Reg. No.										

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

A Constituent Institution of Manipal University

VII SEMESTER B.TECH. (CHEMICAL ENGINEERING)

MAKEUP EXAMINATIONS, JAN 2017

SUBJECT: AIR POLLUTION MONITORING AND CONTROL [CHE 415]

REVISED CREDIT SYSTEM
DATE: 2/1/2017

Time: 3 Hours MAX MARKS: 100

Instructions to Candidates:

- Answer **ANY FIVE FULL** questions.
- Missing data may be suitable assumed.

1A	Explain the different background information needed while designing an air pollution monitoring network?	**10**
1B	Explain the different objectives of monitoring air pollution.	**10**

2A	With a neat sketch explain any five types of plume behavior in stack based on atmospheric conditions.	**10**
2B	A city is located near an airport. The smelter stack is 300 m high and has a plume rise of 100m. It is emitting 5000 g/s of SO_2. Assume stability class is C (Refer chart in next page) and that wind speed is 3 m/s. A flight path for airport is perpendicular to the plume and 5km downwind of the smelter. The airport safety office has determined that it is unsafe for planes if the planes if the plume concentration > 500 µg/m3. They have also decided that it is unsafe to fly under the plume. a) What is the minimum altitude the plane can fly safely above the plume? Assume Gaussian plume and neglect ground reflection of plume b) List steps you would propose to reduce the effect of the air pollution caused by the plant if the other contaminant from the plant includes Particulate matter	**8** **2**

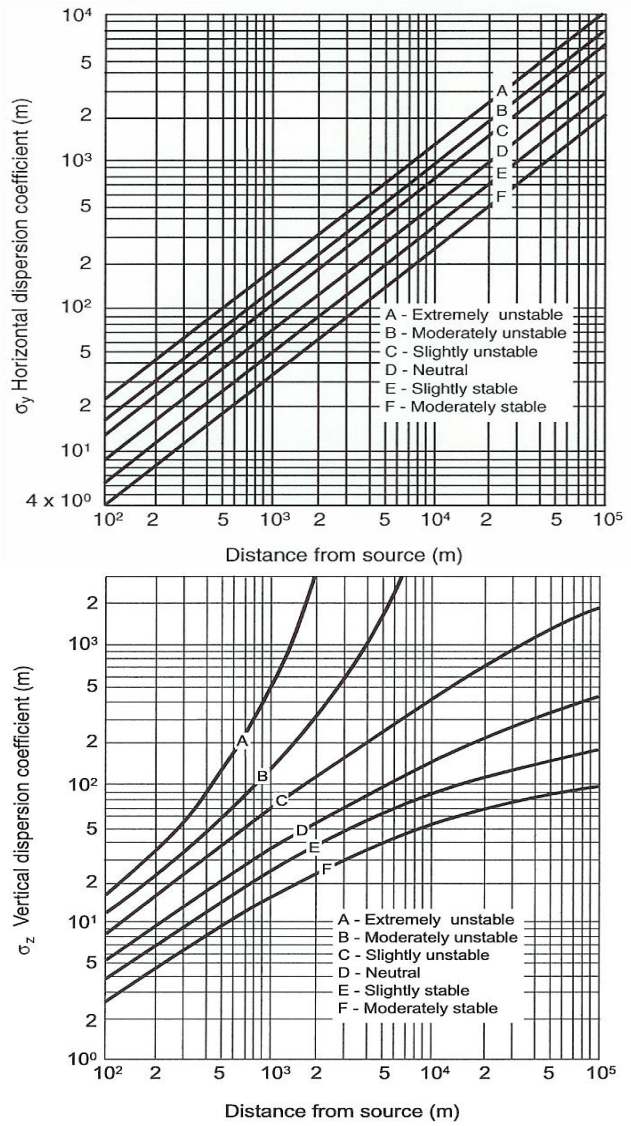
3A	With a neat sketch explain the working of a high volume sampler and electrostatic precipitator	**10**
3B	Explain wind rose diagram with a neat sketch	**10**

4A	Draw a neat chart of temperature dependence of NOx formation and explain thermal NOx, fuel NOx and prompt NOx.	**10**
4B	Explain briefly post combustion methods for control of NOx	**10**

