Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources.* AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

AP-42
Section 1.9
Ref #7

DEVELOPMENT OF AP-42 EMISSION FACTORS FOR RESIDENTIAL FIREPLACES

APEX, NORTH CAROLINA

VOLUME ONE

EPA CONTRACT NO. 68D90155
WORK ASSIGNMENT NUMBERS. 1, 1.5, 3, 4

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Prepared for:

U.S. Environmental Protection Agency
Emissions Measurement Branch

Task Manager: Dennis Holzschuh

Draft: January 11, 1990

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DEVELOPMENT OF AP-42 EMISSION FACTORS FOR RESIDENTIAL FIREPLACES

APEX, NORTH CAROLINA

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SECTION 1
Introduction

Advanced Systems Technology, Inc. (AST) was requested by the U.S. EPA., Emission Measurement Branch (EMB), to perform source emission testing on fireplaces for the development of fireplace emission factors. The work was conducted under Contract No. 68D90155, Work Assignment No. 1, 1.5, 3, 4.

The test program was conducted to measure the following criteria pollutants: particulates, sulfur dioxide (SO_2), carbon monoxide (CO), nitrogen oxides (NO_x, plus semi-volatile and volatile organic compounds.

AST performed the emission measurement program as a combined effort with Apex Environmental Services, Inc. (AES). The testing was conducted at the AES Wood Burning Laboratory located in Apex, North Carolina during the months of August and September, 1990. Field testing was supervised by Mr. William Howe who was assisted by Mr. James Bacik and Mr. James Winegar of Apex Environmental. Mr. Thomas Yaroch of AST served as project manager and was on site for the second part of testing. Mr. Dennis Holzschuh of U.S. EPA Emission Measurement Branch served as task manager.

Emissions testing was conducted on three different fireplaces that were constructed inside the AES test facility. The test units were selected to represent typical residential fireplaces. The three different fireplaces were tested as four different units; the masonry unit was tested as two different units, once with glass doors installed and closed, and once with the doors open. The other two units were pre-fabricated "zero-clearance" fireplaces with double wall chimneys. Six test runs were conducted on each unit for a total of twenty-four test runs. Particulates were measured for all twenty-four test runs. In addition to particulates, other pollutants were measured during various test runs.

The fireplaces were operated in a manner expected to be similar to that used by a typical homeowner. The fireplaces were tested burning local seasoned cordwood. The testing methodology was based on EPA Reference Methods for testing residential wood heaters by use of a dilution tunnel sampling system.

The following section of the report illustrates the results of testing and is followed by a brief discussion of the test results. Section 4 outlines the test methodologies used for this study. The Appendices include detailed computer generated results of testing, sample calculations, copies of the referenced EPA test methods and laboratory procedures, along with all field and laboratory data sheets.

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SECTION 2

Summary of Results

The results of the test program are illustrated below. The tables are in the simplest format possible. No comparisons or interpretations have been made. The tables list the fireplace configurations, flow conditions and the emission rates for each pollutant.

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TABLE 1
SUMMARY OF EMISSION RATES AND FLOW CHARACTERISTICS
RUNS 1 - 9

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Stove	Masonry wo/doors	Masonry wo/doors	Masonry wo/doors	Masonry w/doors	Masonry w/doors	Masonry w/doors	Prefab HB-42A	Prefab HB-42A	Prefab HB-42A
Burn Rate Kg/hr	5.1	4.0	4.5	4.1	5.0	5.0	3.7	3.3	3.5
Flow DSCF	493.5	509.2	409.6 469.6	495.3	485.0	433.8	400.1	447.4	447.6
CO ppm	---	---	---	429	510	564	294	301	269
NO_x ppm	---	---	---	---	11:0	---	4.1	4.2	3.6
Particulate grams/hr.	110.1	132.9	91.9	52.0	83.9	76.3	45.7	57.9	54.8
Particulate gr/kg fuel	21.5	33.2	20.3	12.6	16.8	15.2	12.4	17.4	15.7
TCO grams/hr.									
TCO gr/kg fuel									

Table 1

TABLE 2
SUMMARY OF EMISSION RATES AND FLOW CHARACTERISTICS
RUNS 10 - 18

	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Run 16	Run 17	Run 18
Stove	Prefab FF-41	Prefab FF-41	Prefab FF-41	Masonry wo/doors	Masonry wo/doors	Masonry wo/doors	Masonry w/doors	Masonry w/doors	Masonry w/doors
Burn Rate Kg/hr	3.8	3.4	3.9	4.1	4.4	4.4	4.3	3.9	3.5
Flow DSCFM	436.1	458.3	450.9	496.7	497.7	502.3	506.2	507.3	513.6
CO ppm	314	276	270	357	407	405	368	349	315
NO_x ppm	3.2	2.9	3.6	3.6	~~11.0~~ 4.3	3.3	3.5	1.8	3.2
Particulate grams/hr.	35.8	50.3	38.2	78.0	82.3	83.2	61.8	62.5	60.6
Particulate gr/kg fuel	9.5	14.9	9.9	19.1	19.0	18.8	14.3	16.2	17.5
TCO grams/hr.									
TCO gr/kg fuel									

Table 2

TABLE 3
SUMMARY OF EMISSION RATES AND FLOW CHARACTERISTICS
RUNS 19 - 24

	Run 19	Run 20	Run 21	Run 22	Run 23	Run 24
Stove	Prefab FF-41	Prefab FF-41	Prefab FF-41	Prefab FF-42A	Prefab FF-42A	Prefab FF-42A
Burn Rate Kg/hr	3.5	4.1	3.5	3.6	3.6	3.41
Flow DSCFM	380.2	427.7	464.6	446.8	439.5	431.5
CO ppm	299	216	230	301	284	269
NO_x ppm	3.5	3.6	2.7	2.6	2.9	2.4
Particulate grams/hr.	36.2	29.2	40.0	49.6	46.1	46.7
Particulate gr/kg fuel	10.4	7.1	11.4	13.8	12.7	13.7
TCO grams/hr.						
TCO gr/kg fuel						

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TABLE 4
SUMMARY OF METHOD 5G-2 RESULTS
RUNS 1 - 9

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9
Stove	Masonry wo/doors	Masonry wo/doors	Masonry ow/doors	Masonry w/doors	Masonry w/doors	Masonry w/doors	Prefab HB-42A	Prefab HB-42A	Prefab HB-42A
Burn Rate Kg/hr	5.1	4.0	4.5	4.1	5.0	5.0	3.7	3.3	3.5
Flow DSCF	493.5	509.2	409.6 469.6	495.3 ?	485.0	433.8	400.1	447.4	447.6
Train Front[1]	116.8	130.4	81.5	62.8	89.8	90.3	65.7	65.8	56.6
Filter 1[1]	328.5	570.6	340.0	208.2	305.0	275.2	188.4	212.7	187.5
Impingers[1]	96.4	119.4	52.9	48.1	71.0	67.1	23.6	48.6	45.4
Extract[1]	86.9	135.6	69.4	64.8	61.1	91.7	45.1	40.8	47.0
Filter 2[1]	38.1	0.6	0.0	0.3	-0.1	0.2	-0.9	-0.3	0.5
Emission grams/hr	110.1	132.9	91.9	52.0	83.9	76.3	45.7	57.9	54.8
Emission gr/kg fuel	21.5	33.2	20.3	12.6	16.8	15.2	12.4	17.4	15.7
Emission Frnt grams/hr.	73.5	97.4	71.2	36.7	62.9	53.2	36.0	43.9	39.7
Emission Frnt gr/kg fuel	14.4	24.4	15.7	8.9	12.6	10.6	9.8	13.2	11.3
Emission Frnt % of total	66.8	73.3	77.5	70.6	74.9	69.7	78.9	75.8	72.4
Emission Back gr/hr	33.6	35.5	20.7	15.3	21.0	23.1	9.6	14.0	15.1
Emission Back gr/kg fuel	7.2	8.9	4.6	3.7	4.2	4.6	2.6	4.2	4.3
Emission Back % of total	33.2	26.7	22.5	29.4	25.1	30.3	21.1	24.2	27.6

