Development of Emission Factors for the Rubber Manufacturing Industry

Volume 3: Test Program Protocol

Presented to

Rubber Manufacturers Association

RMA

Presented by

TRC

TRC Environmental Corporation

January 1995

TRC Project No. 16157

January 1995

DEVELOPMENT OF EMISSION FACTORS FOR THE RUBBER MANUFACTURING INDUSTRY

Volume 3

Test Program Protocol

Prepared for

Rubber Manufacturers Association (RMA)
Suite 900
1400 K Street, N.W.
Washington, District of Columbia 20005

Prepared by

TRC Environmental Corporation
Boott Mills South
Foot of John Street
Lowell, Massachusetts 01852
(508) 970-5600

DISCLAIMER

This report is intended for use solely by Rubber Manufacturers Association for the specific purposes described in the contractual documents between TRC Environmental Corporation and Rubber Manufacturers Association. All professional services performed and reports generated by TRC have been prepared for Rubber Manufacturers Association's purposes as described in the contract. The information, statements and conclusions contained in the report have been prepared in accordance with the work statement and contract terms and conditions. The report may be subject to differing interpretations and/or may be misinterpreted by third persons or entities who were not involved in the investigative or consultation process. TRC Environmental Corporation therefore expressly disclaims any liability to persons other than Rubber Manufacturers Association who may use or rely upon this report in any way or for any purpose.

TABLE OF CONTENTS

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

Appendices

TABLES

Number **Page**

FIGURES

Number **Page**

TABLE OF CONTENTS (CONTINUED)

Number **Page**

SECTION 1.0

INTRODUCTION

The 1990 Clean Air Act Amendments (CAAA) included a list of 189 regulated hazardous air pollutants (HAPs). Facilities emitting these compounds became subject to the 1990 CAAA Title V federal operating permit program. In order to meet the requirements of Title V, a plant wide emission inventory for all regulated pollutants, including HAPs, is necessary.

Accurate emission factors for HAPs are required for preparation of emission inventories in rubber manufacturing plants. The rubber manufacturing industry is one of these industries for which up-to-date emission factors are not available. The Rubber Manufacturers Association (RMA) has initiated an emissions sampling program, on behalf of its members, to develop HAP emission factors for processes with little available air pollutant emission data.

This report describes the results of a program conducted for the Rubber Manufacturers Association on behalf of its members. The technical approach are reported in sufficient detail to allow others to replicate the tests. Topics covered in this report include:

- INTRODUCTION
    - Objective
    - Manufacturing Processes
    - Technical Approach Summary
    - Typical Results
- TEST PROGRAM
    - Objective
    - Target Compounds
    - Test Matrix
- SOURCE DESCRIPTION
    - Processes
    - Design and Construction of Process Enclosures
    - Control Equipment
- SAMPLING LOCATIONS
- FIELD SAMPLING PROCEDURES
    - Presampling Activities
    - Onsite Sampling
- ANALYTICAL PROCEDURES
- QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

1.1 OBJECTIVE

The objective of this test program has been to quantify emissions of hazardous air pollutants (HAPs) from a representative selection of rubber formulations and manufacturing processes.

Emissions are expressed as emission factors which will be suitable for the purposes of Title V of the Clean Air Act Amendments.

1.2 OVERVIEW OF TEST PROGRAM

Six processes common to both the tire and general rubber products industries were the subject of this project. The processes were: mixing (including the drop mill or similar purpose equipment), milling (warmup), extruding, calendering, vulcanizing (curing), and grinding. Twenty six rubber compounds/mixtures, related to the tire and non-tire rubber products manufacturing facilities, were studied in this program.

Ten processes were tested: internal mixers, warmup mills, rubber extruder, calender, tire press, oven curing of tire cuts, platen press, surface grinding, and oven curing of general products. Nine of the processes were tested for: total volatile organic compounds, speciated volatiles, volatile ozone precursors, sulfur compounds, semivolatile organic compounds, particulate organic matter. Two processes (tire press and autoclave) were tested for amines. Four processes (tire press, oven cure of tire cuts, extruder, and some grinding processes) were tested by Fourier transform infrared spectroscopy (FTIR). Three processes (extruder, internal mixers, and grinding) were tested for particulate matter and metals. The test matrix of processes and chemical analyses is presented in Section 2.

The test program has been conducted at a total of eleven locations. These locations included manufacturing facilities as well as research and development facilities.

1.3 TECHNICAL APPROACH SUMMARY

1.3.1 Parameters

Target compounds for this study included the specific chemical compounds from:

- the Clean Air Act Amendments Title III hazardous air pollutant list (HAPs)
- the State Air Toxics lists
- the SARA 313 toxic chemical list (40 CFR 372.65)

any other compounds on the EPA Contract Laboratory Program

- volatile organic chemical (VOC) list
- semivolatile organic chemical list
- metals list

and sulfur compounds. Other parameters monitored for these tests included:

- organic compounds by Fourier transform infrared (FTIR) spectroscopy
- total volatile organic compounds (total VOC, or TVOC)
- polycyclic organic matter (POM)

1.3.2 Emission Calculations

For each test, emission rates were developed as pounds of pollutant emitted per pound of rubber (or product) processed. The amount of rubber or product involved in each test was directly measured or obtained from engineering data (such as rubber makeup of individual tires). The amount of pollutant emitted was determined from laboratory analytical data on a particular sample and by calculation of the fraction of the total emissions represented by the sample. A typical example can be used to illustrate the calculations involved in developing emission factors.

During the three-pass mixing of tread compound in the large Banbury mixer, the total mass of rubber processed was 1942.5 pounds over the 128-minute run time, for a rate of 910.5 pounds of rubber per hour. The mass of the semivolatile organic compound, diphenylamine, collected in the M0010 sampling train was determined through laboratory analysis to be 86.85 micrograms (ug). The volume of exhaust gas sampled by this train was 78.782 dry standard cubic feet (dscf). The resultant average concentration of diphenylamine in the exhaust gas from the Banbury mixer was 1.10 ug/dscf. The exhaust gas flow rate was 680 dscf/minute, yielding a pollutant emission rate for diphenylamine of 9.92 x 10^{-5} pounds per hour.

To calculate pollutant emission based on a production or processing rate, the hourly emission rate was divided by the hourly rubber processing rate:

$$\frac{9.92x10^{-5}\ \mathit{lbs\ diphenylamine/hr}}{910.5\ \mathit{lbs\ tread\ compound/hr}} = 1.09x10^{-7}\ \mathit{lbs\ diphenylamine/lb\text{-}tread\text{-}mixed}$$

1.3.3 Sampling

All sampling for this program involved the collection of samples from air or air condensate (followed by chemical analysis) or the direct monitoring of concentrations in air. No solid samples of rubber were collected for direct chemical analysis.

Sampling locations for each type of process are outlined in Section 3. Samples were taken from enclosures or hoods which captured total air emissions from each process tested.

1.3.4 Monitoring and Chemical Analysis

One real-time monitor, Fourier transform infrared (FTIR) spectroscopy, was used to get an onsite quantitative indication of changes in the concentration of organic compounds during each test. The information was helpful in planning the lengths of sampling runs and flow rates for sampling trains.

Three parametric tests were used: total volatile organic compounds (TVOC), polycyclic organic matter (POM), and particulate matter (PM). Total volatile organic compound data provide close to real-time data on volatile organic compounds throughout each test. These data were later compared to compound-specific chemical analysis data. POM data provide an indication of the total mass of methylene-chloride soluble particulate matter emitted for each test. PM data quantify the particulate emissions from each process.

Three compound-specific chemical analysis tests were used: semivolatile organics, volatile organics, and metals. From these tests, it is possible to assess variation in the composition of emissions for each rubber mixture tested by process. These are the quantitative HAP data which are relevant to federal and state regulatory programs.

SECTION 2.0

TEST PROGRAM

2.1 OBJECTIVES

The objective of the test program has been to quantify the emissions of hazardous air pollutants (HAPs) and total organic compounds from the processes described in Section 3.0. These emissions have been correlated with the operating data obtained during the emissions testing to develop emission factors for each HAP for each process. These emission factors are expressed in units of mass of HAP emitted per mass of material processed or unit of product manufactured. These emission factors will then be employed by rubber manufacturing facilities to assist in completing application forms under Title V of the 1990 Clean Air Act Amendments (CAAA).

The primary focus of the test program has been upon rubber processing. Initially, four generic classes of rubber mix commonly used in the tire industry were studied. These are: tread, sidewall, styrene-butadiene rubber (SBR), and ethylene-propylene-diene copolymer (EPDM). Additional rubber mixes from both the tire and other rubber manufacturing industries have also been incorporated into the program.

Many operating variables exist in the manufacturing of rubber products. Some of these variables consist of the types of raw rubber and chemical additives used, the sequence of the processing steps, operating temperatures and pressures of each process for each product, and the manner in which the product is cured. The emissions sampling has been performed to address many of these variables. However, it is not feasible to address all of the variables involved in this industry. This program has attempted to provide sufficient information to allow facilities to determine the *potential to emit* for each selected process.

2.2 SELECTION OF TARGET COMPOUNDS

The initial step necessary in developing emission factors is to identify which pollutants are emitted to the atmosphere from the process. Previous investigations into the emissions from rubber manufacturing show that the predominant emissions are low molecular weight organic compounds (C_6-C_8). However, the potential for heavier, less volatile organic compound emissions also exists due to the chemistry and the elevated temperatures of many of the processes. Particulate matter emissions can also be significant, especially during the mixing process when carbon black is added to the mix.

Title III of 1990 CAAA lists 189 HAPs. Many of these are applicable to the rubber manufacturing industry. In addition, many states where rubber manufacturing facilities operate have developed their own HAP lists. Since the Title V operating program will be administered by the individual states, there exists the possibility that facilities will need to conduct emission inventories for all of the HAPs in Title III as well as on the state lists. A combined HAP list has been developed from Title III, state HAP lists, as well as the SARA 313 toxic chemical list. All compounds on this combined list (shown in Appendix A) which have the potential to be emitted from the selected processes, have been targeted by this program.

The emissions from each process change depending upon the type of rubber used (natural or synthetic) and the specific additives (metal oxides, accelerators, retardants, antiozonants, softeners, fillers, and vulcanizing agents) in the mix. The emissions vary due to the physical properties of the raw rubber, the physical characteristics of the processes, chemical additives, and the reaction chemistry of the processes. Some historical emissions data is available, although it is not comprehensive. These data have served as a starting point for developing the final target compound list.

The tire manufacturing industry principally uses natural rubber, styrene-butadiene (SBR) rubber, and polybutadiene rubber. Polybutadiene is often mixed with SBR to improve the abrasion and cracking resistance of the tire. For non-tire rubber goods where oil resistance is a priority, rubbers such as polyacrylates, nitrile, neoprene, polyurethanes, epichlorohydrins, chlorosulfonated polyethylene, chlorinated polyethylene, and fluoroelastomers are used. Potential emissions from these rubbers consist of breakdown compounds such as the monomers used to create the rubber.

Accelerators are added to the mix to speed up the vulcanization rate. Typical accelerators are metal oxides (zinc oxide, lead oxide, and magnesium oxide) and a large variety of organic accelerators. These organic accelerators are typically from the following classes of organic compounds: benzothiazoles, benzothiazolesulfonamides, dithiocarbamates, dithiophosphates, guanidines, thioureas, and thiurams.

Antioxidants help to prevent oxidation (aging) of the vulcanized product. Antioxidants are usually high molecular weight amine compounds such as dioctylated diphenylamine. The potential for amine emissions exists upon the degradation of this compound during processing.

Retarders are used to prevent the premature vulcanization (scorching) of the rubber during processing. Retarders currently in use mainly consist of organic acids (salicyclic and benzoic acids), phthalic anhydride, and N-(cyclohexylthio)phthalimide. Again, the potential emissions consist of the retarders themselves along with their thermal breakdown components.

Softeners are used to increase the workability of the mix for lubrication during extrusion and molding and, to aid in the dispersion of fillers. The predominant softener used in the rubber industry is petroleum oil. The potential emission compounds from petroleum oil are extensive. The majority of the compounds would most likely be aromatic hydrocarbons of various sizes and types.

Fillers are added to the rubber mix for several reasons. Fillers provide color but are mainly used to reinforce the final product. Fillers are fine particles which increase the abrasion resistance and tensile strength of the product. Carbon black is used as the primary filler in tire manufacturing. Rubber goods requiring a color other than black use numerous types of inorganic fillers. Due to the extremely fine particle size of fillers, they are easily emitted to the atmosphere during mixing.

Sulfur compounds comprise the vast majority of vulcanizing agents currently used. Sulfur can be added as elemental sulfur or within inorganic or organic sulfur compounds. The presence of sulfur and the high temperatures involved in the processes creates the possibility of sulfur compounds such as carbon disulfide to be emitted.

The available historical data for emissions from rubber manufacturing consists mainly of a doctoral thesis presented by Dr. Stephen Rappaport at the University of North Carolina in 1976. Dr. Rappaport conducted a laboratory study of C_6-C_{25} organic compound emissions from the curing of one type of rubber stock used in tire manufacturing. The rubber stock was a mixture of SBR and polybutadiene rubbers along with the necessary chemical additives. The results of Dr. Rappaport's study showed that a large number of cyclic (aromatic) organic compounds were emitted. Although these results are informative, the study was conducted on only one type of rubber mix using a simulated press mold cure. The potential for hazardous compounds to be emitted, other than those discovered by Rappaport, is considerable.

The formulations studied during this program are shown in Appendix B. The composition of these mixes were examined against the combined HAP list (Appendix A) generated from Title III, state HAP lists, and SARA 313 toxic chemical list. The target compounds for the emission factor development program are the list of HAPs, in addition to total VOCs and other pollutants common to the rubber manufacturing industry.

2.3 TEST MATRIX

Table 2-1 summarizes parameters targeted for a given process. The sampling and analytical summary for each process classification is presented in Table 2-2.

Table 2-1. Test Matrix of Processes and Chemical Analyses

	Tire Press	Oven Cure	Autoclave	Extruder	Banbury Mixers	Surface Grinding	Platen Press	Calender	Warming Mill	Oven Cure-Engineered Products
Total Volatile Organic Compounds	X		X	X	X	X	X	X	X	X
Speciated Volatiles	X		X	X	X	X	X	X	X	X
Volatile Ozone Precursors	X		X	X	X	X	X	X	X	X
Sulfur Compounds	X		X	X	X	X	X	X	X	X
Semivolatiles	X		X	X	X	X	X	X	X	X
Polycyclic Organic Matter	X		X	X	X	X	X	X	X	X
Amines	X		X							
FTIR	X	X		X		(a)				
Particulate Matter				X	X	X				
Metals				X	X	X				

(a) FTIR at one grinding facility.

Table 2-1 Test Matrix of Processes and Chemical Analyses

Table 2-2. Sampling and Analytical Methods Summary

	Parameters	Sampling Method	Analytical Methods
1	Total Volatile Organic Compounds	M25A	M25A/FID
2	Speciated Volatiles	TO-14 (a) Grab Sample	TO-14/GC-MS M 8240
3	Volatile Ozone Precursors	TO-14	TO-14/GC-FID
4	Sulfur Compounds	TO-14	GC/FPD
5	Speciated Semivolatiles	M 0010 Grab Sample (b)	M 8270 M 8270
6	Particulate Organic Matter	M202	Extr./Gravimetric
7	Particulate Matter	M5	Gravimetric
8	Metals	M0012	M 6010, 7000
9	Amines	Midget Impinger Sampling Train	GC
10	FTIR	Extractive	FTIR

(a) Grab sample for autoclave water trap.
(b) Grab/composite sample for autoclave blowdown.

Table 2-2 Sampling and Analytical Methods Summary

SECTION 3.0

SOURCE DESCRIPTION

The majority of rubber manufacturing facilities in the United States produce pneumatic tires for automobile, trucks, airplanes and farm machinery. However, the manufacturing of non-tire rubber products is also quite extensive. The processes involved in these industries are very similar. The differences basically consist of the raw rubber material (natural or synthetic) used, the chemical additives, and the type of curing employed. The following is a description of a generic rubber manufacturing facility applicable to both tire and other manufactured rubber products, except where noted.

3.1 PROCESS DESCRIPTION

The manufacturing of rubber products involves several processing steps. Initially, the raw rubber (natural or synthetic) is mixed with several additives which are chosen based upon the desired properties of the final product. The mixed rubber is often milled and transferred to an extruder where it can be laminated to other compounds. Many rubber products contain synthetic fabric or fibers for strengthening purposes. These fibers are typically coated with mixed rubber using a calendering machine. The extruded rubber and rubber coated materials are then assembled into its final shape and cured. It is during the curing process that the rubber vulcanizes (crosslinks) producing the characteristic properties of finished rubber. Some cured products undergo grinding as a final finishing step. A brief description of each of these processes is provided.

Mixing consists of taking the raw rubber and mixing it with several chemical additives. These additives consist of an accelerator (accelerates the vulcanization rate), zinc oxides (assists in accelerating vulcanization), retarders (prevent premature vulcanization), anti-degradents (prevent aging), softeners (facilitates processing of the rubber), carbon black or other fillers (reinforcing/strengthening agents), and inorganic or organic sulfur compounds (vulcanizing agent).

Mixing is typically performed in one of two types of mixers utilized in the rubber manufacturing industry, the internal intensive mixer and the mill mixer. The internal intensive mixer is a batch mixer while the mill is an external open batch mixer. The internal mixer contains two rotors which shear the rubber mix against the wall of the vessel. Internal mixing is performed at elevated temperatures which range from 120° to 180°C. Internal mixing is the primary mixing method within the tire manufacturing industry and in large volume, non-tire mixing applications.

Mill mixing incorporates parallel rolls rotating in opposing directions at slightly different speeds and are operated at modest temperatures of 40° to 100°C. The mixing occurs at the nip between the two rolls. Mill mixing is the dominant mixer used in many smaller manufacturing operations and is commonly utilized for certain practices in most production operations. Mill mixing is also commonly performed downstream from internal mixers in rubber product manufacturing.

The homogenous rubber mass produced by the Banbury is discharged to a mill or other equipment which forms it into a long strip or sheet. The hot sticky strip or sheet is passed through a water based "anti-tack" solution applied to prevent it from sticking together as it cools to ambient temperature.

The processing of the rubber mixes is performed in either a non-productive or productive mode, or both. In nonproductive mode, all of the materials are mixed with the exception of the accelerators and sulfur compounds. This mixed rubber is then stored until needed and then the accelerators and sulfur are added to make the productive mix. After mixing the accelerators and sulfur compounds, the mix has a finite useful life and is normally processed through completion of the final product.

Once the rubber is properly mixed, it can be extruded. The extruder consists of a power driven screw within a stationary cylinder. A die is attached to the head of the screw to produce the desired shape or cross section of the extruded rubber. Extrusion can be performed with both warm or cold rubber feed. The extruder is temperature-controlled to maintain the desired operating temperature.

Calendering is often used in the rubber manufacturing industry to apply a rubber coat onto fabric. Calenders employ either 3 or 4 rolls which are hollow to allow for heating or cooling. The openings between the rolls can be adjusted to control the final thickness.

A common step in manufacturing of rubber products is curing. There are three predominant curing processes: compression mold curing, autoclave curing, and hot air curing. Compression mold curing uses high temperature and pressure to cure the final product. The high pressure (600-10,000 psi) forces the rubber to conform to the shape of the heated mold. Press mold curing is used in tire and non-tire manufacturing.

Autoclave curing utilizes steam to cure the rubber mix. Autoclave curing is curing method in non-tire rubber manufacturing facilities.

Hot air curing entails passing preshaped, a common uncured engineered products through a chamber with a heated atmosphere. Temperature and residence times vary, depending on the product type and formulation. Some of these processes use a heated oven, while others use continuous feed tunnels or chambers.

Grinding is used in the tire industry in producing white side wall tires and in balancing a finished tire. The 'V' shape of a fan belt is also produced in a grinding operation. The tire retreading process uses grinding to remove the old tread from a tire carcass.

In addition to the operations described above, one other variable may be examined to determine its effect upon the emissions. The addition of carbon black to a mix causes some fugitive carbon black to escape to the atmosphere. Therefore, testing has been performed with and without carbon black being added to the mix to determine its effect upon the overall emissions.

3.2 CONTROL EQUIPMENT DESCRIPTION

Emissions from the internal mixers are typically controlled by baghouses. Exhausts from the collection hoods are ducted to the baghouses for control of particulate and possibly particle-bound semivolatiles and metals. During this program, TRC conducted inlet and outlet sampling of a fabric filter for controlling mixer emissions. Additionally, the surface grinding processes generate dust and rubber particles which are typically controlled by a primary cyclone and a secondary baghouse or electrostatic precipitator. Again, inlet and outlet sampling have been conducted to determine collection efficiency and outlet emissions. Specific details on the control devices tested are presented in the test report.

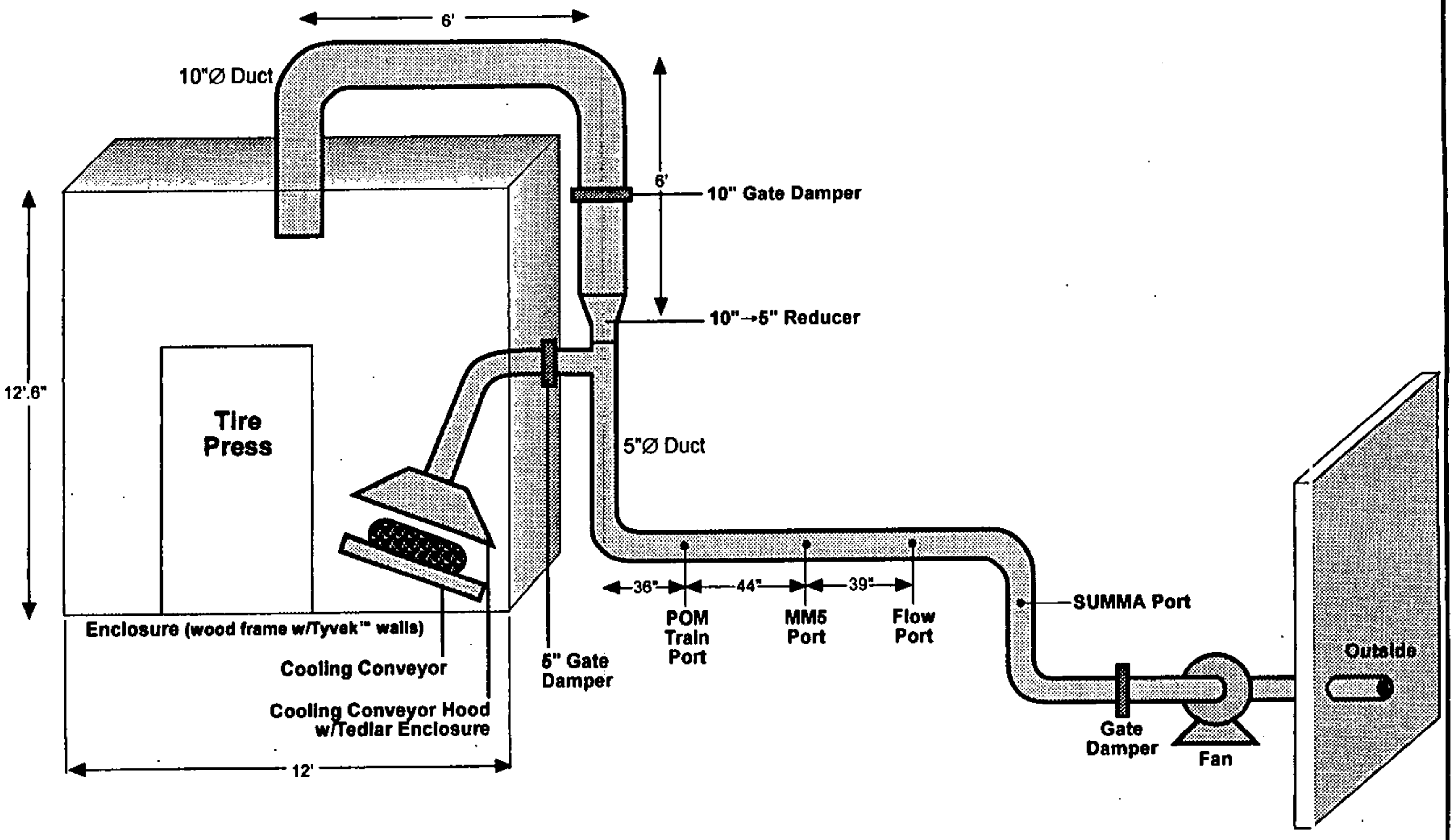
3.3 DESIGN AND CONSTRUCTION OF ENCLOSURES

To accurately quantify the emissions from each process, the emissions were contained to permit sampling of the process offgases. To ensure that all emissions are captured, the design of each enclosure was based upon the criteria in EPA Method 204 for a total enclosure. The objective in using the enclosure approach was to collect and "concentrate" fugitives from the individual process in a way that enclosure exhaust could be sampled.

A highly ventilated enclosure with rapid air turnover would not allow for adequate detection limits of the target parameters. EPA's criteria for enclosures have been followed, as guidance. However, air velocities have been varied to allow for optimal sampling conditions within the exhaust duct. Specific enclosure construction and exhaust details vary with the process, fugitive release rate, and target sampling parameters.

Typical enclosures are illustrated in a Figures 3-1 through 3-16. The figures are presented essentially in the order in which processes were tested during the program.

Process	**Figures**
Tire press and laboratory oven testing of tire cuts	3-1 and 3-2
Autoclave	3-3 and 3-4
Extruder	3-5, 3-6, and 3-7
Mixers and Mills	3-8, 3-9, 3-10, and 3-11
Grinding	3-12
Platen Press	3-13
Calender	3-14
Warmup Mill	3-15
Hot Air Cure of Engineered Products	3-16



Not to Scale

FIGURE 3-1.
TIRE PRESS ENCLOSURE EXHAUST SCHEMATIC

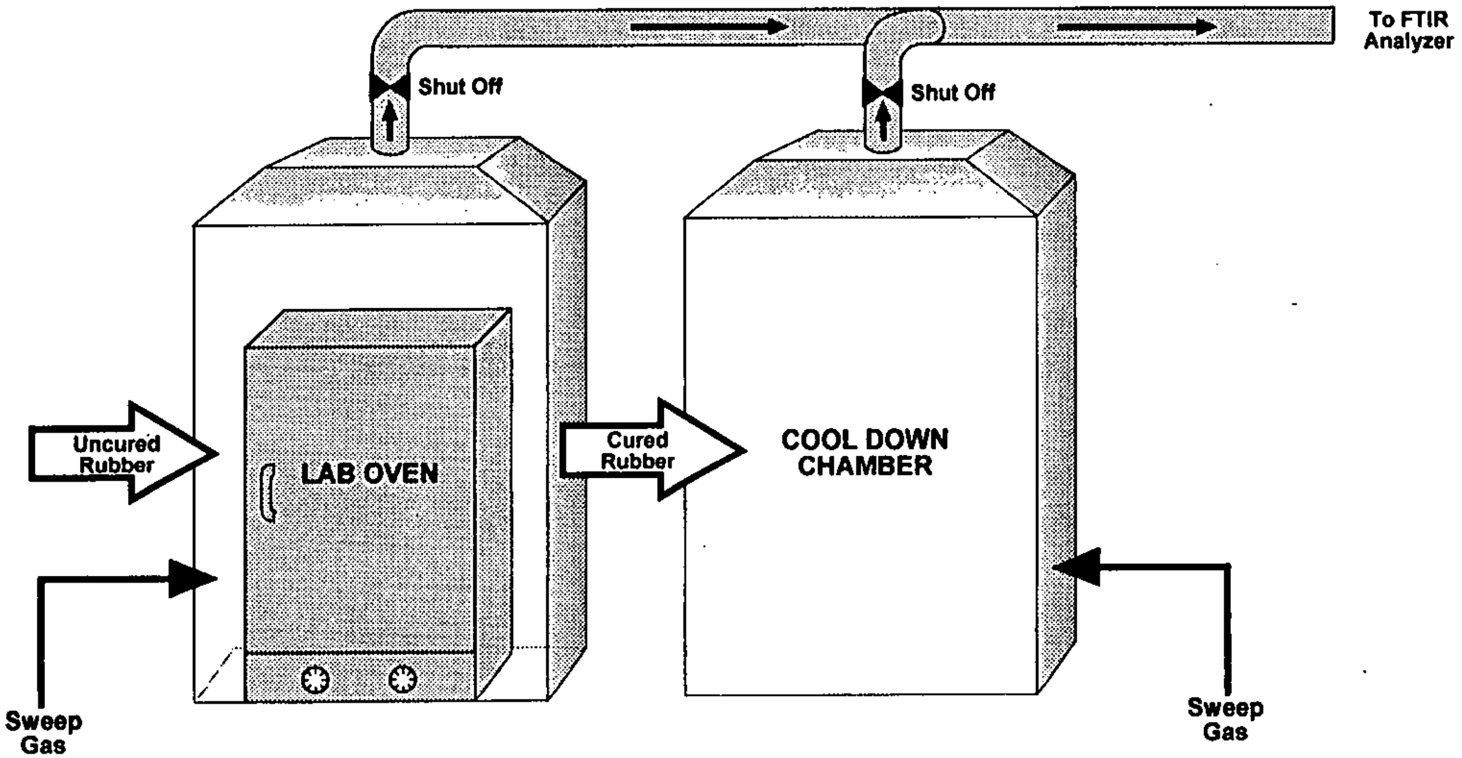
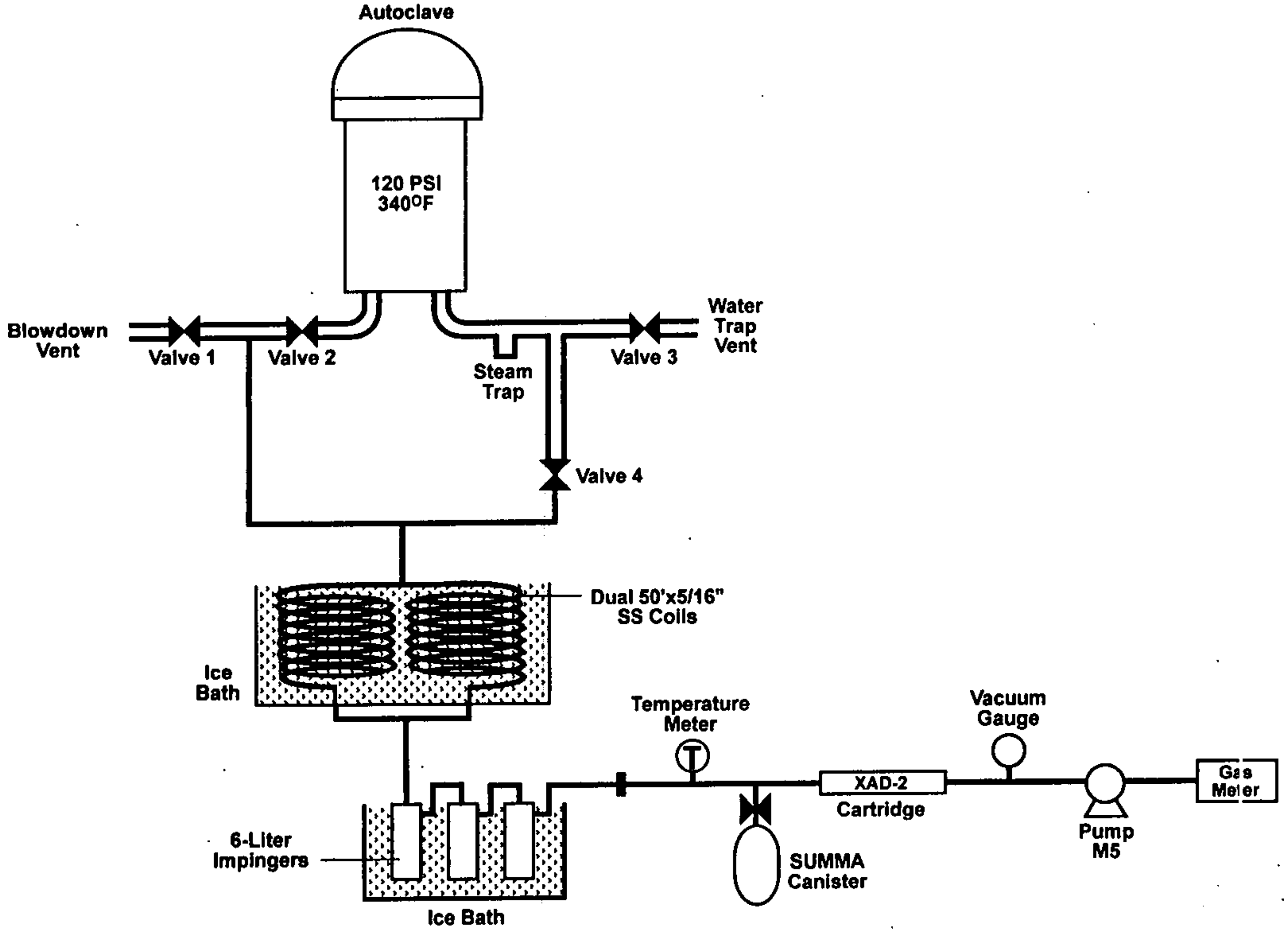


