Temp. T_s (°F)	Δp (in. wg.)	$\sqrt{\Delta p}$
A	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
B	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
Ave.					

Gas Analysis

	1	2	3	Ave.
O_2				
CO_2				
N_2				
CO				

Moisture (Bws) =

Calculations

M_d = .32(%O_2) + .44(%CO_2) + .28 (%N + %CO) = ______

M_s = (1-Bws)M_d + 18 Bws = ______

υ_s = $85.49\ C_p\sqrt{\Delta p}\sqrt{\frac{T_s}{P_s M_s}}$ = ______ fps

Q = $60\upsilon_s$ A = ______ ACFM

Q_{std} = (1-Bws) Q = ______ dscfm

METHOD 25A—DETERMINATION OF TOTAL GASEOUS ORGANIC CONCENTRATION USING A FLAME IONIZATION ANALYZER

1. *Applicability and Principle*

1.1 Applicability. This method applies to the measurement of total gaseous organic concentration of vapors consisting primarily of alkanes, alkenes, and/or arenes (aromatic hydrocarbons). The concentration is expressed in terms of propane (or other appropriate organic calibration gas) or in terms of carbon.

1.2 Principle. A gas sample is extracted from the source through a heated sample line, if necessary, and glass fiber filter to a flame ionization analyzer (FIA). Results are reported as volume concentration equivalents of the calibration gas or as carbon equivalents.

2. *Definitions*

2.1 Measurement System. The total equipment required for the determination of the gas concentration. The system consists of the following major subsystems:

2.1.1 Sample Interface. That portion of the system that is used for one or more of the following: sample acquisition, sample transportation, sample conditioning, or protection of the analyzer from the effects of the stack effluent.

2.1.2 Organic Analyzer. That portion of the system that senses organic concentration and generates an output proportional to the gas concentration.

2.2 Span Value. The upper limit of a gas concentration measurement range that is specified for affected source categories in the applicable part of the regulations. The span value is established in the applicable regulation and is usually 1.5 to 2.5 times the applicable emission limit. If no span value is provided, use a span value equivalent to 1.5 to 2.5 times the expected concentration. For convenience, the span value should correspond to 100 percent of the recorder scale.

2.3 Calibration Gas. A known concentration of a gas in an appropriate diluent gas.

2.4 Zero Drift. The difference in the measurement system response to a zero level calibration gas before and after a stated period of operation during which no unscheduled maintenance, repair, or adjustment took place.

2.5 Calibration Drift. The difference in the measurement system response to a mid-level calibration gas before and after a stated period of operation during which no unscheduled maintenance, repair or adjustment took place.

2.6 Response Time. The time interval from a step change in pollutant concentration at the inlet to the emission measurement system to the time at which 95 percent of the corresponding final value is reached as displayed on the recorder.

2.7 Calibration Error. The difference between the gas concentration indicated by the measurement system and the known concentration of the calibration gas.

3. *Apparatus*

A schematic of an acceptable measurement system is shown in Figure 25A-1. The essential components of the measurement system are described below:

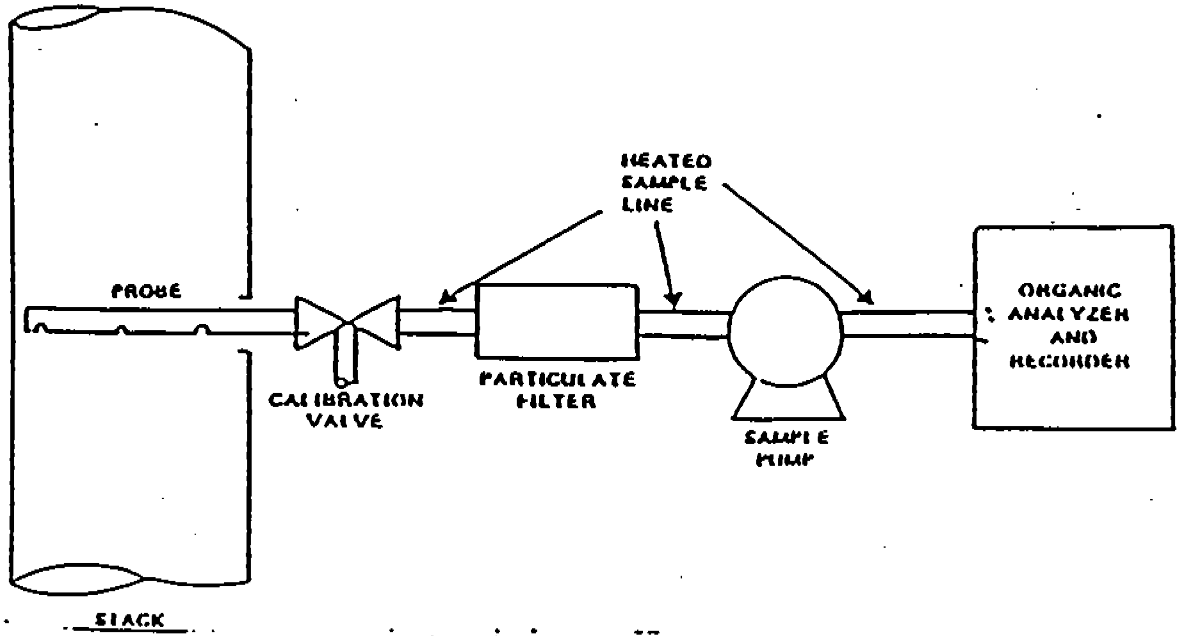


Figure 25A-1. Organic Concentration Measurement System.

3.1 Organic Concentration Analyzer. A flame ionization analyzer (FIA) capable of meeting or exceeding the specifications in this method.

3.2 Sample Probe. Stainless steel, or equivalent, three-hole rake type. Sample holes shall be 4 mm in diameter or smaller and located at 16.7, 50, and 83.3 percent of the equivalent stack diameter. Alternatively, a single opening probe may be used so that a gas sample is collected from the centrally located 10 percent area of the stack cross-section.

