Stack Measurements

SOURCE EMMISSION MONITORING

Why Monitoring?

- **Process control**
- **Regulatory compliance**
- **Air quality modeling**
- **Develop emission factors**
- **Performance of pollution control devices**

Fundamentals of Gas Laws:

- **Boyle's Law:**

  PV = Constant (at fixed mass and temperature)

- **Charles's Law:**

  V/T = Constant (at constant mass and pressure)

- **Perfect Gas Law:**

PV/T = Constant

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

- **Particulate Sampling: Isokinetic Sampling**

WHY?

Units: ppm, mg/Nm^3, µg/m^3

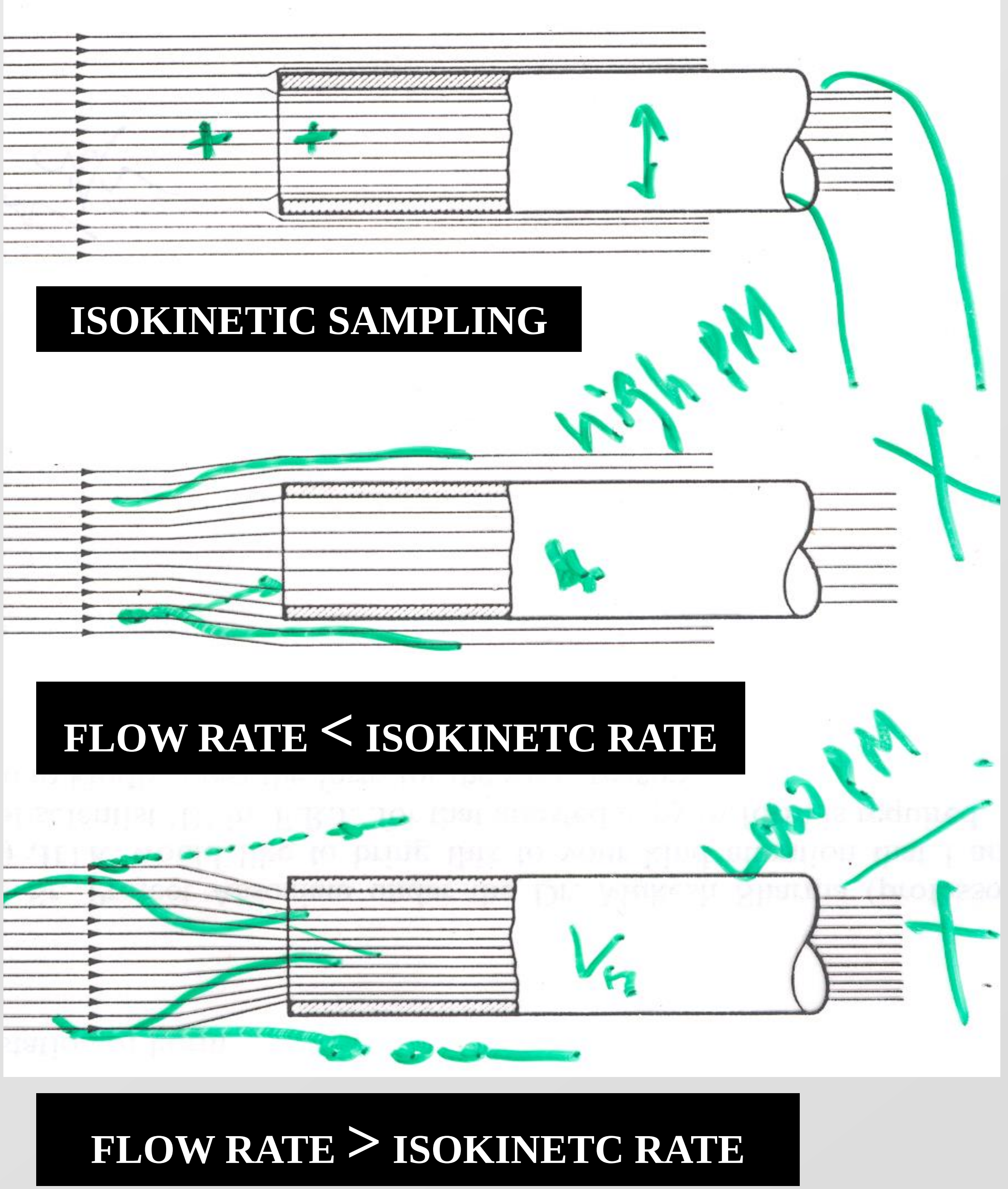
Particulate Inertia

↓

Velocity Measurement

↓

Isokinetic Sampling

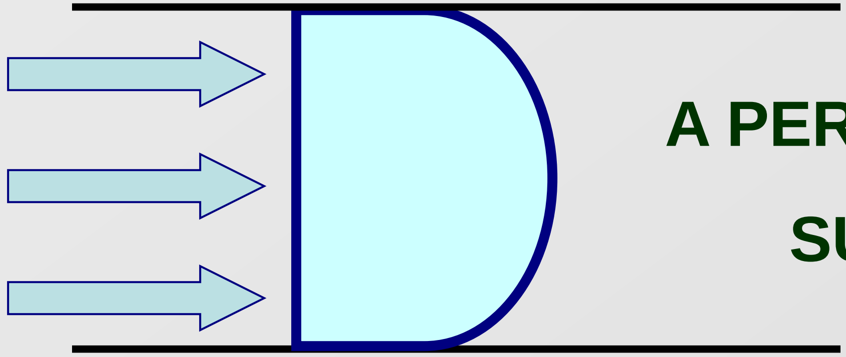


SAMPLING LOCATIONS

Any source Monitoring requires VELOCITY MEASUREMETNS

Flow in ducts and stacks is

fully developed TURBULANT FLOW (Re > 10,000)



