



UNIVERSITI KUALA LUMPUR
MALAYSIAN INSTITUTE OF CHEMICAL AND BIO-ENGINEERING TECHNOLOGY

FINAL EXAMINATION
OCTOBER 2025 SEMESTER

COURSE CODE : CKB30103
COURSE TITLE : INDUSTRIAL SAFETY & HEALTH
PROGRAMME NAME : BACHELOR OF CHEMICAL ENGINEERING TECHNOLOGY
(PROCESS) WITH HONOURS
DATE : 28 JANUARY 2026
TIME : 9:00AM - 12:00PM
DURATION : 3 HOURS

INSTRUCTIONS TO CANDIDATES

1. Please read the instructions given in the question paper CAREFULLY.
2. This question paper is printed on both sides of the paper.
3. This question paper consist of TWO sections.
4. Answer ALL questions for Section A.
5. Section B consist of four questions. Answer THREE (3) questions only.
6. Please write your answer on the answer booklet provided.
7. Please answer all questions in English only.
8. Please answer MCQ/EMQ questions using OMR sheet. ☐ *Tick if applicable*
9. Refer to the attached Formula/ Appendices. ☐ *Tick if applicable*

THERE ARE 21 PAGES OF QUESTIONS INCLUDING THIS PAGE

SECTION A (Total: 40 marks)

Answer ALL questions.

Please use the answer booklet provided.

1. The following are type of local sources ignition for fire to occur, **EXCEPT**
 - A. Open fire like welding
 - B. Friction ignition
 - C. Spark ignition
 - D. Hot surface ignition

2. Exposure to heat stress can be controlled by
 - I. work organization
 - II. frequent break time
 - III. ventilation
 - IV. engineering control
 - A. II and III
 - B. All the answers
 - C. I and II
 - D. I, II, and III

3. The effect of cold hazard is
 - A. keratitis
 - B. nosea and vomitting
 - C. immersion foot
 - D. all the answers

4. Jamil found that one of the contents of Occupational Safety and Health Management System Standard, ISO 45001, matches the requirement of Section 16 of Act 514, which is the establishment of Occupational Safety and Health (OSH) Policy. Choose the correct element from the options below."
- A. Operation
 - B. Performance evaluation
 - C. Support
 - D. Planning
5. In Hazard and Operability Study (HAZOP), all of the following guide words can be used for process parameter "Pressure" **EXCEPT**,
- A. No
 - B. Less
 - C. More
 - D. As well as

6. The most appropriate type of control measure used for the wood multi blade rip saw (as shown in the following picture) is

Refer Below - Figure1 : Multi blade rip saw .

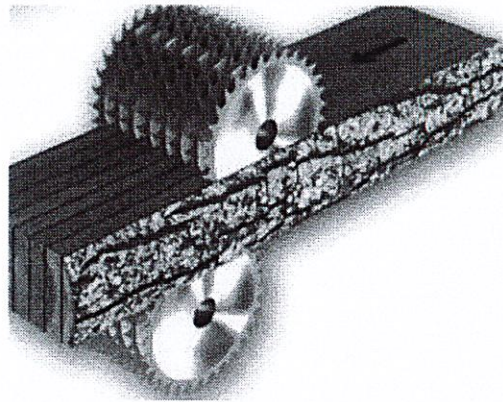


Figure 1: Multi blade rip saw

- A. Enclosure
 - B. Isolation
 - C. Substitution
 - D. Elimination
7. Marburg viruses are classified as risk group ____ agents.
- A. group 4
 - B. group 1
 - C. group 3
 - D. group 2
8. The legal responsibilities of an employer with regards to health and safety include.....
- A. one staff for a dangerous job.
 - B. replacing damaged or lost PPE.
 - C. providing safe workplace.
 - D. additional insurances for dangerous work.

9. Exposure to chemicals hazardous to health during handling can be controlled by
- I. Substitution
 - II. Wet Method
 - III. Ventilation
 - IV. Engineering control
- A. III and IV
- B. II and III
- C. I and II
- D. All the above
10. The information must have on the label for chemical used in the chemical laboratory according to the regulation Classification, Labelling and Safety Data Sheet (CLASS), 2013 must have
- A. Product identifier, pictogram, hazard statement and emergency contact number
- B. Product identifier, supplier identifier and pictogram
- C. Product identifier
- D. Product identifier, pictogram, and emergency contact number
11. Methods to identify hazards at the design stage include
- A. task analysis
- B. hazard and operability study
- C. walk through survey.
- D. review previous accident report.
12. Advanced ergonomic risk assessment method for awkward posture is
- A. Rapid Office Strain Assessment (ROSA)
- B. Hand - Arm Vibration Calculator (HAV)
- C. Rapid Upper Limb Assessment (RULA)
- D. Assessment of Repetitive Tasks (ART)

13. Fault Tree Analysis can be described as
- I. deductive method for identifying ways in which hazards can lead to accidents
 - II. a common tool using logic symbols to provide graphics presentation; known as gates.
 - III. end result or unwanted /unplanned event is at the top of the tree
 - IV. analysis whereby the consequences and events are constructed from a defined primary event
- A. II, III and IV
 - B. I, and IV
 - C. I, II and III
 - D. II and III
14. Toxicants are eliminated from the body by several routes of excretion, like
- I. Renal elimination
 - II. Exhalation
 - III. Fecal elimination
 - IV. Biotransformation
- A. All of the above.
 - B. I, II and III
 - C. I and II
 - D. II and III
15. The incident name which involved cases of occupational injury or illness which did not involve fatalities or lost workdays, but did results in another job transfer is called
- A. Occupational Poisoning
 - B. Dangerous occurrences.
 - C. Near - misses
 - D. Non Fatal Case without Lost Workdays.

