UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2010/2011 Academic Session

April/May 2011

EKC 367 – Plant Safety
[Keselamatan Loji]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains SIX printed pages and FIVE printed page of Appendix before you begin the examination.

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

Instruction: Answer **ALL** questions.

*[**Arahan:** Jawab **SEMUA** 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].

1. [a] Define and explain the three Safety Indices that are widely used in chemical process industries.

Takrif dan jelaskan tiga Indek Keselamatan yang biasa digunakan dalam industri proses kimia.

[6 marks/markah]

[b] What do you understand by the term Probit Analysis?
Apakah yang anda faham tentang terma Analisis Probit?

[4 marks/markah]

[c] A storage tank containing 36,750 gallon liquid is ruptured, releasing all the fuel into the confined diked underneath the tank. Accidently the confined liquid caught fire, resulting a huge pool fire incident. Table Q.1. indicates the predicted radiated heat flux at various distances from the flame.
Sebuah tangki simpanan yang mengandungi 36,750 gelen cecair telah pecah lalu melepaskan semua bahan api ke dalam takungan di bawah tangki. Dengan tidak sengaja cecair yang terkurung itu terbakar, mengakibatkan kebakaran yang besar. Jadual S.1. menunjukkan ramalan sinar fluks haba pada pelbagai jarak dari nyalaan api.

[i] Plot the variations of the heat flux (kW/m^2) against the distance (m).
Plotkan perubahan fluks haba (kW/m^2) terhadap jarak (m).

[ii] By using the given probit correlation, plot the variations of the percentage fatality against the distance (m).

Dengan menggunakan hubungkait probit yang diberi, plotkan perubahan peratusan kematian terhadap jarak (m).

[iii] Determine the safe zone i.e. the distance with approximately zero fatality.
Tentukan zon selamat, iaitu jarak di mana kematian menghampiri sifar.

[15 marks/markah]

Data:

Table Q.1.: Predicted heat fluxes at various distance from fireball centre.
Jadual S.1.: Ramalan fluks haba pada pelbagai jarak dari pusat bola api.

Distance from Fireball Centre (km) *Jarak dari pusat bola api (km)*	Heat Flux, *I* (kW/m^2) *Fluks haba,* I *(kW/ m^2)*
50	1076.13
100	269.03
150	119.60
200	67.30
250	43.00
300	29.90
350	21.96
400	16.00
450	13.00
500	10.80

Probit correlation:
Hubungkait probit:

$$Y = -14.9 + 2.56 \ln\left[\frac{20 \text{ x } I^{4/3}}{10^4}\right] \quad \text{where : } I\ (W/m^2)$$

di mana: I (W/m^2)

2. [a] List down 3 parameters that will affect the atmospheric dispersion of toxic materials.
Senaraikan 3 parameter yang akan mempengaruhi serakan atmosfera bahan-bahan beracun.

[3 marks/markah]

[b] A copper smelter located in a rural area in Malaysia emits 1000 g/s of SO_2 from a 150 m height stack with a plume rise of 75 m. In the daytime with slight insolation, the wind speed is 3 m/s.

Sebuah peleburan tembaga yang terletak di kawasan luar bandar di Malaysia membebaskan 1000 g/s SO_2 daripada sebuah paip tumpu berketinggian 150 m dengan kenaikan plum setinggi 75 m. Pada siang hari dengan sedikit sinaran solar kemasukan (insolation), kelajuan angin ialah 3 m/s.

[i] Calculate the ground-level concentration of SO_2 from this source at 5 km directly downwind.
Kirakan kepekatan SO_2 di aras bumi daripada sumber ini pada jarak 5 km di hiliran terus angin.

[6 marks/markah]

[ii] The management of the smelter has been informed by the local authority that the concentration calculated in part [i] is twice the allowable value. They propose to remedy this situation by installing a higher stack. How high should the new stack be so that the concentration will be exactly half of that in part [i]? Assume the same plume rise.

Pihak pengurusan peleburan telah diberitahu oleh pihak berkuasa tempatan bahawa kepekatan yang dihitung dalam bahagian [i] adalah dua kali ganda nilai yang dibenarkan. Bagi memperbaiki situasi ini, mereka mencadangkan untuk memasang paip tumpu yang lebih tinggi. Berapakah ketinggian yang diperlukan bagi paip tumpu yang baru supaya kepekatannya adalah setengah daripada bahagian [i]? Andaikan peningkatan plum yang sama.