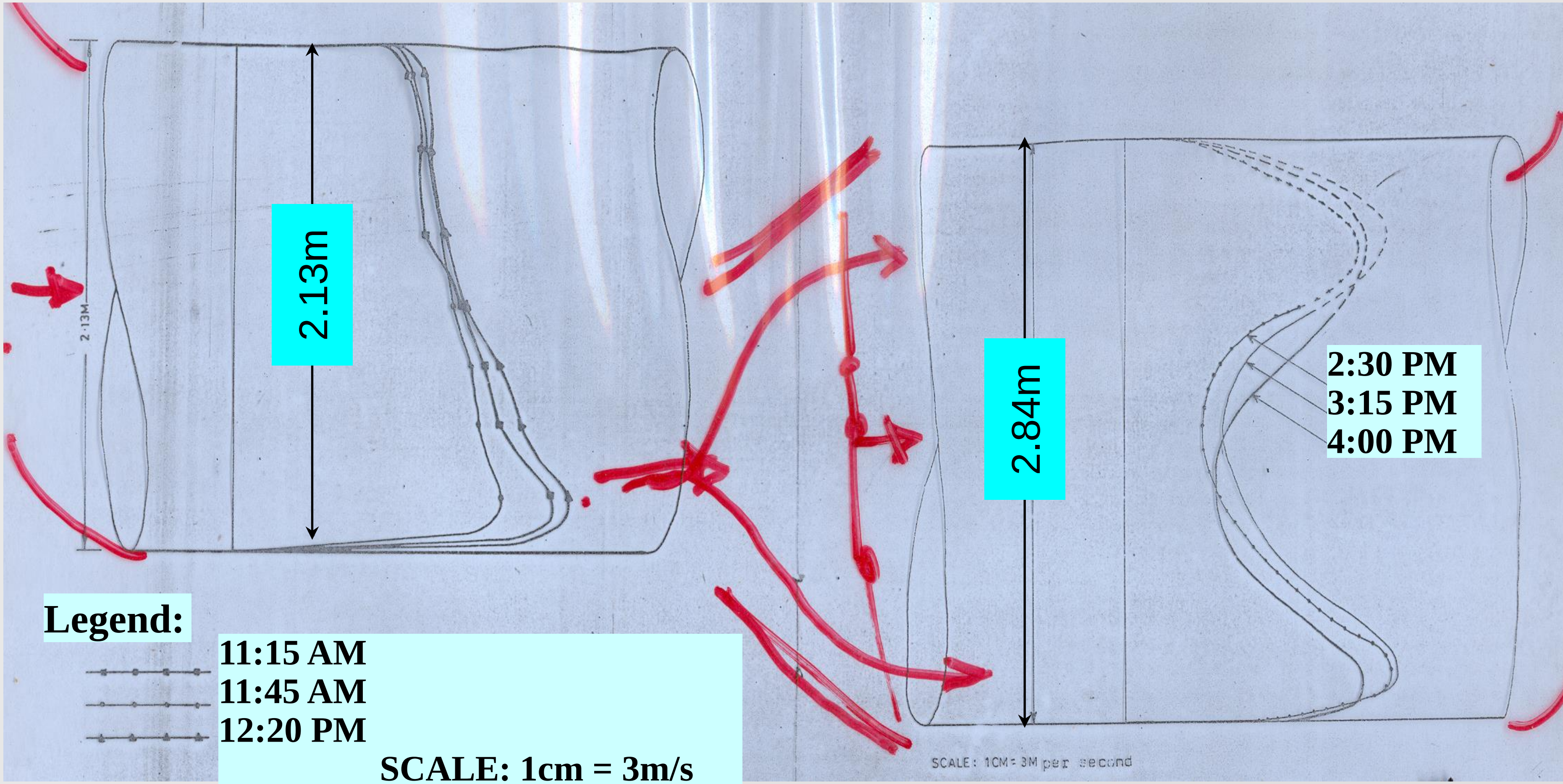
A PERFECT VELOCITY PROFILE

SUITED FOR SAMPLING

But ? Bends, Expansions, Contractions ID & FD Fans and Dampers in Ducts and Stacks cause