16. Choose the correct example of hazardous deviation use in Level three (3) for constructing a generic Fault Tree Analysis.
- A. Failure to control alarm system
 - B. Inadequate emergency control system
 - C. Failure to recover from emergency situation
 - D. Inadequate process shutdown system.
17. The reaction front and shock front move together and propagate, producing supersonic waves that travel faster than the speed of sound. This statement refers to _____.
- A. detonation
 - B. shock waves
 - C. reaction waves
 - D. deflagration
18. Risk rating is a function of
- I. likelihood of exposure
 - II. degree of exposure
 - III. adequacy of control measure
 - IV. severity of outcome
- A. I and IV
 - B. III and IV
 - C. II and III
 - D. I and II

19. Under hierarchy of control, the ideal solution and control at source is known as
- A. Substitution
 - B. Enclosure
 - C. Elimination
 - D. Isolation
20. The statement below referred to:
"This accident has a low probability of occurrence, high potential of fatalities and low potential for economic loss"
- A. Jet fire
 - B. Dispersion of toxic gas
 - C. Vapor cloud explosion
 - D. Pool fire
21. Select the equipment or machines that may cause hand arm vibration syndrome.
- I. Sewing machines and looms.
 - III. Pneumatic chisels.
 - II. Rock drills.
 - IV. Pounding machines.
- A. II, III and IV
 - B. I, II, and III
 - C. All of the above
 - D. I, II and IV
22. A chemical fume hood is all the following, **EXCEPT**
- A. used for storing hazardous chemicals
 - B. inspected by a hygiene technician
 - C. regulated under USECHH, 2000
 - D. used as engineering control measures

23. The following are type of hazardous chemicals categorized according to its health hazard, **EXCEPT**
- A. Germ cell mutagen
 - B. Aspiration hazard
 - C. Acute toxicity (skin)
 - D. Pyrophoric liquids
24. Workplace related injuries, illnesses and deaths impose cost upon.....
- A. employees.
 - B. employers.
 - C. all of the answers.
 - D. stakeholders.
25. Portable ladder is one ofhazards.
- A. Electrical
 - B. Chemical
 - C. Physical
 - D. Environmental
26. An emergency planning includes the following elements
- I. An evacuation plans.
 - II. Staging officer must declare emergency.
 - III. Focus on internal threat.
 - IV. Fire drill frequency.
- A. II and III
 - B. I and II
 - C. III and IV
 - D. I and IV

27. OSHA requires employers to implement a hearing conservation program at the following noise level (measured in decibels)
- A. 100 dB
 - B. 65 dB
 - C. 75 dB
 - D. 85 dB
28. The following are the factors that may influence dust explosibility, EXCEPT.
- A. confinement and suspension
 - B. chemical composition
 - C. humidity
 - D. size
29. The following position in the company can be in the multi-discipline Hazard and Operability Study (HAZOP) team member.
- I. Process engineer
 - II. Safety and Health Engineer
 - III. Maintenance and Electrical Engineer
 - IV. Procurement Manager
- A. III and IV
 - B. All of the above
 - C. I and II
 - D. II and IV
30. Dust Explosion class, ST 2 is organic dye dust. ST 2 will cause dust explosion.
- A. strong
 - B. weak
 - C. very strong
 - D. no or very weak

31. According to OSH regulation, Notification of accident, dangerous occurrences, occupational poisoning, and occupational diseases (NADOPOD), 2004, all employers must report their previous year accident statistic at workplace to Department of Occupational Safety and Health (DOSH) by
- A. 31 May of the coming year.
 - B. 31 March of the coming year.
 - C. 31 January of the coming year.
 - D. 31 July of the coming year
32. A chemical container of 500 milliliter, must have a label size of at least
- A. 74 x 105 mm
 - B. 52 x 74 mm
 - C. 105 x 148 mm
 - D. 148 x 210 mm
33. Biohazard may come from the following waste.
- I. Human waste
 - II. Water reservoir
 - III. Animal abattoir
 - IV. Sanitary landfills
- A. I and IV
 - B. II and III
 - C. I, II and III
 - D. All the answers

34. The validity of Safety Data Sheet is
- A. 5 years
 - B. 4 years
 - C. 6 years
 - D. 3 years
35. Health problem associated with poor Indoor Air Quality is
- A. Raynauld's disease
 - B. Bronchitis and pneumonia
 - C. Trench Foot
 - D. Keratitis
36. Choose the term that refers to the gradual loss of hearing caused by prolonged exposure to loud noise.
- i. Temporary Threshold Shift (TTS)
 - ii. Stress and social isolation
 - iii. Fatigue and anxiety
 - iv. Tinnitus
- A. iii and iv
 - B. i and ii
 - C. ii and iii
 - D. i and iv
37. The legal responsibilities of an employer regarding health and safety include.....
- A. talking out additional insurance for dangerous work
 - B. charging employees for replacing for replacing damaged or lost PPE
 - C. ensuring that only one member of staff works on a dangerous job
 - D. providing safe ingress and egress to workplace for all employees

38. The probability in risk assessment process can be determined based on

- I the number of employees exposed and their competency level.
- II the frequency and duration of exposure.
- III the proximity of employees to the danger zone.
- IV all the above.