[1] Weights are in milligrams

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TABLE 5
SUMMARY OF METHOD 5G-2 RESULTS
RUNS 10 - 18

	Run 10	Run 11	Run 12	Run 13	Run 14	Run 15	Run 16	Run 17	Run 18
Stove	Prefab FF-41	Prefab FF-41	Prefab FF-41	Masonry wo/doors	Masonry wo/doors	Masonry wo/doors	Masonry w/doors	Masonry w/doors	Masonry w/doors
Burn Rate Kg/hr	3.8	3.4	3.9	4.1	4.4	4.4	4.3	3.9	3.5
Flow DSCFM	436.1	458.3	450.9	496.7	497.7	502.3	506.2	507.3	513.6
Train Front[1]	37.6	55.1	46.9	81.0	93.4	93.9	66.6	63.4	45.0
Filter 1[1]	117.0	190.3	119.5	235.0	242.0	273.2	239.2	226.5	182.7
Impingers[1]	14.2	30.9	23.9	58.3	60.6	44.8	88.2	70.9	50.6
Extract[1]	26.7	43.4	31.2	78.4	61.5	88.8	52.9	86.6	59.0
Filter 2[1]	-0.2	0.1	0.2	0.3	1.0	0.9	0.5	0.4	0.2
Emission grams/hr	35.8	50.3	38.2	78.0	83.3	83.2	61.8	62.5	60.6
Emission gr/kg fuel	9.5	14.9	9.9	19.1	19.0	18.8	14.3	16.2	17.5
Emission Frnt grams/hr.	28.3	38.6	28.6	54.3	60.9	60.9	42.2	40.5	40.0
Emission Frnt gr/kg fuel	7.5	11.4	7.4	13.3	13.9	13.8	9.8	10.5	11.6
Emission Frnt % of total	79.2	76.7	75.1	69.8	73.2	73.2	68.4	64.7	65.9
Emission Back gr/hr	7.5	11.7	9.5	23.5	22.4	22.3	19.6	22.0	19.3
Emission Back gr/kg fuel	2.0	~~3.0~~ 3.5	2.5	5.8	5.1	5.0	4.5	5.7	5.6
Emission Back % of total	20.8	23.3	24.9	14.0	26.9	26.8	31.6	35.3	31.8

[1] Weights are in milligrams

TABLE 6
SUMMARY OF METHOD 5G-2 RESULTS
RUNS 19 - 24

	Run 19	Run 20	Run 21	Run 22	Run 23	Run 24
Stove	Prefab FF-41	Prefab FF-41	Prefab FF-41	Prefab FF-42A	Prefab FF-42A	Prefab FF-42A
Burn Rate Kg/hr	3.5	4.1	3.5	3.6	3.6	3.4
Flow DSCFM	380.3	427.7	464.6	446.8	439.5	431.5
Train Front[1]	37.2	35.6	40.2	55.4	45.0	48.0
Filter 1[1]	115.5	75.1	98.8	146.6	146.0	160.8
Impingers[1]	20.0	19.0	27.2	44.3	26.4	23.4
Extract[1]	28.7	16.3	33.8	39.3	27.7	21.8
Filter 2[1]	0.7	0.7	0.5	0.0	0.1	0.2
Emission grams/hr	36.2	29.2	40.0	49.6	46.1	46.7
Emission gr/kg fuel	10.4	7.1	11.4	13.8	12.7	13.7
Emission Frnt grams/hr.	26.7	21.5	27.1	34.3	35.1	37.5
Emission Frnt gr/kg fuel	7.7	5.2	7.7	9.6	9.7	11.0
Emission Frnt % of total	73.8	73.8	67.8	69.1	76.1	80.3
Emission Back gr/hr	8.6	7.0	12.0	14.2	10.0	8.2
Emission Back gr/kg fuel	2.5	1.7	3.4	4.0	2.8	2.4
Emission Back % of total	23.9	24.0	30.0	28.6	21.6	17.5

[1] Weights are in milligrams

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TABLE 7
SUMMARY OF TOTAL GASEOUS NONMETHANE ORGANIC COMPOUND EMISSION RATES

Concentration (ppmC)	Run 13A Masonry wo/doors	Run 13B Masonry wo/doors	Run 13C Masonry wo/doors	Run 14A Masonry wo/doors	Run 14B Masonry wo/doors	Run 14C Masonry wo/doors	Run 15B Masonry wo/doors	Run 15C Masonry wo/doors	Run 16A Masonry w/doors
Burn Rate Kg/hr	4.1	4.1	4.1	4.4	4.4	4.4	4.4	4.4	4.3
Flow DSCFM	496.7	496.7	496.7	497.7	497.7	497.7	502.3	502.3	506.2
Flow DSCMM	14.1	14.1	14.1	14.1	14.1	14.1	14.2	14.2	14.3
CO ppm	384	353	288	444	641	214	522	238	494
CH_4 ppm	44	56	39	49	60	16	55	32	48
CO_2 ppm	10680	6169	6383	7690	11758	1952	12454	6108	10859
Non-Condensibles ppm	39	40	17	16	30	4	26	9	43
Condensibles ppm	178	207	319	236	474	139	196	109	325
TGNMO ppm	218	247	335	252	504	143	222	118	367
TGNMO $_3$ mg C/m^3	109	123	168	126	252	72	111	59	183
TGNMO grams/hr	92.0	103.8	141.8	106.6	212.1	60.9	94.7	50.4	157.4
TGNMO grams/kg	22.5	25.4	34.7	24.3	48.3	13.9	21.4	11.4	36.4

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TABLE 8
SEMI-VOLATILE ORGANIC COMPOUND RESULTS
GRAVIMETRIC AND TCO ANALYSIS RUNS 13 - 18

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TABLE 9
SEMI-VOLATILE ORGANIC COMPOUND RESULTS
GRAVIMETRIC AND TCO ANALYSIS RUNS 19 - 24

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TABLE 10
SEMI-VOLATILE ORGANIC COMPOUND RESULTS
SEPARATION ANALYSIS RUNS 13 - 18

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TABLE 11
SEMI-VOLATILE ORGANIC COMPOUND RESULTS
SEPARATION ANALYSIS RUNS 14 - 24

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SECTION 3
Discussion of Results

Test runs were performed in sets of three for each of the fireplace configurations. The first set of test runs for each fireplace configuration included determination of flow rates, particulates, sulfur dioxide, carbon monoxide, carbon dioxide, oxygen and nitrogen oxides. The second set of test runs for each fireplace included determination of flow rates, particulates, carbon monoxide, carbon dioxide, oxygen, nitrogen oxides, and semi-volatile organic compounds. During the second set of test runs (runs 13-15) on the masonry fireplace, total gaseous non-methane organic compounds were measured.

The following sections discuss each of the parameters involved with the sampling program. Each section includes a detailed table of results along with a discussion of observations made and problems encountered during sampling and analytical procedures.

Particulate Sampling

A total of twenty-four (24) test runs were conducted on four fire place configurations, six runs per fireplace. The following tables summarize the results of testing.

