Clean Air Engineering

FIELD HANDBOOK
1st EDITION
1/1/93

REVISION 1 - 8/9/95
REVISION 2 - 1/14/98

REVISION HISTORY

Revision 1 - 8/9/95

TOC - Equation for excess air correction added to Emission section and Relative Humidity added to the Moisture Section.

Page 6 - Equation B7 is now also written in terms of Dn.

Page 9 - Page reference corrected.

Page 11 - Equation E2 clarified. ppm measured must be on a dry basis.

Page 11 - Equation E4 - units for Fc corrected to scf/MBtu. Also, the equation was clarified - %CO2 and concentration of pollutant must be on the same moisture basis - both wet or both dry.

Page 12 - Correction to a percent excess air added.

Page 16 - Equation F3 - Molecular weight of water changed from 18 to 18.01.

Page 17 - Note added for calculating the relative humidity based on wet bulb and dry bulb temperatures.

Page 17 - Equation F4 - Clarified by stating temperatures are in Fahrenheit.

Page 20 - Equation G3 corrected. The constant 0.75 was corrected to 0.075; and 0.01060 was corrected to 0.001060.

Page 28 - Comment on blank correction added.

Revisions 2 - 1/14/98

Page 19 - Critical orifice procedure modified.

PREFACE

This is the first edition of the *Field Handbook*. This manual is designed to provide practical help to those working in the field and for use in-house as a reference. Similar equations are grouped together with the variable names indexed on the following page.

Current plans for the next edition include adding calculations for:

- PM_{10} (Method 201A)
- Anderson Impactor
- Cyclade for particle sizing
- 3D Calculations

Contact Dave Nasralla with any equations you feel would make a helpful contribution.

The following codes are used through out the manual for references:

SSPP Student Manual.......EPA APTI Course 450 Source Sampling for Particulate Pollutants - EPA 450/2-79-006 by J.A. Janke and G.J. Aldina

PH......................................Perry's Chemical Engineer's Handbook, Sixth Edition, McGraw Hill, 1984.

EPA....................................Title 40 of the Code of Federal Regulations, Part 60, Appendix A. July 1st, 1992.

QAH...................................The Quality Assurance Handbook for Air Pollution Measurement Systems, Vol III, Stationary Source Specific Methods. EPA 600/9-9-76-005.

Clean Air Engineering

Table of Contents

Clean Air Engineering

Table of Contents (CONTINUED)

PAGE

Method 5 K Factor

Information required:	Variable	Example	Units
From the meter card:	$\Delta H@$	1.817	
Expected meter temp:	T_m	71	°F
Stack temp:	T_s	459	°F
Static Pressure of Stack:	P_{static}	-0.20	" H_2O
Barometric Pressure:	P_b	29.62	" Hg
Oxygen:	$\%O_2$	9.2	%
Carbon Dioxide:	$\%CO_2$	11.7	%
Nitrogen:	$\%N_2$	79.1	%
Carbon Monoxide:	%CO	0.0	%
Moisture Content Estimate:	B_{wo}	0.053	none
Pitot tube calibration factor:	C_p	0.84	none
Root ΔP average:	$\left(\sqrt{\Delta P}\right)_{ave}$	0.90	root "H_2O
The square of the root ΔP average:	ΔP	0.81	"H_2O
Diameter of available nozzle:	D_n	0.276	inches
Desired meter flow rate:	ΔH	1.8	"H_2O
Meter correction factor:	Yd:	1.0050	

Preliminary Calculations

A1. Absolute pressure of stack gas: **EPA M2- Eq. 2-6 and PH**

$$P_s = P_b + \frac{P_{static}\ "H_2O}{13.6\ \frac{"H_2O}{"Hg}} = 29.62 + \frac{-0.20}{13.6} = 29.605 \text{ inches Hg}$$

A2. Molecular weight of gas (dry): **EPA M3- Eq. 3-1**

$$M_d = 0.44(\%CO_2) + 0.32(\%O_2) + 0.28(\%CO + \%N_2)$$

$$= 0.44(11.7) + 0.32(9.2) + 0.28(0 + 79.1) = 30.24 \text{ lb/lb} \bullet \text{mole}$$

A3. Molecular weight of gas (wet): **EPA M2- Eq. 2-5**

$$M_s = M_d\ (1 - B_{wo}) + 18\,(B_{wo})$$

$$= 30.24\ (1 - 0.053) + 18(0.053) = 29.59 \text{ lb/lb} \bullet \text{mole}$$

Clean Air Engineering

Method 5 K Factor (Continued)

Nozzle size, K factor and V_{mstd} determination

An example hand calculation can be found on the following page.

A4. Ideal nozzle size (squared) based on the $V_{mstd\ desired}$*: **From equation A6**

$$D_n^2 = \frac{V_{desired}\sqrt{\dfrac{M_s(T_s + 460)}{P_s}}}{(493.4)\ C_p \Theta (1 - B_{wo}) \left(\sqrt{\Delta P}\right)_{ave}}$$

A5. K factor: **see Derivation Section**

$$K = 850\,(C_p)^2 (\Delta H@) \left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2 (D_n)^4$$

A6. Estimated V_{mstd}: **see Derivation Section**

$$\text{Est } V_{mstd} = (493.4)\,C_p \sqrt{\frac{P_s}{M_s(460 + T_s)}}\left(\sqrt{\Delta P}\right)_{ave} D_n^2\, \Theta (1 - B_{wo})$$

A7. Estimated V_{meter} reading for entire test or single point **see Derivation Section**

$$\text{Est } V_m = \left[\frac{(27.98)(T_m + 460)}{Y_d\left(P_b + \frac{\Delta H}{13.6}\right)}\right] C_p \sqrt{\frac{P_s}{M_s(460 + T_s)}}\left(\sqrt{\Delta P}\right)_{ave} D_n^2\, \Theta (1 - B_{wo})$$

Substitute point values for Θ, ΔH, T_s, and T_m when calculating point volumes.

***A8 Alternate ideal nozzle calculation based on desired ΔH and average ΔP.**

$$\text{Ideal } D_n = \left[\frac{\Delta H}{K1\,(\Delta P)}\right]^{0.25} = \left[\frac{1.8}{576.80\,(0.81)}\right]^{0.25} = 0.2491 \text{ in}$$

Derived from the equation $\Delta H = (\Delta P)\, K1\, (D_n)^4$

K1 is defined on the following page..

Method 5 K Factor (Continued)

Example hand calculation:

1) To simplify calculations, define two intermediate factors - K1 and D1:

$$K1 = 850\,(C_p)^2\,(\Delta H@)\left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2$$

$$= 850\,(0.84)^2\,(1.817)\left(\frac{71 + 460}{459 + 460}\right)\left(\frac{29.605}{29.62}\right)\left(\frac{30.24}{29.59}\right)(1 - 0.053)^2 = 576.80$$

$$D1 = (493.4)\,C_p\sqrt{\frac{P_s}{M_s\,(460 + T_s)}}\,(1 - B_{wo})$$

$$= (493.4)(0.84)\sqrt{\frac{(29.605)}{(29.59)(460 + 459)}}\,(1 - 0.053) = 12.95$$

2) Find the ideal nozzle size based on the $V_{mstd\ desired}$:

$$D_{n\ ideal} = \sqrt{\frac{V_{mstd\ desired}}{D1\ \Theta\ \left(\sqrt{\Delta P}\right)_{ave}}} = \sqrt{\frac{(30)}{(12.95)(60)(0.90)}} = 0.2071$$

3) Find the closest <u>larger</u> nozzle size and calculate the K factor: (eg. 0.250")

$$K\ factor = K1\,(D_{n\ actual})^4 = (576.80)(0.250)^4 = 2.25$$

4) The highest ΔH will be:

$$\Delta H_{highest} = K\,(\Delta P_{highest}) = (2.25)(0.81) = 1.8$$

If ΔH is too high, then reduce D_n to decrease the K factor, and increase the test time to pull the required V_{mstd}.

5) The estimated V_{mstd} will be:

$$V_{mstd} = D1\ \Theta\ \left(\sqrt{\Delta P}\right)_{ave}\,D^2_{n\ actual} = (12.95)(60)(0.90)(0.250)^2 = 43.71$$

Method 5 Results

Information required:

	Variable	Example	Units
From the meter card:	$\Delta H@$	1.817	none
Barometric pressure:	P_b	29.62	" Hg
Static pressure of stack:	P_s	-0.20	" H_2O
Volume of water collected:	V_{lc}	32	ml
Weight of particulate collected:	M_n	0.040	grams
Test Time:	θ	65.3	minutes
%O_2, CO_2, N_2, CO:	from previous example		
Average ΔH:	ΔH	0.603	"H_2O
Pitot tube calibration factor:	C_p	0.84	none
Average meter temp:	T_m	71	°F
Average of ΔP square roots:	$\sqrt{\Delta P}$	0.4068	Root of inches of H_2O
Average stack temp:	T_s	459	°F
Volume metered:	V_m	26.94	ft^3
Diameter of nozzle:	D_n	0.276	inches
Area of stack:	A_s	213.72	ft^2
From the meter card:	Y_d	0.9991	none

B1. Volume of water vapor collected, standard: **EPA M5- Eq. 5-2**

$$V_{wstd} = \left(0.04707\ \frac{ft^3}{ml}\ @\ 68°F\right)(V_{lc}) = (0.04707)\ (32) = 1.5062 \approx 1.51\ \mathbf{scf}$$

B2. Volume of gas metered, standard: **EPA M5- Eq. 5-1**

$$V_{mstd} = \frac{\left(17.64\ \frac{°R}{in.\ Hg}\right)(V_m)\left[P_b + \frac{\Delta H}{13.6}\right]}{(460 + T_m)}(Y_d)$$

$$= \frac{(17.64)\ (26.94)\ \left[29.62 + \frac{0.603}{13.6}\right]}{(460+71)}(0.9991) = 26.5244 \approx 26.52\ \mathbf{dscf}$$

B3. Moisture content: **EPA M5- Eq. 5-3**

$$B_{wo} = \frac{V_{wstd}}{V_{mstd} + V_{wstd}} = \frac{1.5062}{26.5244 + 1.5062} = 0.053736 \approx 0.0537\ \mathbf{vol/vol}$$

Note: **B_{wo} should also be calculated assuming saturated conditions. See equation F1 on page 15. The lower of the two values should be used (cf. EPA M5- Note 6.5).**

Md, Ms, and Ps are calculated using equations A1, A2, and A3, respectively.

Method 5 Results (Continued)

B4. Velocity of stack gas: EPA M2- Eq. 2-9

$$V_s = K_p C_p \sqrt{\frac{T_s + 460}{(M_s)(P_s)}} \left(\sqrt{\Delta P}\right)_{ave} \quad \text{where } K_p = 85.49 \frac{ft}{sec}\sqrt{\frac{\left(\frac{lb}{lb \cdot mole}\right) in.\ Hg}{°R\,(in.\ H_2O)}}$$

$$= 85.49\,(0.84)\sqrt{\frac{459 + 460}{(29.59)(29.605)}}\,(0.4068) = 29.921 \approx 29.92\ ft/sec$$

B5. Actual flow of stack gas: General Equation

$$Q_a = (60\ \tfrac{sec}{min})\,(A_s)\,(V_s) = (60)\,(213.72)\,(29.921) = 383,683 \approx 383,700\ acfm$$

B6. Standard stack gas flow: Derived from EPA M2- Eq. 2-10

$$Q_{std} = \frac{Q_a\,P_s\,(17.64\ \frac{°R}{in.\ Hg})\,(1 - B_{wo})}{\overline{T_s} + 460}$$

$$= \frac{(383,683)\,(29.605)\,(17.64)\,(1 - 0.053736)}{459 + 460} \approx 206,300\ dscfm$$

B7. Percent Isokinetic: EPA M5- Eq. 5-8

$$\%I = \frac{(0.09450)\,(\overline{T_s} + 460)\,V_{mstd}}{P_s\,V_s\,A_n\,\Theta\,(1 - B_{wo})} = \frac{(17.326)\,(T_s + 460)}{P_s\,V_s\,(D_n)^2\,\Theta\,(1 - B_{wo})}$$

$$= \frac{(0.09450)\,(459 + 460)\,(26.5244)}{(29.605)\,(29.921)\,(0.000415475)\,(65.3)\,(1 - 0.053736)} = 101.3\ \%$$

B8. Particulate Grain Loading: EPA M5- Eq. 5-6

$$gr/dscf = \frac{(15.43\ \frac{grains}{gram})\,(M_n)}{V_{mstd}} = \frac{(15.43)\,(0.040)}{26.5244} = 0.0233$$

Clean Air Engineering

Method 6

C1. Normality of Titrant:

Dimensional analysis

$$N = \frac{\left(\text{Normality of } H_2SO_4 \text{ Standard } \frac{meq}{ml}\right)(\text{ml } H_2SO_4 \text{ Standard})}{(\text{ml Titrant})}$$

C2. Concentration (lb/dscf)

EPA M6- Eq. 6-2

$$lb/dscf = (7.061 \text{ x } 10^{-5})\,\frac{lb}{meq} \text{ x } \frac{(V_t - V_{tb})\,ml\,\left(N\,\frac{meq}{ml}\right)\left(\frac{V_{soln}}{V_a}\,\frac{ml}{ml}\right)}{(V_{mstd}\;dscf)}$$

See Equation B2 to calculate V_{mstd}.
See Equation E5 and E6 to calculate lb/MBtu.

C3. Conversion of lb/dscf SO_2 to ppm SO_2

Variation of Eq. E2, where MW = 64.06

$$ppm_{SO_2} = (lb/dscf) \bullet 6.015 \text{ x } 10^6$$

C4. Audit Concentration Calculation (mg/dscm):

From audit sheet

$$mg/dscm = \left(32.03\,\frac{mg}{meq}\right) \text{ x } \frac{(V_t - V_{tb})\,ml\,\left(N\,\frac{meq}{ml}\right)\left(\frac{100}{V_a}\,\frac{ml}{ml}\right)}{(21 \text{ x } 10^{-3}\;dscm)}$$

Clean Air Engineering

D1. Drift Calibration: **EPA M6C- Eq. 6C-1**

Define:

C_{avg} = **Average concentration indicated by the gas analyzer (ppm).**
C_o = **Average of initial and final system calibration bias check responses for the zero gas (ppm).**
C_m = **Average of initial and final system calibration bias check responses for the upscale calibration gas (ppm).**
C_{ma} = **Actual concentration of the upscale calibration gas (ppm).**

$$ppm_{drift\ calibrated} = (C_{avg} - C_o)\frac{C_{ma}}{(C_m - C_o)}$$

See Emission Section (page 11) for lb/hr and lb/dscf equations.

D2. Conversion of ppm_{dry} to ppm_{wet} **See proof in Derivation section.**

$$ppm_{wet} = ppm_{dry}(1 - B_{wo})$$

(and for those rare occasions)

D3. Conversion of $ppm_{volume\ basis}$ to $ppm_{mass\ basis}$

$$ppm_{mass\ basis} = \frac{M_p\left(ppm_{volume\ basis}\right)}{M_d\left(1 - \frac{ppm_{volume\ basis}}{10^6}\right)} \approx \left(\frac{M_p}{M_d}\right) ppm_{volume\ basis}$$

where M_p = molecular weight of the pollutant
M_d = molecular weight of the stack gas.

The derivation is very similar to that of the conversion of moisture content on a mass/mass basis to vol/vol basis shown in the Derivation Section.

Monitors (Continued)

D4. Standard deviation of the difference between the monitor and the reference method:

Appendix B, Spec 2, Eq. 2-2

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} d_i^2 - \frac{(\sum_{i=1}^{n} di)^2}{n}}{n-1}} = \sqrt{\frac{\text{sum of}\left[(\text{each difference})^2\right] - \frac{(\text{sum of all differences})^2}{\text{number of data sets}}}{\text{number of data sets} - 1}}$$

D5. Confidence coefficient:

$$cc = (t_{0.975})\frac{\sigma}{\sqrt{n}}$$

$t_{0.975}$ table **Appendix B, Spec 2, Eq. 2-3, Table 2-1**

n	t	n	t	n	t
2	12.706	7	2.447	12	2.201
3	4.303	8	2.365	13	2.179
4	3.182	9	2.306	14	2.160
5	2.776	10	2.262	15	2.145
6	2.571	11	2.228	16	2.131

D6. Relative Accuracy:

Appendix B, Spec 2, Eq. 2-4

$$RA = \frac{|\text{absolute value of the mean of the difference}| + |cc|}{(\text{reference method average or applicable emission standard})}(100)$$

Example:

Run No.	Plant CEM Average	Your Average		Difference	Difference Squared
1	550	560		-10	100
2	455	465		-10	100
3	460	455		5	25
4	490	500		-10	100
5	485	500		-15	225
6	435	450		-15	225
7	500	490		10	100
8	550	530		20	400
9	555	560		-5	25
Average	**497.8**	**501.1**	**Sum**	**-30**	**1300**

Average of differences = -3.333

D4. $\sigma = \sqrt{\frac{1300 - \frac{(-30)^2}{9}}{9-1}} = 12.2474$

D5. $cc = (2.306)\frac{12.2474}{\sqrt{9}} = 9.4142$

D6. $RA = \frac{|-3.333| + |9.4142|}{(501.1)}(100) = 2.5\ \%$

Clean Air Engineering

Emissions

E1. Pounds per hour - particulate:

Dimensional analysis

$$lb/hr = \frac{(gr/dscf)\ (Q_{std}\ \frac{dscf}{min})\ (60\frac{min}{hr})}{7000\ \frac{grains}{lb}} = \frac{(0.0233)\,(206,300)\,(60)}{7000} = 41.2$$

E2. Conversion of ppm (dry basis) to lb/dscf for any gas:

$$lb/dscf = \frac{(ppm_{drift\ calibrated})\,(MW\frac{lb}{lb \cdot mole})}{385.3\ \frac{dscf}{lb \cdot mole}\ x\ 10^6}$$

Common Molecular Weights

SO_2 = 64.06, CO = 28.01

NO_x = 46.01, THC = 44.10 (propane)

Derived from dimensional analysis based on v/v ppm reading. Derivation of molar volume constant can be found in the Derivation section of this manual. Conversion constants for NOx, SO2, and CO pre-done in Appendix C.

E3. Pounds per hour from ppm and Q_{std}:

Dimensional analysis

$$lb/hr = \frac{(ppm_{drift\ calibrated})\,(MW\frac{lb}{lb \cdot mole})\,(Q_{std}\ \frac{dscf}{min})\ (60\frac{min}{hr})}{385.3\ \frac{dscf}{lb \cdot mole}\ x\ 10^6}$$

E4. Conversion of lb/dscf or gr/dscf to lb/MBtu for gas or particulate (Fc factor*):

Notice: Pollutant concentration and $\%CO_2$ should be on the same moisture basis **EPA M19- Eq. 19-6**

$$lb/MBtu = \frac{(lb/dscf)\,(F_c\ \frac{scf}{MBtu})\,(100)}{\%CO_{2\,(dry\ basis)}}\ \ or\ = \frac{(gr/dscf)\,(F_c\ \frac{scf}{MBtu})\,(100)}{(7000\ \frac{grains}{lb})\ \ \%CO_{2\,(dry\ basis)}}$$

E5. Conversion of lb/dscf or gr/dscf to lb/MBtu for gas or particulate (Fd factor*):

EPA M20- Eq. 20-6

$$lb/MBtu = \frac{(lb/dscf)\,(F_d\ \frac{dscf}{MBtu})\,(20.9)}{(20.9 - \%O_2)}\ \ or\ = \frac{(gr/dscf)\ (F_d\ \frac{dscf}{MBtu})\ (20.9)}{(7000\ \frac{grains}{lb})\ (20.9 - \%O_2)}$$

E6. Calculation of lb/MBtu - heat input method

Dimensional analysis

$$lb/MBtu = \frac{lb/hr_{emission}}{MBtu/hr_{fired}}$$

*** F_d = 9,780 dscf/MBtu for bituminous coal. See Appendix A for other F_d and F_c factors.**

Emissions (Continued)

E7. Correction to a percent CO_2. (eg 12 % CO_2): **EPA M20- Eq. 20-5**

$$= \frac{(\text{gr/dscf or lb/dscf})\ (\%CO_2\ \text{correction})}{\%CO_2\ \text{actual}}$$

$$\text{eg.} = \frac{(\text{gr/dscf})(12)}{\%CO_2}$$

E8. Correction to a percent O_2. (eg 7 % O_2): **EPA M20- Eq. 20-6**

$$= \frac{(\text{gr/dscf or lb/dscf})\ (20.9 - \%O_2\ \text{correction})}{(20.9 - \%O_2\ \text{actual})}$$

$$\text{eg.} = \frac{(\text{gr/dscf})(20.9 - 7)}{(20.9 - \%O_2)}$$

E9. Removal Efficiency for a control device: **General Equation**

$$\% = \frac{\text{Inlet} - \text{Outlet}}{\text{Inlet}}(100)$$

E10. Percent Excess Air: **EPA M3B- Eq. 3B-3**

$$\%EA = \frac{\%O_2 - 0.5\ \%CO}{0.264\ \%N_2 - (\%O_2 - 0.5\ \%CO)}$$

$$0.264 = \text{Ratio of } O_2 \text{ to } N_2 \text{ in air, v/v}$$

Note: The equation above assumes that ambient air is used as the source of O_2 and that the fuel does not contain appreciable amounts of N_2 (as do coke oven or blast furnace gases). For those cases when appreciable amounts of N_2 are present (coal, oil and natural gas do not contain appreciable amounts of N_2) or when oxygen enrichment is used, alternative methods, subject to the approval of the administrator, are required. Reference EPA Method 3B, Section 4.1.

E10.1 Correction to a Percent Excess Air: **similar eq. in 40 CFR 60 Subpart E - 60.54**

$$= (\text{lb/dscf})\left[\frac{100 + \%EA_{actual}}{100 + \%EA_{correction}}\right]$$

E11. Pounds per 1000 pounds stack gas: **Dimensional analysis and intuition:**

$$= \frac{\left(M_n\ \frac{\text{grams}}{}\right)\left(\frac{1}{453.59}\ \frac{\text{lb}}{\text{grams}}\right)}{\left(V_{mstd}\ \frac{\text{ft}^3}{}\right)\left(2.595 \times 10^{-3}\ \frac{\text{lb}\cdot\text{mole}}{\text{ft}^3}\right)\left(M_d\ \frac{\text{lb}}{\text{lb}\cdot\text{mole}}\right) + \left(V_{lc}\ \frac{\text{ml}}{}\right)\left(2.205 \times 10^{-3}\ \frac{\text{lbs}}{\text{ml}}\right)} \times 1000$$

2.595×10^{-3} is n/V=P/RT from the ideal gas law.
2.205×10^{-3} assumes 1 ml of water = 1 gram.

Emissions (Continued)

Corrections for Soot Blowing
Information required

E_s	Average lb/Mbtu of particulate for soot blowing runs
E_{ns}	Average lb/Mbtu of particulate for non-soot blowing runs
A	Hours of soot-blowing during test runs containing soot blowing
B	Hours **not** soot blowing during test runs containing soot blowing
R	Average hours of boiler operation per 24 hour day
S	Average hours of soot blowing per 24 hour day

E12. Weighted average for all runs: **Wisconsin Administrative Code DNR: NR 439.07 (8)**

$$E_{avg} = E_s \left[\frac{(A + B) \bullet S}{(A \bullet R)} \right] + E_{ns} \left[\frac{(R \bullet S)}{R} - \frac{B \bullet S}{A \bullet R} \right]$$

Example

Company XXX runs their boiler 24 hours per day. They blow soot for five minutes, three times per day. Three particulate runs were performed. The results were as follows:

Soot Blowing Runs			Non Soot Blowing Runs		
Run#	Run Time	lb/MBtu	Run#	Run Time	lb/MBtu
1	60 min	0.4000	3	60 min	0.3000
2	72 min	0.5000			

$$E_s = \frac{(0.5000 + 0.4000)}{2} = 0.4500 \text{ lb/MBtu} \qquad E_{ns} = 0.3000 \text{ lb/MBtu}$$

$$A = \frac{(5 + 5) \text{ min}}{60 \frac{\text{min}}{\text{hr}}} = 0.1667 \text{ hr} \qquad B = \frac{(72 + 60 - 5 - 5) \text{ min}}{60 \frac{\text{min}}{\text{hr}}} = 2.0333 \text{ hr}$$

$$R = 24 \text{ hr} \qquad S = \frac{(3 \times 5) \text{ min}}{60 \frac{\text{min}}{\text{hr}}} = 0.25 \text{ hr}$$

$$E_{avg} = 0.4500 \left[\frac{(0.1667 + 2.0333) \times 0.25}{(0.1667 \times 24)} \right] + 0.3000 \left[\frac{(24 - 0.25)}{24} - \frac{2.0333 \times 0.25}{0.1667 \times 24} \right]$$

$$= 0.06186 + 0.25875 = 0.3206 \text{ lb/MBtu}$$

The weighted average for all three runs is 0.3206 lb/MBtu.

F1. Moisture content, assuming saturated conditions:

Calculate the absolute stack pressure P_s, and look in Appendix F to find the saturated vapor pressure (SVP) at the average stack temperature. Calculate the saturated moisture content as follows:

$$B_{wo} = \frac{svp\ @\ T_s}{P_s}$$

If P_s = 30.5 "Hg and T_s = 140°F, then svp @ T_s = 5.879

$$B_{wo} = \frac{5.879}{30.5} = 0.1928$$

Best used if P_s does not deviate from more than 1 in Hg from standard conditions.

F2. Ambient Conditions: **(EPA M19 - Section 2.2.1.1)**

B_{wo} = 0.027
M_d = 28.84

Assuming:

$\%N_2$ = 78.2%
$\%O_2$ = 20.9
%CO = 0.0
%CO = 0.0

Note: The above assumption does not consider argon in air (about 0.9 percent, molecular weight of 39.9). A negative error of 0.4 percent is introduced. The tester may choose to include argon in the analysis using procedures subject to the approval of the administrator. EPA M3- Section. 7.1.