FIGURE 3-2.
LABORATORY OVEN TESTING AND COOL DOWN CHAMBER (TIRE CUTS)

Not to Scale

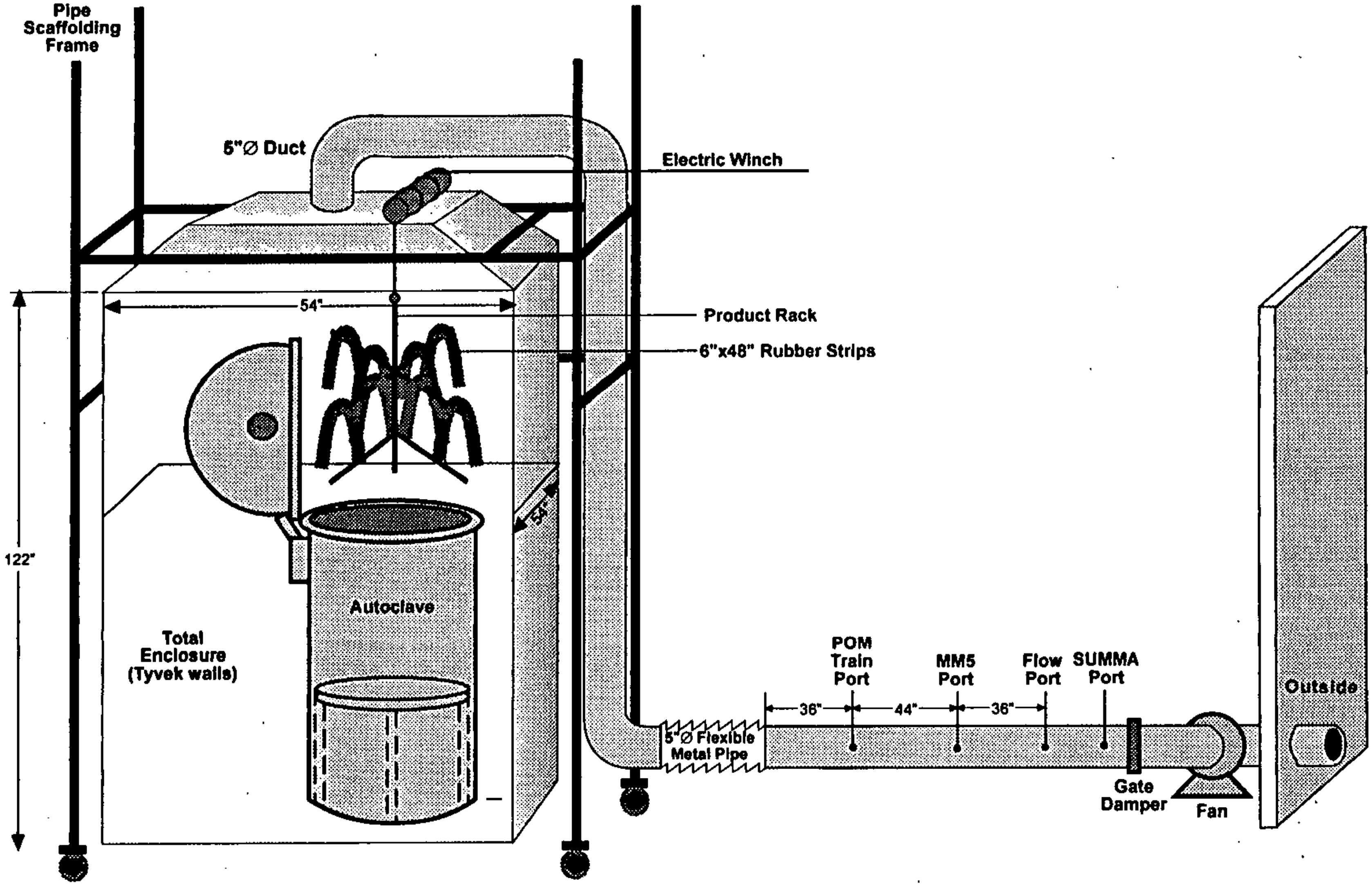
16157-M



Not to Scale

FIGURE 3-3.
AUTOCLAVE CONDENSATE SAMPLING SCHEMATIC

16157-G



Not to Scale

FIGURE 3-4.
AUTOCLAVE ENCLOSURE SCHEMATIC

16157-A

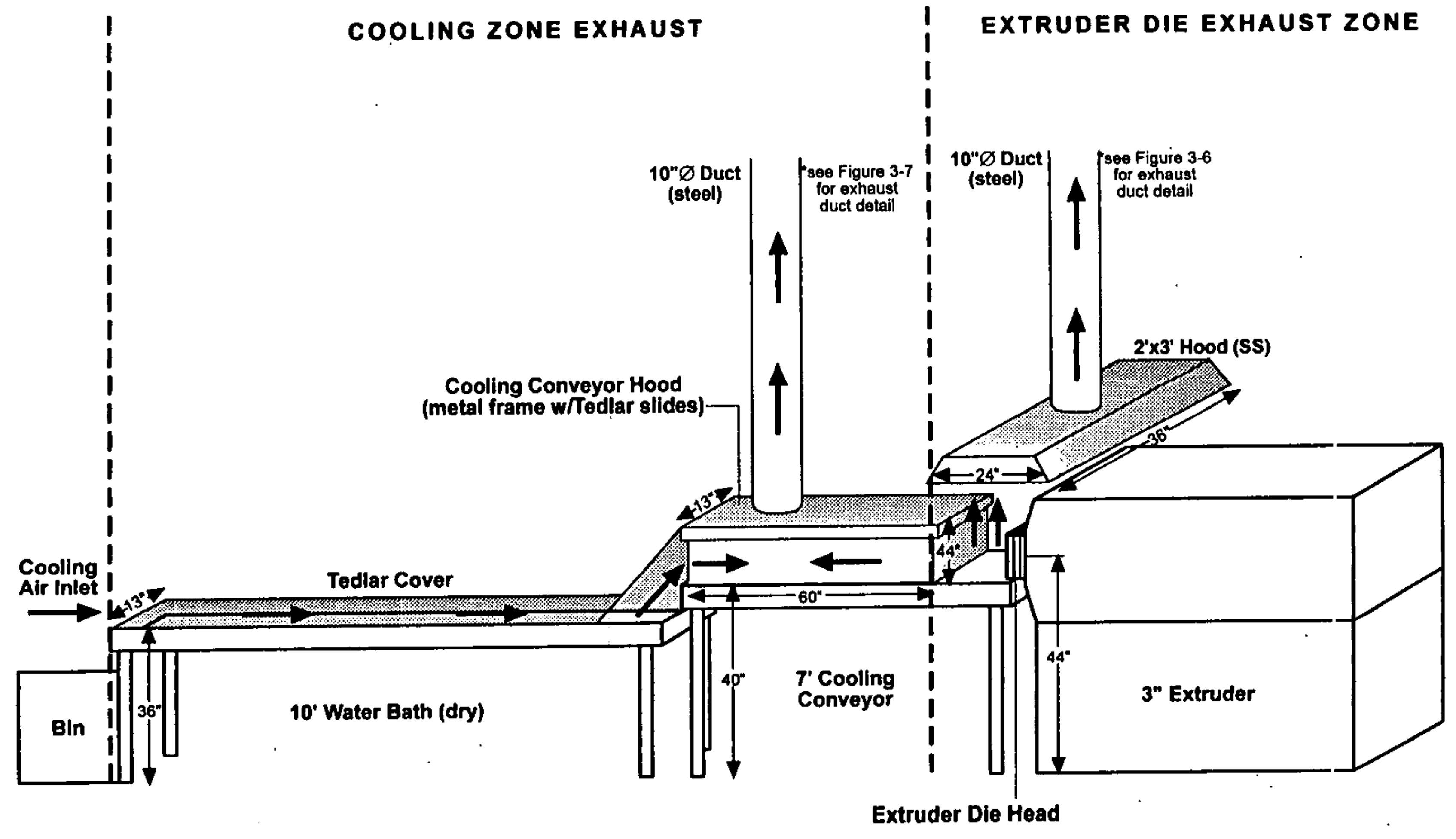


FIGURE 3-5.
THREE-INCH EXTRUDER TEMPORARY EXHAUST DUCT SCHEMATIC (OVERVIEW)

Not to Scale

16157-I

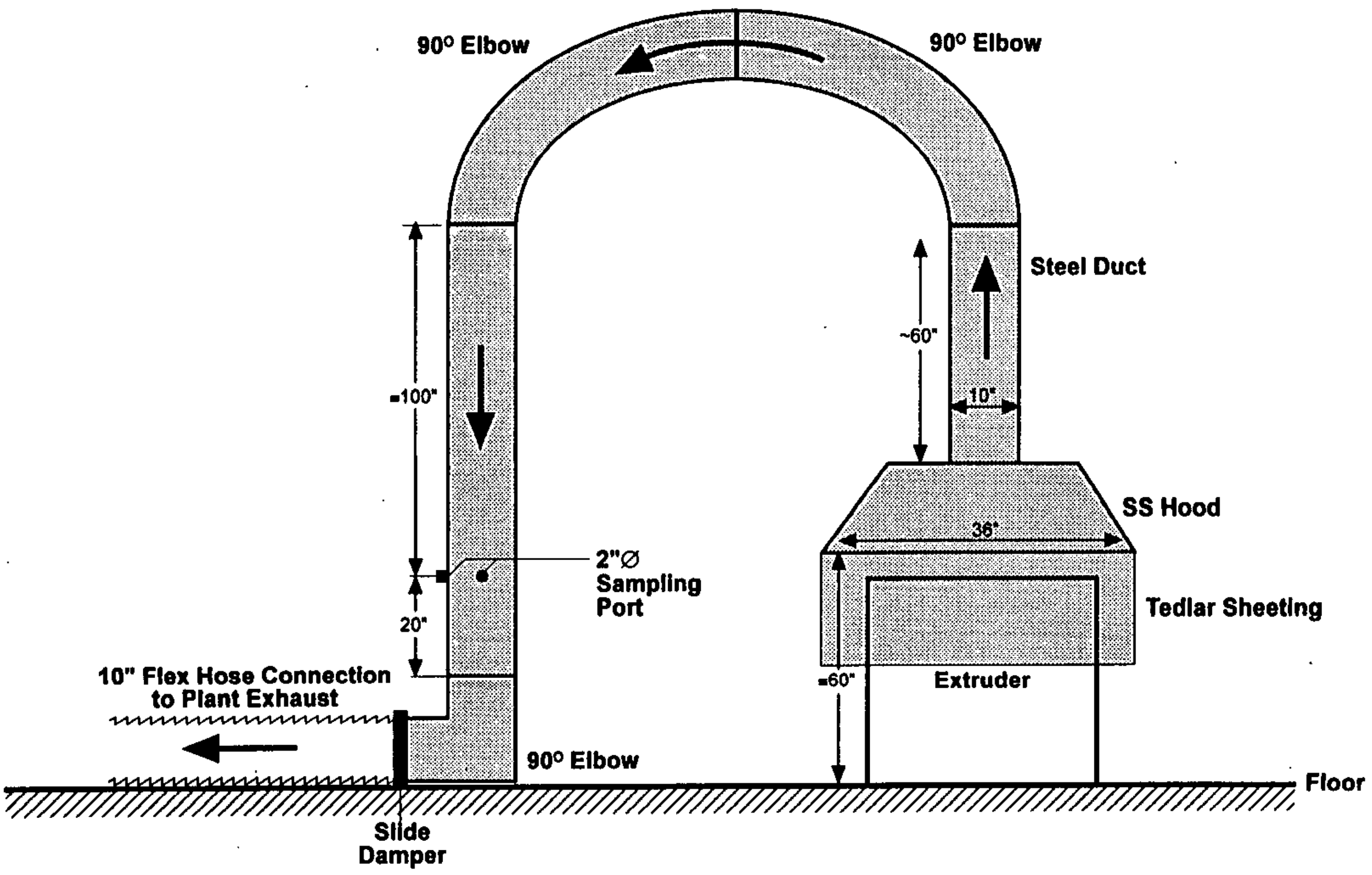


FIGURE 3-6.
EXHAUST DUCT SCHEMATIC FOR THE EXTRUDER DIE

Not to Scale

16157-B

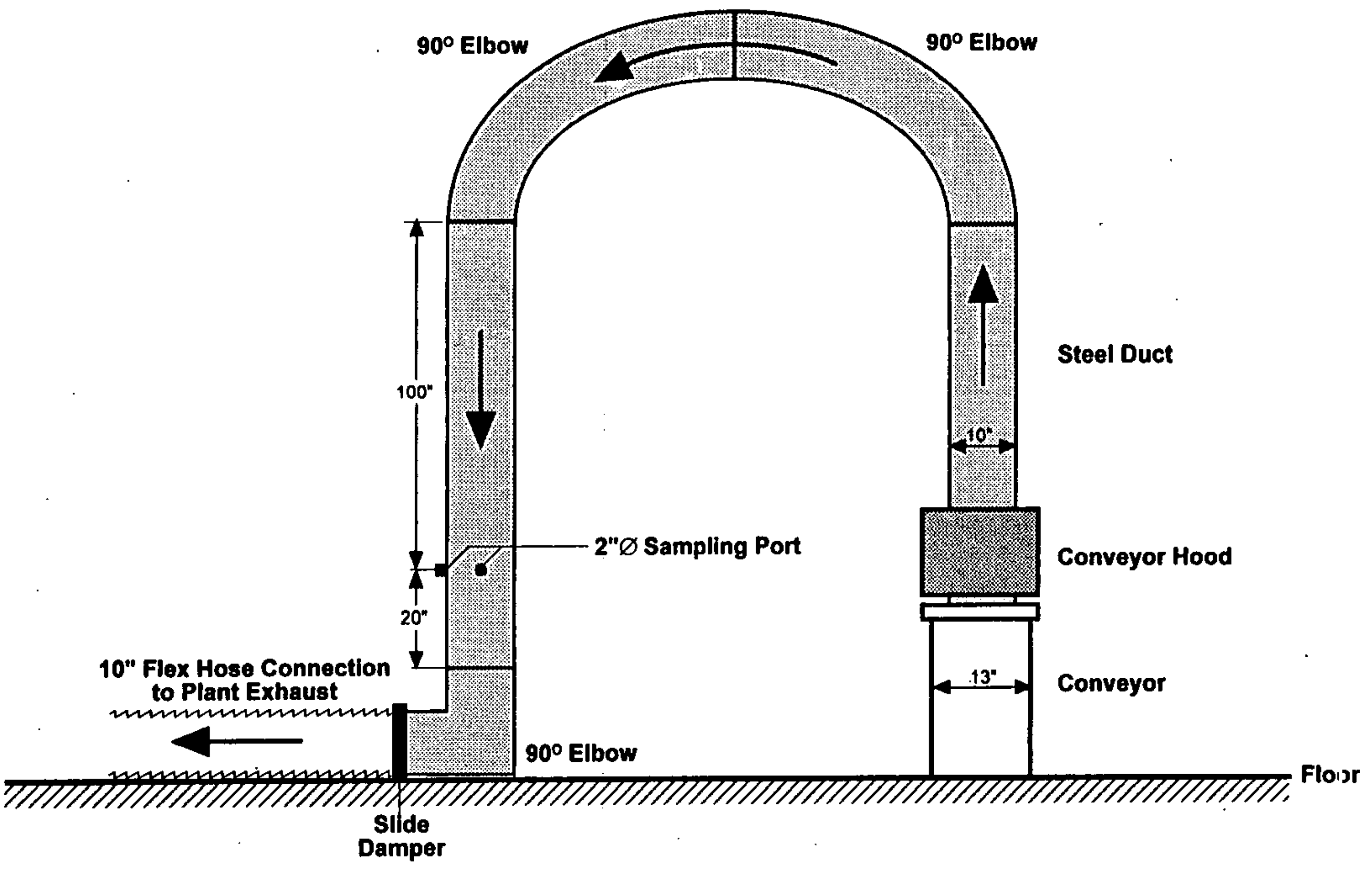
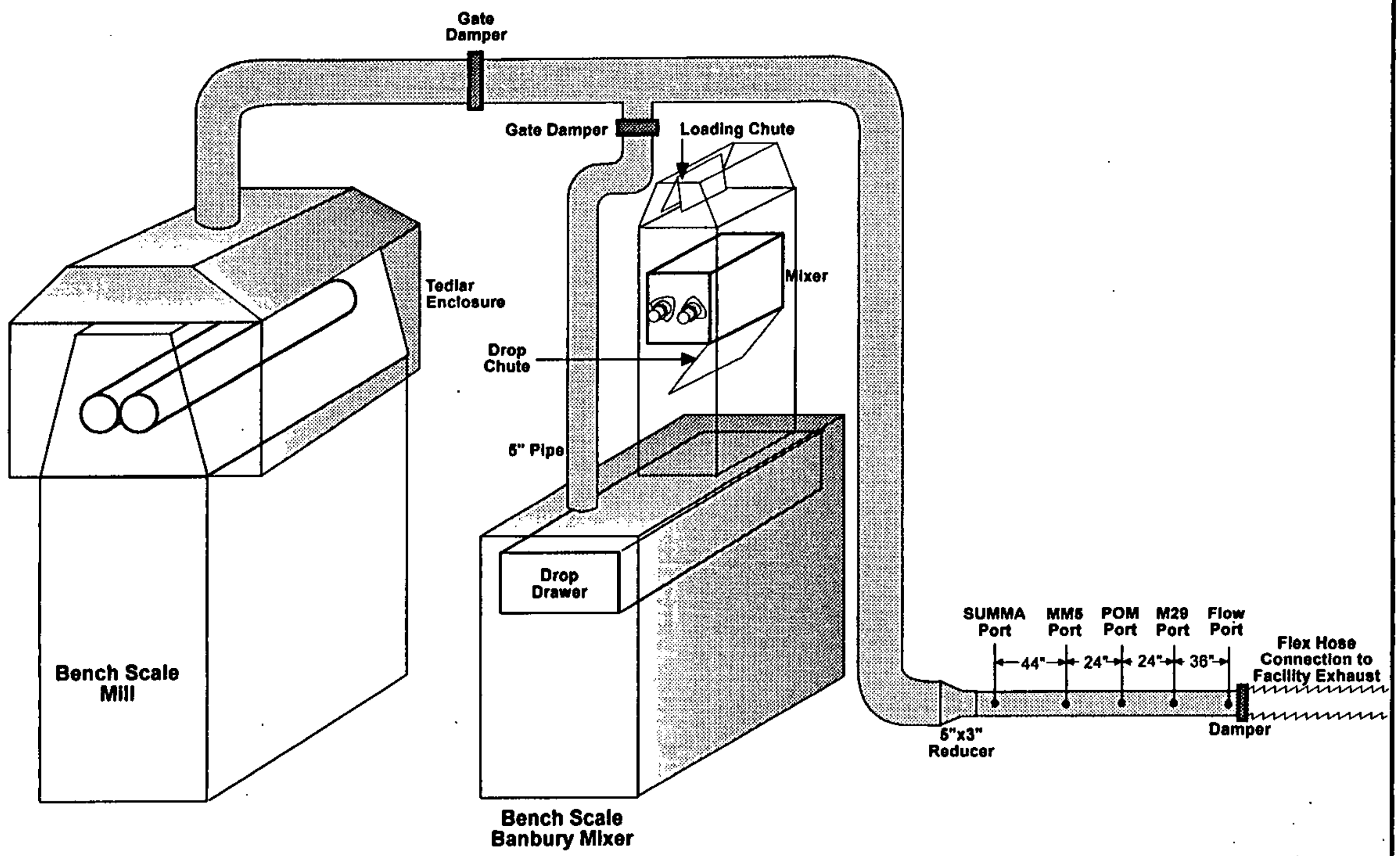


FIGURE 3-7.
EXHAUST DUCT SCHEMATIC FOR THE EXTRUDER COOLING ZONE

Not to Scale



Not to Scale

FIGURE 3-8.
LABORATORY SCALE MIXER/MILL EXHAUST SCHEMATIC

16157-L

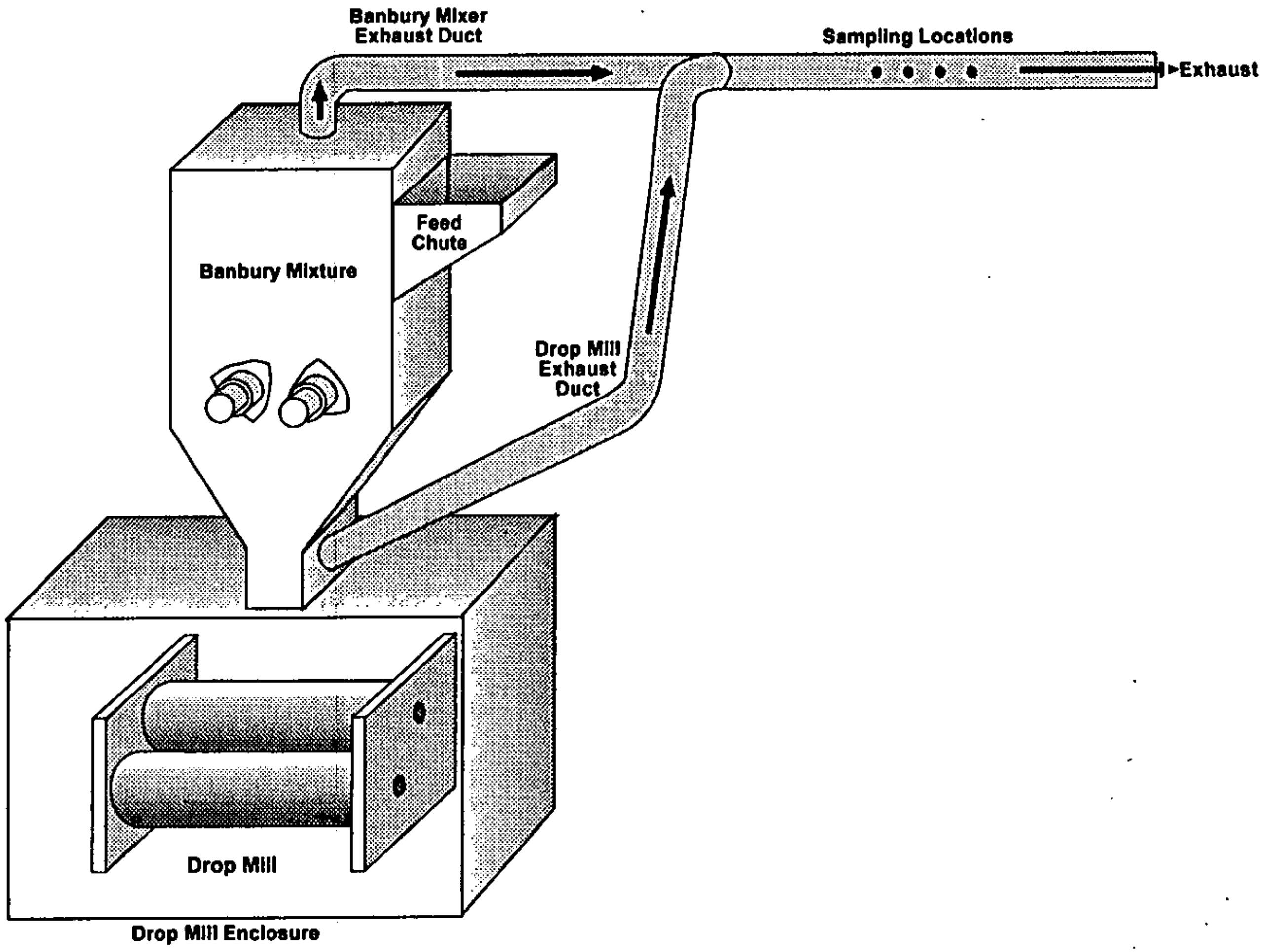


FIGURE 3-9.
LARGE BANBURY MIXER/DROP MILL SCHEMATIC

Not to Scale

16157-P

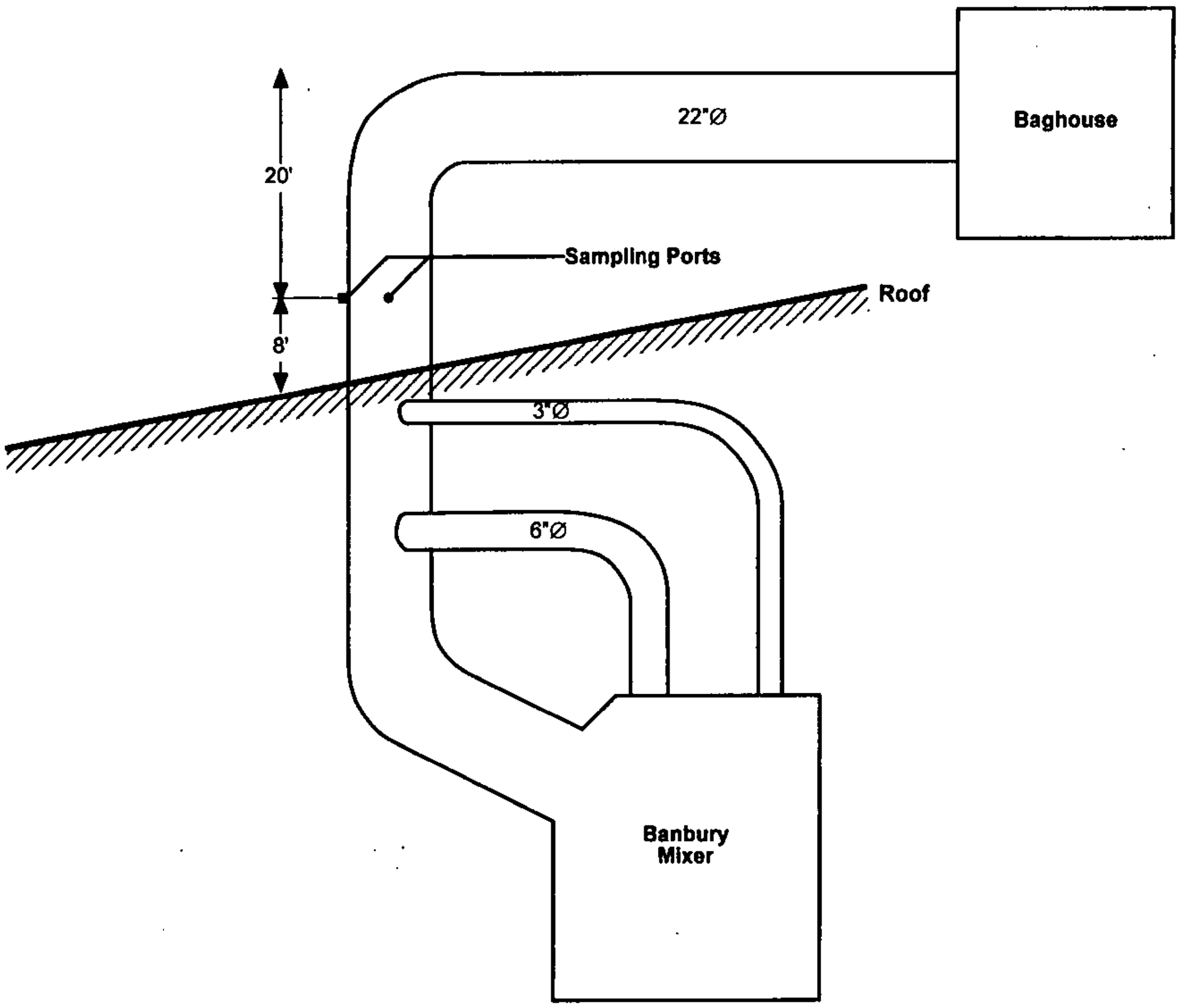


FIGURE 3-10.
BANBURY BAGHOUSE INLET SCHEMATIC

Not to Scale

16157-E

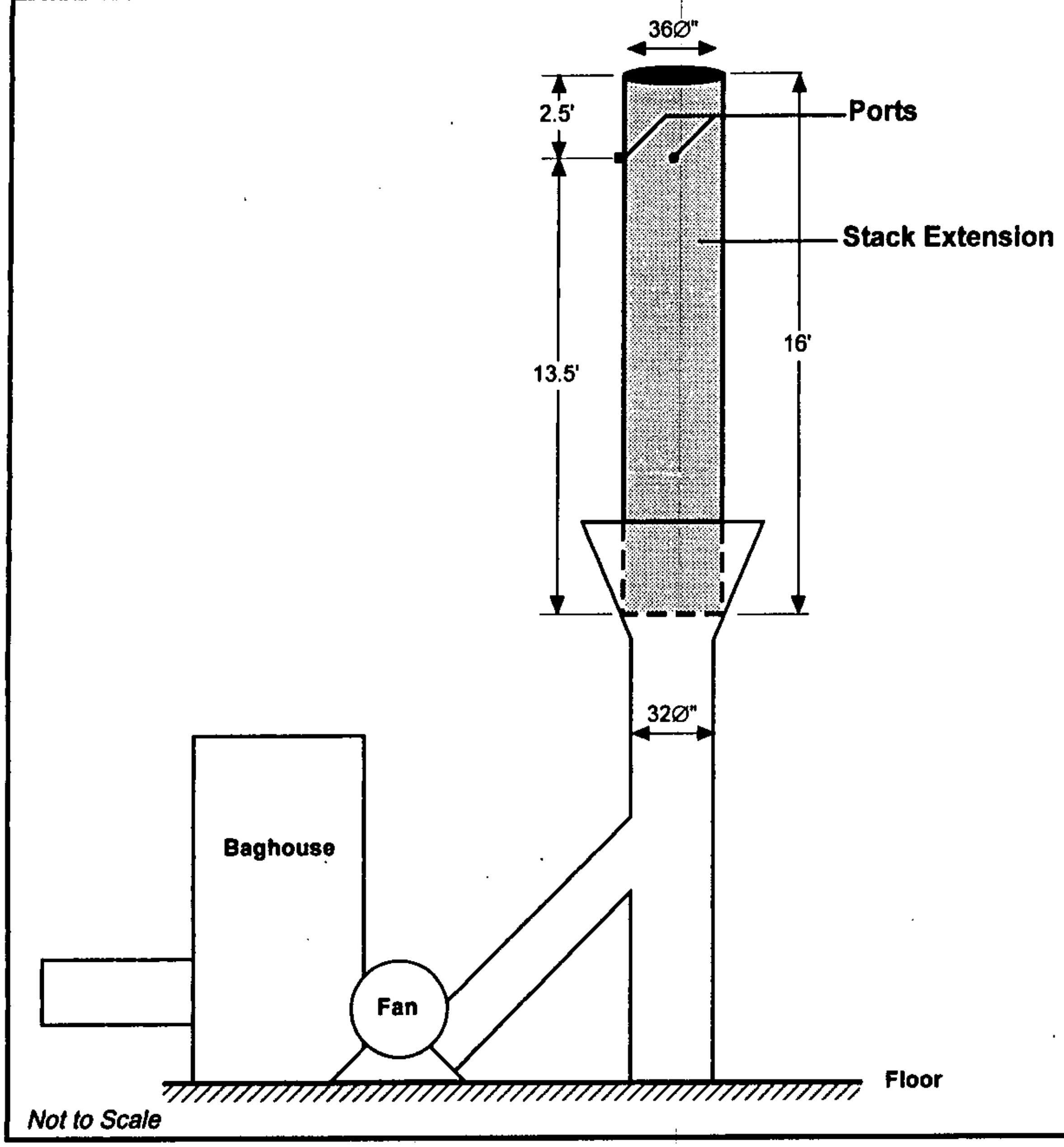
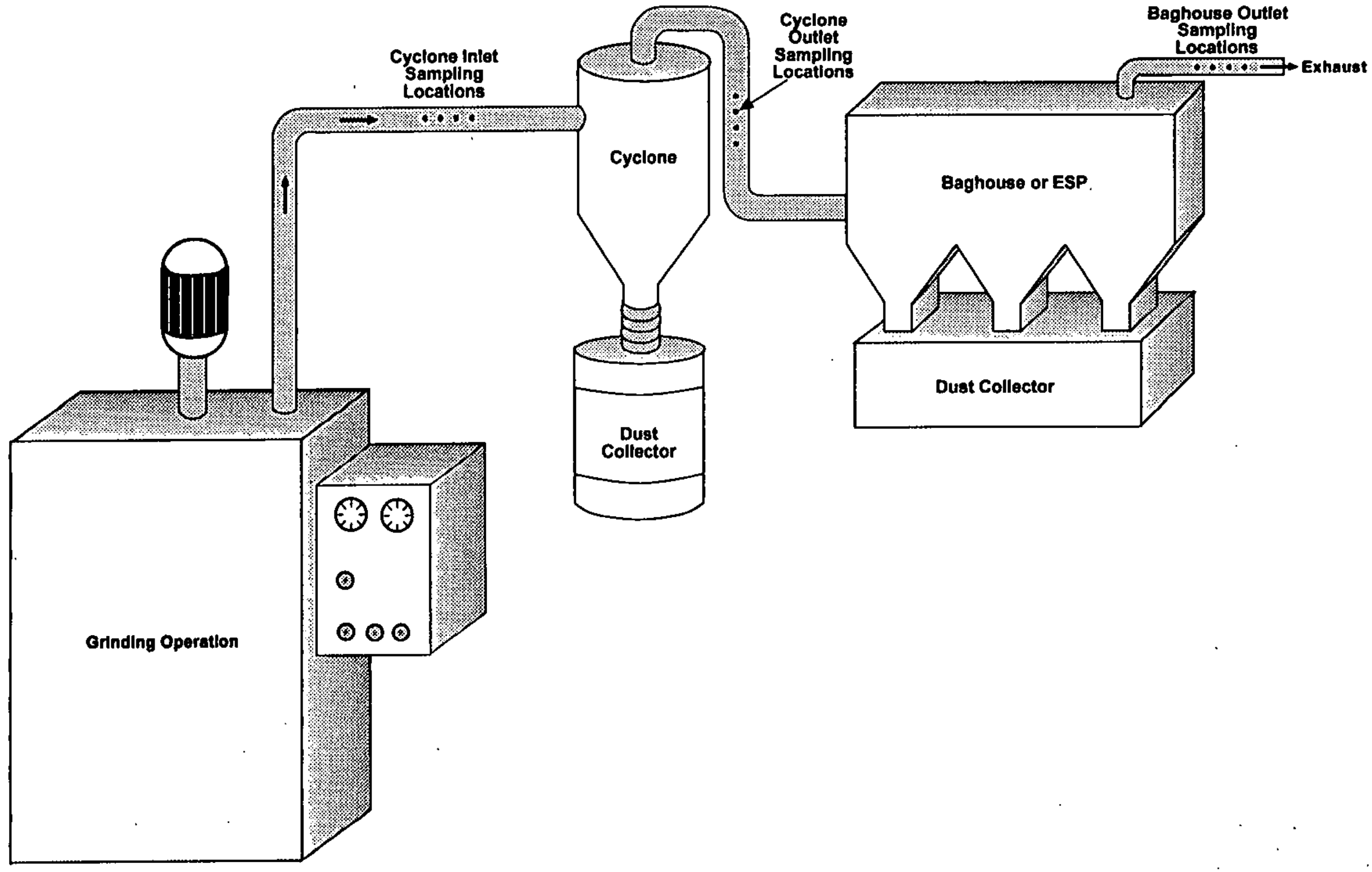