Gas Analysis

In the original test plan, integrated bag samples were to be collected directly from the stack and analyzed for CO, CO_2, O_2, NO_x. This data would be used for the determination of emission factors for the criteria pollutants; CO, NO_x,. Emission rates were to be determined by carbon mass balance. However due to the low CO_2 concentrations, improper monitor ranges and drift problems with the NO_x monitor, the protocol was modified.

Consequently, CO concentrations were measured using a continuous emission monitor, drawing a gas sample from the dilution tunnel. NO_x samples were collected in tedlar bags and analyzed on the TECO NO_x monitor, in triplicate. CO_2 concentrations were measured using a CEM for the first few runs. The concentrations of CO_2 for these runs was less than 1%, which is below the proper operating range of the monitor. Therefore, sampling for CO_2 was discontinued. Likewise the concentrations of O_2 measured from the dilution tunnel were so close to the ambient O_2 value that sampling was also discontinued.

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Sulfur Dioxide

Sulfur Dioxide samples were conducted for the first fourteen test runs. The concentrations of sulfur dioxide for each of the test runs was just at or below the detectable limit of 1.2 mg/dscm. Therefore it was determined to stop testing for sulfur dioxide and report the levels from all fireplaces to be below the detectable limit of 1.2 mg/dscm.

Semi-Volatile Organics

The Modified Method 5 sample train was used to measure the levels of semi-volatile organic compounds for three runs on each fireplace configuration. The samples were analyzed for total chromatographic organics (TCO), gravimetric analysis, and to determine the levels of thirteen organic compounds commonly encountered in the combustion of wood products. These results are show in the tables in Section 2.

Total Gaseous Non-Methane Organic Compounds

Sampling for total gaseous non-methane organic compounds (TGNMO) was conducted during the second set of test runs on the masonry fireplace with the glass doors open. Three Method 25 samples were collected for each of three test runs. One hour samples were collected at three different phases of each of the three fireplace test runs. The first sample was taken at the start of the test burn, the second sample during the middle or main burn phase, and the last sample taken starting approximately two hours before the fire was out.

The tank used to sample the start of the test burn, run 15, was inadvertently reused for collection of the middle or main burn test section of the same run. Therefore an additional test run was conducted during the start-up phase of test run 16. The tank portion of the sample results for the main burn section of test run 15 reflects sample collected for two (2) one hour runs, the start of the test burn and the main burn test section. Therefore the tank analysis portion for run 15b is inaccurately high.

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SECTION 4
TESTING METHODOLOGY

4.1 Fireplace Descriptions and Operations

Emissions testing was conducted on four different fireplace configurations at the AES laboratory located in North Carolina. Figures 1 through 4 located in Appendix D illustrate the masonry and prefabricated fireplaces. The fireplaces were operated in a manner expected to be similar to that used by a typical homeowner. Emission measurements were made while burning local seasoned cordwood. The cordwood consisted primarily of oak and hickory. Each piece of cordwood was measured for moisture content with a calibrated electrical resistance meter and weighed to the nearest 0.05 Kg prior to loading into the fireplace.

The four fireplace units are identified below:

Masonry Fireplace
Masonry Fireplace with glass doors
Heatilator HB42A
Preway FF41

The fireplaces and associated chimneys were assembled/built inside the test facility. The chimneys discharged into a space freely communicating with the test facility. A hood captured the exhaust gases and diluted the gases with ambient room air. The gases were then drawn through a tunnel to the sampling location and exhausted outside the facility through the roof by a high volume blower.

Sampling was begun just prior to the ignition of the initial test charge. The initial test charge consisted of crumbled paper, approximately 3 kilograms of kindling and two to three small to medium size pieces of split cordwood. Additional newspaper was added when necessary to insure satisfactory combustion of the initial test charge.

Cordwood was added to the fire and the fire was poked over the first four hours of the test run as necessary to maintain a moderate fire. After the four-hour mark, no further wood additions were made and poking was allowed till the fifth hour. After the five-hour mark no manipulations of the fire were allowed.

Sampling continued approximately two hours after the last addition of the cordwood until combustion was virtually complete. Stack temperature, carbon monoxide levels, and visual appearance were used in determining the end of the sampling period. Combustion was considered complete when no visual flames were seen, the carbon monoxide levels in the dilution tunnel had decreased to approximately 100 ppm and the stack temperature was in a stable decline.

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4.2 General

The development of the sampling methods were based on the test methods and procedures published in the Federal Register, 40 CFR Part 60, for certification and compliance testing of New Residential Wood Heaters. Reference Method 5G-Determination of Particulate Emissions From Wood Heaters From a Dilution Tunnel Sampling Location was the primary method used in development of the test protocol. All samples were withdrawn from the dilution tunnel except for the first three runs where integrated gas sample bags were collected directly from the stack for determination of the primary constituents.

The sampling and operational procedures were modified for the purpose of testing uncontrolled fireplace emissions. EPA Method 28 was used as a guideline; for maintaining the test facility at a set of prescribed conditions, for the moisture measurements of the test fuel, and for calculation of the dry burn rate. A modified EPA Method 5G dilution tunnel was used for collection and sampling of the fireplace emissions. A Method 5G-2 sampling train was used for sampling particulates from the dilution tunnel, and both front- and back-half catches were analyzed. A Modified Method 5 train was used for the determination of semi-volatile organic and particulate emissions. EPA Method 8 was used to determine sulfur dioxide emissions. An integrated gas sample was collected and analyzed for nitrogen oxides. EPA Method 25 was used to determine the total gaseous non-methane organic emissions. Carbon monoxide concentrations were measured with a Bendix Model 8501, nondispersive infrared analyzer.

The three fireplaces (four configurations) were installed on the floor of the test facility, with the chimney extending to a height of 4.6 +/- 0.3 meters from the floor. The room temperature was monitored approximately 1 meter to the side of the fireplace. No attempt was made to keep the room temperature below 90 degrees fahrenheit.

The dilution tunnel and hood were constructed as described in Method 5G section 2.2, except that 12 inch duct was used for construction of the tunnel. The larger duct was required to handle the higher exhaust flow rates associated with fireplaces. The gas velocity in the dilution tunnel was maintained at approximately 220 m/min and the ratio of the average mass flow rate in the dilution tunnel to the average fuel burn rate was maintained between 100:1 and 400:1.

The stack gas temperature and draft were monitored at a distance 2 diameters down from the chimney outlet.

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Samples were collected in the dilution tunnel from a point were it was felt that the fireplace exhaust was well combined with ambient dilution air. The sample point locations are shown in Appendix D Figure 5.

The following sub-sections include a short description of the sampling methods used and special considerations:

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4.3 Method 5G-2 Determination of Particulate Emissions

Principle: For Method 5G particulate matter is withdrawn proportionally at a single point from a total collection hood and sampling tunnel that combines the fireplace exhaust with ambient dilution air.

Sample train: The sample train is based on the Method 5 sample train. The particulate matter is collected on two 8.26 cm glass fiber filters separated by standard Method 5 impingers immersed in an ice bath. The first filter was maintained at a temperature of no greater than 120 degrees Celsius. The second filter and the impinger system were cooled such that the exiting temperature of the gas was no greater 20 degrees Celsius. Figure 4.1 is an illustration of the Method 5G-2 sample train.