3.3 Sample Line. Stainless steel or Teflon* tubing to transport the sample gas to the analyzer. The sample line should be heated, if necessary, to prevent condensation in the line.

3.4 Calibration Valve Assembly. A three-way valve assembly to direct the zero and calibration gases to the analyzers is recommended. Other methods, such as quick-connect lines, to route calibration gas to the analyzers are applicable.

3.5 Particulate Filter. An in-stack or an out-of-stack glass fiber filter is recommended if exhaust gas particulate loading is significant. An out-of-stack filter should be heated to prevent any condensation.

3.6 Recorder. A strip-chart recorder, analog computer, or digital recorder for recording measurement data. The minimum data recording requirement is one measurement value per minute. Note: This method is often applied in highly explosive areas. Caution and care should be exercised in choice of equipment and installation.

4. *Calibration and Other Gases*

Gases used for calibrations, fuel, and combustion air (if required) are contained in compressed gas cylinders. Preparation of calibration gases shall be done according to the procedure in Protocol No. 1, listed in Reference 9.2. Additionally, the manufacturer of the cylinder should provide a recommended shelf life for each calibration gas cylinder over which the concentration does not change more than ±2 percent from the certified value. For calibration gas values not generally available (i.e., organics between 1 and 10 percent by volume), alternative methods for preparing calibration gas mixtures, such as dilution systems, may be used with prior approval of the Administrator.

Calibration gases usually consist of propane in air or nitrogen and are determined in terms of the span value. Organic compounds other than propane can be used following the above guidelines and making the appropriate corrections for response factor.

4.1 Fuel. A 40 percent H_2/60 percent He or 40 percent H_2/60 percent N_2 gas mixture is recommended to avoid an oxygen synergism effect that reportedly occurs when oxygen concentration varies significantly from a mean value.

4.2* Zero Gas. High purity air with less than 0.1 parts per million by volume (ppmv) of organic material (propane or carbon equivalent) or less than 0.1 percent of the span value, whichever is greater.

4.3 Low-level Calibration Gas. An organic calibration gas with a concentration equivalent to 25 to 35 percent of the applicable span value.

4.4 Mid-level Calibration Gas. An organic calibration gas with a concentration equivalent to 45 to 55 percent of the applicable span value.

4.5 High-level Calibration Gas. An organic calibration gas with a concentration equivalent to 80 to 90 percent of the applicable span value.

5. *Measurement System Performance Specifications*

5.1 Zero Drift. Less than ±3 percent of the span value.

5.2 Calibration Drift. Less than ±3 percent of span value.

5.3 Calibration Error. Less than ±5 percent of the calibration gas value.

6. *Pretest Preparations*

6.1 Selection of Sampling Site. The location of the sampling site is generally specified by the applicable regulation or purpose of the test; i.e., exhaust stack, inlet line, etc. The sample port shall be located at least 1.5 meters or 2 equivalent diameters upstream of the gas discharge to the atmosphere.

6.2 Location of Sample Probe. Install the sample probe so that the probe is centrally located in the stack, pipe, or duct and is sealed tightly at the stack port connection.

6.3 Measurement System Preparation. Prior to the emission test, assemble the measurement system following the manufacturer's written instructions in preparing the sample interface and the organic analyzer. Make the system operable.

FIA equipment can be calibrated for almost any range of total organics concentrations. For high concentrations of organics (>1.0 percent by volume as propane) modifications to most commonly available analyzers are necessary. One accepted method of equipment modification is to decrease the size of the sample to the analyzer through the use of a smaller diameter sample capillary. Direct and continuous measurement of organic concentration is a necessary consideration when determining any modification design.

6.4 Calibration Error Test. Immediately prior to the test series, (within 2 hours of the start of the test) introduce zero gas and

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* Mention of trade names or specific products does not constitute endorsement by the Environmental Protection Agency.

high-level calibration gas at the calibration valve assembly. Adjust the analyzer output to the appropriate levels, if necessary. Calculate the predicted response for the low-level and mid-level gases based on a linear response line between the zero and high-level responses. Then introduce low-level and mid-level calibration gases successively to the measurement system. Record the analyzer responses for low-level and mid-level calibration gases and determine the differences between the measurement system responses and the predicted responses. These differences must be less than 5 percent of the respective calibration gas value. If not, the measurement system is not acceptable and must be replaced or repaired prior to testing. No adjustments to the measurement system shall be conducted after the calibration and before the drift check (Section 7.3). If adjustments are necessary before the completion of the test series, perform the drift checks prior to the required adjustments and repeat the calibration following the adjustments. If multiple electronic ranges are to be used, each additional range must be checked with a mid-level calibration gas to verify the multiplication factor.

6.5 Response Time Test. Introduce zero gas into the measurement system at the calibration valve assembly. When the system output has stabilized, switch quickly to the high-level calibration gas. Record the time from the concentration change to the measurement system response equivalent to 95 percent of the step change. Repeat the test three times and average the results.

7. *Emission Measurement Test Procedure*

7.1 Organic Measurement. Begin sampling at the start of the test period, recording time and any required process information as appropriate. In particular, note on the recording chart periods of process interruption or cyclic operation.

7.2 Drift Determination. Immediately following the completion of the test period and hourly during the test period, reintroduce the zero and mid-level calibration gases, one at a time, to the measurement system at the calibration valve assembly. (Make no adjustments to the measurement system until after both the zero and calibration drift checks are made.) Record the analyzer response. If the drift values exceed the specified limits, invalidate the test results preceding the check and repeat the test following corrections to the measurement system. Alternatively, recalibrate the test measurement system as in Section 6.4 and report the results using both sets of calibration data (i.e., data determined prior to the test period and data determined following the test period).

8. *Organic Concentration Calculations*

Determine the average organic concentration in terms of ppmv as propane or other calibration gas. The average shall be determined by the integration of the output recording over the period specified in the applicable regulation.