[5 marks/markah]

[c] A storage tank contains a hazardous material dissolved in water. The tank is 3 m in diameter and 7 m high. Initially, the liquid height is within 1 m of the top of tank. Assume an orifice-type leak with a discharge coefficient of 0.61.

Sebuah tangki simpanan mengandungi bahan merbahaya yang dilarutkan di dalam air. Tangki tersebut berdiameter 3 m dan ketinggian 7 m. Pada asalnya, ketinggian cecair berada dalam 1 m dari bahagian atas tangki. Andaikan kebocoran jenis orifis dengan pekali kadar alir 0.61.

…4/-

[i] If a 3 cm (internal diameter) feed pipe at the bottom of the tank breaks off, how much liquid (in m^3) is spilled if an emergency response procedure requires 20 min to stop the flow?

Jika 3 sm (diameter dalam) paip suapan di bahagian bawah tangki pecah, berapa banyakkah cecair (dalam m^3) yang tumpah jika tatacara reaksi kecemasan memerlukan 20 minit untuk menghentikan aliran?

[6 marks/markah]

[ii] What is the final liquid level (in m) from the bottom of the tank?
Apakah paras cecair akhir (dalam m) dari dasar tangki?

[5 marks/markah]

3. [a] [i] What is inerting in the term of process safety?
Apa itu lengaian mengikut terma keselamatan proses?

[2 marks/markah]

[ii] What is the difference between confined and unconfined explosion?
Apakah perbezaan antara letupan terkurung dan tidak terkurung?

[2 marks/markah]

[b] Determine the number of vacuum purges required to reduce a vessel's oxygen concentration from 21% to 1% by using

Hitungkan nombor pembersihan vakum yang diperlukan untuk mengurangkan kepekatan oksigen dalam bekas dari 21% kepada 1% dengan menggunakan

[i] pure nitrogen
nitrogen tulen

[3 marks/markah]

[ii] nitrogen contains 8000 ppm of oxygen
nitrogen mengandungi 8000 ppm oksigen

[3 marks/markah]

[iii] comment on the results that you obtained in [i] and [ii]
Berikan komen anda terhadap jawapan yang diperolehi dalam [i] dan [ii]

[2 marks/markah]

Assume that the vacuum system goes down to 30 mmHg absolute.
Andaikan bahawa sistem vakum turun sehingga 30 mmHg mutlak.

[c] An explosion occurred in a chemical plant involving the ruptured of the storage tank containing 1500 kg propane gas. If given the equivalent mass of trinitrotoluene (TNT) is 550 kg and the scaled distance is 50 $mkg^{-1/3}$. Determine the:

Satu letupan berlaku di sebuah kilang kimia yang melibatkan keretakan sebuah tangki simpanan yang mengandungi 1500 kg gas propana. Jika diberikan jisim setara trinitrotoluena (TNT) ialah 550 kg dan jarak skala ialah 50 $mkg^{-1/3}$. Hitungkan:

[i] distance from the source of this consequence explosion?
jarak daripada sumber letupan ini?

[3 marks/markah]

[ii] explosion efficiency?
kecekapan letupan?

[5 marks/markah]

[iii] type of the damage resulted from this explosion?
jenis kerosakan daripada letupan ini?

[5 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, $\mathbf{H_f^o}$

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*

4. [a] By using your own words, explain what do you understand by the term HAZOP Analysis.
Dengan menggunakan perkataan anda sendiri, jelaskan apa yang anda faham dengan sebutan Analisis HAZOP.

[10 marks/markah]

[b] Anhydrous ammonia is one of the most valuable and versatile chemical compounds used in a variety of industries including food production and processing, textile and chemical manufacturing. A simplified piping and instrumentation drawing on one node of a large metallurgical and metal working plant is shown in Figure Q.4. A large, 100 ton storage tank holds the bulk of the plant's ammonia capacity. However, to use the ammonia effectively, it is transferred to a holding tank or Ready Storage. From the Ready Storage the ammonia is dispersed to the various parts of the plant. The distance from the storage tank to the Ready Tank is approximately 1 mile. A positive displacement pump and various control and manual valves are used to transfer the ammonia. Both tanks are fitted with relief valves. A dry nitrogen gas system is used periodically to purge the system of contamination. All venting is connected to the unit scrubbers. Perform HAZOP analysis on the node by using the following guidewords:

Amonia anhidrat adalah salah satu sebatian kimia yang paling berharga dan serbaguna yang digunakan dalam pelbagai industri termasuk pengeluaran dan pemprosesan makanan, tekstil dan pembuatan kimia. Lukisan mudah perpaipan dan peralatan pada satu nod dari kilang pelogaman dan pengerjaan logam besar ditunjukkan dalam Rajah S.4. Sebuah tangki penyimpanan bersaiz besar 100 tan boleh memuatkan kapasiti pukal loji amonia. Walau bagaimanapun, untuk menggunakan amonia secara berkesan, ia dipindahkan ke tangki penyimpanan atau penyimpanan yang sedia ada. Dari penyimpanan sedia ada, ammonia diagihkan ke pelbagai bahagian loji. Jarak dari tangki penyimpanan ke tangki sedia ada ialah kira-kira 1 batu. Pam anjakan positif dan pelbagai injap kawalan dan manual digunakan untuk memindahkan amonia. Kedua-dua tangki dilengkapi dengan injap pelega. Sistem gas nitrogen kering digunakan secara berkala untuk membersihkan sistem pencemaran. Semua bolong disambungkan ke unit penjerap. Lakukan analisis HAZOP pada nod dengan menggunakan kata pandu berikut:

[i] No Flow
Tiada aliran

[ii] Less Flow
Aliran kurang

[iii] More Flow
Aliran Lebih

[iv] More Pressure
Tekanan Lebih

[15 marks/markah]

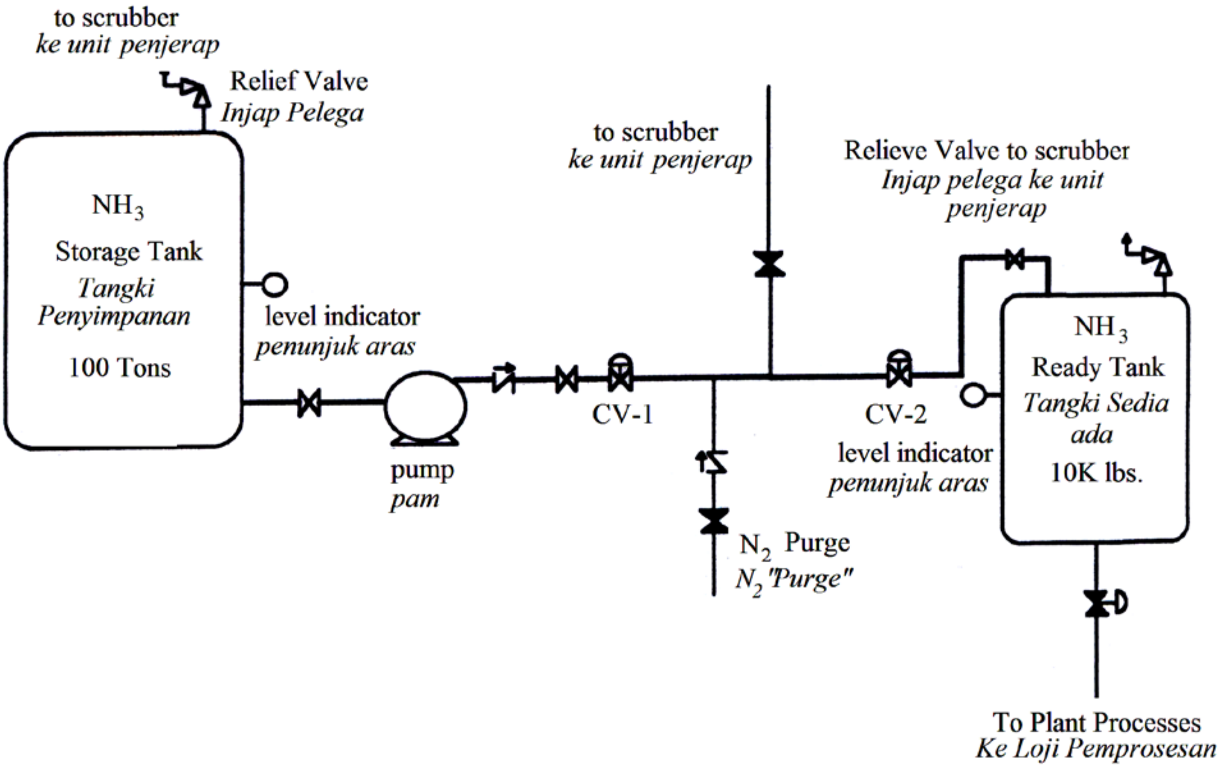

Figure Q.4.
Rajah S.4.