- A. I and II
- B. II and III
- C. III and IV
- D. All the above.

39. The facility and practices of Biosafety Level 3 must have

- I. Self-closing, double door access.
- II. Full body air - supplied suit
- III. Bench top worked
- IV. Exhaust HEPA filter

- A. I and IV
- B. I and II
- C. II and III
- D. III and IV

40. Choose the factors that influence toxicity from the following statement.

- I. Age.
- II. Chemical composition
- III. Toxicant with synergism effect
- IV. Route of exposure

- A. I and IV
- B. II and III
- C. All of the above.
- D. I and II

SECTION B (Total: 60 marks)

Answer THREE (3) questions only.

Please use the answer booklet provided.

Question 1

There are various types of hazard such physical, chemical and biological hazard. The risk assessment need to be carried out in order to determine the risk level, hence control measure can be implemented.

- (a) Discuss the control methods and its example that can be used to mitigate chemical hazard.

(10 marks)

- (b) Layer of Protection Analysis (LOPA) is a simplified form of semi quantitative of risk assessment.

- i. Explain All layers of defense or Independent Protection Layers in the emergency event.

(7 marks)

- ii. Segregate the Independent Protection layers in (i) into prevention and mitigation type.

(3 marks)

Question 2

Answer the following question.

- (a) A 100 kg of butane had leaked from the cracked storage tank. The tank is located 50 meters away from the administration area.

(Butane – C_4H_{10} , Energy of explosion of TNT: 4686 kJ/kg. The heat of combustion for butane; Lower: -2657.5 kJ/mol, Upper: -2877.5 kJ/mol. MW: Carbon – 12; Hydrogen – 1).

- i. Compute the side-on peak overpressure, if the explosion occurs and assume the explosion efficiency is 2%.

(7 marks)

- ii. Based on your answer in (i), calculate the percentage of human injuries due to this explosion.

(3 marks)

- (b) Compare and contrast about Biosafety Level 2 (BSL 2) and Biosafety Level 4 (BSL 4) to control biological hazard.

Refer Appendix Attachment - Answer BSL 2 vs BSL 4 .

(10 marks)

Question 3

Chemical labeling will help the user and handler to recognize hazardous and non hazardous chemical. Hazardous chemical may come from various types, such as organic hydrocarbon, benzene, toluene and many mores. Biotransformation is type of metabolism process, that occurred to eliminate it from the human body.

- (a) Alcohol is one of chemicals used by TOP medical devices manufacturer. It been supplied by TMD Sdn Bhd in 30 litres. TMD Sdn Bhd is a chemical distributor in Malaysia. The office and storage area located in Lot 102, Jalan P/5, Bandar Baru Bangi, 63750, Selangor Darul Ehsan. The contact number, which also served as emergency contact number, is 03-8923445. Design a label of this chemical distributed by TMD Sdn Bhd. The label must comply to the following statutory laws:
- Occupational Safety and Health (Classification, Labelling and Safety Data Sheet of Hazardous Chemicals) Regulations 2013 (CLASS Regulations).
 - Industry Code of Practice on Chemicals Classification and Hazard Communication (ICoP)

Refer Appendix Attachment - SDS of Alcohol page 2 of 2 .

(10 marks)

- (b) Benzene is one of the hazardous hydrocarbons. It can enter human body via various routes. Discuss the biotransformation that occurred in the human body to change benzene to the non - hazardous metabolites, hence, it can be excreted in the urine during the excretion process.

(10 marks)

Question 4

Among the requirements of Occupational Safety and Health Act (OSHA), 1994 to identify hazard and potential accident at the workplace. The safety and health committee is also need to be established, if an organization has 40 and more employee.

- (a) Mr Abu Hanifah bin Ali, The General Manager of Nova Petrochemical Limited in Malaysia. This company has 250 staff. The following table showed their established safety and health committee. During the audit conducted in November 2025 the certification body. Five noncompliance were issued for the safety and health committee established.

Refer Below - Table 1 : Safety and Health Committe of Nova Petrochemical Limited .