- Drastic change in velocity profile
- Variations in Velocity with time

Difficult Situation for Sampling

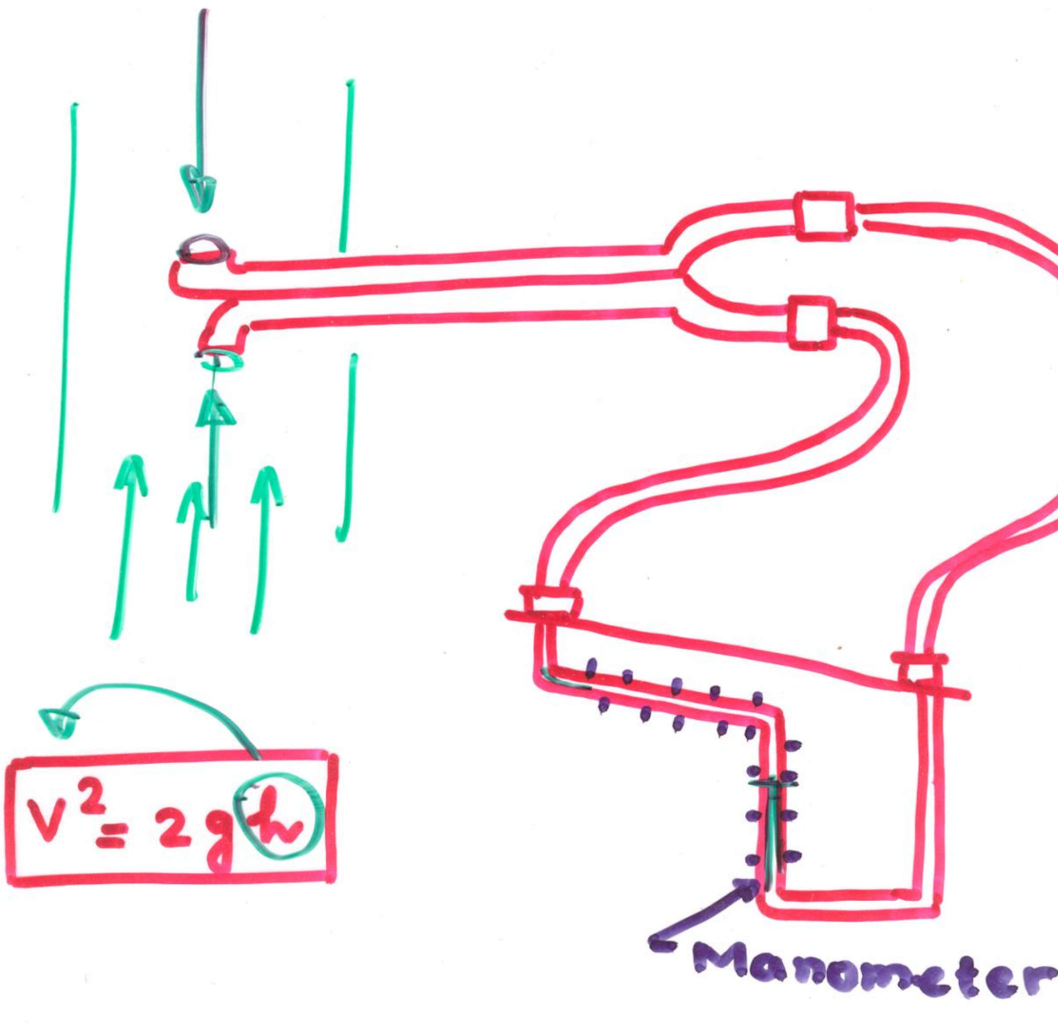


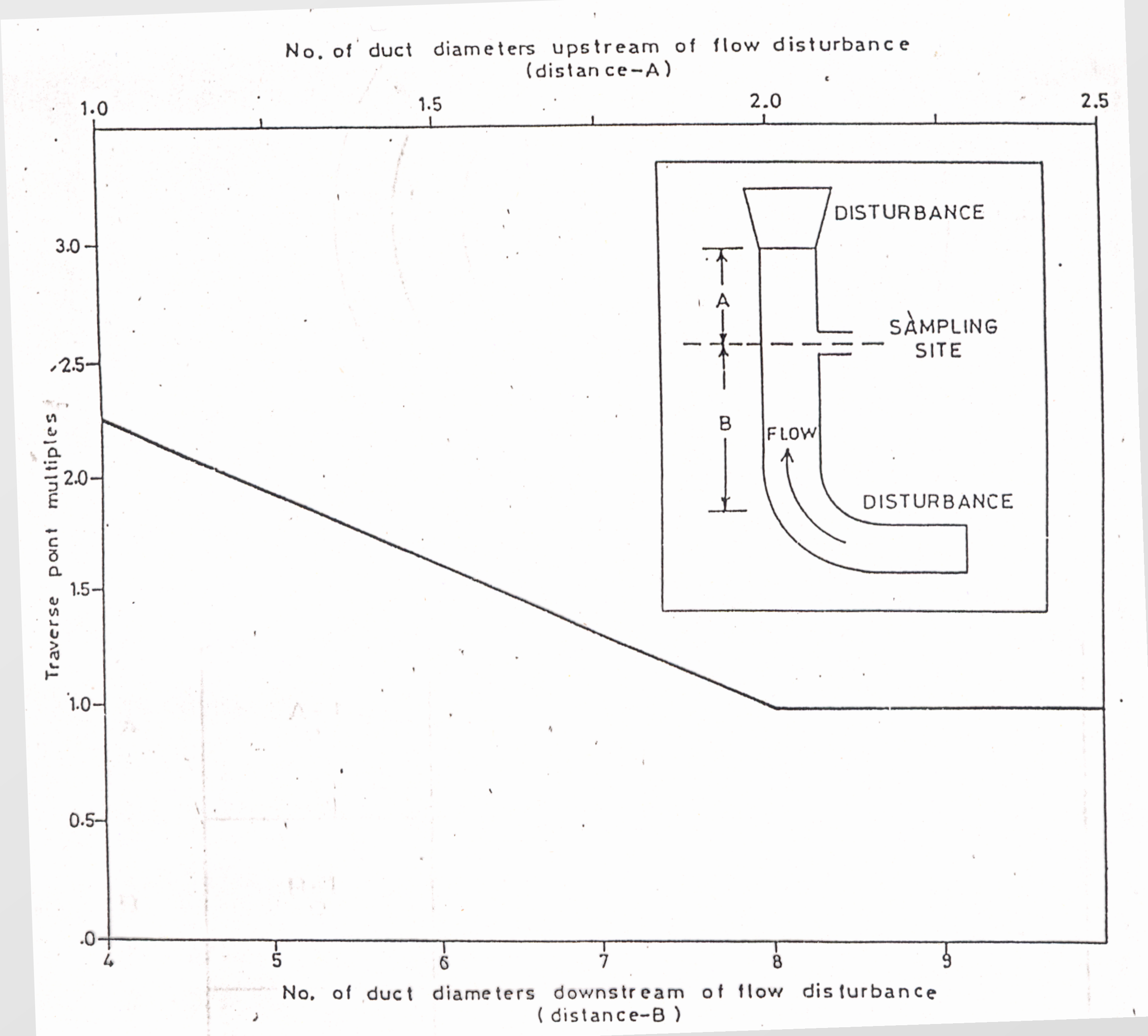
Spatial Variation in Velocity Profile:
A 90º Bend in UP stream of Sampling Port at 3.16 times Equivalent Diameter