Sampling: The Method 5G-2 sampling train was operated at to draw approximately 0.5 cubic feet of stack gas a minute. Sample rates were adjusted regularly at 10 minute intervals to remain proportional to the tunnel flow rate. Two 6 point velocity transverses of the dilution tunnel were conducted at 90 degrees apart prior to the start of each test run. The traverse points were located approximately 8 diameters downstream from an elbow and approximately 2 diameters upstream from the sampling locations. The "S" type pitot was set at an average point of velocity for the duration of the test run. The sample point was located at a minimum of 2 diameters upstream from any flow disturbance. Tape was wrapped around the probe to seal any gaps between the probe and sample port.

Sample recovery and analysis: Sample recovery and analysis for the 5G-2 train was conducted as described in Method 5H, Sections 5.3 and 5.4. The particulate mass collected in the probe, on the filters, and in the impingers is recovered and the mass was determined gravimetrically after removal of uncombined water. Figure 4.2 illustrates the procedures used for sample recovery and analysis.

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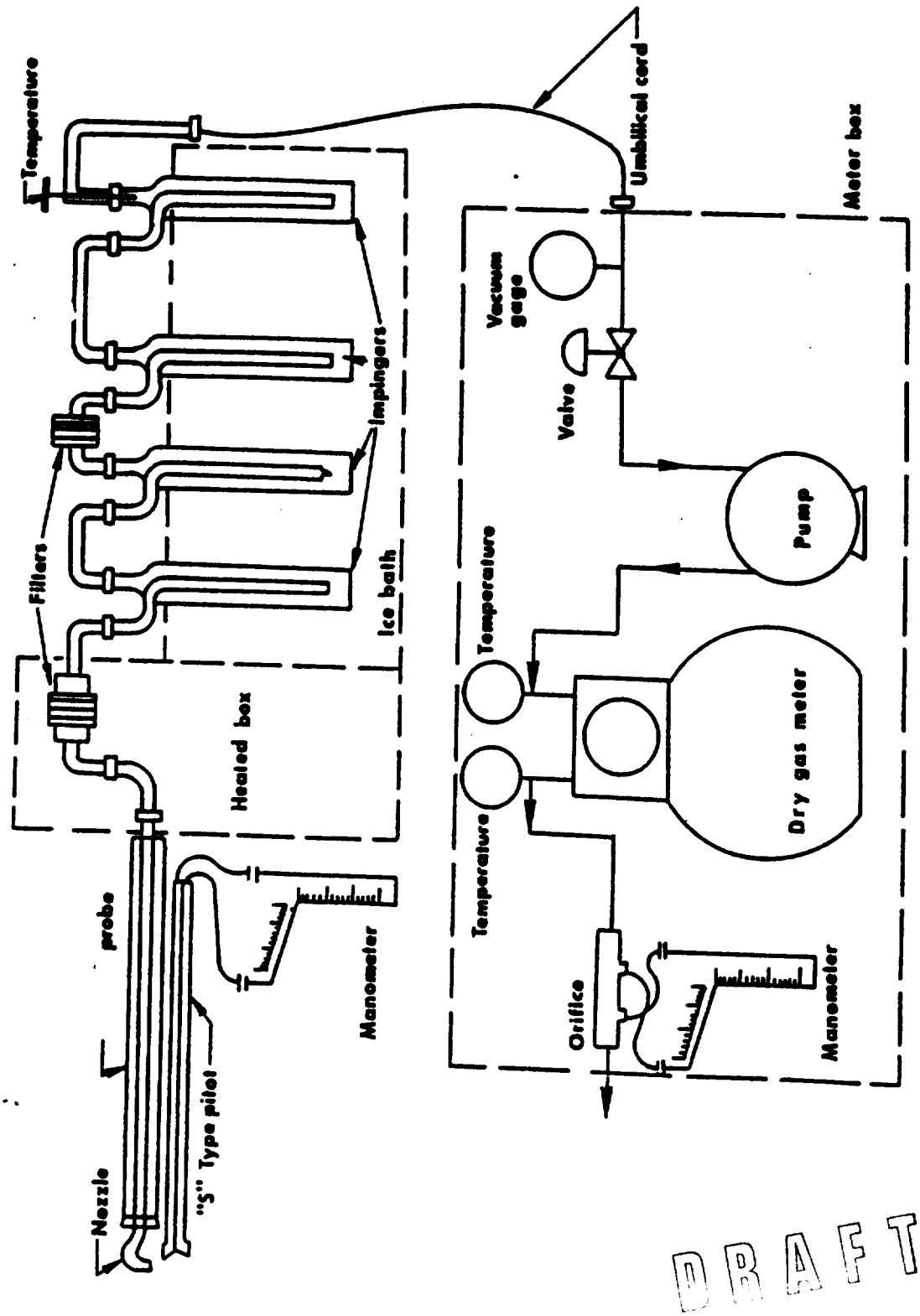
FIGURE 4.1
METHOD 5G-2 SAMPLE TRAIN



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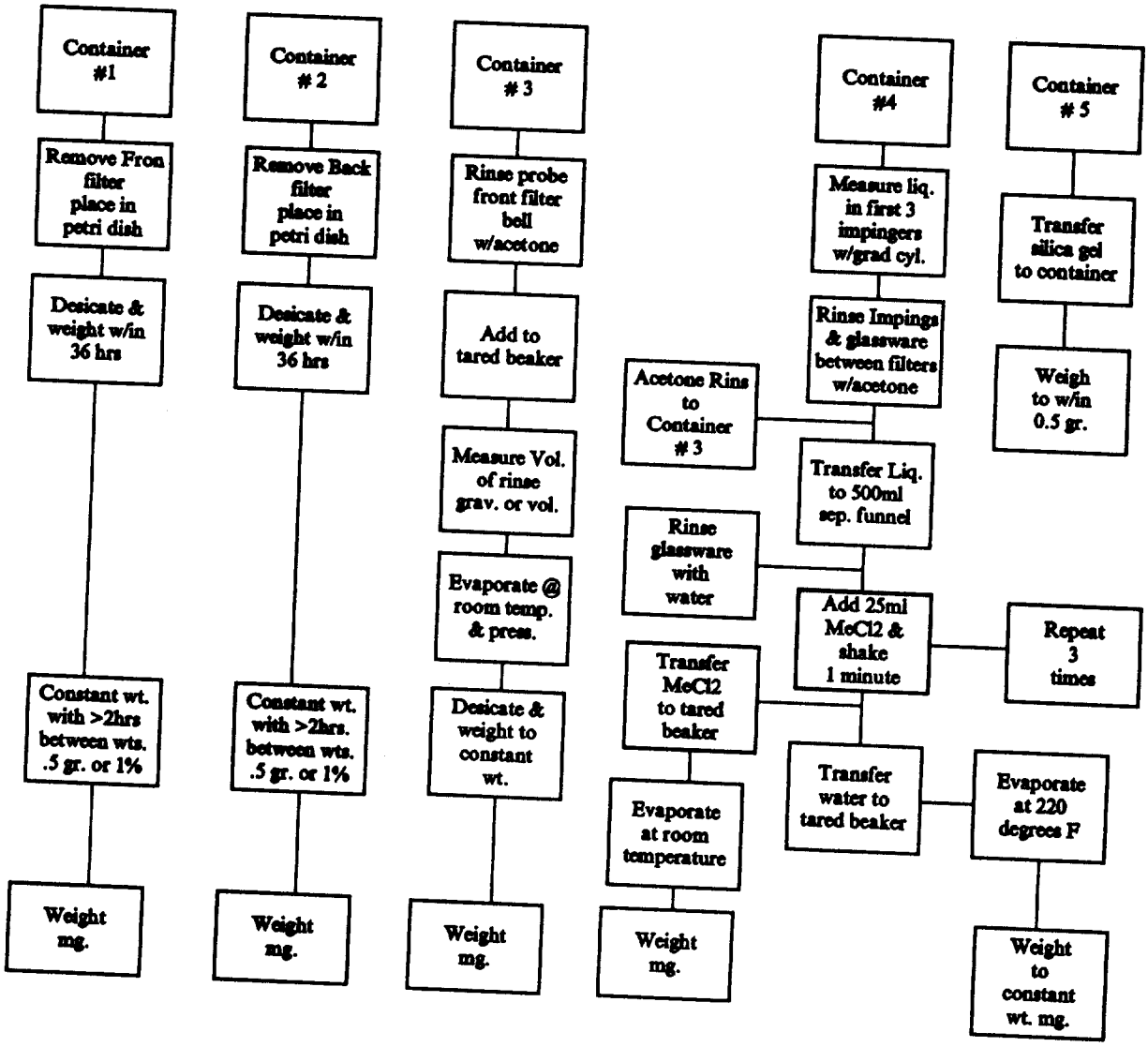