If results are required in terms of ppmv as carbon, adjust measured concentrations using Equation 25A-1.

$$C_c = K\,C_{meas} \qquad \text{Eq. 25A-1}$$

Where:

C_c=Organic concentration as carbon, ppmv.

C_{meas}=Organic concentration as measured, ppmv.

K=Carbon equivalent correction factor.

K=2 for ethane.

K=3 for propane.

K=4 for butane.

K=Appropriate response factor for other organic calibration gases.

9. *Bibliography*

9.1 Measurement of Volatile Organic Compounds—Guideline Series. U.S. Environmental Protection Agency. Research Triangle Park, NC. Publication No. EPA-450/2-78-041. June 1978. p. 46–54.

9.2 Traceability Protocol for Establishing True Concentrations of Gases Used for Calibration and Audits of Continuous Source Emission Monitors (Protocol No. 1). U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory. Research Triangle Park, NC. June 1978.

9.3 Gasoline Vapor Emission Laboratory Evaluation—Part 2. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC. EMB Report No. 75-GAS-6. August 1975.

Method 1001 - Sample Site and Sample Point Location for Stationary Sources.*

1. Principle and Applicability

1.1 Principle. A sampling site and the number of sample points are selected to aid in the extraction of a representative sample.

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; (2) a stack is smaller than about 0.30 meter (12 in) in diameter; or 0.071 m^3 (113 in^2) in 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 distrubance.

2. Procedure

2.1 Selection of a sampling site and minimum number of sample points.

2.1.1 Select a sampling site that is at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, contraction or visible flame. For rectangular cross section, determine an equivalent diameter from the following equation:

$$\text{equivalent diameter} = 2 \times \frac{\text{length} \times \text{width}}{\text{length} + \text{width}}$$

Equation 1-1

2.1.2 When the above sampling site criteria can be met, the minimum number of sample points is twelve (12) if the stack diameter is sufficiently large as indicated in 2.1.5.

2.1.3 Some sampling situations render the above sampling site criteria impractical. When this is the case, choose a convenient sampling location and use Figure 1-1 to determine the recommended number of sample points.

2.1.4 To use Figure 1-1, first measure the distance from the chosen sampling location to the nearest upstream and downstream disturbances. Determine the corresponding number of sample points for each distance from Figure 1-1. Select the higher of the two numbers of sample points, or a greater value, such that for circular stacks, the number is a multiple of 4 and for rectangular stacks, the number follows the criteria of section 2.2.2.

2.1.5 For circular stacks, after determining the recommended number of sample points from Figure 1-1; consult Table 1-1 to see if that number may actually be sampled. Table 1-1 indicates the minimum stack diameter required for a given number of sample points if each point is to represent an equal amount of area of the sampling cross section and not lie within 1 inch of the stack wall. Under no circumstances are points that lie within one inch of the stack wall or points that do not represent equal areas of the sampling cross-section to be sampled. If the number of sample points determined from Figure 1-1 may not be sampled, select from Table 1-1 the highest possible number of points for the stack diameter in question.

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*Adapted from the Federal Register, Vol. 42, No. 160-Thursday, August 18, 1977, pp. 41755-41758.

2.2 Cross-sectional layout and location of sample points.

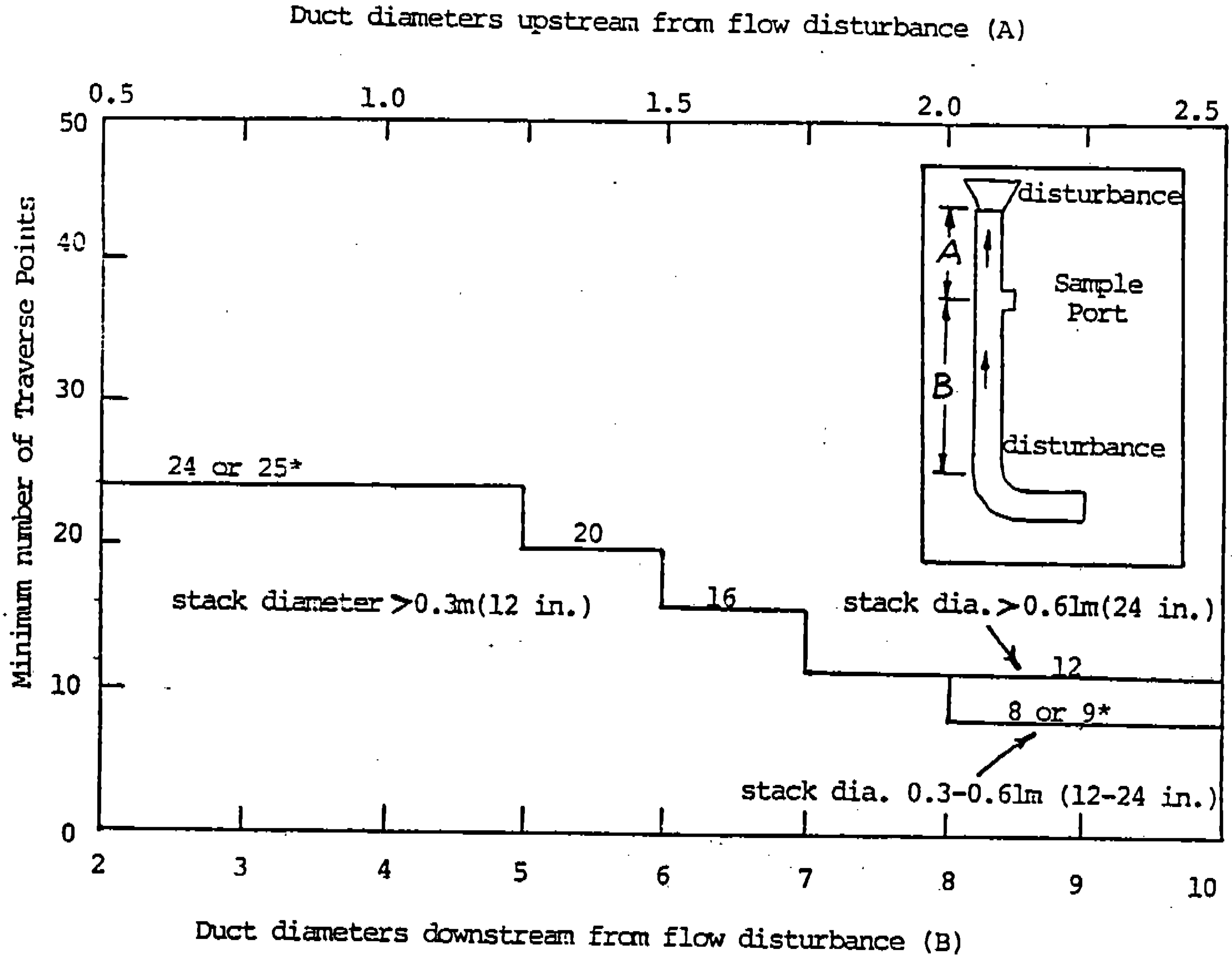
2.2.1 For circular stacks, locate the sample points on two diameters according to Table 1-2. The sample axes shall divide the stack cross section into equal parts.