Spatial Variation in Velocity Profile:
A 90º Bend in DN stream and Dampers, Expansion and ID Fan in UP Stream of Sampling Port

Velocity Measurement

Pitot Tube





Traverse point multiplier to determine minimum number of traverse points required when A<2 or B<8

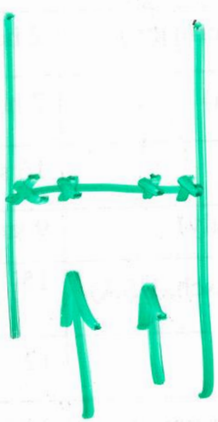
Under no condition shall a sampling point be selected within 3 cm of stack wall.

Table 1 Minimum Required Number of Traverse Points for Sampling Sites Meeting the Specified Criteria

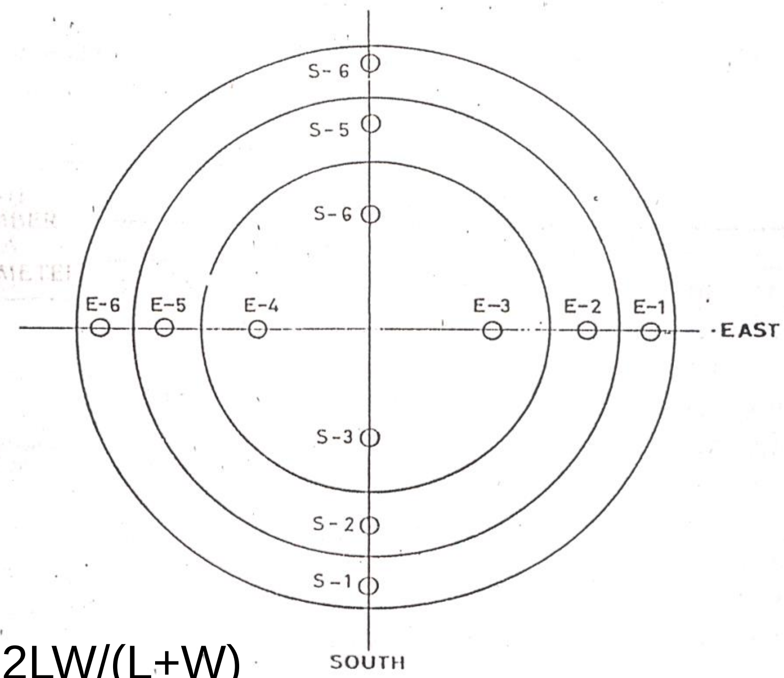
Inside diameter of stack or duct (m)	Number of points
I.D <= 0.3	4
0.3 <= I.D <= 0.6	8
0.6 <= I.D <= 1.2	12
1.2 <= I.D <= 2.4	20
2.4 <= I.D <= 5.0	32

LOCATION OF TRAVERSE POINTS ON DIAMETERS OF CROSS SECTIONS OF CIRCULAR STACKS

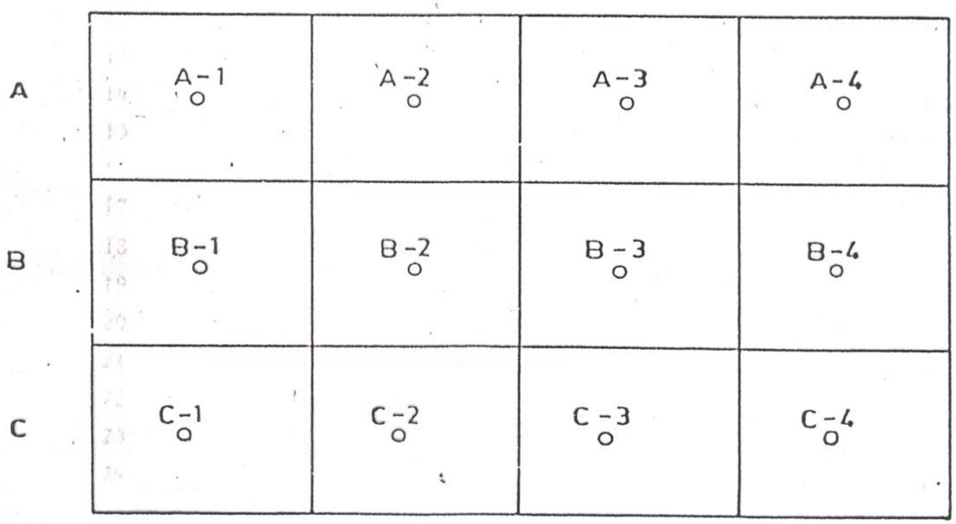
TRAVERSE POINT NUMBER ON A DIAMETER	PERCENT OF STACK DIAMETER FROM INSIDE WALL TO TRAVERSE POINT											
	Number of traverse points on a diameter											
	2	4	6	8	10	12	14	16	18	20	22	24
1	14.6	6.7	4.4	3.3	2.5	2.1	1.8	1.6	1.4	1.3	1.1	1.1
2	85.4	25.0	14.7	10.5	8.2	6.7	5.7	4.9	4.4	3.9	3.5	3.2
3		75.0	29.5	19.4	14.6	11.8	9.9	8.5	7.5	6.7	6.0	5.5
4		93.3	70.5	32.3	22.6	17.7	14.6	12.5	10.9	9.7	8.7	7.9
5			85.3	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	35.5	26.9	22.0	18.8	16.5	14.6	13.2
7				89.5	77.4	64.5	36.6	28.3	23.6	20.4	18.0	16.1
8				96.7	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	26.1	23.0
10					97.5	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	73.9	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