5A	With a neat diagram derive the expression for fixed box model and list the assumptions.	**10**
5B	With a neat diagram explain Forced oxidation limestone wet scrubber for	**10**

	SO_2 removal	

6A	i) Name two green house gases ii) Write short notes on CO_2 sequestration ii) What are the reasons for high air pollution in India	**1** **4** **5**
6B	List five major air pollutants, their corresponding Indian National ambient air quality (NAAQ) limits in residential areas and their sources	**10**



Dispersion coefficients for various stability criteria

VII SEMESTER B.TECH. (CHEMICAL ENGINEERING)

END SEMESTER EXAMINATIONS, NOV/DEC 2016

SUBJECT: AIR POLLUTION MONITORING AND CONTROL [CHE 415]

SOLUTIONS

1 A) Explain the different background information needed while selecting an air pollution monitoring site? (10M)

Explain any five **(2 M each)**

1. Sources and emissions
2. Health and demographic information
3. Meteorological information
4. Topographical information
5. Pervious air quality information
6. Land use zoning considerations

1B) What are the reasons for high air pollution in India?

10 reasons (1 M each)

1. Vehicles growth
2. Corruption in PCB
3. Construction
4. Old design
5. Lack of public awareness
6. Low quality fuel
7. Coal has more sulfur
8. Use of non-clean fuel
9. High population
10. Burning of crops
11. Wrong situation of industries
12. Old process technology

1C) Explain the terms: a)Dust b) fumes c) mist d) summer smog and e) winter smog (2 M each)

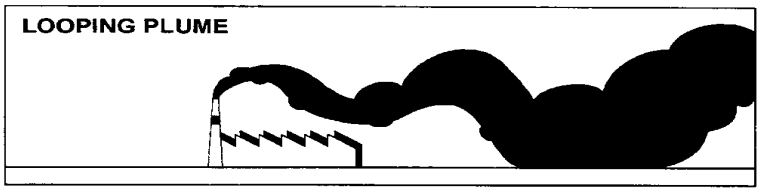
Definition as in M.N. Rao
Dust: solid particles (1-200uM)
Fumes: solid or liquid particles form condensation of gaseous state after volatilization
Mist: (40-500um) It refers to a low concentration dispersion of liquid particles in air
Summer smog: Due to ozone + NOx or Sox
Winter Smog: Due to inversion in winter +smoke

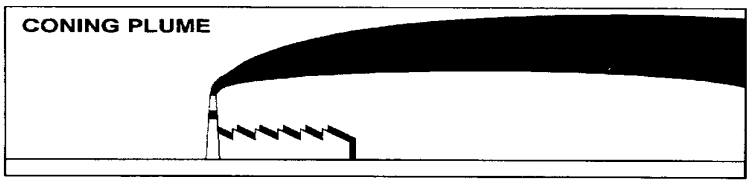
2A) With a neat sketch explain any five types of plume behavior in stack based on atmospheric conditions.