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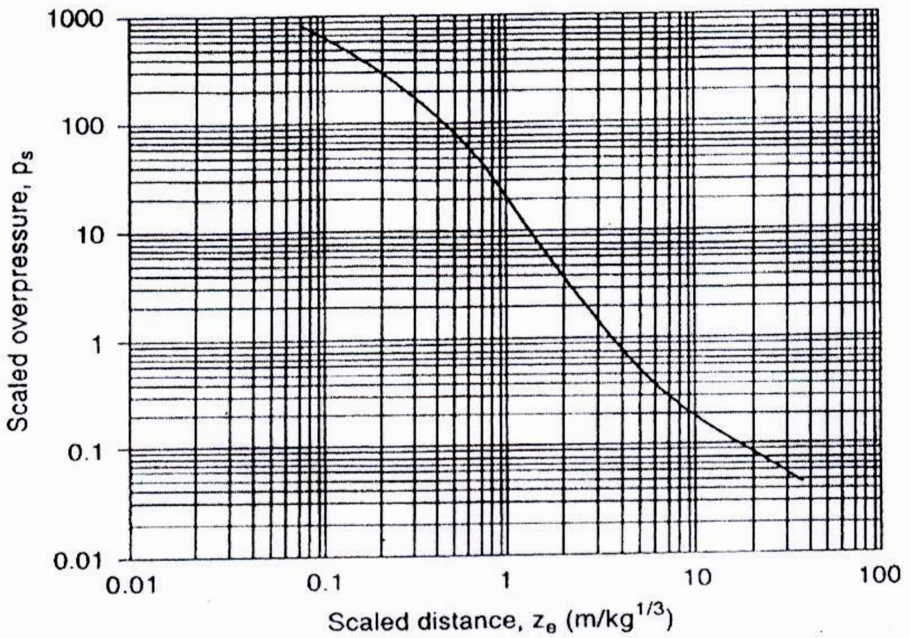
Appendix

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

Table : Transformation from Percentages to Probits[1]

%	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

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



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).

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.

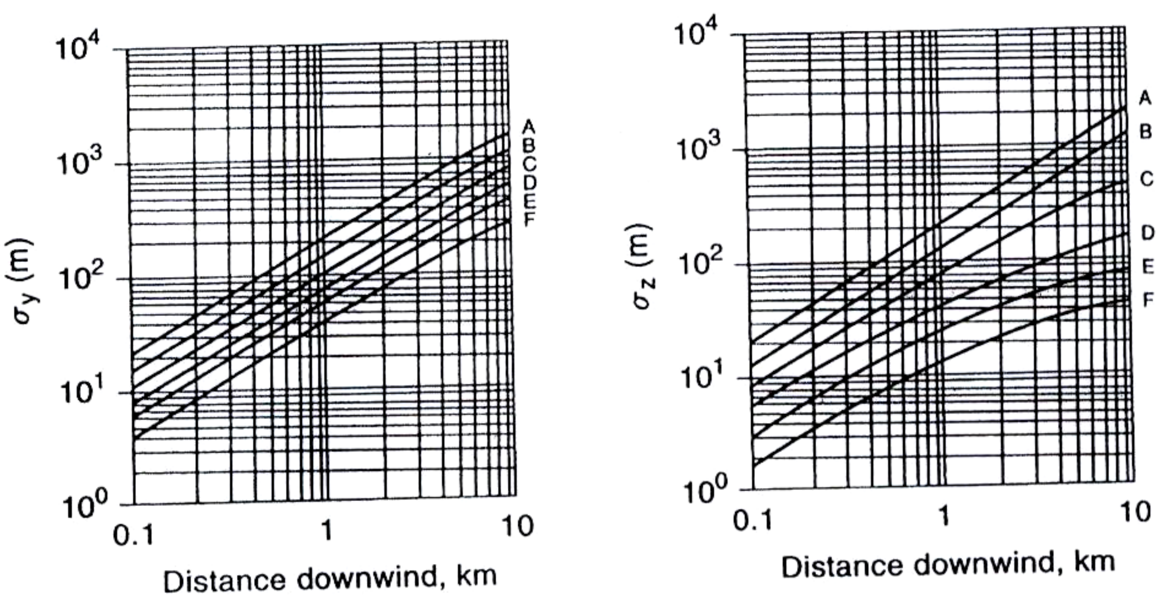
[2]F. A. Gifford, "Turbulent Diffusion-Typing Schemes: A Review," *Nuclear Safety* (1976), 17(1): 68.