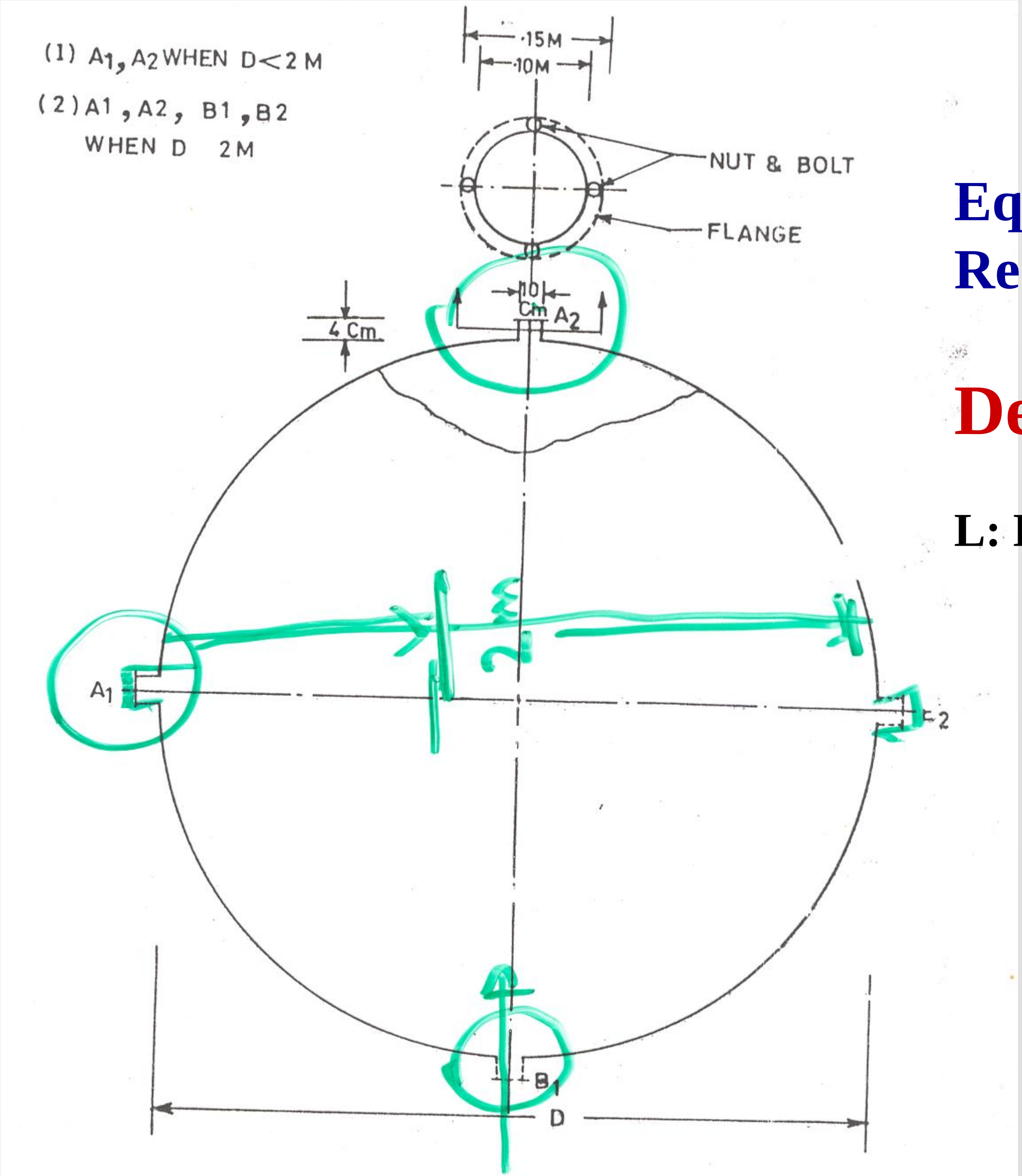
e.g. For 8 TP look downward and locate at 3.3, 10.5 19.4,32.3,67.7,80.6,89.5,96.7 % dia.



$$De = 2LW/(L+W)$$



Locations of Traverse Points on Circular and Rectangular Cross Sections into Twelve equal areas

