UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

EKC 367 – Plant Safety
[Keselamatan Loji]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains <u>TEN</u> printed pages and <u>FIVE</u> printed pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi <u>SEPULUH</u> muka surat yang bercetak dan <u>LIMA</u> muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

<u>Instruction:</u> Answer **<u>ALL</u>** questions.

*[**<u>Arahan</u>:** Jawab **<u>SEMUA</u>** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai].

Answer ALL questions.
Jawab SEMUA soalan.

1. [a] Identify two categories of hazards that feasible to be corrected. Give an example to each category.

Kenalpasti dua kategori hazad yang boleh diperbetulkan. Berikan satu contoh bagi setiap kategori. *[4 marks/markah]*

[b] Fire and explosion are the two primary hazards associated with flammable and combustible liquids. Explain which one is more hazardous, flammable or combustible.

Api dan letupan adalah dua hazad sekutu utama yang dikaitkan dengan cecair mudah bakar dan boleh bakar. Jelaskan yang mana satu lebih merbahaya, yang mudah bakar atau boleh bakar. *[3 marks/markah]*

[c] A small airplane takeoff from Penang International Airport. If the average airplane speed is 300 km/h, how far the airplane has flown before the fatality is expected. If a formula one (F1) car is used to travel at the same average speed, what is the expected distance before the fatality occur. Discuss the differences.

Sebuah kapal terbang kecil berlepas dari Lapangan Terbang Antarabangsa Pulau Pinang. Jika halaju purata kapal terbang adalah 300 km/j, sejauh manakah kapal terbang diterbangkan sebelum kemalangan maut dijangka. Jika kereta formula satu (F1) digunakan untuk bergerak pada halaju purata yang sama, apakah jarak yang dijangkakan sebelum berlaku kemalangan maut. Bincangkan perbezaannya. *[6 marks/markah]*

[d] A storage cylinder contains 200 L of benzene. The lid diameter of that cylinder is 1 m. The temperature is 27 °C and the pressure is 1 atm. The lid of the cylinder is left open.

Sebuah silinder simpanan mengandungi 200 L benzena. Diameter penutup silinder adalah 1 m. Suhunya 27 °C dan tekanan adalah 1 atm. Penutup silinder tersebut dibiarkan terbuka.

[i] Calculate the time required to evaporate all the benzene inside the cylinder.

Kirakan masa diperlukan untuk menyejat kesemua benzena di dalam silinder.

[ii] Determine the concentration of benzene (in ppm) near the cylinder, if the local ventilation rate is 25 m^3/min.

Tentukan kepekatan benzena (dalam ppm) berdekatan dengan silinder, jika kadar pengalihudaraan setempat adalah 25 m^3/min.
[12 marks/markah]

<u>Data</u>:

Molecular weight of benzene = 78
Molecular weight of water = 18
Saturation vapor pressure of benzene (at 300 K) = 103.5 mmHg
1 atm = 760 mmHg
R_g = 82.06 x 10^{-3} m^3.atm/kgmol.K
Mass transfer coefficient (water) = 0.83 cm/s
$SG_{benzene}$ = 0.8794
ρ_{water} = 1000 kg/m^3
Mixing factor k = 1

<u>Data</u>:

Berat molekul benzana = 78
Berat molekut air = 18
Tekanan wap tepu benzena (pada 300 K) = 103.5 mmHg
1 atm = 760 mmHg
R_g = 82.06 x 10^{-3} m^3.atm/kgmol.K
Pekali pemindahan jisim (air) = 0.83 sm/s
$SG_{benzena}$ = 0.8794
ρ_{air} = 1000 kg/m^3
Faktor percampuran k = 1

2. [a] Most accidents follow a three step sequence. Briefly explain in theory and in practice, how to eliminate the accident process based on this sequence.

Kebanyakan kemalangan mengikuti 3 langkah turutan. Terangkan dalam teori dan amali, bagaimana untuk menghindari proses kemalangan berdasarkan turutan tersebut. *[4 marks/markah]*

[b] As a safety engineer, under what circumstances would you recommend atmosphere-supplying respirators?

Sebagai seorang jurutera keselamatan, dalam keadaan apakah anda akan cadangkan penggunaan respirator pembekal-atmosfera? *[3 marks/markah]*

[c] A storage tank contains water used for dilution of hazardous solution. This water is pumped with a flow rate of 1500 L/h using a peristaltic pump through a commercial steel pipeline with internal diameter of 2.54 cm. The pipe section is horizontal and without fittings or valves. If the pressure at one point in the pipe is 5 x 10^5 N/m^2 and a small leak develops 10 m downstream, determine the fluid pressure at the leak.

Sebuah tangki yang mengandungi air digunakan untuk mencairkan larutan merbahaya. Air ini dipam dengan kadar aliran 1500 L/j menggunakan pam peristaltik menerusi aliran paip besi komersial berdiameter dalaman 2.54 sm. Paip tersebut dalam keadaan melintang dan tanpa pemasangan atau injap. Jika tekanan pada satu titik di dalam paip adalah 5 x 10^5 N/m^2 dan kebocoran kecil terhasil pada 10 m aliran ke bawah, tentukan tekanan cecair pada kebocoran itu.