FIGURE 4.2
METHOD 5G-2 SAMPLE RECOVERY AND ANALYSIS

4.4 Determination of Sulfur Dioxide Emissions From Stationary Sources

Principle: EPA Method 8 - Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions From Stationary Sources was followed for determination of SO2 emissions. A gas sample was extracted from a single sampling point in the dilution tunnel. The sulfuric acid mist (including sulfur trioxide) and the sulfur dioxide were separated in the sample train and the sulfur dioxide fraction was measured by the barium-thorin titration method.

Sample train: The sample train used is as prescribed in Method 8. A schematic of the sampling train used in this method is shown in Figure 4.3. Unheated Teflon tubing was used for a probe; heating was not necessary to prevent visible condensation during sampling. Standard Method 5 glassware was used in the sample train. The filter holder indicated between the first and second impingers was not heated.

Sampling: The sample train was operated at a constant rate drawing approximately 0.5 cubic feet of sample gas per minute for the duration of the run. The impinger exit temperature was monitored and kept below 68 degrees Fahrenheit. At the conclusion of the test run the train was leak checked, the ice bath was drained, and the probe was disconnected. The remaining parts of the train were purged by drawing ambient air through the system for 15 minutes at the average flow rate used for sampling.

Sample Recovery: SO_2 sampling was done concurrently with the Method 5G-2 sampling. Therefore, moisture content analysis from the SO_2 sample train was not required. The contents of the first impinger and the sample filter were discarded. The contents of the second and third impingers, containing the hydrogen peroxide solution, were quantitatively recovered and transferred to a 1000 ml volumetric flask and diluted to the mark and shaken. A portion of the sample was transferred to a storage container for later analysis. Figure 4.4 is an illustrating showing the procedures used for SO_2 sample recovery.

Analysis: A 20-ml aliquot was pipetted from the sample container and transferred to a 250 ml Erlenmeyer flask. Eighty milliliters of 100% isopropanol and two to four drops of thorin indicator was added to the flask. The sample was titrated to a pink end point using 0.0100 N barium perchlorate. Sample analysis was done in duplicate, and additional analysis was conducted if the volume of titrate between the duplicate analysis differed by more than 0.2 m.l.

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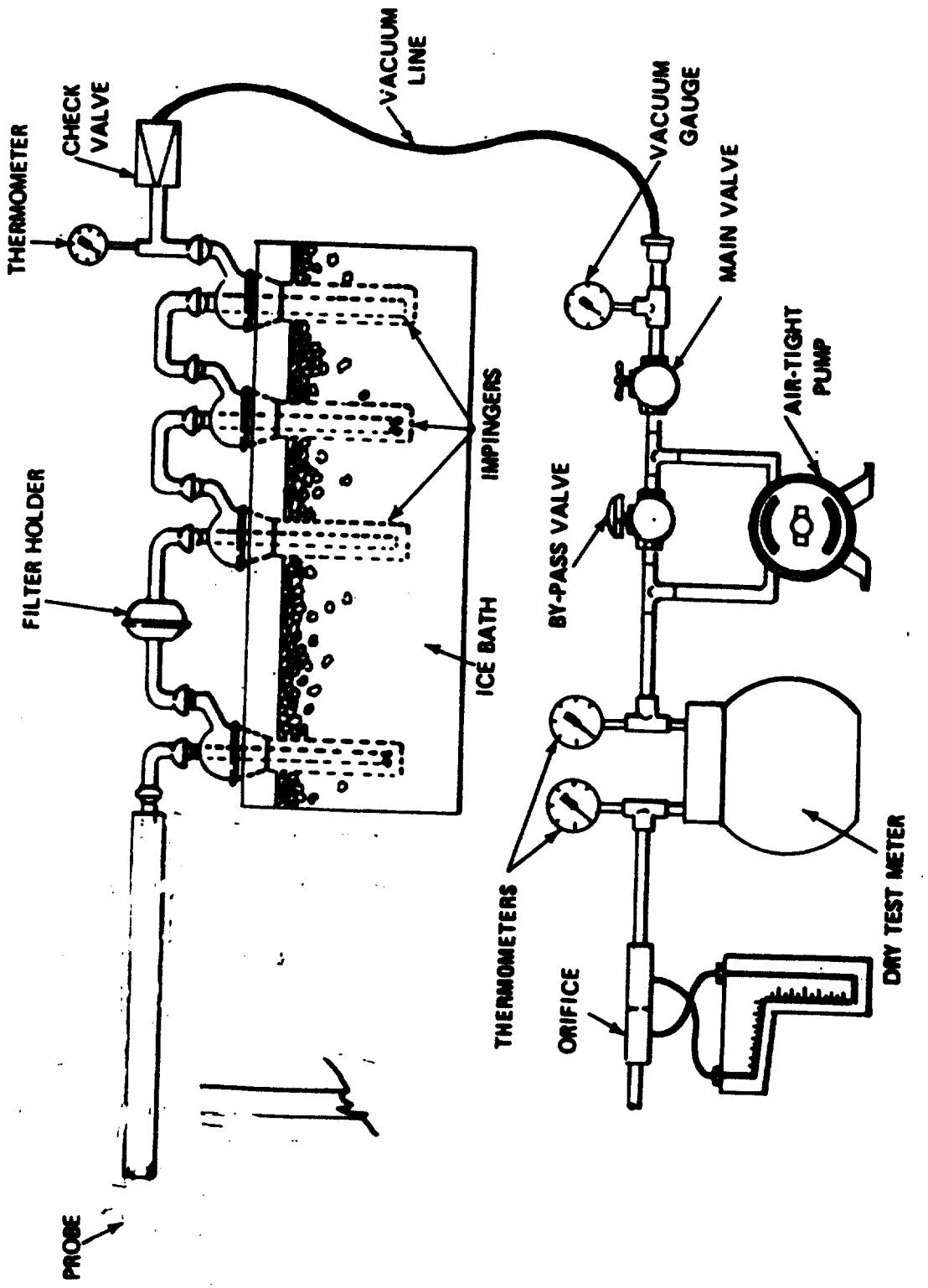
FIGURE 4.3
EPA METHOD 8 SAMPLE TRAIN