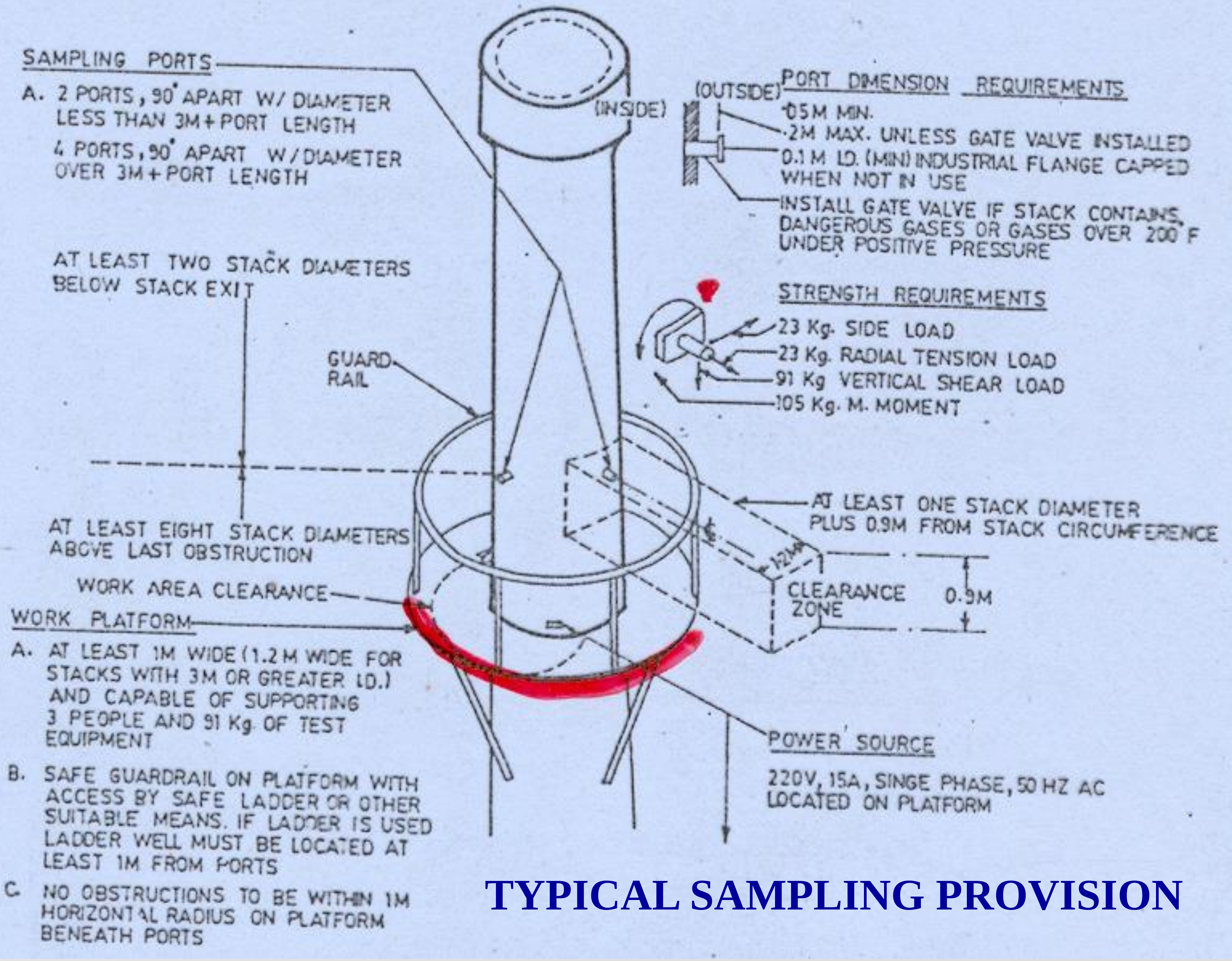


Position of Sampling Ports in Circular Chimney

Equivalent Diameter for Rectangular Duct

De = (2LW)/(L+W)

L: Length **W: Width**



TYPICAL SAMPLING PROVISION

Stack Measurements

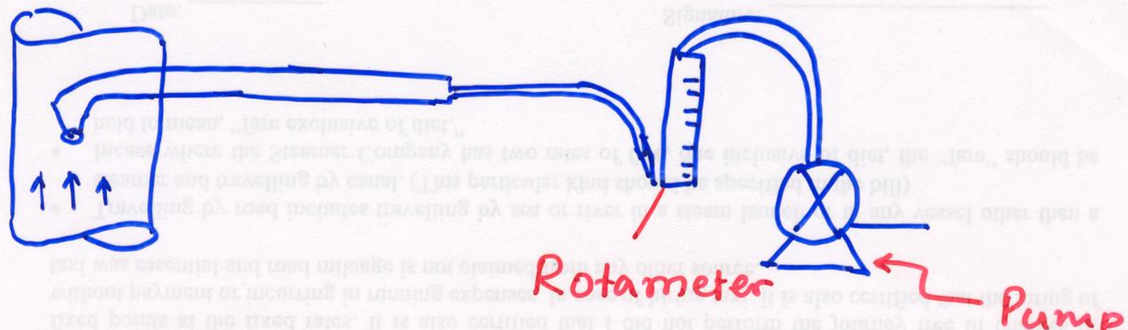
Sampling Control

Stack Sampling

Detail

How to ensure ISOKINETIC SAMPLING

$V_s = V_n$ (Vel. in stack = Vel. at Sampling nozle)



Concept

- Adjust the flow rate at rotameter

so that $V_s = V_n$ (remember dia of nozzle is known)

$Q = A_n \times V_s$ — (1)

Eq (1) is not quite right, why we want Q in the stack but it can only be measured outside at rotameter? Rotameter temp & Pressure is different - Revise Q

$$Q = A_n \times V_s \times \left(\frac{T_m}{T_s}\right)\left(\frac{P_{bar} - P_s}{P_{bar} - P_m}\right)$$