Data:

Gravitational constant (g_c) = 1 kg.m/N.s^2
Viscosity of water = 10^{-3} N.s/m^2 (kg/m.s)
Density of water = 1000 kg/m^3

Data:

Graviti tetap (g_c) = 1 kg.m/N.s^2
Kelikatan air = 10^{-3} N.s/m^2 (kg/m.s)
Ketumpatan air = 1000 kg/m^3 *[10 marks/markah]*

[d] A 2100-MW power plant is designed to burn coal having a 1.25% sulfur content. It has been estimated that the emission of SO_2 from this power plant is 1750 g/s. The effective stack height is 120 m. At 3 km downwind rural area on an overcast evening, what is the centreline concentration of SO_2 if the wind speed at the top of the stack is 4.5 m/s.

Sebuah loji berkuasa 2100-MW direkabentuk untuk membakar arang yang mempunyai 1.25% kandungan sulfur. Ianya telah dijangka mengeluarkan SO_2 dari loji kuasa sebanyak 1750 g/s. Ketinggian tindan cekap adalah 120 m. Pada 3 km angin bawah di kawasan luar bandar pada petang yang mendung, apakah kepekatan aliran pusat bagi SO_2 jika pecutan udara pada atas tindan adalah 4.5 m/s.

[8 marks/markah]

3. [a] Explain how to apply ETA and FTA under Bow-Tie Risk Model Approach.

Terangkan bagaimana ETA dan FTA diaplikasikan di bawah Pendekatan Model Risiko "Bow-Tie"? *[4 marks/markah]*

[b] In a pumping system as shown in Figure Q.3.[b].[i]., the filled-in time for a tank is 10 min. After the switch is closed, the timer is set to open the contact after 10 min. If the mechanism fails, the alarm horn sounds and the operator opens the switch to prevent overfilling to the tank. By considering the primary failure mean that the operator fails to push the emergency close button when the alarm sounds and the secondary failure means that the operator has fainted due to the smoke of a fire when alarm sounded.

Dalam sistem mengepam yang ditunjukkan dalam Rajah S.3.[b].[i]., masa untuk mengisi tangki adalah 10 min. Selepas suis ditutup, pengukur masa ditetapkan untuk membuka penghubung dalam 10 min. Jika mekanisma gagal, penggera berbunyi dan pengendali akan membuka suis untuk mencegah pengisian lebih ke tangki. Dengan menganggapkan kegagalan primer bermakna bahawa pengendali gagal untuk menekan butang kecemasan apabila penggera berbunyi dan kegagalan sekunder bermakna bahawa pengendali telah tidak sedarkan diri kerana asap kebakaran semasa penggera berbunyi.

P(primary failure) = 0.1
P(secondary failure) = 0.05

P(kegagalan primer) = 0.1
P(kegagalan sekunder) = 0.05

Based on the Fault Tree Analysis shown in Figure Q.3.[b].[ii], compute the probability of the top event.

Berdasarkan Analisis Pokok Kegagalan yang ditunjukkan dalam Rajah S.3.[b].[ii]., kirakan kebarangkalian peristiwa utama. [6 marks/markah]

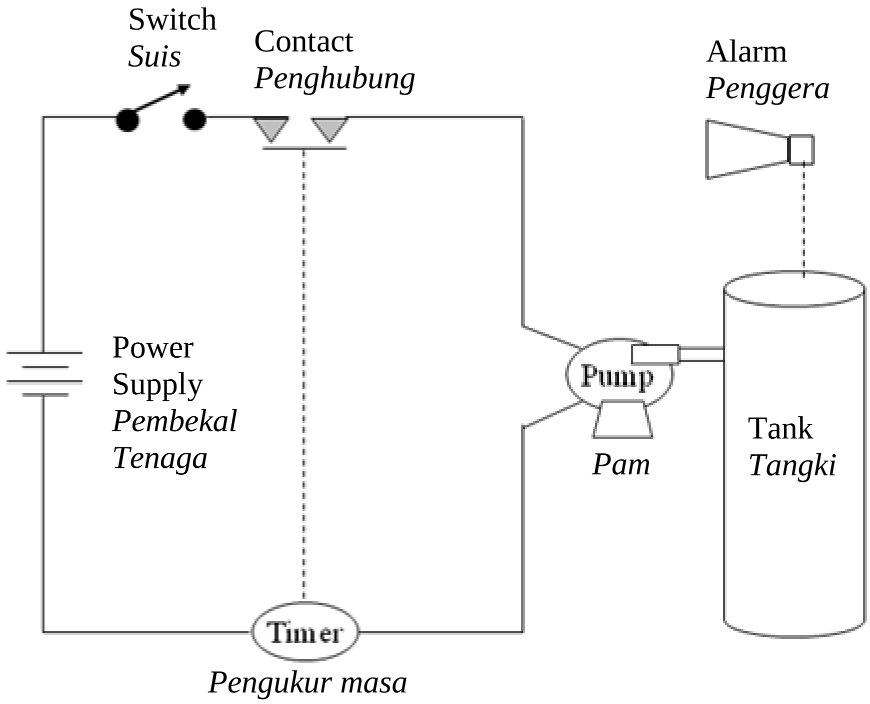

Figure Q.3.[b].[i].
Rajah S.3.[b].[i].