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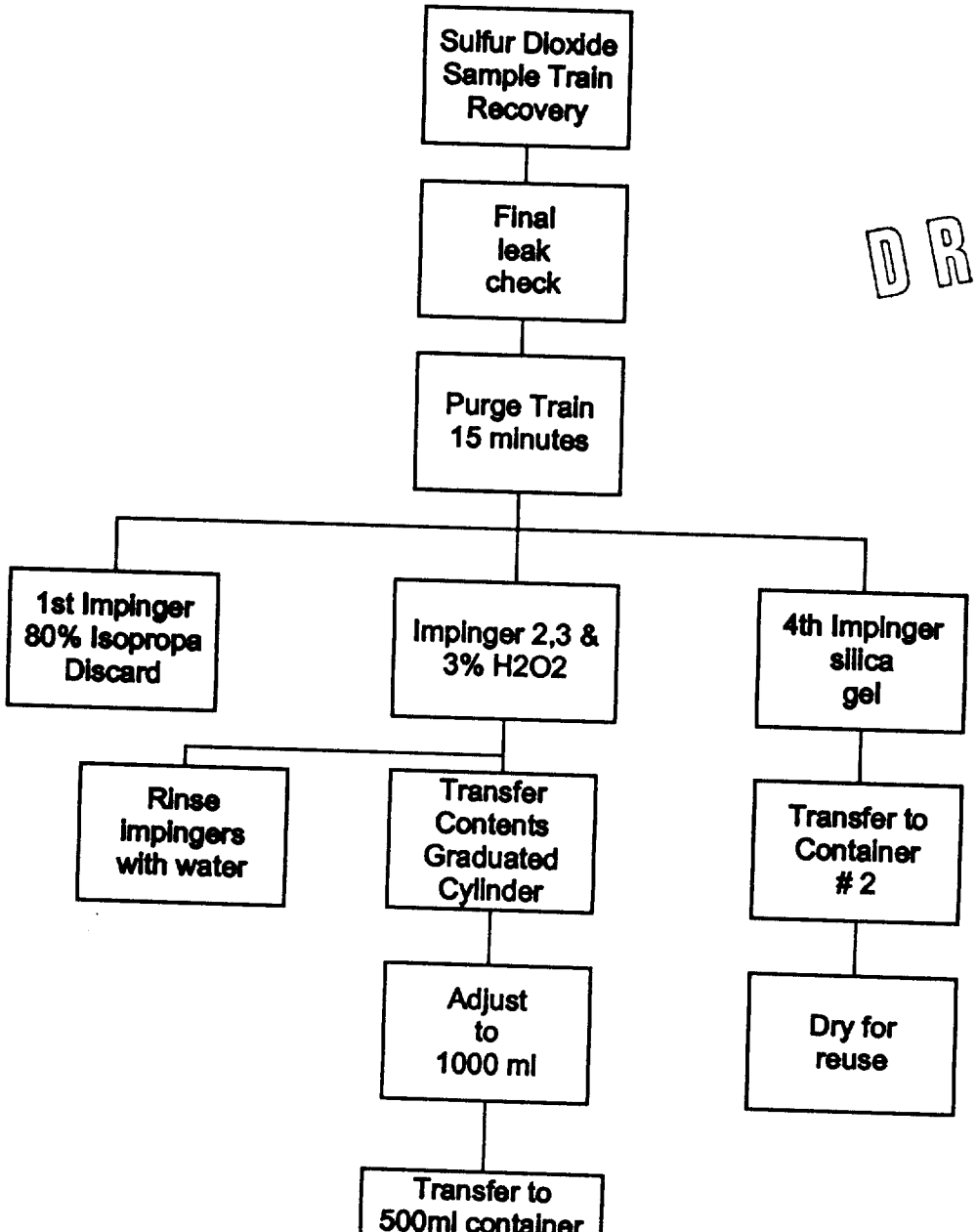
4.5 Determination of Oxygen, Carbon Dioxide, Carbon Monoxide, and Nitrogen Oxides

Principle: An integrated or continuous gas sample was extracted from the dilution tunnel at a constant rate and analyzed by continuous emission monitor (CEM).

Gas Analysis

All gas samples were drawn from the dilution tunnel using a



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4.6 Determination of Semi-Volatile Organic Compounds

Principle: The Modified Method 5 sample train was operated to withdraw sample gas proportionally at a single point from a total collection hood and sampling tunnel that combines the fireplace exhaust with ambient dilution air. The sample point was located perpendicularly to the sample location that the Method 5G-2 sample was taken.

Sample train: The MM5 train was based on the Method 5 sample train except that the heated filter was followed by a condenser coil and a water jacketed sorbent module containing XAD-2 resin, The XAD-2 resin was used to collect semi-volatile organic materials that pass through the glass filter in the gaseous phase. Figure 4.5 is an illustration of the MM5 sample train.

Sampling: Sampling was done concurrently with and in the same manner as outlined in section 4.2 Method 5G-2. The probe was not heated in any way. The filter compartment was maintained at a temperature of approximately 250 degrees Fahrenheit. The condenser and the impinger system was cooled such that the exiting temperature of the gas was no greater 68 degrees Fahrenheit.

Sample recovery and analysis. Following the completion of the test run the sample train was leak checked and the sample was recovered. The XAD-2 module was sealed and stored at a temperature less than 32 degrees Fahrenheit. The filter was recovered and placed in a glass petri dish which was sealed with teflon tape. The moisture in the impingers was measured and recorded. All glassware located after the filter was rinsed with water. The impinger contents and water wash was placed into a separatory funnel and the ph adjusted to 2. Three (3) twenty five (25) ml. methylene chloride extractions were performed on the impinger solution and were saved in a glass sample bottle. The impinger solution ph was adjusted to 11 and an additional three (3) twenty five (25) ml $MeCl_2$ extractions were performed. All the $MeCl_2$ extractions were combined in one sample bottle, which was sealed with a teflon lined cap and labeled for storage and analysis.

The samples were analyzed for total chromatographic organics (TCO), gravimetric analysis, and to determine the levels of thirteen organic compounds commonly encountered in the combustion of wood products. A sample train blank and multiple laboratory spikes and blanks were also included done for the MM5 sampling portion of sampling. The results of blanks and spikes can be found in Appendix C-Quality Assurance.

Figures 4.6 and 4.7 illustrate the procedures used for sample recovery and analysis.