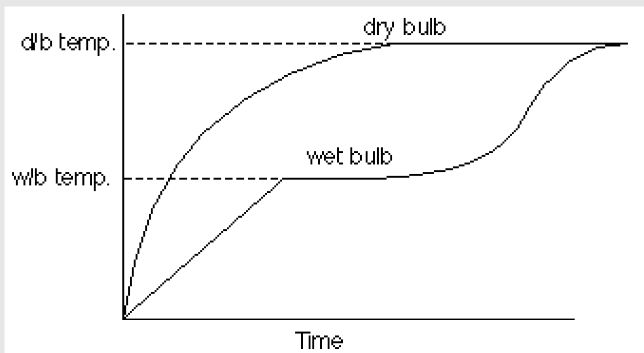
Moisture Determination (Bwo)
Using Wet Bulb/ Dry Bulb Method

Information required: **Variable** **Example** **Units**

	Variable	Example	Units
Static Pressure of Stack:	P_{static}	-0.20	" H_2O
Barometric Pressure:	P_b	29.62	" Hg
Wet Bulb Temperature:	t_w	77	°F
Dry Bulb Temperature:	t_d	100	°F

Obtain the Wet and Dry Bulb Temperatures

The graph below illustrates how the temperature changes when a wet bulb is placed in an air stream. The temperature reaches equilibrium at the wet bulb temperature and then continues to rise as the water on the bulb dries. Above around 130°F, the moisture on the bulb dries too quickly to determine the stabilized temperature. Also, the stack gas velocity should be at least 10 ft/sec to acquire an accurate reading.



State of Oregon

The dry bulb temperature is the normal temperature measured by a dry thermometer.

Calculate the absolute stack pressure using equation A1:

$$P_s = P_b + \frac{P_{static}\ "H_2O}{13.6 \frac{"H_2O}{"Hg}} = 29.62 + \frac{-0.20}{13.6} = 29.605 \text{ inches Hg}$$

Determine B_{wo} using a Psychrometric chart <u>or</u> Vapor Pressure Tables

By Psychrometric Chart:

Using the Psychrometric chart in the back of this manual locate the dry bulb temperature on the x-axis and the wet bulb temperature along the curved saturation line. From their intersection read directly left to the y-axis to find the humidity, H, in pounds water per pounds bone dry air. Convert H to Bwo with the following equation.

(Eg. If t_w = 77 and t_d = 100, then H = 0.01475 lb water/ lb bone dry air.)

F3. Conversion of lb/lb moisture content (H) to B_{wo} **see Derivation Section**

$$B_{wo} = \frac{H M_d}{H M_d + 18.01} \ (v/v) \qquad = \frac{(0.01475)(28.84)}{(0.01475)(28.84) + 18} \approx 0.0231$$

M_d = 28.84 for ambient conditions.

The psychrometric chart is based on a standard barometric pressure of 29.92 in. Hg. If the absolute stack pressure deviates significantly from standard conditions the result must be corrected (which is beyond the present scope of this manual).

Moisture (Continued)

Moisture Determination (B_{wo})
Using Wet Bulb/ Dry Bulb Method (Continued)

By Vapor Pressure Table:

Nomenclature:

Saturated Vapor Pressure:	s.v.p.
Vapor Pressure:	v.p.

Find the saturated vapor pressure (s.v.p) from the vapor pressure table in Appendix E, based on the wet bulb temperature (t_w):

Eg. s.v.p @ 77 °F = 0.9352 in. Hg

F4. Calculate the actual vapor pressure (v.p.):(temperatures are in °F)

$$\text{v.p} = \text{s.v.p. if } t_d = t_w$$

$$\text{else v.p.} = \text{s.v.p.} - (3.67 \times 10^{-4})(P_s)(t_d - t_w)\left(1 + \frac{t_w - 32}{1571}\right)$$

$$\text{v.p.} = 0.9352 - (3.67 \times 10^{-4})(29.605)(100 - 77)\left(1 + \frac{77 - 32}{1571}\right) = 0.67815 \text{ in. Hg}$$

If P_S is below 29.5 in. Hg. the QAH, Section 3.12, for EPA Method 9 uses a constant of 3.57×10^{-4} in place of 3.67×10^{-4}.

F4.1 Relative Humidity

Calculate the relative humidity by dividing the v.p. calculated in equation F4, by the s.v.p. at the **dry** bulb temperature.

F5. Calculate B_{wo} :

$$B_{wo} = \frac{\text{v.p.}}{P_s} \qquad B_{wo} = \frac{0.67815}{29.605} = .0229$$

F6. If no vapor pressure table is available, the vapor pressure for a given wet bulb temperature can be found from the follow equation:

$$\text{s.v.p.} = 0.0375 + 0.2103\left(T_1\right) + 0.28665\left(T_2\right) + 0.17595\left(T_3\right) + 0.04615417\left(T_4\right) + 0.00452083\left(T_5\right)$$

where:

$T_1 = t_w / 40$; $T_2 = T_1 (T_1 - 1)$; $T_3 = T_2 (T_1 - 2)$; $T_4 = T_3 (T_1 - 3)$; $T_5 = T_4 (T_1 - 4)$

Critical Orifice Check

A critical orifice can be used to check the calibration on a dry gas meter. Each orifice has two parameters: the orifice coefficient, K'; and the critical vacuum. Above the critical vacuum, only a fixed rate of molecules are allowed to enter the dry gas meter.

Check the meter calibration as follows:

- Turn the meter on and let it run for about 15 minutes to let it warm up and stabilize the temperature inside.
- Attach the critical orifice (quick-connect) and crank up the meter to get the highest possible flow rate.
- While the meter is running start your watch and read the starting volume on the fly.
- Run the meter for fifteen minutes, taking volume readings on the fly every five minutes. Be sure to record the meter temperatures as well as the ambient temperature near the critical orifice. Each five minute interval can be considered a separate trial.

Calculations:

Calculate the Vmstd as normal using equation B2.

$$V_{mstd} = \frac{\left(17.64 \frac{^{o}R}{in.\ Hg}\right) (V_m) \left[P_b + \frac{\Delta H}{13.6}\right]}{(460 + T_m)} (Y_d)$$

Calculate the volume drawn through the orifice.

G1. Criticial Orifice Volume: **EPA M5 - Eq. 5-11**

$$V_{or\ std} = \frac{P_b\,(\text{elapsed time})\,(K')}{\sqrt{T_{amb} + 460}}$$

where K' = is the orifice coefficient $= \frac{\left(ft^3\right)\sqrt{^{\circ}R}}{(in.\ Hg)\,(min)}$

and T_{amb} = ambient temperature

Calculate the percent difference.

G2. Percent Difference:

$$\%\ Diff = \frac{(V_{mstd} - V_{or\ std})}{V_{or\ std}} \times 100$$

Miscellaneous (Continued)

G3. To find barometric pressure at your altitude given barometric at sea level:

$$B.P._{@\ \text{Altitude}} = B.P._{@\ \text{sealevel}} - \frac{\left(0.075\ \frac{\text{lb air}}{\text{ft}^3}\right)_{\text{density of air}} (\text{Altitude})\left(29.92\ \text{in. Hg}\right)_{\text{std Pb @ sea level}}}{144\ \frac{\text{in}^2}{\text{ft}^2}\left(14.7\ \frac{\text{lb}}{\text{ft}^2}\right)_{\text{standard pressure @ sea level}}}$$

$$= B.P._{@\ \text{sealevel}} - (\text{Altitude})\left(0.001060\ \frac{\text{in. Hg}}{\text{ft}}\right)$$

Derivations

Commonly Used Constants

17.64 Combination of standard barometric pressure and temperature: EPA M5- Eq. 5-1

$$17.64 = \frac{T_{std}}{P_{std}} = \frac{527.67\ °R}{29.921\ in.\ Hg}$$

85.49 Velocity constant Kp*: EPA M2- Section 5.1, 5.2

$$K_p = \sqrt{2(\rho)(g)(R)}$$

where
ρ = density of water $\frac{lb}{ft^3}$
g = gravitational constant $\frac{ft}{sec^2}$
R = ideal gas law constant $\frac{in.\ Hg\ \ ft^3}{lb \bullet mole\ °R}$

$$= \sqrt{\frac{2(62.428)\frac{lb}{ft^3}(32.174)\frac{ft}{sec^2}(21.83)\frac{in.\ Hg\ \ ft^3}{lb \bullet mole\ °R}}{12\frac{in}{ft}}}$$

$$= 85.4857\ \frac{ft}{sec}\sqrt{\frac{\left(\frac{lb}{lb \bullet mole}\right)(in.\ Hg)}{(°R)(in.\ H_2O)}} \approx 85.49$$

The derivation of this constant was taken from the SSPP Student Manual Appendix C and uses a gas constant (R) of 21.83 which differs from the PH value of 21.85. None-the-less, Kp = 85.49 is used in EPA M2- Eq. 2.9.

385.3 Molar volume of 1 lb•mole of air at STP:

Where P_{std} = 1 atm = 29.921 in. Hg
T_{std} = 68° F = 527.67 °R
R = 21.85 $\frac{in.\ Hg\ \ ft^3}{lb \bullet mole\ °R}$

From $PV = nRT$ ideal gas law

$$\frac{V}{n} = \frac{RT}{P} = \frac{(21.85)\frac{in.\ Hg\ \ ft^3}{lb \bullet mole\ °R}(527.67)°R}{(29.921)in.\ Hg} = 385.3\ \frac{dscf}{lb \bullet mole}$$

Derivations (Continued)

Derivation of $ppm_{wet} = ppm_{dry} (1-B_{wo})$:

Define

V_{pol} = Volume of pollutant

V_{dry} = Volume of dry air

V_{vap} = Volume of water vapor

By Definition

$$ppm_{dry} = \frac{V_{pol}}{V_{dry} \times 10^6}$$

$$ppm_{wet} = \frac{V_{pol}}{\left(V_{dry} + V_{vap}\right) \times 10^6}$$

$$B_{wo} = \frac{V_{vap}}{V_{dry} + V_{vap}}$$

Therefore

$$1 - B_{wo} = \frac{V_{dry} + V_{vap}}{V_{dry} + V_{vap}} - \frac{V_{vap}}{V_{dry} + V_{vap}}$$

$$= \frac{V_{dry}}{V_{dry} + V_{vap}}$$

$$ppm_{dry} (1 - B_{wo}) = \frac{V_{pol}}{V_{dry} \times 10^6} \times \left(\frac{V_{dry}}{V_{dry} + V_{vap}}\right)$$

$$= \frac{V_{pol}}{\left(V_{dry} + V_{vap}\right) \times 10^6}$$

$$= ppm_{wet}$$

QED

Derivations (Continued)

Moisture Content Conversion

Derivation of the conversion of the moisture content measured on a mass/mass basis to a volume/volume basis and vice versa.

Define:

H = humidity (kg/kg or lb/lb)
m_w = mass of water
n_w = moles of water
M_d = molecular weight of air
B_{wo} = moisture content (vol/vol)
m_a = mass of air
n_a = moles of air

Convert mass to moles:

$$H\left(\frac{\text{kg water}}{\text{kg air}}\right) \times \left(\frac{\text{kg-mole of water}}{18\ \text{kg water}}\right) \times \left(\frac{M_d\ \text{kg}}{\text{kg-mole of air}}\right) = \frac{n_w}{n_a}$$

$$\frac{HM_d}{18} = \frac{n_w}{n_a}$$

Invert:

$$\frac{18}{H\,M_d} = \frac{n_a}{n_w} \qquad \text{(A)}$$

Convert volume to moles:
(Ideal gas law with T and P constant)

$$B_{wo} \equiv \frac{V_{vap}}{V_{vap} + V_{dry}} = \frac{n_w}{n_w + n_a}$$

Invert:

$$\frac{1}{B_{wo}} = \frac{n_w + n_a}{n_w}$$

$$\frac{1}{B_{wo}} = 1 + \frac{n_a}{n_w} \qquad \text{(B)}$$

Substitute equation A into B:

$$\frac{1}{B_{wo}} = 1 + \frac{18}{H\,M_d}$$

Rearrange to solve for B_{wo} and H:

$$B_{wo} = \frac{H\,M_d}{H\,M_d + 18} \quad (v/v)$$

$$H = \frac{18\,(B_{wo})}{M_d\,(1 - B_{wo})} \quad (\text{mass}/\text{mass})$$

Clean Air Engineering

Derivations (Continued)

K Factor Equations

There are three sources for the K factor equation. The final is a compromise whose constant more closely reflects the SSPP Student Manual and the EPA spreadsheet. Each equation's impact on the final K factor is shown.

1) The generally accepted CAE equation:

$$K = 2.89 \times 10^7 \, (C_p)^2 (\Delta H@) \left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2 (A_n)^2$$

Substituting $A_n = \pi \left(\frac{D_n}{24}\right)^2$ yields:

$$K = 859.7 \, (C_p)^2 (\Delta H@) \left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2 (D_n)^4$$

Using the example numbers in on page 1:

$$K = 859.7 \, (0.84)^2 (1.817) \left(\frac{71 + 460}{459 + 460}\right)\left(\frac{29.605}{29.62}\right)\left(\frac{30.24}{29.59}\right)(1 - 0.053)^2 (0.25)^4 = 2.28$$

2) The SSPP Student Manual:

$$K = 846.72 \, (C_p)^2 (\Delta H@) \left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2 (D_n)^4$$

= 2.24

3) An EPA spreadsheet from the EMTIC bulletin board by Bob McCracken:

$$K = 846.872 \, (C_p)^2 (\Delta H@) \left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b + \frac{\Delta H@}{13.6}}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2 (D_n)^4$$

= 2.23

Final Equation:

$$K = 850 \, (C_p)^2 (\Delta H@) \left(\frac{T_m + 460}{T_s + 460}\right)\left(\frac{P_s}{P_b}\right)\left(\frac{M_d}{M_s}\right)(1 - B_{wo})^2 (D_n)^4$$

= 2.25

Derivations (Continued)

Estimated Volume Metered at Standard Conditions

The equation assumes isokinetic conditions. The volume is calculated from the flow through the nozzle and is corrected to dry standard conditions.

Define:

- V_{mstd} = Volume metered at standard conditions
- Q_{nozzle} = flow rate though nozzle (ft^3/min)
- Θ = Total test time (min)
- B_{wo} = Moisture content (vol/vol)
- A_n = Area of nozzle (ft^2)
- V_s = Velocity of stack gas (ft/sec)
- M_s = Molecular weight of stack gas
- $\left(\sqrt{\Delta P}\right)_{ave}$ = Average of the square root delta P's
- T_{std} = Standard temperature (527.67 °R)
- T_s = Temperature of stack (°R)
- P_{std} = Standard pressure (29.921 "Hg)
- P_s = Absolute stack pressure ("Hg)
- D_n = Diameter of nozzle (inches)
- C_p = Pitot coefficient (0.84 for S-Type)

Basic equation:

$$V_{mstd} = \left[Q_{nozzle\,\frac{ft^3}{min}}\ \Theta_{min} \right] \left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)(1 - B_{wo})$$

Substitute Q=VA:

$$= \left[\left(V_{s\,\frac{ft}{sec}}\right)\left(A_{n\,ft^2}\right)\left(60\,\tfrac{sec}{min}\right)\right]\Theta_{min}\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)(1-B_{wo})$$

Substitute for Vs and An:

$$V_s = 85.49\ C_p \sqrt{\frac{T_s}{M_s P_s}}\left(\sqrt{\Delta P}\right)_{ave} \qquad A_n = \pi\left(\frac{D_n}{24}\right)^2$$

$$= \left[85.49\ C_p \sqrt{\frac{T_s}{M_s P_s}}\left(\sqrt{\Delta P}\right)_{ave}\ \tfrac{ft}{sec}\right]\left[\pi\left(\frac{D_n}{24}\right)^2 ft^2\right]\left(60\,\tfrac{sec}{min}\right)\Theta_{min}\left(\frac{T_{std}}{T_s}\right)\left(\frac{P_s}{P_{std}}\right)(1-B_{wo})$$

Combine constants and like terms:

$$= \left[\frac{(85.49)(60)\pi(527.67)}{(24)^2(29.921)}\right] C_p \sqrt{\frac{T_s}{M_s P_s}}\left(\frac{P_s}{T_s}\right)\left(\sqrt{\Delta P}\right)_{ave} D_n^2\,\Theta(1-B_{wo})$$

Reduce:

$$Est\ V_{mstd} \approx (493.4)\,C_p\sqrt{\frac{P_s}{M_s T_s}}\left(\sqrt{\Delta P}\right)_{ave} D_n^2\,\Theta(1-B_{wo})$$

Estimated actual volume meter reading:

To determine the volume meter reading (ie. at meter conditions) substitute the meter temperature, T_m (°F) + 460, for T_{std} and the meter pressure, P_m, for P_{std} and divide by Y_d.

$$Est\ V_m \approx \left[\frac{(27.98)(T_m + 460)}{Y_d\ \left(P_b + \frac{\Delta H}{13.6}\right)}\right] C_p\sqrt{\frac{P_s}{M_s T_s}}\left(\sqrt{\Delta P}\right)_{ave} D_n^2\,\Theta(1-B_{wo})$$

where $P_m = P_b + \frac{\Delta H}{13.6}$

Appendix A

Fc and Fd Factors

AA1. Calculation of F_d factor from fuel analysis (as received basis)

EPA M19- Eq. 19-13

$$F_d = \frac{\left[(3.64)\ \%H_2 + (1.53)\ \%C + (0.57)\ \%S + (0.14)\ \%N - (0.46)\ \%O_2 \right] \frac{scf}{lb} \bullet 10^6 \frac{Btu}{MBtu}}{GCV \frac{Btu}{lb}}$$

AA2. Calculation of F_c factor from fuel analysis (as received basis)

EPA M19- Eq. 19-14

$$F_c = \frac{\left[(0.321)\ \%C \right] \frac{scf}{lb} \bullet 10^6 \frac{Btu}{MBtu}}{GCV \frac{Btu}{lb}}$$

Percent H_2, C, S, N, and O_2 taken from **Ultimate** coal analysis.

F Factors for Various Fuels

EPA M19, Table 19-1

Fuel Type	F_d dscf/MBtu	F_w wscf/MBtu	F_c scf/MBtu
Coal:			
Anthracite..........	10,100	10,540	1,970
Bituminous	9,780	10,640	1,800
Lignite..................	9,860	11,950	1,910
Oil	9,190	10,320	1,420
Gas:			
Natural.................	8,710	10,610	1,040
Propane...............	8,710	10,200	1,190
Butane.................	8,710	10,390	1,250
Wood	9,240		1,830
Wood Bark................	9,600		1,920
Municipal	9,570		1,820

Appendix B

Blank Residue Limits

		VOLUME OF BLANK					
SOLVENT	DENSITY	50 ml	100 ml	150 ml	200 ml	250 ml	500 ml
ACETONE	0.7857	0.0004	0.0008	0.0012	0.0016	0.0020	0.0039
BENZENE	0.8787	0.0004	0.0009	0.0013	0.0018	0.0022	0.0044
CHLOROFORM	1.4832	0.0007	0.0015	0.0022	0.0030	0.0037	0.0074
ETHYL ETHER	0.7138	0.0004	0.0007	0.0011	0.0014	0.0018	0.0036
HEXANE	0.6603	0.0003	0.0007	0.0010	0.0013	0.0017	0.0033
2-PROPANOL	0.7855	0.0004	0.0008	0.0012	0.0016	0.0020	0.0039
METHANOL	0.7914	0.0004	0.0008	0.0012	0.0016	0.0020	0.0040
METHYLENE CHLORIDE	1.3266	0.0007	0.0013	0.0020	0.0027	0.0033	0.0066
TOLUENE	0.8669	0.0004	0.0009	0.0013	0.0017	0.0022	0.0043
WATER	1.0000	0.0005	0.0010	0.0015	0.0020	0.0025	0.0050
		RESIDUE IN GRAMS					

The maximum allowable blank for acetone used for an EPA M5 test is 0.001 percent of the acetone weight. (EPA M5- Section 3.2) The same criteria is used for Methylene Chloride in EPA M202.

To calculate the allowable blank residue weight for other solution volumes, divide the density by 100,000 (0.001 percent), then multiple by the new volume. Do all calculations first, then round the final value to four decimal places, which is the accuracy of the analytical balance.

Limit on liquid blank = (Liquid Density g/ml) * (Volume ml) * (0.001)/100

The density of acetone was taken from its VWR Scientific container. All other densities were taken from the <u>CRC Handbook of Chemistry</u>, 56th Edition, 1975 - 1976.

Note for Backhalf water condensibles:

For backhalf water condensibles, subtract Vlc from the total (sample collected plus the rinse). Use this volume when calculating allowable blank value.

Length				Velocity			
1 cm	=	0.3937	in	1 m/s	=	3.2808	ft/s
1 m	=	3.2808	ft	1 mph	=	1.4667	ft/s
1 yd	=	3	ft	1 mph	=	0.8684	knot
1 mi	=	5280	ft	1 km/h	=	0.27778	m/s
1 km	=	3280.8	ft	1 km/h	=	0.62138	mph

Pressure				Area			
1 "Hg	=	33.864	mbar	1 cm^2	=	0.15500	in^2
1 atm	=	29.921	"Hg	1 m^2	=	10.76391	ft^2
1 atm	=	1013.25	mbar	1 mi^2	=	2.5899	m^2
1 atm	=	760	mm Hg	1 yd^2	=	0.8361274	m^2
1 atm	=	14.696	psi	1 acre	=	4074	m^2
1 psi	=	2.036	"Hg	1 acre	=	43,560	ft^2
1 psi	=	6.895	kPa	1 mi^2	=	2.5900	km^2

Volume			Mass		
1 ft^3	= 28.316	liter	1 oz	= 28.350	g
1 liter	= 0.03532	ft^3	1 lb	= 0.45359	kg
1 liter	= 0.26418	gal	1 kg	= 2.2046	lb
1 m^3	= 264.18	gal	1 g	= 15.432	grains
1 ft^3	= 7.4806	gal	1 lb	= 7000	grains
1 m^3	= 35.314	ft^3	1 kip	= 1000	lb
1 in^3	= 16.3871	cm^3			

Volume Flow Rate			Temperature	
1 cfm	= 7.4805	gal/min	°F	= (9/5)•°C + 32
1 cfm	= 0.4719	liter/s	°R	= °F + 459.67
1 m^3/s	= 35.316	ft^3/s	°C	= 5/9•(°F - 32)
1 m^3/s	= 2119	cfm	°K	= °C + 273.15
1 gal/min	= 0.13368	cfm	°K	= (5/9)•(°F - 32) + 273

Work and Heat			Power		
1 Btu	= 777.65	ft-lb	1 Hp	= 550.00	ft-lb/s
1 Btu	= 1054.3	J	1 Hp	= 2545.5	Btu/hr
1 Btu	= 0.292875	W-hr	1 Hp	= 745.70	W
1 J	= 9.4845 x 10^{-4}	Btu	1 W	= 3.4135	Btu/hr
1 J	= 107	ergs	1 kW	= 1.3410	Hp
1 kW-hr	= 3414.4	Btu			
1 Cal	= 3.0860	ft-lb			

Gas Concentration Conversions:

lb/scf	**=** $(\text{ppm } SO_2)(1.660 \times 10^{-7})$ **or**	EPA M19 - Section 2
	= $(\text{ppm } NO_x)(1.194 \times 10^{-7})$ **or**	EPA M19 - Section 2
	= $(\text{ppm } CO)(7.270 \times 10^{-8})$	From Equation E2

Common Molecular Weights

SO_2 = 64.06, CO = 28.01

NO_x = 46.01, THC = 44.10 (propane)

Clean Air Engineering

Appendix D

Shipping Information

Air Freight	Phone #	Account #
SEKO	1-800-323-1964	414824
American	1-800-334-7400	F639370
Continental	1-312-686-4720	235546
Fed Ex	1-800-238-5355	0605-1738-0
Northwest	1-800-692-2746	433440
TWA	1-800-892-6398	STL 1472015
United	1-800-631-1500	362655
US Air	1-312-686-7150	C 493710

General Notes on Shipping:
The shipper will want to know the number of packages being shipped and the total weight. Label each box as # ___ of ___ (eg # 5 of 25). Clean Air Shipping labels are generally acceptable.

Be sure to clear it with the client in terms of where the goods may be left for pickup (eg. do they have a shipping and receiving building.)

Appendix E

Saturated Vapor Pressure Table

Temperature (T) in °F and SVP in "Hg

T	SVP	T	SVP	T	SVP	T	SVP	T	SVP
30	0.1647	67	0.6669	104	2.178	141	6.032	178	14.62
31	0.1715	68	0.6903	105	2.243	142	6.188	179	14.95
32	0.1803	69	0.7144	106	2.310	143	6.348	180	15.29
33	0.1878	70	0.7392	107	2.379	144	6.511	181	15.63
34	0.1955	71	0.7648	108	2.449	145	6.678	182	15.98
35	0.2035	72	0.7912	109	2.521	146	6.848	183	16.33
36	0.2118	73	0.8183	110	2.596	147	7.022	184	16.69
37	0.2203	74	0.8462	111	2.672	148	7.200	185	17.06
38	0.2292	75	0.8750	112	2.749	149	7.382	186	17.44
39	0.2383	76	0.9046	113	2.829	150	7.567	187	17.82
40	0.2478	77	0.9352	114	2.911	151	7.756	188	18.21
41	0.2576	78	0.9666	115	2.995	152	7.950	189	18.60
42	0.2677	79	0.9989	116	3.081	153	8.147	190	19.01
43	0.2783	80	1.032	117	3.169	154	8.349	191	19.42
44	0.2891	81	1.066	118	3.259	155	8.554	192	19.84
45	0.3004	82	1.102	119	3.351	156	8.765	193	20.26
46	0.3120	83	1.138	120	3.446	157	8.979	194	20.70
47	0.3240	84	1.175	121	3.543	158	9.198	195	21.14
48	0.3364	85	1.213	122	3.642	159	9.421	196	21.59
49	0.3493	86	1.253	123	3.744	160	9.649	197	22.04
50	0.3626	87	1.293	124	3.848	161	9.882	198	22.51
51	0.3764	88	1.335	125	3.954	162	10.12	199	22.98
52	0.3906	89	1.378	126	4.063	163	10.36	200	23.46
53	0.4052	90	1.422	127	4.174	164	10.61	201	23.95
54	0.4203	91	1.467	128	4.289	165	10.86	202	24.45
55	0.4359	92	1.513	129	4.406	166	11.12	203	24.95
56	0.4520	93	1.561	130	4.525	167	11.38	204	25.47
57	0.4586	94	1.610	131	4.647	168	11.65	205	25.99
58	0.4858	95	1.660	132	4.772	169	11.92	206	26.53
59	0.5035	96	1.712	133	4.900	170	12.20	207	27.07
60	0.5218	97	1.765	134	5.031	171	12.48	208	27.62
61	0.5407	98	1.819	135	5.165	172	12.77	209	28.18
62	0.5601	99	1.875	136	5.302	173	13.06	210	28.75
63	0.5802	100	1.932	137	5.442	174	13.36	211	29.33
64	0.6009	101	1.992	138	5.585	175	13.67	212	29.92
65	0.6222	102	2.052	139	5.732	176	13.98		
66	0.6442	103	2.114	140	5.879	177	14.30		

SVP values for temperatures ranging from 30 to 139°F were taken from the Quality Assurance Handbook for Air Pollution Measurement Systems: Volume III., Stationary Source Specific Methods, Addition Section 3.12, Method 9 - Visible Determination of Opacity Emissions from Stationary Sources, Table 6.2.