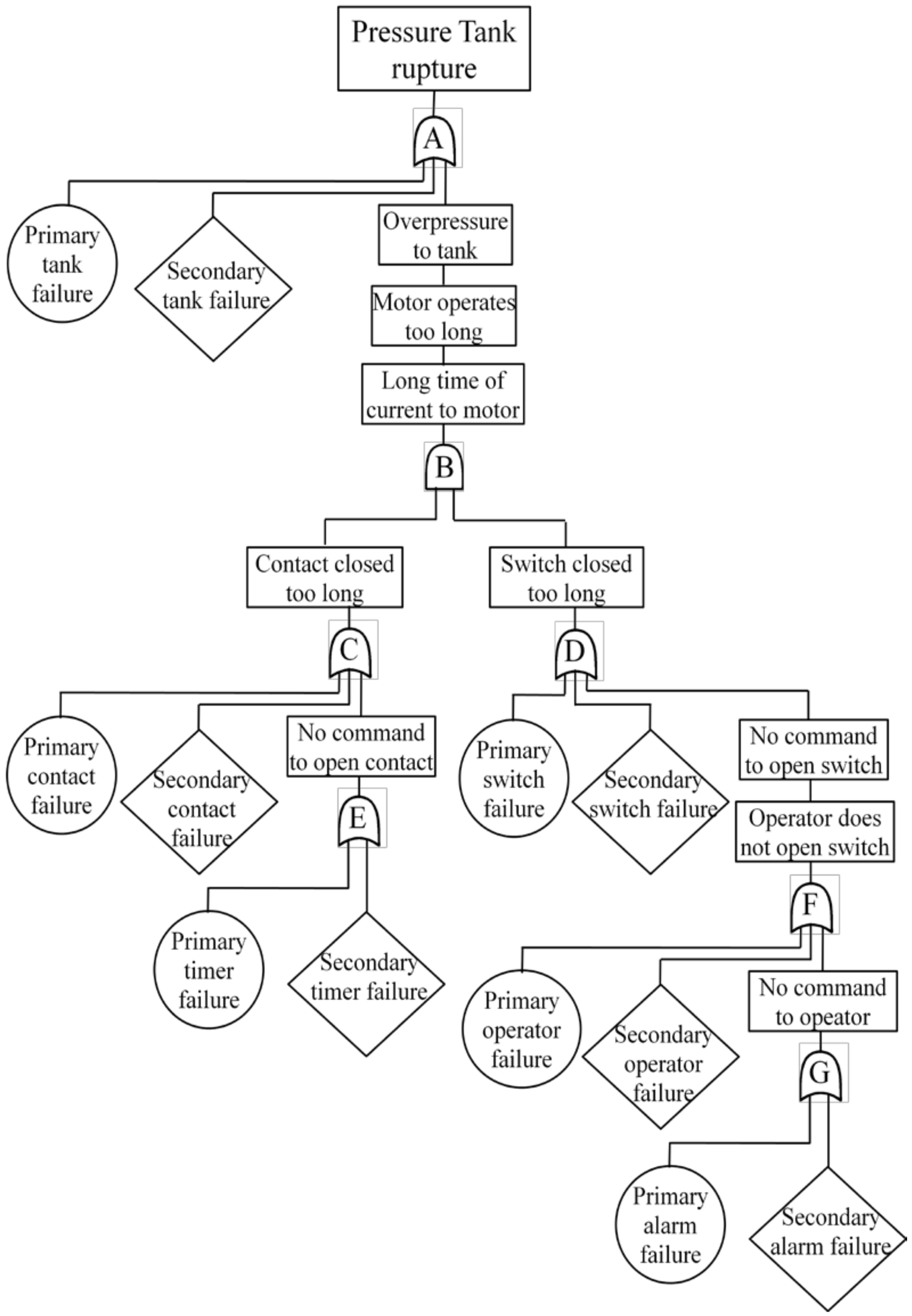

Figure Q.3.[b].[ii].
Rajah S.3.[b].[ii].