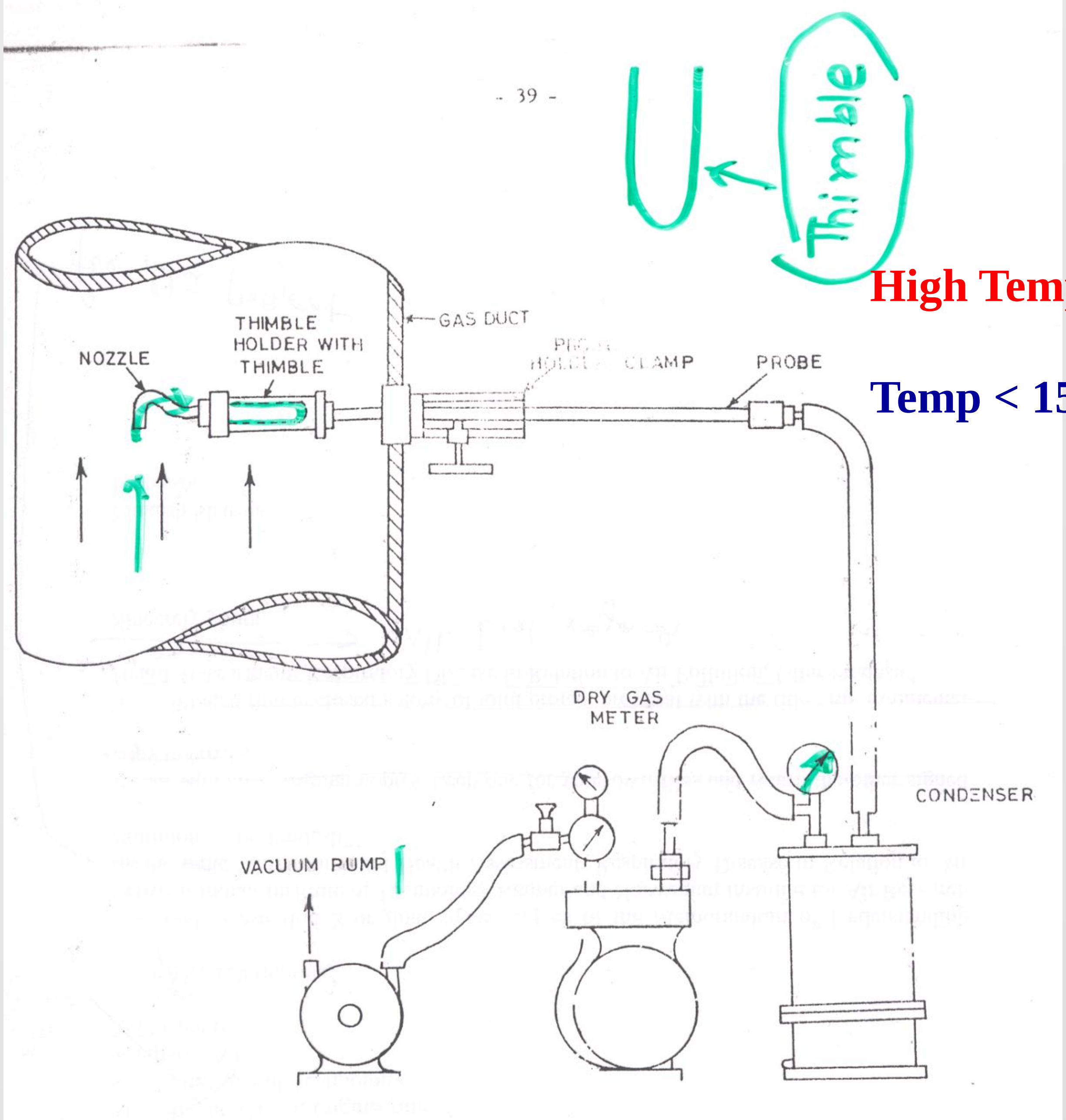
at Rotameter

If moisture is trapped

$$Q = A_n \times V_s \left(T_m / T_s\right)\left(\frac{P_{bar} - P_s}{P_{bar} - P_m}\right)\left(\frac{V_m}{V_m + V_v}\right)$$

V_m → volume of air sampled at meter

V_v → equivalent vapour vol. condensed.

