

**JK Lakshmipat University Jaipur**  
**INSTITUTE OF ENGINEERING AND TECHNOLOGY**

End Term Examination, December 2022

M. Tech. (HSEE), Semester III, 2022-23

Roll No.....

ME2202: Chemical Safety

Time: 3 hours

Max. Marks: 60

**Instructions to students:**

1. Do not write anything other than your roll number on the question paper.
2. Mention all the assumptions for your answers clearly.
3. Choice for attempt Question-3 or Question-4.

In a plant manufacturing rayon textile yarn, a viscose solution comprising alkali cellulose dissolved in caustic soda lye is passed through a spinning machine jet and immersed in the bath of clean dilute sulphuric acid.



After the separation of sodium sulfate salt and sulphuric acid in the slurry collected from the spinning machine, through the filtration process in the Rotary Vacuum Filter, the recovered acid, spent acid, is stored in the spent acid tank and filtered through Columbia filters, concentrated to the desired level, stored in a clean acid tank and, from there, reused on spinning machines.

Four large rectangular tanks were provided in the basement of the spinning room, two for storing spent acid and two for clean acid, in a row adjacent to each other. One of the spent acid tanks was taken out of circulation for maintenance. The tank was thoroughly emptied, isolated from inlet lines, and was to be cleaned manually from the inside. A safe entry permit was procured with the gas concentration, tested and certified, to be within threshold limits.

After an hour or so of working inside the tank, the workman on the job of cleaning was observed, by the supervisor, to be lying flat. Realizing the gravity of the situation, the supervisor rushed into the tank to rescue the workman. He also became unconscious and fell down inside the tank. Others working nearby rescued both the affected persons in time, making use of self-breathing apparatus during their rescue operation. Both victims survived on receiving immediate first aid followed by medical treatment in the hospital without any loss of time.

The hold up in the adjacent spent acid tank had increased to a greater extent during the one-hour period while the workman was cleaning the other tank. H<sub>2</sub>S gas liberated from the tank, being heavier than air, spread out and entered the empty tank.

|        |                                                                                                                                                   |                |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Q. 1.1 | Investigate the above accidents find the root cause and suggest the most suitable control measures for prevent the hazards in the above accident. | 5.0<br>(LO1,5) |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------|----------------|

|        |                                                                                                                                                                |                |
|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|
| Q. 1.2 | Develop effective methods for proper care and maintenance of respiratory protective equipment.                                                                 | 5.0<br>(LO4)   |
| Q. 1.3 | Determine factors necessary when selecting appropriate personal protective equipment for protecting the human from hazardous chemicals similar above accident. | 5.0<br>(LO3,4) |
| Q. 1.4 | Prepare the safety procedure as per legislation to protect life, society, and property from the above toxic chemical accident.                                 | 5.0<br>(CO4,6) |

A massive explosion in Pasadena, Texas, on October 23, 1989, resulted in 23 fatalities, 314 injuries, and capital losses of over \$715 million. This explosion occurred in a high-density polyethylene plant after the accidental release of 85,000 pounds of a flammable mixture containing ethylene, isobutane, hexane, and hydrogen. The release formed a large gas cloud instantaneously because the system was under high pressure and temperature. The cloud was ignited about 2 minutes after the release by an unidentified ignition source.

The damage resulting from the explosion made it impossible to reconstruct the actual accident scenario. However, evidence showed that the standard operating procedures were not appropriately followed.

The release occurred in the polyethylene product takeoff system, as illustrated in Figure 1. Usually, the polyethylene

particles (product) settle in the settling leg and are removed through the product takeoff valve. Occasionally, the product plugs the settling leg, and the plug is removed by maintenance personnel. The normal - and safe - procedure includes closing the DEMCO valve, removing the air lines, and locking the valve in the closed position. Then the product takeoff valve is removed to give access to the plugged leg.

The accident investigation evidence showed that this safe procedure was not followed; specifically, the product takeoff valve was removed, the DEMCO valve was in the open position, and the lockout device was removed. This scenario was a serious violation of well-established and well-understood procedures and created the conditions that permitted the release and subsequent explosion.