2.2.2 For rectangular stacks, divide the cross section into as many equal rectangular areas as sample points, such that the ratio of the length to the width of the elemental areas is between one and two. Locate the sample points at the centroid of each equal area according to Table 1-3 and Figure 1-2.

2.3 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essentially 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.

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 10°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administration, must be used to perform accurate sample and velocity traverses.

Figure 1-1. Recommended No. of Traverse Points



* for rectangular stack

Table 1-1

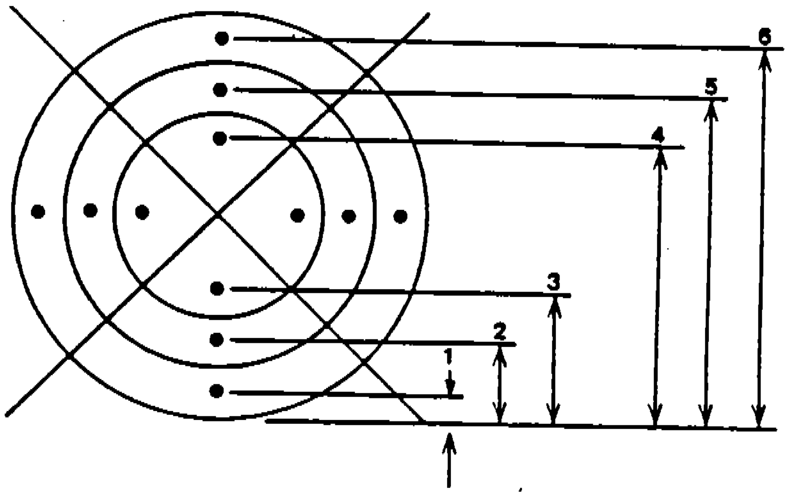
No. of Sample Points	Minimum Stack Diameter for Circular Stacks [a] (In.)
8	14.9
12	22.7
16	30.3
20	40.0
24	47.6

[a] To sample points which represent equal areas of the stack cross section such that no point lies within 1 inch of the stack wall.

Table 1.2. LOCATION OF TRAVERSE POINTS IN CIRCULAR STACKS

Example Showing Circular Stack Cross Section Divided Into 12 Equal Areas With Location of Traverse Points Indiciated

Traverse point	Distance, % of diameter
1	4.4
2	14.6
3	29.6
4	70.4
5	85.4
6	95.6



Percent of Stack Diameter From Inside Wall to Traverse Point

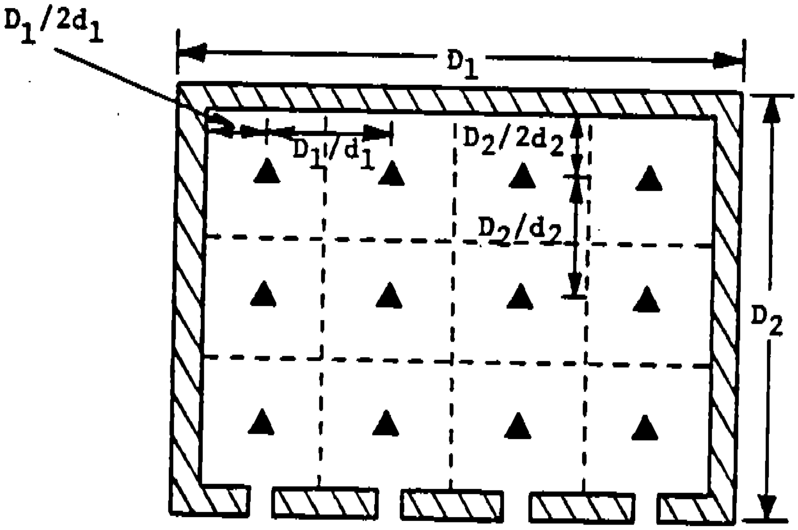
Traverse point number on a diameter[a]	Number of traverse points on a diameter[b]											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.4	32.3	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	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

[a] Points numbered from outside wall toward opposite wall.

[b] The total number of points along two diameters would be twice the number along a single diameter.

Table 1.3. LAYOUT OF CROSS-SECTIONAL SUBAREAS IN RECTANGULAR DUCTS

Number of traverse points	Subarea layout matrix
9	3 × 3
12	4 × 3
16	4 × 4
20	5 × 4
25	5 × 5
30	6 × 5
36	6 × 6
42	7 × 6
49	7 × 7



where:

▲ = sampling point

d_1= number of areas across flue width

d_2= number of areas across flue perpendicular to width

Figure 1.2. Example showing rectangular stack cross section divided into twelve equal areas, with a traverse point at the centroid of each area.