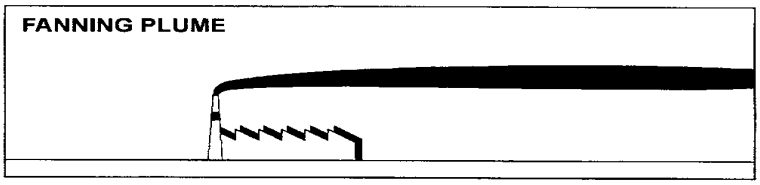
(Figure 1M, Explanation 1M)X5

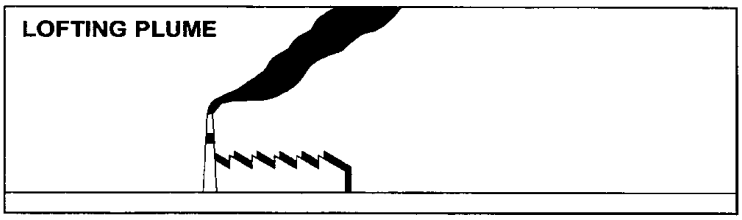
TYPES OF PLUMES

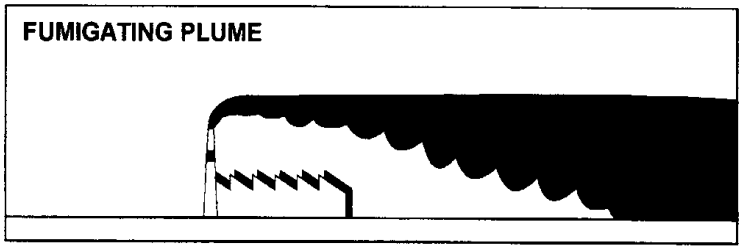
- Fanning plumes
- Looping plumes
- Coning plumes
- Fumigating
- Lofting
- Trapping plume

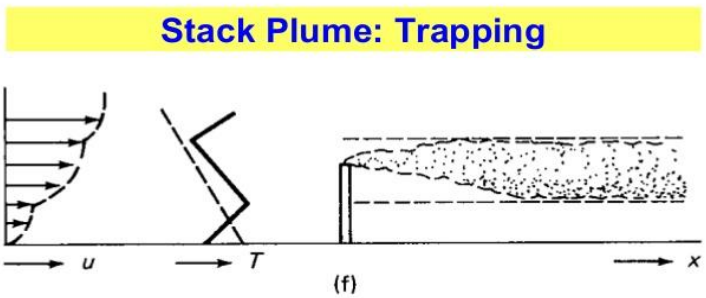












2B) It is proposed to establish a 750 MW power plant in your city. The plant emits 143,000 lb/day of SO_2 from effective height of 250m. Estimate concentration of SO_2 at a house which is at downwind distance of 4km if the wind speed is 6.63 m/s. Assume stability class is C. Does the plant satisfy the PCB NAAQ standards? Assume Gaussian plume. Consider ground reflection of plume. Dispersion coefficients in figure below
a) At ground level.
b) At the centerline of the plume.
c) List steps you would propose to reduce the effect of the air pollution caused by the plant if the other contaminants from the plant include particulate matter and NO_x

V	6.63	m/s
Q	751.412037	g/s
H	250	m
x	4000	m

SOLN

σy	370	m
σZ	215	m

ANSWER

A)	230.7777138	ug/m3	With reflection (4M)
	115.3888569		Without reflection
		At center of plume	
B)	242.0467085	(4M)	

STEPS FOR SO_2 (0.25 marks each)

1. **Forced oxidation limestone scrubber**
2. **Low sulfur coal**
3. **Scrubbing with wat**

STEPS FOR NOx

1. **Control of burning temperature**
2. **Catalytic convertors**
3. **NH3 addition**

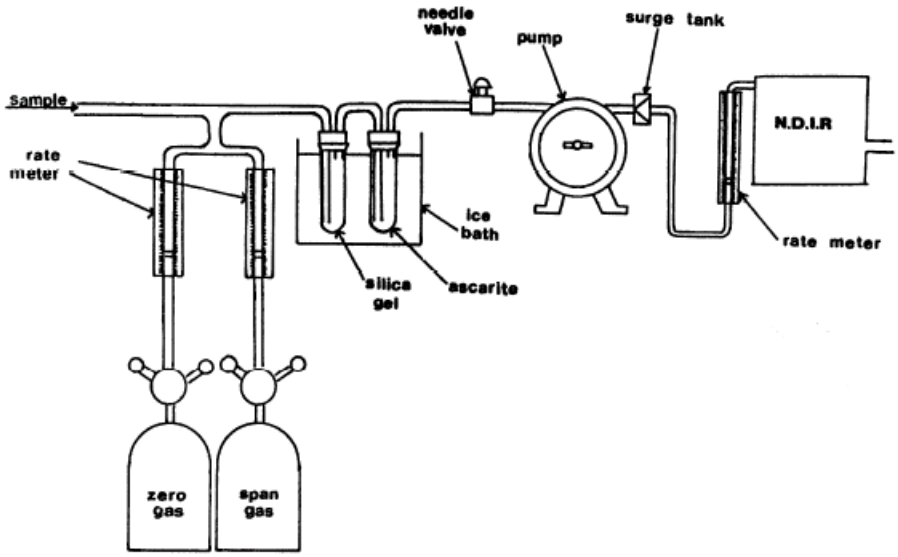
STEPS FOR Particulate matter

1. **Electrostatic precipitator**
2. **Bag house filter**
3. **Water Scrubber**

3A)i)With a neat diagram explain the NDIR method of CO_2 measurement.