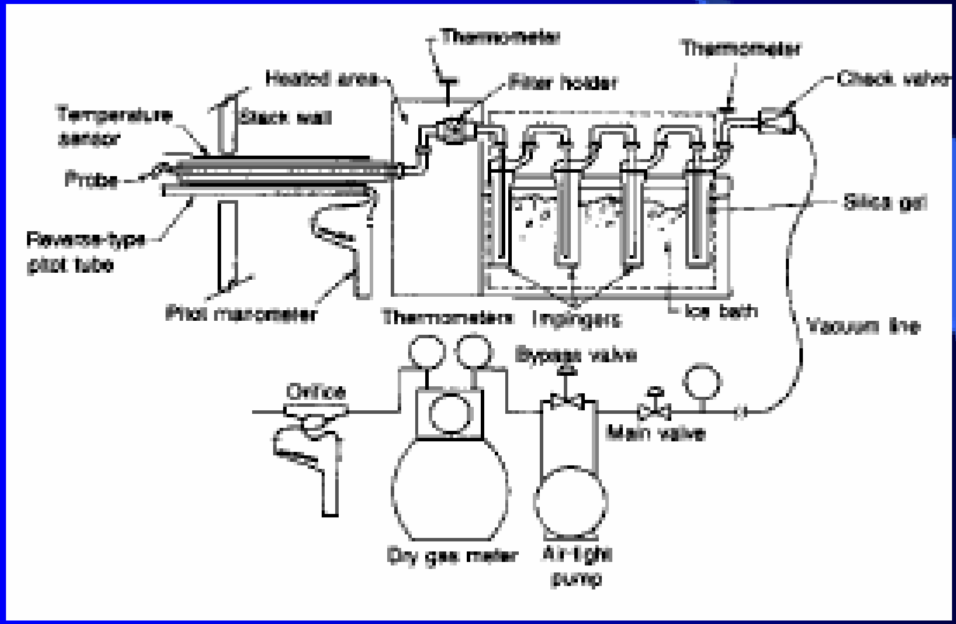


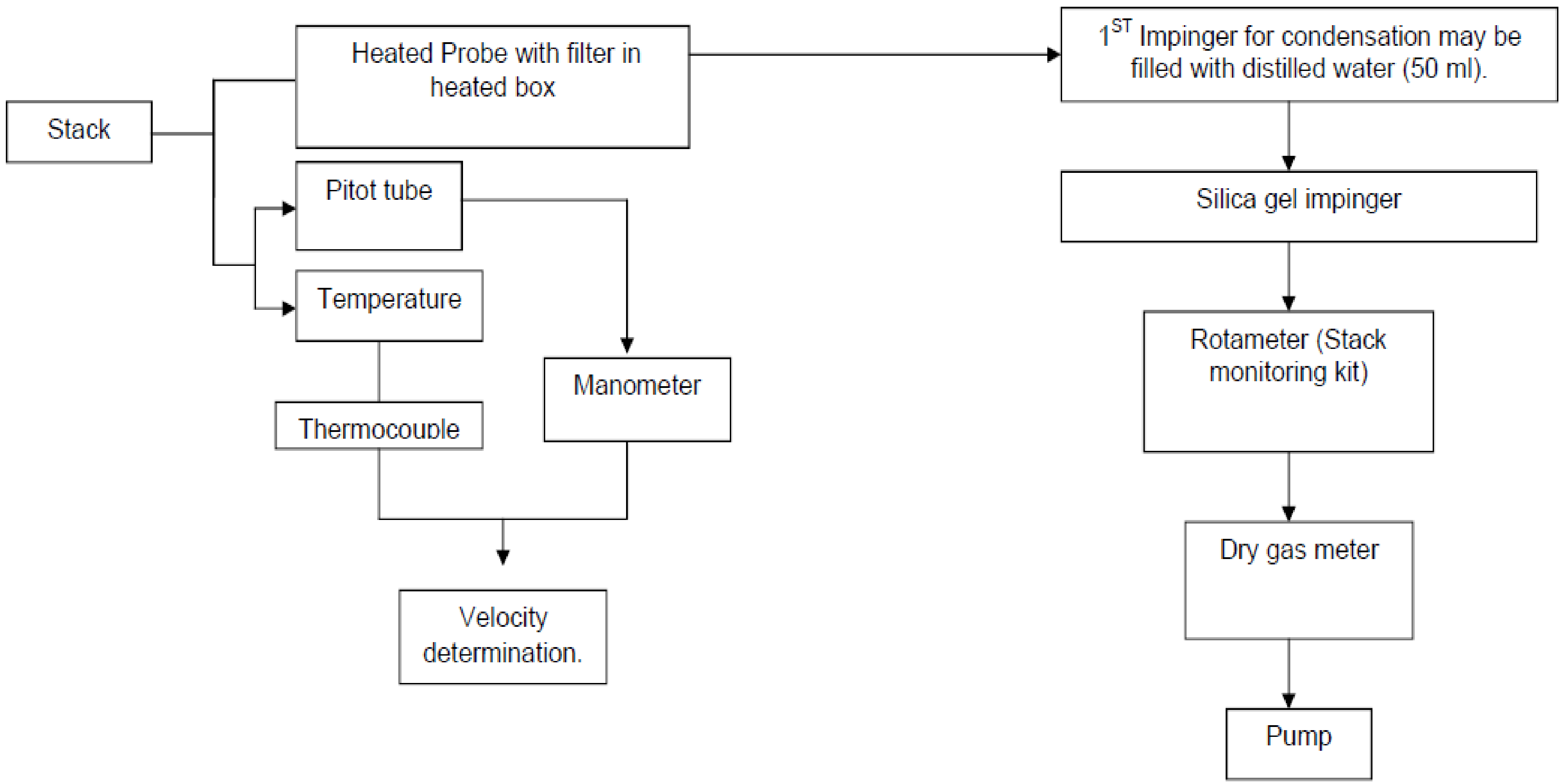
High Temp: Teflon Thimble

Temp < 150^{o}C: Cellulose Thimble

THIMBLE SAMPLING TRAIN

Stack Sampling, Method 5





Summary of Stack sampling Procedure for Particulate

Table- 1
Field Data Sheet

Name & Address
Date & time of Sampling
Ambient Temperature °C
Barometric Pressure (mm mercury column)
Moisture in the flue gas (%) flue gas composition (CO_2 %, O_2 %, N_2)
Filter No and weight (Initial as well as Final)

Travers Point	Δ P (mm)	Ts (°K)	Ps	Us (m/s)	Qs (m^3/hr)	Rs (LPM)	P_m		Rm (LPM)	Time (min)	DGM (m^3)		Vstd (Nm^3)
							P_{m0}	P_{m1}			Initial	Final	

Δ P = Stack Gas Velocity Pressure, (mm water column), **Ts** = Stack temperature (°K),
Ps= Static pressure (mm water column), **Us** = Velocity of stack gas (m/s),
Qs = Volumetric Flow Rate/ Discharge, **Rs** = Flow at nozzle (LPM),
P_m = Vaccum Pressure Drop (mm mercury column),
Rm = Determination of sampling rate at gas meter. (LPM),
Vstd = Determination of volume of Gas Sampled

Other required information:

- Feed rate of hazardous waste
- The nature, composition and quantity of the material being incinerated during monitoring
- Installed and operating capacity of the incinerator
- No of sampling ports
- Internal diameter of the stack
- Nozzle size selected for sampling
- Pitot tube constant
- ID fan capacity
- Pollution control equipment installed and its status
- House keeping

Signature of sample collector **Verified by** **Approved by** **Occupier/ Representative of the incinerator facility**

Determine the Dry molecular weight (M_d) by following equation

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