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

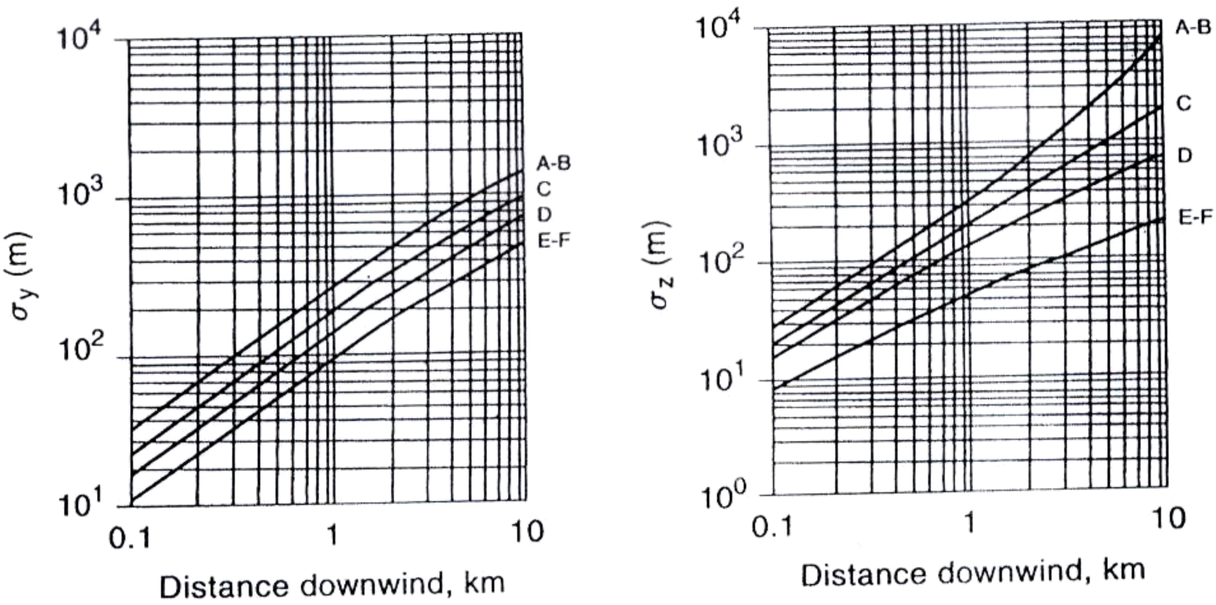
[4]Night refers to the period 1 hour before sunset and 1 hour after dawn.

[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).

Damage Estimates for Common Structures Based on Overpressure (these values are approximations)[1]

Pressure		
psig	kPa	Damage
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).

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

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

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

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

$$\Delta H_r=\frac{\bar{u}_s d}{\bar{u}}\left[1.5+2.68\text{ x }10^{-3}Pd\left(\frac{T_s-T_a}{T_s}\right)\right]$$

$$1\text{ bar}=1\text{ x }10^5\text{ Pa}$$

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

$$y_j=y_{j-1}\left(\frac{P_L}{P_H}\right)+y_{oxy}\left(1-\frac{P_L}{P_H}\right)$$

$$\left(y_j-y_{oxy}\right)=\left(\frac{P_L}{P_H}\right)^j\left(y_o-y_{oxy}\right)$$

$$t_e=\frac{1}{C_o g}\left(\frac{A_t}{A}\right)\left[\sqrt{2\left(\frac{g_c P_g}{\rho}+gh_L^o\right)}-\sqrt{\frac{2g_c P_g}{\rho}}\right]$$

$$t_e=\frac{1}{C_o g}\left(\frac{A_t}{A}\right)\sqrt{2gh_L^o}$$

$$h_L=h_L^o-\frac{C_o A}{A_t}\sqrt{\frac{2g_c P_g}{\rho}+2gh_L^o}+\frac{g}{2}\left(\frac{C_o A}{A_t}t\right)^2$$

$$Q_m=\rho\bar{u}A=\rho A C_o\sqrt{2\left(\frac{g_c P_g}{\rho}+gh_L\right)}$$

$$Q_m=\rho C_o A\sqrt{2\left(\frac{g_c P_g}{\rho}+gh_L^o\right)}-\frac{\rho g C_o^2 A^2}{A_t}t$$