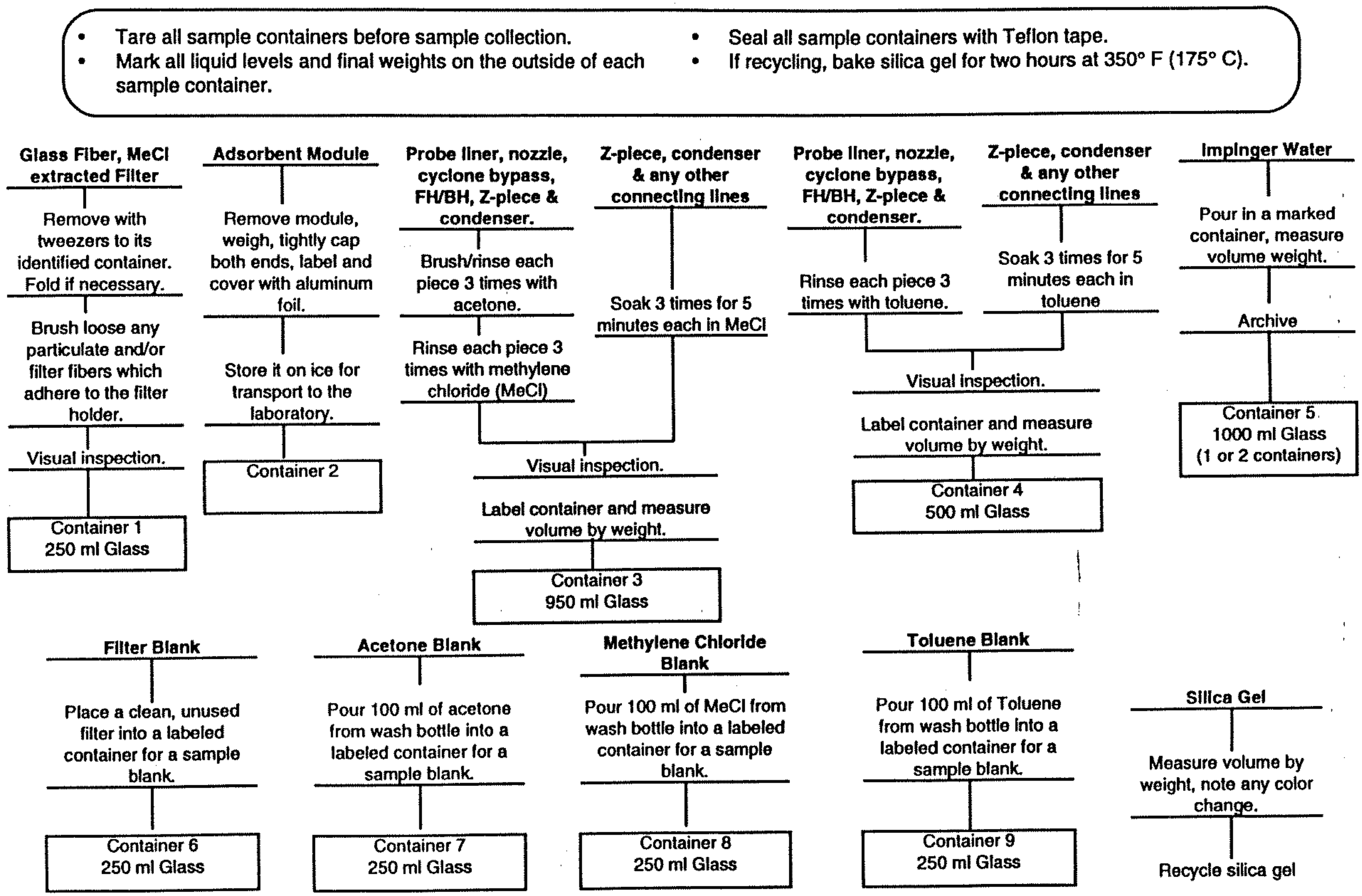
High temperatures were approximated from polynomial F6 shown on page 17 based on empirical data.

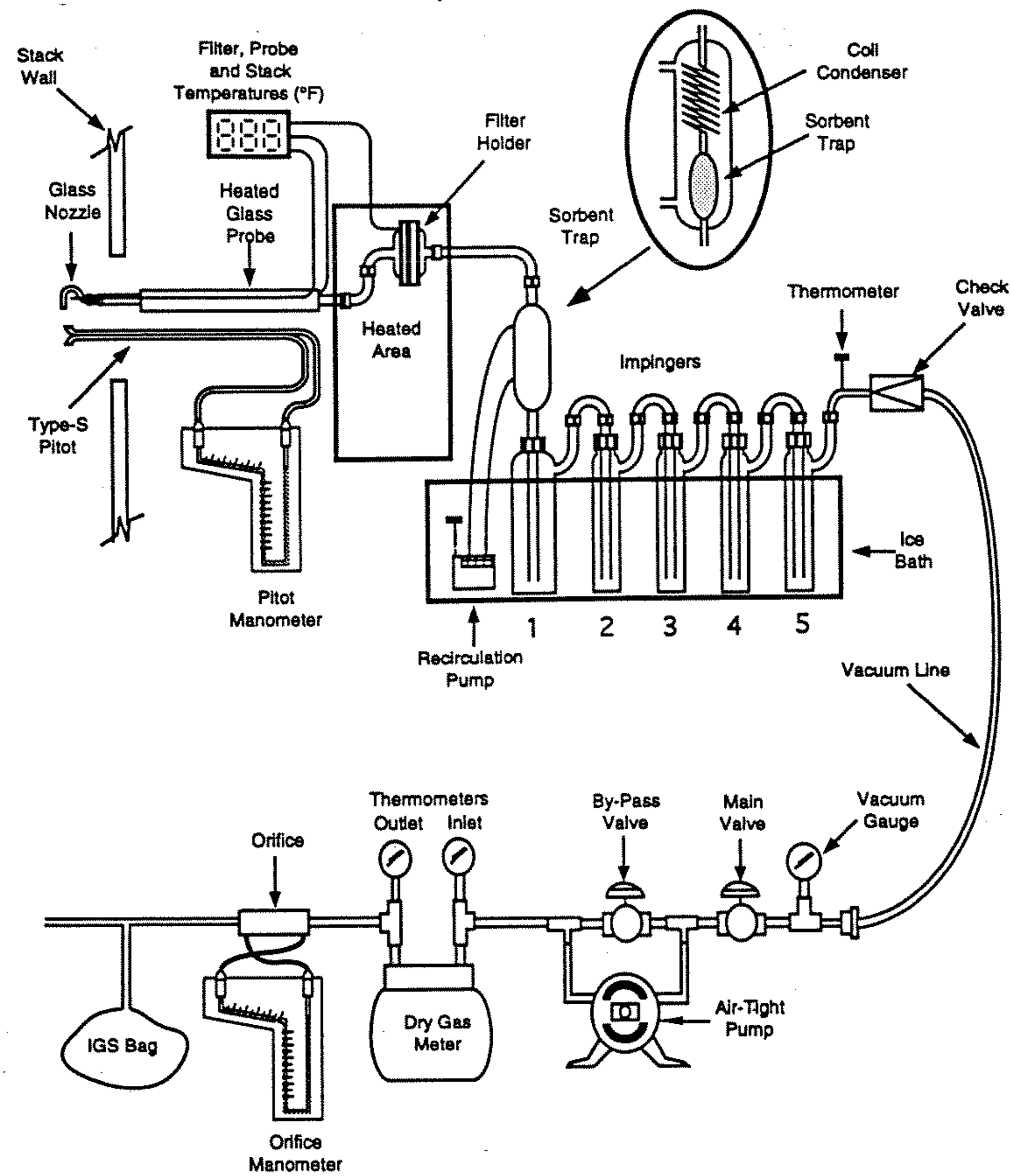
CLEAN AIR ENGINEERING

SAMPLING RECOVERIES AND TRAINS

REVISION 0: NOVEMBER 10, 1995

METHOD 23 - DETERMINATION OF POLYCHLORINATED DIBENZO-P-DIOXINS AND POLYCHLORINATED DIBENZOFURANS EMISSIONS FROM STATIONARY SOURCES





M23 - Dioxins/Furans

Impinger 1	empty
Impinger 2	100 ml HPLC water
Impinger 3	100 ml HPLC water
Impinger 4	empty
Impinger 5	silica gel

Method 12 - Determination of Inorganic Lead Emissions from Stationary Sources

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Unweighed, Gelman Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
Petri Dish

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Brush/rinse 3 times with 0.1 N HNO_3.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Plastic

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into labeled container.

Clean each piece 3 times with 0.1 N HNO_3.

Visual inspection.

Label container and measure volume by weight.

Container 3
1000 ml Plastic

Filter Blank

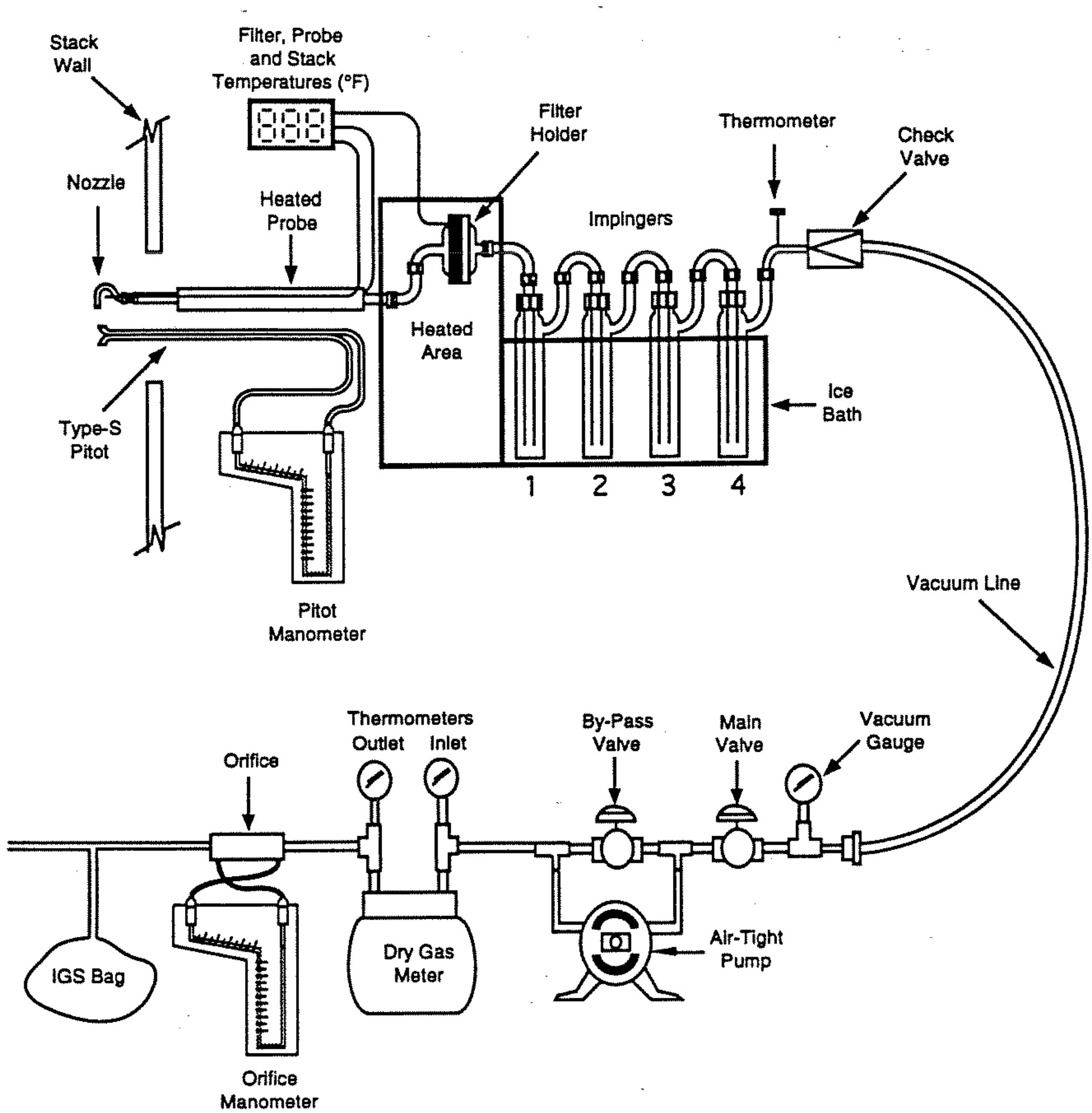
Place a clean, unused filter into a labeled container for a sample blank.

Container 4
Petri Dish

0.1 N HNO_3 Blank

Pour 200 ml of HNO_3 from wash bottle into a labeled container for a sample blank.

Container 5
250 ml Plastic

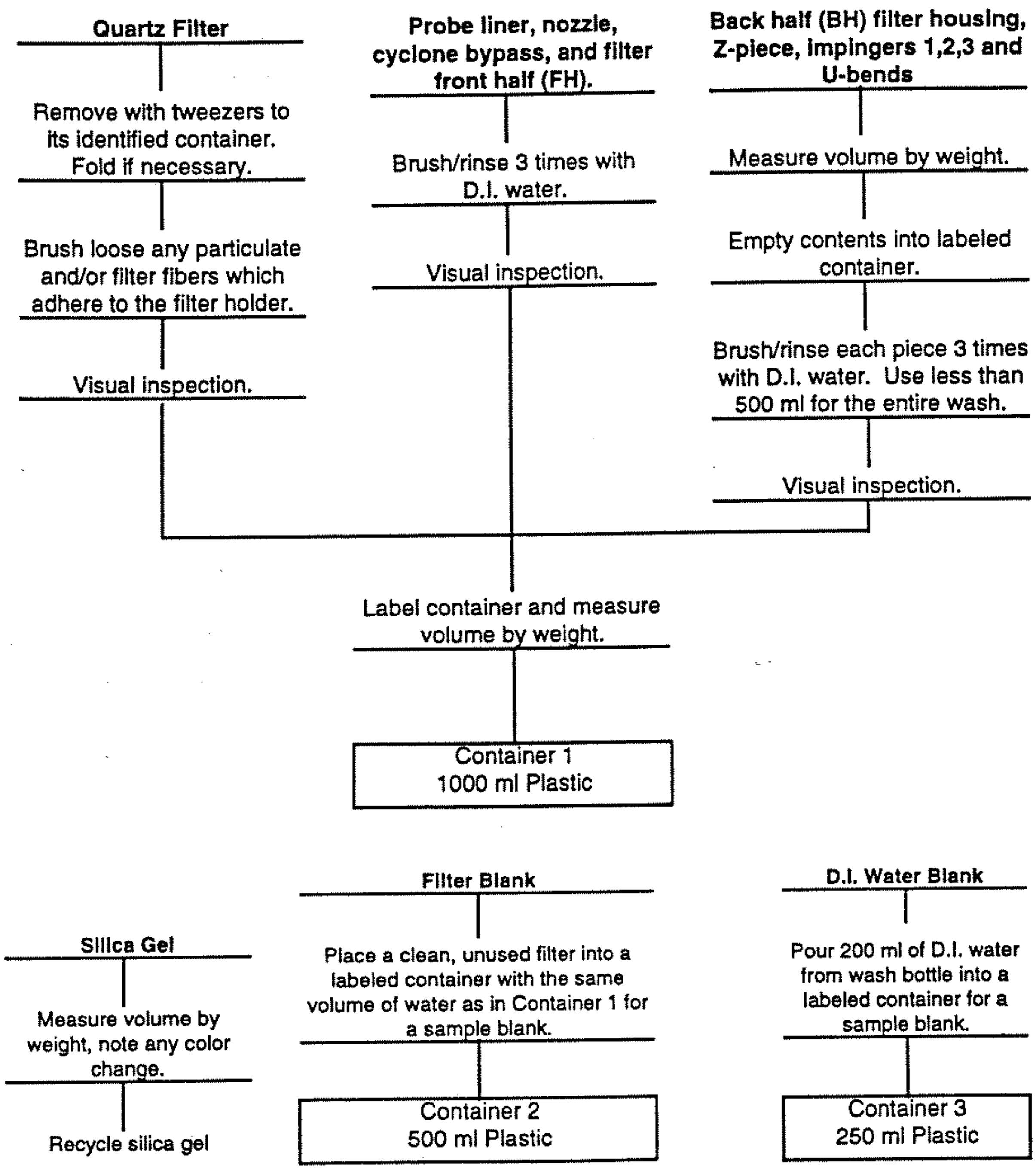


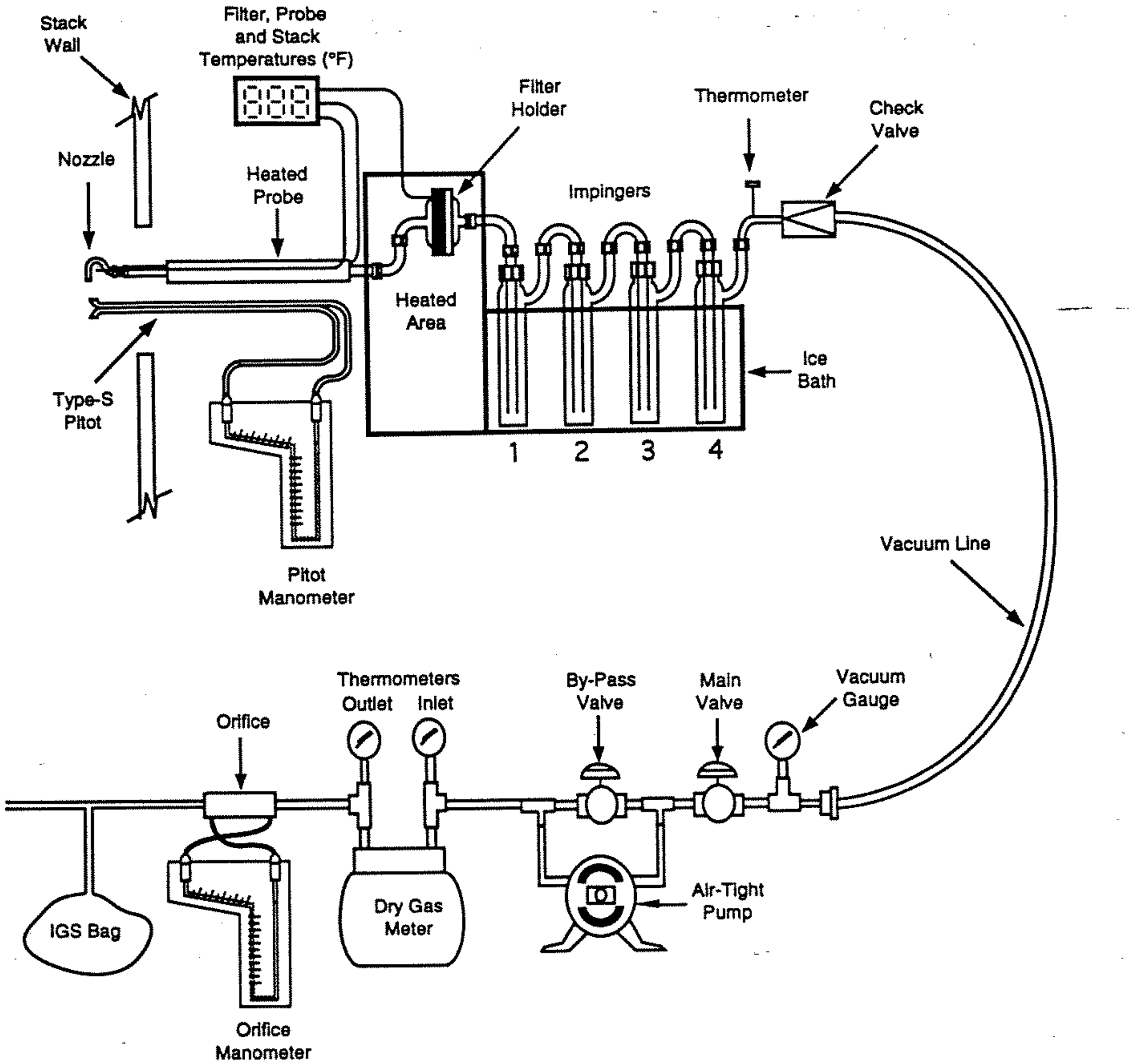
Method 12- Lead

absorbing solution (0.1 N HNO_3)	Dilute 6.5 ml of concentrated nitric acid (HNO_3) to 1 liter with DI water
Impinger 1	100 ml 0.1 N HNO_3
Impinger 2	100 ml 0.1 N HNO_3
Impinger 3	empty
Impinger 4	silica gel

METHOD 13B - DETERMINATION OF TOTAL FLUORIDE EMISSIONS FROM STATIONARY SOURCES

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).





M13B - Hydrogen Fluoride

Impinger 1	100 ml DI water
Impinger 2	100 ml DI water
Impinger 3	empty
Impinger 4	silica gel

Method 8 - Determination of Sulfuric Acid Mist and Sulfur Dioxide Emissions from Stationary Sources

- **Immediately after sampling the train should be purged with ambient air for 15 minutes, during this time the ice bath should also be drained.**
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Quartz Filter

- Remove filter with tweezers to its identified container. Fold if necessary.
- Brush loose any particulate and/or filter fibers which adhere to filter holder
- Visual Inspection
- → Container 1, 250 ml Plastic

Probe liner, nozzle, cyclone bypass, and filter FH

- Brush/rinse with acetone or 80% isopropyl alcohol (IPA) depending on the project.
- Visual Inspection
- Label container and measure volume by weight.
- → Container 1, 250 ml Plastic

Container 1
250 ml Plastic

Filter BH, Z-piece, Impinger 1, second filter holder, glass wool or U-bend

- Measure impinger 1 volume by weight.
- Brush/rinse with acetone or 80% isopropyl alcohol (IPA).
- Place 2nd filter or glass wool into the container.
- Visual Inspection
- → Container 2, 500 or 1000 ml Plastic

Impingers 2, 3 and U-bends

- Measure volume by weight.
- Transfer contents to labeled container.
- Rinse 3 times with D.I. water.
- Visual Inspection
- Measure volume by weight
- → Container 3, 500 ml Plastic

Silica Gel

- Measure volume by weight, note any color change.
- Recycle silica gel

Filter Blank

- Place a clean, unused quartz filter into a labeled container for a sample blank.
- → Container 4, Petri Dish

Acetone Blank

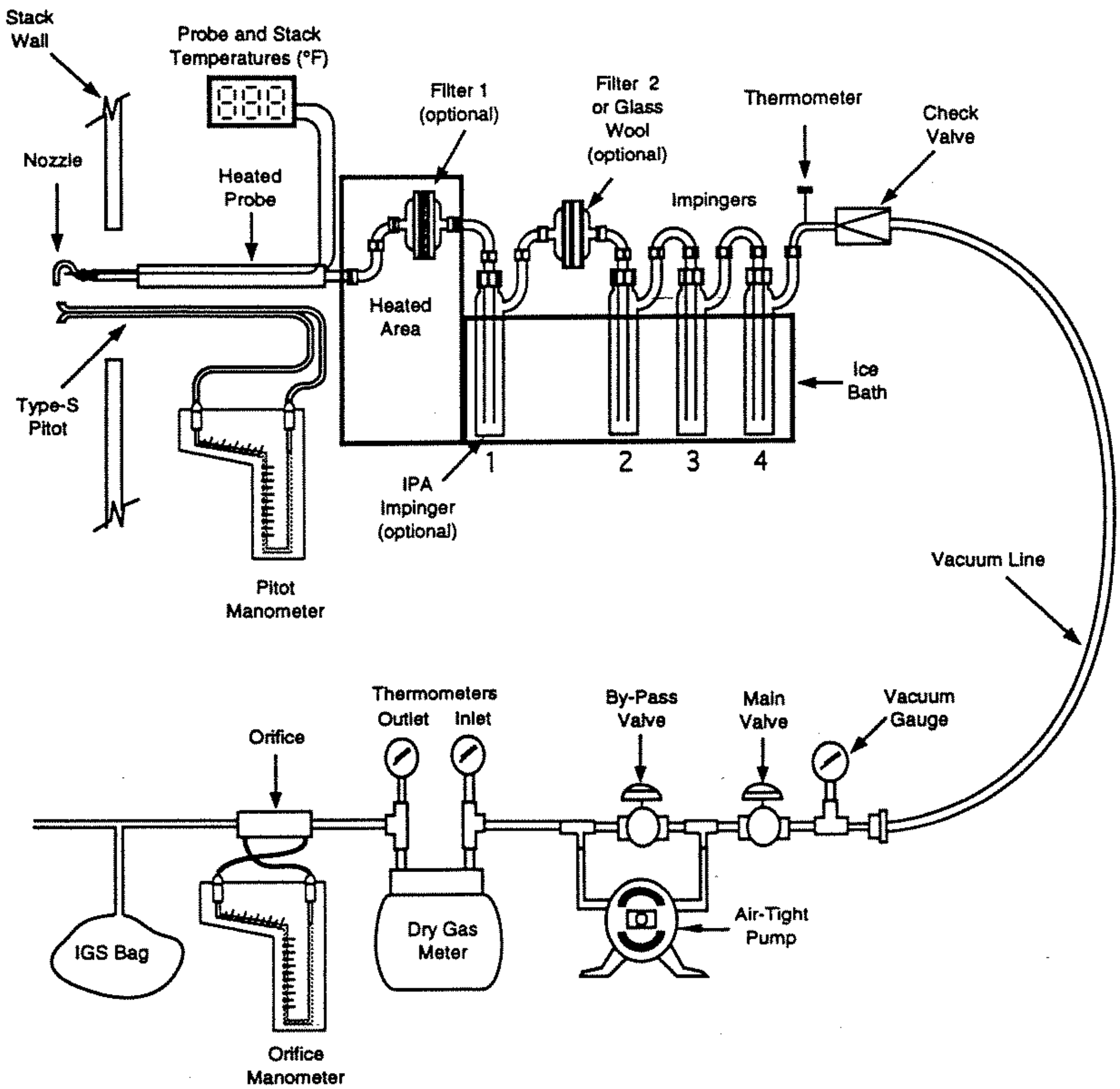
- Pour 100 ml of acetone from wash bottle into a labeled container for a sample blank.
- → Container 5, 250 ml Glass

IPA Blank

- Pour 100 ml of IPA from wash bottle into a labeled container for a sample blank.
- → Container 6, 250 ml Plastic

Hydrogen Peroxide Blank

- Pour 200 ml of water from wash bottle into a labeled container for a sample blank.
- → Container 7, 250 ml Plastic



M8 - Sulfuric Acid Mist and Sulfur Dioxide

absorbing solution (80% IPA)	Mix 800 ml isopropanol (IPA) with 200 ml DI water
absorbing solution (3%H_2O_2)	Dilute 100 ml of 30% hydrogen peroxide (H_2O_2) with 1 liter of DI water, prepare daily

Impinger 1	100 ml 80% IPA
Impinger 2	100 ml 3% H_2O_2
Impinger 3	100 ml 3% H_2O_2
Impinger 4	silica gel

Filter 1 used only if separating condensed acid mist particles.
Filter 2 or glass wool and IPA impinger only used when looking for gaseous SO_3.

