UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2008/2009

April/May 2009

EKC 367 – Plant Safety
[Keselamatan Loji]

Duration : 3 hours
[Masa : 3 jam]

Please check that this examination paper consists of NINE pages of printed material and FOUR pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN muka surat yang bercetak dan EMPAT muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instructions: Answer **FOUR** (4) questions. Answer **ALL** (3) questions from Section A. Answer **ONE** (1) question from Section B.

[Arahan: *Jawab **EMPAT** (4) soalan. Jawab **SEMUA** (3) soalan dari Bahagian A. Jawab **SATU** (1) soalan dari Bahagian B.]*

You may answer the question either in Bahasa Malaysia or in English.

[Anda dibenarkan menjawab soalan sama ada dalam Bahasa Malaysia atau Bahasa Inggeris.]

Section A : Answer ALL questions.
Bahagian A : Jawab SEMUA soalan.

1. [a] Hundred people are tested for breathing difficulty because of a specific dose of a substance. The responses are recorded on a scale from 0 to 10, with 0 indicating no response and 10 indicating a high response. The number of individuals exhibiting a specific response is given in the Table Q.1.[a]

1. [a] Seratus orang diuji untuk kesukaran bernafas akibat dos spesifik sesuatu bahan. Maklumbalas direkodkan dari skala 0 hingga 10, dengan 0 menunjukkan tiada maklumbalas dan 10 menunjukkan maklumbalas tinggi. Bilangan individu yang menunjukkan maklumbalas spesifik diberikan di dalam Jadual S.1.[a]

Table Q.1. [a]
Jadual S.1. [a]

Response (Breathing difficulty) *Maklumbalas (Kesukaran bernafas)*	Number of individuals affected *Bilangan individu terjejas*
0	0
1	7
2	13
3	17
4	17
5	15
6	12
7	8
8	5
9	4
10	2

[i] Plot a histogram of the number of individuals affected versus the response.

[i] Lukiskan histogram bilangan individu terjejas melawan maklumbalas.

[2 marks/markah]

[ii] Determine the mean and the standard deviation.

[ii] Tentukan nilai purata dan nilai sisihan piawai.

[2 marks/markah]

[iii] Plot the normal distribution curve on the histogram of the original data.

[iii] Lukis lengkung taburan normal di atas histogram data yang asal.

[6 marks/markah]

[iv] Use the calculated Gaussian distribution function to determine the fraction of individuals demonstrating a response between the range of 2.5 to 7.5.

[iv] Gunakan fungsi taburan Gaussian untuk menentukan pecahan individu yang menunjukkan maklumbalas di antara julat 2.5 hingga 7.5.

[5 marks/markah]

[b] A substance has a TLV-TWA of 200 ppm, a TLV-STEL of 250 ppm, and a TLV-C of 300 ppm. The following data represented in Table Q.1.[b] were taken in a work area:

[b] Satu bahan mempunyai TLV-TWA 200 ppm, TLV-STEL 250 ppm, dan TLV-C 300 ppm. Data berikut di dalam Jadual S.1.[b] diambil dalam kawasan kerja:

Table Q.1.[b]
Jadual S.1.[b]

Time *Masa*	Concentration, ppm *Kepekatan, ppm*
0801	185
0917	240
1005	270
1122	230
1208	190
1306	150
1405	170
1509	165
1600	160
1705	130

A worker on an 8-hour shift is exposed to this toxic vapor. Determine if the exposure within compliance or not? If not, what are the violations?

***Assumption*:** The worker experiences no exposure to the chemical at lunch time between the hours of 1200 -1300.

Seorang pekerja syif 8 jam terdedah kepada wap toksik. Tentukan samada pendedahan pada paras dibenarkan atau tidak? Jika tidak, apakah kesalahannya?

***Anggapan:** Pekerja tidak mengalami pendedahan terhadap bahan kimia pada waktu makan tengah hari di antara jam 1200 -1300.*

[10 marks/markah]

2. [a] Figure Q.2. shows the relationships between various flammability properties. Label properties [i] to [viii] on the Figure Q.2.