Ans: Diagram 3M, principle 2M, Explanation 1M

NdiR method the infrared absorption shows the presence of CO_2



ii) What are the methods of control of CO_2 emissions?
Ans: Each point 1 M

1. Energy efficiency -fuel efficient vehicles. energy efficient appliances
2. Energy conservation -turn off lights when not in use
3. Fuel switching -renewable sources and low carbon fuels
4. Coal to gas substitution
5. Carbon capture and sequestration from coal and gas fired plants

3B) With a neat diagram explain Wet Dry Method of limestone scrubber for removal of SO_2 from flue gases.
Figure 6M, principle 4M

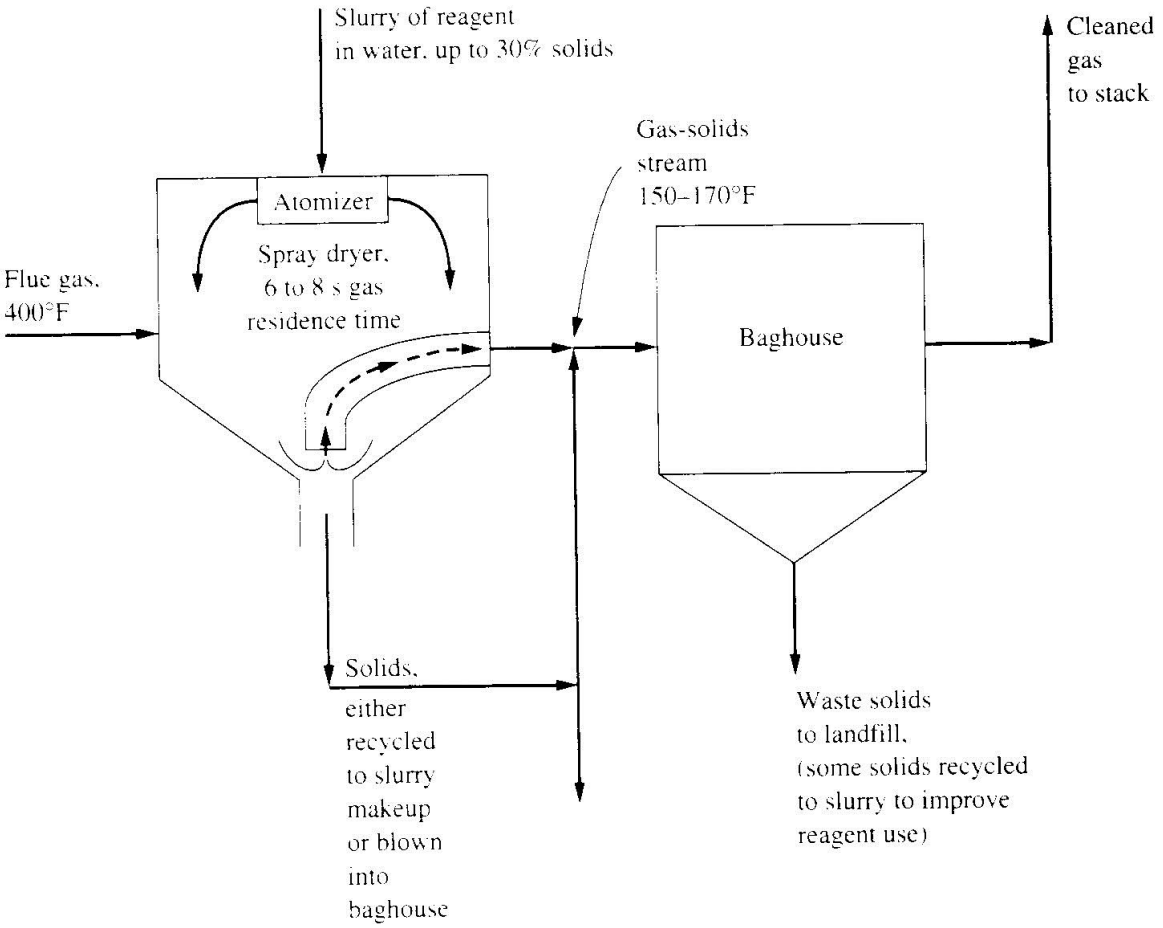


FIGURE 11.8
Flow diagram for spray dryer process for removal of SO_2 from stack gases.