METHOD 26 : DETERMINATION OF HYDROGEN CHLORIDE EMISSIONS FROM STATIONARY SOURCES

(NO SODIUM HYDROXIDE IMPINGER)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Teflon Filter

No recovery necessary

Impingers 1,2,3 and U-bends

Empty contents into container.

Rinse components 3x with D.I. water

Label container and measure volume by weight.

Visual inspection

Container 1
500 ml plastic

Sulfuric Acid Blank(H_2SO_4)

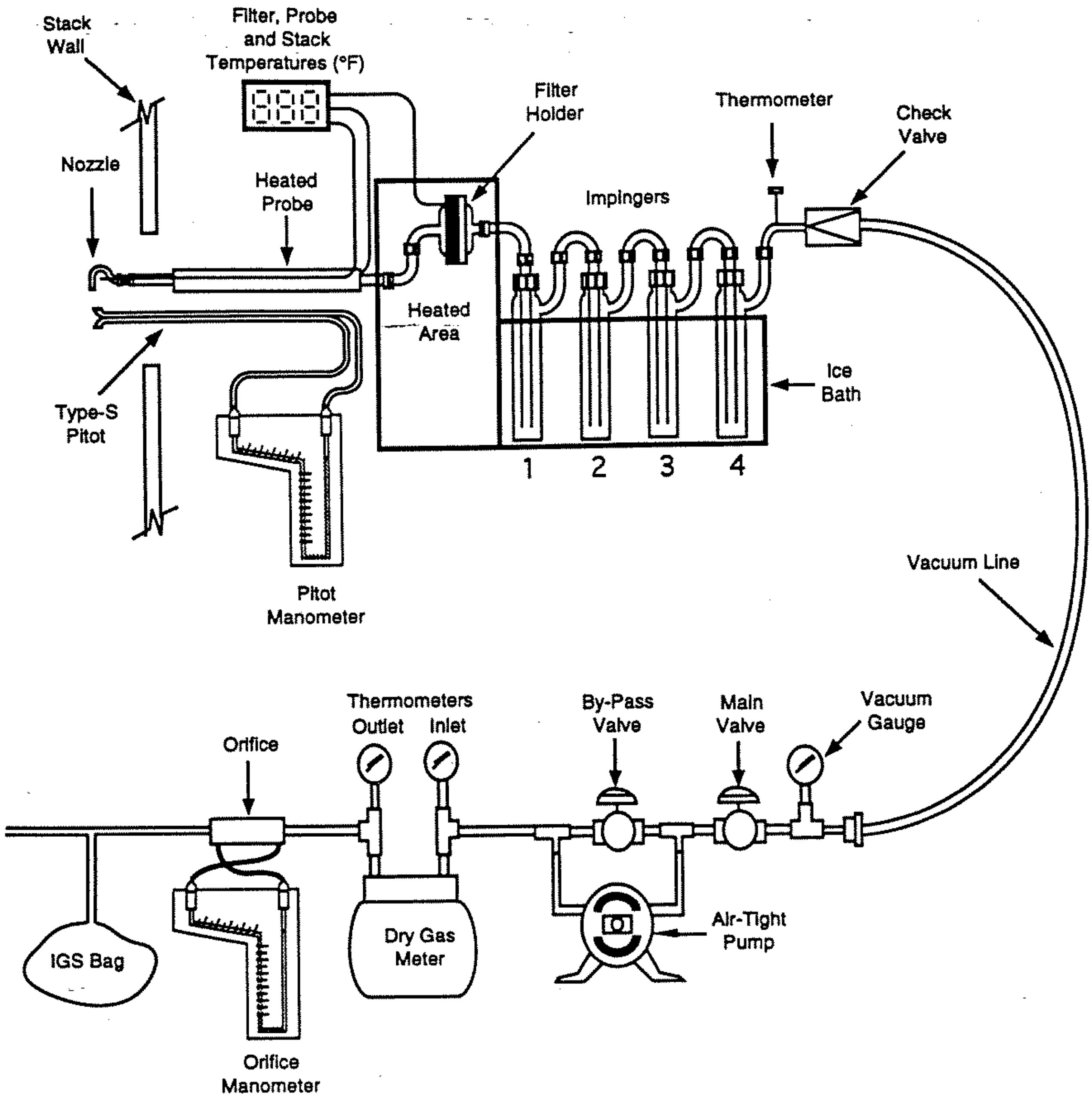
Pour 200 ml of 0.1N H_2SO_4 in a labeled container for a sample blank.

Container 2
250 ml plastic

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel



Modified M26 - Hydrogen Chloride absorbing solution (0.1 N H_2SO_4)

Slowly add 2.8 ml concentrated sulfuric acid (H_2SO_4) to approximately 1000 ml DI water. Shake well to mix the solution.

Impinger 1	100 ml 0.1 N H_2SO_4
Impinger 2	100 ml 0.1 N H_2SO_4
Impinger 3	empty
Impinger 4	silica gel

Note: This is generally single point non-isokinetic sampling train.

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Tared, Quartz Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
Petri Dish

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Glass

Back half (BH) filter housing, Z-piece, Impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into labeled container.

Rinse with water.

Visual inspection.

Label container and measure volume by weight.

Container 3*
500 ml Plastic

Filter Blank

Place a clean, unused tared filter into a labeled container for a sample blank.

Container 4
Petri Dish

Acetone Blank

Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 5
250 ml Glass

Silica Gel

Measure volume by weight, note any color change.

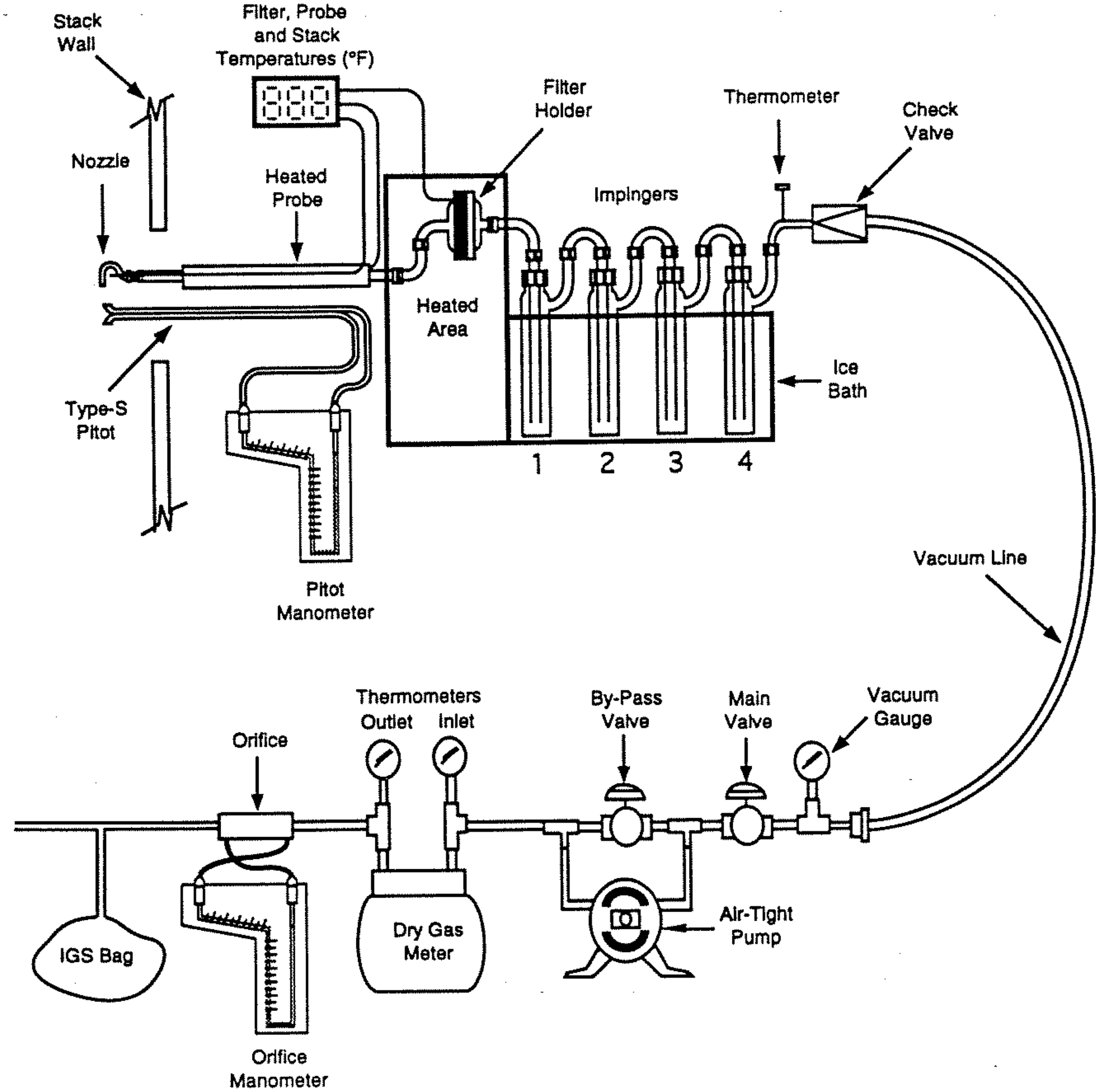
Recycle silica gel

Water Blank

Pour 200 ml of water from wash bottle into a labeled container for a sample blank.

Container 6*
250 ml Plastic

*Containers 3 and 6 are required only when the testing includes a back half analysis.



M5 - Particulate

Impinger 1	100 ml H_2O
Impinger 2	100 ml H_2O
Impinger 3	empty
Impinger 4	silica gel

METHOD 29 - DETERMINATION OF METALS EMISSIONS FROM STATIONARY SOURCES
(INCLUDING MERCURY DETERMINATION, EXCLUDING PARTICULATE DETERMINATION)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Unweighed Quartz filter

Remove with ACID-WASHED poly propylene or Teflon tweezers, to an identified container.

If necessary, fold the filter and transfer it to its identified container. Remove any particulate or filter fibers that may adhere to the filter housing

Container 1
250 ml Plastic

Probe liner, nozzle, cyclone bypass, and FH filter housing

Brush/rinse 3 times with a total of 100 ml of 0.1 N HNO_3.

Visual inspection.

Label container and measure volume by weight.

Container 3
250 ml Plastic

BH filter housing, Z-piece, Impingers1,2,3 and U-bends

Measure impingers' volume by weight.

Clean each piece 3 times with 0.1 N HNO_3, use a total of 100 ml.

Visual inspection.

Label container and measure volume by weight.

Container 4
1000 ml Plastic

Impinger 4 and U-bend

Measure impinger's volume by weight.

Rinse with 100 ml of with 0.1 N HNO_3.

Visual inspection.

Label container and measure volume by weight.

Container 5A
250 ml ~~Glass~~ Plastic

Impingers 5, 6 and U-bends

Measure impingers' volume by weight.

Clean each piece 3 times with acidic permanganate solution, use 100 ml total

Rinse each piece 3 times with water, use a total of 350 ml.

Visual inspection.

Label container and measure volume by weight.

**Container 5B
950 ml Glass

Remove any residue with a total of 25 ml of 8 N HCl.

Place 200 ml of water in container, then add the HCl rinse.

Label container and measure volume by weight.

**Container 5C
250 ml Glass

**Note: There may be some pressure build up in the sample container. These should NOT be filled full. Venting is highly recommended.

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel

Nitric Acid Blank

Pour 200 ml of 0.1 N HNO_3 from wash bottle into a labeled container.

Container 8A
250 ml Plastic

Water Blank

Place 200 ml of water in sample bottle.

Container 8B
250 ml Plastic

5% HNO_3/10% H_2O_2 Blank

Pour 400 ml of nitric acid absorbing solution from wash bottle into a labeled container.

Container 9
500 ml Plastic

Permanganate Blank

Place 200 ml of $KMnO_4$ solution in a labeled container for sample blank.

**Container 10
500 ml Glass

HCl Rinse Blank

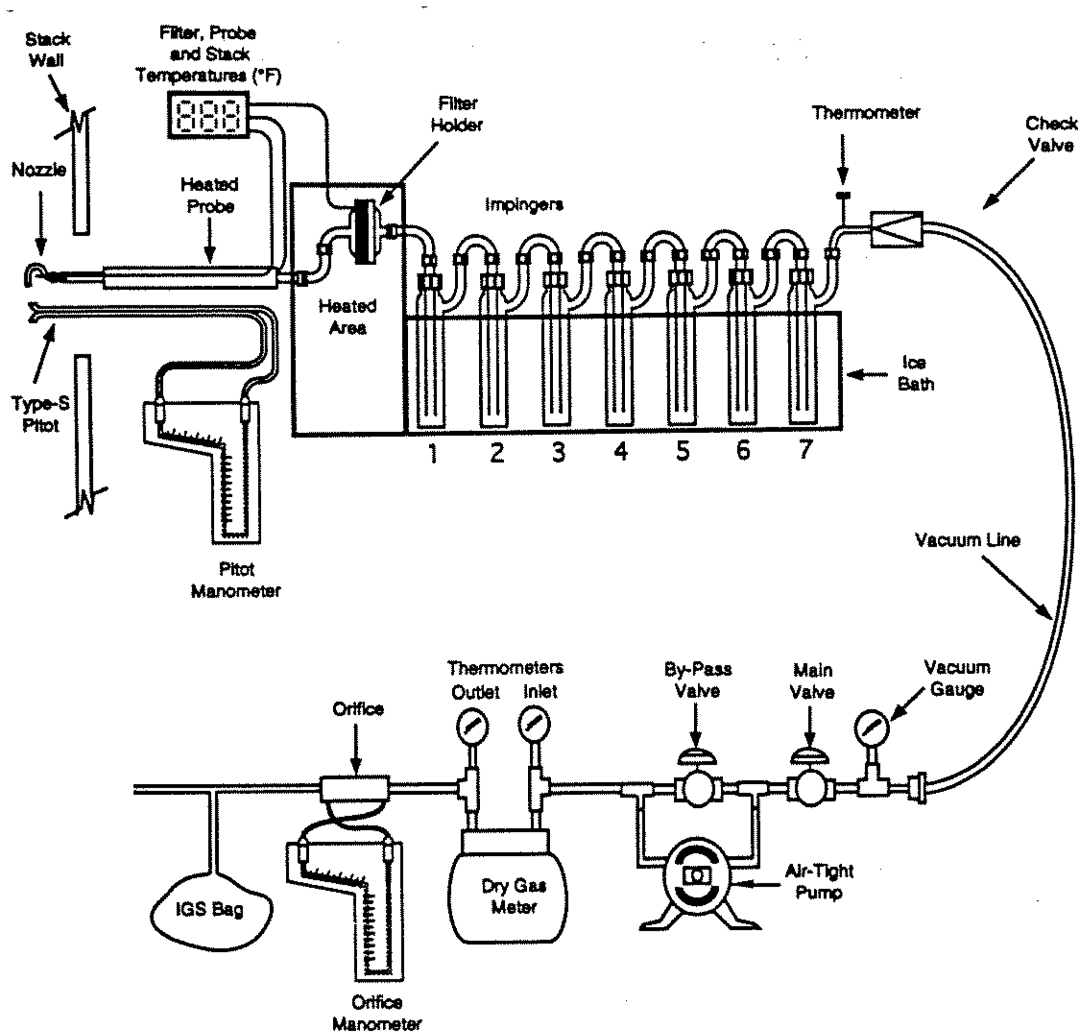
Place 200 ml of water in sample bottle add 25 ml of 8 N HCl carefully with stirring. Only need 1 per set of 3 runs. Mix well and seal.

Container 11
250 ml Glass

Filter Blanks

Place 3 clean, unused filters into a labeled container.

Container 12
Petri Dish



Proposed EPA Method 29 - Metals

Metals absorbing soln (5%HNO_3/10% H_2O_2)

Mix 50 ml concentrated nitric acid (HNO_3) in 500 ml of DIUF water, add 333 ml of 30% H_2O_2 and dilute to 1 liter

Mercury absorbing solution (4% $KMnO_4$/10% H_2SO_4)

Dissolve, with stirring, 40 grams pottasium permanganate ($KMnO_4$) in 900 ml of DIUF water. Slowly add 100 ml concentrated sulfuric acid (H_2SO_4) and mix well, just prior to testing.

Mercury rinse solution (8N HCl) — Add 69 ml of concentrated HCl to 25 ml deionized distilled water (Add acid to water). Dilute with DIUF water to 100 ml.

Impinger 1	empty
Impinger 2	100 ml 5% HNO_3/10% H_2O_2
Impinger 3	100 ml 5% HNO_3/10% H_2O_2
Impinger 4	empty
Impinger 5	100 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 6	100 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 7	silica gel

Note: If mercury emissions are not to be determined, then the mercury absorbing solution and mercury rinse solution as well as Impingers 5 and 6 are not needed.

Method 6 - Determination of Sulfur Dioxide Emissions from Stationary Sources

- **Immediately after sampling the train should be purged with ambient air for 15 minutes, during this time the ice bath should also be drained.**
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Quartz Filter

- Remove filter with tweezers to its identified container. Fold if necessary.
- Brush loose any particulate and/or filter fibers which adhere to filter holder
- Visual Inspection
- → Container 1 (250 ml Plastic)

Probe liner, nozzle, cyclone bypass, and filter FH

- Brush/rinse with acetone or 80% isopropyl alcohol (IPA) depending on the project.
- Visual Inspection
- Label container and measure volume by weight.
- → Container 1 (250 ml Plastic)

Container 1
250 ml Plastic

Filter Blank

- Place a clean, unused quartz filter into a labeled container for a sample blank.
- → Container 4 (Petri Dish)

Acetone Blank

- Pour 100 ml of acetone from wash bottle into a labeled container for a sample blank.
- → Container 5 (250 ml Plastic)

Filter BH, Z-piece, Impinger 1, second filter holder or U-bend

- Measure impinger 1 volume by weight.
- Brush/rinse with acetone or 80% isopropyl alcohol (IPA).
- Place 2nd filter or glass wool into the container.
- Visual Inspection
- → Container 2 (250 ml Plastic)

Impingers 2, 3 and U-bends

- Measure volume by weight.
- Transfer contents to labeled container.
- Rinse 3 times with D.I. water.
- Visual Inspection
- Measure volume by weight
- → Container 3 (500 ml Plastic)

IPA Blank

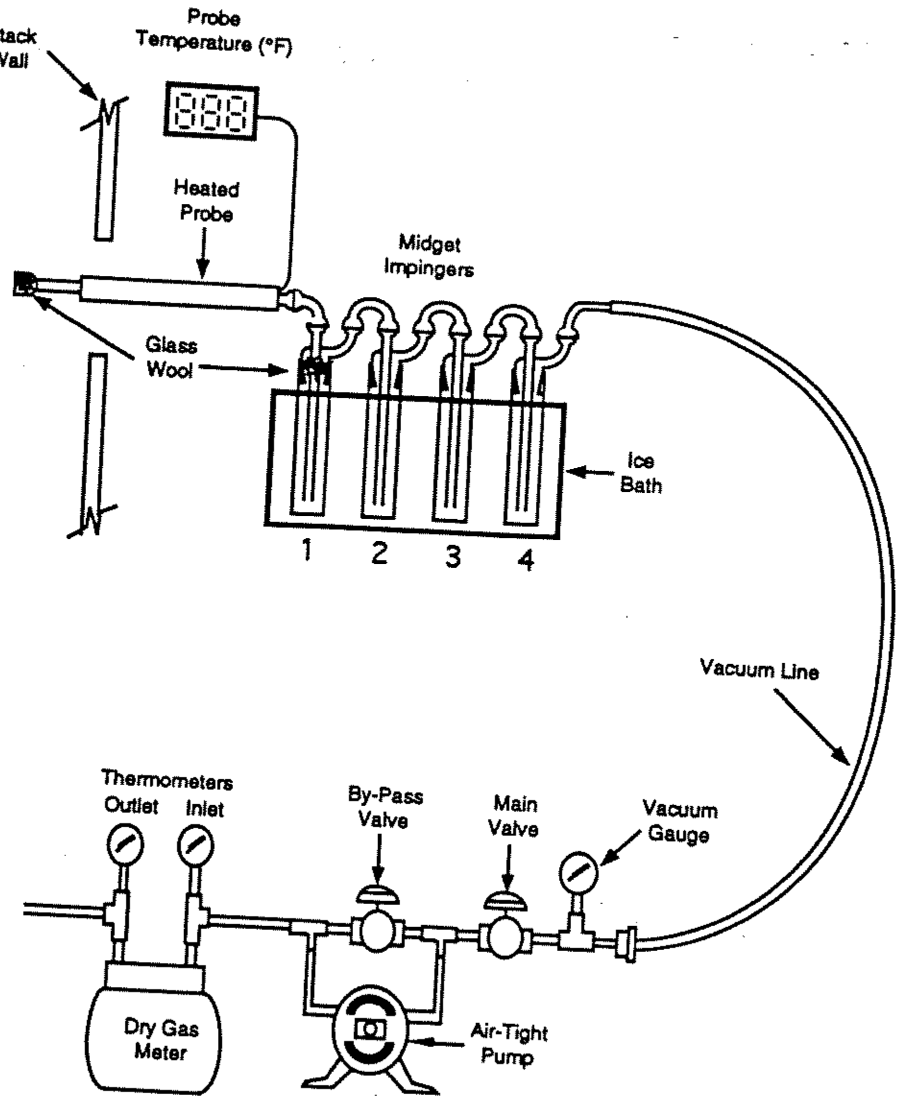
- Pour 100 ml of IPA from wash bottle into a labeled container for a sample blank.
- → Container 6 (250 ml Plastic)

Silica Gel

- Measure volume by weight, note any color change.
- Recycle silica gel

Hydrogen Peroxide Blank

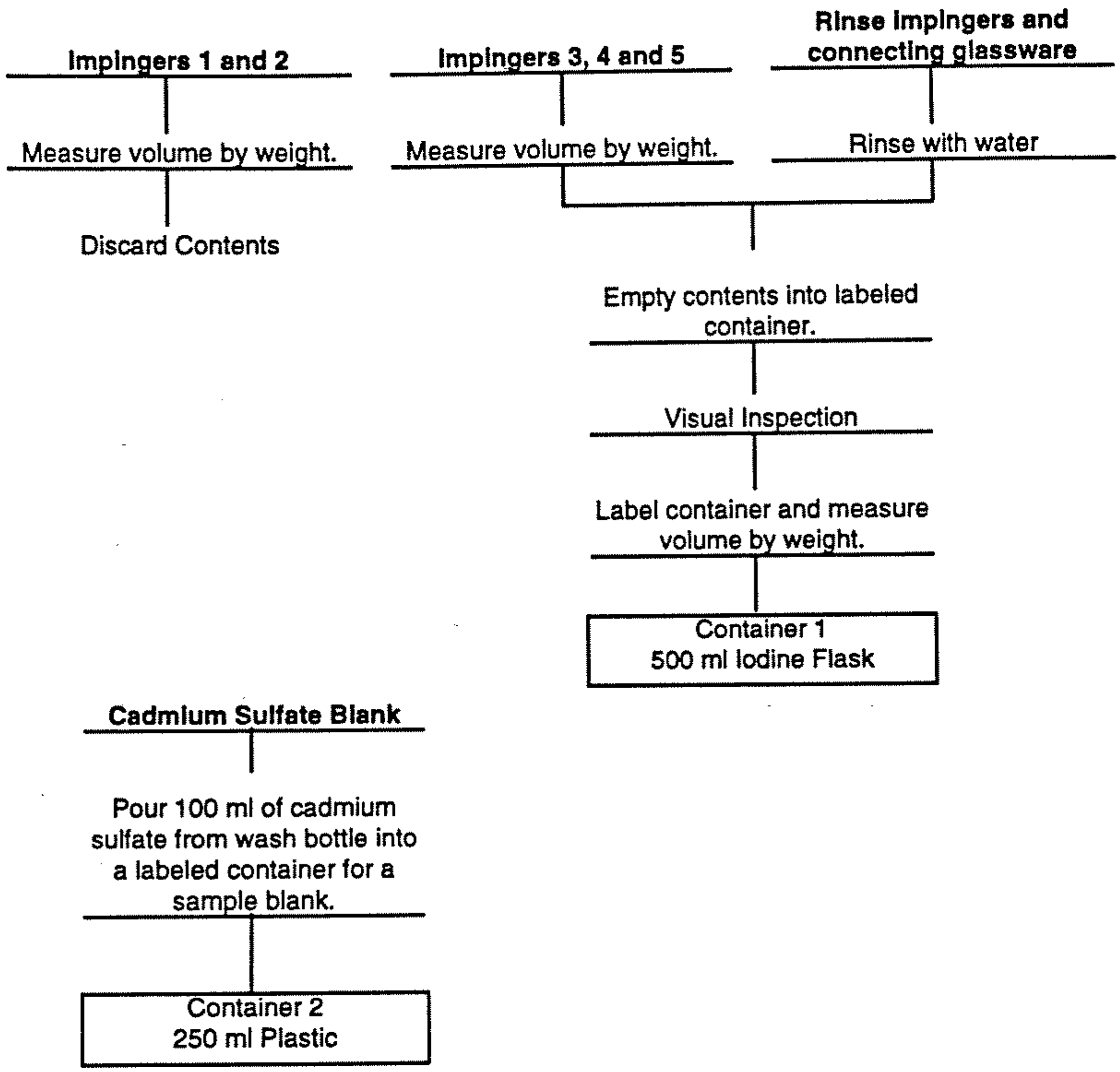
- Pour 200 ml of water from wash bottle into a labeled container for a sample blank.
- → Container 7 (250 ml Plastic)