[c] The safety team in company XYZ is requested to carry out an Event Tree Analysis due to the loss of cooling water to a vessel where a controlled exothermic reaction is in the process by the steady addition of one reactant to the bulk solution. As long as the reaction process is concerned, even with loss of cooling, only a small temperature excursion will occur. The first layer of protection is a high temperature alarm (TA^{Hi}) to alert the operator when the temperature increases beyond the set point. The operator may then succeed in restoring normal conditions and the process can proceed. If the temperature excursion still continues at a high level (major temperature excursion), a trip system will be activated to cut off the supply of the reactant. Finally, if the excursion continuous beyond this, a runaway reaction will develop. The final protection against the vessel overpressure is a bursting disc relieving the product to a dump tank. By using the following data in Table Q.3.[c].:

Pasukan keselamatan di syarikat XYZ diminta untuk menjalankan Analisis Acara Pokok disebabkan kehilangan air penyejuk ke sebuah tangki di mana tindak balas eksotermik terkawal sedang berlaku dengan menambahkan satu bahan tindak balas ke dalam larutan pukal. Selagi proses tindak balas di ambil kira, walaupun kehilangan penyejukan, hanya perbezaan suhu yang kecil akan berlaku. Lapisan pelindung pertama adalah penggera suhu tinggi (TA^{Hi}) untuk memberi amaran kepada pengendali apabila suhu melampaui titik set. Pengendali mungkin berjaya memulihkan keadaan kepada normal dan proses boleh diteruskan. Jika perbezaan suhu masih berterusan pada tahap yang tinggi (perbezaan suhu yang besar), sistem penamatan akan diaktifkan untuk memotong bekalan bahan tindak balas. Akhirnya, jika perbezaan suhu berterusan dan menjangkaui keadaan ini, tindak balas tidak terkawal akan berlaku. Perlindungan terakhir untuk mengelakkan tekanan lampau tangki adalah cakera pemecah yang akan mengalirkan produk ke tangki buangan. Dengan menggunakan data dalam Jadual S.3.[c].:

Table Q.3.[c].
Jadual S.3.[c].

Sub-Event ***Sub-Acara***	**Probability to occur** ***Kebarangkalian berlaku***
Major Temperature excursion *Perbezaan Suhu Besar*	0.90
Operator restores control *Pengendali mengembalikan kawalan*	0.80
Alert by (TA^{Hi}) alarm *Amaran oleh penggera (TA^{Hi})*	0.98
Relieves of Bursting Disc *Pelegaan Cakera Pemecah*	0.90
Successful of Trip action *Kejayaan tindakan penamatan*	0.95

[i] Construct an Event Tree Analysis for this system using the "Loss of cooling water during reaction stage" as the initiating event that finally leads to the four possible outcomes, 1 to 4 below:

Bina satu Analisis Acara Pokok untuk sistem ini dengan menggunakan "Kehilangan air penyejuk semasa peringkat tindak balas" sebagai acara mula yang akhirnya membawa kepada empat hasil kemungkinan, 1 hingga 4 di bawah:

1) Minor temperature excursion – process continues
Perbezaan suhu kecil - proses diteruskan

2) Major temperature excursion – process stop by trip system
Perbezaan suhu besar – proses dihentikan oleh sistem penamatan

3) Runaway reaction relieved to dump tank – product lost
Tindak balas tidak terkawal dialirkan ke tangki buangan – kehilangan produk

4) Runaway reaction leading to overpressure in vessel
Tindak balas tidak terkawal yang menyebabkan tekanan melampau tindak balas di dalam tangki *[10 marks/markah]*

[ii] Given that the “loss of cooling water during reaction stage” happens 30 times/yr, estimate the expected number of possible outcomes in the above part [i] (2) per year.

Diberikan bahawa “Kehilangan air penyejuk semasa peringkat tindak balas” berlaku 30 kali/tahun, anggarkan bilangan hasil kemungkinan yang dijangka bagi bahagian [i](2) di atas setiap tahun.

[5 marks/markah]

4. [a] Identify two hazard identification approaches and how these methods are carried out for indentifying hazards?

Kenal pasti dua pendekatan pengenalan hazad dan bagaimana kaedah-kaedah ini dilaksanakan untuk mengenalpasti hazad?

[6 marks/markah]

[b] What are the differences between HAZOP and HAZID.
Apakah perbezaan di antara HAZOP dan HAZID. *[4 marks/markah]*

[c] A P&ID of a plant is shown in Figure Q.4.[c]. A HF supply system is designed to supply gaseous HF to a fluid bed reactor to produce uranium tetrafluoride. When the system is in operation, 30 psig nitrogen is supplied to the top of the portable liquid HF cylinder. The nitrogen pressure forces liquid HF to the vaporizer, which is heated by a hot water blanket supplied by a water heater and circulating pump. The liquid HF is heated to its vaporization temperature at the desired pressure, and the resulting gaseous HF is directed to the fluid bed reactor (line to B-1 Wing). To provide overpressure protection for the vaporizer, relief valves are fitted to piping connected to the top of the HF vaporizer and portable supply HF cylinder. A rupture disc, with a rupture pressure rating higher than the relief valve setting to protect the relief valve from continuous exposure to the corrosive HF environment. The "HF vaporizer, water heater and circulating pump" and "Nitrogen supply pipework to portable cylinder HF" are served as two description nodes. Perform HAZOP analysis on the node by using the following guidewords:

P&ID sebuah loji ditunjukkan dalam Rajah S.4.[c]. Satu sistem bekalan HF direkabentuk untuk membekalkan gas HF ke reaktor lapisan cecair untuk menghasilkan uranium tetrafluorida. Apabila sistem beroperasi, 30-psig nitrogen (N_2) dibekalkan ke bahagian atas silinder mudah-gerak HF. Tekanan nitrogen memaksa cecair HF ke pengewap, di mana ia dipanaskan oleh air panas yang dibekalkan oleh pemanas air dan pam sirkulasi. HF cecair dipanaskan kepada suhu pengewapan pada tekanan yang dikehendaki, dan HF gas yang terhasil diarahkan ke reaktor lapisan cecair (aliran "Wing B-1"). Untuk memberi perlindungan tekanan lampau untuk pengewap, injap pelega dipasang pada paip yang disambungkan ke atas pengewap HF dan silinder bekalan mudah-gerak HF. Satu cakera pecah, dengan kadar tekanan pecah lebih tinggi daripada tetapan injap pelega, disediakan untuk melindungi injap pelega daripada pendedahan berterusan terhadap persekitaran hakisan HF. "Pengewap HF, pemanas air dan pam sirkulasi" dan "Sistem paip bekalan nitrogen kepada silinder mudah-gerak HF" adalah dianggapkan sebagai dua nod keterangan. Lakukan analisa HAZOP pada nod dengan menggunakan petunjuk-petunjuk berikut:

Node description: "HF vaporizer, water heater and circulating pump"
Nod keterangan: "Pengewap HF, pemanas air dan pam sirkulasi"

[i] Less Flow
Aliran Rendah

[ii] High Temperature
Suhu Tinggi

[iii] Low Temperature
Suhu Rendah

Node description: "Nitrogen supply pipework to HF cylinder"
Nod keterangan: " Sistem paip bekalan nitrogen kepada silinder mudah-gerak HF"

[iv] High Pressure
Tekanan Tinggi

[v] Part of Moisture
Sebahagian daripada Lembapan *[15 marks/markah]*

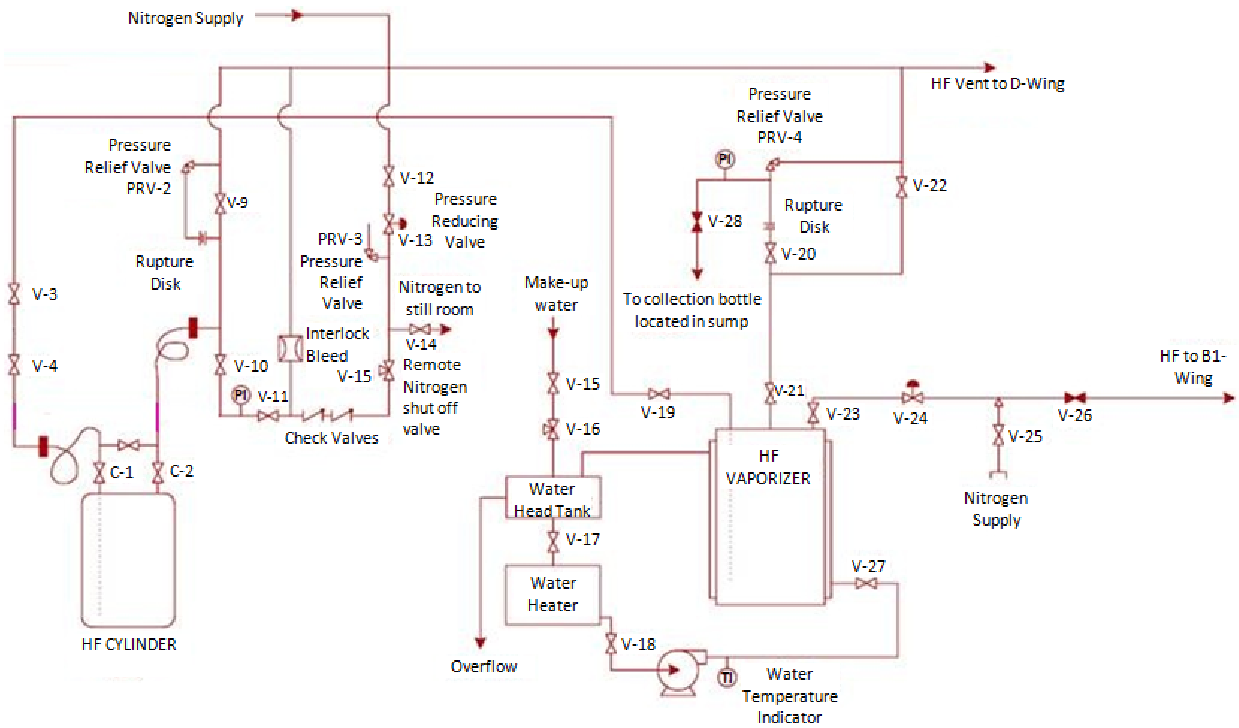

Figure Q.4.[c].
Rajah S.4.[c].