[i] Lower flammability limit
[ii] Upper flammability limit
[iii] Saturation vapor pressure curve
[iv] Autoignition region
[v] Flashpoint temperature
[vi] Autoignition temperature
[vii] Flammable area
[viii] Not flammable areas

2. [a] *Rajah S.2. menunjukkan hubungan di antara pelbagai sifat kemudahbakaran. Labelkan sifat [i] hingga [viii] pada rajah S.2.*

[i] *Had kemudahbakaran bawah*
[ii] *Had kemudahbakaran atas*
[iii] *Lengkung tekanan wap tepu*
[iv] *Kawasan pengautocucuhan*
[v] *Suhu takat kilat*
[vi] *Suhu pengautocucuhan*
[vii] *Kawasan mudah bakar*
[viii] *Kawasan-kawasan tidak mudah bakar*

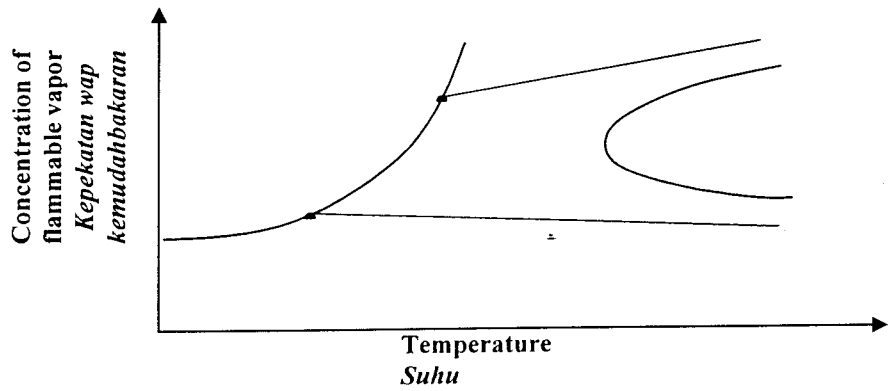

Figure Q.2.
Rajah S.2.

[4 marks/markah]

[b] Using the stoichiometric concentration method, estimate both lower flammability limit (LFL) and upper flammability limit (UFL) for ethyl ether ($CH_3CH_2OCH_2CH_3$).

[b] Gunakan kaedah kepekatan stoikiometri, anggarkan kedua-dua had kemudahbakaran bawah (LFL) dan had kemudahbakaran atas (UFL) bagi etil eter ($CH_3CH_2OCH_2CH_3$).

[6 marks/markah]

[c] A coal plant located in a rural area emits 200 g/s of SO_2 from a stack with physical stack height 80 m and plume rise 120 m. The wind speed is 2.8 m/s during the shining day with slight daytime insolation.

[i] How far downwind of the source does the maximum occur?
[ii] What is the estimated maximum ground-level concentration of SO_2 due to this source?

[c] Sebuah loji arang batu yang terletak di kawasan luar bandar membebaskan 200 g/s of SO_2 daripada sebuah paip tumpu dengan ketinggian fizikal 80 m dan plum naik 120 m. Halaju angin ialah 2.8 m/s pada siang hari yang mendung.

[i] Berapa jauhkah punca hiliran angin yang mana berlakunya kepekatan maksimum?
[ii] Apakah anggaran kepekatan SO_2 aras bumi maksimum disebabkan oleh punca ini?

[15 marks/markah]

3. Figure Q.3 shows the feed section of a proposed olefin dimerisation unit. An alkene/alkane fraction containing small amounts of suspended water is continuously pumped from bulk intermediate storage via a half-mile pipeline section into a buffer/settling tank. Residual water is settled out prior to passing via a feed/product heat exchanger and preheater to the reactor section. The water, which has an adverse effect on the dimerisation reaction, is run off manually from the settling tank at interval time. Residence time in the reaction section must be held within closely defined limits to ensure adequate conversion of the alkene and to avoid excessive formation of polymer. Perform HAZOP analysis using the following guidewords:

[a] NO FLOW of the feed
[b] MORE FLOW of the feed
[c] LESS FLOW of the feed
[d] HIGH PRESSURE in the unit
[e] HIGH TEMPERATURE in the unit