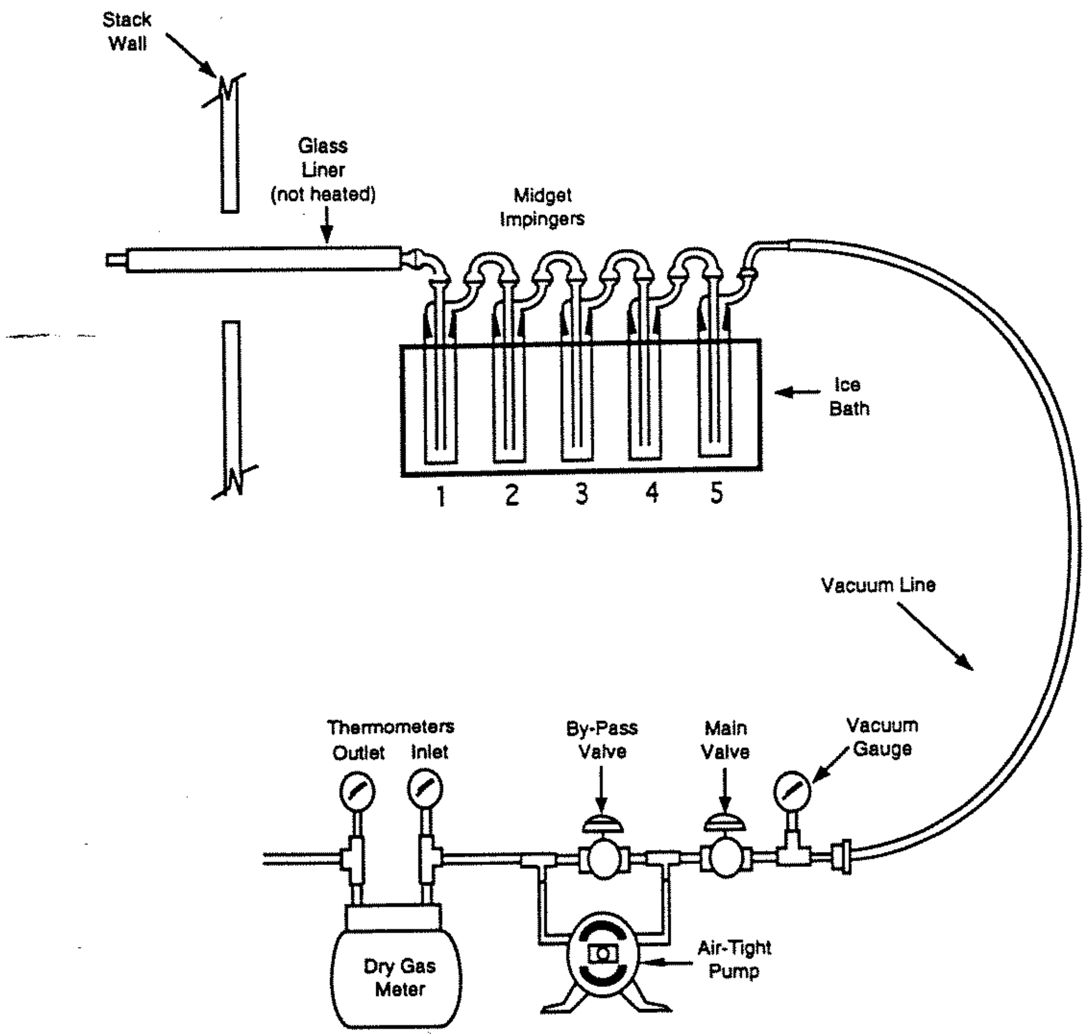


M6 - Sulfur Dioxide

absorbing solution (80% IPA)	Mix 800 ml isopropanol (IPA) with 200 ml DI water
absorbing solution (3%H_2O_2)	Dilute 100 ml of 30% Hydrogen peroxide (H_2O_2) with 1 liter of DI water, prepare daily
Midget Bubbler	15 ml 80% IPA
Midget Impinger 1	15 ml 3% H_2O_2
Midget Impinger 2	15 ml 3% H_2O_2
Midget Impinger 3	empty

- **Immediately after sampling the train should be purged with ambient air for 15 minutes, during this time the ice bath should also be drained.**
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.





Method 11 - Hydrogen Sulfide

absorbing solution (3%H_2O_2)	Dilute 100 ml of 30% Hydrogen peroxide (H_2O_2) with 1 liter of DI water
absorbing solution (cadmium sulfate)	Dissolve 41 g of $3CdSO_4{\bullet}8H_2O$ and 15 ml of 0.1 M sulfuric acid in a 1-liter volumetric flask that contains approximately 3/4 liter of DI water

Midget Impinger 1	15 ml 3% hydrogen peroxide
Midget Impinger 2	empty
Midget Impinger 3	15 ml cadmium sulfate
Midget Impinger 4	15 ml cadmium sulfate
Midget Impinger 5	15 ml cadmium sulfate

METHOD 13B/26: - DETERMINATION OF FLUORIDE/HYDROGEN CHLORIDE EMISSIONS FROM STATIONARY SOURCES

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Impingers 1,2,3 and U-bends

Empty contents into container.

Rinse components 3 times with D.I. water.

Label container and measure volume by weight.

Visual inspection.

Container 1
500 ml plastic

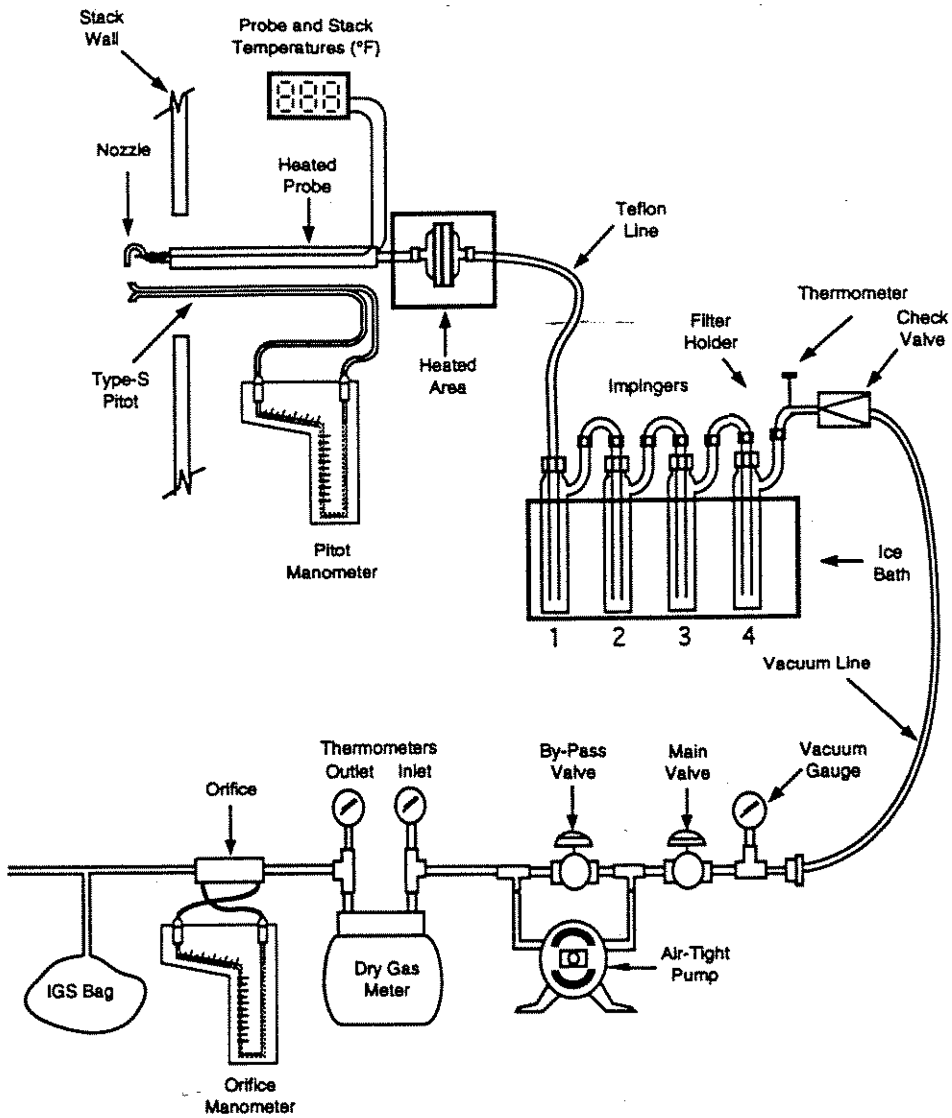
Sulfuric Acid Blank(H_2SO_4)

Pour 200 ml of 0.1N H_2SO_4 into a labeled container for a sample blank.

Container 2
250 ml glass

Filter

No recovery



Modified M26 - Hydrogen Chloride absorbing solution (0.1 N H_2SO_4)

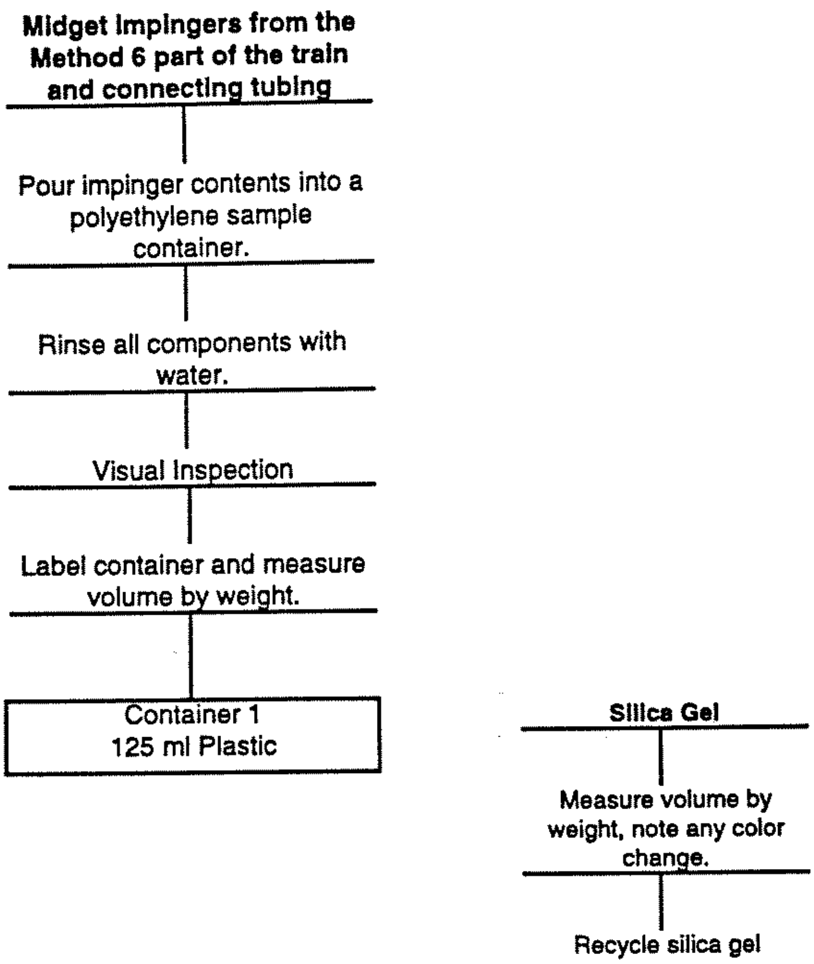
Slowly add 2.8 ml concentrated sulfuric acid (H_2SO_4) to approximately 1000 ml DI water. Shake well to mix the solution.

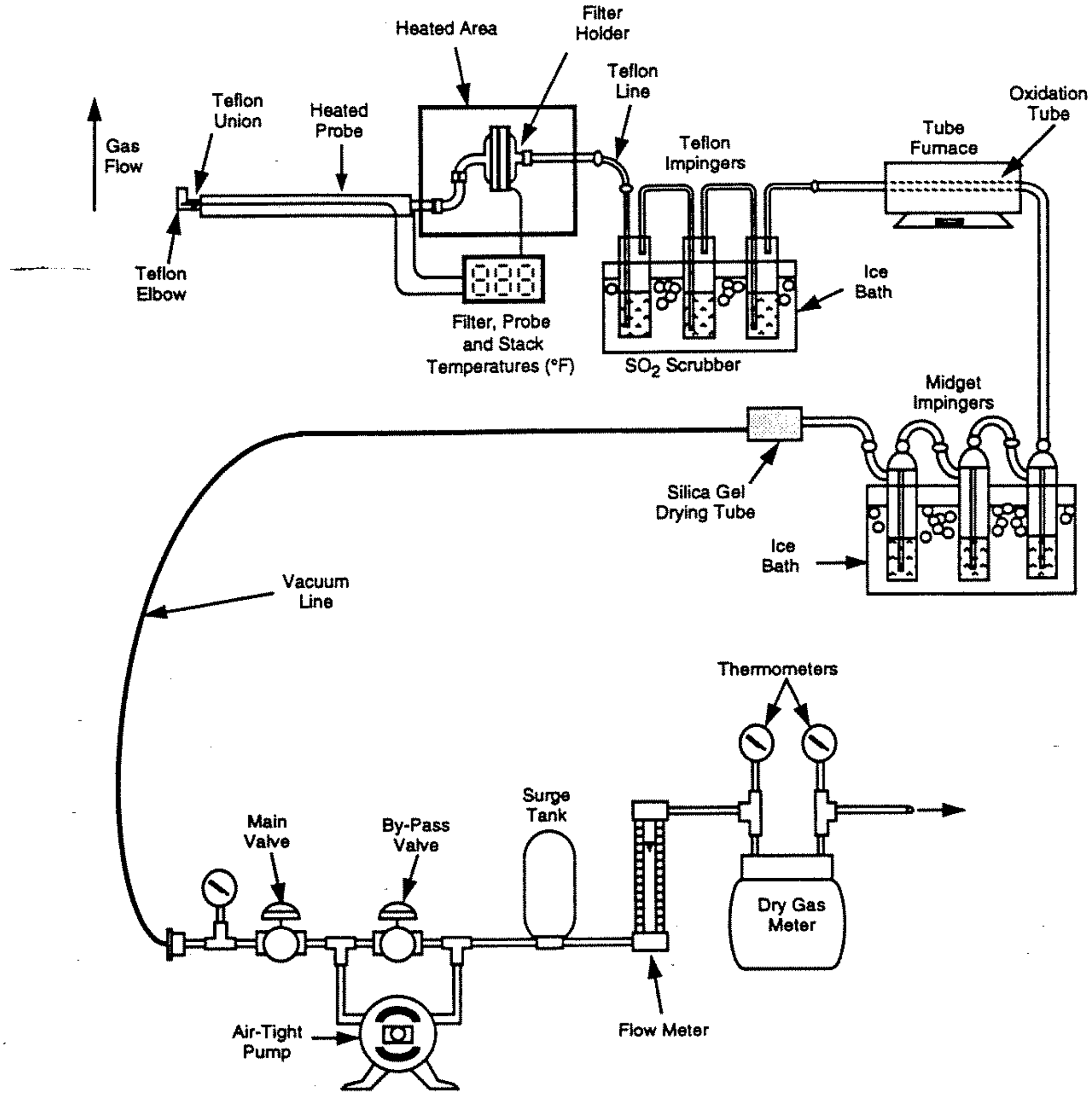
Impinger 1	100 ml 0.1 N H_2SO_4
Impinger 2	100 ml 0.1 N H_2SO_4
Impinger 3	empty
Impinger 4	silica gel

Note: This is generally single point non-isokinetic sampling train.

Method 16A - Determination of Total Reduced Sulfur Emissions from Stationary Sources

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).





M16A - Total Reduced Sulfur

Citrate Buffer	300 g of pottasium citrate and 41 g of anhydrous citric acid dissolved in 1 liter of water. Adjust pH (5.4-5.6) with pottasium citrate or citric acid as needed.
absorbing solution (3%H_2O_2)	Dilute 100 ml of 30% Hydrogen peroxide (H_2O_2) with 1 liter of DI water, prepare daily

SO_2 Scrubber

Impinger 1	100 ml citrate buffer
Impinger 2	100 ml citrate buffer
Impinger 3	empty

Method 6 Part of Train

Midget Impinger 1	20 ml 3% H_2O_2
Midget Impinger 2	20 ml 3% H_2O_2
Midget Impinger 3	empty

Method 17 - Determination of Particulate Emissions from Stationary Sources (In-Stack Filtration Method)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Tared, Glass Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
Petri Dish

Thimble

Remove to its identified container.

Visual inspection.

Container 2
250 ml Nalgene

Nozzle and filter front half (FH).

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 3
250 ml Glass

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into labeled container.

Rinse with water.

Visual inspection.

Label container and measure volume by weight.

Container 4*
500 ml Plastic

Acetone Blank

Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 6
250 ml Plastic

Filter Blank

Place a clean, unused tared filter into a labeled container for a sample blank.

Container 5
Petri Dish

Silica Gel

Measure volume by weight, note any color change.

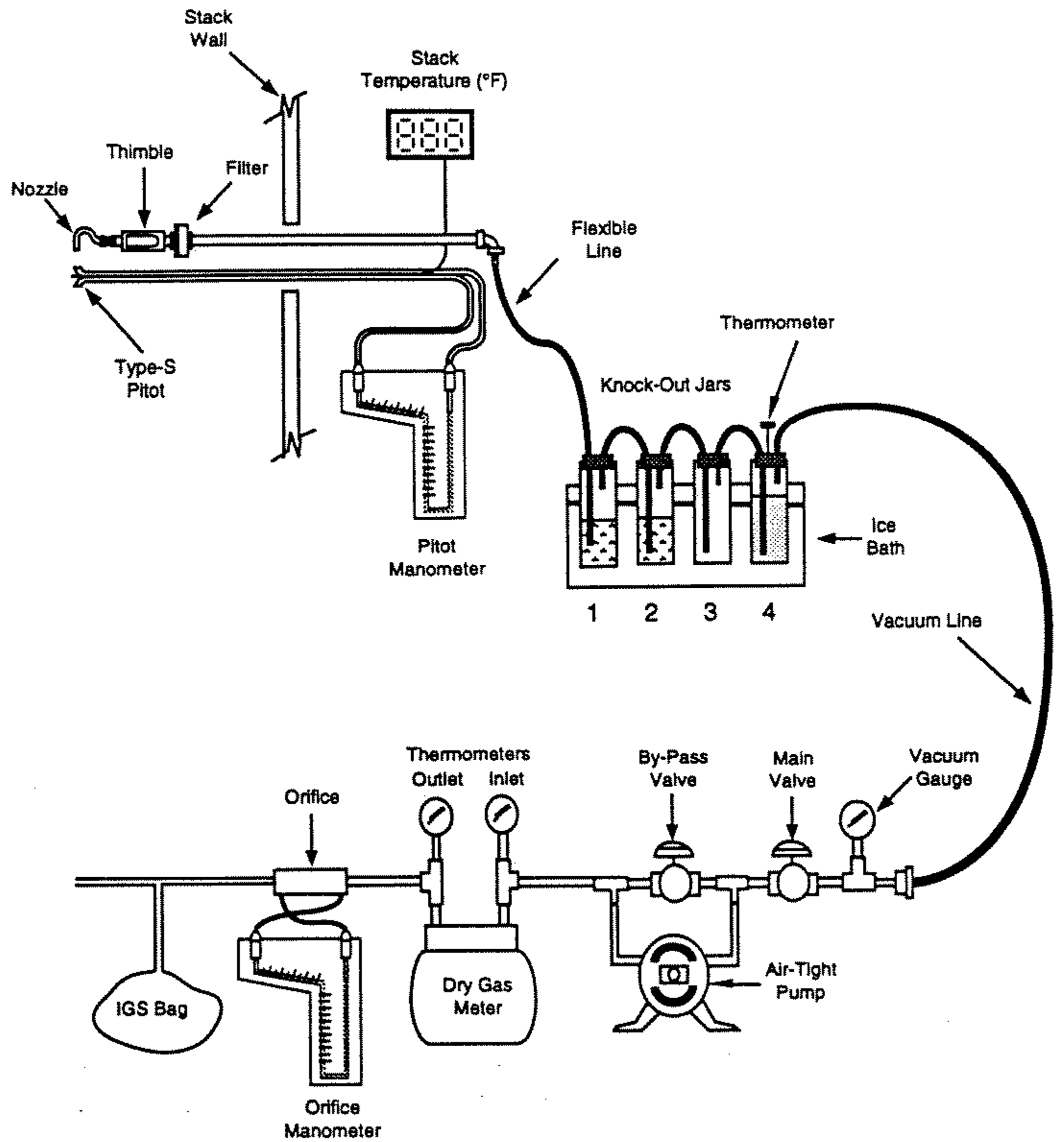
Recycle silica gel

Water Blank

Pour 200 ml of water from wash bottle into a labeled container for a sample blank.

Container 7*
250 ml Plastic

*Containers 4 and 7 are required only when the testing includes a back half analysis.

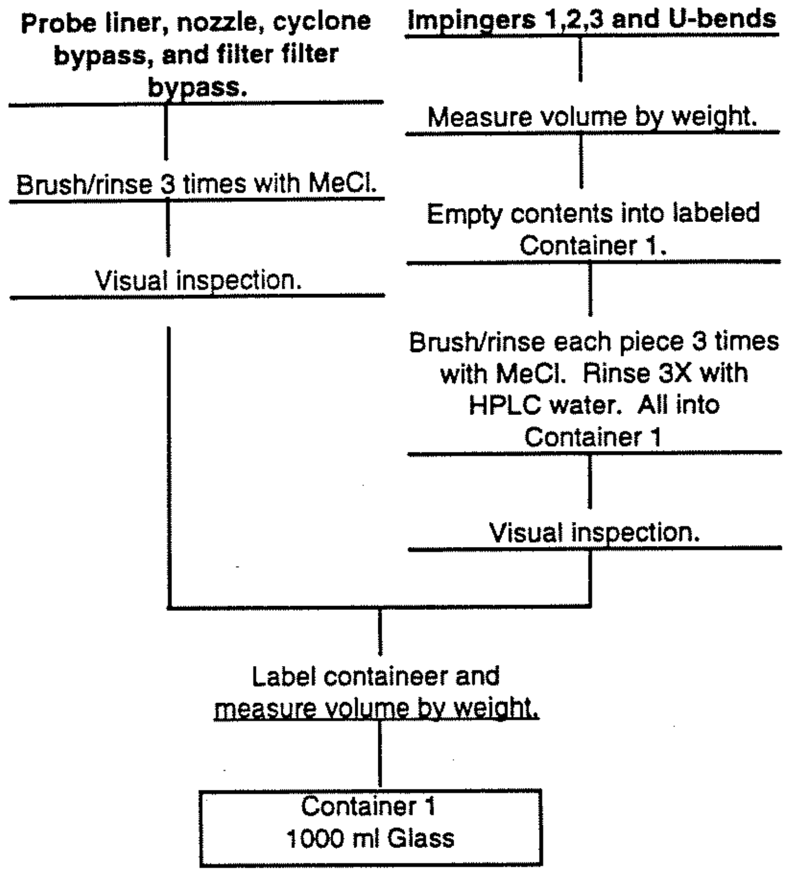


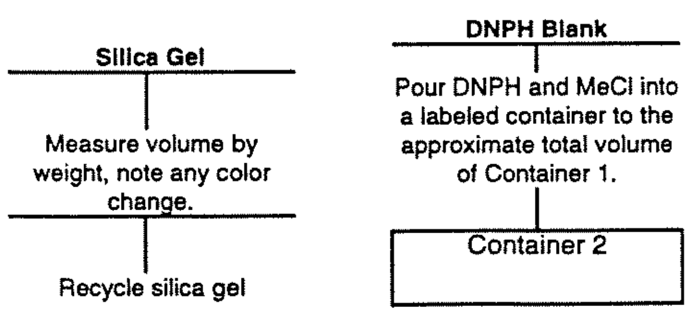
M17 - Particulate

Knock-out Jar 1	100 ml H_2O
Knock-out Jar 2	100 ml H_2O
Knock-out Jar 3	empty
Knock-out Jar 4	silica gel

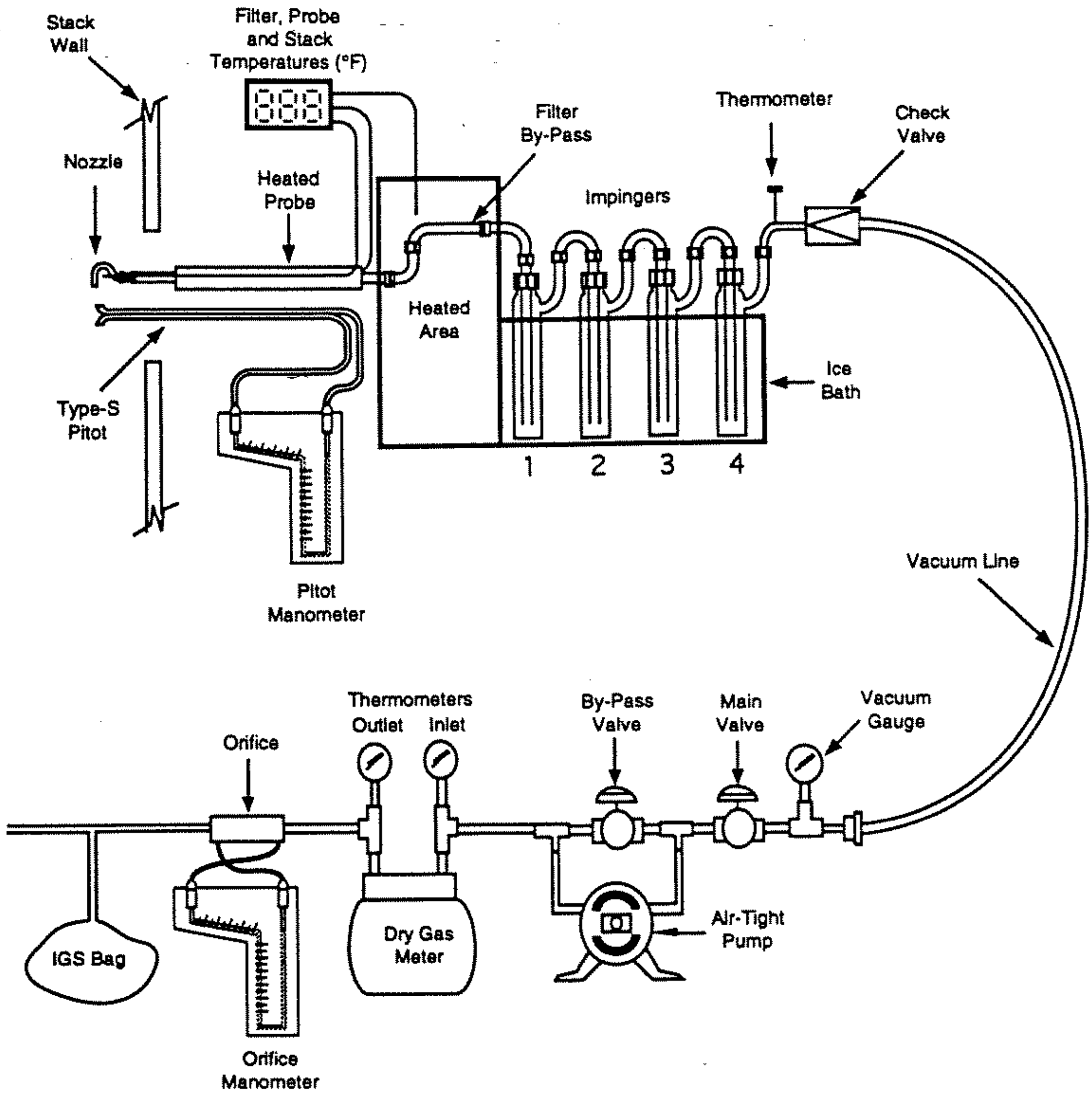
METHOD 0011- DETERMINATION OF FORMALDEHYDE EMISSIONS FROM STATIONARY SOURCES

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).