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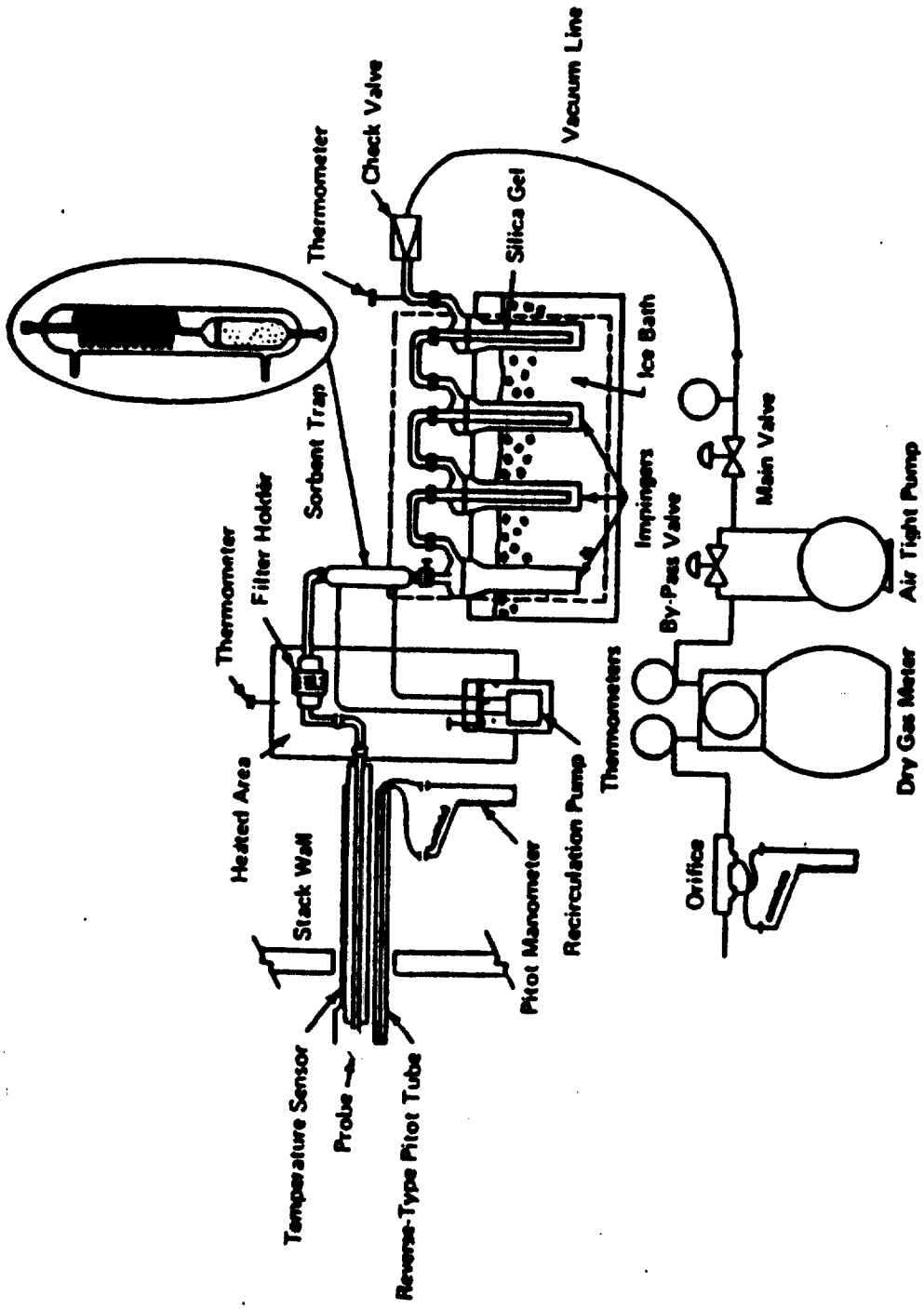
FIGURE 4.5
MODIFIED METHOD 5 SAMPLE TRAIN



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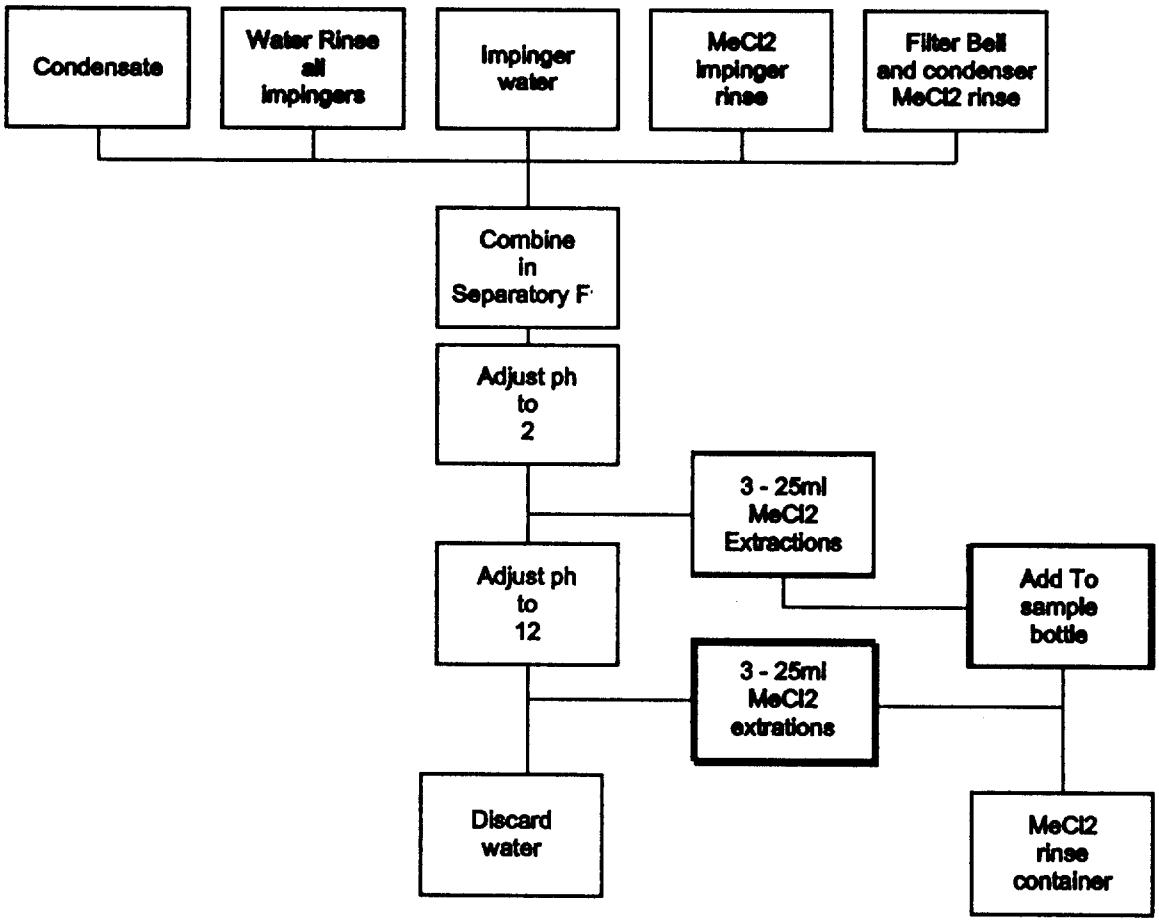