FIGURE 3-11.
BANBURY BAGHOUSE OUTLET SCHEMATIC



Not to Scale

FIGURE 3-12.
GRINDING AND CONTROL DEVICE SCHEMATIC (TYPICAL)

16157-Q

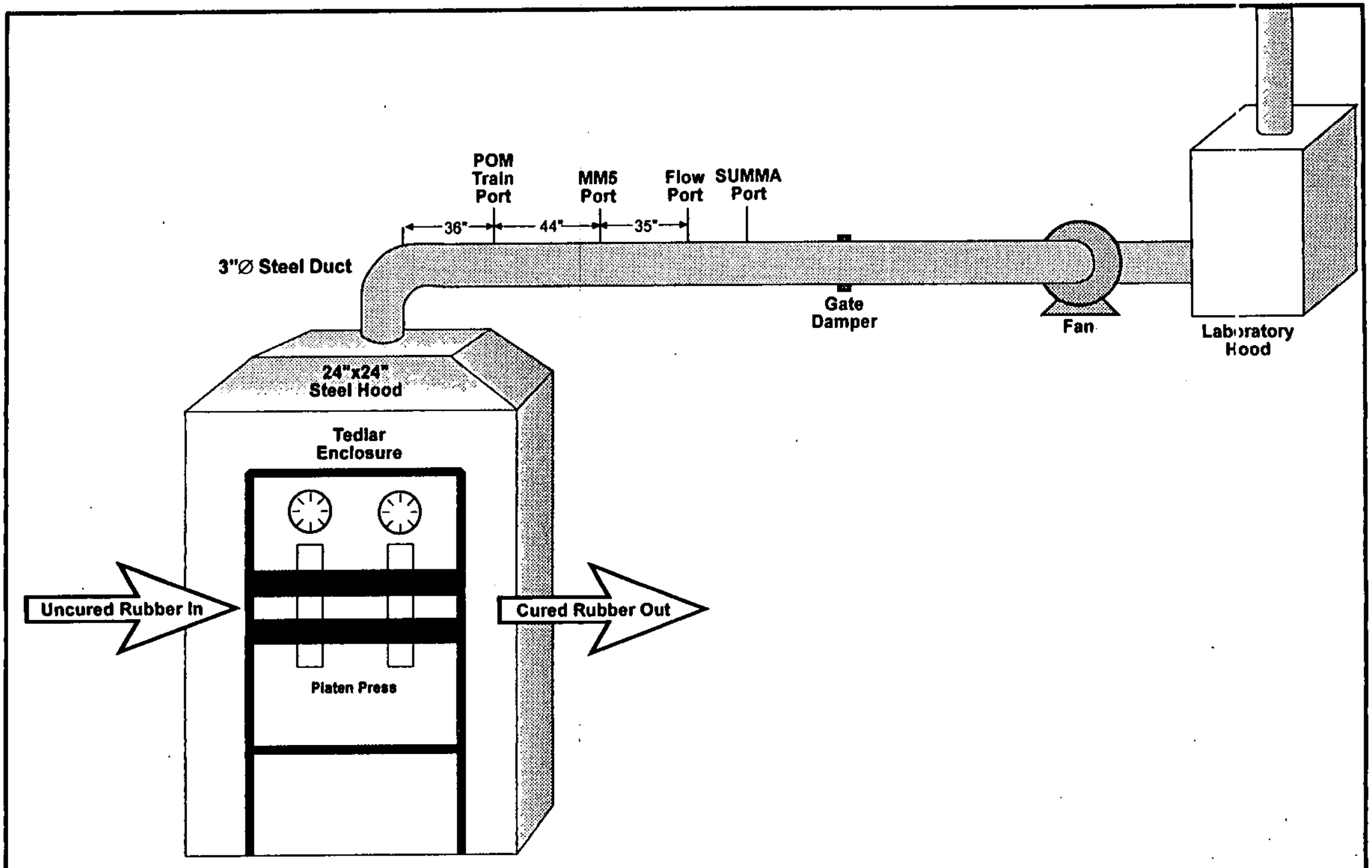


FIGURE 3-13.
PLATEN PRESS CURE SCHEMATIC

Not to Scale

18157-J

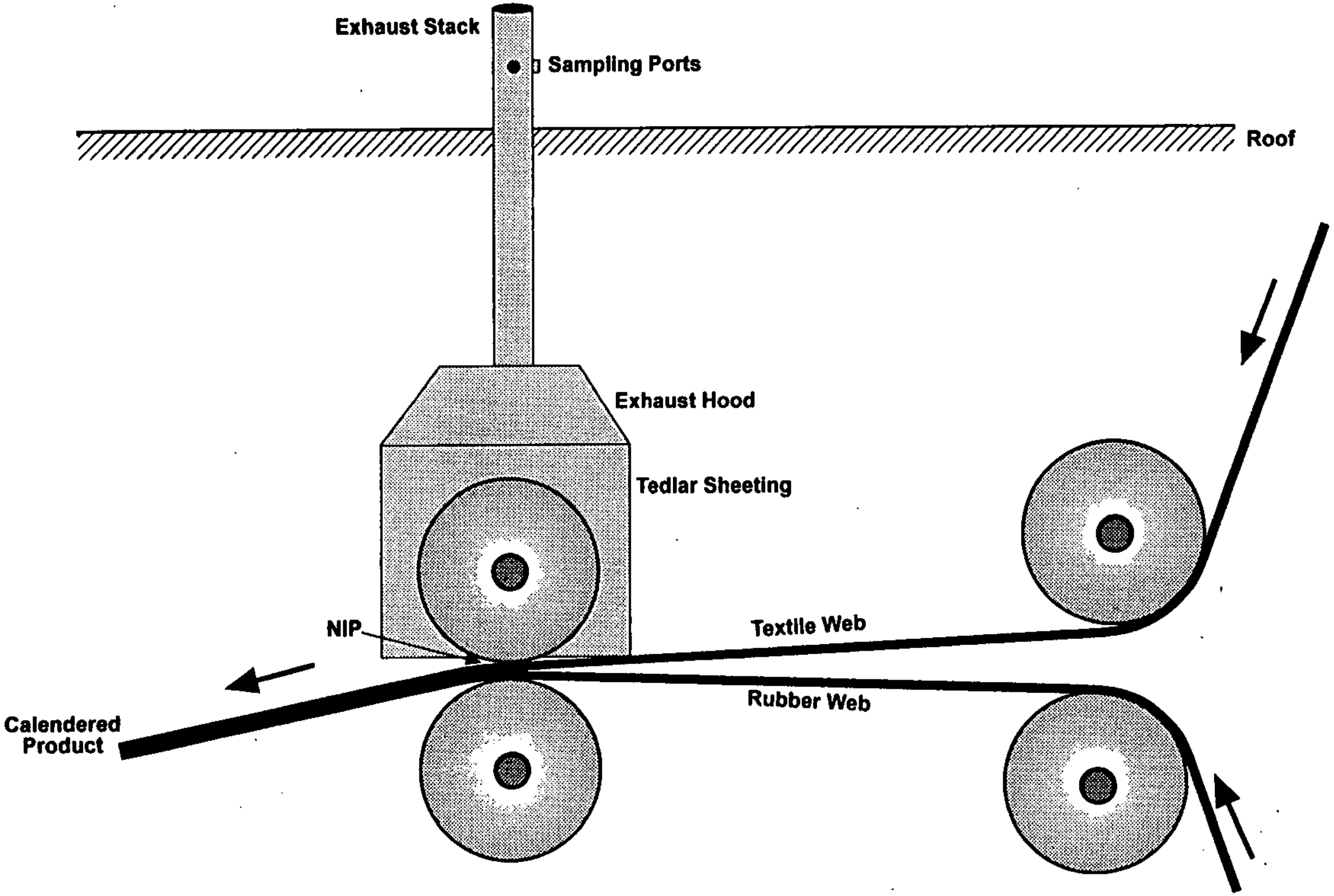


FIGURE 3-14.
CALENDER SCHEMATIC

Not to Scale

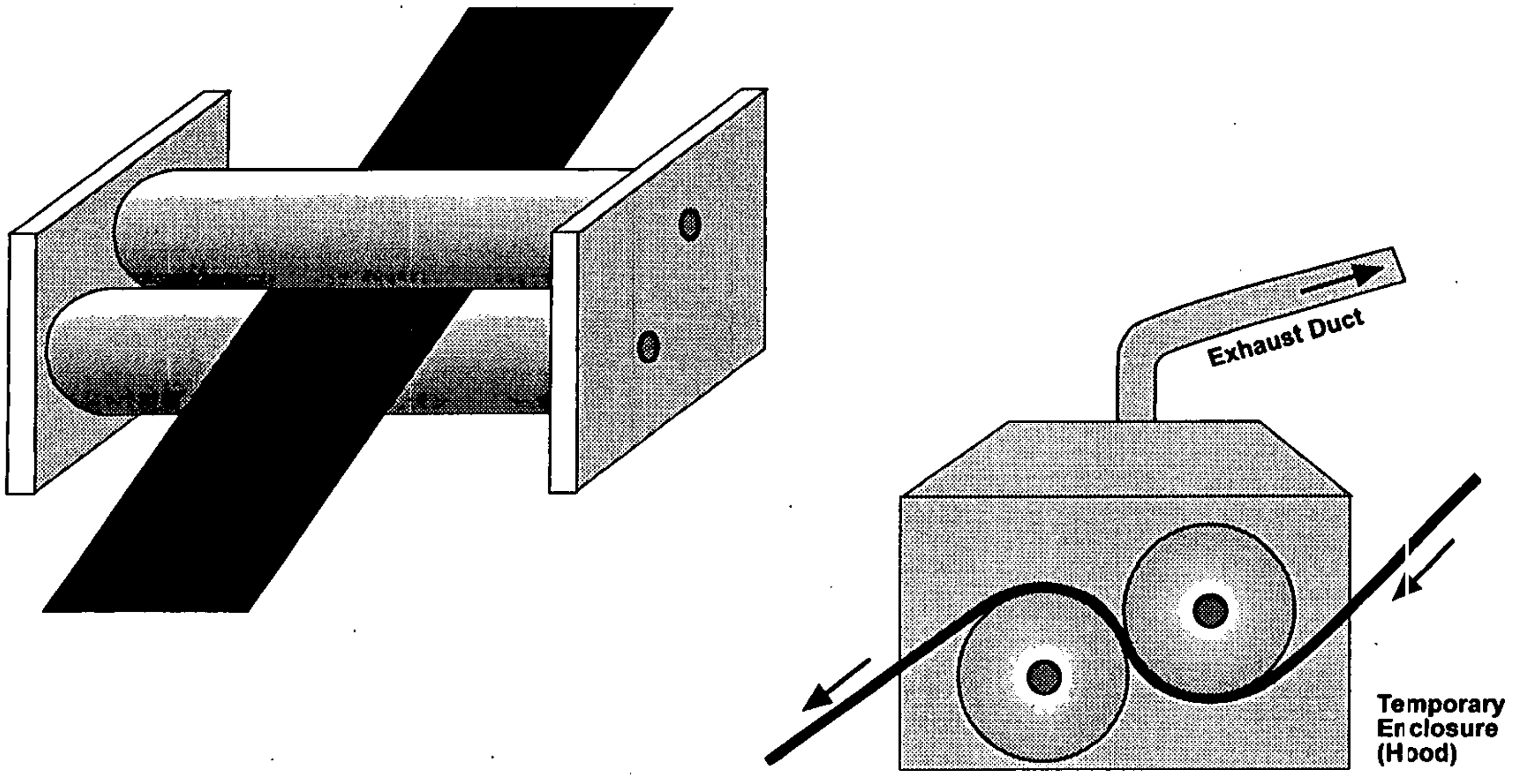


FIGURE 3-15.
WARMING MILL SCHEMATIC

Not to Scale

16157-O

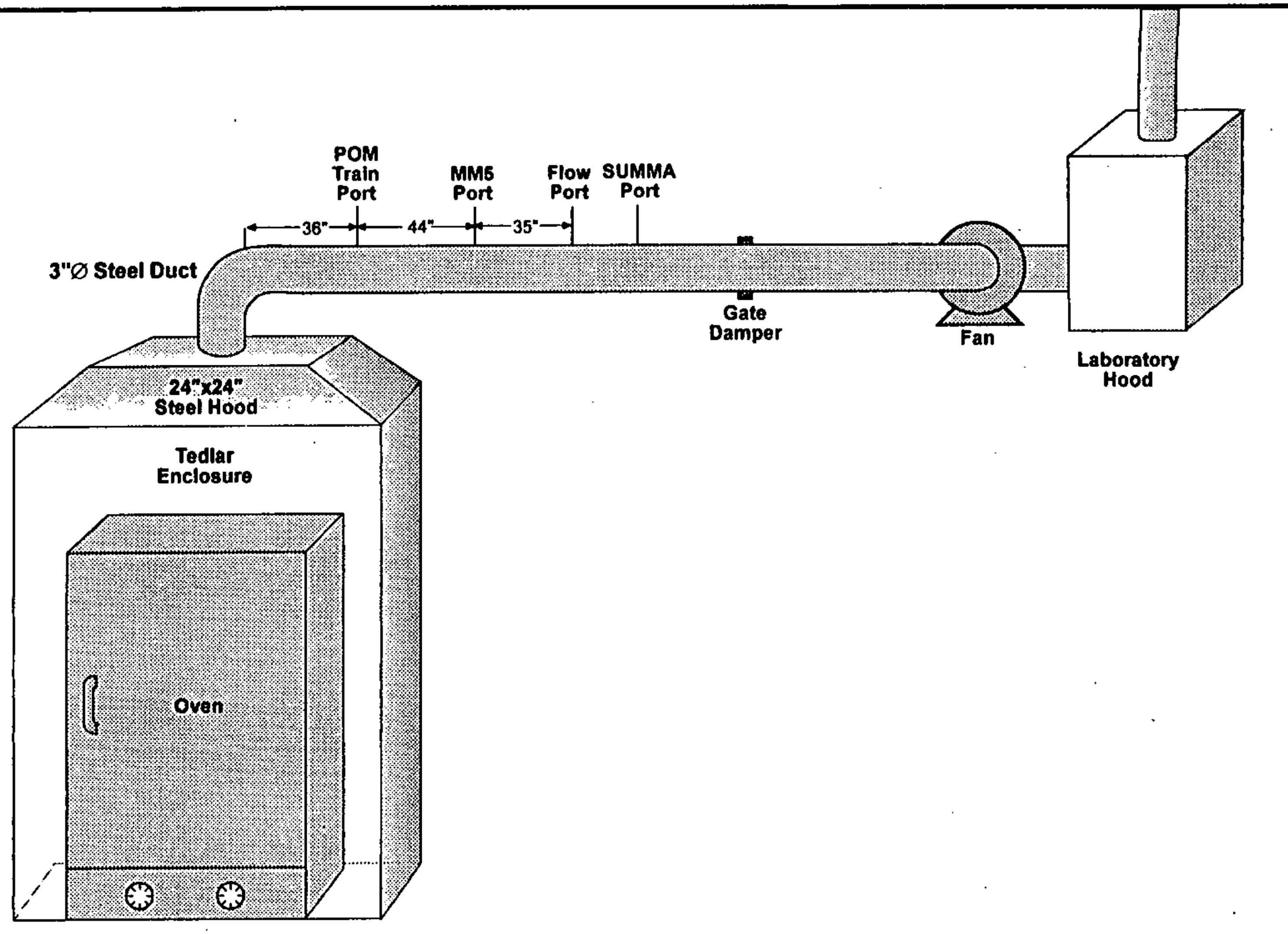


FIGURE 3-16.
HOT AIR CURE SCHEMATIC (ENGINEERING PRODUCTS)

Not to Scale

SECTION 4.0

SAMPLING LOCATIONS

Each of the rubber manufacturing processes described in Section 3.1 have been sampled. Emissions from the processes occur at one or more zones. Samples have been taken at each emission zone.

The emissions zones of rubber manufacturing processes require essentially three types of sampling setups. The first type is a fixed hood or collector system already in place, such as with the large Banbury mixer. This type of system may or may not need a more complete enclosure to capture emissions, but has an existing duct and fan system for moving pollutants to the control device. Hood/duct configurations vary by process.

The second type of sampling setup is a temporary enclosure or hood set up on a process to collect emissions at the desired emission zone. The enclosure includes an exhaust duct with sampling ports, and a fan to keep the system under negative pressure. Enclosure configurations vary by process.

The last type is specific to the autoclave curing system and is described below.

The emissions from each sampling setup are delivered to a single exhaust vent. The vent for each sampling setup is typically 3, 5, or 8-inches in diameter. Sampling ports for flow rate measurements are located a minimum of four diameters downstream and two duct diameters upstream from the nearest bend or flow obstruction.

Due to the number of sampling methods necessary to quantify the emissions from each process, several sets of sampling ports are required in each sample duct to perform all sampling simultaneously. Each set of sampling ports is located a minimum of two duct diameters downstream from the nearest sample train.

Throughout this section, the reader is referred to process schematics contained in the previous section. These schematics include information regarding sampling locations, as well as process information.

4.1 TIRE PRESS

There were two emission zones sampled on the tire press: the press itself and the tire cool-down zone (Figure 3-1). An enclosure was set up on the tire press to collect fugitive emissions during the press curing of green tires. The enclosure was equipped with an outlet exhaust duct in which sampling was conducted for the target parameters.

A similar enclosure was erected around the cool-down rack where the tire cools after completion of the press curing.

4.2 OVEN CURE OF TIRE CUTS

There were two zones sampled during hot air curing of tire cut samples. An oven was set up with a sweep gas inlet and a sample gas outlet leading to the Fourier transform infrared (FTIR) analyzer as shown in Figure 3-2. This system was used to analyze tire cut off-gases during the curing phase. After completion of curing, the tire cut was removed and immediately placed in a cooldown chamber equipped similarly to the oven with a sweep gas inlet and a sample gas outlet.

4.3 AUTOCLAVE

Sampling of the autoclave process represents the most unique approach in this program. Sampling was initiated during the curing phase, conducted during the blow-down phase, and continued through the cool-down phase.

TRC's approach was to set up a total capture method whereby all steam and pollutant releases were sampled. The autoclave curing entailed sampling of the water trap condensate (during curing), the blowdown steam, and cooldown air emissions. All steam releases were vented through the 1-inch water trap or blow-down pipe into a series of condensing impingers and sorbent tubes kept under negative pressure by a metering pump (Figure 3-3). During curing, the water trap condensate was directed into sample containers and large impingers for volume determination. The blow-down pipe was connected to the condensing coils and the first of a series of large impingers. Steam and entrained pollutants were directed into the impingers for condensing and gross pollutant scrubbing through impingement. Remaining gaseous or entrained pollutants then passed through the sorbent traps for the collection of organic species. TRC installed a controlling valve on the blow-down system to control the rate of steam release during the blow-down cycle.

Following completion of each autoclave run, the rack containing the rubber products was removed from the autoclave but kept within the temporary enclosure as shown in Figure 3-4. Sampling continued during the cooldown period.

4.4 EXTRUDER

There were two zones sampled during operation of the extruder process (Figure 3-5). The extruder outlet, or head, was enclosed to permit capture of emissions throughout operation. The small enclosure was equipped with an outlet exhaust duct from which sampling was conducted (Figure 3-6). After extrusion, the product entered the cool-down zone which was also enclosed to allow for sampling of pollutant emissions (Figure 3-7).

4.5 INTERNAL INTENSIVE MIXERS

4.5.1 Small Internal Mixer

The small internal mixer was sampled from a section of duct installed in a flexible exhaust hose (Figure 3-8). Sampling took place during charging and mixing. At the completion of the mixing, the rubber dropped into a tray drawer for transfer to the adjacent milling unit.

The milling unit was enclosed to contain pollutants released during operation. The enclosure was equipped with an outlet exhaust duct to facilitate sampling. Monitoring/sampling continued once the mixed rubber was placed inside the enclosure and continued throughout the milling process.

4.5.2 Large Internal Mixer

Emissions from the large internal mixer occur at 2 points in the process, during charging and mixing, and during drop milling (Figure 3-9). The configuration of the unit tested allows for sampling of the present collector and duct system. The charging/mixing zone is serviced by an 18-inch exhaust duct leading to a baghouse for control of emissions. Sampling was conducted in the round duct in an area with a suitable length of straight run. Emissions from the drop milling zone were handled similarly, being routed to a collector duct via a long rectangular duct. It was necessary to more fully enclose the milling area prior to sampling. Sampling was conducted in the rectangular duct prior to its joining the collector duct.

Control efficiencies of emissions from internal mixers have been determined through the simultaneous sampling of inlet (Figure 3-10) and outlet (Figure 3-11) ducts of a typical baghouse. The necessary ports were located and installed in accordance with EPA Reference Method 1. The sampling was conducted during 2 modes of operation, charging/mixing and drop milling.

4.6 GRINDING

The grinding processes used in tire manufacturing are specific to each application. Four types were identified for this program: retread, belt, whitewall, and truing. The grinding processes, in general, generate quantities of rubber dust and particles, and may generate HAP emissions, depending on the rubber formulation and the amount of heat generated during grinding. To control these emissions, cyclones, baghouses, and electrostatic precipitators (ESPs) are used either alone, or in combination (Figure 3-12).

Grinding operations are typically conducted in a collector hood with an exhaust duct leading to a primary and possibly secondary control device. Emissions sampling was conducted in the hood's exhaust duct (control device inlet) to determine the process' potential to emit. Simultaneous sampling was also conducted at the outlet duct of each downstream control device to determine control efficiency and the final pollutant emissions rate.

4.7 PLATEN PRESS

The platen press curing process is a general approach to pressure curing engineered rubber products in molds. Specific molds are used to form the desired engineered product at set pressures and curing temperatures. Emissions from platen presses can be controlled using an exhaust hood and duct. Most emissions occur during mold release, at the end of the curing cycle.

During this program, 17 rubber compounds were cured at 345° F and pressures of 30 tons for the first 3 minutes and 20 tons for the second 3 minutes. Nine samples of approximately 50 grams each were cured for each rubber type. The cooldown period lasted for 6 minutes when the cured samples were removed from the press and left inside the enclosure. Emissions were contained by an exhaust hood and flexible Tyvek sheeting, and exhausted by a single 5-inch duct and blower. Figure 3-13 presents a schematic of the platen press and exhaust duct configuration.

4.8 CALENDER

The calendering process is used to bond a continuous textile or metal mesh web to one or two layers of rubber for use in building tires or other engineered rubber products. The latex-dipped textile passes through a series of rollers through which one or two rubber strips also passes. Under pressure and elevated temperatures induced by the rollers, the rubber is bonded to the web. The nip of the rollers can be adjusted to vary the thickness of the calendered product. The rubberized fabric is then cooled and cut to the proper dimensions. Figure 3-14 presents a schematic of the calendering process and associated exhaust system.

During this program, emissions from the calendering process were tested at two facilities. The first tested was a continuous production process where the rubber was continuously fed from a warming mill. A tire ply coat rubber compound was being run on the test days. Testing was conducted from an exhaust collector system outlet stack. The second process tested involved a batch or "pig" fed calender during calendering of a neoprene compound. The emissions from this system were measured using a temporary enclosure and exhaust duct configuration.

4.9 WARMUP MILL

Warmup mills are utilized by the industry for further mixing of rubber compounds following each drop from an internal mixer or, to warm the rubber to prepare it for subsequent processing (eg. calendering). A warmup mill is similar or identical to a drop mill in that it has a series of rollers, some toothed, to increase the shearing of the compound. The mill can be batch or continuously fed, depending of the production need. A schematic of a typical warmup mill is shown in Figure 3-15.

The emissions from two warming mills were tested during this program. One was a batch fed, production scale unit and the other was a lab scale warming mill. Emissions from both were captured using a temporary enclosure and exhaust duct system. On the first mill, three test runs were conducted while milling one rubber type (neoprene). On the lab scale unit, a single test run was conducted while milling three types of rubber (tire ply coat, tire belt coat, and tire base/sidewall).

4.10 OVEN CURE OF ENGINEERED PRODUCTS

Hot air oven curing of engineered rubber products is used to final cure preformed products. Three rubber compounds were evaluated. One compound used in tire manufacturing (Tire Apex, Compound #5) and two compounds typical of engineered rubber products manufacturing (EPDM 1, sulfur-cured, Compound #8; and Emulsion SBR 1502, Compound #22) were selected. To simulate the process for this program, a lab scale system with enclosure was designed and set up to evaluate the emissions during curing and cooldown. The rubber compound samples were placed in the oven and allowed to reach the curing temperature of 400° F for a period of 5-8 minutes. Each sample weighed 50 grams. After completion of curing, each rubber sample was removed and allowed to cool down in the enclosure and another sample of the same compound placed in the oven and brought up to temperature.

The oven was set up with a preheated sweep gas inlet and an exhaust gas outlet. A temporary enclosure was erected around the oven to contain emissions during the curing and cooldown and when the door was opened. An exhaust duct similar to that used for the platen press was constructed to vent the enclosure and to provide the sampling locations. Figure 3-16 presents a schematic of this setup.

SECTION 5.0

FIELD SAMPLING PROCEDURES

5.1 OVERVIEW

This section describes the procedures that TRC followed during the field sampling program. Throughout the program TRC followed EPA reference methods presented in 40 CFR Part 60 Appendix A, Part 266 Appendix IX, and SW-846. Any deviations from the specified test methods will be fully documented in the test report.

The remainder of this section is divided into several subsections: Field Program Description, Presampling Activities, and Onsite Sampling Activities.

5.2 FIELD PROGRAM DESCRIPTION

The objective of the test program was to accurately quantify the emissions of hazardous air pollutants (HAPs) from the processes described in Section 2.0. These emissions have been correlated with the operating data obtained during the emission testing to develop emission factors for each HAP. These emission factors are in units of mass of HAP emitted per mass of material processed or unit of product manufactured. These emission factors will then be employed by rubber manufacturing facilities to assist in completing application forms under Title V of the 1990 CAAA.

The test methods utilized are as follows:

- Method 1, and 2 - Velocity Profile
- Method 4 - Percent Moisture
- Method 5 - Particulate Matter Determination
- Method 25A - Total Hydrocarbons (Total Volatile Organic Compounds)
- Method 29 - Multiple Metals
- Method 202 - Condensibles (Polycyclic Organic Matter)
- Method 0010 - Semivolatile Organic Compounds
- Method TO14 - Volatile Organics
- FTIR - Fourier Transform Infrared Spectroscopy
- NIOSH P&CAM Method 221 - Amines

5.3 PRESAMPLING ACTIVITIES

Presampling activities include equipment calibration, precleaning of the sample train glassware, and other miscellaneous tasks. Each of these activities are described or referenced in the following subsections. Other presampling activities include team meetings, equipment packing, and finalization of all details leading up to the coordinated initiation of the sampling program.

5.3.1 Equipment Calibration

TRC follows an orderly program of positive actions to prevent the failure of equipment or instruments during use. This preventative maintenance and careful calibration helps to ensure accurate measurements from field and laboratory instruments.

Once the equipment has gone through the cleaning and repair process it is then calibrated. All equipment that is scheduled for field use is cleaned and checked prior to calibration. Once the equipment has been calibrated, it is packed and stored to ensure the integrity of the equipment. An adequate supply of spare parts is taken in the field to minimize downtime from equipment failure.

Inspection and calibration of the equipment is a crucial step in ensuring the successful completion of the field effort. All equipment is inspected for proper operation and durability prior to calibration. Calibration of the following equipment is conducted in accordance with the procedures outlined in EPA documents entitled "*Quality Assurance Handbook for Air Pollution Measurement Systems; Volume III - Stationary Source Specific Methods*" (EPA-600/4-77-027b) and 40 CFR Part 60 Appendix A.

- Probe nozzles (QA Handbook, Vol III, Section 3.4.2, pp. 19) - average three ID measurements of nozzle; difference between high and low ≤ 0.1 mm. Recalibrate, reshape and sharpen when nozzle becomes nicked, dented, or corroded.

- Pitot tubes (QA Handbook, Vol III, Section 3.1.2, pp. 1-13) - measured for appropriate spacing and dimensions or calibrated in a wind tunnel. Rejection criteria given on the calibration sheet. Post-test check - inspect for damage.

- Thermocouples (QA Handbook, Vol III, Section 3.4.2, pp. 12-18) - verified against a mercury-in-glass thermometer at three points including the anticipated measurement range. Acceptance limits - impinger ± 2°F; DGM ± 5.4°F; stack ± 1.5 percent of stack temperature.

- Dry gas meters (EPA 40 CFR Part 60, Method 5, Section 5.3) - calibrated against a wet test meter. Acceptance criteria - pretest $Y_i = Y = \pm 0.02$; post test $Y = \pm 0.05\ Y_i$.

- Field barometer (QA Handbook, Vol III, Section 3.4.2, pp. 18-19) - compared against a mercury-in-glass barometer or use Airport Station BP and corrected for elevation. Acceptance criteria - ± 0.02 in. Hg; post-test check - same.

- Analytical balances (QA Handbook, Vol III, Section 3.4.2, pp. 19) - Acceptance criteria -calibrate with Standard Class-S weights within ± 0.5 g of stated value. Rejection criteria: Have manufacturer recalibrate or adjust.

5.3.2 Glassware Preparation

Sample train glassware and sample containers require specialized precleaning to avoid contamination of the sample. The sample train glassware necessary for the Method 29 multiple metals sampling was precleaned using an Alconox soap and water wash. Deionized water was used for rinsing followed by soaking in 10% nitric acid for a minimum of 4 hours. The glassware was then rinsed with deionized water followed by an acetone rinse. The glassware was then sealed with Parafilm.

The Method 0010 semivolatile organics sampling train glassware was precleaned with an Alconox soap and water wash. Deionized water was used for rinsing followed by an acetone and hexane rinse. The glassware was then sealed with hexane-rinsed aluminum foil.

The sample train glassware necessary for the Method 5 Particulate Matter, Method 202 POM, and Method 221 Amines sampling trains was precleaned using an Alconox soap and water wash. The glassware was then rinsed with deionized water. The glassware was then sealed with Parafilm.

Note that all amber sample bottle caps were fitted with Teflon^R liners which were cleaned in the same manner as the bottles themselves.

5.3.3 Sample Media Preparation

All reagents and sorbents are checked in accordance with TRC's existing QC Program to minimize the probability of using contaminated sampling media. This includes the use of spectro-grade solvents from the same lot and the collection and analysis of appropriate blanks.

5.4 ONSITE SAMPLING ACTIVITIES

Onsite sampling activities include the emissions testing of the sources and collection of operational data.