Note: Try to use a total of less than 250 ml of DNPH to rinse each train. Definitely use less than 500 ml. Samples should be kept cool.



M0011 - Aldehyde and Ketone absorbing solution (DNPH)

2,4-dinitrophenylhydrazine; Obtain from laboratory doing the analysis. This solution can be very dangerous. Once prepared the shelf life is 3 days.

Impinger 1	100 ml DNPH
Impinger 2	100 ml DNPH
Impinger 3	empty
Impinger 4	silica gel

Method 26 : Determination of Hydrogen Chloride Emissions from Stationary Sources

(Including sodium hydroxide impinger)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Teflon Filter

No recovery necessary

Impingers 1,2,3 and U-bends

Empty contents into container.

Rinse components 3 times with D.I. water

Label container and measure volume by weight.

Visual inspection

Container 1
500 ml plastic

Impinger 4 and U-bend

Discard contents.

Rinse components 3x with D.I. water

Discard rinses.

Sulfuric Acid Blank(H_2SO_4)

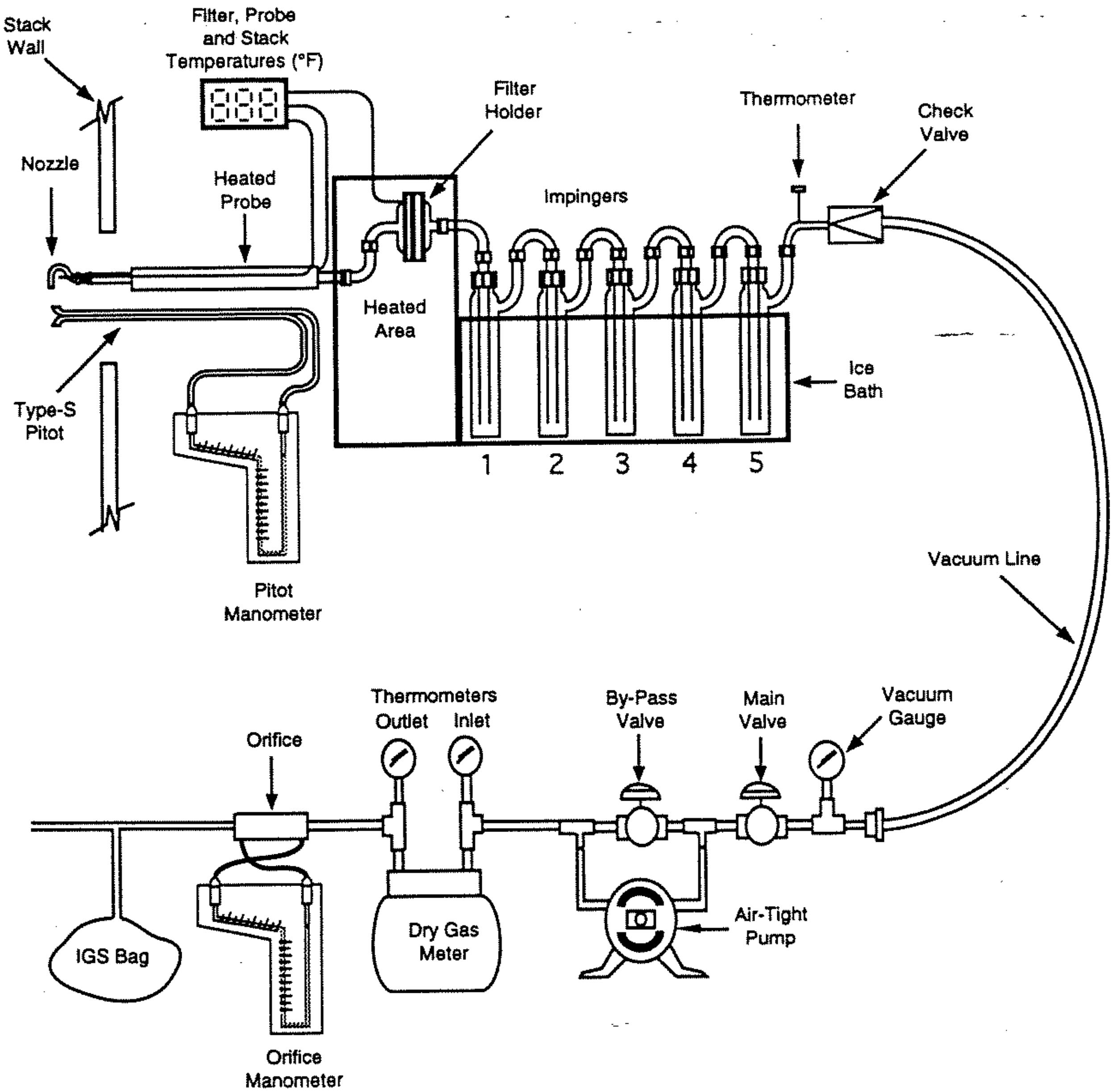
Pour 200 ml of 0.1N H_2SO_4 in a labeled container for a sample blank.

Container 2
250 ml plastic

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel



M26 - Hydrogen Chloride

absorbing solution (0.1 N H_2SO_4)

Slowly add 2.8 ml concentrated sulfuric acid (H_2SO_4) to approximately 1000 ml DI water. Shake well to mix the solution.

chlorine scrubber solution (0.1 N NaOH)

Dissolve 4.0 grams of solid NaOH in approximately 1000 ml of DI water. Shake well to mix the solution.

Impinger 1	empty
Impinger 2	15 ml 0.1 N H_2SO_4
Impinger 3	15 ml 0.1 N H_2SO_4
Impinger 4	15 ml 0.1 N NaOH
Impinger 5	silica gel

Note: This is a single point non-isokinetic sampling train.

METHOD 29 - DETERMINATION OF METALS EMISSIONS FROM STATIONARY SOURCES
(INCLUDING PARTICULATE DETERMINATION, EXCLUDING MERCURY DETERMINATION)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Weighed Quartz filter
- Remove with ACID-WASHED poly propylene or Teflon tweezers, to an identified container.
- If necessary, fold the filter and transfer it to its identified container. Remove any particulate or filter fibers that may adhere to the filter housing
- Container 1 Petri Dish

Probe liner, nozzle, cyclone bypass, and FH filter housing
- Brush/rinse 3 times with a total of 100 ml of acetone.
- Visual inspection.
- Label container and measure volume by weight.
- Container 2 250 ml Glass

Probe liner, nozzle, cyclone bypass, and FH filter housing
- Rinse 3 times with a total of 100 ml of 0.1 N HNO_3.
- Visual inspection.
- Label container and measure volume by weight.
- Container 3 250 ml Plastic

BH filter housing, Z-piece, Impingers1,2,3 and U-bends
- Measure impingers' volume by weight.
- Clean each piece 3 times with 0.1 N HNO_3, use a total of 100 ml.
- Visual inspection.
- Label container and measure volume by weight.
- Container 4 1000 ml Plastic

Silica Gel
- Measure volume by weight, note any color change.
- Recycle silica gel

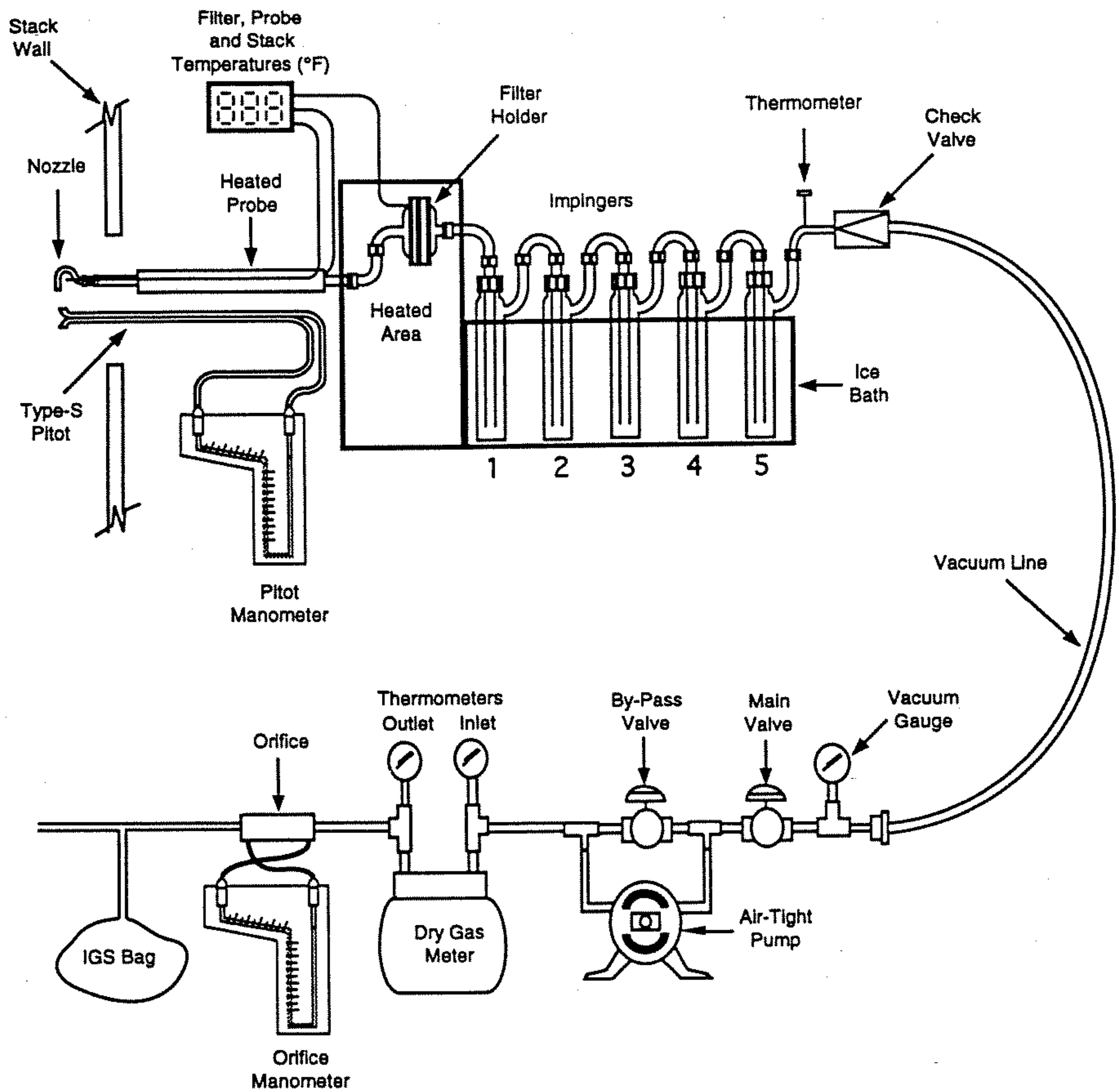
Acetone Blank
- Pour 200 ml of acetone from wash bottle into a labeled container.
- Container 7 250 ml Glass

Nitric Acid Blank
- Pour 200 ml of 0.1 N HNO_3 from wash bottle into a labeled container.
- Container 8A 250 ml Plastic

Water Blank
- Place 200 ml of water in sample bottle.
- Container 8B 250 ml Plastic

5% HNO_3/10% H_2O_2 Blank
- Pour 400 ml of nitric acid absorbing solution from wash bottle into a labeled container.
- Container 9 500 ml Plastic

Filter Blanks
- Place 3 clean, unused filters into a labeled container.
- **Container 5 Petri Dish



~~Proposed EPA~~ **Method 29** - Metals

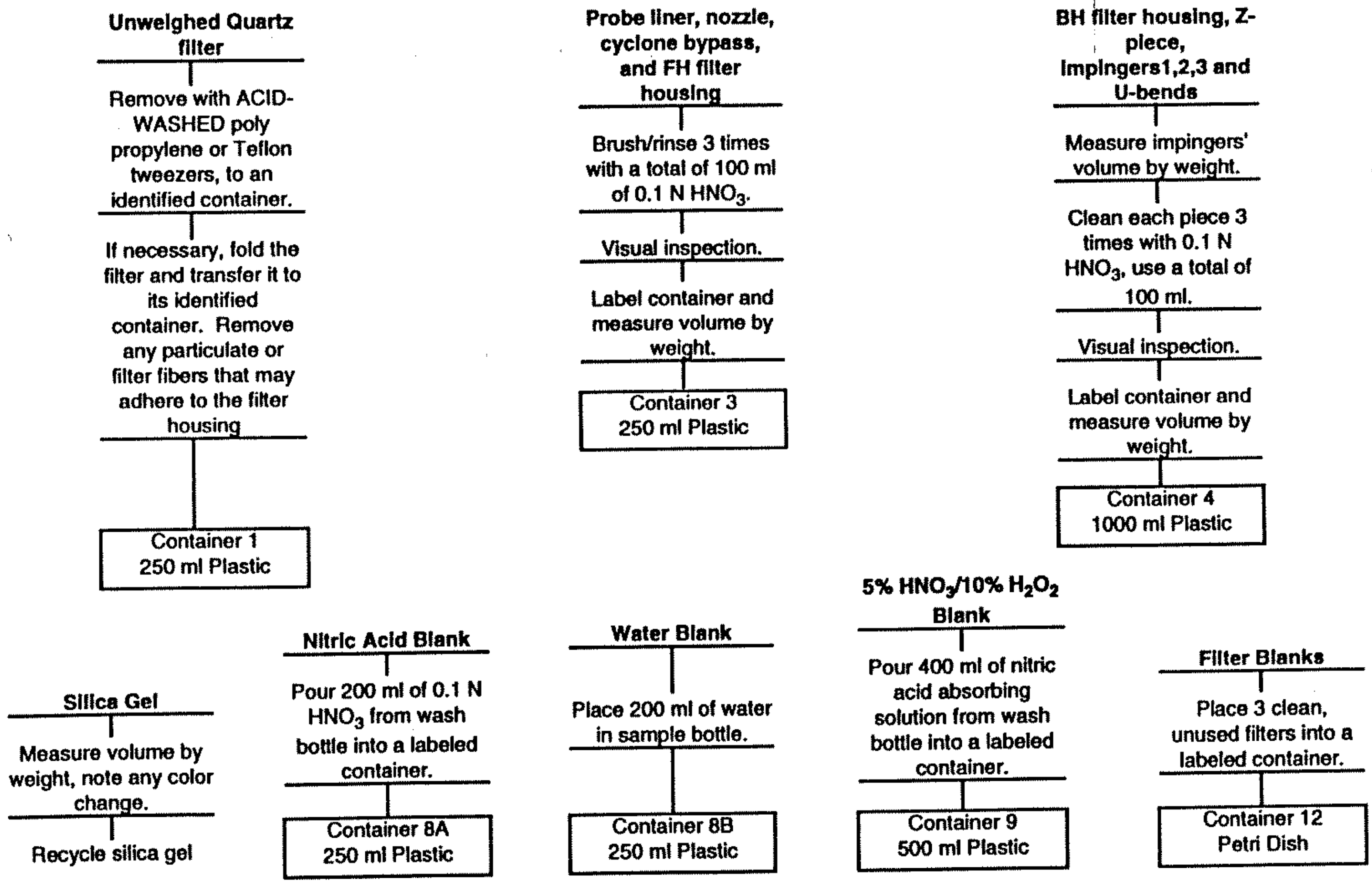
Metals absorbing soln (5%HNO_3/10% H_2O_2)

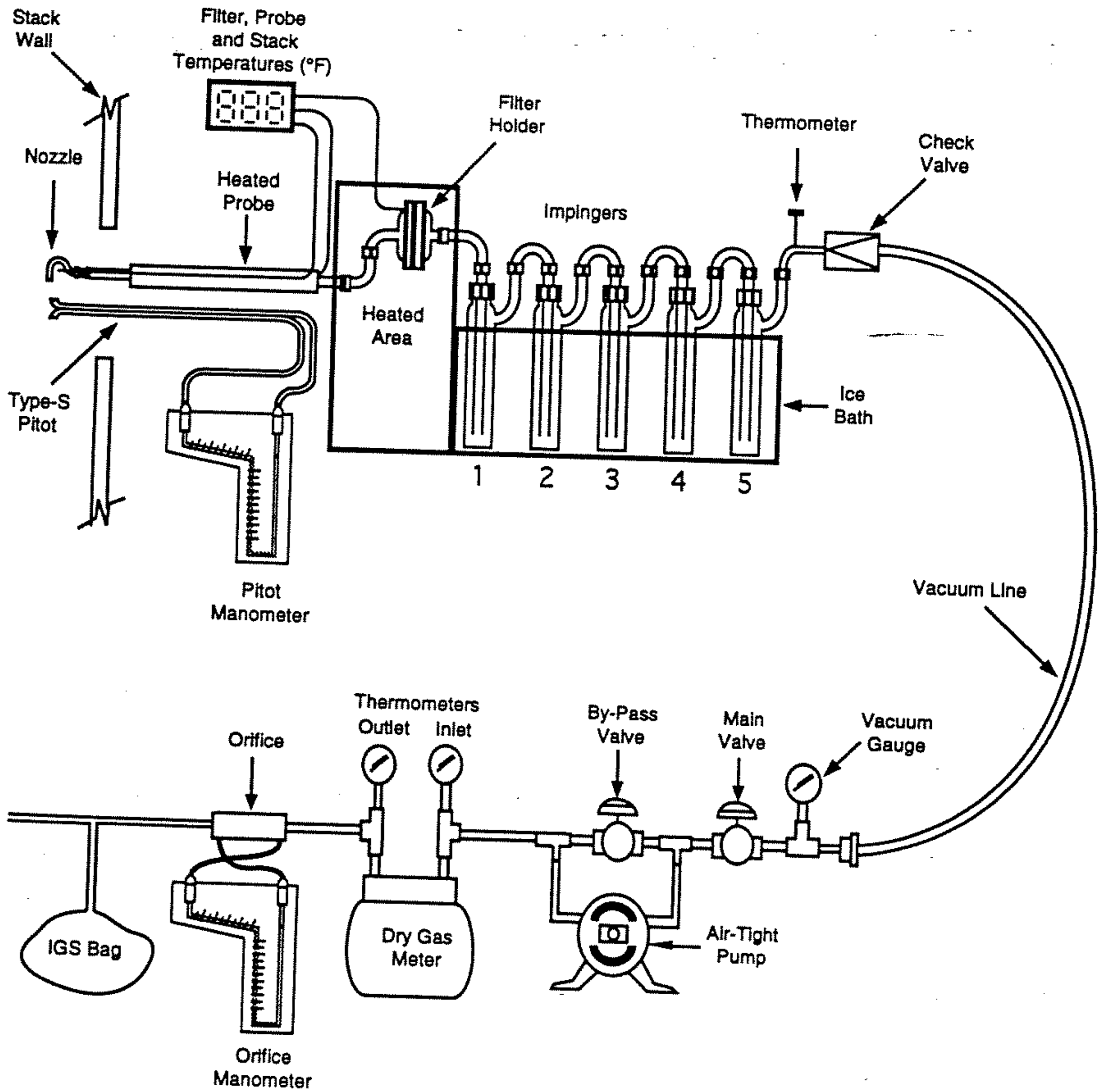
Mix 50 ml concentrated nitric acid (HNO_3) in 500 ml of DIUF water, add 333 ml of 30% H_2O_2 and dilute to 1 liter

Impinger 1	empty
Impinger 2	100 ml 5% HNO_3/10% H_2O_2
Impinger 3	100 ml 5% HNO_3/10% H_2O_2
Impinger 4	empty
Impinger 5	silica gel

Method 29 - Determination of Metals Emissions from Stationary Sources
(Excluding Mercury determination, Excluding Particulate determination)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).





Proposed EPA Method 29 - Metals

Metals absorbing soln (5%HNO_3/10% H_2O_2)

Mix 50 ml concentrated nitric acid (HNO_3) in 500 ml of DIUF water, add 333 ml of 30% H_2O_2 and dilute to 1 liter

Impinger 1	empty
Impinger 2	100 ml 5% HNO_3/10% H_2O_2
Impinger 3	100 ml 5% HNO_3/10% H_2O_2
Impinger 4	empty
Impinger 5	silica gel

METHOD 101A: DETERMINATION OF PARTICULATE AND GASEOUS MERCURY EMISSIONS FROM SEWAGE SLUDGE INCINERATORS.

(FOR M101A TRAIN WITH FILTER)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Clean each piece 3 times with fresh acidic permanganate($KMnO_4$)

Rinse with water

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure impingers' volume by weight.

Clean each piece 3 times with fresh acidic permanganate($KMnO_4$)

Rinse with water

Use a total of 350 ml $KMnO_4$ and 100 ml water on each train including probe liner.

Visual inspection.

Label container and measure volume by weight.

**Container 1 & 1A 950 & 500 ml Glass

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Remove any residue or brown spots with 25 ml 8 N HCl

Place 150 ml water into a labeled container, add the 25 ml of 8 N HCl rinse, then rinse with a total of 50 ml water and add to container.

**Container 2 250 ml glass

Unweighed Quartz filter

Remove to identified container, and add 20 to 40 ml of 4% $KMnO_4$.

Transfer any particulate matter and filter fibers that adhere to the filter holder gasket by using a dry nylon bristle brush and a sharp-edged blade to a 150 ml sample bottle.

Seal the container, label its contents and fluid level.

Container 3 250 ml glass

**Note: There may be some pressure build up in the sample container. These should NOT be filled full. Venting is highly recommended.

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel

Filter Blank

Place a clean, unused filter into a labeled container for a sample blank.

Container 4 250 ml glass

Permanganate Blank

Place 650 ml of $KMnO_4$ solution in a labeled container for sample blank.

**Container 5 950 ml glass

HCl Rinse Blank

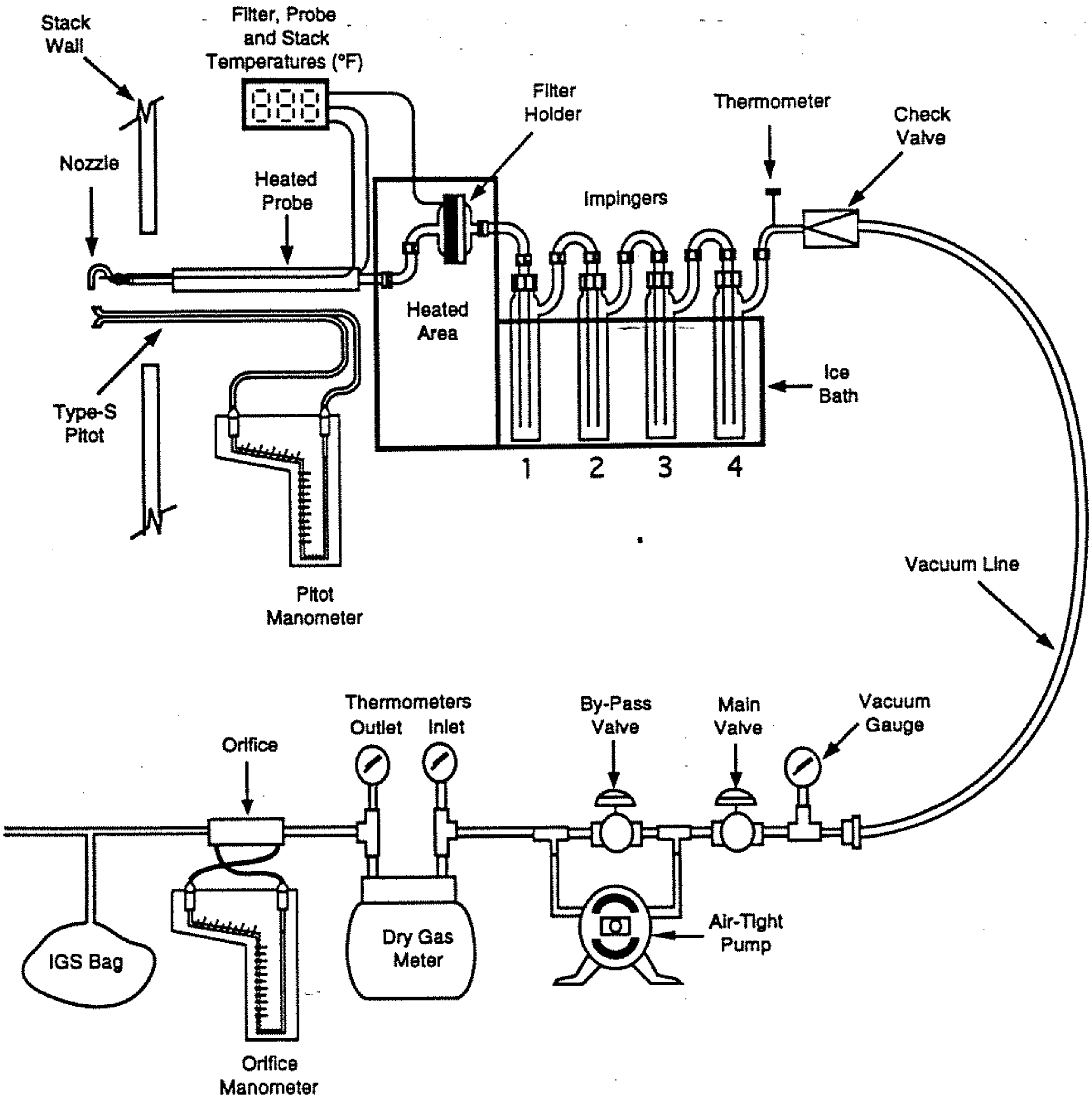
Place 200 ml of water in sample bottle add 25 ml of 8 N HCl carefully with stirring. Only need 1 per set of 3 runs.