Method 1002 - Determination of Stack Gas Velocity (Type S Pitot Tube).*

1. Principle and Applicability

1.1 Principle. Stack gas velocity is determined from the gas density and from measurement of the velocity head using 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. If the minimum criteria of Method 1 are not met or if the measurement site has a swirling or cyclonic gas stream, the procedures outlined in Method 2 for stack gas velocity determination are not applicable. When unacceptable flow conditions exists, alternative procedures such as the use of flow straightening devices or stack extensions must be employed as necessary to make accurate flow rate determinations. These alternative procedures are subject to approval by the Air Management Administration.

2. Apparatus

2.1 Pitot Tube - Type S (Figure 2-1), or equivalent, with a coefficient within ±5% over the working range. See specifications in the "Nozzle and Pitot Tube Calibration Sheet" and Figure 2-3.

2.2 Differential pressure gauge - Inclined manometer, or equivalent, to measure velocity head to within 10% of the minimum value.

2.3 Temperature gauge - Thermocouple or equivalent attached to the pitot tube to measure stack temperature to within 1.5% of the minimum absolute stack temperature.

2.4 Pressure gauge - Mercury-filled U-tube manometer, or equivalent, to measure stack pressure to within 0.1 in. Hg.

2.5 Barometer - To measure atmospheric pressure to within 0.1 in. Hg. (Barometeric pressure may be obtained from the nearest weather service station.)

2.6 Gas analyzer - To analyze gas composition for determining molecular weight. Use Methods 1003, 1004 or 1005.

2.7 Pitot Tube - Standard type, to calibrate Type S pitot tube. Unit should be traceable to NBS standard type pitot tube.

3. Procedure

3.1 Set up the apparatus as shown in Figure 2-1. Make sure all connections are tight and leak free. Level and zero the manometer at the beginning and relevel and zero periodically during the traverse. Measure the velocity head and temperature at the sample points specified by Method 1001.

3.2 Measure the static pressure in the stack.

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*Adapted from the Federal Register, Vol. 42, No. 160-Thursday, August 18, 1977, pp. 41758-41768.

3.3 Obtain the barometeric pressure from the nearest weather service station and correct to sample site elevation by subtracting 2.5mm for each 100 foot difference between the weather station and sampling site.

3.4 Determine the stack gas molecular weight by gas analysis and appropriate calculations as indicated in Method 1003.

4. Calibration

4.1 Type S Pitot Tube. Before each 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 on the "Nozzle and Pitot Tube Calibration Sheet". Measure each of the parameters called for on this Calibration Sheet and record them on the Sheet. If any of the alignments are not within the specifications listed on Figure 2-3, than another pitot must be used.

Normal practice is to use the baseline coefficient value of 0.84 if all of the alignments of the "Nozzle and Pitot Tube Calibration Sheet" and Figure 2-3 are correct. However, the calibration procedure of 4.1.1 through 4.1.3 can be used if desired and is preferable if the facilities for calibration are available.

4.1.1 To calibrate the pitot tube, measure the velocity head at some point in a flowing gas stream with both a Type S pitot tube and a standard type pitot tube with known coefficient. Calibration should be done in the laboratory and the velocity of the flowing gas stream should be varied over the normal working range. It is recommended that the pitot tube be inspected after each use and recalibrated if it has become disfigured.

4.1.2 Calculate the pitot tube coefficient using equation 2-1.

$$Cp_{test} = Cp_{std}\sqrt{\frac{\Delta P_{std}}{\Delta P_{test}}}$$

Equation 2-1

Cp_{test} = Pitot tube coefficient of Type S pitot tube.

Cp_{std} = Pitot tube coefficient of standard type pitot tube (if unknown, use 0.99).

ΔP_{std} = Velocity head measured by standard type pitot tube.

ΔP_{test} = Velocity head measured by Type S pitot tube.

4.1.3 Compare the coefficients of the Type S pitot tube determined first with one leg and then the other pointed downstream. Use the pitot tube only if the two coefficient differ by no more than 0.01.

4.2 Temperature Gauge. After each field use calibrate all temperature indicators used by comparison to a reference ASTM mercury-in-glass thermometer for a temperature range up to 405°C. For temperatures above 405°C use an NBS calibrated reference thermocouple-potentiometer system. If the absolute temperatures measured during calibration differ by more than ±1.5 percent, appropriate adjustments to the test results shall be made or the test shall be considered invalid.

5. Calculations

Use equation 2-2 to calculate the stack gas velocity.

Average Velocity of Stack Gas at Sample Site, V_s (ft/sec)

$$V_s = (Kp)\ (Cp)\ (\Delta P)^{\frac{1}{2}}\ \text{avg}\ [T_{savg}/(P_{savg} \times M_w)]^{\frac{1}{2}}$$ where:

Equation 2-2

Kp = constant, (85.48 ft/sec (lb · in. Hg/lb mole · in. H_2O · $^oF)^{\frac{1}{2}}$)
Cp = pitot tube coefficient, (dimensionless)
$(\Delta P)^{\frac{1}{2}}$ avg = average square root of velocity head of stack gas, (in. $H_2O)^{\frac{1}{2}}$
T_{savg} = average absolute stack temperature, (^oR)
P_{savg} = average absolute stack pressure, (in. Hg)
Mw = molecular weight of stack gas, wet basis, (lb/lb mole)