5.4.1 EPA Methods 1 and 2 - Velocity Measurements and Cyclonic Flow

Velocity traverses were conducted at the sampling locations with either an S-type or standard pitot assembly in accordance with EPA Reference Methods 1, 2, and 2A. A pitot tube with an attached inclined manometer was used to measure the exhaust velocities of each source. An attached Type-K thermocouple with remote digital display was used to determine the flue gas temperature. During the test programs, velocity measurements were conducted during each test run. The required number of velocity measurements points for each sampling location was determined following EPA Method 1.

Cyclonic flow checks were conducted on each source prior to sampling in accordance with Section 2.4 of EPA Method 1 as described in the July 1, 1988 edition of the *Federal Register*.

This procedure is referred to as the nulling technique. A pitot tube connected to an inclined manometer was used for this method. The pitot tube was positioned at each traverse point so that the face openings of the pitot tube are perpendicular to the stack cross-sectional plane. This position is called the "0° reference". The velocity pressure (ΔP) measurement is noted. If the ΔP reading was zero, the cyclonic angle was recorded as 0°. If the ΔP reading was not zero, the pitot tube was rotated clockwise or counter clockwise until the ΔP reading became zero. This angle was then measured with a leveled protractor and reported to the nearest degree. After this null technique was applied at each traverse point, the average of the cyclonic angles was calculated. If this average was less than 20°, the flow condition in the source was acceptable to test. This check was performed on the emission sources before testing.

5.4.2 EPA Method 4 - Moisture Determination

Moisture is determined for each test run according to EPA Reference Method 4, "*Determination of Moisture Content in Stack Gases*". The principle of this method is to remove the moisture from the sample stream and measure it either volumetrically or gravimetrically. This reference method was conducted simultaneously with the Method 5 sampling train, Method 0010 sampling train, Method 29 sampling train, Method 202 sampling train, and the Method 221 sampling train.

5.4.3 EPA Method 5 - Particulate Matter

The Particulate Matter train was operated as described in "*Determination of Particulate Emissions from Stationary Sources*" (40 CFR Part 60 Appendix A). The Method 5 train was used to measure and determine the emission rate of particulate matter.

The sampling train consisted of a heated, glass-lined probe, with a glass button-hook nozzle. A thermocouple and S-type pitot tube were attached to the probe for the measurement of gas temperature and velocity. The sample gas passed through the probe assembly to a heated quartz fiber filter. The filter holder was maintained at 248°F ± 25°F throughout each test period. Downstream of the heated filter, the gas passed through a series of four ice-cooled impingers kept below 68°F to enable condensation of entrained moisture. The first two impingers each contained 100 mL of deionized water. The third impinger was empty and the fourth impinger contained a preweighed amount of silica gel. The impingers were followed by a Nutech Model 2010 dry gas meter, pump, and calibrated orifice meter. A schematic of the Method 5 sampling train is presented in Figure 5-1.

Sampling was isokinetic (± 10 percent) with readings of flue gas parameters recorded at every sampling point during the traverse.

Leak checks of the entire Method 5 sampling train were performed before and after each sampling run. In the event any portion of the train was disassembled and reassembled, leak checks were performed prior to disassembling the train. All leak checks and leakage rates are documented on the relevant field test data sheet. The acceptance criteria for the Method 5 train is a leak rate of ≤ 0.02 cfm at the highest vacuum obtained during the run.

Following the completion of each test run, the Method 5 train was transported to a recovery area onsite. The sample recovery sequence was as follows:

- Removed the sampling train to the recovery area.
- Noted the condition of the train (i.e., filter condition, impinger contents color, silica gel color, etc.).
- Disassembled the filter housing and transferred the filter to its original glass petri dish. Sealed the container with Teflon^R tape and labeled it with the appropriate sample information.
- The front half of the train, nozzle, probe, and front-half filter housing was then brush-rinsed with acetone into an amber glass container with a Teflon^R-lined cap. The rinse procedure was performed three times after which the container was sealed and labeled.
- The contents of the first three impingers were measured for volume only and the contents were discarded.
- The silica gel was returned to its original container and weighed to obtain a final weight.
- All containers were checked to ensure proper sealing, proper labeling, and that all liquid levels were marked. All samples were then logged onto the chain-of-custody record.

The Method 5 train produced the following samples:

- Filter
- Front-Half Acetone Rinse

5.4.4 EPA Method 25A - Total Volatile Organic Compounds (TVOC)

Total volatile organic compounds were continuously monitored in accordance with EPA Method 25A, "*Determination of Total Gaseous Organic Concentration using a Flame Ionization Analyzer*". Flue gas samples were drawn through a heated sample probe, heated Teflon^R sample line, and a Ratfisch Model RS55 flame ionization detection (FID) total hydrocarbon analyzer.

A Ratfisch Model RS 55 Total Hydrocarbon analyzer measured total volatile organic compounds C_1 through C_{18}. A small amount of sample containing total volatile organic compounds was introduced to the system through a heated filter and sample line. The sample gas then entered the heated detector bench, which contained the flame ionization detector (FID). The resulting current was detected and amplified by an electrometer/amplifier circuit. The output of the amplifier provided a signal for direct readout on a meter and for output to a strip chart recorder. The FID was calibrated with certified methane gas standards.

The continuous emissions monitoring system consists of three subsystems: sample acquisition/conditioning, sample analysis, and a data acquisition system. The sample acquisition/conditioning unit is designed to deliver a representative sample of the stack gas stream to the sample analysis subsystem. Sample analysis was achieved using the following analyzer:

- Ratfisch Model RS 55 Total Hydrocarbon analyzer;

In each case, accurate interpretation of analyzer response required the systematic calibration of the instrument against gases of known concentrations. A calibration equation was determined from a linear regression of known gas concentrations versus instrument response. The equation used to convert instrument signal to concentration units follows:

$$\text{Concentration} = m * (\text{response}) + b$$

where:

m = slope of calibration curve
response = instrument signal (volts)
b = y-intercept of calibration curve

The data acquisition subsystem consisted of a Yokogawa Data Logger designed to receive and log instrument signals (raw voltages) at user defined intervals. In addition, the Yokogawa was programmed to perform the previously mentioned concentration calculation. The resulting values were instantaneously accessible (updated every 15 seconds) on a personal computer. A CEM Report program allowed the generation of an emissions summary upon user request. Once the system was set up, the THC analyzer was connected to a power source and brought online. Sample line and signal wires were strung between the sampling and the THC location, and the probe was placed in the duct at the sampling port.

Prior to insertion of the probe into the stack, the sample/acquisition system was leak checked by the following procedure:

a. plug probe;
b. observe that flow in rotameter reaches zero Lpm;
c. observe vacuum; and
d. confirm that sample vacuum during sampling does not exceed vacuum attained during leak check.

The initial phase of instrumental analysis methods requires calibration of all involved monitors. At the beginning of each day, direct instrument calibrations for zero and three upscale gases were performed prior to initiation of testing by direct calibration gas injection. Following these direct calibrations, system calibrations were performed both prior to and following each run using zero and one upscale gas concentration. This was accomplished by directing calibration gas through the sample line and conditioning system to assess system bias. Following completion of the required runs, final system and final direct calibrations was performed. These procedures allowed for determination of initial and final system bias, as well as system drift. Typical calibration gas values and instrument range settings are listed below:

Gas	Calibration Gas Value	Instrument Range
THC	25, 50, 100 ppm	0 - 100 ppm

5.4.5 EPA Method 29 - Multiple Metals

The Multiple Metals train was operated in accordance with EPA Method 29 to measure and determine the emission rates of multiple metals. Particulate matter was also determined from the front half of this train in accordance with EPA Method 5, described earlier.

The sampling train consisted of a heated, glass-lined probe, with a glass button-hook nozzle. A thermocouple and S-type pitot tube were attached to the probe for the measurement of gas temperature and velocity. The samples gas passed through the probe assembly to a heated glass fiber filter. The filter holder was maintained at 248°F ± 25°F throughout each test run. Downstream of the heated filter, the sample gas passed through a series of six ice-cooled impingers kept below 68°F to enable condensation of entrained moisture. The first and second impingers contained 100 mL 5% HNO_3/10% H_2O_2. The third impinger was empty. The fourth and fifth impingers contained 100 mL 4% $KMnO_4$/10% H_2SO_4. The sixth impinger contained a preweighed amount of silica gel. The impingers were followed by a Nutech Model 2010 dry gas meter, pump, and calibrated orifice meter. A schematic of the Method 29 sampling train is presented in Figure 5-3.

Sampling was isokinetic (± 10 percent) with readings of flue gas parameters recorded at every sampling point during the traverse.

Leak checks of the entire Method 29 sampling train were performed before and after each sampling run. In the event any portion of the train was disassembled and reassembled, leak checks were performed prior to disassembling the train. All leak checks and leakage rates are documented on the relevant field test data sheets. The acceptance criteria for the Method 29 train is a leak rate of $\leq$ 0.02 cfm at the highest vacuum obtained during the test run.

Following the completion of each test run, the Method 29 train was transported to a recovery area onsite. The sample recovery sequence was:

- Removed the sampling train to the recovery area.

- Noted the condition of the train (i.e., impinger contents color, silica gel color, etc.).

- Disassembled the filter housing and transferred the filter to its original petri dish. Sealed the petri dish with Teflon^R tape and labeled it with the appropriate sample information.
- The front half of the train, nozzle, probe, and front-half filter housing was brush-rinsed with 100 mL of 0.1N HNO_3 into an amber glass container with a Teflon^R-lined cap. The container was sealed and labeled.

- The contents of the first two impingers were measured for volume and transferred to a glass amber container with a Teflon^R-lined cap. The impingers, back-half filter housing, right angle, and U-tubes were rinsed with 100 mL of 0.1N nitric acid into the sample container. The container was sealed and labeled.

- The contents of the third impinger was measured for volume and transferred to a glass amber container with a Teflon^R-lined cap. The impinger and U-tubes were rinsed with 100 mL of 0.1N nitric acid into a sample container. The container was sealed and labeled.

- The contents of the fourth and fifth impingers were measured for volume and transferred to a glass amber container with a Teflon^R-lined cap. The impingers and U-tubes were rinsed with 100 mL of 4% $KMnO_4$/10% H_2SO_4 into a sample container. The impingers and U-tubes were also rinsed with 100 mL of deionized water into the same container. The container was sealed and labeled.

- The fourth and fifth impingers and connecting U-tubes were rinsed with 25 mL of 8N HCl into a sample container containing 200 mL of deionized water. The container was sealed and labeled.

- The silica gel was returned to its original container and weighed to obtain a final weight.

- All containers were checked to ensure proper sealing, proper labeling, and that all liquid levels were marked. All samples were logged onto the chain-of-custody record.

The Method 29 train produced the following samples:

- Filter
- Front-half 0.1N nitric acid rinse
- Back-half 0.1N nitric acid impinger catch
- Impinger 3 - 0.1N nitric acid rinse

- Impinger 4 & 5 - $KMnO_4$ impinger catch
- HCl rinse

5.4.6 EPA Method 202 - Condensibles (Polycyclic Organic Matter - POM)

The EPA Method 202 sampling train was used to measure and determine the emission rates of Condensibles (Polycyclic Organic Matter - POM).

The sampling train consisted of a heated, glass-lined probe, with a glass button-hook nozzle. A thermocouple and S-type pitot tube were attached to the probe for the measurement of gas temperature and velocity. The sample gas passed through the probe assembly to a series of four ice-cooled impingers kept below 68°F to enable condensation of entrained moisture. The first two impingers contained 100 mL of deionized water. The third impinger was empty and the fourth impinger contained a preweighed amount of silica gel. All connections within the train were glass or Teflon^R, no sealant greases were used. The impingers were followed by a Nutech Model 2010 dry gas meter, pump, and calibrated orifice meter. A schematic of the Method 202 sampling train is presented in Figure 5-4.

Sampling was isokinetic (± 10 percent) with readings of flue gas parameters recorded at every sampling point during the traverse.

Leak checks of the entire Method 202 sampling train were performed before and after each sampling run. In the event any portion of the train was disassembled and reassembled, leak checks were performed prior to disassembling the train. All leak checks and leakage rates are documented on the relevant field test data sheets. The acceptance criteria for the Method 202 train is a leak rate of $\leq$ 0.02 cfm at the highest vacuum obtained during the run.

Following the completion of each test run, the Method 202 train was transported to a recovery area onsite. The sample recovery sequence was as follows:

- Removed the sampling train to the recovery area.
- Noted the condition of the train (i.e., impinger contents color, silica gel color, etc.).
- The contents of the first three impingers were measured for volume and transferred to a precleaned glass amber container.
- The probe, impingers, and U-tubes, were rinsed with methylene chloride into a sample amber glass container with a Teflon^R-lined cap. The rinse procedure was performed three times after which the container was sealed and labeled.
- The silica gel was returned to its original container and weighed to obtain a final weight.

- All containers were checked to ensure proper sealing, proper labeling, and that all liquid levels were marked. All samples were logged onto the chain-of-custody record.

The Method 202 train produced the following sample:

- Methylene Chloride Rinse

5.4.7 EPA Method 0010 - Semivolatile Organic Compounds

The Modified Method 5 (MM5) sampling train was operated in accordance with EPA Reference Method 0010, SW-846, 3rd Edition. The MM5 train was used to measure and determine the emission rates of semivolatile organic compounds.

The sampling train consisted of a heated, glass-lined probe, with a glass button-hook nozzle. A thermocouple and S-type pitot tube were attached to the probe for the measurement of gas temperature and velocity. The sample gas passed through the probe assembly to a heated glass fiber filter. The filter holder was maintained at 248°F ± 25°F throughout each test run. Downstream of the heated filter, the sample gas passed through a water-cooled condenser module, then through a sorbent module containing approximately 25g of XAD-2 resin. The XAD module was kept at a temperature below 68°F. The sample gas then passed through a series of four ice-cooled impingers kept below 68°F to enable condensation of entrained moisture. The first two impingers contained 100 mL of deionized water. The third impinger was empty and the fifth impinger contained a preweighed amount of silica gel. All connections within the train were glass or Teflon^R, no sealant greases were used. The impingers were followed by a Nutech Model 2010 dry gas meter, pump, and calibrated orifice meter. A schematic of the Method 0010 sampling train is presented in Figure 5-5.

Sampling was isokinetic (± 10 percent) with readings of flue gas parameters recorded at every sampling point during the traverse.

Leak checks of the entire Method 0010 sampling train were performed before and after each sampling run. In the event any portion of the train was disassembled and reassembled, leak checks were performed prior to disassembling the train. All leak checks and leakage rates are documented on the relevant field test data sheets. The acceptance criteria for the Method 0010 train is a leak rate of ≤ 0.02 cfm at the highest vacuum obtained during the run.

Following the completion of each test run, the Method 0010 train was transported to a recovery area onsite. The sample recovery sequence was as follows:

- Removed the sampling train to the recovery area.

- Noted the condition of the train (i.e., filter condition, impinger contents color, silica gel color, etc.).

- Disassembled the filter housing and transferred the filter to its original glass petri dish with hexane rinsed forceps. Sealed the container with Teflon^R tape and labeled it with the appropriate sample information.

- The XAD-2 resin sorbent module was capped tightly at both ends with glass dead ends and labeled. The module was covered with aluminum foil and stored on ice for transport to the laboratory.

- The front half of the train, nozzle, probe, and front-half filter housing were brush-rinsed with methylene chloride. This was followed by a methanol rinse into the same amber glass container with a Teflon^R-lined cap. The rinse procedure was performed three times with each solvent after which the container was sealed and labeled.

- The contents of the three impingers were measured for volume and transferred to a precleaned glass amber container.

- The back half of the train, back-half filter housing, condenser, impingers, and U-tubes were brush-rinsed with methylene chloride. This was followed by a methanol rinse into the same amber glass container with a Teflon^R-lined cap. The rinse procedure was performed three times with each solvent after which the container was sealed and labeled.

- The silica gel was returned to its original container and weighed to obtain a final weight.

- All containers were checked to ensure proper sealing, proper labeling, and that all liquid levels were marked. All samples were logged onto the chain-of-custody record.

The Method 0010 train produced the following samples:

- Filter
- XAD-2 Module
- Front-Half Methylene Chloride/Methanol Rinse
- Impinger Condensate
- Back-Half Methylene Chloride/Methanol Rinse

5.4.8 EPA Method TO14 - Speciated Volatile Organic Compounds, Ozone Precursors, and Sulfur Compounds

Air samples were collected for volatile organics utilizing EPA Method TO14 from *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air* (EPA 600/4-84-041). A sample of air was drawn through a sampling train comprised of components that regulate the rate and duration of sampling into a pre-evacuated SUMMA passivated canister. Air samples were collected over a 1-hour time frame, typically, using an evacuated canister. After the air sample was collected, the canister valve was closed. Figure 5-6 presents a schematic of this sampling system.

5.4.9 Fourier Transform Infrared (FTIR)

Sampling System - For extractive FTIR measurements, the sample gas was sampled continuously or integrated, in accordance with EPA Method 18. The sample gas was transferred to a 5-meter effective pathlength FTIR gas cell through a PTFE (or 316 SS) transfer line. Gases could be sampled continuously from various points in the process. An 80486 personal computer (PC) controls solenoid valves to alternately switch between the sampling locations, and periodically switch to reference gas for measurement of a current background spectrum.

Field Measurements - The FTIR spectrometer and PC are transported to the test site and installed. After installation and alignment, proper instrument operation was confirmed via Bomem's "Valid" frequency calibration program. This program verifies that the frequency accuracy of the spectrometer is within 0.1 cm^{-1} and measures the true instrument resolution. If the frequency accuracy is not within 0.1 cm^{-1} or the resolution if less than 1.7 cm^{-1}, then the optics were realigned to improve system performance. Following the check of frequency accuracy, the system S/N was measured using the Bomem "SN" program. If the system S/N was not adequate (single-beam RMS S/N $\leq$ 2500 at 2100 $cm^{-1)}$ further improvements in optical alignment, electrical isolation, and/or vibration isolation were employed to improve the S/N. If adjustments were made, verification of the frequency accuracy and resolution with the "Valid" program was then repeated.

Screening - The absorbance spectrum of a single sample of inlet gas was measured. The absorbance spectrum was compared to reference spectra for the compounds expected in the inlet. Any unexpected peaks were searched against a qualitative spectral library to identify unknown compounds. The sample analysis was performed for a sample of outlet gas with the addition of expected destruction products and products of incomplete destruction included in the initial analysis.

Based on the measured gases in the inlet and outlet, the most abundant 20 compounds were chosen for continuous analysis, and the most important 6 compounds for continuous display during the continuous monitoring phase of the test. If unidentified peaks remained in either spectrum, other spectra were obtained (after the initial testing) based on potential contaminants and process chemistry in an attempt to identify the unknown compounds.

Continuous Analysis - The continuous analysis software alternately directs reference gas, inlet gas, and outlet gas into the analyzer. At this time, it was expected that reference spectra would be collected once every two hours (1 minute cell purge, 1 minute spectrum collection). The rest of the measurement time was devoted to system sampling. The exact time required for reference, sample purging was determined by site-specific characteristics such as sample flow rate and the expected time between process variance. Every measured interferogram was stored on hard disk with the associated sample time. Concentration vs. time was continuously displayed for 6 chosen compounds (inlet and outlet concentrations displayed on the same trace). These concentration vs. time traces were recorded along with the concentration vs. time of the other 14 most abundant species. The traces present the results of 119 one minute averages every 2 hours. The system was configured to run continuously for up to 6 hours with minimal attention.

Additional QA/QC - Randomly selected absorbance spectra were compared to reference spectra to insure reported concentrations were not the result of abnormal spectral interference. Also, the reported concentrations based on FTIR analysis were compared to concurrent analyses by standard methods.

Technical Approach - Sampled gases continuously flow through a multi-pass, heated gas cell with an effective optical pathlength of 20 m. Infrared (IR) radiation, modulated by a Michelson interferometer, pass through the gas cell prior to be detected by a photoelectric detector. The resulting, digitized signal corresponds to total infrared intensity vs. time. By applying a complex Fourier Transform (FT) on the digitized interferogram, a single beam ($I(v)$) spectrum is obtained corresponding to intensity vs. frequency (measured in wavenumbers, or cm^{-1}). The absorbance spectrum was calculated according to the formula:

$$Absorbance\ (v) = -\log \frac{(I\ (v))}{(I_o\ (v))}$$

where $I_o\ (v)$ is the background, a single-beam spectrum measured with no sample gas (only non-absorbing gases in the cell). According to Beer's Law, the absorption intensity of a given spectral feature, at constant temperature and pressure, is directly proportional to product of the gas concentration (mols/liter) and the optical pathlength (m). When multiple absorption bands and/or multiple gas species are present, the measured absorbance is a linear superposition of the individual bands. Linear regression analysis can be used to solve for the individual species concentrations when absorbance vs. concentration data are available for the pure species.

5.4.10 NIOSH P&CAM Method 221 - Amines

The NIOSH P&CAM Method 221 sampling train was used to measure and determine the emission rate of amines.

The sampling train consisted of a heated, glass-lined probe, with a glass button-hook nozzle. A thermocouple and S-type pitot tube were attached to the probe for the measurement of gas temperature and velocity. The samples gas passed through the probe assembly to a series of four ice-cooled impingers kept below 68°F to enable condensation of entrained moisture. The first and second impingers contained 100 mL of 0.1N H_2SO_4. The fourth impinger was empty. The fifth impinger contained a preweighed amount of silica gel. The impingers were followed by a Nutech Model 2010 dry gas meter, pump, and calibrated orifice meter. A schematic of the Method 221 sampling train is presented in Figure 5-7.

Sampling was isokinetic (± 10 percent) with readings of flue gas parameters recorded at every sampling point during the traverse.

Leak checks of the entire Method 221 sampling train were performed before and after each sampling run. In the event any portion of the train was disassembled and reassembled, leak checks were performed prior to disassembling the train. All leak checks and leakage rates are documented on the relevant field test data sheets. The acceptance criteria for the Method 221 train is a leak rate of ≤ 0.02 cfm at the highest vacuum obtained during the test run.

Following the completion of each test run, the Method 221 train was transported to a recovery area onsite. The sample recovery sequence was as follows:

- Removed the sampling train to the recovery area.
- Noted the condition of the train (i.e., impinger contents color, silica gel color, etc.).
- The contents of the first three impingers were measured for volume and transferred to a glass amber container with a Teflon^{R}-lined cap. The probe, impingers, right angle, and U-tubes were rinsed three times with distilled deionized water into the same sample container. The container was sealed and labeled.
- The silica gel was returned to its original container and weighed to obtain a final weight.
- All containers were checked to ensure proper sealing, proper labeling, and that all liquid levels were marked. All samples were logged onto the chain-of-custody record.

The Method 221 train produced the following samples:

- 0.1N H_2SO_4 Impinger Catches

5.4.11 Process Data

During each test run, all pertinent operating parameters are recorded. These parameters consist of the quantity and type of materials being processed, processing and/or production rate, process temperature, and process pressure. This data are recorded at the start of each test run and at fifteen minute intervals thereafter until the completion of the test run.

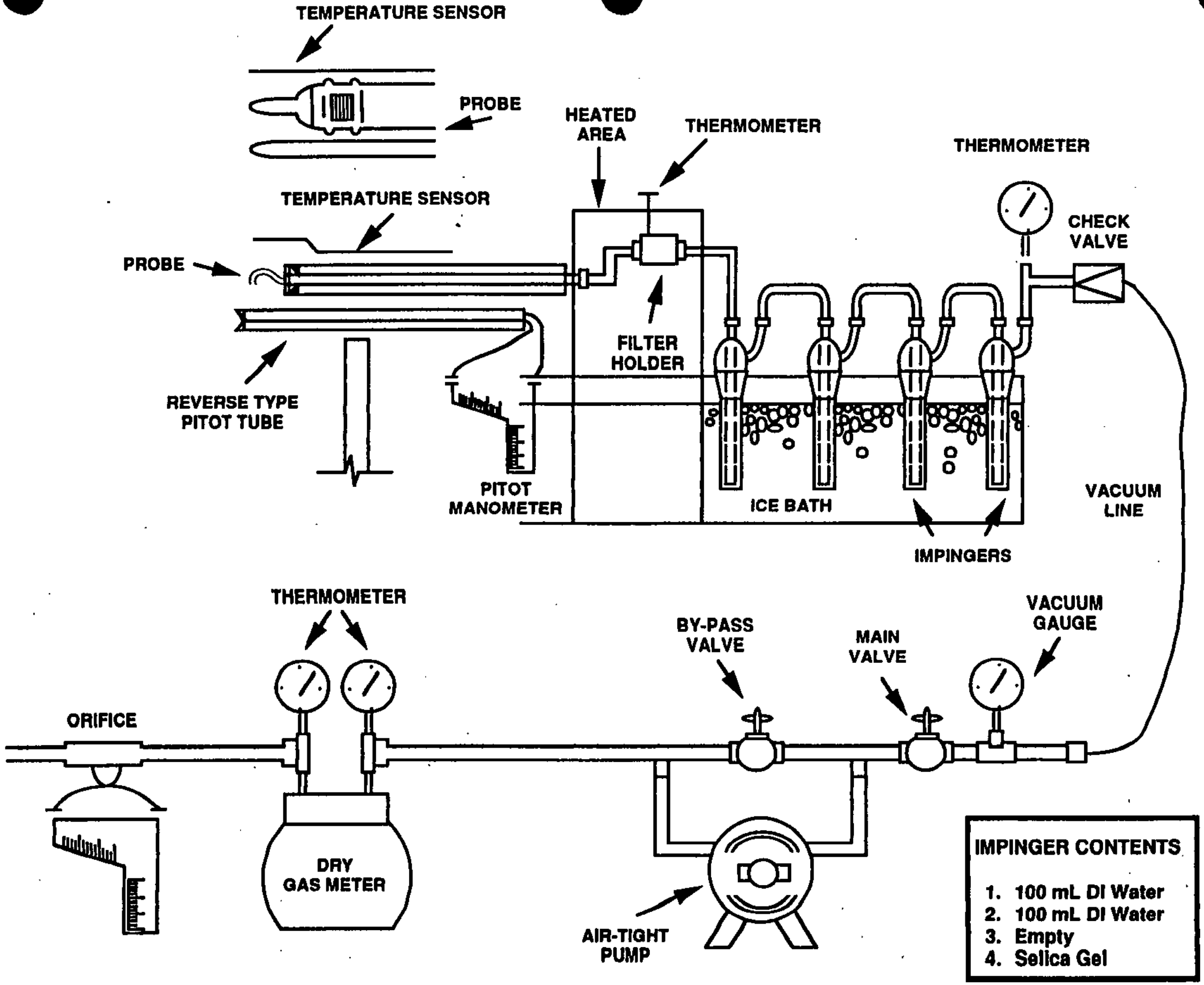


Figure 5-1. Method 5 - Particulate Matter Sampling Train.

L94-909/D

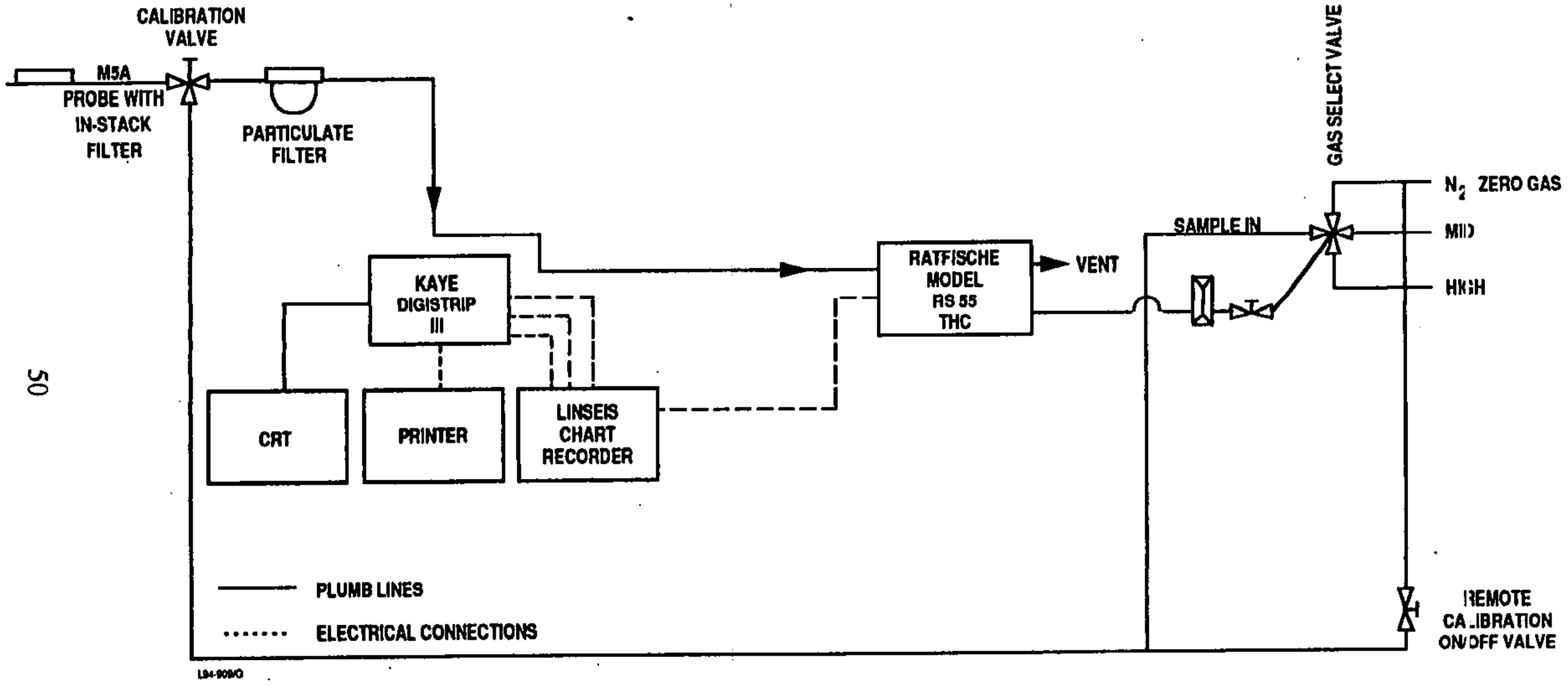


Figure 5-2. TCEM System Schematic.

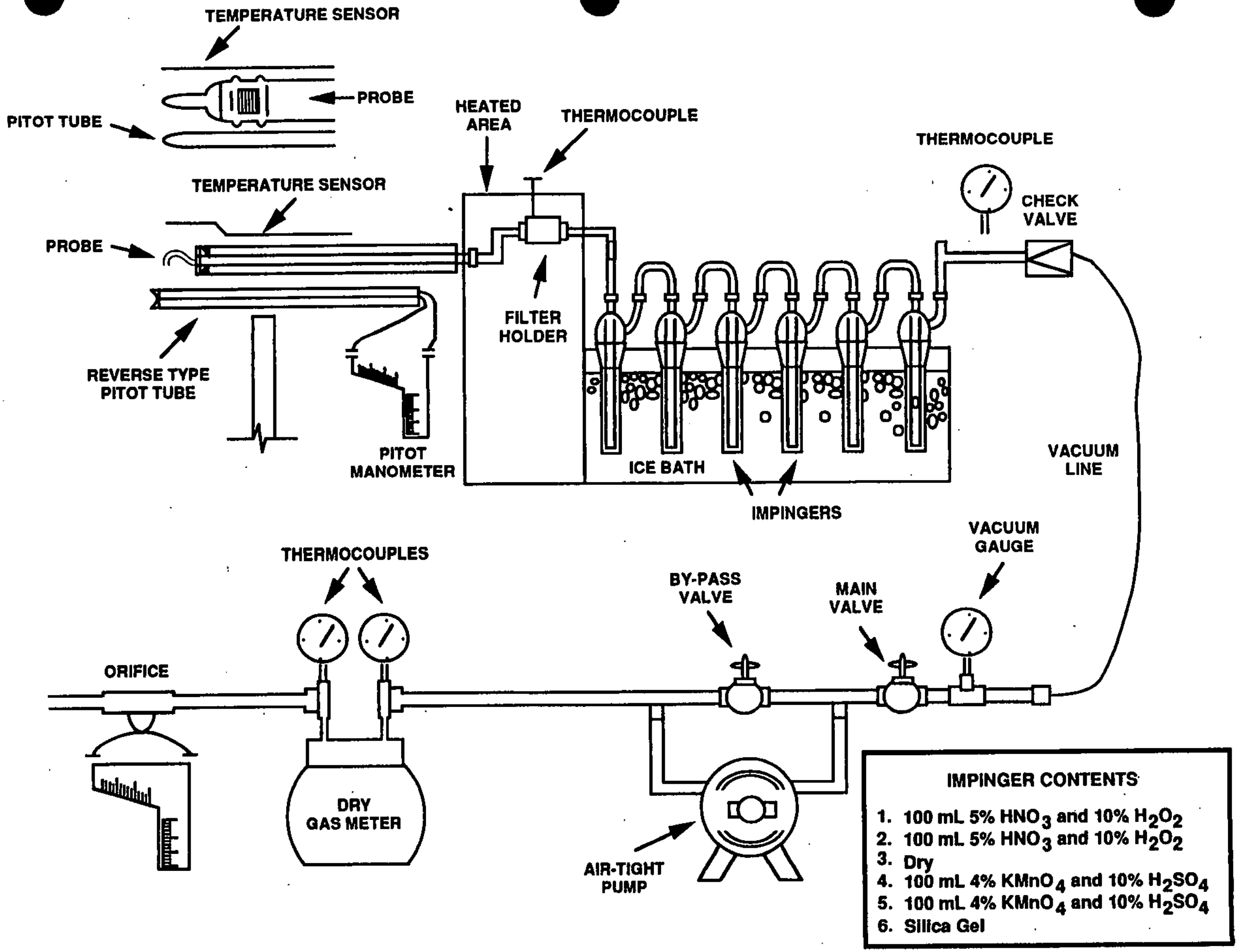


Figure 5-3. Method 29 - Multiple Metals Sampling Train.