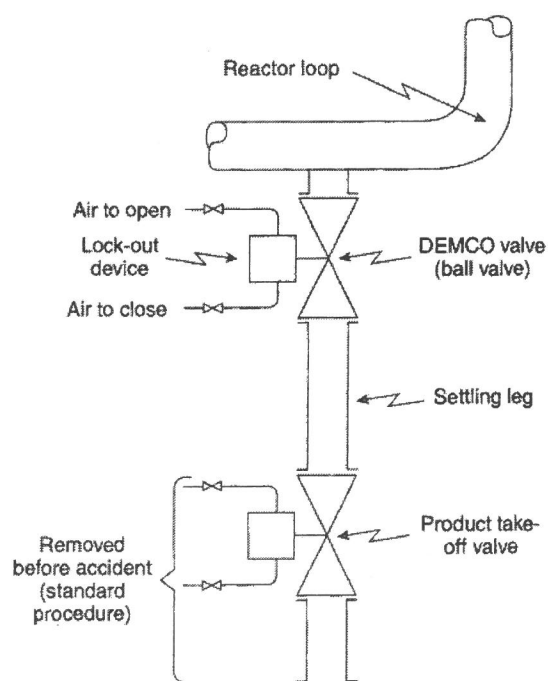
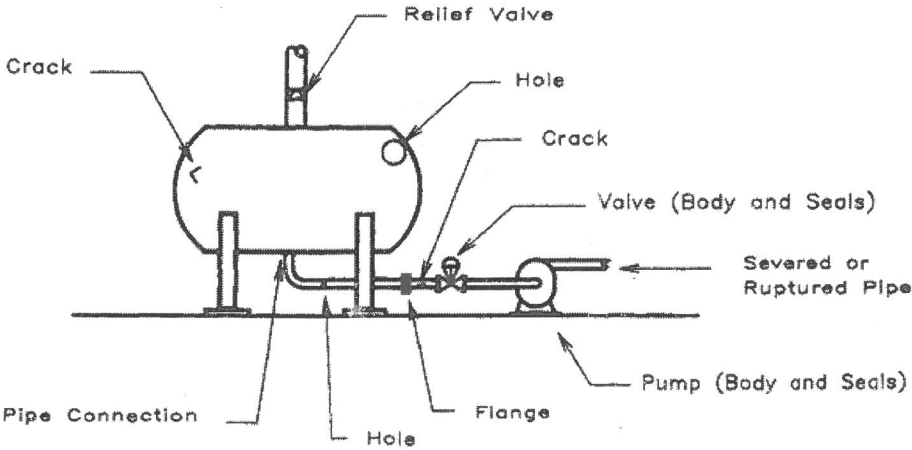


Figure. 1 Polyethylene plant settling leg and product takeoff system

|        |                                                                                                                                               |                    |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------|
| Q. 2.1 | Investigate the above accidents to find the root causes/ factors that contributed to the severity of this disaster as per OSHA investigation. | 5.0<br>(LO2, 3, 4) |
|--------|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------|

|        |                                                                                                                               |                |
|--------|-------------------------------------------------------------------------------------------------------------------------------|----------------|
| Q. 2.2 | Laid down the procedure for proper handling storage and use of flammable and toxic chemicals as per OSHA regulation.          | 5.0<br>(LO1,5) |
| Q. 2.3 | Suggest and explain the most suitable techniques for identifying the hazards and calculating the risk for the above accident. | 5.0<br>(LO2,3) |
| Q. 2.4 | Develop the onsite and off te emergency plan for chemical spills or fires.                                                    | 5.0<br>(LO6)   |

|        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                  |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|
| Q. 3.1 | <p>Write the consequence analysis procedure for spill/leak out of the toxic material in the figure-2.</p>  <p style="text-align: center;"><i>Figure.2 Various types of limited aperture releases.</i></p>                                                                                                                                                                                                                                                                                                                                                                                        | 5.0<br>(LO4,5)   |
| Q. 3.2 | <p>A cylindrical tank 25 ft high and 10 ft in diameter is used to store benzene. The tank is padded with nitrogen to a constant regulated pressure of 1 atm gauge to prevent an explosion. The liquid level within the tank is presently at 20 ft. A 1-in puncture occurs in the tank 5 ft off the ground because of the careless driving of a forklift truck. Estimate</p> <ul style="list-style-type: none"> <li>(a) the gallons of benzene spilled,</li> <li>(b) the time required for the benzene to leak out, and</li> <li>(c) the maximum mass flow rate of benzene through the leak.</li> </ul> <p><i>The specific gravity of benzene at these conditions is 0.8794.</i></p> | 5.0<br>(LO2,5)   |
| Q. 3.3 | <p>Dispersion models describe the airborne transport of toxic material away from the accident site and into the plant and community. After a release, the airborne toxic material is carried away by the wind in a characteristic plume, as shown in Figure-5.1, or a puff, as shown in Figure 5.2. find out the Parameters Affecting Dispersion for both type of dispersion with suitable diagram.</p>                                                                                                                                                                                                                                                                             | 5.0<br>(LO1,2,3) |