K_p is derived from:

$$K_p = \left(\frac{2g\ R\ {}^n\Delta P}{{}^n p_s}\right)^{\frac{1}{2}} = \left(\frac{2 \times 32.14 \times 1543 \times \frac{62.4}{12}}{\frac{14.7 \times 144}{29.92}}\right)^{\frac{1}{2}}$$

$$= 85.48 \text{ ft/sec (lb} \cdot \text{in Hg/lb mole} \cdot \text{in. } H_2O \cdot {}^oR)^{\frac{1}{2}}$$

where g = acceleration due to gravity ft/sec^2

R = gas constant ft lbs/Mol ^oR

$^n\Delta P$= conversion factor $\frac{\text{lb}}{\text{ft}^2 - \text{in W.C.}}$

$^n p_s$= conversion factor $\frac{\text{lbs}}{\text{ft}^2 - \text{in Hg}}$

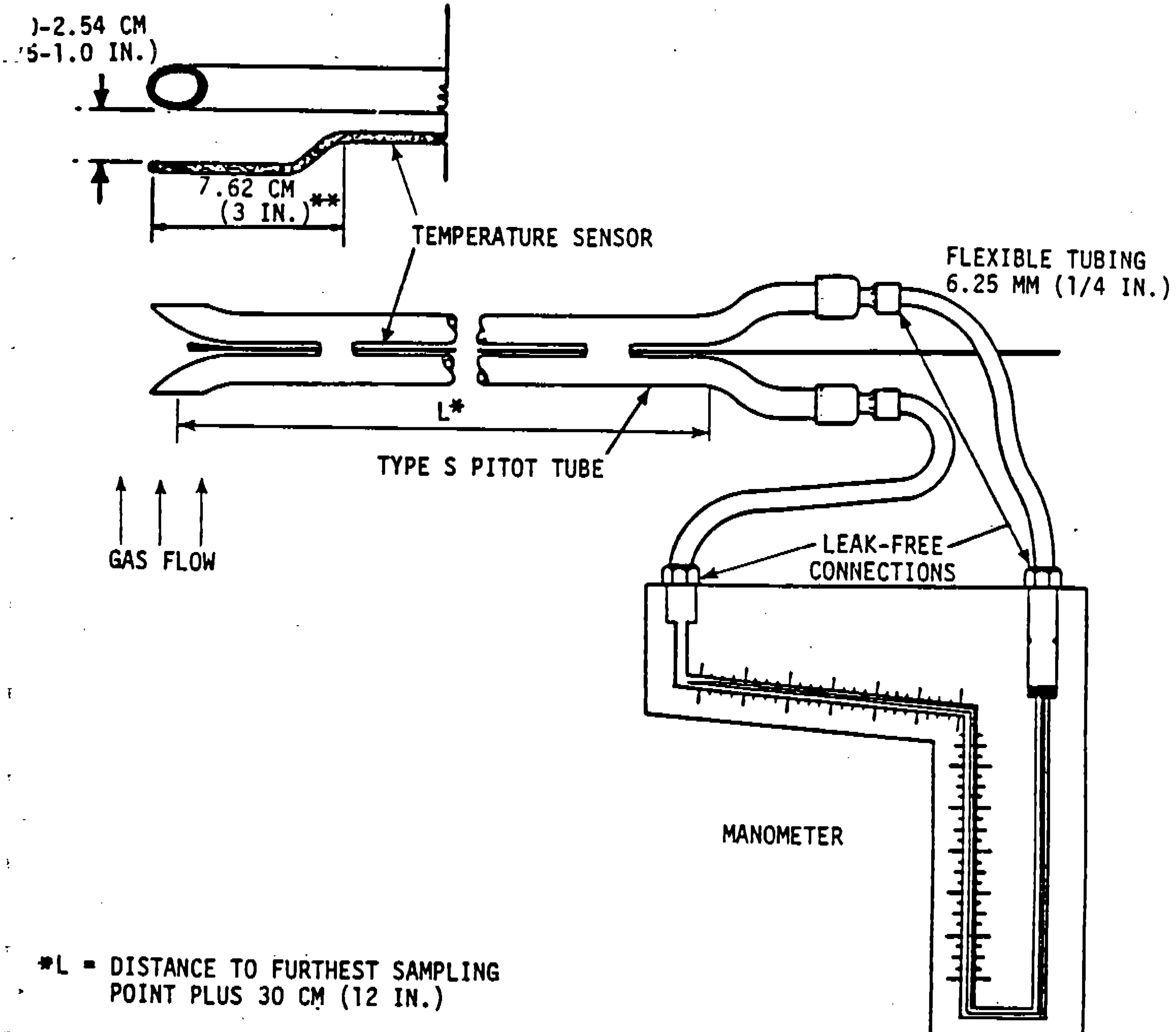
Figure 2-2 shows a sample recording sheet for velocity traverse data. Other forms may be used. Use the averages in the last two columns of Figure 2-2 to determine the average stack gas velocity from Equation 2-2.

Actual Stack Gas Volumetric Flow Rate, Dry Basis, Q_s (acfm)

Equation 2-3

$$Qs = 60\ (1 - Bw)\ (Vs)\ (As)$$ where:

Bw = moisture content of stack gas, (mole fraction, dimensionless)
Vs = average velocity of stack gas at sample site, (ft/sec)
As = cross sectional area of stack at sample site, (ft^2)
60 = conversion factor, (sec/min)



*L = DISTANCE TO FURTHEST SAMPLING POINT PLUS 30 CM (12 IN.)

**PITOT TUBE - TEMPERATURE SENSOR SPACING

Figure 2.1 Type S pitot tube-manometer assembly.