- Spray dryers are widely used in the process industries, e.g., powdered milk, instant coffee, laundry detergents, etc.
- In all such spray dryers a liquid (almost always water) containing dissolved or suspended solids is dispersed as droplets into a hot gas stream.
- The dispersion can be done by a high-pressure gas-atomizing nozzle or a rapidly rotating (about 10,000 rpm) atomizing wheel.
- The hot gas is well above the boiling temperature of water, so that the water in the droplets evaporates rapidly.

4) A. Draw a neat chart of temperature dependence of NOx formation and explain thermal NOx, fuel NOx and prompt NOx.

Fig: 4M
Explanation: 2 M each

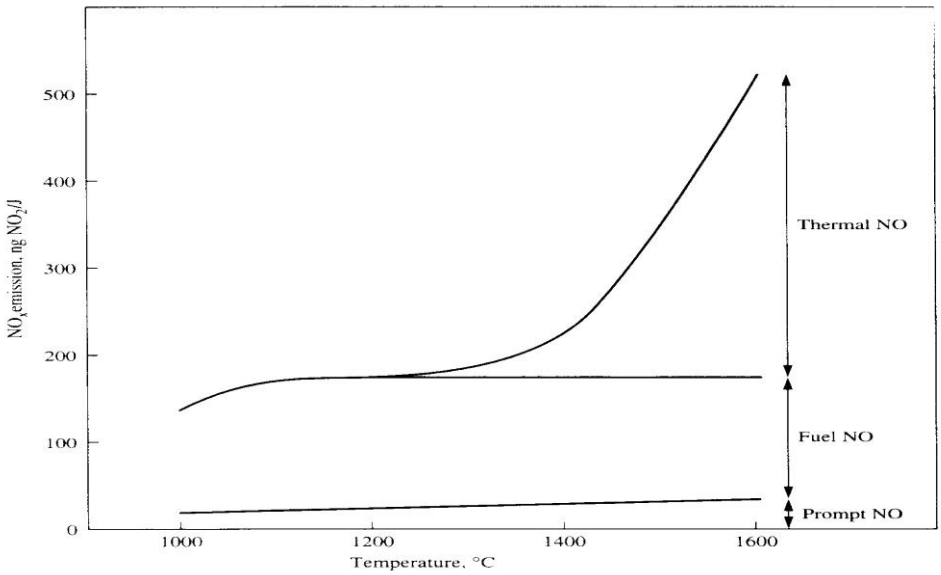


FIGURE 12.4
Estimated contributions of the three NO mechanisms to total NO_x formation in coal combustion. (Courtesy of the Air and Waste Management Association, from Ref. 7.)

Thermal NOx: formed by reaction between N2 and O2 in the air; sensitive to temperature

Fuel (NOx: formed from combustion of fuel containing organic nitrogen; dependent on local combustion conditions and nitrogen content in the fuel.

Prompt NOx)

Not all of the fuel nitrogen compounds are released during combustion. Unlike sulfur, a significant fraction of the fuel nitrogen remains in the bottom ash or in the fly ash