3. Gambarajah S.3 menunjukkan seksyen suapan bagi cadangan unit "dimerisation" olefin. Suatu pecahan alkena/alkana mengandungi sedikit air terampai dipamkan secara berterusan daripada sebuah tangki pukal pertengahan melalui seksyen talian paip setengah batu ke tangki mendapan. Air baki dimendapkan sebelum dialirkan melalui suatu penukar haba suapan/produk dan prapemanas ke seksyen reaktor. Air yang mempunyai efek bertentangan ke atas tindakbalas "dimerisation" dialir keluar secara manual daripada tangki penetapan pada selang masa. Masa mastautin dalam seksyen tindakbalas mesti dikekalkan dalam jangka masa tertentu untuk memastikan penukaran alkena mencukupi dan mengelakkan pembentukan polimer secara berlebihan. Jalankan analisis HAZOP menggunakan katakunci berikut:

[a] TIADA ALIRAN pada suapan
[b] LEBIH ALIRAN pada suapan
[c] KURANG ALIRAN pada suapan
[d] TEKANAN TINGGI pada unit
[e] SUHU TINGGI pada unit

[25 marks/markah]

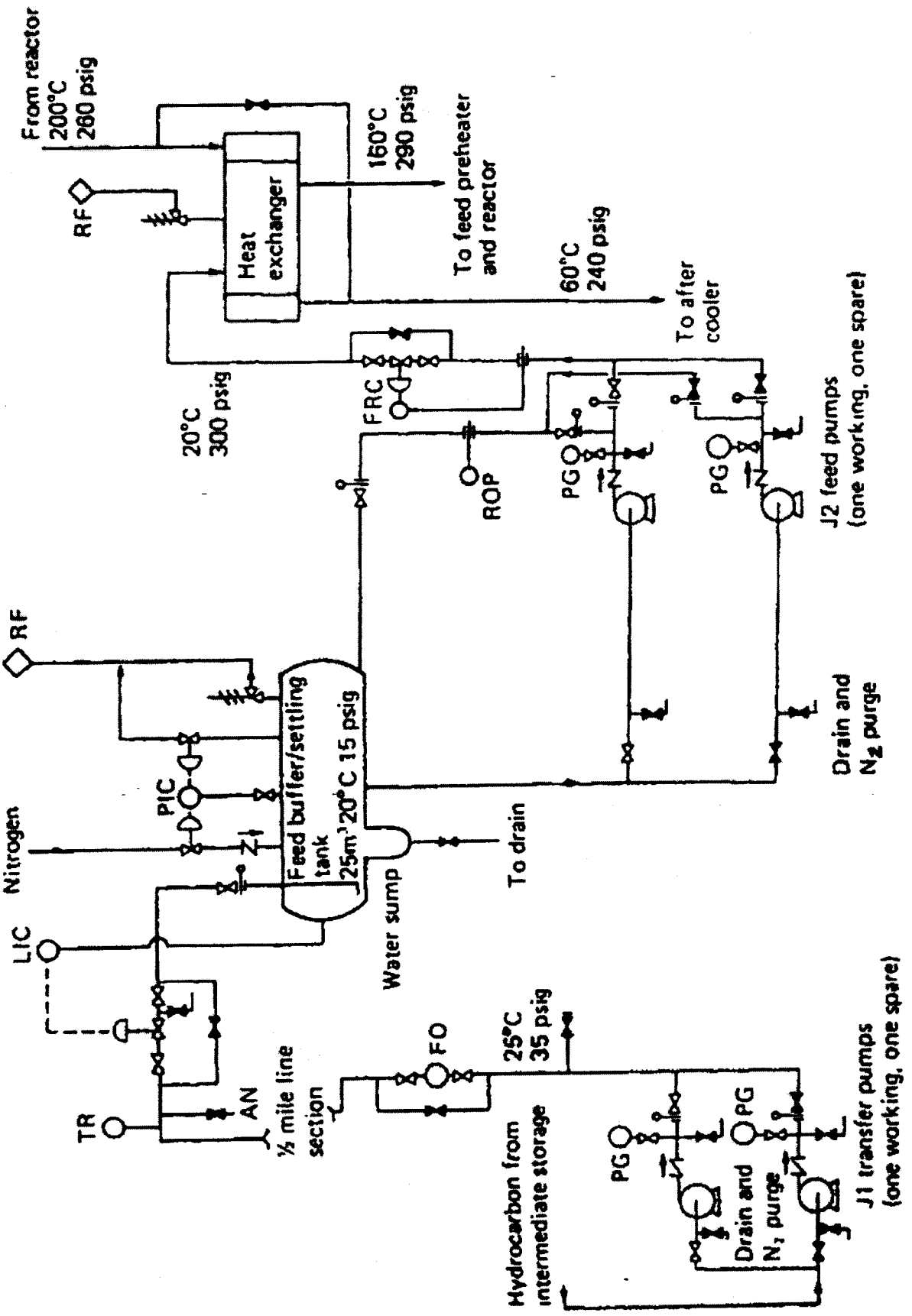

Figure Q. 3
Gambarajah S. 3

Section B : Answer any ONE question.
Bahagian B : Jawab mana-mana SATU soalan.

4. [a] According to the accident likelihood data, rock climbing activity (FAR = 4000 deaths/0^8 hours) kills more people than driving a car (FAR = 57 deaths/ 10^8 hours). However, in reality the numbers of deaths caused by car accidents were much higher as compared to the rock climbing activity. Justify the statement.

4. [a] Berdasarkan data kemungkinan kemalangan, aktiviti mendaki gunung (FAR = 4000 kematian/10^8 jam) membunuh lebih ramai orang berbanding memandu kereta (FAR = 57 kematian / 10^8 jam). Namun, secara realitinya, bilangan kematian yang diakibatkan oleh kemalangan kereta sangat tinggi berbanding dengan aktiviti memanjat gunung. Terangkan kenyataan di atas.