FIGURE 4.6
MODIFIED METHOD 5 GLASSWARE RECOVERY

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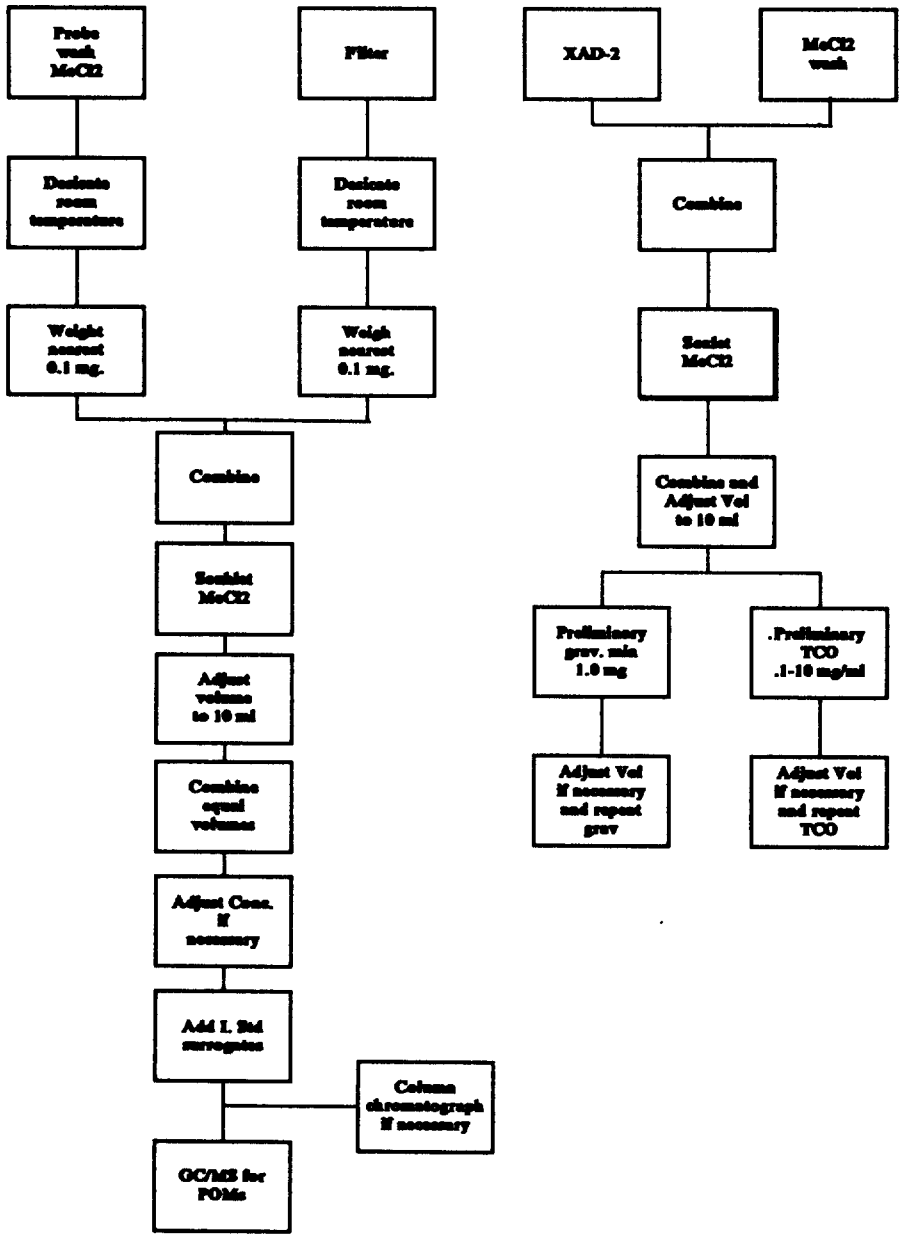

FIGURE 4.7
MODIFIED METHOD 5 SAMPLE ANALYSIS

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4.7 Determination of Total Nonmethane Organic Emissions as Carbon

Principle: A sample is withdrawn from the dilution tunnel at a constant rate. The sample passes through a chilled condensate trap follows: and into the evacuated sample tank. Total gaseous nonmethane organics (TGNMO) are determined by combining the analytical results obtained from the independent analysis of the tanks and traps.

Sample Train: EPA Method 25 will be used to determine the TGNMO. The "new" type sample train consisting of a heated sample probe, heated particulate filter, sample trap immersed in dry ice, and evacuated two liter tank was used for sampling. The sample train schematic unit is shown in Figure 4.8.

Sampling: Sampling was conducted as specified in Method 25 section 4.1. Three samples were collected for each fireplace burn. The first sample was collected starting with ignition of the fuel. The second sample was collected starting around the midpoint of the burn. The final sample was collected during the "burn down" or last couple of hours of the burn. Each sample was collected over a period of approximately one hour.

At the conclusion of the Method 25 sampling program, two standard Method 25 audit cylinders, supplied by the Research Triangle Institute (RTI) were sampled. Sampling and analysis of the audit cylinders was conducted as outlined by RTI. A copy of audit procedures and results can be found in Appendix B and C respectively.

Recover and Analysis: Samples were recovered and analyzed as outlined in Method 25 sections 4.2 and 4.3 respectively.

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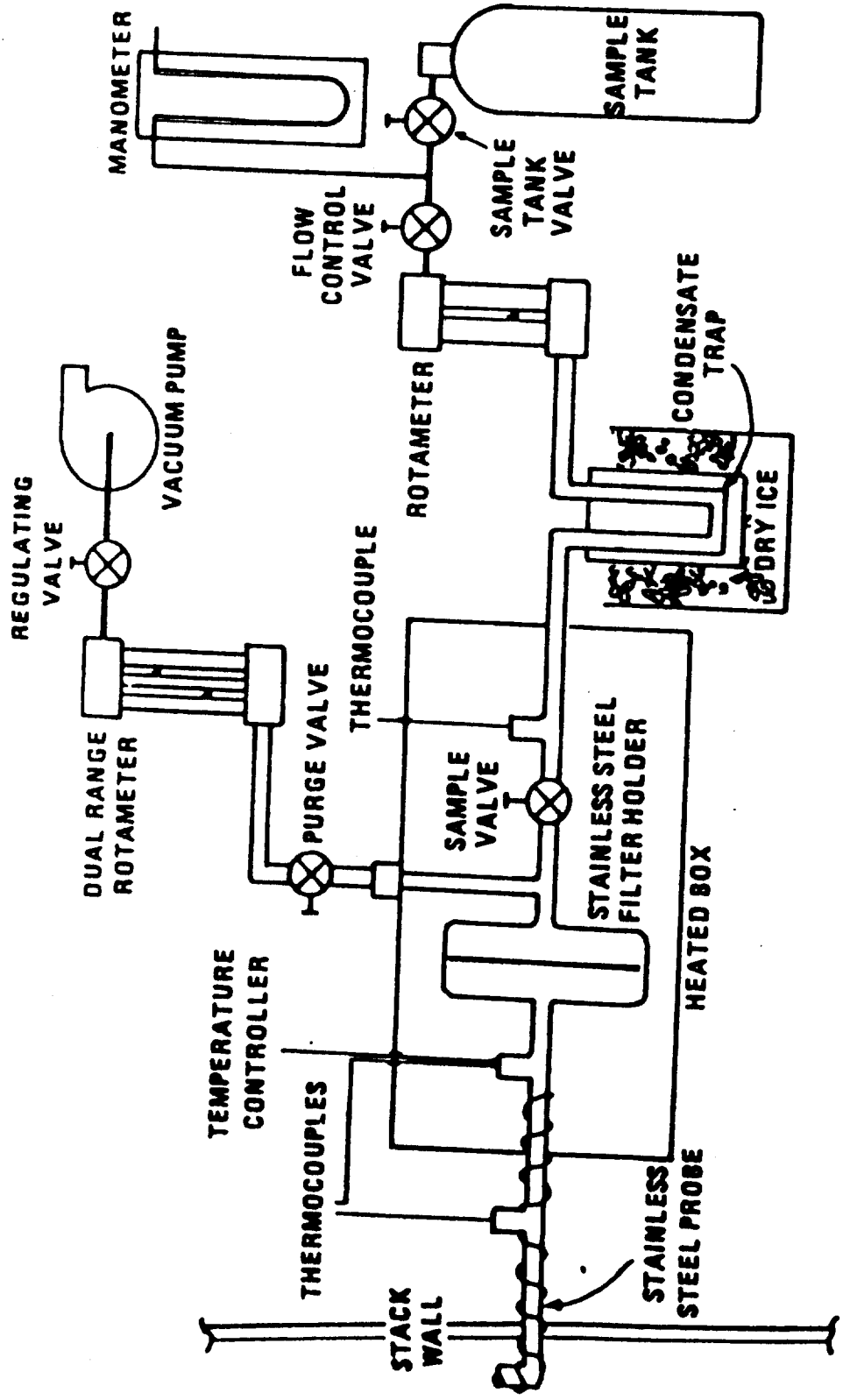
FIGURE 4.8
EPA METHOD 25 SAMPLE TRAIN



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