PLANT________________________

DATE________________________

RUN NO.________________________

STACK DIAMETER, in.________________

BAROMETRIC PRESSURE, in. Hg.__________

STATIC PRESSURE IN STACK (P_g), in. Hg.______

OPERATORS________________________

Pitot Coefficient ____________

Last Calibrated ____________

SCHEMATIC OF STACK CROSS SECTION

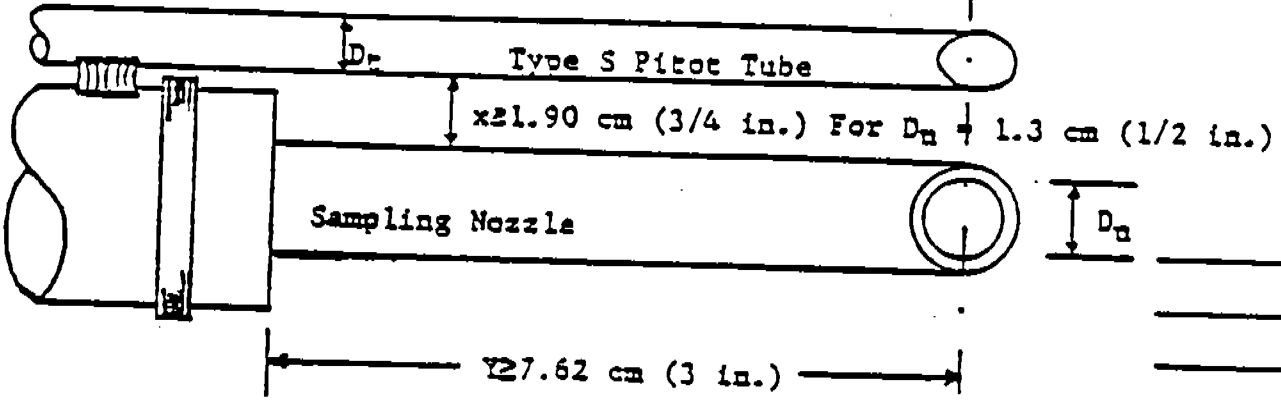
Traverse point number	Velocity head, in. H_2O	$\sqrt{\Delta_p}$	Stack Temperature (T_S), °F
	AVERAGE:		

Figure 2-2. Velocity traverse data.