Container 6 1000 ml glass

Water Blank

Place 200 ml of water in sample bottle.

Container 7 250 ml glass



M101A- Mercury

absorbing solution (4% $KMnO_4$/10% H_2SO_4)	Dissolve, with stirring, 40 grams pottasium permanganate ($KMnO_4$) in 900 ml of DIUF water. Slowly add 100 ml concentrated sulfuric acid (H_2SO_4) and mix well, just prior to testing.
rinse solution (8N HCl)	Add 69 ml of concentrated HCl to 25 ml of DIUF water (Add acid to water). Dilute with water to 100 ml.

Impinger 1	50 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 2	100 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 3	100 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 4	silica gel

Method 101A - Determination of Particulate and Gaseous Mercury Emissions from Sewage Sludge Incinerators (For M101A Train without a filter)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Probe liner, nozzle, cyclone bypass, and filter bypass

Clean each piece 3 times with fresh acidic permanganate($KMnO_4$)

Rinse with water

Filter bypass, Z-piece, Impingers 1,2,3 and U-bends

Measure impingers' volume by weight.

Clean each piece 3 times with fresh acidic permanganate($KMnO_4$)

Rinse with water

Use a total of 350 ml $KMnO_4$ and 100 ml water on each train including probe liner.

Visual inspection.

Label container and measure volume by weight.

**Container 1 & 1A
950 ml Glass (2)

Filter bypass, Z-piece, Impingers 1,2,3 and U-bends

Remove any residue or brown spots with 25 ml 8 N HCl

Place 150 ml water into a labeled container, add the 25 ml of 8 N HCl rinse, then rinse with a total of 50 ml water and add to container.

**Container 2
250 ml glass

**Note: There may be some pressure build up in the sample container. These should NOT be filled full. Venting is highly recommended.

Permanganate Blank

Place 650 ml of $KMnO_4$ solution in a labeled container for sample blank.

**Container 5
950 ml Glass

HCl Rinse Blank

Place 200 ml of water in sample bottle add 25 ml of 8 N HCl carefully with stirring. Need only 1 for 3 runs.

Container 6
1000 ml glass

Water Blank

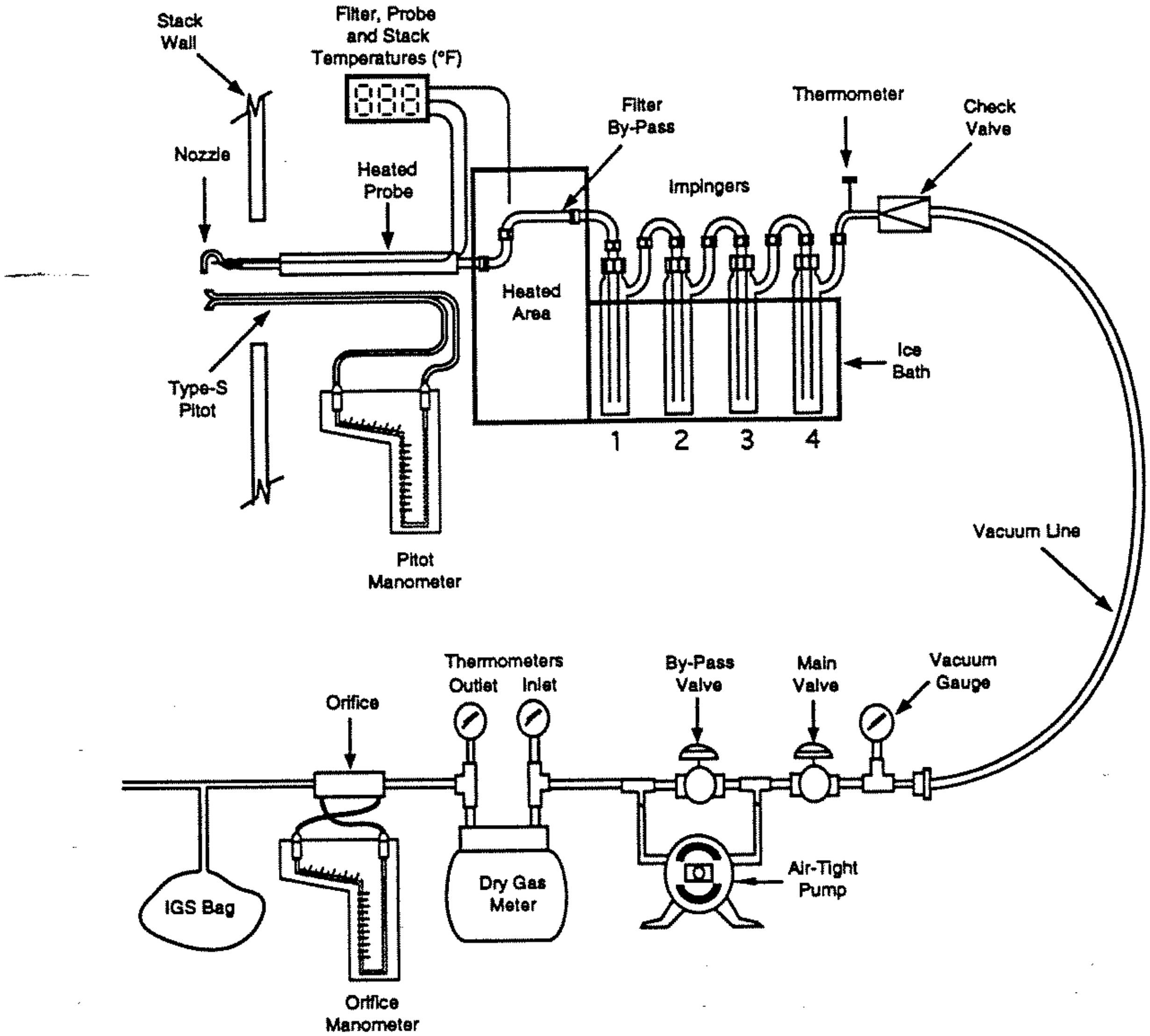
Place 200 ml of water in sample bottle.

Container 7
250 ml glass

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel



M101A- Mercury

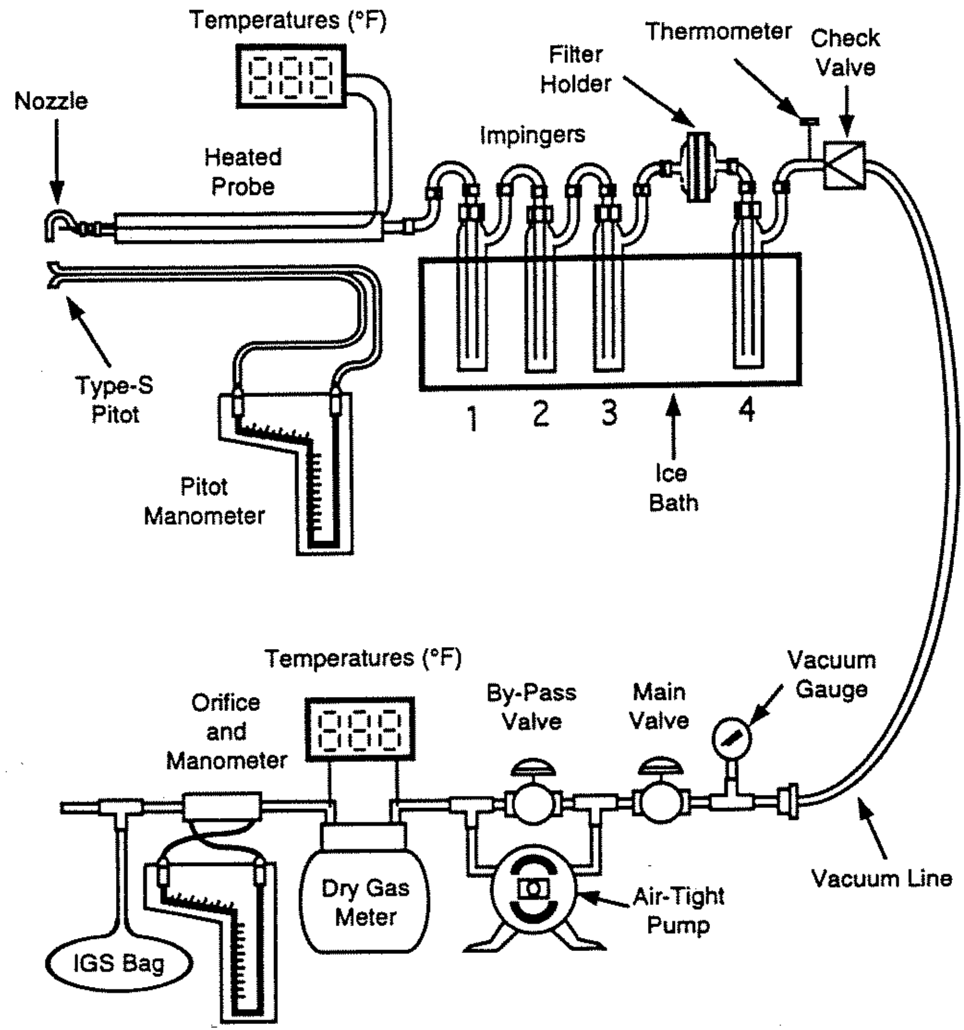
absorbing solution (4% $KMnO_4$/10% H_2SO_4)

Dissolve, with stirring, 40 grams pottasium permanganate ($KMnO_4$) in 900 ml of DIUF water. Slowly add 100 ml concentrated sulfuric acid (H_2SO_4) and mix well, just prior to testing.

rinse solution (8N HCl)

Add 69 ml of concentrated HCl to 25 ml of DIUF water (Add acid to water). Dilute with water to 100 ml.

Impinger 1	50 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 2	100 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 3	100 ml 4% $KMnO_4$/10% H_2SO_4
Impinger 4	silica gel



M104 - Beryllium (Be)

Impinger 1	100 ml H_2O
Impinger 2	100 ml H_2O
Impinger 3	empty
Impinger 4	silica gel

METHOD 108 - Determination of Particulate and Gaseous Arsenic Emissions

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Untared, Quartz Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
250 ml Plastic

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Brush/rinse 3 times with 0.1 N NaOH.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Plastic

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into labeled container.

Rinse with 0.1 N NaOH.

Visual inspection.

Label container and measure volume by weight.

Container 3
500 ml Plastic

Filter Blank

Place a clean, unused filter into a labeled container for a sample blank.

Container 4
250 ml Plastic

0.1 N NaOH Blank

Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 5
250 ml Plastic

Silica Gel

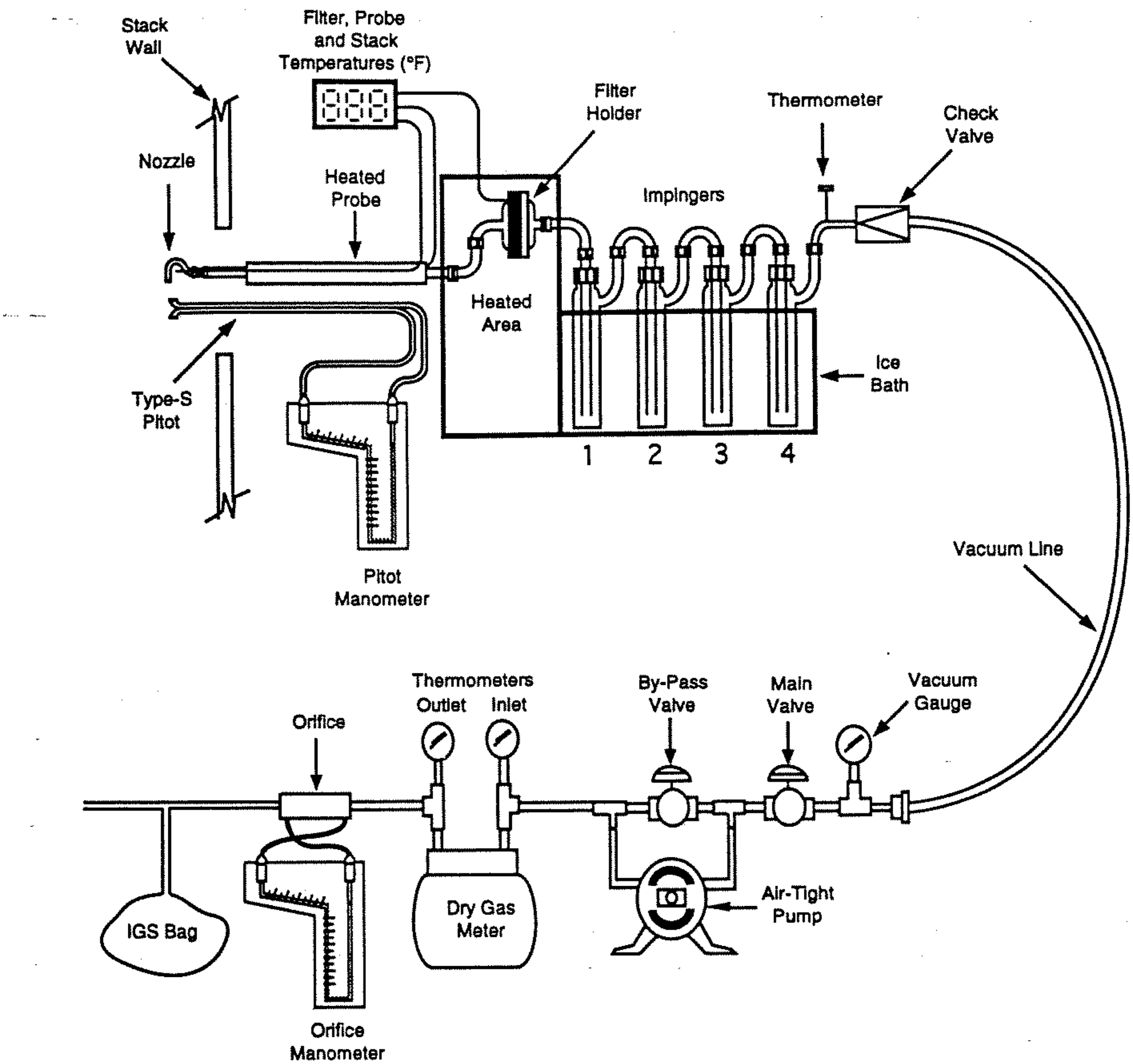
Measure volume by weight, note any color change.

Recycle silica gel

Water Blank

Pour 200 ml of water from wash bottle into a labeled container for a sample blank.

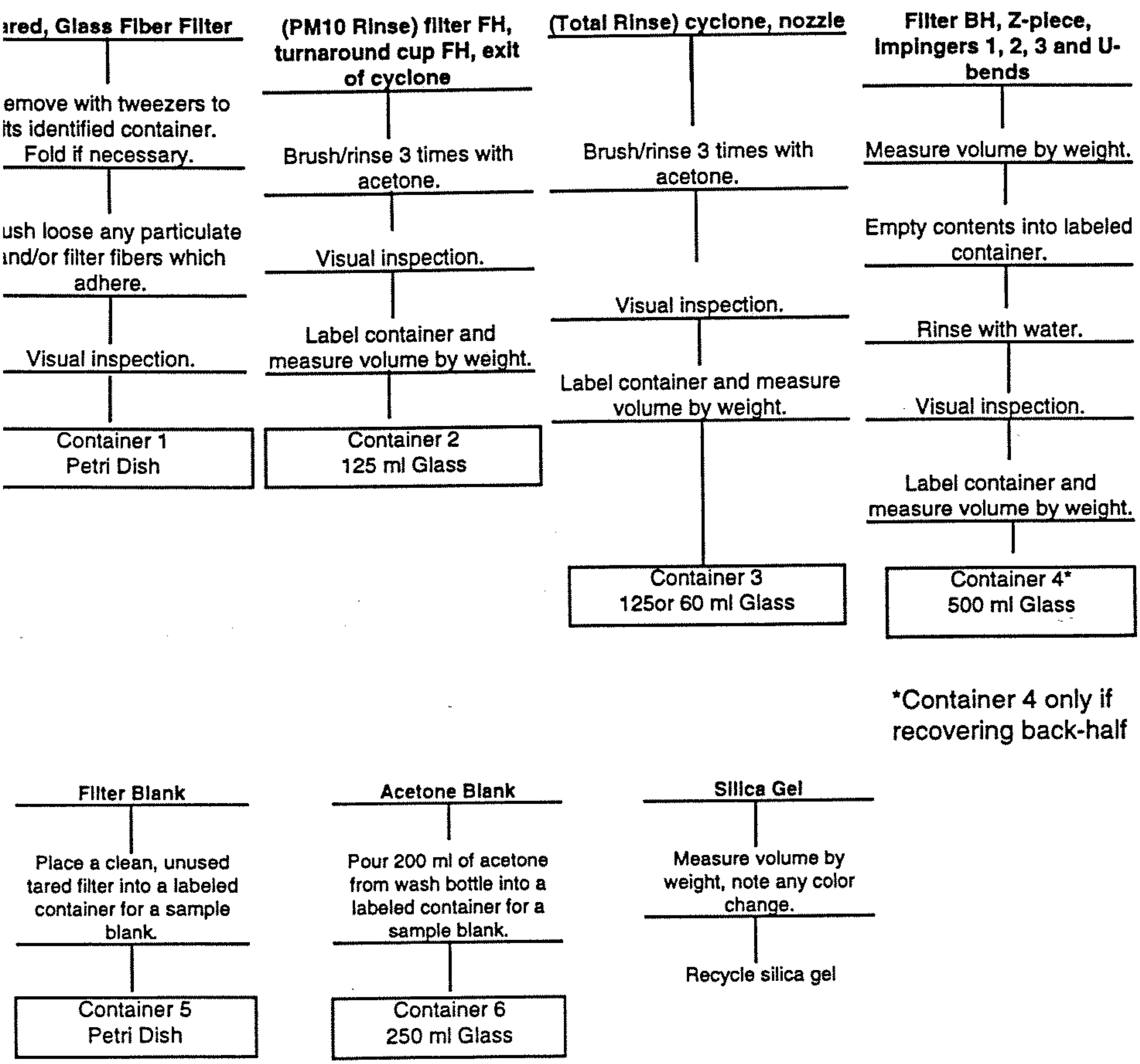
Container 6
250 ml Plastic

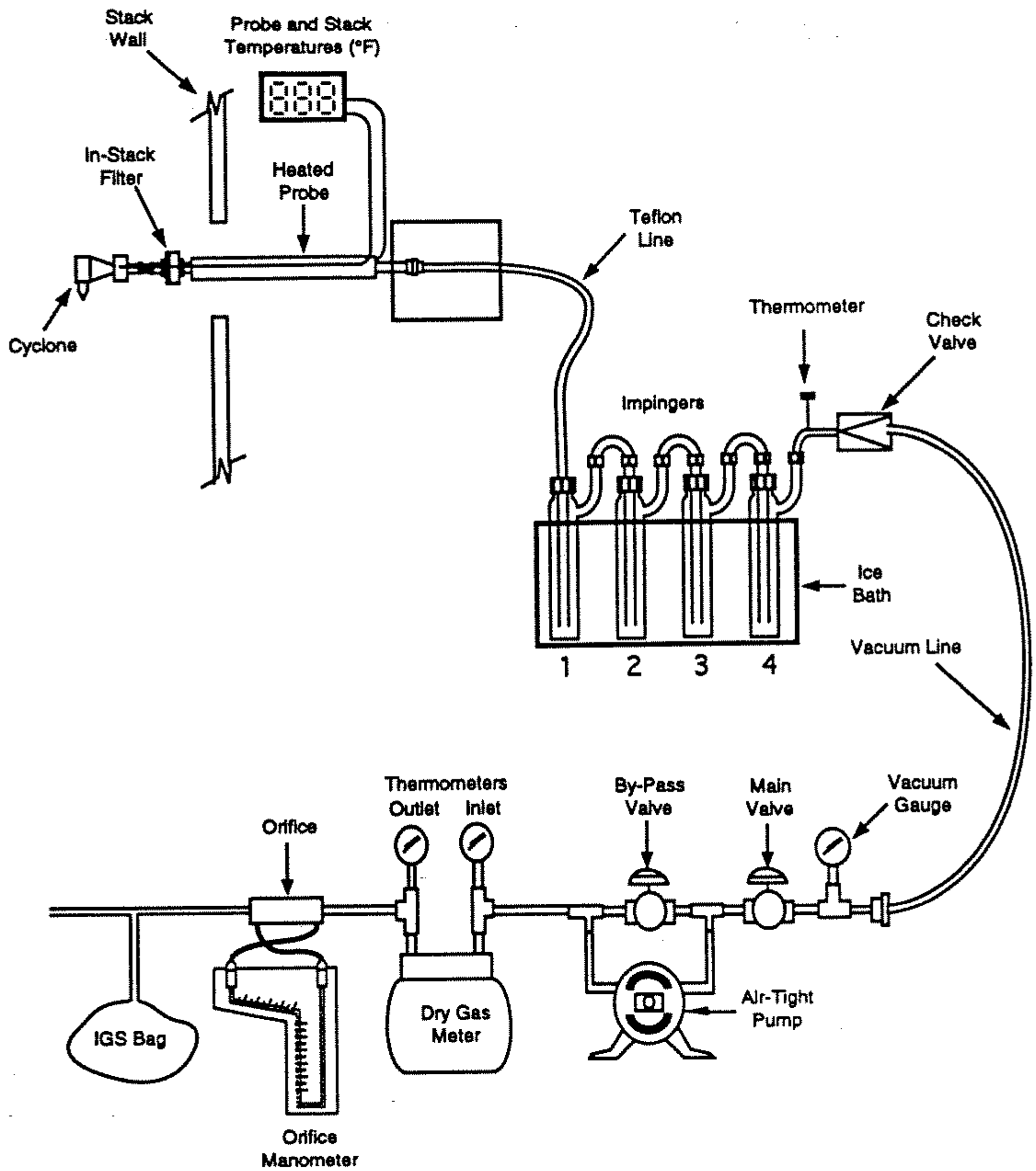


M108 - Arsenic (As)

Impinger 1	100 ml H_2O
Impinger 2	100 ml H_2O
Impinger 3	empty
Impinger 4	silica gel

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).





M201A - PM_{10}

Impinger 1	100 ml H_2O
Impinger 2	100 ml H_2O
Impinger 3	empty
Impinger 4	silica gel

Method 201A - Determination of PM_{10} Emissions from Stationary Sources (Not including back half)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Tared, Quartz Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere to the filter holder.

Visual inspection.

Container 1
Petri Dish

Nozzle and cyclone

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Glass

Cyclone outlet and front half filter holder

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 3
250 ml Glass

Filter Blank

Place a clean, unused tared filter into a labeled container for a sample blank.