L94-909/A

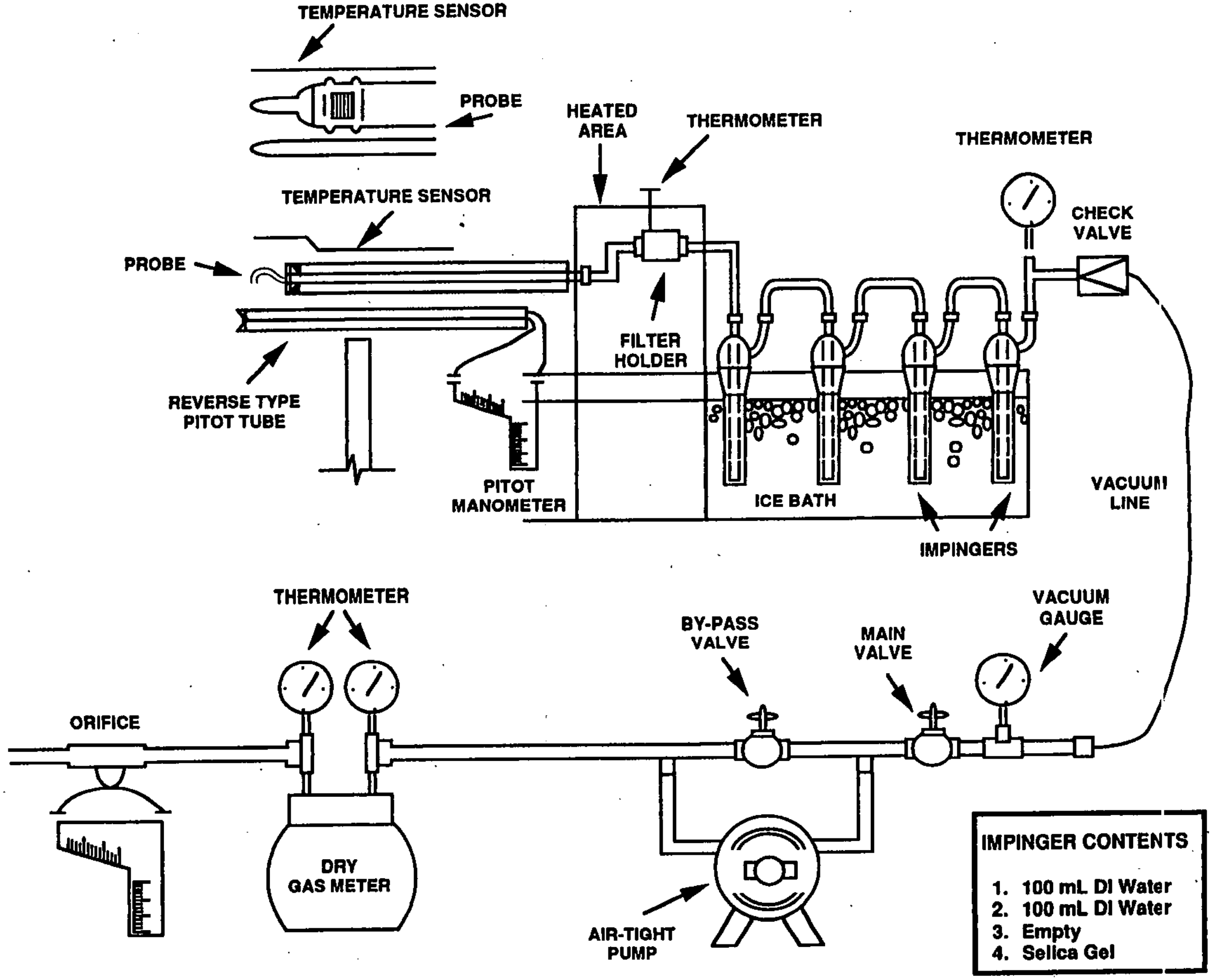


Figure 5-4. Method 202 - Condensibles (Polycyclic Organic Matter) Sampling Train.

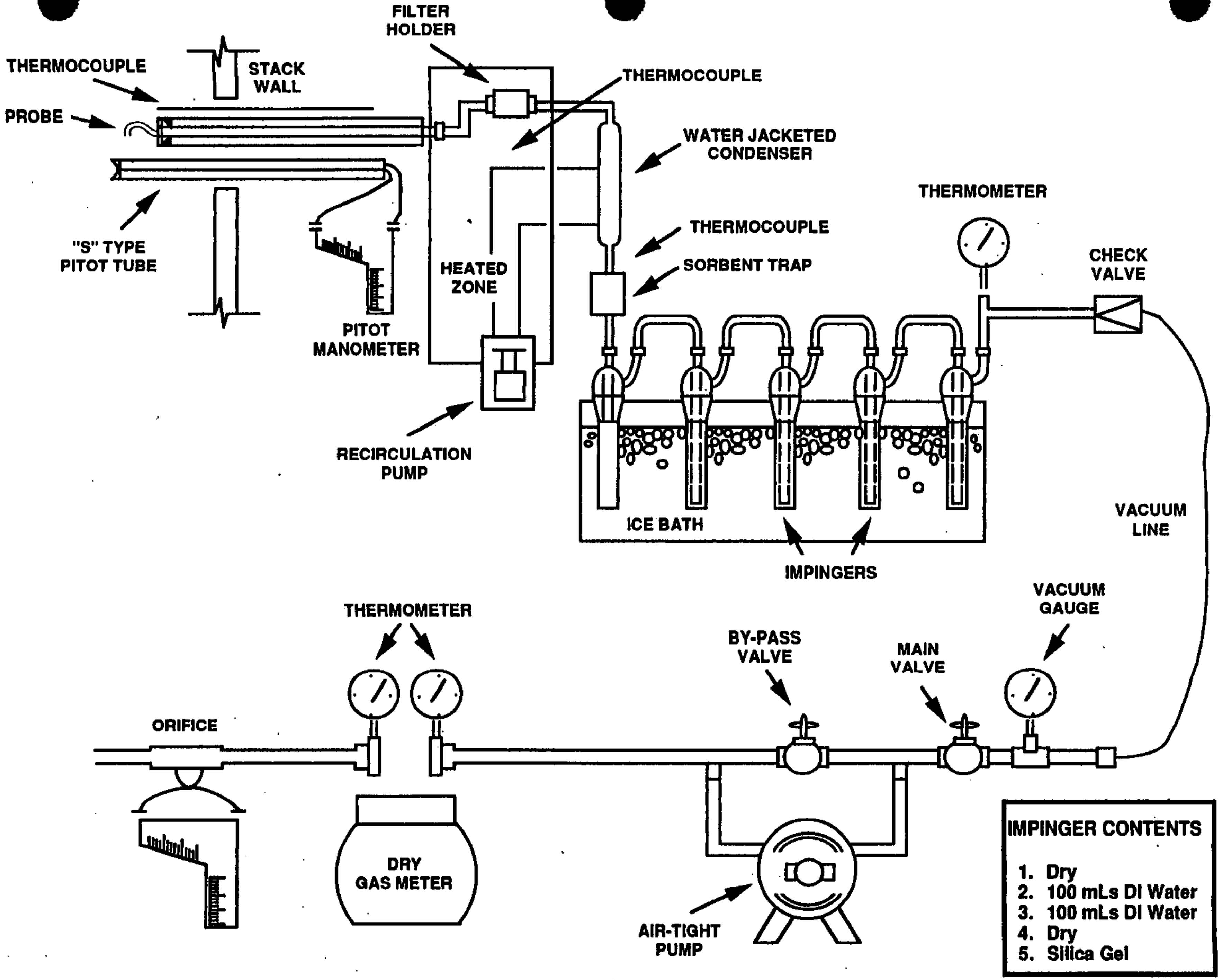


Figure 5-5. Method 0010 - Semivolatile Organic Compound Sampling Train.

L94-909/E

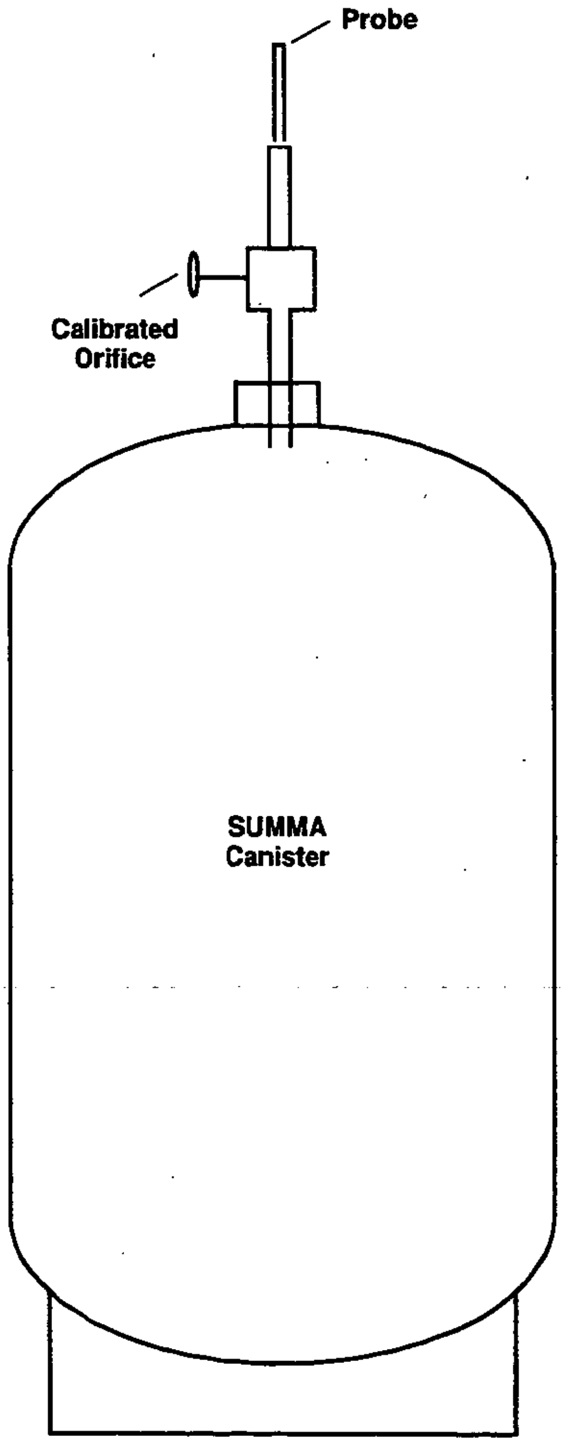


Figure 5-6. Method TO14 Sampling System.

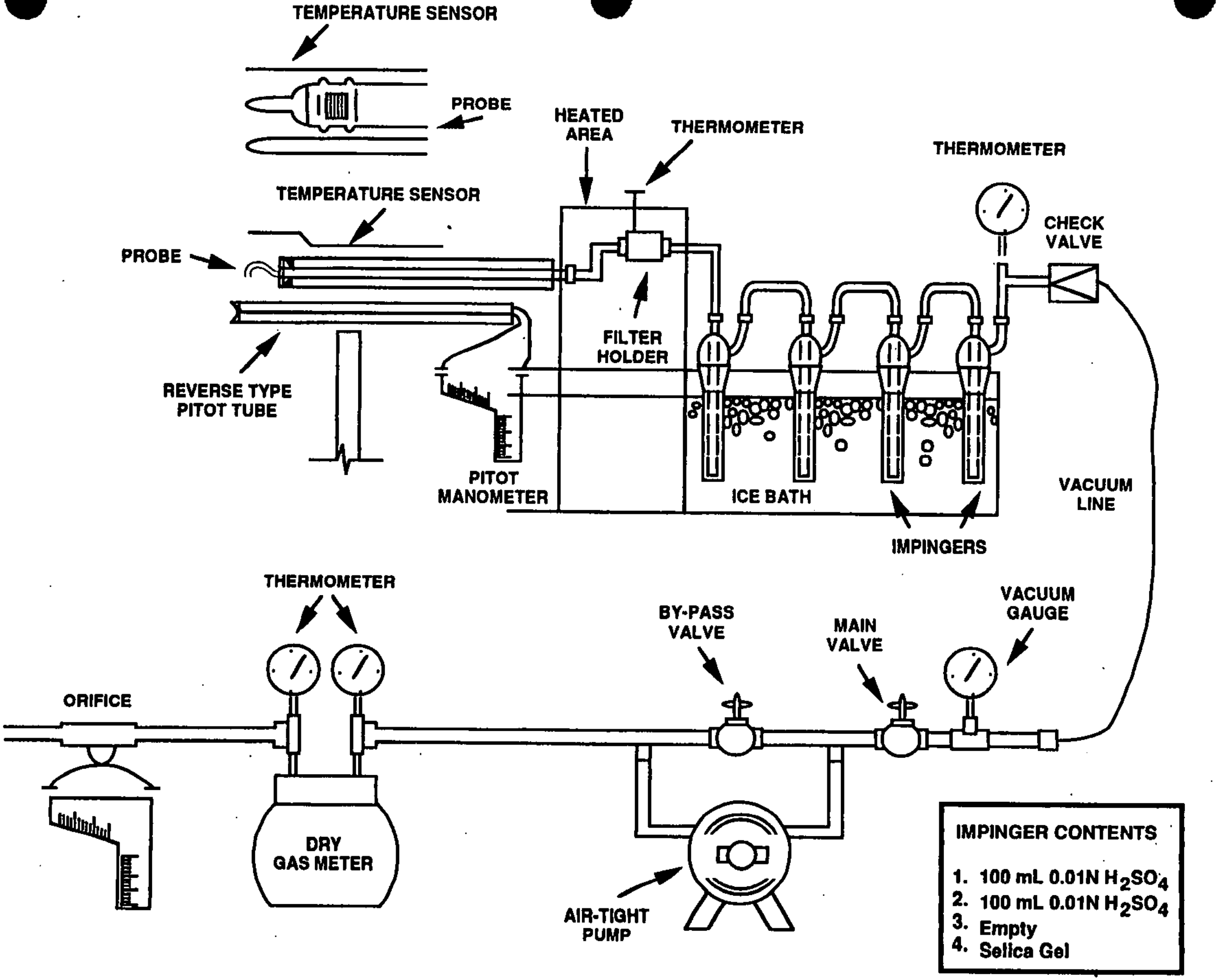


Figure 5-7. NIOSH P&CAM Method 221 - Amines Sampling Train

194-909/C

SECTION 6.0

ANALYTICAL PROCEDURES

This section delineates the analytical protocols used to analyze samples during the Rubber Manufacturers Association Test Program. The analysis and quality control protocols for each parameter are summarized below in Sections 6.1 through 6.2. The actual number of spikes and blanks required are a function of the number of actual samples collected, the analytical method requirements, and the method of sample recovery employed.

6.1 TOTAL VOLATILE ORGANIC COMPOUNDS

Total volatile organic compounds were determined continuously in the exhaust gases of the various processes using EPA Reference Method 25A as described earlier in Section 5.4.4.

6.2 SPECIATED VOLATILE ORGANICS

Volatile organic samples are collected in a 6-liter SUMMA canister according to EPA Method TO14. The samples are aliquoted using a vacuum pump, a mass flow controller, and a cryogenic trap. Internal standard/surrogate spike gas is added to the sample stream. The sample is cryogenically trapped using liquid nitrogen. The cryogenic trap is thermally desorbed by rapid heating. The sample is cryogenically refocussed, then injected onto a capillary column. The analysis is performed using a Finnigan 4500 GC/MS/DS interfaced to a Tekmar 5010GT Automatic Desorber. The estimated detection limit for these analyses is 1 $\mu g/m_3$.

6.3 VOLATILE OZONE PRECURSORS

Volatile organic samples are collected in a 6-liter SUMMA canister according to EPA Method TO14. The samples are aliquoted using a vacuum pump, a mass flow controller, and a cryogenic trap. Internal standard/surrogate spike gas is added to the sample stream. The sample is cryogenically trapped using liquid nitrogen. The cryogenic trap is thermally desorbed by rapid heating.

The speciation and measurement of gaseous ozone precursors is performed by gas chromatography/flame ionization detection (GC/FID). Analysis is performed utilizing the methodology outlined in the *Technical Assistance Document for Sampling and Analysis of Ozone Precursors*, EPA 600/8-91-215, U.S. EPA, Research Triangle Park, NC, October 1991. A subambient GC temperature program is utilized for the analysis. A standard of 54 target hydrocarbons is analyzed daily as a retention time marker. Results are calculated using individual peak responses and the average response factor for n-Propane. Results are reported in ppbC (parts per billion, Carbon).

6.4 SULFUR COMPOUNDS

Reduced sulfur gases are analyzed by gas chromatography/flame photometric detection (GC/FPD) using a direct injection technique according to modified EPA Method 16. The analysis is performed on a Hewlett-Packard 5890A gas chromatograph using a thick film (5micron) crossbonded 100% dimethylpolysiloxane megabore capitallary column (60 meter x 0.53 mm RT_x-1, Restek Corporation). A subambient GC temperature program is utilized for this analysis. An initial six-point calibration curve is prepared with hydrogen sulfide, methyl mercaptan, and carbonyl sulfide.

6.5 SEMIVOLATILE ORGANIC COMPOUNDS

The EPA Method 0010 sampling train is used to collect samples for the determination of emission levels of semivolatile organic compounds. The sample trains are extracted according to Method 0010 and analyzed for semivolatile organic compounds by SW-846 Method 8270. Quality control protocols include the spiking of the sampling train (XAD trap) with surrogate standards prior to sampling and the addition of more surrogate and internal standards in the laboratory prior to analysis. Laboratory analyses are conducted by Triangle Laboratories.

Surrogates are used to monitor efficiencies and are not used in the quantitation of unlabeled analytes. Low recoveries (< 70%, < 40%) would be indicative of possible breakthrough during the sampling session. A Laboratory Control Sample (LCS) is a laboratory blank spiked with the compounds of interest which are prepared and analyzed along with the field samples to further monitor the extraction efficiency of the method.

The Gas Chromatograph and Mass Spectrometer (GC/MS) to be used for the analysis of semivolatile organic compounds are calibrated according to Section 7.3 of SW-846 Method 8270.

6.6 POLYCYCLIC ORGANIC MATTER as Extractable Organic Matter

Polycyclic organic matter (POM) sampling is accomplished utilizing an EPA Method 5 sampling train. POM analysis is conducted by TRC Environmental Corporation.

The recovered POM train is extracted three times with methylene chloride in a separatory funnel. Following each extraction, the methylene chloride containing the extractable organic matter is decanted into a tared beaker. The methylene chloride is then allowed to evaporate and the beaker is desiccated and weighed to a constant weight. The beaker weight gain, following blank correction, is extractable organic matter.

6.7 PARTICULATE MATTER

Particulate sampling is accomplished by following the procedures in EPA Method 5. The sampling of particulate is done with the use of the EPA Method 5 sampling train. Particulate analysis is conducted by TRC Environmental Corporation.

The filters are desiccated to a constant weight. The filters are then placed in glass petri dishes and sealed with Teflon^{R} tape. An identification label is placed on the dish. The beakers used for the dry down of the acetone rinse are cleaned and dried in an oven at 225°F. The beakers are desiccated to a constant weight.

The front-half acetone rinse is air dried in a tared beaker and then desiccated and weighed to a constant weight. The filter is desiccated and weighed to constant weight. The sum of the net weights for the probe wash and filter catch is used to calculate the concentration of particulate matter in gr/dscf. The emission rate in lbs/hr is also calculated.

6.8 METALS

The Multiple Metals train is operated in accordance with EPA Method 29 to measure and determine the emission rates of the cadmium (Cd), cobalt (Co), lead (Pb), and zinc (Zn). Laboratory analyses are conducted by Triangle Laboratories.

Method 29 sampling train components are recovered and digested in separate front- and back-half fractions. Materials collected in the sampling train are digested with acid solutions to dissolve organics and to remove organic constituents that may create analytical interferences. Acid digestion is performed using conventional Parr^{R} Bomb or microwave digestion techniques.

The nitric acid and hydrogen peroxide solution, the probe rinse, and digested filter solutions of the train catches are analyzed for cadmium, cobalt, lead, and zinc by inductively coupled argon plasma emission spectroscopy (ICAP) or atomic absorption spectroscopy (AAS). Graphite furnace atomic absorption spectroscopy (GFAAS) is used for cadmium and lead, if these elements require greater analytical sensitivity than can be obtained by ICAP.

6.9 AMINES

The 0.01N sulfuric acid solution sample is analyzed by direct injection gas chromatography (GC) utilizing a nitrogen phosphorous detector. The sample pH is neutralized with sodium hydroxide (100ul in 3mL of sample) prior to injection.

Compounds in each sample are separated using a 30 meter 0.53mm Stabilwax-DB capillar column. Two four-point calibration curves are used to calibrate the gas chromatograph. The first solution contains trimethylamine, dimethylamine, diethylamine and butylamine at a concentration range from 0.5 ug/mL to 2.0 ug/mL. The second curve consists of cyclohexylamine and diphenylamine at the same concentration range as the first curve.

Duplicate analysis and matrix spike analysis are used to determine the precision and accuracy of the method. Replicate analysis objectives are an RPD of less than or equal to 10%. Matrix spike objectives are 80 to 120% recover.

6.10 FOURIER TRANSFORM INFRARED SPECTROSCOPY (FTIR)

Spectrometer and Data Acquisition - An MB100 FT-IR spectrometer (Bomem Inc. Quebec, Canada) is used for IR modulation and detection. The MB100 can operate with a variable resolution from 1 to 128 cm^{-1}. The lower the spectral resolution (higher number) the faster the sampling time and the greater the signal-to-noise ratio (S/N); however, with low resolution absorbance non-linearities are more pronounced and it is difficult to separate absorbance features from multiple gas species. Therefore, more accurate quantitative results can be achieved with higher spectral resolution. 1 cm^{-1} resolution spectra are measured for quantitative analysis. The detector is liquid nitrogen - cooled Mercury-Cadmium-Telluride (MCT) detector with linearized preamp (Graseby Infrared, Orlando, FL). Digitized data are transferred to the PC via a Digital Signal Processor (DSP) board. Instrument control, data collection, and data reduction are performed by executable routines written in Array Basic™ for Grams™ (Galactic Industries Corp., Salem, NH). All measured interferograms are stored on an internal hard drive in the PC for quality control and potential secondary analysis. Concentrations of up to 20 gas species are calculated continuously while up to six are displayed. Concentration vs. time traces for the 20 measured species are stored periodically and at the conclusion of each run. When mass flow rates are determined, destruction efficiencies and total mass-based emissions are calculated from the measured inlet and outlet concentrations.

Standards Development - All spectra are obtained at 1 cm^{-1} spectral resolution, with the cell temperature and pressure maintained at 150° C and 1 atm, respectively. Therefore, pure component reference spectra need to be obtained at these same conditions. Gas phase spectra of CO_2 (from 424.1 to 50,000 ppm), CO (from 0.56 to 10,000 ppm), and NO (0.85 ppm) have been previously measured under these conditions and are available for use in this program. Theoretical, high resolution reference spectra (≤ 0.0625 cm^{-1} data point spacing) were generated from the HITRAN Optical Spectroscopy Database using USF HITRAN-PC (University of South Florida Research Foundation, Tampa, FL) for CO_2 (from 12.5 ppm to 1,250 ppm), H_2O (from 100 to 10,000 ppm), and NO (From 1 to 100 ppm) and data is available for CO. The high resolution reference spectra were de-resolved to 1 cm^{-1} in the Fourier domain using triangular apodization to approximate the instrument line shape function of the spectrometer. Quantitative reference spectra for the other species have been obtained from the EPA FT-IR on-line database for 100 hazardous air pollutants (HAPs). The absorbance spectra of the standard gases are measured in the laboratory using the same sampling protocol described for the field analysis. This measurement is used to verify pre-installation instrument calibration and sampling accuracy. Pure component reference spectra are used to calculate calibration curves and choose a suitable reference spectrum for use in a modified classical least squares algorithm. A pre-treatment procedure is applied to the spectra to remove the effects of baseline variations, and the optimal spectral region for quantitation is selected. The pre-treated sample spectra are then reconstructed from the pure component spectra, and previously computed calibration curves are applied to the results to determine the concentrations. Mixed gas standards can then be used to determine potential interference effects between the gas various gas species.

The sensitivity limits for the given species depend upon the absorbance coefficient of each gas as well as the S/N for the instrument and the degree to which other species absorbances interfere. The S/N can be increased by increasing the sampling time, but the ratio increases as the square root of the sampling time and time resolution sets practical limits on the time per measurement. It is expected that each measurement will be the result of 1 minute of scanning but this may be adjusted depending on the desired sensitivities, the absorbance coefficients of the species of interest, and the measured S/N.

Report Preparation and Support - The FT-IR system measures and records volume mixing concentrations (mol/mol) for each measured compound. When supplied with the volume and mass flow rates, mass-based emissions can be calculated for each device. Following each test, previously unidentified peaks are compared with potential compounds. If a match is found, quantitative reference spectra can be obtained or measured, and the recorded spectra can be re-analyzed to determine concentration vs. time information for the unknown. "Valid" and "S/N" reports are included for each test, as are the results of the pathlength calculation, zero and calibration error measurements, and sample bias measurements.

SECTION 7.0

QUALITY ASSURANCE/QUALITY CONTROL PROCEDURES

7.1 OVERVIEW

TRC's QA Program conforms with EPA recommendations and is directed by the Corporate QA Director, a full-time professional who reports directly to the Company President. This give the QA Director the necessary authority and independence to find and correct any existing quality problems. Division QC Coordinators are responsible for the QC Program within each technical division; they report both to their Division Manager and the Corporate QA Director.

This section highlights the specific QA/QC procedures to be followed on this Test Program. The QA Director has reviewed and approved this Test Plan and has attended project review meetings, as needed, to ensure that appropriate QA/QC procedures are followed.

7.2 FIELD QUALITY CONTROL SUMMARY

7.2.1 Calibration Procedures

Calibration of the field sampling equipment is performed prior to the field sampling effort. Copies of the calibration sheets are submitted to the field team leader to take onsite and for the project file. Calibrations are performed as described in the EPA publications "*Quality Assurance Handbook for Air Pollution Measurement Systems; Volume III - Stationary Source Specific Methods*" (EPA-600/4-77-027b) and EPA 40 CFR Part 60 Appendix A. Equipment to be calibrated includes the sample metering system, nozzles, barometers, thermocouples, and pitot tubes. All calibrations are available for review at the test program. Copies of the equipment calibration forms can be found in Appendix E.

7.2.2 Equipment Leak Checks

Prior to sampling, each sampling train is leak checked according to the procedures outlined in EPA Reference Method 5. During the course of a test run, a leak check is conducted before and after every test, or if replacement of a component becomes necessary. Final leak checks are performed to ensure that no leaks developed in the train during the course of the test run. All leakage rates, if any found, are recorded on the appropriate field data sheet.

7.2.3 Cyclonic Flow Check

The presence of cyclonic flow within each sampling location is checked during preliminary traverses prior to sampling, in accordance with Section 2.4 of EPA Method 1 as described in the July 1, 1988 edition of the Federal Register.

7.2.4 Method and Field Blanks

One Method blank for the Method 0010 and Method 29 sampling trains is taken during the field sampling program. One field blank for the Method 5, Method 25, and Method 0030 are taken during the field sampling program. This is to ensure sample quality and integrity.

7.3 SAMPLE CHAIN OF CUSTODY

The chain-of-custody of the samples is initiated and maintained as follows:

- Each sample is collected, labeled, sealed, and the liquid level marked on appropriate samples.
- The sample is then be recorded on the sample chain-of-custody form.
- Custody of the samples are retained by TRC until shipment by Federal Express. Upon receipt of the samples at the analytical laboratory, custody is reestablished by the labs' internal custody procedures.

An example of the TRC chain-of-custody form can be found in Appendix C.

7.4 DATA REDUCTION, VALIDATION, AND REPORTING

Specific QC measures are used to ensure the generation of reliable data from sampling and analysis activities. Proper collection and organization of accurate information followed by clear and concise reporting of the data is a primary goal in all projects.

7.4.1 Field Data Reduction

Appendix D of this Test Plan presents the standardized forms that are used to record field sampling data. The data collected are reviewed in the field by the Field Team Leader and at least one other field crew member. Errors or discrepancies are noted in the field book. Appendix D provides the calculation worksheets used in the field to check on isokinetic sampling conditions and a listing of formulas to be used to reduce the field data.

7.4.2 Laboratory Analysis Data Reduction

Analytical results are reduced to concentration units specified by the analytical procedures, using the equations provided in the analytical procedures. If units are not specified, data from the analysis of gas samples are reported as $\mu g/m^3$.

The emission test results and the calculated emission factors are subjected to a rigorous statistical analysis. This analysis determines the arithmetic mean, standard deviation, confidence limits, and testing for outlying data. If there is any outlying data which is not representative of actual emissions, this data is discarded prior to final quantitation of the emission factors. An explicit explanation is provided for any data that is discarded.

The arithmetic mean (X) for a series of test data is determined from the summation of the results for each test run (U) by the number of test runs (N). This method is used for calculating average emission test results and the average emission factor for a specific test condition. Outlying data are not included in these calculations.

The standard deviation (S) is determined for each series of test data. The standard deviation is utilized to determine the confidence level for the results obtained for each test series. The standard deviation for a series of data is calculated using Equation 7-1.

(Equation 7-1)

$$S = \sqrt{\left(\frac{\Sigma(x-u)^2}{n}\right)}$$

The confidence level is calculated for the final results (F) for each test series. Due to the relatively small number of test runs that are conducted for each operating condition, the confidence level is determined using the Student *t* distribution. The confidence interval is calculated for a 95% confidence in the data. The *t* value for a 95% confidence interval is $t_{.025}$. The equation that is used is defined in Equation 7-2.

(Equation 7-2)

$$X-t_{.025}(S/\sqrt{N})\leq F\leq X+t_{.025}(S/\sqrt{N})$$

Outlying data are eliminated to preserve the accuracy of the final results. Data are considered outlying if its value has a difference of > 20% from the arithmetic mean for the test series in which the data was acquired.

7.4.3 Data Validation

TRC supervisory and QC personnel use validation methods and criteria appropriate to the type of data and the purpose of the measurement. Records of all data are maintained, including that judged to be an "outlying" or spurious value. The persons validating the data have sufficient knowledge of the technical work to identify questionable values.

Field sampling data is validated by the Field Team Leader and/or the Field QC Coordinator based on their review of the adherence to an approved sampling protocol and written sample collection procedure.

Analytical data are validated by the subcontractor laboratory QC or supervisory personnel using criteria outlined below. TRC utilizes results from field and laboratory method blanks, replicate samples and internal QC samples to further validate analytical results. Furthermore, TRC QC personnel review all subcontractor laboratory raw analytical data to verify calculated results presented.

The following criteria are used to evaluate the field sampling data:

- Use of approved test procedures;
- Proper operation of the process being testing;
- Use of properly operating and calibrated equipment;
- Leak checks conducted before and after tests;
- Use of reagents conforming to QC specified criteria;
- Proper chain-of-custody maintained.

The criteria listed below are used to evaluate the analytical data:

- Use of approved analytical procedures;
- Use of properly operating and calibrated instrumentation;
- Acceptable results from analyses of QC samples (i.e., the reported values should fall within the 95 percent confidence interval for these samples).