- oooOooo –

Appendix

Table 1

Fatality Statistics for Common Nonindustrial Activities[1,2]

Activity	FAR (deaths/10^8 hours)	Fatality rate (deaths per person per year)
Voluntary activity		
Staying at home	3	
Traveling by		
Car	57	17×10^{-5}
Bicycle	96	
Air	240	
Motorcycle	660	
Canoeing	1000	
Rock climbing	4000	4×10^{-5}
Smoking (20 cigarettes/day)		500×10^{-5}
Involuntary activity		
Struck by meteorite		6×10^{-11}
Struck by lightning (U.K.)		1×10^{-7}
Fire (U.K.)		150×10^{-7}
Run over by vehicle		600×10^{-7}

[1] Frank P. Lees, *Loss Prevention in the Process Industries* (London: Butterworths, 1986), p. 178.
[2] Frank P. Lees, *Loss Prevention in the Process Industries*, 2d ed. (London: Butterworths, 1996), p. 9/96.

Table 2

Roughness Factor ε for Pipes[a]

Pipe material	Condition	Typical ε mm	Typical ε inch
Drawn brass, copper, stainless	New	0.002	0.00008
Commercial steel	New	0.046	0.0018
	Light rust	0.3	0.015
	General rust	2.0	0.08
Iron	Wrought, new	0.045	0.0018
	Cast, new	0.30	0.025
	Galvanized	0.15	0.006
Concrete	Very smooth	0.04	0.0016
	Wood floated, brushed	0.3	0.012
	Rough, visible form marks	2.0	0.08
Glass or plastic	Drawn tubing	0.002[c]	0.0008[c]
Rubber	Smooth tubing	0.01	0.004
	Wire reinforced	1.0	0.04
Fiberglass[b]		0.005	0.0002

[a] Ron Darby, "Fluid Flow," *Albright's Chemical Engineering Handbook*, Lyle F. Albright, ed. (Boca Raton, FL: CRC Press, 2009), p. 421.
[b] William D. Stringfellow, ed., *Fiberglass Pipe Handbook* (Washington, DC: Society of the Plastics Industry, Inc., 1989).
[c] Generally considered smooth pipe with ε = 0.

Table 3

Atmospheric Stability Classes for Use with the Pasquill-Gifford Dispersion Model[1,2]

Surface wind speed (m/s)	Daytime insolation[3]			Nighttime conditions[4]	
	Strong	Moderate	Slight	Thin overcast or >4/8 low cloud	≤3/8 cloudiness
<2	A	A–B	B	F[5]	F[5]
2–3	A–B	B	C	E	F
3–4	B	B–C	C	D[6]	E
4–6	C	C–D	D[6]	D[6]	D[6]
>6	C	D[6]	D[6]	D[6]	D[6]

Stability classes:
- A, extremely unstable
- B, moderately unstable
- C, slightly unstable
- D, neutrally stable
- E, slightly stable
- F, moderately stable

[1]F. A. Gifford, "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion," *Nuclear Safety* (1961), 2(4): 47.

[2]F. A. Gifford, "Turbulent Diffusion-Typing Schemes: A Review," *Nuclear Safety* (1976), 17(1): 68.

[3]Strong insolation corresponds to a sunny midday in midsummer in England. Slight insolation to similar conditions in midwinter.

[4]Night refers to the period 1 hour before sunset and 1 hour after dawn.

[5]These values are filled in to complete the table.

[6]The neutral category D should be used, regardless of wind speed, for overcast conditions during day or night and for any sky conditions during the hour before or after sunset or sunrise, respectively.

Table 4

Recommended Equations for Pasquill-Gifford Dispersion Coefficients for Plume Dispersion[1,2] (the downwind distance x has units of meters)

Pasquill-Gifford stability class	σ_y (m)	σ_z (m)
Rural conditions		
A	$0.22x(1 + 0.0001x)^{-1/2}$	$0.20x$
B	$0.16x(1 + 0.0001x)^{-1/2}$	$0.12x$
C	$0.11x(1 + 0.0001x)^{-1/2}$	$0.08x(1 + 0.0002x)^{-1/2}$
D	$0.08x(1 + 0.0001x)^{-1/2}$	$0.06x(1 + 0.0015x)^{-1/2}$
E	$0.06x(1 + 0.0001x)^{-1/2}$	$0.03x(1 + 0.0003x)^{-1}$
F	$0.04x(1 + 0.0001x)^{-1/2}$	$0.016x(1 + 0.0003x)^{-1}$
Urban conditions		
A–B	$0.32x(1 + 0.0004x)^{-1/2}$	$0.24x(1 + 0.0001x)^{+1/2}$
C	$0.22x(1 + 0.0004x)^{-1/2}$	$0.20x$
D	$0.16x(1 + 0.0004x)^{-1/2}$	$0.14x(1 + 0.0003x)^{-1/2}$
E–F	$0.11x(1 + 0.0004x)^{-1/2}$	$0.08x(1 + 0.0015x)^{-1/2}$

A–F are defined in Table 5-1.