NOZZLE & PITOT TUBE CALIBRATION SHEET

Facility ______________

Pitobe ID ______________

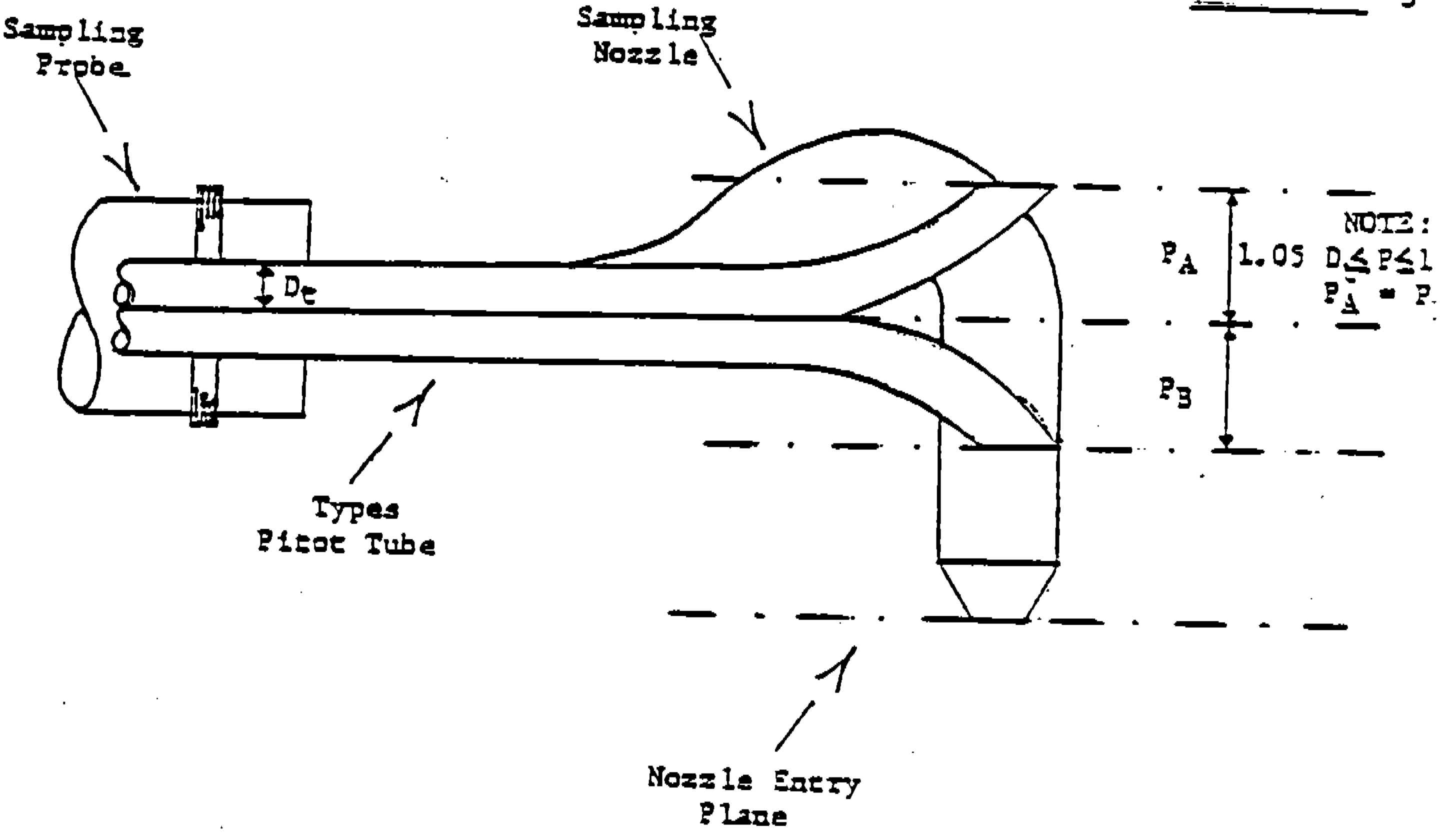


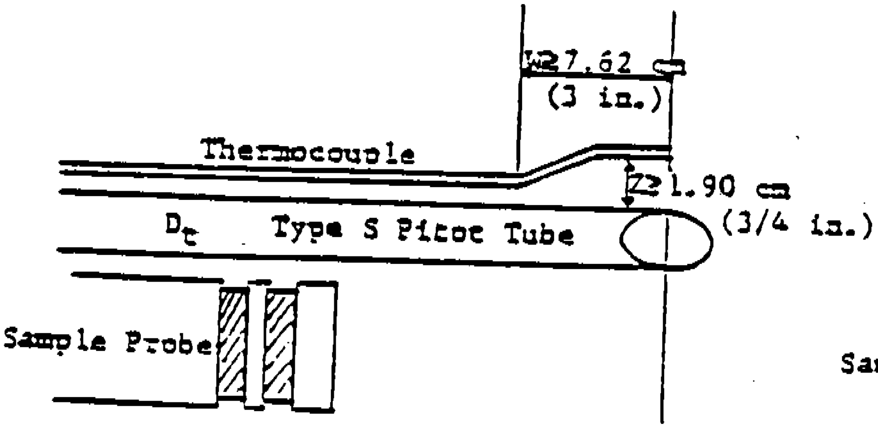
______________ AVG

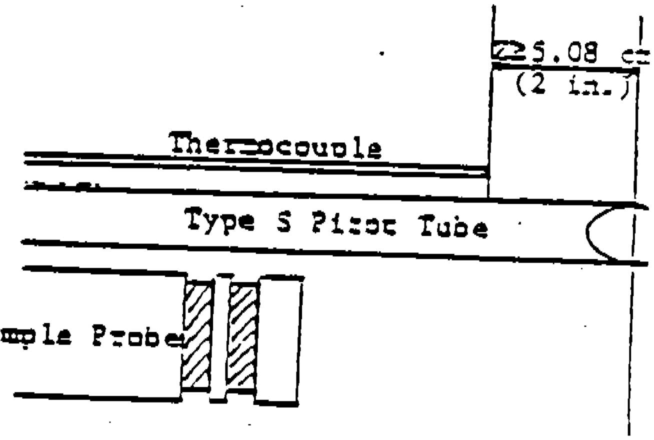
______________ 1

______________ 2

______________ 3







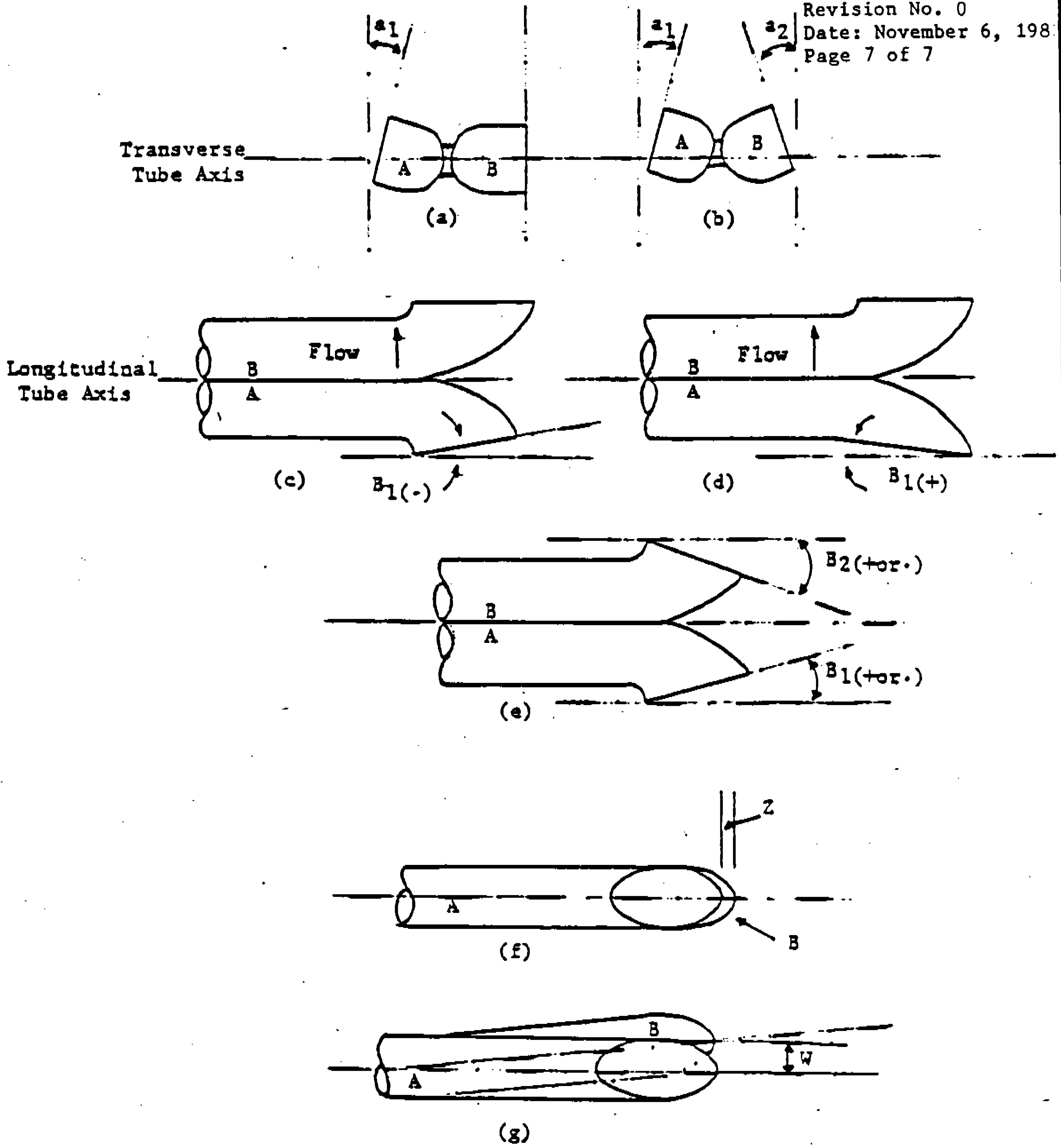


Figure 2-3. Types of face-opening misalignment that can result from Field use or improper construction of Type S pitot tubes. These will not affect the baseline value of Cp(s) so long as a_1 and a_2 10°, B_1 and B_2 5°.z 0.32 cm (1/8 in.) and w 0.08 cm (1/32 in.) PITOT ALIGMENT OK ____________________

TEMPERATURE MEASURING UNIT CALIBRATION: DATE: ____________________

BY: ____________________