[4 marks/markah]

[b] Using the ideal gas law and Dalton's law formulas, show that for a particular vessel through a vacuum purging process after j purge cycles, vacuum and relief, is given by the following general equation:-

[b] Dengan menggunakan hukum gas unggul dan hukum Dalton, tunjukkan untuk sesuatu bekas yang melalui satu proses vakum pembersihan selepas j kitaran pembersihan, vakum dan pelega boleh diberikan dalam persamaan am:-

$$y_i = y_o\left(\frac{n_L}{n_H}\right)^j = y_o\left(\frac{P_L}{P_H}\right)^j$$

where y_i = final target oxygen concentration
y_o = initial oxygen concentration
n_H = total moles in the atmospheric state
n_L = total moles in the vacuum state
P_H = high pressure
P_L = low pressure

di mana y_i = kepekatan oksigen sasaran akhir
y_o = kepekatan oksigen awal
n_H = jumlah mol pada keadaan atmosfera
n_L = jumlah mol pada keadaan vakum
P_H = tekanan tinggi
P_L = tekanan rendah

[6 marks/markah]

[c] Figure Q. 4.[c] shows the schematic of a cracking heater for a plant producing ethylene. A combined effect of "Damage due to high temperature" and "Radiant tube rupture due to mechanical stress" may result a typical fire and explosion in the furnace. Construct a fault tree diagram with the top event of "Fire/Explosion in the furnace".

[c] Gambarajah S. 4.[c] menunjukkan skematik suatu pemanas peretakan bagi sebuah loji menghasilkan etilena. Kesan gabungan "Rosak disebabkan suhu tinggi" dan "Pecahan tiub sinaran disebabkan oleh tekanan mekanikal" boleh menyebabkan suatu kebakaran dan letupan dalam kebuk pemanas tersebut. Bangunkan satu pokok kegagalan dengan peristiwa teratas "Kebakaran/ Letupan dalam kebuk".