Table 1: Safety and Health Committe of Nova Petrochemical Limited

SAFETY & HEALTH COMMITTEE OF NOVA PETROCHEMICAL LIMITED.	
Chairman: Mr Abu Hanifah bin Ali (General Manager)	
Secretary: <u>Hayati</u> Ismail (Secretary of General Manager)	
Management Representative	Worker Representative
Adam (Production Manager)	Fauzi (Production Line leader)
Then Vien (Maintenance Manager)	Razak (Forklift operator)
Rafael (Warehouse Clerk)	Anuar (Account Executive)

- i. Explain ALL the noncompliance issued by the certification body.
(5 marks)
- ii. Provide the reason for each of your answers in (i). [Hint: Statutory law needs to be referred for the reason given. It is recommended to use table in your answer].
(5 marks)

- (b) Consider the continuous process shown below. In this process, the phosphoric acid and ammonia are mixed, and a non-hazardous product, diammonium phosphate (DAP), results if the reaction of ammonia is complete. If too little phosphoric acid is added, the reaction is incomplete, and ammonia is produced. Too little ammonia available to the reactor results in a safe but undesirable product. Carry out Hazard and Operability study (HAZOP) for the following deviation. {Hint: Use HAZOP template to answer this question}

- i. Less flow of ammonia into reactor.
- ii. Part of phosphoric acid flow into reactor.

Refer Below - Figure2 : DAP Manufacturing Process .

(10 marks)

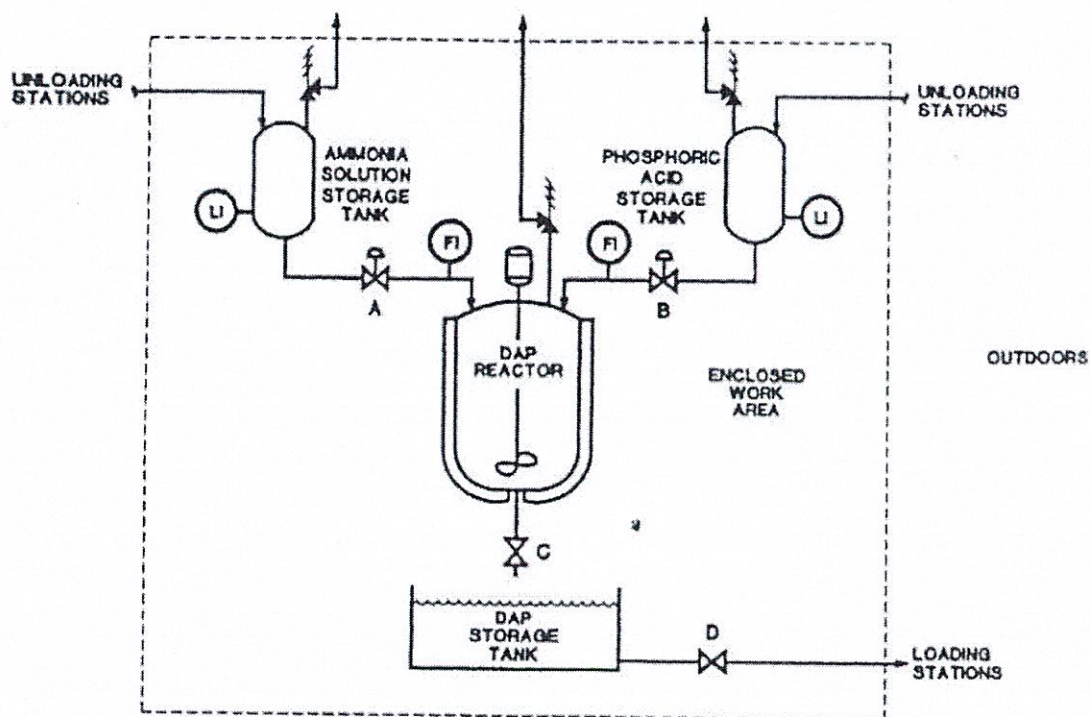


Figure 2: DAP Manufacturing Process

END OF EXAMINATION PAPER

APPENDIX

SDS ALCOHOL PAGE 3 OF 3

SECTION 7: Handling and storage**7.1 Precautions for safe handling**

Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
Keep away from sources of ignition - No smoking. Take measures to prevent the build up of electrostatic charge.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated.

SECTION 8: Exposure controls and personal protection**8.1 Control parameters****Components with workplace control parameters**

Component	CAS-No.	Value	Control parameters	Basis
ethanol	64-17-5	TWA	1,000 ppm 1,880 mg/m ³	Malaysia: Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000.
Methanol	67-56-1	TWA	200 ppm 262 mg/m ³	Malaysia: Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000.
	Remarks	Skin		
2-Propanol	67-63-0	TWA	400 ppm 983 mg/m ³	Malaysia: Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000.

8.2 Exposure controls**Appropriate engineering controls**

Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment**Eye/face protection**

Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact

Sigma- R3154

Page 4 of 9

The life science business of Merck operates as MilliporeSigma in the US and Canada

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Appendix for Section B Question 3 (a) : SDS of Alcohol page 2 of 3

Precautionary statement(s)

Prevention

P210

Keep away from heat/sparks/open flames/hot surfaces. No smoking.

P233

Keep container tightly closed.

P260

Do not breathe dust/ fume/ gas/ mist/ vapours/ spray.

Response

P303 + P361 + P353

IF ON SKIN (or hair): Remove/ Take off immediately all contaminated clothing. Rinse skin with water/ shower.

P309 + P311

IF exposed or if you feel unwell: Call a POISON CENTER or doctor/ physician.