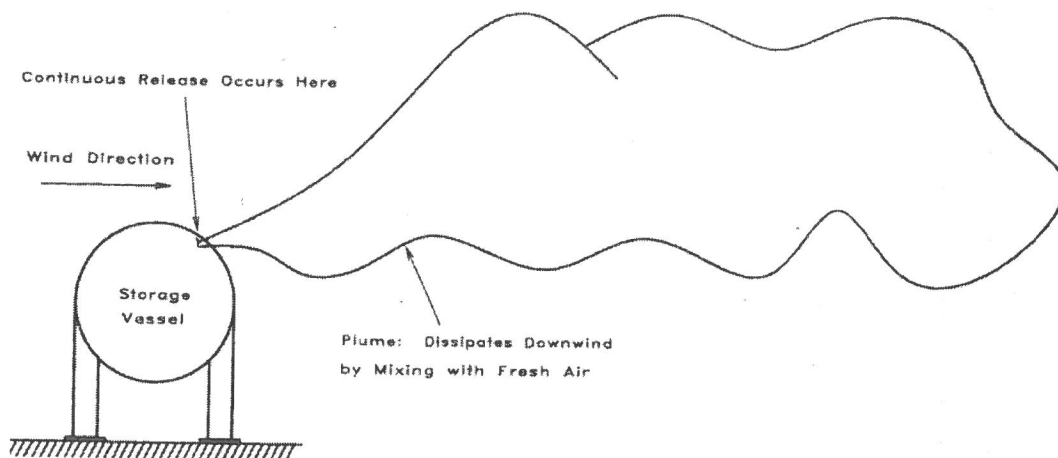


Figure 5-1 Characteristic plume formed by a continuous release of material.

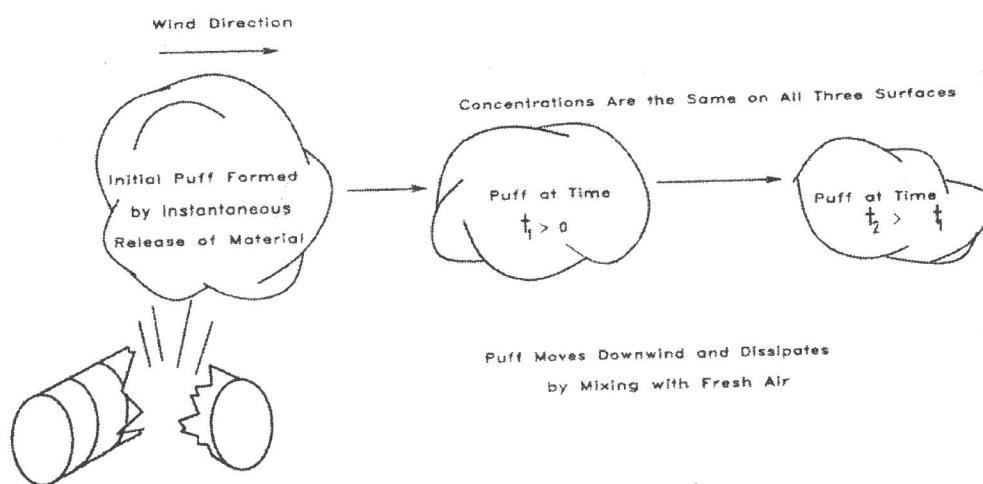
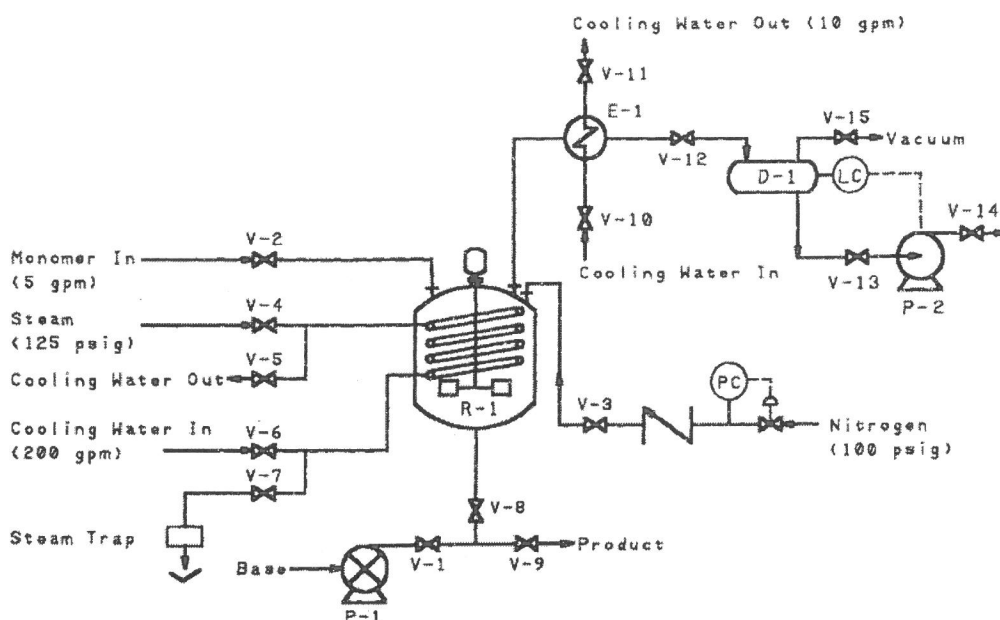