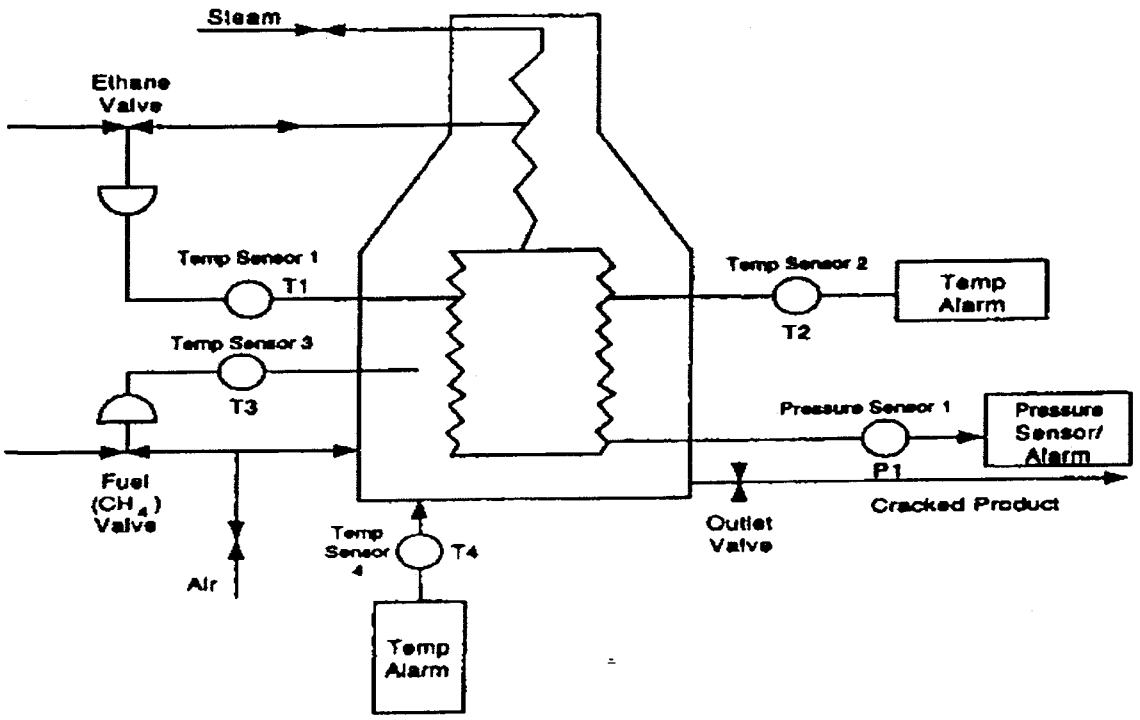

Figure Q.4.[c]
Gambarajah S.4.[c]

[15 marks/markah]

5. [a] Give the advantages and disadvantages of Fault Tree Analysis.

5. *[a] Berikan kebaikan dan keburukan Analisis Pokok Kegagalan.*

[4 marks/markah]

[b] An open toluene container in an enclosure is weighed as a function of time. It is determined that the average evaporation rate is 1 x 10^{-4} kg/min. The temperature is 300 K and the pressure is 101.3 kPa. The TLV for toluene is 50 ppm.

[b] Satu bekas terbuka mengandungi toluena di dalam ruangan tertutup ditimbang mengikut fungsi masa. Telah ditentukan kadar purata pengewapan ialah 1 x 10^{-4} kg/min. Suhu 300 K dan tekanan 101.3 kPa. TLV untuk toluena ialah 50 ppm.

[i] Estimate the concentration of toluene vapor in the enclosure if the ventilation rate is 2.832 m^3/min. Compare the results to the TLV for toluene.

[i] Anggarkan kepekatan wap toluena dalam ruangan tertutup sekiranya kadar pengudaraan ialah 2.832 m^3/min. Bandingkan keputusan dengan nilai TLV untuk toluena.

[3 marks/markah]

[ii] Estimate the concentration of toluene vapor in the enclosure if the ventilation rate increases 10 times higher. Compare the results to the TLV for toluene.

[ii] Anggarkan kepekatan wap toluena dalam mangan tertutup sekiranya kadar ventilosi ditingkatkan 10 kali. Bandingkan keputusan dengan TLV untuk toluena.

[4 marks/markah]

[iii] Recommend necessary actions that should be taken for each case above based on your answers in [i] and [ii].

[iii] Sarankan tindakan yang perlu diambil bagi setiap kes berdasarkan jawapan [i] dan [ii].

[2 marks/markah]

Additional data:

$R = 8.314\ m^3\ kPa/kg\text{-}mol\ K$
$M_{toluene} = 92\ kg/kg\text{-}mol$
$101.3\ kPa = 1\ atm$

Data tambahan:

$R = 8.314\ m^3\ kPa/kg\text{-}mol\ K$
$M_{toluena} = 92\ kg/kg\text{-}mol$
$101.3\ kPa = 1\ atm$

[c] A worker in a chemical industry ordered a tank of 2000 kg propane gas from Petronas. The tank accidentally ruptured after half of the initial amount of propane has been utilized. The cloud was ignited and a huge explosion occurred. By using TNT method, determine the consequence of that explosion at 500 m from the source of explosion. Assume an explosion efficiency of 5%.