[1]R. F. Griffiths, "Errors in the Use of the Briggs Parameterization for Atmospheric Dispersion Coefficients," *Atmospheric Environment* (1994), 28(17): 2861–2865.

[2]G. A. Briggs, *Diffusion Estimation for Small Emissions,* Report ATDL-106 (Washington, DC: Air Resources, Atmospheric Turbulence, and Diffusion Laboratory, Environmental Research Laboratories, 1974).

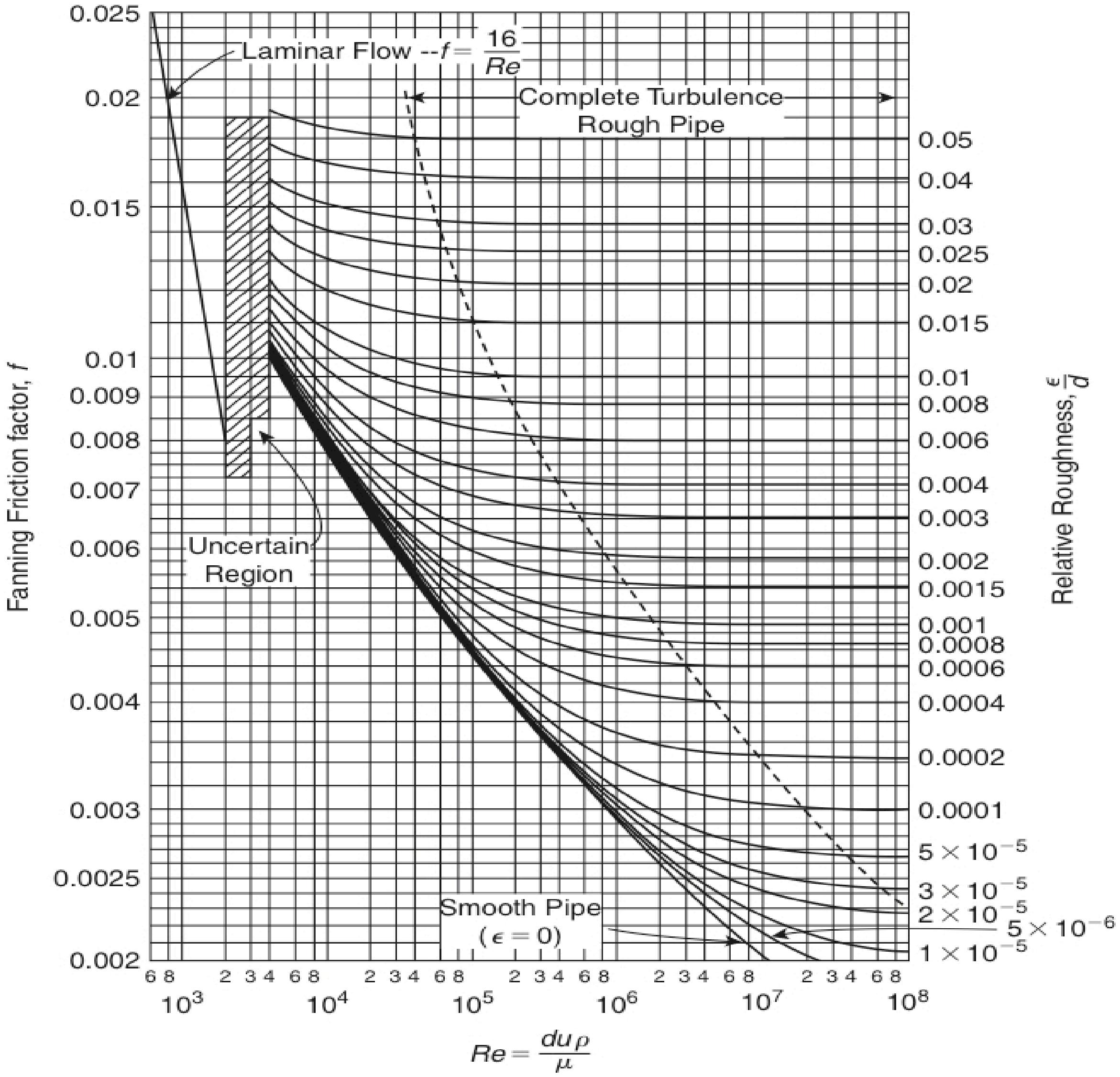

Figure 1: Plot of Fanning friction factor f versus Reynolds number.
(Source: Octave Levenspiel, *Engineering Flow and Heat Exchange* (New York: Plenum Press, 1984), p. 20)