4B) Explain briefly different combustion modifications for control of NOx

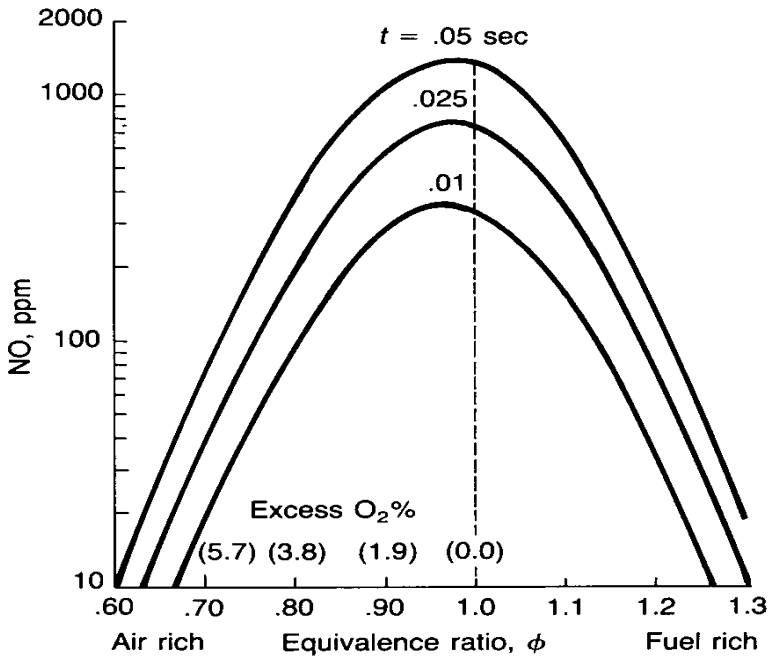
EACH METHOD (2.5 M) X 4

Modify combustion to suppress NOx formation

- Low excess air operation
- Off-stoichiometric combustion
- Flue gas recirculation
- Natural gas reburning
- Low Nox burners
- Overfire air

Off-stoichiometric combustion: Involves the mixing of the fuel and air in a way that reduces the peak
gas temperatures and peak oxygen concentrations.

- ❑ Low NOx burners: Keeps temperatures down and dissipates heat quickly
- ❑ Overfire air (OFA): Keeps mixture fuel rich and completes combustion process using air injection nozzles
- ❑ Burners out of service (BOOS): Operates alternate burners in combustion zone as fuel rich, air rich, and air only



Fuel reburning: Involves the operation of the main burners in a boiler at very low excess air (fuel rich conditions). A series of overfire air ports are used in this upper region to provide all of the air needed for complete combustion.

Flue gas recirculation : Involves the return of cooled combustion gases to the burner area of the boiler. Reduced temperatures produce less NOx. The process requires a recirculation fan and duct system.

Figure 2. Off-Stoichiometric Combustion in Burner (Low NO_x Burner)

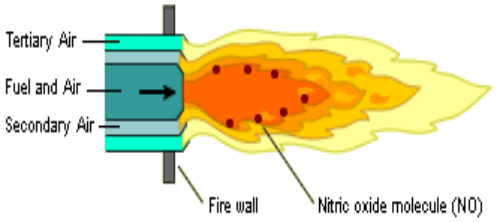


Figure 3. Off-Stoichiometric Combustion (Overfire Air)

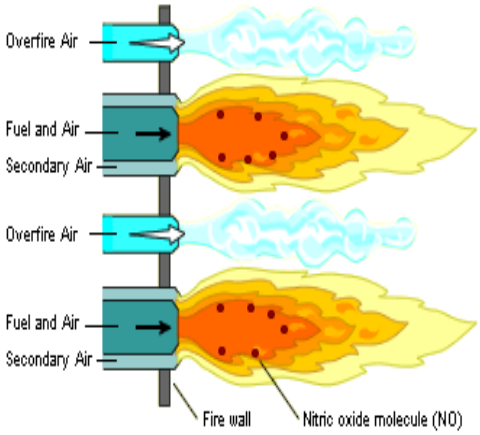


Figure 4. Off-Stoichiometric Combustion (Burners-Out-of-Service)