P370 + P378

In case of fire: Use dry sand, dry chemical or alcohol-resistant foam for extinction.

2.3 Other hazards - none

SECTION 3: Composition and information of the ingredients of the hazardous chemical

Substance / Mixture : Mixture

3.2 Mixtures

Synonyms : Absolute Alcohol

Hazardous components

Component		Classification	Concentration
ethanol			
CAS-No.	64-17-5	Flam. Liq. 2; H225	>= 60 - <= 100 %
EC-No.	200-578-6		
Index-No.	603-002-00-5		
Methanol			
CAS-No.	67-56-1	Flam. Liq. 2; Acute Tox. 3; STOT SE 1; H225, H301, H331, H311, H370	>= 3 - < 5 %
EC-No.	200-659-6		
Index-No.	603-001-00-X		
2-Propanol			
CAS-No.	67-63-0	Flam. Liq. 2; 2; STOT SE 3; H225, H319, H336 Concentration limits: >= 20 %: STOT SE 3, H336;	>= 3 - < 5 %
EC-No.	200-661-7		
Index-No.	603-117-00-0		

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first aid measures

General advice

Consult a physician. Show this safety data sheet to the doctor in attendance.

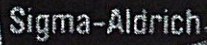
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Page 2 of 9

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Appendix for Section B Question 3 (a) : SDS of Alcohol page 1 of 3

		www.sigmaaldrich.com
SAFETY DATA SHEET		Version 8.2 Revision Date 30.03.2020 Print Date 28.04.2020
SECTION 1: Identification of the hazardous chemical and of the supplier		
1.1 Product identifiers		
Product name	: Reagent Alcohol	
Product Number	: R3154	
Brand	: Sigma	
1.2 Other means of identification		
Absolute Alcohol		
1.3 Relevant identified uses of the substance or mixture and uses advised against		
Identified uses	: For R&D use only. Not for pharmaceutical, household or other uses.	
1.4 Details of the supplier of the safety data sheet		
Company	: SIGMA-ALDRICH (M) SDN BHD Level 3, Menara Sunway Annexe, Jalan Lagoon Timur, Bandar Sunway, 46150 PETALING JAYA, SELANGOR MALAYSIA	
Telephone	: +60 (603)03-563-53321	
Fax	: +60 (603)03-563-54116	
1.5 Emergency telephone number		
Emergency Phone #	: +62 08001401253	
Section 2: Hazard identification		
2.1 GHS Classification		
Classification according to CLASS regulations 2013		
Flammable liquids (Category 2), H225		
Specific target organ toxicity - single exposure (Category 2), H371		
For the full text of the H-Statements mentioned in this Section, see Section 16.		
2.2 GHS Label elements, including precautionary statements		
Labelling according to CLASS regulations 2013		
Pictogram		
Signal word	Danger	
Hazard statement(s)	H225 Highly flammable liquid and vapour. H371 May cause damage to organs.	
Sigma- R3154		
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Page 1 of 9		
		

APPENDIX: Formulas and Tables of References.

1.

$$\text{OSHA}^* = \frac{\text{Number of fatality, injuries \& illness} \times 200,000}{\text{total hours worked by all employees during period covered}}$$

Number of injuries & illness must include Number of injuries, illness & fatality

2.

$$\text{FAR} = \frac{(\text{Number of fatalities} \times 10^8)}{\text{Total hours worked by all employees}}$$

3.

$$\text{Fatality rate} = \frac{(\text{Number of fatalities per year})}{\text{Total number of people (per year) in applicable population}}$$

4. Scaled Distance, Z_e

$$Z_e = \frac{r}{m_{TNT}^{1/3}}$$

Z_e = scaled distance ($\text{m}/\text{kg}^{1/3}$)

5. The scaled overpressure p_s is given by

$$p_s = p_0 / p_a$$

where p_s - the scaled overpressure (unitless.)

p_0 - peak side-on overpressure.

p_a - the ambient temperature.

The ambient pressure is 1 atm=101.3kPa

6.

The data in Figure 6-23 are also represented by the empirical equation

6-27.

$$\frac{p_0}{p_a} = \frac{1616 \left[1 + \left(\frac{z_e}{4.5} \right)^2 \right]}{\sqrt{1 + \left(\frac{z_e}{0.048} \right)^2} \sqrt{1 + \left(\frac{z_e}{0.32} \right)^2} \sqrt{1 + \left(\frac{z_e}{1.35} \right)^2}}$$

7. The equivalent mass TNT is estimated using the following equation:

210

mass behaves like exploding TNT on an equivalent energy basis. The equivalent mass of TNT is estimated using the following equation:

$$m_{\text{TNT}} = \frac{\eta m \Delta H_c}{E_{\text{TNT}}}, \quad (6-24)$$

where

m_{TNT} is the equivalent mass of TNT (mass),

η is the empirical explosion efficiency (unitless),

m is the mass of hydrocarbon (mass),

ΔH_c is the energy of explosion of the flammable gas (energy/mass), and

E_{TNT} is the energy of explosion of TNT.