[c] Seorang pekerja di industri kimia menempah sebuah tangki yang mengandungi 2000 kg propana daripada Petronas. Tangki tersebut retak secara tidak disangka selepas separuh daripada kandungan propana asal telah digunakan. Awan itu tercucuh menyebabkan satu letupan besar berlaku. Dengan menggunakan kaedah TNT, tentukan kesan daripada letupan itu pada jarak 500 m daripada punca letupan. Anggapkan kecekapan letupan sebanyak 5%.

[12 marks/markah]

Data:

Standard heat of formation, H_f^o

C_3H_8	= -103.8 kJ/mol
CO_2	= -393.5 kJ/mol
H_2O	= -241.8 kJ/mol
Molecular weight of propane	= 44 kg/kmol
Equivalent energy of TNT	= 4686 kJ/kg

Ambient pressure 1 atm = 14.7 psi = 101.3 kPa

Data:

Haba pembentukan piawai, H_f^o

C_3H_8	= -103.8 kJ/mol
CO_2	= -393.5 kJ/mol
H_2O	= -241.8 kJ/mol
Berat molekul propana	= 44 kg/kmol
Tenaga setara bagi TNT	= 4686 kJ/kg

Tekanan ambien 1 atm = 14.7 psi = 101.3 kPa

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Appendix

Lampiran

$$C_{st} = \frac{100}{1 + \left(\frac{z}{0.21}\right)}$$

$$LFL = 0.55\,C_{st} = \frac{0.55\ (100)}{4.76\ m + 1.19\ x - 2.38\ y + 1}$$

$$UFL = 3.50\,C_{st} = \frac{3.50\ (100)}{4.76\ m + 1.19\ x - 2.38\ y + 1}$$

$$LFL_{mix} = \frac{1}{\sum_{i=1}^{n} \frac{y_i}{LFL_i}}$$

$$UFL_{mix} = \frac{1}{\sum_{i=1}^{n} \frac{y_i}{UFL_i}}$$

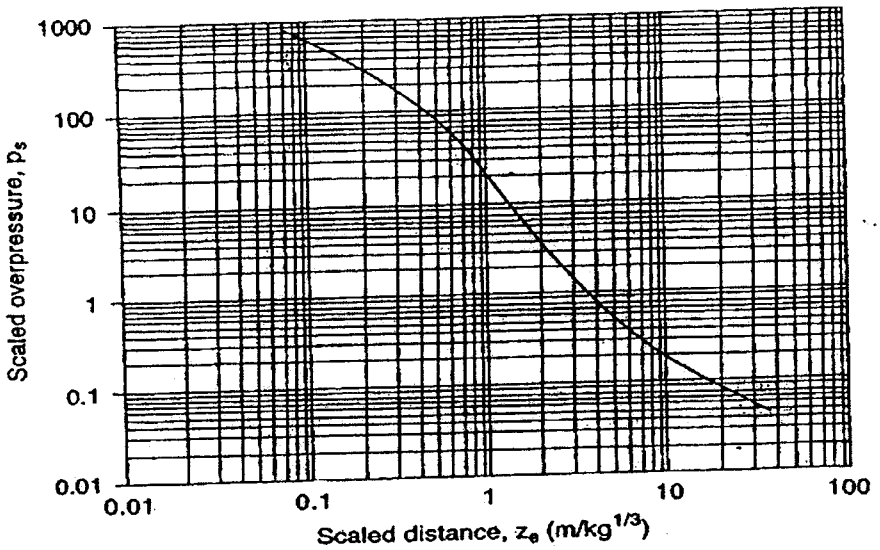
$$\langle C \rangle (x, y, z) = \frac{Q_m}{\pi \sigma_y \sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2}\right)\right]$$

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

$$\langle C \rangle_{max} = \frac{2Q_m}{e\pi u H_r^2}\left(\frac{\sigma_z}{\sigma_y}\right)$$

$$\sigma_z = \frac{H_r}{\sqrt{2}}$$

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



Correlation between scaled distance and explosion peak side-on overpressure for a TNT explosion occurring on a flat surface. Source: G. F. Kinney and K. J. Graham, *Explosive Shocks in Air* (Berlin: Springer-Verlag, 1985).