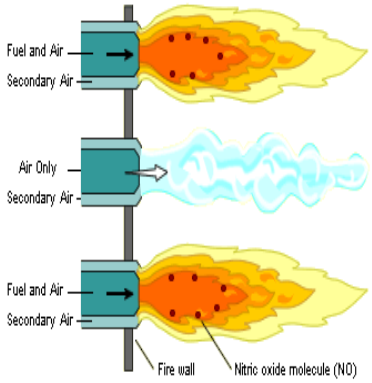
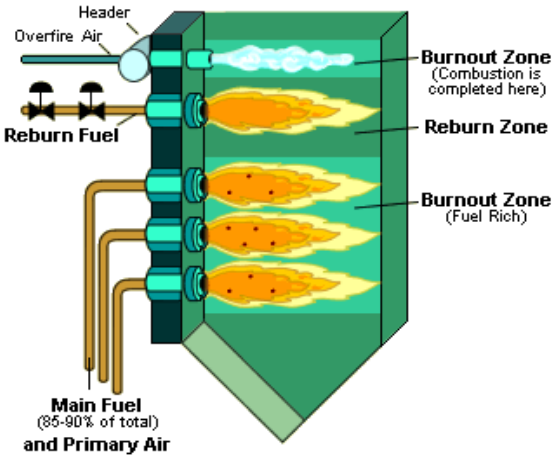


Figure 5. Fuel Reburning



5A) Derive the expression for displacement losses for VOCs.
Assumptions and initial preamble: 2M
Fig: 4M
Derivation: 4M

Filling, Breathing, and Emptying Losses

Tank containing liquid VOCs can emit VOC vapors because of filling and emptying activities as well as changes in temperature and atmospheric pressure.

These emissions are called filling or displacement losses, emptying losses, and breathing losses, or, collectively, working losses.

Fig. shows a simple tank of some kind being filled with liquid from a pipeline.

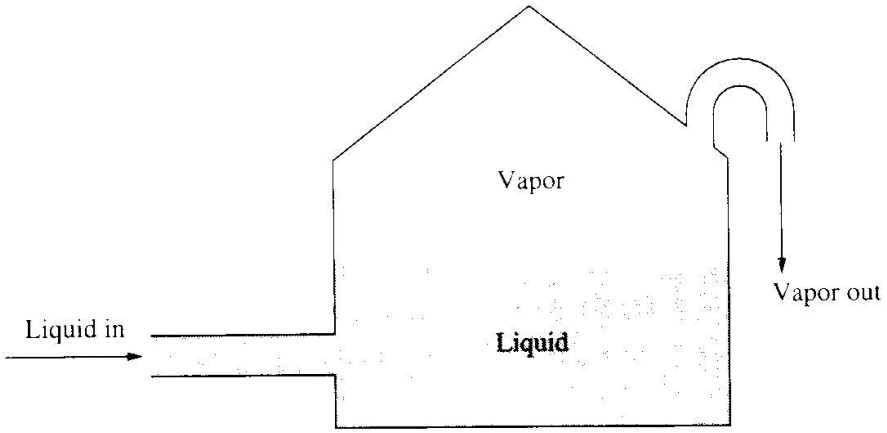


FIGURE 10.2
Displacement losses occur when a vented tank is filled with liquid, thus displacing vapor from the tank's headspace. The tank walls support the roofs of small cone-roof tanks; large ones have internal supports. All have some kind of vent on the roof.

For all three kinds of working losses,

$$VOC\ emission = \begin{pmatrix} volume\ of\ air\text{-}VOC\ mix \\ expelled\ from\ the\ tank \end{pmatrix}\begin{pmatrix} concentration\ of \\ VOC\ in\ that\ mix \end{pmatrix}$$

$$m_i = \Delta V c_i \qquad (3)$$

where m_i = mass emission of component i

c_i = concentration in the displaced gas

$$= \frac{y_i M_i}{V_{molar,gas}}$$

$$\frac{m_i}{\Delta V} = \frac{x_i p_i M_i}{P} \cdot \frac{P}{RT} = \frac{x_i p_i M_i}{RT} \qquad (5)$$

5B)Estimate the volume of gasoline vapor emitted as displacement losses per cubic meter of gasoline when gasoline is transferred from petrol station storage tanks to the gasoline tanks of the customers' vehicles at 250C. The vapor pressure of gasoline is 6 psia and the molecular weight is 60 g/mol. (1 atm = 14.7 psia). Density of gasoline is 750 kg/m3. What volume % of gasoline is lost?