A typical value for the energy of explosion of TNT is 1120 cal/g = 4686 kJ/kg = 2016 Btu/lb. The heat of combustion for the flammable gas can be used in place of the energy of explosion for the combustible gas.

The explosion efficiency is one of the major problems in the equivalency method. The ex-

8. FIGURE 6-23: CORRELATIONS BETWEEN SCALED DISTANCE AND EXPLOSION PEAK SIDE – ON OVERPRESSURE FOR A TNT EXPLOSION ON A FLAT SURFACE.

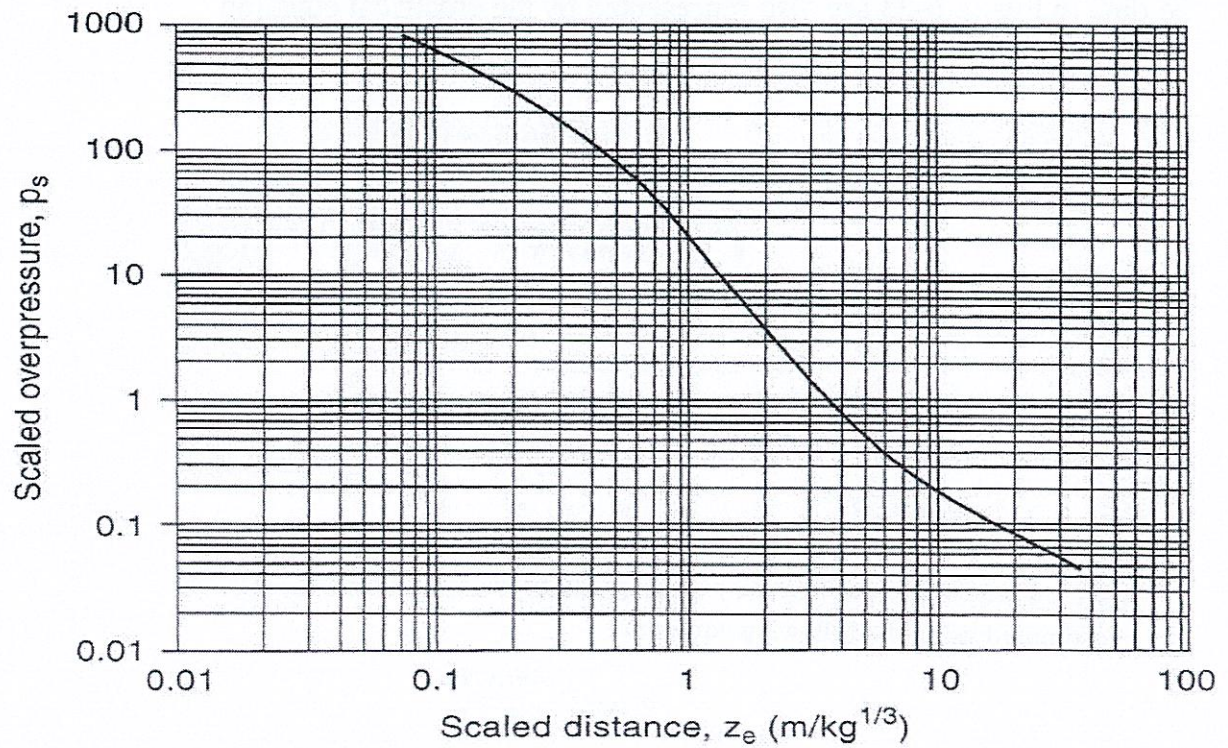


Table 6-9 Damage Estimates for Common Structures Based on Overpressure (these values are approximations) ¹

Pressure		Damage
psig	kPa	
0.02	0.14	Annoying noise (137 dB if of low frequency, 10–15 Hz)
0.03	0.21	Occasional breaking of large glass windows already under strain
0.04	0.28	Loud noise (143 dB), sonic boom, glass failure
0.1	0.69	Breakage of small windows under strain
0.15	1.03	Typical pressure for glass breakage
0.3	2.07	"Safe distance" (probability 0.95 of no serious damage below this value); projectile limit: some damage to house ceilings; 10% window glass broken
0.4	2.76	Limited minor structural damage
0.5–1.0	3.4–6.9	Large and small windows usually shatter; occasional damage to window frames
0.7	4.8	Minor damage to house structures
1.0	6.9	Partial demolition of houses, made uninhabitable
1–2	6.9–13.8	Corrugated asbestos shatters; corrugated steel or aluminum panels, fastenings fail, followed by buckling; wood panels (standard housing), fastenings fail, panels blow in
1.3	9.0	Steel frame of clad building slightly distorted
2	13.8	Partial collapse of walls and roofs of houses
2–3	13.8–20.7	Concrete or cinder block walls, not reinforced, shatter
2.3	15.8	Lower limit of serious structural damage
2.5	17.2	50% destruction of brickwork of houses
3	20.7	Heavy machines (3000 lb) in industrial buildings suffer little damage; steel frame buildings distort and pull away from foundations
3–4	20.7–27.6	Frameless, self-framing steel panel buildings demolished; rupture of oil storage tanks
4	27.6	Cladding of light industrial buildings ruptures
5	34.5	Wooden utility poles snap; tall hydraulic presses (40,000 lb) in buildings slightly damaged
5–7	34.5–48.2	Nearly complete destruction of houses
7	48.2	Loaded train wagons overturned
7–8	48.2–55.1	Brick panels, 8–12 in thick, not reinforced, fail by shearing or flexure
9	62.0	Loaded train boxcars completely demolished
10	68.9	Probable total destruction of buildings; heavy machine tools (7000 lb) moved and badly damaged, very heavy machine tools (12,000 lb) survive
300	2068	Limit of crater lip

¹V. J. Clancey, "Diagnostic Features of Explosion Damage," paper presented at the *Sixth International Meeting of Forensic Sciences* (Edinburgh, 1972).