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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.

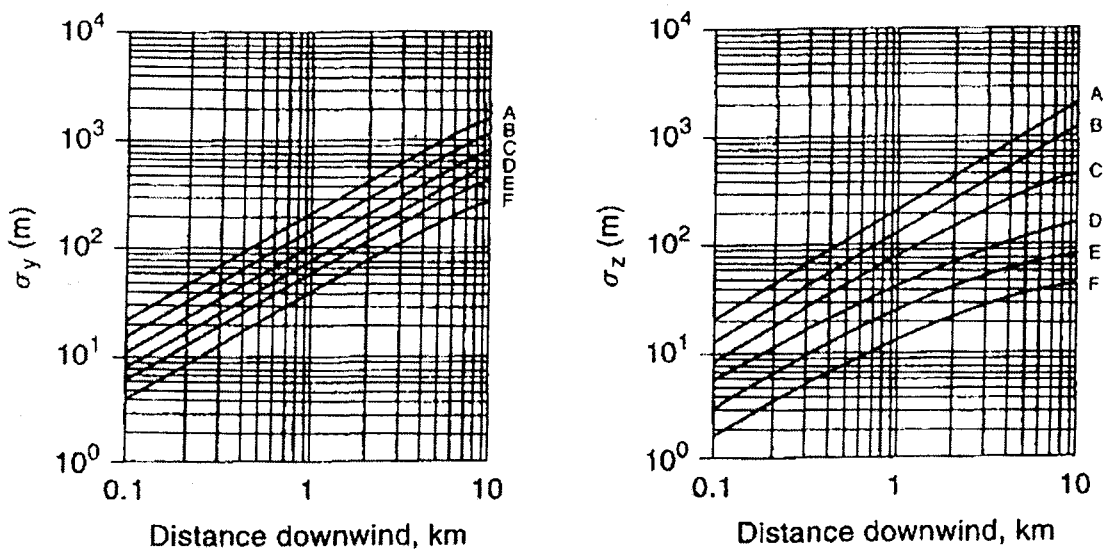
[2]F. A. Gifford, "Turbulent Diffusion-Typing Schemes: A Review," *Nuclear Safety* (1976), 17(1): 68.

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

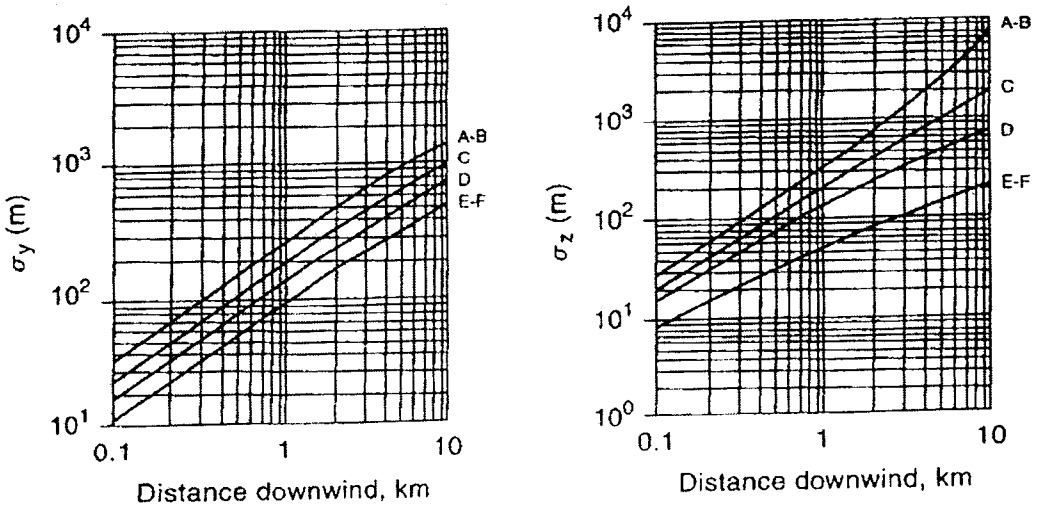
[4]Night refers to the period 1 hour before sunset and 1 hour after dawn.

[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.



Dispersion coefficients for Pasquill-Gifford plume model for rural releases.



Dispersion coefficients for Pasquill-Gifford plume model for urban releases.

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).

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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

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