Container 4
Petri Dish

Acetone Blank

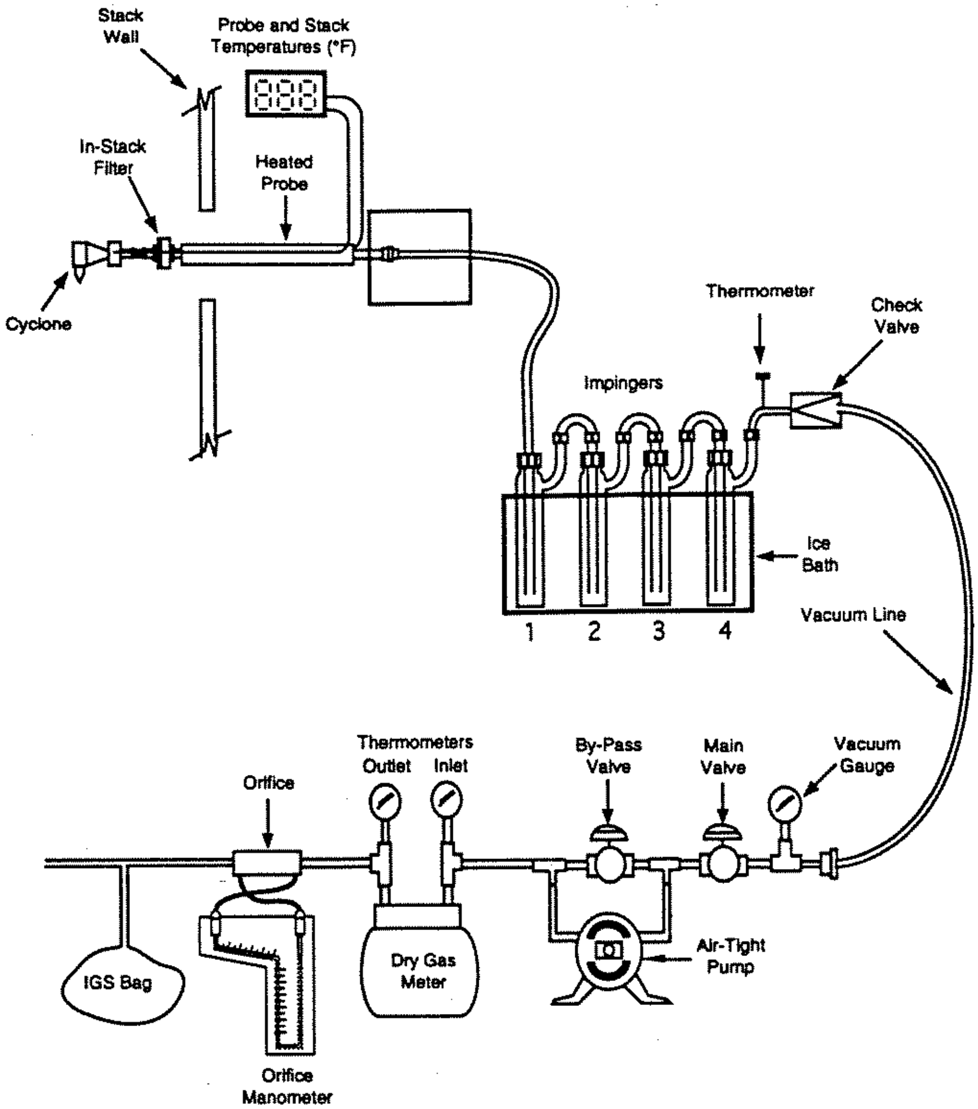
Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 5
250 ml Glass

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel



M201A - PM_{10}

Impinger 1	100 ml H_2O
Impinger 2	100 ml H_2O
Impinger 3	empty
Impinger 4	silica gel

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

0.2 µm or 0.4 µm Polycarbonate Filter

1. Remove with tweezers to its identified container. Fold if necessary.
2. Brush loose any particulate and/or filter fibers which adhere.
3. Visual inspection.
4. Container 1 Petri Dish

Nozzle and filter front half (FH)

1. Brush/rinse 3 times with acetone.
2. Visual inspection.
3. Label container and measure volume by weight.
4. Container 2 250 ml Plastic

Impingers 1,2,3

1. Measure volume by weight.
2. Discard contents.
3. Container 3* 500 ml Plastic

Filter Blank

1. Place a clean, unused tared filter into a labeled container for a sample blank.
2. Container 4 Petri Dish

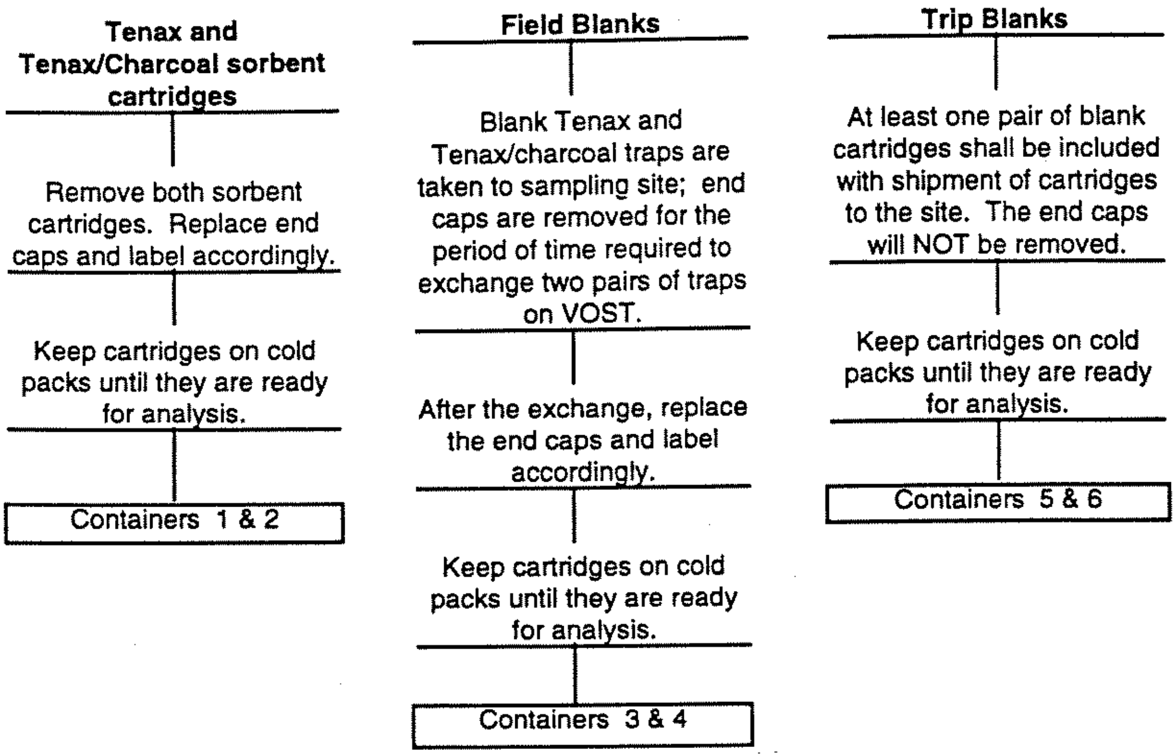
Acetone Blank

1. Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.
2. Container 5 250 ml Plastic

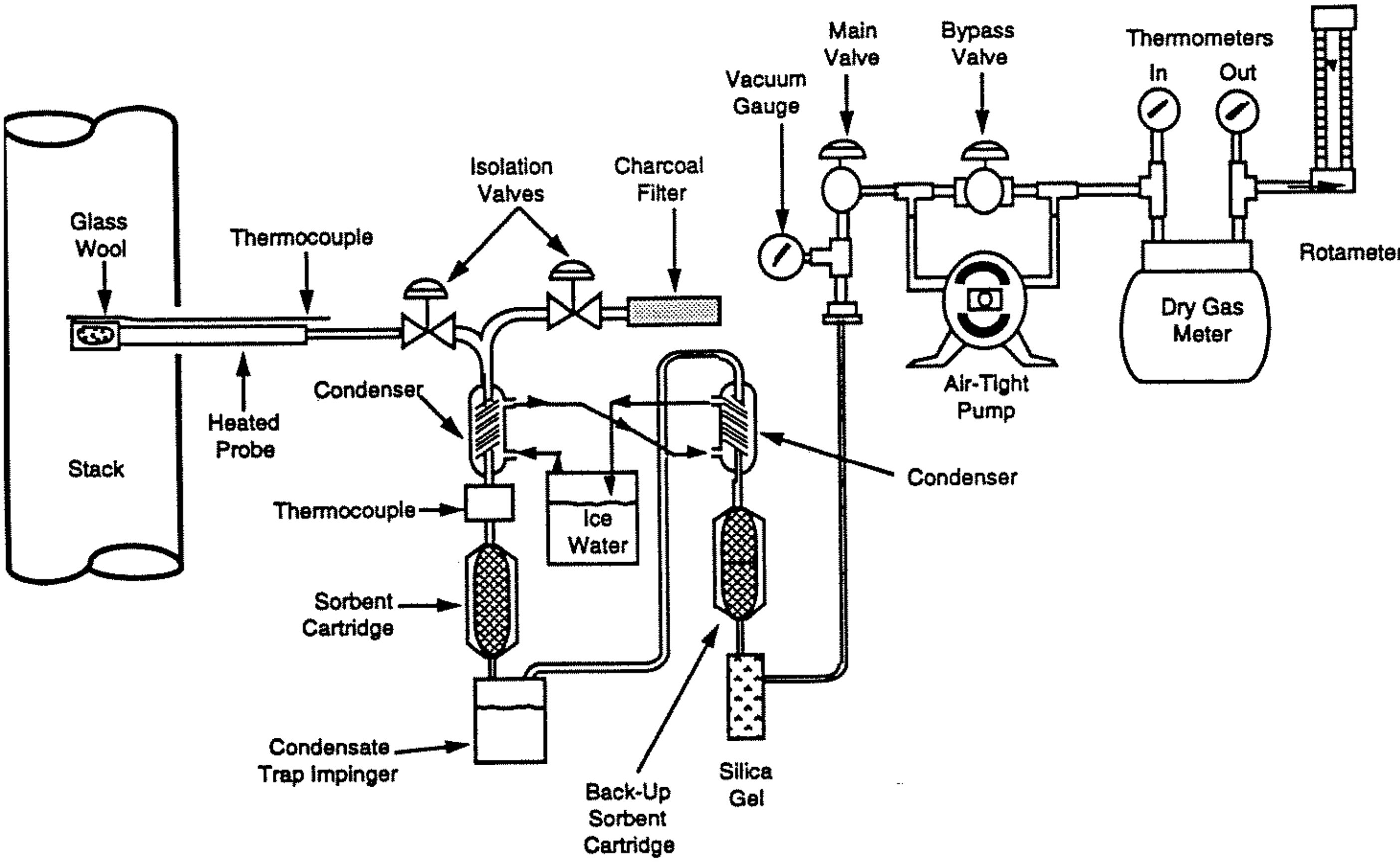
Silica Gel

1. Measure volume by weight, note any color change.
2. Recycle silica gel

- 1 pair of each set of blanks per 6 pairs of tested traps.
- Mark direction of flow on Tenax cartridges with a PENCIL.



Note: If condensate is collected, place it in a 20 or 40 ml VOA vial. Fill the vial to the top with HPLC water so that no air is present in the vial.



Main
Valve
Bypass
Valve
Thermometers
In
Out
Vacuum
Gauge
Isolation
Valves
Charcoal
Filter
Glass
Wool
Thermocouple
Rotameter
Dry Gas
Meter
Air-Tight
Pump
Condenser
Heated
Probe
Stack
Condenser
Thermocouple
Ice
Water
Sorbent
Cartridge
Condensate
Trap Impinger
Silica
Gel
Back-Up
Sorbent
Cartridge

METHOD 0050 - ISOKINETIC HCl/Cl_2 EMISSION SAMPLING TRAIN (INCLUDING PARTICULATE EMISSIONS, EXCLUDING Cl_2 EMISSIONS)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Weighed Quartz Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
Petri Dish

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Glass

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into glass container.

Rinse with water.

Visual inspection.

Label container and measure volume by weight.

Container 3
500 ml Glass

Filter Blank

Place a clean, unused filter into a labeled container for a sample blank.

Container 4
Petri Dish

0.1 N H_2SO_4 Blank

Pour 200 ml of 0.1N H_2SO_4 into a labeled container for a sample blank.

Container 5
250 ml glass

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel

Water Blank

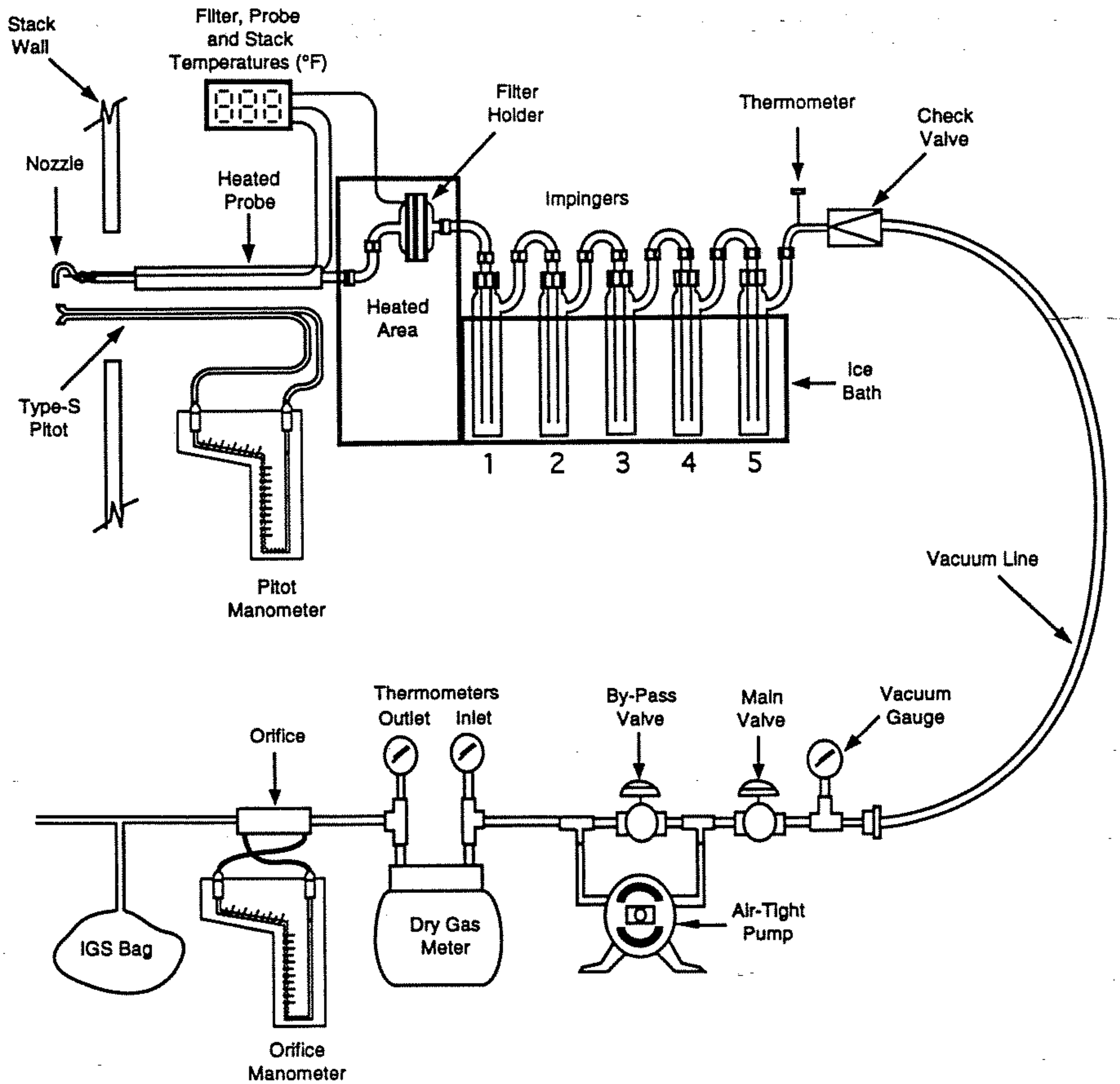
Pour 200 ml of water from wash bottle into a labeled container for a sample blank.

Container 6
250 ml Glass

Acetone Blank

Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 7
250 ml Glass



M0050 - Particulate/Hydrogen Chloride/Chlorine

HCl absorbing solution (0.1 N H_2SO_4) — Slowly add 2.8 ml concentrated sulfuric acid (H_2SO_4) to approximately 1000 ml DI water. Shake well to mix the solution.

Cl_2 absorbing solution (0.1 N NaOH) — Dissolve 4.0 grams of solid NaOH in approximately 1000 ml of DI water. Shake well to mix the solution.

Impinger 1	50 ml 0.1 N H_2SO_4 **(OPTIONAL)**
Impinger 2 (1)	100 ml 0.1 N H_2SO_4
Impinger 3 (2)	100 ml 0.1 N H_2SO_4
Impinger 4 (3)	100 ml 0.1 N NaOH
Impinger 5 (4)	100 ml 0.1 N NaOH
Impinger 6 (5)	silica gel

Note: This is a traversing, isokinetic sampling train.

Method 0050 - Isokinetic HCl/Cl_2 Emission Sampling Train (Including Particulate Emissions, Including Cl_2 Emissions)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Weighed Quartz Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
Petri Dish

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Glass

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into glass container.

Rinse with water.

Visual inspection.

Label container and measure volume by weight.

Container 3
500 ml Glass

Impingers 4 and 5 and U bends

Measure volume by weight.

Empty contents into glass container.

Rinse with water.

Visual inspection.

Label container and measure volume by weight.

Container 4
500 ml Glass

Filter Blank

Place a clean, unused filter into a labeled container for a sample blank.

Container 5
Petri Dish

0.1 N H_2SO_4 Blank

Pour 200 ml of 0.1N H_2SO_4 into a labeled container for a sample blank.

Container 6
250 ml glass

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel

Water Blank

Pour 200 ml of water from wash bottle into a labeled container for a sample blank.

Container 7
250 ml Glass

Acetone Blank

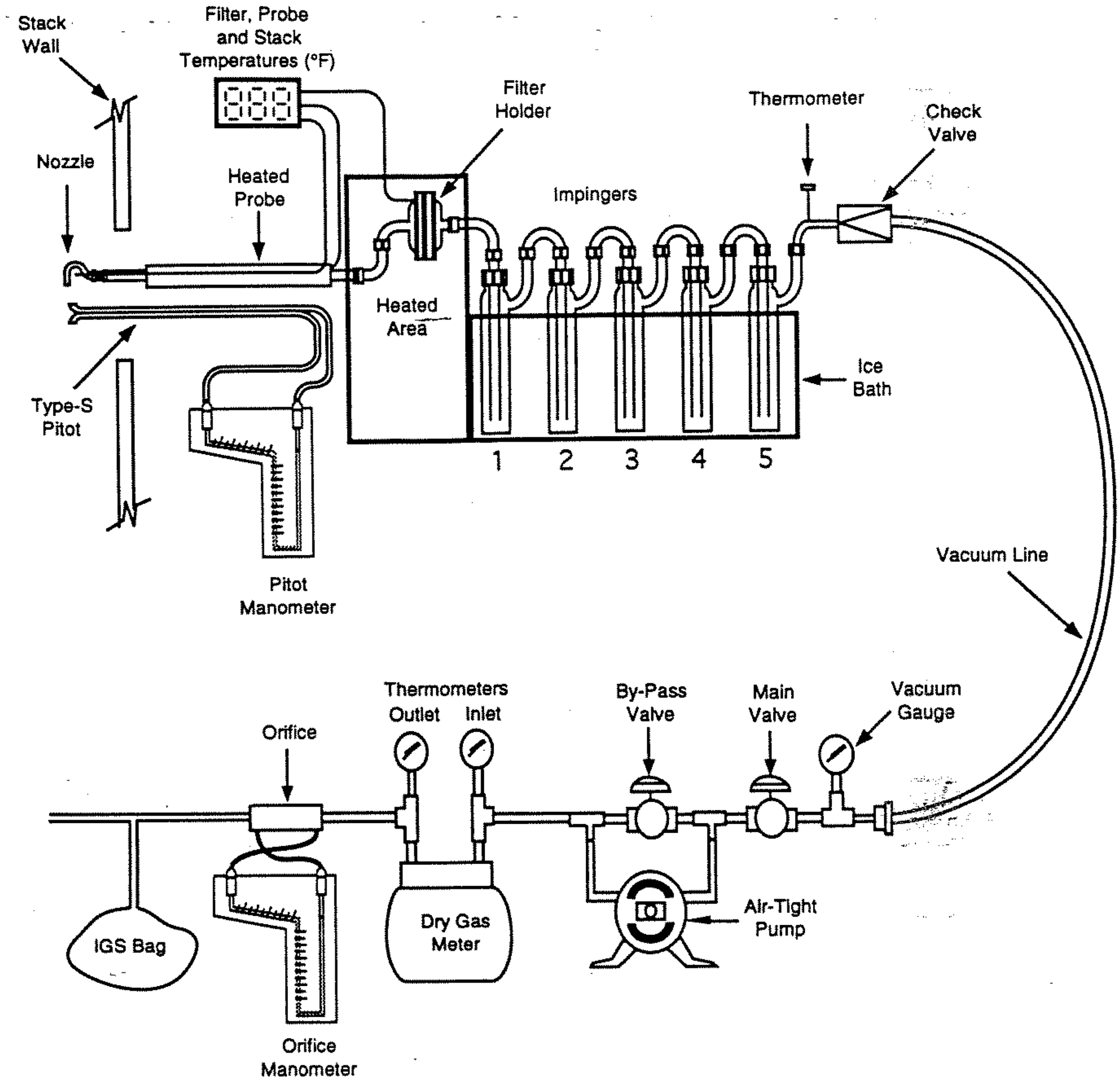
Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 8
250 ml Glass

0.1 N NaOH Blank

Pour 200 ml of 0.1N NaOH into a labeled container for a sample blank.

Container 9
250 ml glass



M0050 - Particulate/Hydrogen Chloride/Chlorine

HCl absorbing solution (0.1 N H_2SO_4): Slowly add 2.8 ml concentrated sulfuric acid (H_2SO_4) to approximately 1000 ml DI water. Shake well to mix the solution.

Cl_2 absorbing solution (0.1 N NaOH): Dissolve 4.0 grams of solid NaOH in approximately 1000 ml of DI water. Shake well to mix the solution.

Impinger 1	50 ml 0.1 N H_2SO_4 **(OPTIONAL)**
Impinger 2 (1)	100 ml 0.1 N H_2SO_4
Impinger 3 (2)	100 ml 0.1 N H_2SO_4
Impinger 4 (3)	100 ml 0.1 N NaOH
Impinger 5 (4)	100 ml 0.1 N NaOH
Impinger 6 (5)	silica gel

Note: This is a traversing, isokinetic sampling train.

Method 0051 - HCl/Cl_2 Emission Sampling Train (Including Particulate Emissions, Excluding Cl_2 Emissions)

- Tare all sample containers before sample collection.
- Mark all liquid levels and final weights on the outside of each sample container.
- Seal all sample containers with Teflon tape.
- If recycling, bake silica gel for two hours at 350° F (175° C).

Weighed Quartz Filter

Remove with tweezers to its identified container. Fold if necessary.

Brush loose any particulate and/or filter fibers which adhere.

Visual inspection.

Container 1
Petri Dish

Probe liner, nozzle, cyclone bypass, and filter front half (FH).

Brush/rinse 3 times with acetone.

Visual inspection.

Label container and measure volume by weight.

Container 2
250 ml Glass

Back half (BH) filter housing, Z-piece, impingers 1,2,3 and U-bends

Measure volume by weight.

Empty contents into glass container.

Rinse with water.

Visual inspection.

Label container and measure volume by weight.

Container 3
500 ml Glass

Filter Blank

Place a clean, unused filter into a labeled container for a sample blank.

Container 4
Petri Dish

0.1 N H_2SO_4 Blank

Pour 200 ml of 0.1N H_2SO_4 into a labeled container for a sample blank.

Container 5
250 ml glass

Silica Gel

Measure volume by weight, note any color change.

Recycle silica gel

Water Blank

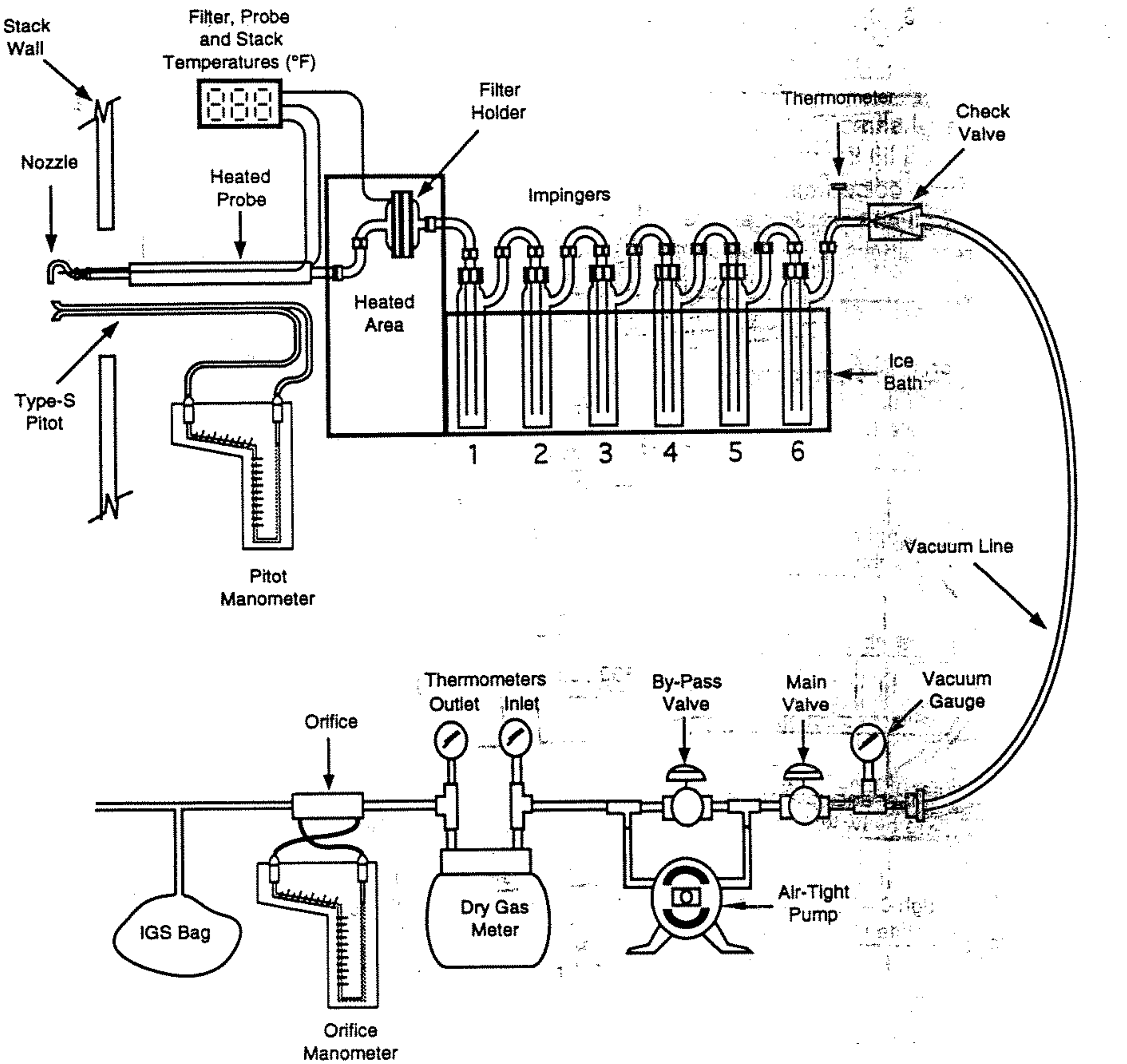
Pour 200 ml of water from wash bottle into a labeled container for a sample blank.

Container 6
250 ml Glass

Acetone Blank

Pour 200 ml of acetone from wash bottle into a labeled container for a sample blank.

Container 7
250 ml Glass



M0051 - Hydrogen Chloride/ Chlorine

HCl absorbing solution (0.1 N H_2SO_4)	Slowly add 2.8 ml concentrated sulfuric acid (H_2SO_4) to approximately 1000 ml DI water. Shake well to mix the solution.
Cl_2 absorbing solution (0.1 N NaOH)	Dissolve 4.0 grams of solid NaOH in approximately 1000 ml of DI water. Shake well to mix the solution.

Midget Impinger 1	empty
Midget Impinger 2	15 ml 0.1 N H_2SO_4
Midget Impinger 3	15 ml 0.1 N H_2SO_4
Midget Impinger 4	15 ml 0.1 N NaOH
Midget Impinger 5	15 ml 0.1 N NaOH
Midget Impinger 6	silica gel

Note: Because you are also sampling for particulate, this is an isokinetic sampling train.