10.TABLE 2-4 Transformation from Percentages to Probits.

50

Chapter 2 • Toxicology

Table 2-4 Transformation from Percentages to Probits¹

%	0	1	2	3	4	5	6	7	8	9
0	—	2.67	2.95	3.12	3.25	3.36	3.45	3.52	3.59	3.66
10	3.72	3.77	3.82	3.87	3.92	3.96	4.01	4.05	4.08	4.12
20	4.16	4.19	4.23	4.26	4.29	4.33	4.36	4.39	4.42	4.45
30	4.48	4.50	4.53	4.56	4.59	4.61	4.64	4.67	4.69	4.72
40	4.75	4.77	4.80	4.82	4.85	4.87	4.90	4.92	4.95	4.97
50	5.00	5.03	5.05	5.08	5.10	5.13	5.15	5.18	5.20	5.23
60	5.25	5.28	5.31	5.33	5.36	5.39	5.41	5.44	5.47	5.50
70	5.52	5.55	5.58	5.61	5.64	5.67	5.71	5.74	5.77	5.81
80	5.84	5.88	5.92	5.95	5.99	6.04	6.08	6.13	6.18	6.23
90	6.28	6.34	6.41	6.48	6.55	6.64	6.75	6.88	7.05	7.33
%	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
99	7.33	7.37	7.41	7.46	7.51	7.58	7.65	7.75	7.88	8.09

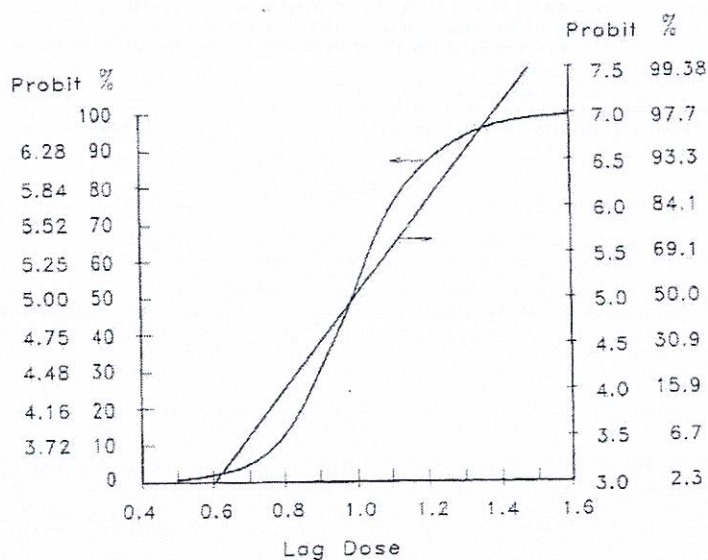
¹D. J. Finney, *Probit Analysis*, (Cambridge: Cambridge University Press, 1971), p. 25. Reprinted by permission.

Figure 2-10 The probit transformation converts the sigmoidal response vs. log dose curve into a straight line when plotted on a linear probit scale. Source: D. J. Finney, *Probit Analysis*, 3d ed. (Cambridge: Cambridge University Press, 1971), p. 24. Reprinted by permission.

11. The Probit (probability unit) variable Y is computed from $Y = k_1 + k_2 \ln P$

TABLE 2-5 PROBIT CORRELATION FOR VARIETY OF EXPOSURES.

Table 2-5 Probit Correlations for a Variety of Exposures (The causative variable is representative of the magnitude of the exposure.)

Type of injury or damage	Causative variable	Probit parameters	
		k_1	k_2
Fire ¹			
Burn deaths from flash fire	$t_e I_e^{4/3} / 10^4$	-14.9	2.56
Burn deaths from pool burning	$t I^{4/3} / 10^4$	-14.9	2.56
Explosion ¹			
Deaths from lung hemorrhage	p^0	-77.1	6.91
Eardrum ruptures	p^0	-15.6	1.93
Deaths from impact	J	-46.1	4.82
Injuries from impact	J	-39.1	4.45
Injuries from flying fragments	J	-27.1	4.26
Structural damage	p^0	-23.8	2.92
Glass breakage	p^0	-18.1	2.79
Toxic release ²			
Ammonia deaths	$\Sigma C^{2.0} T$	-35.9	1.85
Carbon monoxide deaths	$\Sigma C^{1.0} T$	-37.98	3.7
Chlorine deaths	$\Sigma C^{2.0} T$	-8.29	0.92
Ethylene oxide deaths ³	$\Sigma C^{1.0} T$	-6.19	1.0
Hydrogen chloride deaths	$\Sigma C^{1.0} T$	-16.85	2.0
Nitrogen dioxide deaths	$\Sigma C^{2.0} T$	-13.79	1.4
Phosgene deaths	$\Sigma C^{1.0} T$	-19.27	3.69
Propylene oxide deaths	$\Sigma C^{2.0} T$	-7.42	0.51
Sulfur dioxide deaths	$\Sigma C^{1.0} T$	-15.67	1.0
Toluene	$\Sigma C^{2.5} T$	-6.79	0.41

t_e = effective time duration (s)