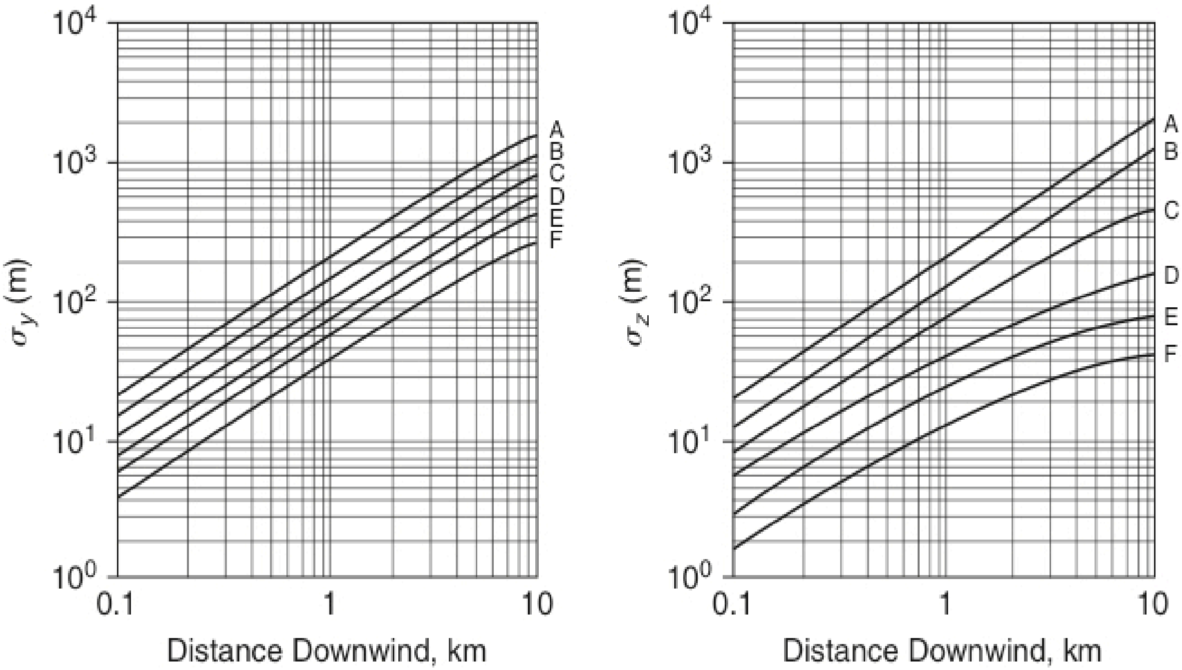

Figure 2: Dispersion coefficients for Pasquill-Gifford plume model for rural releases.

Formulae

$$Q_m = \frac{MKAP^{sat}}{R_g T_L}$$

$$C_{ppm} = \frac{KATP^{sat}}{kQ_v PT_L} \times 10^6$$

$$C_{ppm} = \frac{KAP^{sat}}{kQ_v P} \times 10^6$$

$$K = K_o \left(\frac{M_o}{M} \right)^{1/3}$$

$$C_{ppm} = \frac{P^{sat}}{kQ_v P} (\phi r_f V_c + KA) \times 10^6$$

$$\frac{\Delta P}{\rho} + \Delta \frac{\bar{u}^2}{2\alpha g_c} + \frac{g}{g_c} \Delta z + F = -\frac{W_s}{\dot{m}}$$

$$F = K_f \left(\frac{u^2}{2g_c} \right)$$

$$K_f = \frac{4fL}{d}$$

$$\frac{1}{\sqrt{f}} = -4 \log \left(\frac{\varepsilon/d}{3.7065} - \frac{5.0452 \log A}{Re} \right)$$

$$A = \left[\frac{(\varepsilon/d)^{1.1098}}{2.8257} + \frac{5.8506}{Re^{0.8981}} \right]$$

$$\langle C \rangle (x, y, z) = \frac{Q_m}{2\pi \sigma_y \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right]$$
$$\times \left\{ \exp \left[-\frac{1}{2} \left(\frac{z - H_r}{\sigma_z} \right) \right] + \exp \left[-\frac{1}{2} \left(\frac{z + H_r}{\sigma_z} \right)^2 \right] \right\}$$

$$\langle C \rangle (x,0,0) = \frac{Q_m}{\pi \sigma_y \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{H_r}{\sigma_z} \right)^2 \right]$$

$$\langle C \rangle (x, y, z, t) = \frac{Q_m^*}{\sqrt{2} \pi^{3/2} \sigma_x \sigma_y \sigma_z} \exp \left\{ -\frac{1}{2} \left[\left(\frac{x - ut}{\sigma_x} \right)^2 + \frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2} \right] \right\}$$

$$\langle C \rangle (x, y, z) = \frac{Q}{\pi \sigma_y \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2} \right) \right]$$