7.4.4 Data Reporting

All data are reported in standard units depending on the measurement and the ultimate use of the data. The bulk of the data are computer processed. Data fore the exhaust gas streams will be reported as follows:

- Gas Properties
  - Moisture, percent by volume
  - Flow rate, dscfm and acfm
  - Pressure, mm of Hg
  - Temperature, °F

- Particulate Matter
  - gr/dscf
  - gr/ascf
  - lbs/hr
  - mass emitted per mass of product produced or processed

- Total Volatile Organic Compounds
  - ppm (v/v)
  - lbs/hr
  - mass emitted per mass of product produced or processed

- Speciated Semivolatile Organic Compounds
  - ng
  - lbs/hr
  - mass emitted per mass of product produced or processed

- Multiple Metals
  - µg/dscf
  - lbs/hr
  - mass emitted per mass of product produced or processed

- Speciated Volatile Organic Compounds
  - ng
  - lbs/hr
  - mass emitted per mass of product produced or processed

Results of the emission factor test program are being reported in sufficient detail to allow RMA to check all results and plan confirmatory measurements. The final report includes six sections:

- Introduction
- Summary and Discussion of Results
- Process Descriptions and Operation
- Sampling Locations
- Sampling and Analytical Procedures
- Data Reduction and Reporting

Report appendices include:

- Field Sampling Data Sheets
- Field Recovery Data Sheets
- Field Reduced Data
- Flue Gas Analytical Data Reports
- Process Data
- Calibration Sheets

APPENDIX A

COMBINED HAP, SARA 313, STATE AIR TOXICS LIST

05/03/93

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
0	Aluminum compounds	(CA,KY)
0	Antimony compounds	(EPA 189)
0	Arsenic compounds	(EPA 189)
0	Barium compounds	(CA,KY)
0	Beryllium compounds	(EPA 189)
0	Bromine compounds	(CA)
0	Cadmium compounds	(EPA 189)
0	Chromium compounds	(EPA 189)
0	Cobalt compounds	(EPA 189)
0	Coke oven emissions	(EPA 189)
0	Copper compounds	(CA)
0	Creosotes	(CA)
0	• Cyanide compounds	(EPA 189)
0	Dialkylnitrosamines	(CA)
0	Fine mineral fibers	(EPA 189)
0	Glycol ethers	(EPA 189)
0	Indium compounds	(KY)
0	Iron	(KY)
0	Iron salts	(KY)
0	Lead compounds	(EPA 189)
0	Manganese compounds	(EPA 189)
0	Mercury compounds	(EPA 189)
0	Molybdenum compounds	(KY)
0	Nickel compounds	(EPA 189)
0	Phosporous compounds	(CA)
0	Platinum compounds	(KY)
0	Polycyclic organic matter	(EPA 189)
0	Radionuclides	(EPA 189)
0	Rhodium compounds	(KY)
0	Selenium compounds	(EPA 189)
0	Silver compounds	(CA,KY)
0	Tellurium compounds	(KY)
0	Thallium compounds	(KY)
0	Thallium compounds	(CA)
0	Tin compounds	(KY)
0	Tungsten compounds	(KY)
0	Uranium compounds	(KY)
0	Vanadium	(CA)
0	• Zinc compounds	(CA)
76119	1,1,1,2-Tetrachloro-2,2-difluorethane	(NC)
71556	1,1,1-Trichloroethane	(EPA 189)
79345	1,1,2,2-Tetrachloride	(EPA 189)
76120	1,1,2,2-Tetrachloro-1,2-difluoroethane	(NC)
79005	1,1,2-Trichloroethane	(EPA 189)
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	(CA,IL,NY,NC,TX)
	1,1-Butanediol dimethanesulphonate	(KY)
394729	1,1-Dichloro-1-nitroethane	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
57147	1,1-Dimethyl hydrazine	(EPA 189)
96184	1,2,3-Trichloropropane	(IL,KY,NY,TX)
120821	1,2,4-Trichlorobenzene	(EPA 189)
95636	1,2,4-Trimethylbenzene	(CA)
96128	1,2-Dibromo 3-chloropropane	(EPA 189)
540590	1,2-Dichloroethylene	(KY)
	1,2-Diethylhydrazine	(KY)
540738	1,2-Dimethylhydrzine	(KY)
122667	1,2-Diphenylhydrazine	(EPA 189)
106887	1,2-Epoxybutane	(EPA 189)
75558	1,2-Propylenimine	(EPA 189)
106990	• 1,3-Butadiene	(EPA 189)
107880	1,3-Butylene glycol	(NY,TX)
541731	1,3-Dichlorobenzene	(CA,IL,NY,TX)
542756	1,3-Dichloropropene	(EPA 189)
118525	1,3-Dichloro-5,5-dimethylhydantoin	(KY)
1120714	1,3-Propane sultone	(EPA 189)
106467	1,4-Dichlorobenzene(p)	(EPA 189)
123911	1,4-Diethyleneoxide	(EPA 189)
82280	1-Amino-2-Methylanthraquinone	(KY)
106989	1-Butene	(IL,NY,TX)
600259	1-Chloro-1-nitropropane	(KY)
108032	1-Nitropropane	(KY,SC)
109671	1-Pentene	(IL,NY,TX)
	1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosurea	(KY)
	1-[(5-Nitrofurfurylidene)amino]-2-imidazolidinone	(KY)
540841	2,2,4-Trimethylpentane	(EPA 189)
75990	2,2-Dichloropropionoic acid	(KY)
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin	(EPA 189)
78886	2,3-Dichloropropene	(SARA 313)
95954	2,4,5-Trichlorophenol	(EPA 189)
93765	2,4,5-Trichlorophenoxyacetic acid	(KY)
88062	2,4,6-Trichlorophenol	(EPA 189)
118967	2,4,6-Trinitrotoluene	(KY)
94757	2,4-D, salts & esters	(EPA 189)
615054	2,4-Diaminoanisole	(CA)
39156417	2,4-Diaminoanisole sulfate	(KY)
	2,4-Dichlorophenyl-p-nitrophenyl ether	(KY)
120832	2,4-Dichlorphenol	(CA)
105679	2,4-Dimethylphenol	(SARA 313)
51285	2,4-Dinitrophenol	(EPA 189)
121142	2,4-Dinitrotoluene	(EPA 189)
95807	2,4-Toluene diamine	(EPA 189)
584849	• 2,4-Toluene diisocyanate	(EPA 189)
606202	2,6-Dinitrotoluene	(CA)
128370	2,6-Ditertiary butyl-p-cresol	(KY)
91087	* 2,6-Toluene diisocyanate	(CA)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
53963	2-Acetylaminofluorene	(EPA 189)
117793	2-Aminoanthraquinone	(KY)
	2-Aminopyridine	(KY)
	2-Amino-5-(5-Nitro-2-furyl)-1,3,4-thiadiazole	(KY)
532274	2-Chloracetophenone	(EPA 189)
110805	2-Ethoxyethanol	(SARA 313)
104767	2-Ethylhexanol	(IL,NY,TX)
109864	2-Methoxyethanol	(SARA 313)
	2-Methylaziridine	(KY)
	2-Methyl-1-nitroanthraquinone	(KY)
88755	• 2-Nitrophenol	(IL,NY,TX)
79469	2-Nitropropane	(EPA 189)
102818	2-N-Dibutylaminoethanol	(KY)
90437	2-Phenylphenol	(SARA 313)
	2-(2-Formylhydrazine)-4-(5-nitro-2-furyl)thiazole	(KY)
91941	3,3-Dichlorobenzene	(EPA 189)
	3,3-Dichloro-4,4-diaminodiphenyl ether	(KY)
119904	3,3-Dimethoxybenzidine	(EPA 189)
119937	3,3-Dimethyl benzidine	(EPA 189)
99343	3,5-Dinitrobenzoic acid	(IL,NY,TX)
101804	4,4-Diaminodiphenyl ether	(SARA 313)
101611	4,4-Methylene bis benzenamine	(KY)
101144	4,4-Methylene bis(2-chloroaniline)	(EPA 189)
101779	4,4-Methylenedianaline	(EPA 189)
139651	4,4-Thiodianiline	(KY)
534521	4,6-Dinitro-o-cresol, & salts	(EPA 189)
60093	4-Aminoazobenzene	(SARA 313)
92671	4-Aminobiphenyl	(EPA 189)
95830	4-Chloro-o-phenylenediamine	(CA,KY)
150765	4-Methoxyphenol	(KY)
92933	4-Nitrobiphenyl	(EPA 189)
100027	4-Nitrophenol	(EPA 189)
99592	5-Nitroacenaphthene	(KY)
	5-Nitro-o-anisidine	(KY)
96695	6-tert-Butyl-m-cresol	(KY)
105575	Acetal	(IL,NY,TX)
75070	* Acetaldehyde	(EPA 189)
107891	Acetaldol	(IL,NY,TX)
60355	Acetamide	(EPA 189)
103844	Acetanilide	(IL,NY,TX)
64197	Acetic acid	(IL,KY,NY,NC,TX)
108247	Acetic anhydride	(IL,KY,NY,SC,TX)
67461	Acetone	(CA,IL,KY,NY,TX)
75865	Acetone cyanohydrin	(IL,NY,TX)
75058	Acetonitrile	(EPA 189)
98862	Acetophenone	(EPA 189)
75365	Acetyl chloride	(IL,NY,TX)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
74862	Acetylene	(IL,NY,TX)
79276	Acetylene tetrabromide	(KY)
50782	Acetylsalicyclic acid	(KY)
107028	Acrolein	(EPA 189)
79061	* Acrylamide	(EPA 189)
79107	• Acrylic Acid	(EPA 189)
107131	* Acrylonitrile	(EPA 189)
124049	Adipic acid	(IL,NY,TX)
111693	Adiponitrile	(IL,NY,TX)
	Adriamycin	(KY)
116063	Aldicarb	(SC)
309002	Aldrin	(KY)
	Alkyl napthalenes (linear)	(NY,TX)
	Alkyl sulfunate (linear)	(NY,TX)
123013	* Alkylbenzene (linear)	(IL,NY,TX)
107186	Allyl alcohol	(IL,KY,NY,TX)
107051	Allyl chloride	(EPA 189)
106923	Allyl glycidyl ether	(KY)
2179591	Allyl propyl disulfide	(KY)
97563	Aminoazotoluene(o)	(KY)
1321115	Aminobenzoic acid	(IL,NY,TX)
111411	Aminoethylethanolamine	(IL,NY,TX)
123308	• Aminophenol(p)	(IL,NY,TX)
61825	Amitrole	(CA,KY)
7664417	Ammonia	(CA,KY,NC)
12125029	Ammonium chloride	(KY,SC)
7788989	Ammonium chromate	(NC)
	Ammonium dichromate	(NC)
6484522	Ammonium nitrate	(CA)
7783202	Ammonium sulfate	(CA,KY)
628637	Amyl acetates	(IL,KY,NY,TX)
71410	Amyl alcohols	(IL,NY,TX)
110587	Amyl amine	(IL,NY,TX)
543599	Amyl chloride	(IL,NY,TX)
110687	Amyl mercaptans	(IL,NY,TX)
1322061	Amyl phenol	(IL,NY,TX)
62533	* Aniline	(EPA 189)
142041	Aniline hydrochloride	(IL,NY,TX)
29191524	Anisidine	(IL,NY,TX)
134292	Anisidine hydrochloride(o)	(SARA 313)
90040	Anisidine(o)	(EPA 189)
04949	Anisidine(p)	(SC)
100663	Anisole	(IL,NY,TX)
120127	Anthracene	(SARA 313)
118923	Anthranilic acid	(IL,NY,TX)
84651	Anthraquinone	(IL,NY,TX)
	Aramite	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
7784421	Arsine	(KY)
1332214	Asbestos	(EPA 189)
1912249	Atrazine	(KY)
492808	Auramine	(KY)
	Azaserine	(KY)
	Azathioprine	(KY)
86500	Azinphos–methyl	(KY)
17804352	Benomyl	(KY)
100527	• Benzaldehyde	(IL,NY,TX)
55210	• Benzamide	(IL,NY,TX)
71432	* Benzene	(EPA 189)
98486	Benzenedisulfonic acid	(IL,NY,TX)
98113	Benzenesulfonic acid	(IL,NY,TX)
92875	Benzidine	(EPA 189)
134816	Benzil	(IL,NY,TX)
76937	Benzilic acid	(IL,NY,TX)
271896	Benzofuran	(CA)
65850	• Benzoic acid	(IL,NY,TX)
119539	Benzoin	(IL,NY,TX)
100470	Benzonitrile	(IL,NY,TX)
119619	Benzophenone	(IL,NY,TX)
98077	Benzotrichloride	(EPA 189)
98884	Benzoyl chloride	(CA,IL,KY,NY,TX)
94360	Benzoyl peroxide	(CA,KY)
100516	Benzyl alcohol	(IL,NY,TX)
120514	Benzyl benzoate	(IL,NY,TX)
100447	Benzyl chloride	(EPA 189)
98873	Benzyl dichloride	(IL,KY,NY,TX)
100469	• Benzylamine	(IL,NY,TX)
92524	Biphenyl	(EPA 189)
	Bischloroethyl nitrosurea	(KY)
1304821	Bismuth telluride	(KY)
80057	Bisphenyl A	(IL,NY,TX)
11144	Bis(2–chloroethyl) ether	(CA,KY)
108601	Bis(2–chloro–1–methylethyl) ether	(SARA 313)
103231	Bis(2–ethylhexyl) adipate	(CA)
117817	Bis(2–ethylhexyl)phthalate	(EPA 189)
542881	Bis(chloromethyl)ether	(EPA 189)
	Borates	(KY)
1303862	Boron oxide	(KY)
10294334	Boron tribromide	(KY)
10294345	Boron trifluoride	(KY)
314409	Bromacil	(KY)
10861	Bromobenzene	(IL,NY,TX)
421012	Bromochlorodifluoromethane	(SARA 313)
75252	Bromoform	(EPA 189)
27497514	Bromonapthalene	(IL,NY,TX)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
75638	Bromotrifluoromethane	(SARA 313)
109795	Butanethiol	(SC)
123864	• Butyl acetate(n)	(IL,KY,NY,TX)
105464	• Butyl acetate(sec)	(KY)
540885	• Butyl acetate(tert)	(KY)
141322	Butyl acrylate	(CA,IL,KY,NY,TX)
71363	Butyl alcohol(n)	(CA,IL,KY,NY,TX)
78922	Butyl alcohol(sec)	(CA,IL,KY,NY,TX)
75650	Butyl alcohol(tert)	(IL,KY,NY,TX)
98737	Butyl benzoic acid(p–tert)	(IL,NY,TX)
85687	Butyl benzyl phthalate	(CA)
2426086	Butyl glycidyl ether(n)	(KY)
138227	Butyl lactate(n)	(KY)
	Butyl mercaptan	(KY)
109739	• Butylamine(n)	(IL,KY,NY,SC,TX)
13952846	• Butylamine(sec)	(IL,KY,NY,TX)
75649	• Butylamine(tert)	(IL,KY,NY,TX)
89725	Butylphenol(o–sec)	(KY)
98511	Butyltoluene(p–tert)	(KY)
123728	• Butyraldehyde(n)	(IL,NY,TX)
107926	Butyric acid	(IL,NY,TX)
106310	Butyric anhydride	(IL,NY,TX)
109740	Butyrnitrile	(IL,NY,TX)
96480	Butyrolactone(b)	(KY)
156627	Calcium cyanamide	(EPA 189)
1305620	Calcium hydroxide	(KY)
79925	Camphene	(KY)
76222	Camphor	(KY)
105602	Caprolactum	(EPA 189)
2425061	Captafol	(CA,KY)
133062	Captan	(EPA 189)
63252	Carbaryl	(EPA 189)
1563602	Carbofuran	(KY)
1333864	• Carbon black	(KY)
75150	• Carbon disulfide	(EPA 189)
558134	Carbon tetrabromide	(IL,KY,NY,TX)
56235	Carbon tetrachloride	(EPA 189)
353504	Carbonyl fluoride	(KY)
463581	• Carbonyl sulfide	(EPA 189)
120809	Catechol	(EPA 189)
9004357	Cellulose acetate	(IL,NY,TX)
21351791	Cesium hydroxide	(KY)
133904	Chloramben	(EPA 189)
	Chlorambicil	(KY)
56757	Chloramphenicol	(CA,KY)
57749	Chlordane	(EPA 189)
	Chlorinated diphenyl oxide	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
7782505	Chlorine	(EPA 189)
10049044	Chlorine dioxide	(KY)
7790912	Chlorine trifluoride	(KY)
79118	Chloroacetic acid	(EPA 189)
79049	Chloroacetyl chloride	(KY)
108429	Chloroaniline(m)	(IL,NY)
95512	Chloroaniline(o)	(IL,NY)
106478	Chloroaniline(p)	(IL,NY)
35913098	Chlorobenzaldehyde	(IL,NY)
108907	Chlorobenzene	(EPA 189)
510156	Chlorobenzilate	(EPA 189)
118912	Chlorobenzoic acid	(IL,NY)
2136814	Chlorobenzotrichloride	(IL,NY,TX)
1321035	Chlorobenzoyl chloride	(IL,NY,TX)
	Chlorobenzylidene malononitrile(o)	(KY)
74975	Chlorobromomethane	(KY)
75456	Chlorodifluoroethane	(IL,NY,TX)
25497294	Chlorodifluoromethane	(IL,NY,TX)
11097219	Chlorodiphenyl	(KY)
67663	Chloroform	(EPA 189)
107302	Chloromethyl methyl ether	(EPA 189)
25586430	Chloronapthalene	(IL,KY,NY,TX)
88733	Chloronitrobenzene(o)	(IL,NY,TX)
100005	Chloronitrobenzene(p)	(IL,KY,NY,SC,TX)
	Chlorophene	(NC)
25167800	Chlorophenols	(IL,KY,NY,TX)
76062	Chloropicrin	(CA,KY)
126998	Chloroprene	(EPA 189)
2039874	Chlorostyrene(o)	(KY)
779945	Chlorosulfonic acid	(IL,NY,TX)
1897456	Chlorothalonil	(SARA 313)
108418	Chlorotoluene(m)	(IL,NY,TX)
95498	Chlorotoluene(o)	(IL,KY,NY,TX)
106434	Chlorotoluene(p)	(IL,NY,TX)
75729	Chlorotrifluoromethane	(IL,NY,TX)
218019	Chrysene	(KY)
	Cisplatin	(KY)
2971906	Clopidol	(KY)
8001589	Creosote	(SARA 313)
120718	Cresidine(p)	(CA,KY)
1319773	Cresols/Cresylic acid	(EPA 189)
108394	• Cresol(m)	(EPA 189)
95487	• Cresol(o)	(EPA 189)
106445	• Cresol(p)	(EPA 189)
3724650	Crontonic acid	(IL,NY,TX)
4170300	Crotonaldehyde	(IL,KY,NY,TX)
299865	Cruformate	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
98828	Cumene	(EPA 189)
80159	Cumene hydroperoxide	(CA,IL,NY,TX)
135206	Cupferron	(CA,KY)
107915	Cyanoacetamide	(SC)
372098	Cyanoacetic acid	(IL,NY,TX)
506774	Cyanogen chloride	(IL,NY,TX)
108805	Cyanuric acid	(IL,NY,TX)
108770	Cyanuric chloride	(IL,NY,TX)
66819	Cyclohexamide	(CA)
110827	• Cyclohexane	(CA,IL,KY,NY,TX)
108930	Cyclohexanol	(IL,KY,NY,TX)
108941	• Cyclohexanone	(IL,KY,NY,TX)
110838	Cyclohexene	(IL,KY,NY,TX)
108918	Cyclohexylamine	(IL,KY,NY,TX)
121824	Cyclonite	(KY)
111784	• Cyclooctadiene	(IL,NY,TX)
542927	Cyclopentadiene	(KY)
287923	Cyclopentane	(KY)
50180	Cyclophosphamide	(KY)
1312705	Cyhexatin	(KY)
	Dacarbazine	(KY)
20830813	Daunomycin	(KY)
3547044	DDE	(EPA 189)
17702419	Decaborane	(KY)
1163195	Decabromodiphenyl oxide	(SARA 313)
112301	Decanol	(IL,NY,TX)
8065483	Demeton	(KY)
123422	Diacetone alcohol	(IL,KY,NY,TX)
2303164	Diallate	(SARA 313)
27576041	Diaminebenzoic acid	(IL,NY,TX)
33415	Diazinon	(KY)
334883	Diazomethane	(EPA 189)
132649	Dibenzofurans	(EPA 189)
124732	Dibromotetrafluoroethane	(SARA 313)
107664	Dibutyl phosphate	(KY)
84742	Dibutylphthalate	(EPA 189)
7572294	Dichloroacetylene	(KY)
95761	Dichloroaniline	(IL,NY,TX)
95501	Dichlorobenzene(o)	(CA,IL,NY,TX)
75274	Dichlorobromomethane	(SARA 313)
75718	Dichlorodifluourmethane	(IL,NY,NC,TX)
72559	Dichlorodiphenyldichloroethylene	(CA)
111444	Dichloroethyl ether	(EPA 189)
	Dichlorofluromethane	(KY,NC)
96231	Dichlorohydrin	(IL,NY,TX)
26952238	Dichloropropene	(IL,KY,NY,TX)
76142	Dichlorotetrafluoroethane	(SARA 313)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
62737	Dichlorvos	(EPA 189)
115322	Dicofol	(SARA 313)
141662	Dicrotophos	(KY)
77736	Dicyclopentadiene	(KY)
102595	Dicyclopentadienyl iron	(KY)
101837	Dicycohexylamine	(IL,NY,TX)
60571	Dieldrin	(KY)
	Dienoestrol	(KY)
1464535	Diepoxybutane	(KY)
111422	Diethanolamine	(EPA 189)
96220	Diethyl ketone	(KY)
84662	Diethyl phthalate	(SC)
64675	Diethyl sulfate	(EPA 189)
109897	* Diethylamine	(IL,KY,NY)
100378	Diethylaminoethanol	(KY)
111466	Diethylene glycol	(CA,IL,NY,TX)
56531	Diethylstilbestrol	(KY)
	Difluorobromomethane	(KY)
75376	Difluourethane	(IL,NY)
2238075	Diglycidyl ether	(KY)
	Dihydrosafrole	(KY)
	Dihydroxymethylfuratrizine	(KY)
108838	Diisobutyl ketone	(KY)
25167708	Diisobutylene	(IL,NY,TX)
26761400	Diisodecyl phthalate	(IL,NY,SC,TX)
27554263	Diisooctyl phthalate	(IL,NY,TX)
674828	Diketene	(IL,NY,TX)
127195	Dimethyl acetamide	(KY)
60117	Dimethyl aminoazobenzene	(EPA 189)
79447	Dimethyl carbamoyl chloride	(EPA 189)
115106	Dimethyl ether	(IL,KY,NY,TX)
68122	• Dimethyl formamide	(EPA 189)
131113	Dimethyl phthalate	(EPA 189)
77781	Dimethyl sulfate	(EPA 189)
75183	Dimethyl sulfide	(NY,TX)
67685	Dimethyl sulfoxide	(NY,TX)
120616	Dimethyl terephthalate	(IL,NY,TX)
124403	• Dimethylamine	(IL,KY,NY,TX)
121697	Dimethylaniline	(KY,NY,SC,TX)
528290	Dinitrobenzene(o)	(SARA 313)
100254	Dinitrobenzene(p)	(SARA 313)
	Dinitrolimide	(KY)
25321146	Dinitrotoluene	(IL,KY,NY,TX)
117840	Dioctyl phthalate	(SC)
78342	Dioxathion	(KY)
646060	Dioxolane	(IL,KY,NY,TX)
122394	• Diphenyl amine	(IL,KY,NY,TX)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
101844	Diphenyl oxide	(IL,NY,TX)
102089	Diphenyl thiourea	(IL,NY,TX)
	Diphenylhydrazine	(KY)
123193	Dipropyl ketone	(KY)
25265718	Dipropylene glycol	(CA,IL,NY,TX)
85007	Diquat	(KY)
97778	Disulfiram	(KY)
298044	Disulfoton	(KY)
330541	Diuron	(KY)
1321740	Divinyl benzene	(KY)
25378227	Dodecene	(IL,NY,TX)
28657174	Dodecylaniline	(IL,NY,TX)
27193868	Dodecylphenol	(IL,NY,TX)
115297	Endosulfan	(KY)
72208	Endrin	(KY)
106898	Epichlorhydrin	(EPA 189)
12510428	Erionite	(CA)
75081	Ethanethiol	(KY,NC,SC)
64175	Ethanol	(IL,NY,TX)
141435	Ethanolamines	(IL,KY,NY,SC,TX)
57636	Ethinyloestradiol	(KY)
563122	Ethion	(KY)
141786	* Ethyl acetate	(IL,KY,NY,NC,TX)
141979	Ethyl acetoacetate	(IL,NY,TX)
140885	* Ethyl acrylate	(EPA 189)
541855	Ethyl amyl ketone	(KY)
100414	• Ethyl benzene	(EPA 189)
74964	Ethyl bromide	(IL,KY,NY,TX)
51796	• Ethyl carbamate	(EPA 189)
75003	Ethyl chloride	(EPA 189)
105395	Ethyl chloroacetate	(IL,NY,TX)
60297	Ethyl ether	(IL,KY,NY,TX)
109940	Ethyl formate	(KY)
	Ethyl methanesulphonate	(KY)
122510	Ethyl orthoformate	(IL,NY,TX)
95921	Ethyl oxalate	(IL,NY,TX)
78104	Ethyl silicate	(KY)
41892711	Ethyl sodium oxaloacetate	(IL,NY,TX)
75047	• Ethylamine	(IL,KY,NY,TX)
9004573	Ethylcellulose	(IL,NY,TX)
541413	Ethylchloroformate	(SARA 313)
105566	Ethylcyanoacetate	(IL,NY)
74851	Ethylene	(CA,IL,NY,TX)
151564	• Ethylene amine	(EPA 189)
96491	Ethylene carbonate	(IL,NY,TX)
107073	Ethylene chlorohydrin	(IL,KY,NY,TX)
106934	Ethylene dibromide	(EPA 189)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
107062	Ethylene dichloride	(EPA 189)
107211	• Ethylene glycol	(EPA 189)
111557	Ethylene glycol diacetate	(IL,NY,TX)
628996	Ethylene glycol dinitrate	(KY)
75218	• Ethylene oxide	(EPA 189)
96457	* Ethylene thiorea	(EPA 189)
107153	• Ethylenediamine	(IL,KY,NY,NC,TX)
75343	Ethylidene dichloride	(EPA 189)
16219753	Ethylidene norborene	(KY)
100743	Ethylmorpholine(n)	(KY)
2224926	Fenamiphos	(KY)
115902	Fensulfothion	(KY)
55389	Fenthion	(KY)
14484641	Ferbam	(KY)
2164172	Fluometuron	(SARA 313)
944229	Fonofos	(KY)
50000	• Formaldehyde	(EPA 189)
75127	Formamide	(IL,KY,NY,SC,TX)
64186	Formic acid	(IL,KY,NY,SC,TX)
110178	Fumaric acid	(IL,NY,TX)
98011	Furfural	(IL,KY,NY,SC,TX)
98000	Furfuryl alcohol	(KY,SC)
778652	Germanium tetrahydride	(KY)
111308	Glutaraldehyde	(CA,KY)
56815	Glycerol	(IL,NY,TX)
26545737	Glycerol dichlorohydrin	(IL,NY,TX)
25791962	Glycerol triether	(IL,NY,TX)
7654344	Glycidaldehyde	(KY,SC)
556525	Glycidol	(KY)
56406	Glycine	(IL,NY,TX)
107222	Glyoxal	(IL,NY,TX)
126078	Griseofulvin	(CA)
7440586	Hafnium	(KY)
76448	Heptachlor	(EPA 189)
142825	Heptane	(NIOSH)
118741	Hexachlorobenzene	(EPA 189)
87683	Hexachlorobutadiene	(EPA 189)
608731	Hexachlorocyclohexane	(KY,SC)
77474	Hexachlorocyclopentadiene	(EPA 189)
67721	Hexachloroethane	(EPA 189)
1335871	Hexachloronapthalene	(KY,SC)
36653824	Hexadecyl alcohol	(IL,NY,TX)
648162	Hexafluoroacetone	(KY)
629118	Hexamethylene glycol	(IL,NY,TX)
124094	Hexamethylenediamine	(IL,NY,TX)
100970	• Hexamethylenetetramine	(IL,NY,TX)
822060	Hexamethylene-1,6-diisocyanate	(EPA 189)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
680319	Hexamethylphosphoramide	(EPA 189)
110543	* Hexane	(EPA 189)
108849	Hexyl acetate(sec)	(KY)
107415	Hexylene glycol	(KY)
302012	Hydrazine	(EPA 189)
10034932	Hydrazine sulfate	(KY)
7647010	Hydrochloric acid	(EPA 189)
10035106	Hydrogen bromide	(KY)
7664393	Hydrogen fluoride	(EPA 189)
7722841	Hydrogen peroxide	(KY)
7783064	* Hydrogen sulfide	(EPA 189)
61788327	Hydrogenated terphenyls	(KY)
123319	* Hydroquinone	(EPA 189)
99967	Hydroxybenzoic acid(p)	(IL,NY,TX)
95136	Indene	(KY)
7553562	Iodine	(KY)
75478	Iodoform	(KY)
123922	Isoamyl acetate	(KY)
123513	Isoamyl alchol	(KY)
26760645	Isoamylene	(IL,NY,TX)
78831	Isobutanol	(IL,KY,NY,TX)
110190	Isobutyl acetate	(IL,KY,NY,TX)
115117	Isobutylene	(IL,NY,TX)
78842	Isobutyraldehyde	(IL,NY,TX)
79312	Isobutyric acid	(IL,NY,TX)
25339177	Isodecanol	(IL,NY,TX)
26952216	Isooctyl alcohol	(IL,KY,NY,TX)
78784	Isopentane	(IL,NY,TX)
78591	Isophorene	(EPA 189)
4098719	Isophorone diisocyanate	(KY)
78795	Isophrene	(IL,NY,TX)
121915	Isophthalic acid	(IL,NY,TX)
109591	Isopropoxyethanol	(KY)
108214	Isopropyl acetate	(IL,KY,NY,TX)
67630	• Isopropyl alcohol	(CA,IL,NY,TX)
75296	Isopropyl chloride	(IL,NY,TX)
4016142	Isopropyl glycidyl ether	(KY)
75310	Isopropylamine	(IL,KY,NY,SC,TX)
768525	Isopropylaniline(n)	(KY)
25168063	Isopropylphenol	(IL,NY,TX)
120581	Isosafrole	(KY)
108203	Ispropyl ether	(KY)
143500	Kepone	(KY,SC)
463514	Ketene	(IL,KY,NY,SC,TX)
	Lasiocarpine	(KY)
58899	Lindane (all isomers)	(EPA 189)
7580678	Lithium hydride	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
121755	Malathion	(KY,SC)
110167	Maleic acid	(IL,NY,TX)
108316	Maleic anhydride	(EPA 189)
6915157	Malic acid	(IL,NY,TX)
55867	Mechlorethamine hydrochloride	(KY)
	Mechlorethamine hydrochloride oxide	(KY)
148823	Melphalan	(KY)
141797	Mesityl oxide	(IL,KY,NY,TX)
	Mestranol	(KY)
121471	Metanilic acid	(IL,NY,TX)
79414	Methacrylic acid	(IL,KY,NY,TX)
563473	Methallyl chloride	(IL,NY,TX)
67561	Methanol	(EPA 189)
	Methomyl	(KY)
72435	Methoxychlor	(EPA 189)
137053	Methyl 2−cyanocrylate	(KY)
79209	Methyl acetate	(IL,KY,NY,TX)
105453	Methyl acetoacetate	(IL,NY,TX)
74997	Methyl acetylene	(KY)
96333	Methyl acrylate	(KY)
74839	Methyl bromide	(EPA 189)
37365712	Methyl butynol	(IL,NY,TX)
74873	Methyl chloride	(EPA 189)
108872	Methyl cyclohexane	(IL,KY,NY,TX)
1331222	Methyl cyclohexanone	(IL,NY,TX)
8022002	Methyl demeton	(KY)
78933	• Methyl ethyl ketone	(EPA 189)
1338234	Methyl ethyl ketone peroxide	(KY)
107313	Methyl formate	(IL,KY,NY,TX)
60344	Methyl hydrazine	(EPA 189)
74884	Methyl iodide	(EPA 189)
108101	• Methyl iosbutyl ketone	(EPA 189)
110123	Methyl isoamyl ketone	(KY)
108112	Methyl isobutyl carbinol	(IL,KY,NY,TX)
624839	Methyl isocyanate	(EPA 189)
74931	• Methyl mercaptan	(NC,SC)
80626	Methyl methacrylate	(EPA 189)
110430	Methyl n−amyl ketone	(KY)
298000	Methyl parathion	(KY)
107879	Methyl propyl ketone	(KY)
681845	Methyl silicate	(KY)
1634044	Methyl tert butyl ether	(EPA 189)
	Methylacrylonitrile	(KY)
109875	Methylal	(KY)
74895	Methylamine	(IL,KY,NY,SC,TX)
100618	Methylaniline(n)	(IL,KY,NY,TX)
	Methylazoxymethanol	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
25639423	Methylcyclohexanol	(KY)
583608	Methylcyclohexanone(o)	(KY)
74953	Methylene bromide	(SARA 313)
75092	Methylene chloride	(EPA 189)
101688	Methylene diphenyl diisocyanate	(EPA 189)
77758	Methylpentynol	(IL,NY,TX)
98839	• Methylstyrene(a)	(IL,KY,NY,TX)
	Methylthiouricil	(KY)
21087649	Metribuzin	(KY)
443481	Metronidazole	(CA,KY)
7786347	Mevinphos	(KY)
2385855	Mirex	(KY,SC)
1313275	Molybdenum trioxide	(CA)
	Monocrotaline	(KY)
	Monocrotophos	(KY)
110918	* Morpholine	(IL,KY,NY,TX)
99650	m–Dinitrobenzene	(KY,SC)
	m–Xylene–a,a–diamine	(KY)
121697	N,N–Diethyl aniline	(EPA 189)
	Nafenopin	(KY)
300765	Naled	(KY)
91203	• Napthalene	(EPA 189)
85472	Napthalene sulfonic acid(a)	(IL,NY,TX)
120183	Napthalene sulfonic acid(b)	(IL,NY,TX)
90153	* Napthol(a)	(IL,TX)
135193	* Napthol(b)	(IL,NY,TX)
134327	• Napthylamine(a)	(SC)
91598	* Napthylamine(b)	(KY,SC)
86884	• Napthylthiorea(a)	(ACGIH)
75989	Neopentanoic acid	(IL,NY,TX)
61574	Nirodazole	(CA,KY)
1928824	Nitrapyrin	(KY)
7697372	Nitric acid	(CA,KY,NC,SC)
	Nitriloacetic acid	(KY)
139139	Nitrilotriacetic acid	(CA,KY)
88744	Nitroaniline(o)	(IL,NY,TX)
100016	Nitroaniline(p)	(IL,KY,NY,TX)
91236	Nitroanisole(o)	(IL,NY,TX)
100174	Nitroanisole(p)	(IL,NY,TX)
98953	Nitrobenzene	(EPA 189)
27178832	Nitrobenzoic acid (o,m, & p)	(IL,NY,TX)
79243	Nitroethane	(IL,KY,NY,TX)
1836755	Nitrofen	(SARA 313)
51752	Nitrogen mustard	(SC)
7783542	Nitrogen trifluoride	(KY)
55630	Nitroglycerin	(KY,SC)
75525	Nitromethane	(IL,KY,NY,TX)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
25322014	Nitropropane	(IL,NY,TX)
156105	Nitrosodiphenylamine(p)	(KY)
104916	Nitrosophenol(p)	(SC)
1321126	Nitrotoluene	(IL,KY,NY,SC,TX)
111842	* Nonane	(ACGIH)
11842	* Nonane	(KY)
27215958	Nonene	(IL,NY,TX)
25154523	Nonylphenol	(IL,NY,TX)
	Norethisterone	(KY)
	N–Methyl–N–nitro–n–nitrosoguanidine	(KY)
55185	* N–Nitrosodiethylamine	(KY)
62759	* N–Nitrosodimethylamine	(EPA 189)
86306	* N–Nitrosodiphenylamine	(SARA 313)
	N–Nitrosomethylethylamine	(KY)
4549400	N–Nitrosomethylvinylamine	(KY)
59892	N–Nitrosomorpholine	(EPA 189)
16543558	N–Nitrosonornicotine	(KY)
100754	N–Nitrosopiperidine	(CA,KY)
930552	N–Nitrosopyrollidine	(CA,KY)
	N–Nitrososarcosine	(KY)
924163	N–Nitroso–n–butylamine	(KY)
759739	N–Nitroso–n–ethylurea	(KY)
684935	N–Nitroso–N–methylurea	(EPA 189)
	N–Nitroso–n–methylurethane	(KY)
621647	N–Nitroso–n–propylamine	(KY)
135886	N–Phenyl–2–napthylamine	(KY)
2234131	Octachloronapthalene	(KY,SC)
57114	Octadecanoic acid(n)	(SC)
111659	* Octane	(ACGIH)
27193288	Octylphenol	(IL,NY,TX)
	Oestradiol–17 beta	(KY)
	Oestrone	(KY)
20816120	Osmium tetroxide	(KY)
144627	Oxalic acid	(KY,SC)
	Oxymetholone	(KY)
	Paraffin wax fume	(KY)
123637	Paraldehyde	(IL,NY,TX)
1910425	Paraquat	(KY,SC)
56382	Parathion	(EPA 189)
19624227	Pentaborane	(KY)
1321648	Pentachloronapthalene	(KY)
82688	Pentachloronitrobenzene	(EPA 189)
87865	Pentachlorophenol	(EPA 189)
115775	Pentaerythritol	(IL,NY,TX)
109660	*Pentane(n)	(IL,NY,TX)
79210	Peracetic acid	(CA)
	Perchloro fluoride	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
594423	Perchloromethyl mercaptan	(IL,KY,NY,TX)
	Phenazopyridine	(KY)
	Phenazopyridine hydrochloride	(KY)
	Phencatin	(KY)
94702	Phenetidine(o)	(IL,NY,TX)
156434	Phenetidine(p)	(IL,NY,TX)
50066	Phenobarbital	(CA)
108952	* Phenol	(EPA 189)
98679	Phenolsulfonic acids	(IL,NY,TX)
92842	Phenothiazine	(KY)
91407	Phenyl anthanilic acid	(IL,NY,TX)
101840	Phenyl ether	(KY)
122601	Phenyl glycidyl ether	(KY)
108985	Phenyl mercaptan	(KY)
106503	* Phenylenediamine(p)	(EPA 189)
100630	Phenylhydrazine	(KY,SC)
	Phenylphosphine	(KY)
	Phenytoin	(KY)
298022	Phorate	(KY)
75445	* Phosgene	(EPA 189)
7803512	Phosphine	(EPA 189)
7664382	Phosphoric acid	(SC)
7723140	Phosphorous	(EPA 189)
85416	Phthalamide	(IL,NY,TX)
85449	• Phthalic anhydride	(EPA 189)
	Picloram	(KY)
108996	Picoline(b)	(IL,NY,TX)
88891	Picric acid	(KY,SC)
83261	Pindone	(KY)
110850	Piperazine	(IL,NY,TX)
142643	Piperazine dihydrochloride	(KY)
	Polybrominated biphenyls (PBB's)	(KY)
9003296	Polybutylenes	(NY,TX)
1336363	Polychloinated byphenyls	(EPA 189)
9002884	Polyethylene	(IL,NY)
25322683	Polyethylene glycol	(IL,NY,TX)
9003070	Polypropylene	(NY)
25322694	Polypropylene glycol	(IL,NY,TX)
9009536	* Polystyrene	(IL,NY)
1310583	Potassium hydroxide	(KY)
	Procarbazine hydrochloride	(KY)
57830	Progesterone	(CA,KY)
107197	Propargyl alcohol	(KY)
57578	Propioactone(b)	(EPA 189)
123386	Propionaldehyde	(EPA 189)
79094	Propionoic acid	(IL,KY,TX)
114261	Propoxur	(EPA 189)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
109604	Propyl acetate(n)	(KY)
71238	Propyl alcohol(n)	(IL,NY,TX)
540545	Propyl chloride	(IL,KY,TX)
627134	Propyl nitrate(n)	(KY)
107108	Propylamine	(IL,KY,TX)
115071	Propylene	(CA,IL,NY,TX)
127004	Propylene chlorohydrin	(IL,KY,TX)
78875	Propylene dichloride	(EPA 189)
108656	Propylene glycol	(CA,NY,TX)
6423434	Propylene glycol dinitrate	(KY)
75569	Propylene oxide	(EPA 189)
51525	Propylthiouricil	(KY)
121211	Pyrethrin I	(SC)
121299	Pyrethrin II	(SC)
8003347	Pyrethrum	(KY,SC)
110861	• Pyridine	(CA,IL,KY,NY,TX)
95692	p-Chloro-o-toluidine	(CA)
91225	Quinoline	(EPA 189)
106514	• Quinone	(EPA 189)
50555	Reserpine	(KY)
108463	• Resorcinol	(IL,NY,TX)
27138574	Resorcylic acid	(IL,NY,TX)
299843	Ronnel	(KY)
83794	Rotenone	(KY,SC)
81072	Saccharin	(KY)
94597	Safrole	(KY)
69727	• Salicyclic acid	(IL,NY,TX)
136787	Sesone	(KY)
7803625	Silicon tetrahydride	(KY)
127093	Sodium acetate	(IL,NY)
7778430	Sodium arsenate	(KY)
7784465	Sodium arsenite	(KY)
26628228	Sodium azide	(KY)
532321	Sodium benzoate	(IL,NY,TX)
7681381	Sodium bisulfite	(KY)
9004324	Sodium carboxymethyl cellulose	(IL,NY,TX)
3926623	Sodium chloroacetate	(IL,NY,TX)
10588019	Sodium dichromate	(KY)
62748	Sodium fluoroacetate	(KY)
141537	Sodium formate	(IL,NY,TX)
1310732	Sodium hydroxide	(CA,KY,SC)
7681574	Sodium metabisulfite	(KY)
139026	Sodium phenate	(IL,NY,TX)
128449	Sodium saccharin	(KY)
110441	Sorbic acid	(IL,NY,TX)
52017	Spironolacetone	(KY)
	Sterigmatocystin	(KY)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
	Streptozotocin	(KY)
7789062	Strontium chromate	(KY)
57249	Strychnine	(KY)
100425	Styrene	(EPA 189)
96093	Styrene oxide	(EPA 189)
110156	Succinic acid	(IL,NY,TX)
110612	Succinitrile	(IL,NY,TX)
	Sulfallate	(KY)
121573	Sulfanic acid	(IL,NY,TX)
126330	Sulfolane	(IL,NY,TX)
3689245	Sulfotep	(KY)
10025679	Sulfur monochloride	(KY)
5714227	Sulfur pentachloride	(KY)
	Sulfur tetrachloride	(KY)
7664939	Sulfuric acid	(CA,KY,NC,SC)
2699798	Sulfuryl fluoride	(KY)
35400432	Sulprofos	(KY)
1401554	Tannic acid	(IL,NY,TX)
7440257	Tantalum	(KY)
3383968	Temephos	(KY)
100210	Terephthalic acid	(CA,IL,NY,TX)
92944	Terphenyls	(KY)
58220	Testosterone	(KY)
79345	Tetrachloroethanes	(NY,TX)
127184	Tetrachloroethylene	(EPA 189)
1335886	Tetrachloronapthalene	(KY)
117088	Tetrachlorophthalic anhydride	(IL,NY,TX)
961115	Tetrachlorvinphos	(SARA 313)
78002	Tetraethyl lead	(IL,KY,NY,TX)
109999	Tetrahydrofuran	(KY)
119642	Tetrahydronapthalene	(IL,NY,TX)
85438	Tetrahydrophthalic anhydride	(IL,NY,TX)
75741	Tetramethyl lead	(IL,NY,TX)
3333526	Tetramethyl succinonitrile	(KY)
90948	Tetramethyldiaminobenzophenone	(KY)
110601	Tetramethylenediamine	(IL,NY,TX)
110189	Tetramethylethylenediamine	(IL,NY,TX)
509148	Tetranitromethane	(KY)
7722885	Tetrasodium pyrophosphate	(KY)
479458	Tetryl	(KY)
62555	Thioacetamide	(CA,KY)
68111	Thioglycolic acid	(KY)
62566	Thiourea	(CA,KY)
137268	Thiram	(KY)
1314201	Thorium dioxide	(KY)
13463677	Titanium dioxide	(KY)
7550450	Titanium tetrachloride	(EPA 189)