I_e = effective radiation intensity (W/m^2)

t = time duration of pool burning (s)

I = radiation intensity from pool burning (W/m^2)

p^0 = peak overpressure (N/m^2)

J = impulse ($N \cdot s/m^2$)

C = concentration (ppm)

T = time interval (min)

¹ Selected from Frank P. Lees, *Loss Prevention in the Process Industries* (London: Butterworths, 1986), p. 208.

² CCPS, *Guidelines for Consequence Analysis of Chemical Releases* (New York: American Institute of Chemical Engineers, 1999), p. 254.

³ Richard W. Purgh, "Quantitative Evaluation of Inhalation Toxicity Hazards," in *Proceedings of the 29th Loss Prevention Symposium* (American Institute of Chemical Engineers, July 31, 1995).

12. Chemical exposure or Volatile Hazardous material exposure:

Formula 1:

$$TWA = \frac{C_1T_1 + C_2T_2 + C_3T_3 + \dots + C_nT_n}{8}$$

Formula 2:

$$(TLV - TWA)_{mix} = \frac{\sum_{i=1}^n C_i}{\sum_{i=1}^n \frac{C_i}{(TLV - TWA)_i}}$$

n = total no. of toxicants

Ci = the conc. of chemical species i

With respect to the other toxicants

(TLV-TWA)_i = TLV-TWA for chemical species i

13. Noise Reduction Rate formula 1.

$$NRR_{actual} = \frac{NRR - 7}{2}$$

$$Estimated\ exposure, dB(A) = L_{EX,8h} dB(A) - \left[\frac{(NRR - 7)}{2} \right]$$

Where;

- (i) $L_{EX,8h}$ is daily noise exposure level;
- (ii) 2 is de-rating factor (to lower the rating of a device, especially because of a deterioration in efficiency or quality).

14. Noise Reduction Rate formula 2

$$Estimated\ exposure, dB(A) = L_{EX,8h} dB(A) - \left[\frac{(NRR_h - 7)}{2} + 5 \right]$$

Where;

- (i) NRR_h is NRR for the **higher** rated protector; and
- (ii) $L_{EX,8h}$ is daily noise exposure level.

15. Table daily exposure duration limit.

Table 10.1: Daily Exposure Duration Limit

NOISE LEVEL dB(A)	DAILY EXPOSURE DURATION LIMIT
82	16 hrs
83	12hrs 42 mins
84	10 hrs 5 mins
85	8 hrs
86	6hrs 21mins
87	5hrs 2 mins
88	4 hrs
89	3 hrs 10 mins
90	2 hrs 31 mins
91	2 hrs
92	1 hr 35 mins
93	1 hr 16mins
94	1 hr
95	48 mins

Daily exposure limit continue

96	38 mins
97	30 mins
98	24 mins
99	19 mins
100	15 mins
101	12 mins
102	9 mins
103	7 mins 30 sec
104	6 mins
105	5 mins
106	3 mins 45 sec
107	3 mins
108	2 mins 22 sec
109	1 min 53 sec
110	1 min 30 sec
111	1 min 11 sec
112	56 sec
113	45 sec
114	35 sec
115	28 sec

16. NOISE EXPOSURE: Combining two sound sources.

TABLE 2: Estimation of noise exposure – Factors for combining two sources.

1 Difference between two sound sources (dB)	2 Amount to add to greater sound source (dB)	1 Difference between two sound sources (dB)	2 Amount to add to greater sound source (dB)
0.0 – 0.1	3.0	4.8 – 5.1	1.2
0.2 – 0.3	2.9	5.2 – 5.6	1.1
0.4 – 0.5	2.8	5.7 – 6.1	1.0
0.6 – 0.7	2.7	6.2 – 6.6	0.9
0.8 – 0.9	2.6	6.7 – 7.2	0.8
1.0 – 1.2	2.5	7.3 – 7.9	0.7
1.3 – 1.4	2.4	8.0 – 8.6	0.6
1.5 – 1.6	2.3	8.7 – 9.6	0.5
1.7 – 1.9	2.2	9.7 – 10.7	0.4
2.0 – 2.1	2.1	10.8 – 12.2	0.3
2.2 – 2.4	2.0	12.3 – 14.5	0.2
2.5 – 2.7	1.9	14.6 – 19.3	0.1
2.8 – 3.0	1.8	19.4 or more	0.0
3.1 – 3.3	1.7		
3.4 – 3.6	1.6		
3.7 – 4.0	1.5		
4.1 – 4.3	1.4		
4.4 – 4.7	1.3		