Figure 5-2 Puff formed by near instantaneous release of material.

- Q. 3.4 Specify the location of reliefs in the simple polymerization reactor system illustrated in Figure 5. The major steps in this polymerization process include
- (1) pumping 100 lb of initiator into reactor R-1,
  - (2) heating to the reaction temperature of 240 °F,
  - (3) adding monomer for a period of 3 hr, and
  - (4) stripping the residual monomer by means of vacuum using valve V-15.
- Because the reaction is exothermic, cooling during monomer addition with cooling water is necessary.

5.0  
(LO2,3)



Specifications

| Name | Description      | Max. psig | Gpm at 50 psig |
|------|------------------|-----------|----------------|
| D-1  | 100 Gal Drum     | 50        | —              |
| R-1  | 1000 Gal Reactor | 50        | —              |
| P-1  | Gear Pump        | 100       | 100            |
| P-2  | Centrifugal Pump | 50        | 20             |

| Piping:               | Size     |
|-----------------------|----------|
| Steam and Water Lines | 2 inch   |
| Nitrogen              | 1 inch   |
| Vapor Lines           | 0.5 inch |

Figure Error! No text of specified style in document.3 Polymerization reactor without safety reliefs

OR

|        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                 |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Q. 4.1 | <p>Laws and regulations are major tools for protecting people and the environment. Congress is responsible for passing laws that govern the United States. To put these laws into effect, Congress authorizes certain government organizations, including the Environmental Protection Agency (EPA) and OSHA, to create and enforce regulations.</p> <p>Write the process for Creating a Law, Creating a Regulation, or/and Standard, and also prepare a list of laws and regulations particularly relevant to the chemical industries.</p> | 5.0<br>(LO4, 5) |
| Q. 4.2 | <p>Develop the correlation for mass discharge and empty time of Liquid through a Hole in a Tank.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                        | 5.0<br>(LO1,2)  |

Process Vessel

$\rho$  = Liquid Density

A = Leak Cross  
Sectional Area

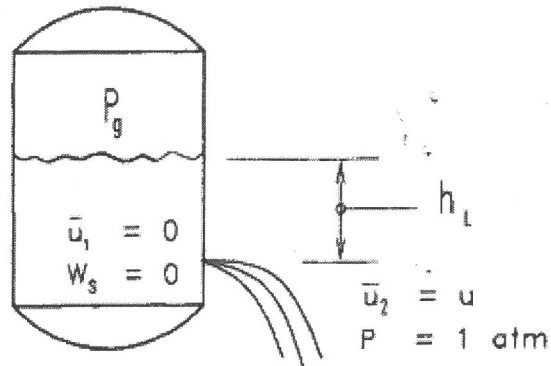


Figure.4 An orifice-type leak in a process vessel

|        |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                 |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|
| Q. 4.3 | <p>On an overcast day, a stack with an effective height of 60 m is releasing sulfur dioxide at the rate of 80 gals. The wind speed is 6 m/s. The stack is located in a rural area. Determine</p> <ol style="list-style-type: none"> <li>The mean concentration of SO<sub>2</sub> on the ground 500 m downwind.</li> <li>The mean concentration on the ground 500 m downwind and 50 m crosswind.</li> <li>The location and value of the maximum mean concentration on ground level directly downwind.</li> </ol> <p>Data: The stability class is D, For D stability, <math>\sigma_z</math> has this value at about 1200 m downwind and <math>\sigma_y = 88</math> m.</p> | 5.0<br>(LO1, 3) |
| Q. 4.4 | <p>Develop the correlation to calculate the Relief Sizing of Conventional Spring-Operated Reliefs in Liquid Service.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | 5.0<br>(LO5,6)  |

*All the best!*