Initial setup: 1M

Equation: 1M

Solution process and correct answer: 3M

The vapor pressure as 6 psia and the molecular weight as 60 g/mol. (given)

$$\frac{m_i}{\Delta V} = \frac{x_i p_i M_i}{RT} = \frac{(1.0)(6\ psia)(60\ lb/lbmol)}{(10.73\ psi \cdot ft^3/lbmol/{}^oR)(528{}^oR)}$$

$$= 0.063\ lb\ gasoline/\ ft^3\ vapor\ = 1.02\ kg\ gasoline/m^3\ vapor$$

- The density of liquid gasoline is roughly 47 lb/ft³, so we can rework finding that the concentration of gasoline in the displaced vapor is:

- The fraction of the gasoline filled that is emitted is:

$$\frac{0.063\ lb\ gasoline/\ ft^3}{47\ lb\ gasoline/\ ft^3} = 1.34 \times 10^{-3} = 0.134\%$$

Above Answer should be multiplied by 2 as pressure is 12 Psia not 6 psia.

So actual answer is 0.268%

5B) Why is air pollution a major worldwide concern? Write short notes on the Indian laws of air pollution control and world treaties of air pollution control
Introduction-concern 2M
Indian Air Pollution Act (4M)
Kyoto treaty (2M)
Paris treaty (2M)

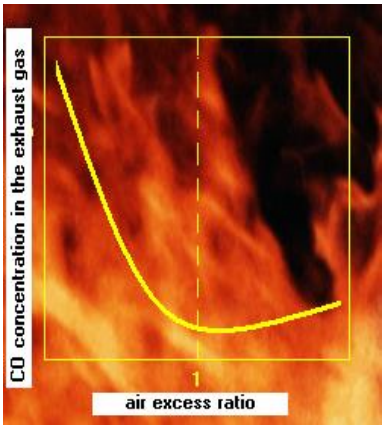
The air (prevention and control of pollution) act of India 1981 and the functions of the central pollution control board under this act.

Air (Prevention and Control of Pollution) Act 1981 Government of India enacted the Air (Prevention and Control of Pollution) Act 1981 to
arrest the deterioration in the air quality. The act prescribes various functions for the Central Pollution Control Board (CPCB) at the apex level and State Pollution Control
Boards at the state level. The main functions of the Central Pollution Control Board are as follows:

• To advise the Central Government on any matter concerning the improvement of the quality of the air and the prevention, control and abatement of air pollution.
• To plan and cause to be executed a nation-wide programme for the prevention, control and abatement of air pollution.
• To provide technical assistance and guidance to the State Pollution Control Board.
• To carry out and sponsor investigations and research related to prevention, control and abatement of air pollution.
• To collect, compile and publish technical and statistical data related to air pollution; and
• To lay down standards for the quality of air and emission quantities.

6A
i) Why is CO called a silent killer?
ii) What are the anthropogenic and natural sources of CO?
ii) With a figure of excess air vs carbon monoxide production explain the strategies to reduce carbon monoxide?

i)it is colorless, odorless and makes u unconscious
ii) Transportation: Internal combustion engines (~75%)
Agricultural burning: (~ 10%)
Industrial process losses: Steal industry, carbon black production, petroleum refineries (~ 10%)
Fuel combustion – stationary sources: coal, fuel oil, natural gas, wood (~ 1%)
natural –swamps
iii)



- n = 1 : In case of perfect mixing the available lowest CO content
- n < 1 : the amount of oxygen is not enough for the $CO \rightarrow CO_2$ transformation
- n > 1 : too much air cools down the combustion chamber and residence time is decreasing. There is not enough time for the slow $CO \rightarrow CO_2$ reaction.

6Bi)Define VOCs. Name a few common VOCs (2M)

- VOLATILE: That which vaoprises
- VOCs: The basic definition is the one given in the Solvents Emission Directive (SED): "any organic compound having at 20 °C a vapour pressure of 0.01 kPa or more or having a corresponding volatility under the particular conditions of use"

VOCs: Ethanol, paint, petroleum

ii)What are the control methods to reduce VOC pollution? (8M)

1. Prevention
   - Substitution
   - Process modification control
   - Leakage prevention
2. Concentration and recovery
   - Condensation
   - Adsorption
   - Absorption (scrubbing)
3. Oxidation
   - Combustion (incineration)
   - Biological oxidation (bio-filtration)