RUBBER MANUFACTURERS ASSOCIATION (RMA)
EMISSION FACTOR DEVELOPMENT PROGRAM
COMBINED EPA 189, SARA 313, & STATE HAP LISTS

CAS NUMBER	CHEMICAL NAME	SOURCE
108883	• Toluene	(EPA 189)
1333079	Toluene sulfonamide	(IL,NY,TX)
98599	Toluene sulfonyl chloride	(IL,NY,TX)
104154	Toluenesulfonic acids	(IL,NY,TX)
636215	Toluidine hydrochloride(o)	(KY)
26915128	• Toluidines	(IL,KY,NY,SC,TX)
95534	• Toluidine(o)	(EPA 189)
8001352	Toxaphene	(EPA 189)
	Treosulphan	(KY)
68768	Triaziquone	(SARA 313)
126738	Tributyl phosphate	(KY)
52686	Trichlorfon	(SARA 313)
76039	Trichloroacetic acid	(KY)
87616	Trichlorobenzenes	(IL,NY,TX)
79016	Trichloroethylene	(EPA 189)
75694	Trichlorofluoromethane	(IL,NY,NC,TX)
121448	Triethylamine	(EPA 189)
112276	Triethylene glycol	(IL,NY,TX)
1582098	Trifluralin	(EPA 189)
7756947	Triisobutylene	(IL,NY,TX)
552307	Trimellitic anhydride	(KY)
25551137	• Trimethyl benzene	(KY)
121459	Trimethyl phosphite	(KY)
75503	Trimethylamine	(IL,KY,NY,TX)
	Triorthocresyl phosphate	(KY)
126727	Tris (2,3-dibromopropyl) phosphate	(KY)
	Tris (2,3-dibromopropyl) phosphite	(KY)
	Tris(1-aziridinyl)phosphine sulfide	(KY)
	Tris(aziridinyl)-p-benzoquinone	(KY)
	Uracil mustard	(KY)
57136	Urea	(IL,NY,TX)
110623	Valeraldehyde	(KY)
108054	Vinyl acetate	(EPA 189)
593602	Vinyl bromide	(EPA 189)
75014	Vinyl chloride	(EPA 189)
106876	Vinyl cyclohexene dioxide	(KY)
75025	Vinyl fluoride	(SC)
25013154	Vinyl toluene	(IL,KY,NY,TX)
75354	Vinylidene chloride	(EPA 189)
81812	Warfarin	(KY)
108383	• Xylene(m)	(EPA 189)
95476	• Xylene(o)	(EPA 189)
106423	* Xylene(p)	(EPA 189)
1300716	Xylenol	(NY,TX)
1300738	Xylidene	(NY,SC,TX)
76153	(Mono)chloropenatfluoroethane	(SARA 313)

• Theoretically emitted during rubber manufacturing.

APPENDIX B

COMPOSITION OF GENERIC RUBBER MIXES

INDEX OF RUBBER COMPOUNDS

Compound #1: Tire Inner Liner (BrIIR/NR)

Compound #2: Tire Ply Coat (Natural Rubber/Synthetic Rubber)

Compound #3: Tire Belt Coat (Natural Rubber)

Compound #4: Tire Base/Sidewall (Natural Rubber/Polybutadiene Rubber)

Compound #5: Tire Apex (Natural Rubber)

Compound #6: Tire Tread (Styrene Butadiene Rubber/Polybutadiene Rubber)

Compound #7: Tire Bladder (Butyl Rubber)

Compound #8: EPDM 1 (EPDM Sulfur Cure)

Compound #9: EPDM 2 (Peroxide Cure)

Compound #10: EPDM 3 (Non–black EPDM Sulfur Cure)

Compound #11: CRW (Polychloroprene W Type)

Compound #12: CRG (Polychloroprene G Type)

Compound #13: Paracryl OZO (NBR/PVC)

Compound #14: Paracryl BLT (NBR)

Compound #15: Hypalon (CSM)

Compound #16: Fluoroelastomer (FKM)

Compound #17: AEM (Vamac)

Compound #18: Hydrogenated Nitrile (HNBR)

Compound #19: Silicone (VMQ)

Compound #20: Acrylate Rubber (ACM)

Compound #21: Chlorinated Polyethylene (CPE)

Compound #22: Emulsion SBR (SBR 1502)

Compound #23: Epichlorohydrin (ECO)

Compound #24: Oil–Extended SBR (SBR 1712) [a]

Compound #25: Emulsion SBR (SBR 1500) [a]

Compound #26: Solution SBR (Duradene 707) [a]

[a] compounds 24, 25, 26 were mixes of polymer only, with no fillers or cure system

RUBBER COMPOUND RECIPES

Compound #1: Tire Inner Liner (BrIIR/NR)

Recipe:

Brominated IIR X−2	85.00
SMR 20 Natural Rubber	15.00
GPF Black	60.00
Stearic Acid	1.00
Paraffinic Medium Process Oil	15.00
Unreactive Phenol formaldehyde type resin (Arofene 8318, SP1068)	5.00
Zinc Oxide	3.00
Sulfur	.50
MBTS	1.50
	186.00

Number of Passes/Temperature:
1 (NP Temperature: 320°F; Chlorobutyl or 290°F Bromobutyl
2 (P) Temperature: 220°F

Compound #2: Tire Ply Coat (Natural Rubber/Synthetic Rubber)

Recipe:

50472 Natural Rubber

SMR−GP Natural Rubber	70.00
Duradene 707	30.00
N330	36.50
Sundex 790	20.00
Flectol H	1.50
Santoflex IP	2.30
Sunproof Super Wax	1.20
Zinc Oxide	5.00
Stearic Acid	1.00
Sulfur	2.30
CBS	.80
	170.60

Number of Passes/Temperature:
1 (NP) Temperature: 330°F
2 (P) Temperature: 220°F

Compound #3: Tire Belt Coat (Natural Rubber)

Recipe:

#1RSS Natural Rubber	100.00
HAF Black (N330)	55.00
Aromatic Oil	5.00
N−(1,3 dimethylbutyl) −N−phenyl−P−phenylene diamine (Santoflex 13)	1.00
Zinc Oxide	10.00
Stearic Acid	2.00
n−tertiary −butyl−2−benzothiazole disulfide (Vanax NS)	.80
Sulfur	4.00
Cobalt Neodecanate (20.5% cobalt)	2.50
	180.30

Number of Passes/Temperatures:
1 (NP) Temperature: 330°F; add 1/2 black, add 1/2 oil
2 (NP) Temperature: 330°F; add remainder of black and oil
3 (remill) Temperature 300°F
4 (P) Temperature: 220°F

RUBBER COMPOUND RECIPES

Compound #4: Tire Base/Sidewall (Natural Rubber/Polybutadiene Rubber)

Non-Productive Recipe:

NR-SMR-5 CV	50.00
Taktene 1220	50.00
N330 Carbon Black	50.00
Zinc Oxide	1.50
Stearic Acid	2.00
Agerite Resin D	2.00
Vulkanox 4020	3.00
Vanwax H Special	3.00
Flexon 580 Oil	10.00
	171.50

Productive Recipe:

Non Productive	171.50
Zinc Oxide	1.50
Rubber Maker Sulfur	1.75
DPG	0.10
CBS	0.60
	175.45

Number of Passes/Temperatures:
1 (NP) Temperature: 330°F
2 (P) Temperature: 220°F

Compound #5: Tire Apex (Natural Rubber)

Recipe:

TSR 20 Natural Rubber	100.00
HAF Black (N330)	80.00
Aromatic Oil	8.00
Stearic Acid	1.00
Resorcinol	3.00
Hexamethylenetetramine	3.00
Zinc Oxide	3.00
N-tertiary-butyl-2-benzothiazole disulfide (Vanax NS)	1.50
n-cyclohexylthiopthalimide (Santogard PVI)	.30
Sulfur	3.00
	202.80

1 (NP) Temperature: 330°F; add 60 parts black, add 6 parts oil
2 (NP) Temperature: 330°F; add Resorcinol, add 20 parts black, add 2 parts oil
3 (P) Temperature 200°F; add Hexam.

RUBBER COMPOUND RECIPES

Compound #6: Tire Tread (Styrene Butadiene Rubber/Polybutadiene Rubber)

Non–Productive Recipe #1:

SBR 1712C	110.00
N299 Carbon Black	60.00
Taktene 1220	20.00
Zinc Oxide	1.50
Stearic Acid	3.00
Vulkanox 4020	2.00
Wingstay 100	2.00
Vanox H Special	2.50
Sundex 8125 Oil	20.00
	221.00

Non–Productive Recipe #2:

Non–Productive #1:	221.00
N299 Carbon Black	20.00
Sundex 8125 Oil	5.00
	246.00

Productive Recipe:

Non Productive #2	246.00
Zinc Oxide	1.50
Rubber Maker Sulfur	1.60
TMTD	0.20
CBS	3.00
	252.30

Number of Passes/Temperatures:
1 (NP) Temperature: 330°F; add 60 parts black, add 20 parts oil
2 (NP) Temperature: 330°F; add 20 parts black; add 5 parts oil
3 (P) Temperature: 220°F

Compound #7: Tire Bladder

Recipe:

BUTYL 268	100.00
N330	55.00
Castor Oil	5.00
SP 1045 Resin	10.00
Zinc Oxide	5.00
Neoprene W	5.00
	180.00

Number of Passes/Temperatures:
NP 1 All Butyl, Castor Oil, Zinc Oxide, 45 phr N330, discharge approx 330°F/340°F
+Resin, 10 phr N330, discharge approx 270/280°F DO NOT EXCEED 290°F
PROD NP2 = neoprene, discharge approx 250F/260°F

RUBBER COMPOUND RECIPES

Compound #8: EPDM 1 (EPDM Sulfur Cure)

Non–Productive Recipe:

Vistalon 7000	50.00
Vistalon 3777	87.50
N650 GPF–HS Black	115.00
N762 SRF–LM Black	115.00
Process Oil Type 104B (Sunpar 2280)	100.00
Zinc Oxide	5.00
Stearic Acid	1.00
	473.50

Productive Recipe:

Non–Productive	473.50
Sulfur	0.50
TMTDS	3.00
ZDBDC	3.00
ZDMDC	3.00
DTDM	2.00
	485.00

Number of Passes/Temperatures
1 (NP) Temperature: 340°F; upside down mix, rubber then black and oil
2 (P) Temperature: 220°F

Compound #9: EPDM 2 (Peroxide Cure)

Non–Productive Recipe:

Royalene 502	100.00
N 762 Carbon Black	200.00
Sunpar 2280 Oil	85.00
Zinc Oxide	5.00
Stearic Acid	1.00
	391.00

Productive:

Non–Productive	391.00
DICUP 40C	6.00
SARET 500 (on carrier/2 parts active)	2.56
	399.56

NP Temperature: 330°F
P Temperature: 240°F

Compound #10: EPDM 3 (Non–black EPDM Sulfur Cure)

Recipe:

Vistalon 5600	50.00
Vistalon 3777	87.50
Hard Clay (Suprex)	180.00
Mistron Vapor Talc	100.00
Atomite Whiting	40.00
Process Oil Type 104B (Sunpar 2280)	60.00
Silane (A–1100)	1.50
Paraffin Wax	5.00
Zinc Oxide	5.00
Stearic Acid	1.00
Sulfur	1.50
Cupsac	0.50
TMTD	3.00
	535.00

Number of Passes/Temperatures:
1 (NP) Temperature: 330°F
2 (P) Temperature: 220°F, add Sulfur, Cupsac, and TMTDS

RUBBER COMPOUND RECIPES

Compound #11: CRW (Polychloroprene W Type)

Recipe:

Non Productive:

Neoprene WRT	100.00
N 550	13.20
N 762	15.70
Agerite Staylite S	2.00
Sunproof Super Wax	2.00
Santoflex IP	1.00
Magnesium Oxide	4.00
Stearic Acid	0.50
PlastHall Doz	15.00
	153.40

Productive Recipe:

Non-Productive	153.40
Zinc Oxide	5.00
TMTD	0.50
Dispersed Ethylene Thiourea	1.00
	159.90

Number of Passes/Temperatures:
1 pass at 240°F; add accelerator package at 200°F

Compound #12: CRG (Polychloroprene G Type)

Non Productive Recipe:

Neoprene GN	100.00
SRF	50.00
Sundex 790	10.00
Octamine	2.00
Stearic Acid	1.00
Maglite D	4.00
	167.00

Productive Recipe:

Non-Productive	167.00
TMTM	0.50
Sulfur	1.00
DOTG	0.50
Zinc Oxide	5.00
	174.00

Number of Passes/Temperatures:
1 (NP) Temperatures: 240°F; add zinc oxide and cureatives late at 200°F
2 (P) Temperature: 200°F

RUBBER COMPOUND RECIPES

Compound #13: Paracryl OZO (NBR/PVC)

Recipe:

PARACRIL OZO	100.00
Zinc Oxide	5.00
OCTAMINE	2.00
Hard Clay	80.00
FEF (N–550) Black	20.00
Stearic Acid	1.00
MBTS	2.50
TUEX	1.50
ETHYL TUEX	1.50
DOP	15.00
KP–140	15.00
Spider Sulfur	0.20
	243.70

Number of Passes:
(NP) Temperature: 330°F
(P) Temperature: 220°F; add MBTS, TUEX, ETHYL TUEX, Spider Sulfur

Compound #14: Paracryl BLT (NBR)

Recipe:

PARACRIL BLT	100.00
Zinc Oxide	5.00
SRF (N–774) Black	100.00
TP–95	15.00
Paraplex G–25	5.00
AMINOX	1.50
Stearic Acid	1.00
ESEN	0.50
MONEX	1.50
Sulfur	0.75
	230.25

Number of Passes/Temperatures:
(NP) Temperature: 280°F
(P) Temperature: 220°F; add sulfur, MONEX, and possibly ESEN

Compound #15: Hypalon (CSM)

Recipe:

Hypalon 40	100.00
CLS 4 PBD	3.00
Carbo wax 4000	3.00
PE 617A	3.00
Mag Lite D	5.00
PE 200	3.00
Whiting (Atomite)	100.00
N650	100.00
TOTM Oil	70.00
MBTS	1.00
Tetrone A	1.50
NBC	0.50
HVA–2	0.50
	390.50

Uses of Formulas/Temperatures:
Number of Passes:
1 (P) Temperature: 280°F

RUBBER COMPOUND RECIPES

Compound #16: Fluoroelastomer (FKM)

Recipe:	
Viton E60C	100.00
N990 Black	20.00
Calcium Hydroxide	6.00
Maglite D	3.00
	129.00

Compound #17: AEM (Vamac)

Recipe:	
VAMAC*B-124 Masterbatch	124.00
ARMEEN 18D	.50
Stearic Acid	.20
SRF Carbon Black (N-774)	10.00
DIAK #1	4.00
DPG	4.00
	142.70

Compound #18: Hydrogenated Nitrile (HNBR)

Non-Productive Recipe:	
HNBR Zetpol 2020	100.00
N650 Black	45.00
Flexone 7P	1.00
Agerite Resin D	1.00
ZMTI	1.00
Kadox 911 C	5.00
Stearic Acid	1.00
Trioctyl trimellitate (TOTM)	7.00
	161.00
Productive Recipe:	
Sulfur	0.50
MBTS	1.50
TMTD	1.50
MTD Monex	.50
	165.00

Number of Passes/Temperatures:
1 (NP) Temperature: 275°F
2 (P) Temperature: 210°F

Compound #19: Silicone (VMQ)

Recipe:	
Silicone Rubber	70.00
Silastic NPC-80 silicone rubber	30.00
5 Micron Min-U-Sil	68.00
Silastic HT-1 modifier	0.80
Vulcanizing agent: Varox DBPH 50	1.00
	169.80

RUBBER COMPOUND RECIPES

Compound #20: Acrylate Rubber (ACM)

Non–Productive Recipe:

Hytemp AR71	100.00
Stearic Acid	1.00
N 550	65.00
	166.00

Productive Recipe:

Non–Productive	166.00
Sodium Stearate	2.25
Potassium Stearate	0.75
Sulfur	0.30
	169.30

Number of Passes/Temperatures:
1 (NP) Temperature: 260°F
2 (P) Temperature: 220°F

Compound #21: Chlorinated Polyethylene (CPE)

Recipe:

CM 0136	100.00
Maglite D	10.00
N 774 Black	30.00
Sterling VH	35.00
DER 331 DLC	7.00
Agerite Resin D	0.20
TOTM Oil	35.00
Triallyl Isocyanurate Cure 5223 (provided by Gates)	2.90
Trigonox 17/40	10.00
	230.10

Number of Passes/Temperatures:
Single pass mixed to 240°F; add Triallyisocyanurate,
Triganox 17/40 at 200°F.

Compound #22: Emulsion SBR (SBR 1502)

Non–Productive Recipe:

SBR 1502	100.00
N330 Carbon Black	58.50
Zinc Oxide	10.00
Stearic Acid	2.00
Agerite Resin D (Naugard Q)	2.00
Flexone 7P	1.00
Sunproof Super Wax	1.50
Sundex 790 Oil	7.00
	182.00

Productive Recipe:

Non–Productive	182.00
Rubber Makers Sulfur	2.00
TBBS	1.80
	185.80

Number of Passes/Temperatures:
Non–productive pass mixed to 330°F,
Second pass mixed to 220°F.

RUBBER COMPOUND RECIPES

Compound #23: Epichlorohydrin (ECO)

Recipe:

Hydrin 2000	100.00
N330 Carbon Black	50.00
Stearic Acid	1.00
Vulkanox MB-2/MG/C	1.00
Calcium Carbonate	5.00
Zisnet F-PT	1.00
Diphenylguanadine	0.50
Santogard PVI	0.50
	159.00

Number of Passes/Temperatures:
1 Pass at 240°F

Compound #24: Oil-Extended SBR (SBR 1712)*

SBR 1712	137.50
	137.50

Compound #25: Emulsion SBR (SBR 1500)*

SBR 1500	100.00
	100.00

Compound #26: Solution SBR (Duradene 707)*

Duradene 707	100.00
	100.00

* – Compounds 24, 25, and 26 were mixes of polymer only, with no fillers or cure system.

APPENDIX C

FIELD SAMPLING DATA SHEETS

FIELD PROGRAM LOG

Project No. ______________________________

Client ______________________________

Plant ______________________________

Team Leader ______________________________

Date	Time	Description of Events

Traverse Point Location for Circular and Rectangular Ducts

Project No.: ____________________

Client: ____________________

Date: ____________________

Sampling Location: ____________________

Internal Stack Diameter: ____________________

Nipple Length: ____________________

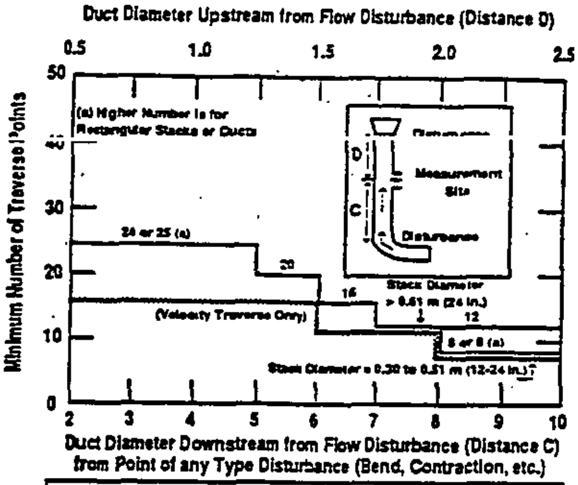
Total Stack Diameter: ____________________

Nearest Upstream Disturbance (C): ____________________

Nearest Downstream Disturbance (D): ____________________

Calculator: ____________________

Traverse Point Number	1 Fraction of Stack ID $\left(\frac{1}{100}\right)$	2 Stack ID	3 Traverse Point (1 x 2=Point)	4 Nipple Length	5 Traverse Point Inside of Far Wall to Outside of Port Nipple (3 + 4 = Point)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
24					



Rectangular Duct Equivalent Diameter Determination $= \frac{2 \times L \times W}{L + W}$

Location of Traverse Points in Circular Stacks

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

Location of Traverse Points in Rectangular Stacks

	2	3	4	5	6	7	8	9	10	11	12
1	25.0	16.7	12.5	10.0	8.3	7.1	6.3	5.6	5.0	4.5	4.2
2	75.0	50.0	37.5	30.0	25.0	21.4	18.8	15.7	15.0	13.6	12.5
3		83.3	62.5	50.0	41.7	35.7	31.3	27.8	25.0	22.7	20.8
4			87.5	70.0	58.3	50.0	43.8	38.9	35.0	31.8	29.2
5				90.0	75.0	64.3	56.3	50.0	45.0	40.9	37.5
6					91.7	78.6	68.8	61.1	55.0	50.0	45.8
7						92.9	81.3	72.2	65.0	59.1	54.2
8							93.8	83.3	75.0	68.2	62.5
9								94.4	85.0	77.3	70.8
10									95.0	85.4	79.2
11										95.5	87.5
12											95.8

AF-233

Moisture Determination
Wet Bulb-Dry Bulb Temperature Techniques

Project No.: ______________________ Date: ______________________

Client: ______________________ Source: ______________________

Plant: ______________________ Sample Location: ______________________

Calculated by: ______________________ Checked by: ______________________

Barometric Pressure PB = $\boxed{\qquad}$ in Hg $\quad$ t_{dry} = $\boxed{\qquad}$ °F

PST $\frac{\qquad}{13.6}$ in H_2O = $\boxed{\qquad}$ in Hg $\quad$ t_{wet} = $\boxed{\qquad}$ °F

PS = PB ± PST = $\boxed{\qquad}$ in Hg

S.V.P. = water saturation vapor press at t_{wet} = $\boxed{\qquad}$ in Hg

$$V.P. = S.V.P. - \left[0.000367\ (PS)\ (t_d - t_w)\left(1 + \frac{tw - 32}{1571}\right)\right]$$

$$V.P. = (\qquad) - \left[0.000367\ (\qquad)\ (\qquad - \qquad)\ 1 + \left(\frac{(\qquad) - 32}{1571}\right)\right]$$

$$(\qquad) - \left[0.000367\ (\qquad)\ (\qquad)\ (\qquad)\right]$$

V.P. = $\boxed{\qquad}$

$$\%M = \frac{V.P.}{PS} \times 100 = \underline{\qquad\qquad} \times 100 = \boxed{\qquad}$$

$$Md = 1 - \frac{\%M}{100} = 1 - \frac{\qquad}{100} = \boxed{0.\qquad}$$

AF-250

SATURATION TABLE

Stack Temp (F)	% H2O	Stack Temp (F)	% H2O	Stack Temp (F)	% H2O	Stack Temp (F)	% H2O
32	0.60	78	3.23	124	12.86	170	40.78
33	0.63	79	3.34	125	13.22	171	41.72
34	0.65	80	3.45	126	13.58	172	42.69
35	0.68	81	3.56	127	13.95	173	43.67
36	0.71	82	3.68	128	14.34	174	44.68
37	0.74	83	3.80	129	14.73	175	45.70
38	0.77	84	3.93	130	15.13	176	46.74
39	0.80	85	4.05	131	15.53	177	47.80
40	0.83	86	4.19	132	15.95	178	48.88
41	0.86	87	4.32	133	16.38	179	48.99
42	0.89	88	4.46	134	16.82	180	51.11
43	0.93	89	4.60	135	17.27	181	52.25
44	0.97	90	4.75	136	17.72	182	53.42
45	1.00	91	4.90	137	18.19	183	54.61
46	1.04	92	5.06	138	18.67	184	55.82
47	1.08	93	5.22	139	19.16	185	57.05
48	1.12	94	5.38	140	19.66	186	58.30
49	1.17	95	5.55	141	20.17	187	59.58
50	1.21	96	5.73	142	20.69	188	60.88
51	1.26	97	5.90	143	21.23	189	62.20
52	1.30	98	6.08	144	21.77	190	63.55
53	1.35	99	6.27	145	22.33	191	64.02
54	1.40	100	6.46	146	22.90	192	66.32
55	1.46	101	6.66	147	23.48	193	67.75
56	1.51	102	6.86	148	24.08	194	69.19
57	1.57	103	7.07	149	24.68	195	70.67
58	1.62	104	7.28	150	25.30	196	72.16
59	1.68	105	7.50	151	25.73	197	73.69
60	1.74	106	7.72	152	26.58	198	75.24
61	1.81	107	7.95	153	27.24	199	76.82
62	1.87	108	8.19	154	27.92	200	78.43
63	1.94	109	8.43	155	28.60	201	80.06
64	2.01	110	8.68	156	29.31	202	81.73
65	2.08	111	8.93	157	30.02	203	83.42
66	2.15	112	9.19	158	30.75	204	85.14
67	2.23	113	9.46	159	31.50	205	86.89
68	2.31	114	9.73	160	32.26	206	88.67
69	2.39	115	10.01	161	33.04	207	90.48
70	2.47	116	10.30	162	33.83	208	92.32
71	2.56	117	10.59	163	34.64	209	94.20
72	2.64	118	10.89	164	35.47	210	96.10
73	2.73	119	11.20	165	36.31	211	98.03
74	2.83	120	11.52	166	37.17	212	100.00
75	2.92	121	11.84	167	38.05		
76	3.02	122	12.17	168	38.84		
77	3.12	123	12.51	169	39.85		

Sheet 1 of ____

K-Factor Calculation Sheet

Project No.: ______________________ Date: ______________________

Client: ______________________ Source: ______________________

Plant: ______________________ Sample Location: ______________________

Calculated by: ______________________ Checked by: ______________________

TM & TS in °R

$$K = \frac{\Delta H}{\Delta P} = 846.72\ (DN)^4\ \Delta H_@\ CP^2\ (Md)^2 \left(\frac{MWD}{MWS}\right)\left(\frac{TM}{TS}\right)\left(\frac{PS}{PM}\right)\ ;\ \Delta H = K\Delta P$$

T_S = ☐ °F + 460 = ________ °R

$$K = \frac{\Delta H}{\Delta P} = 846.72\ (\quad)^4\ (\quad)\ (\quad)^2\ (\quad)^2\ \left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)$$

K = ☐ $\Delta\bar{P}$ = ________, $\Delta\bar{H}$ = ________, ΔP_{MAX} = ________, ΔH_{MAX} = ________,

---

T_S = ☐ °F + 460 = ________ °R

$$K = \frac{\Delta H}{\Delta P} = 846.72\ (\quad)^4\ (\quad)\ (\quad)^2\ (\quad)^2\ \left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)$$

K = ☐ $\Delta\bar{P}$ = ________, $\Delta\bar{H}$ = ________, ΔP_{MAX} = ________, ΔH_{MAX} = ________,

---

T_S = ☐ °F + 460 = ________ °R

$$K = \frac{\Delta H}{\Delta P} = 846.72\ (\quad)^4\ (\quad)\ (\quad)^2\ (\quad)^2\ \left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)$$

K = ☐ $\Delta\bar{P}$ = ________, $\Delta\bar{H}$ = ________, ΔP_{MAX} = ________, ΔH_{MAX} = ________,

---

T_S = ☐ °F + 460 = ________ °R

$$K = \frac{\Delta H}{\Delta P} = 846.72\ (\quad)^4\ (\quad)\ (\quad)^2\ (\quad)^2\ \left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)$$

K = ☐ $\Delta\bar{P}$ = ________, $\Delta\bar{H}$ = ________, ΔP_{MAX} = ________, ΔH_{MAX} = ________,

---

T_S = ☐ °F + 460 = ________ °R

$$K = \frac{\Delta H}{\Delta P} = 846.72\ (\quad)^4\ (\quad)\ (\quad)^2\ (\quad)^2\ \left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)\left(\frac{\quad}{\quad}\right)$$

K = ☐ $\Delta\bar{P}$ = ________, $\Delta\bar{H}$ = ________, ΔP_{MAX} = ________, ΔH_{MAX} = ________,

---

AF-248/A

Calculation for Desired Nozzle Diameter

Project No.: ______________________ Date: ______________________

Client: ______________________ Source: ______________________

Plant: ______________________ Sample Location: ______________________

Calculated by: ______________________ Checked by: ______________________

T_S = ________ °F + 460 = ______ °R ΔP_{AV} = ______

T_M = ________ °F + 460 = ______ °R C_p = ______

MWD = ______ #/#-mole

MWS = ______ #/#-mole

MD = ______

PB (PM) = ______

$PST = \frac{\quad}{13.6}$ = ______

PS-(PB ± PST) = ______

Sampling Rate, dscfm, Q_m

(1) @ $\Delta H@ = 0.75$ (normal)

(2) At any other ΔH:

$$\left(\frac{\Delta H}{\Delta H_{@}}\right)^{1/2} \times 0.75 = \left(\frac{\quad}{\quad}\right)^{1/2} 0.75 = \frac{\quad}{\text{dscfm}}$$

$$D_{N\,(\text{desired})} = \left[\left(\frac{(TS)\ (MWS)}{(PS)\ (\Delta P_{AV})}\right)^{1/2} \left(\frac{0.0357\ (Q_M)\ (PM)}{(TM)\ (C_p)\ (MD)}\right)\right]^{1/2}$$

$$= \left[\left(\frac{(\quad)(\quad)}{(\quad)(\quad)}\right)^{1/2} \left(\frac{0.0357\ (\quad)(\quad)}{(\quad)(\quad)(\quad)}\right)\right]^{1/2}$$

D_N = ______ inches D_N Actual = ______ inches

AF-249

Stack Geometry & Gas Velocity Data

Page __ of __

Project No. ____________________

Client ____________________

Plant ____________________

Operator ____________________

Meter Box No. ____________________

Source ____________________

Sample Location ____________________

Run No. ____________________

Static, In. H_2O ____________________

Time (24 hr. Clock)	Sample Point	Stack Temp. °F or C°	Manom. Reading In. H_2O	Cyclonic Flow Null Angle

Sketch of Sampling Location

Stack Diameter ____________

Diameters Upstream ____________

Diameters Downstream ____________

Wet Bulb ____________

Dry Bulb ____________

%M ____________

Isokinetic Flue Gas Sampling Data Sheet

Page 1 of 2

Project No. ____________

Client ____________

Facility ____________

Source ____________

Sample Location ____________

Stack Diameter ____________

Date ____________

Run No. ____________

Operator ____________

Meter Box No. ____________

Meter Δ H@ ____________

Y Factor ____________

Very Important - Fill in All Blanks

Read and Record at the Start of Each Test Point

Sketch

Sheet ______ of ______

Train Prepared By ____________

Pitot Number and Side ____________

Pitot Tube CP ____________

Filter No. / Thimble No. ____________

Ambient Temp.°F ____________

Bar. Pressure., In. Hg ____________

Assumed Moisture, % ____________

Heater Box Setting, °F ____________

Nozzle # / Dia., In. ____________

Probe Length / Material ____________

Probe Heater Setting ____________

Point	Clock Time		*Dry Gas Meter, (ft³)*	Pitot In. H_2O ΔP	Orifice Δ H In. H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Temperatures °F °C					
	24 - hr	min			Desired	Actual	Inlet	Outlet		Stack	Filter Box	Imp Temp	XAD Cond	Probe	Filter Outlet

Train Leak Check:

Before Test: ________ CF ________ SEC ________ In. Hg

After Test: ________ CF ________ SEC ________ In. Hg

	I	F
Pitot Tube Leak Check		
ORSAT Train Leak Check		

Static Pressure

Port			
In. H_2O			
In. Hg			

Comments:

AF 081

Isokinetic Flue Gas Sampling Data Sheet

Page 2 of 2

Project No. ____________ Date ____________ Sheet ____ of ____

Client ____________ Run No. ____________

Facility ____________ Sample Location ____________ Operator ____________

Source ____________

Point	Clock Time		Dry Gas Meter, (ft³)	Pitot In. H_2O ΔP	Orifice ΔH In. H_2O		Dry Gas Temp. °F		Pump Vacuum In. Hg Gauge	Temperatures °F °C					
	24 - hr	min			Desired	Actual	Inlet	Outlet		Stack	Filter Box	Imp Temp	XAD Cond	Probe	Filter Outlet
		Total													

Meter Leak Check During Test: Meter Reading Stop Start

____ CF ____ SEC ____ In. Hg ____ ____

____ CF ____ SEC ____ In. Hg ____ ____

Static Pressure Port ____ ____ ____

In. H_2O ____ ____ ____

In. Hg ____ ____ ____

AF-060

Comments:

Sampling Train Setup and Recovery Sheet

Project No.

Run No.

Client

Train Type/#

Facility

Date

Source

Recovery Person

Filter No.

Thimble No. (if applicable)

XAD Trap No. (if applicable)

Moisture

Impinger #				
Reagent				
Final Volume (mLs)				
Initial Volume (mLs)				
Net Collected (g)				

Impinger #				
Reagent				
Final Volume (mLs)				
Initial Volume (mLs)				
Net Collected (g)				

Silica Gel				
Final Weight (g)				
Initial Weight (g)				
Net Collected (g)				

Total Moisture (Impingers and Silica Gel) (g)

AF-247

ANALYZER DAILY CALIBRATION CHECK

Location ______________

Date ______________

Day ______________

TIME START/STOP ______________

PERFORMED BY ______________

Contract ______________

INSTRUMENT RESPONSE

Instrument	Zero		1		2		3		4	
	Conc.	Response	Conc.	Response	Conc.	Response	Conc.	Response	Conc.	Response
O_2										
CO_2										
CO										
SO_2										
NO_x										
THC										
THC										

CALIBRATION EQUATION

$y = mx + b$

	O_2	CO_2	CO	SO_2	NO_x	HCl
m =						
b =						
corr. coeff r^2 =						

616-900

Particulate Analysis

Project No. ____________________
Date ____________________
Client ____________________
Source ____________________
Plant ____________________
Analyst ____________________

A. SAMPLE VOLUME

________ mL

B. WASH VOLUME

______ mL
______ mL
______ mL
______ mL
Total: ______ mL

C. BLANK CORRECTION

Sample: _____ mL x _____ g/mL = _____ g

Wash: _____ mL x _____ g/mL = _____ g

D. TARE WEIGHTS

	No.	Wt.
Container		g
Filter		g
Thimble		g
Total		g

E. GROSS WEIGHTS

RH/°F	Date/Time			RH/°F	Date/Time		
/	/	(1)	g	/	/	(4)	g
/	/	(2)	g	/	/	(5)	g
/	/	(3)	g	/	/	(6)	g

Final Gross Weight ____________ g
Total Tare Weight ____________ g
Residue Weight ____________ g
Blank Weight ____________ g

F. NET WEIGHT Net Weight ____________ g = ____________ mg

REMARKS: ____

____

____

AF-198

CHAIN OF CUSTODY RECORD

Project Name ______________________
Project No.: ______________________
Sampling Date(s): ______________________
Laboratory: ______________________
Laboratory P.O. #: ______________________
Shipping Airbill No.: ______________________
Shipping Date(s): ______________________
Shipper's Name: ______________________

Sample Code	Sampled Date	Container		MATRIX						Source Description	ANALYSIS														Comments
		Size	G/P	Aqueous	Organic Solvent	Ash/Soil/Sediment	Acidic	Basic	Other		Trace Metals*	Mercury	Hexavalent Chromium	HCl	Cl2	Particulate Matter	PCDD/PCDF	Semi-Volatile Organics	Volatile Organics	Physical Parameters*					

Relinquished by:	Date/Time:	Relinquished by:	Date/Time:
Received by:	Date/Time:	Received by:	Date/Time:

REMARKS (*):

№ 01846

WHITE — LABORATORY YELLOW — LABORATORY COPY PINK — OFFICE COPY GOLD — FIELD COPY

APPENDIX D

EMISSION CALCULATION SHEETS

Facility ______________________ Job No. ______________________
Source ______________________ Date ______________________
Run ______________________ Calc/Review ______________________

SAMPLE CALCULATIONS

Particulate Isokinetic Sampling

I. Calculations for stack volume and Isokinetic Ratio

Time	Dry Gas Meter ft^3	Pitot ΔP, in. H_2O	Orifice ΔH, in. H_2O	Dry Gas Temp °F In	Dry Gas Temp °F Out	Stack Static Pressure in. H_2O	Stack Temp °F
T	VM	ΔP	PM	TMI	TMO	PST	TS

1. DN = Nozzle Diameter, inches ______________________ in.
2. PB = Barometric Pressure, inches Hg ______________________ in. Hg
3. TT = Net Sampling Time, minutes ______________________ min.
4. VM = VM final - VM initial = Sample Gas Volume, ft^3 ______________________ ft^3

4A. VML = Use only if any final or intermediate leak check rate is over 0.02 cfm.
LI = Leak rate after any given sampling period, cfm
TLI = Total time of sampling period in which leak occurred, min.
VML = VM - [(L1 - 0.02) TL1 + (L2 - 0.02) TL2 + (L3 - 0.02) TL3 + (L4 - 0.02) TL4]
= ______________ ft^3

5. TM = Average Dry Gas Temperature at Meter, °F.

$$TM = \frac{\text{Avg. TMI + Avg. TMO}}{2}$$ = ______________ °F

6. PM = Average Orifice Pressure Drop, inches H_2O

PM = Avg. Δ H = ________ ÷ 13.6 = ________ in. Hg

7. Volume of dry gas sampled at standard conditions, dscf[a]

$$VMSTD = \frac{528(Y)(VM)\left(PB + \frac{PM}{13.6}\right)}{29.92(TM+460)}$$

Y = dry gas meter calibration factor
Y = ____________ = ______________ ft^3

8. VW = Total Water Collected = gm H_2O Silica gel + mL Imp. H_2O = ______________ mL

9. Volume of water vapor at standard conditions, scf[b]

VW gas = 0.04715 x VW = ______________ ft^3

Run No.____________________ Job No. ____________________

Date ____________________

10. Percent moisture in stack gas

$$\% M = \frac{100 \times VW\ gas}{VMSTD + VW\ gas} =$$ = __________%

11. Mole fraction of dry gas (dimensionless)

$$MD = \frac{100 - \% M}{100} =$$ = __________

12. Molecular weight of dry stack gas

$$MWD = \left(\%CO_2 \times \frac{44}{100}\right) + \left(\%O_2 \times \frac{32}{100}\right) + \left[(\%CO + \%N_2) \times \frac{28}{100}\right]$$ = __________ lb/lb mole dry

12A. %EA = %Excess Air =

$$\frac{[(\%O_2) - 0.5(\%CO)] \times 100}{[(0.264)(\%N_2)] - (\%O_2) + 0.5\%(CO)}$$ = __________%

13. Molecular weight of wet stack gas

$MW = MWD \times MD + 18\ (1 - MD)$ = __________ lb/lb mole wet

14. AS = Stack Area, square inches

Circular, $= \left(\frac{\text{stack diameter}}{2}\right)^2 \pi$ = __________ sq. in.

Rectangular, = Length x width = __________ sq. in.

15. PS = Stack Pressure, absolute, inches Hg = PB ± AV PST
PST = Stack static pressure

$$PST\ in.\ Hg = \frac{PST\ in.\ H_2O}{13.6}$$ = __________ in. Hg

PS = PB ± Avg. PST = __________ in. Hg

16. TS_{AV} = Average Stack Temperature = __________ °F

Run No.________________________ Job No. ________________________

Date ________________________

17. $SDE_{AV} = (\sqrt{\Delta P})_{AV} \times \sqrt{TS_{AV} + 460}$ = ____________

18. Stack gas velocity at stack conditions, afpm

$$VS = 5130^{c} \times Cp \times SDE_{AV} \times \left[\frac{1}{PS \times MW}\right]^{1/2} = \text{afpm}$$

Cp = pitot tube coefficient

Cp = ____________ = ____________ afpm

19. Stack gas volumetric flow rate at stack conditions, acfm[d]

$$Q_a = \frac{VS \times AS}{144}$$

= ____________ acfm

20. Stack gas volumetric flow rate at standard conditions, dscfm[e]

$$Q_s = \frac{Q_a \times 528 \times MD \times PS}{(29.92)(TS_{AV} + 460)}$$

= ____________ dscfm

21. Percent isokinetics

$$\%\,I = \frac{1{,}039^{f} \times (TS_{AV} + 460) \times VMSTD}{VS \times TT \times PS \times MD \times (DN)^2}$$

= ____________ %

---

[a] Dry standard cubic feet at 68°F (528R) and 29.92 in. Hg.

[b] Standard conditions at 68°F (528R) and 29.92 in. Hg.

[c] $5130 = 85.5 \; \frac{\text{ft}}{\text{sec}} \left[\frac{(\text{lb/lb mole})(\text{in. Hg})}{(°\text{R})(\text{in. } H_2O)}\right] \times 60 \text{ sec/min}$

[d] Actual cubic feet per minute

[e] Dry standard cubic feet per minute at 68°F (528R) and 29.92 in. Hg.

[f] $1039 = \frac{29.92 \text{ in Hg}}{528 \text{ Deg R}} \times \frac{144 \text{ in.}^2}{\text{ft}^2} \times \frac{4}{\pi} \times 100$

Run No.____________________ Job No. ____________________

Date ____________________

II. Calculations for grain loading and emission rates

22. Particulate, gr/dscf

$$\text{gr/dscf} = 0.0154 \times \frac{\text{mg}}{\text{VMSTD}}$$ = __________ gr/dscf

23. Particulate at stack conditions, gr/acf

$$\text{gr/acf} = \frac{528 \times \text{gr/dscf} \times \text{PS} \times \text{MD}}{29.92\,(\text{TS}_{\text{AV}} + 460)}$$ = __________ gr/acf

24. Particulate, lb/hr conc. method

$$\text{lb/hr} = \frac{60\ \text{min/hr} \times \text{gr/dscf} \times \text{QS}}{7000\ \text{gr/lb}}$$ = __________ lb/hr

25. Particulate, lb/hr area method

$$\text{lb/hr} = 0.132 \times \frac{\text{gms particulate} \times \text{AS}}{\pi \left(\frac{\text{DN}}{2}\right)^2 \times \text{TT}}$$ = __________ lb/hr

26. $$\frac{\text{lb/hr area} \times 100}{\text{lb/hr conc.}} =$$ = __________ % I

27. Particulate, combustion lb/10^6 Btu heat input method

lb/hr = avg. of area and conc. method = __________ lb/hr

10^6 Btu from fuel flow, steam generation or heat rate = __________ 10^6 Btu

28. lb/10^6 Btu F Factor method =

$$\frac{\text{gr/dscf}}{7000} \times \text{F} \times \frac{20.9}{(20.9 - \%\ \text{O}_2)}$$ = __________ lb/10^6 Btu

Run No.____________________ Job No. ____________________

Date ____________________

29. Density of stack gas

a. Wet at stack condition = MW lb/lb mol $/ \left[21.85 \times \left(\frac{TS_{AV} + 460}{PS} \right) \right]$

= __________ lb/lb mole wet

b. Dry at 68°F (528R) and 29.92 in. Hg = MWD/385.6 = __________ lb/lb mole dry

30. Exhaust gas flow rate

a. FRS = lb/hr dry = QS x 60 x dry density = __________ lb/hr

b. FRA = lb/hr wet = QA x 60 x wet density = __________ lb/hr

31. gr/dscf at 12% CO_2 = gr/dscf x $\frac{12}{\% CO_2}$ = __________ gr/dscf

32. gr/dscf at 50% excess air = $\frac{100 + EA}{150}$ x gr/dscf = __________ gr/dscf

33. lb pollutant/1000 lb flue gas at 12% CO_2 (wet or dry)

$= \frac{\text{lb pollutant/hr}}{\text{FRA or FRS}} \times \frac{12}{\% CO_2} \times 1000$ = __________ lb/1000 lb

34. gr/dscf at 7% O_2 =

gr/dscf $\left(\frac{14}{21 - \%O_2 \text{ dry}} \right)$ = __________ gr/dscf

SAMPLE CALCULATIONS

(1) DRE CALCULATIONS FOR POHCs --

$$\text{DRE, \%} = \frac{[(\text{POHCin}) - (\text{POHCout})]}{(\text{POHCin})} \times 100$$

$$\text{POHCin, g/min} = \frac{(\text{WFR})(\text{A})(\text{B})}{(\text{C})}$$

where,

WFR = waste feed rate, lb/min

A = 454 g/lb

B = POHC conc., wt %

C = 100

Compute for all streams fed to incinerator and for all POHCs

$$\text{POHCout, g/min} = \frac{(\text{D})(\text{E})(\text{Qs})(\text{F})}{(\text{SV})}$$

where,

D = POHC quantity detected, ng

E = 28.32 L/dscf @ 68°F (20°C)

Qs = stack gas flowrate, dscfm

F = 1×10^{-9} g/ng

SV = sample volume, dsL @ 68°F (20°C)

$$\text{SV} = \text{Vm}_{\text{std}} = \frac{(\text{Vm}_{\text{act}})(\text{PB}_{\text{act}})(\text{Tstd})}{(\text{Pstd})(\text{Tm}_{\text{act}})}$$

where,

Vm_{std} = sample volume at std. cond., dsL

Vm_{act} = actual sample volume, aL

PB_{act} = atmospheric pressure at sampling location, mm Hg (in. Hg)

T_{std} = standard temperature = 293°K

P_{std} = standard pressure = 760 mm Hg (29.92 in. Hg)

Tm_{act} = actual meter temperature, °K

(2) ACID GAS EMISSION CALCULATIONS --

$$ER = \frac{(A)(B)(Qs)(C)(D)}{(SV)(E)}$$

where,

ER = HCl, HF, HI or HBr emission rate, lb/hr

A = quantity of Cl^-, F^-, I^- or Br^- collected, µg

B = 1×10^{-6} g/µg

Qs = stack gas flowrate, dscfm

C = 60 min/hr

D = 1.0282 g HCl/g Cl = 1.0526 g HF/g F

= 1.0125 g HBr/g Br = 1.0079 g HI/g I

SV = sample volume of air, dscf

E = 454 g/lb

(3) CEM POLLUTANT GAS CALCULATIONS --

$$ER = \frac{(A)(Qs)(MW)(B)}{(C)(D)}$$

where,

ER = emisison rate of CO, NO_x, THC, or SO_2, lb/hr

A = conc. of CO, NO_x, or SO_2, ppm (v)

Qs = stack gas flowrate, dscfm

MW = molecular weight, lb/lb-mole

= 28 for CO = 64 for SO_2

= 46 for NO_x (as NO_2) = 16 for THC (as methane)

B - 60 min/hr

C - 385.3 dscf/lb-mole @ 68°F (20°C)

D - 1×10^6

(4) METAL EMISSION CALCULATIONS --

MC - A/B and MER - $\frac{(MC)(C)(Qs)(D)}{(E)}$

where,

MC - metal conc., µg/dscf
A - µg of metal collected
B - sample volume of air, dscf
MER - metal emission rate, lb/hr
C - 1×10^{-6} g/µg
Qs - stack gas flowrate, dscfm
D - 60 min/hr
E - 454 g/lb

(5) SULFURIC ACID MIST AND SULFUR DIOXIDE BY EPA REFERENCE METHOD 8 --

(a) Sulfuric Acid Mist (H_2SO_4/SO_3)

$$C = \frac{K_2 \; N \; (V_t - V_{tb}) \; (V_{sol}/V_a)}{V_{mstd}}$$

(b) Sulfur Dioxide (SO_2)

$$C = \frac{K_3 \; N \; (V_t - V_{tb}) \; (V_{sol}/V_a)}{V_{mstd}}$$

where,

C - Concentration, g/dscm or lb/dscf
K_2 - 0.04904 g/meq or 1.081×10^{-4} lb/meq
K_3 - 0.03203 g/meq or 7.061×10^{-5} lb/meq
N - Normality of barium perchlorate titrant, meq/mL

V_t = Volume of titrant used for sample, mL

V_{tb} = Volume of titrant used for blank, mL

V_{sol} = Total volume of sample solution, mL

V_a = Volume of sample aliquot titrated, mL

V_{mstd} = Gas sample volume corrected to standard conditions, dscm or dscf

(6) AMBIENT SAMPLING OR AUDIT GAS CALCULATIONS --

Conversion of compound concentration from ng/L to ppb (v):

$$\text{Conc., ppb (v)} = \frac{(A)(B)}{(MW)}$$

where,

A = 24.04 L/g-mole @ 68°F (20°C)

MW = compound molecular weight, g/g-mole

B = conc., ng/L

(7) PARTICULATE CONCENTRATION CORRECTIONS --

(a) Correction to 12% CO_2:

$$\text{gr/dscf @ 12\% } CO_2 = \text{gr/dscf} \left(\frac{12}{\%\ CO_2}\right)$$

(b) Correction to 7% O_2:

$$\text{gr/dscf @ 7\% } O_2 = \text{gr/dscf} \left(\frac{14}{21 - \%\ O_{2_{dry}}}\right)$$

(8) PRORATED EMISSION RATE TO ACCOUNT FOR SOOTBLOWING INTERVALS (Goerner, et al., Texas Air Control Board, 1978)

$$PMR_{AVG} = PMR_{SB} \frac{(A + B)\ S}{(A \times R)} + PMR_{NOSB} \left[\frac{(R - S)}{R} - \frac{(B \times S)}{(A \times R)}\right]$$

where,

PMR = Pollutant Mass Emission Rate (lb/hr, lb/10^6 Btu)

PMR_{AVG} = Average PMR for daily operating time

PMR_{SB} = Average PMR of sample(s) encompassing sootblowing

APPENDIX E

EQUIPMENT CALIBRATION FORMS

Dry Gas Meter Calibration

Calibrated By ____________________ Barometric Pressure, P_b= __________ in. Hg

Date __________ Meter Box No. ____________________

			Temperature								
			Wet test	Dry gas meter						Deviation	
Orifice manometer setting ΔH, in. H_2O	Gas volume wet test meter V_w, ft^3	Gas volume dry test meter V_d, ft^3	Meter t_w, °F	Inlet t_{di}, °F	Outlet t_{do}, °F	Average t_d, °F	Time θ, °F	Y	$\Delta H\partial$	Y	$\Delta H\partial$
						Average					

Calculations

Y	$\Delta H\partial$
$\frac{V_w \; P_b \; (t_d+460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)\left(t_w + 460\right)}$	$\frac{0.0317 \; \Delta H}{P_b(t_d + 460)} \left[\frac{(t_w + 460)\,\theta}{V_w}\right]^2$

Y = Ratio of accuracy of wet test meter to dry test meter.
Tolerance = ± 0.01

$\Delta H\partial$ = Orifice pressure differential that gives 0.75 cfm of air as 68° F and 29.92 inches of mercury, in. H_2O.
Tolerance = ± 0.15

METER BOX CALIBRATION WORKSHEET

Time Minutes	Inlet Temp.	Outlet Temp.	Meter Box Ser. #	Date
0			DGM Serial #	BAR Press (PB)
2			Δ H .5 1.0 2.0	Calibrated by
4				
6			Final DGM	Final WTM
8			Initial DGM	Initial WTM
10			Net DGM	Net WTM
12				
14			Vac. In. HG.	Average DGM Temperature
15				
			$y = \frac{\qquad}{\qquad} =$	
			$\Delta H = \frac{\qquad}{\qquad}\left[\frac{\qquad}{\qquad}\right]^2 =$	
		Wet Test Meter Temperature		
		Total Time, minutes; seconds		15.0

Calculations

Y	$\Delta H\partial$
$\frac{V_w \; P_b \; (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right) \left(t_w + 460\right)}$	$\frac{0.0317 \; \Delta H}{P_b(t_d + 460)} \left[\frac{(t_w + 460)\,\theta}{V_w}\right]^2$

AF-014/A

Thermocouple Calibration Form

Thermocouple Number	Temperature Reading 1	Reference Temperature 1	Temperature Reading 2	Reference Temperature 2	Temperature Reading 3	Reference Temperature 3

Signature of Person Performing Calibration

Calibration Date

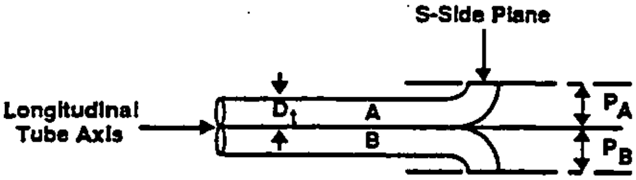
Type S Pitot Inspection Form

Pitot Tube No. ______________

Tubing Diameter, D_t ______________ **in.** $\left(\frac{3}{16} < D_t < \frac{3}{16}\right)$

Pitot Tube Assembly Level? ___Yes/No___

Pitot Tube Opening Damaged? ___Yes/No___



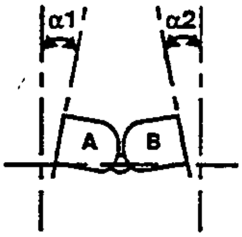
Note:

$1.05\,D_t < P < 1.50\,D_t$

$P_A = P_B$

$P_A =$ ______________ **in.**

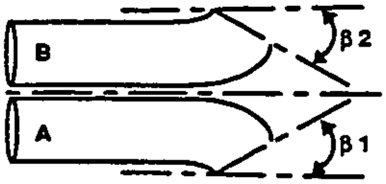
$P_B =$ ______________ **in.**



$\alpha 1 =$ ______°

$\alpha 2 =$ ______°

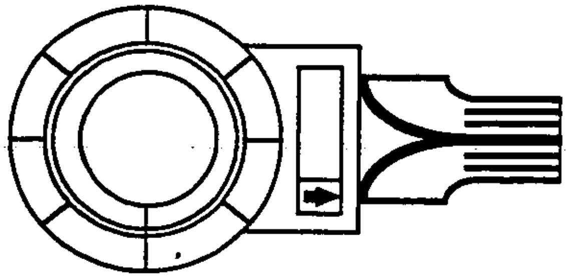
(< 10°)

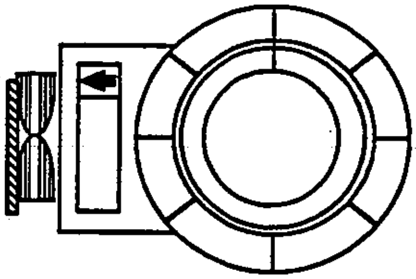


$\beta 1 =$ ______°

$\beta 2 =$ ______°

(< 5°)





Level Position to find γ = ______________

Level Position to find θ = ______________

$Z = A' \sin \gamma$ ______________ **in. (< 1/8 in.)**

$W = A' \sin \theta$ ______________ **in. (< 1/32 in.)**

Comments: ____

____

Checked by: ______________

Date: ______________

Calibration Required? ______________

D_t = External Tube Diameter

A' = Distance Between Tips ($P_A + P_B$) inches

AF-021

Nozzle Calibration Data

Nozzle Set No. Date Tech.

Nozzle No.	Diameter* —	a	b	c	average**

*measure to nearest .001"
**three measurements must be within .004" of each other

4F-114