UNIVERSITI SAINS MALAYSIA

First Semester Examination
2009/2010 Academic Session

November 2009

EKC 512 – Safety Engineering and Environmental Management
[Kejuruteraan Keselamatan dan Pengurusan Persekitaran]

Duration : 3 hours
[Masa : 3 jam]

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

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

Instruction: Answer any **ALL** questions.

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

Answer ALL questions.
Jawab SEMUA soalan.

1. [a] Discuss the importance of sustainability and provide its fundamental elements based on the concept of 'Sustainable Environment'. Explain how sustainability may be approached in our lifes.

Bincangkan kepentingan kelestarian dan berikan element asas berdasarkan tayangan video berjudul "Sustainable Environment'. Terangkan bagaimana kita boleh mendekati kelestarian di dalam kehidupan kita.

[12 marks/markah]

[b] What are the important items in the storm water prevention plan? What are the industries that are required to obtain storm water discharge permit?

Apakah perkara-perkara penting di dalam pelan pencegahan air hujan? Industri manakah yang memerlukan kelulusan pelepasan air hujan?

[8 marks/markah]

[c] List down the categories of activities prescribed under the Environmental Quality Act, 1974 (Amendment 1985).

Senaraikan kategori aktiviti yang disarankan di bawah Akta Kualiti Alam Sekitar, 1974 (Perubahan 1985).

[5 marks/markah]

2. [a] Ground level concentration of SO_2 emitted from a plant can be calculated using the Diffusion model. Determine the maximum ground level concentration of SO_2 (in g/m^3) at 1 km from the plant. Stack height = 3 m, stack tip radius = 3 m, exit velocity = 15 m/s, exit temperature = 150^{o}C, wind speed = 6.5 m/s, horizontal dispersion = 75 m, vertical dispersion = 33 m, source strength = 1.1 Mg/s, ambient temperature = 20^{o}C and pressure = 100 kPa.

Kepekatan aras bumi SO_2 yang dilepaskan dari sebuah kilang boleh dikira menggunakan model pembauran. Kirakan kepekatan maksimum aras bumi SO_2 (dalam g/m^3) pada jarak 1 km daripada kilang. Diberikan, ketinggian serombong = 3 m, jejari serombong = 3 m, kelajuan keluar 15 m/s, suhu keluar = 150^{o}C, kelajuan angin 6.5 m/s, penyerakan mendatar = 75 m, penyerakan menegak = 33 m, kekuatan sumber 1.1 Mg/s, suhu persekitaran = 20^{o}C dan tekanan = 100kPa.

$$C(x,y,z) = \frac{q}{2\pi\sigma_y\sigma_z v}\exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

$$C(t) = \frac{qL}{vH}\left(1 - e^{(-vt/L)}\right)$$

$$\Delta H = \frac{2v_s r_s}{v}\left[1.5 + 2.68 \text{ x } 10^{-2} P\left(\frac{T_s - T_a}{T_s}\right)2r_s\right]$$

[15 marks/markah]

[b] How would the calculated result differ if a Box model is used? Calculate the concentration using the Box model and give the reasons for the discrepancy from the Diffusion model. (Assume mixing height = Stack height, mixing length = distance from the plant).

Bagaimana hasil pengiraan boleh berbeza sekiranya model kotak digunakan? Kirakan kepekatan menggunakan model kotak dan berikan sebab perbezaan daripada model pembauran. (Andaikan ketinggian percampuran = ketinggian serombong, panjang percampuran = jarak daripada kilang).

[10 marks/markah]

3. Figure Q.3. illustrates a C_6 distillation column used to separate hexane and heptane from a feed stream consisting of 58% (wt) hexane and 42 % (wt) heptane. The column operating pressure is 4 barg and the temperature range is 130-160°C from the top to bottom of the column, respectively. The column bottom and reboiler inventory is 6000 kg (rough 6 min holdup). In additions, there are about 10,000 kg of liquid on the trays. The condenser is assumed to have no liquid holdup and the accumulator drum inventory is 12,000 kg. The material in the bottom of the column is approximately 90 % heptane and 10 % hexane. As a safety engineer in the company, you are asked to conduct the following tasks:

Rajah S.3. menunjukkan sebuah turus penyulingan C_6 digunakan untuk memisah hexana dan heptana. Turus tersebut beroperasi pada tekanan 4 bar tolok dan julat suhu 130-160^{o}C daripada atas ke bawah turus tersebut. Inventori bahagian bawah dan pemanas adalah 6000 kg (anggaran 6 min, tertahan). Tambahan, terdapat lebih kurang 10,000 kg cecair di atas dulang-dulang. Pemeluap diandaikan tiada cecair tertahan dan inventori gelendong penumpuk adalah 12,000 kg. Bahan di bahagian bawah turus tersebut dianggarkan 90% heptana dan 10% hexana. Sebagai seorang jurtera keselamatan di syarikat, anda dikehendaki untuk menjalankan tugas-tugas berikut:

[i] Based on your preliminary hazard assessment, list 2 possible scenarios and 1 possible outcome caused by the release of the hazardous material other than the leakages from the pipeline.

Berdasarkan penilaian awal risiko, senarai 2 senario berkemungkinan dan 1 hasil berkemungkinan disebabkan oleh pembebasan bahan berbahaya selain daripada kebocoran daripada talian.

[3 marks/markah]

[ii] Determine the liquid release through a hole of diameter equal to 20% of a 0.15 m diameter line.

Tentukan pembebasan cecair melalui sebuah lubang dengan garispusat bersamaan 20% daripada talian bergarispusat 0.15 m.

[5 marks/markah]

[iii] Determine the vapor release through a hole of diameter equal to 20 % of a 0.5 m diameter line.

Tentukan pembebasan wap melalui sebuah lubang dengan garispusat bersamaan 20% daripada talian bergarispusat 0.5 m.

[5 marks/markah]

[iv] Estimate the impact of explosion caused by 28,000 kg of hexane only.
Anggarkan kesan letupan disebabkan oleh 28,000 kg hexana sahaja.

[12 marks/markah]

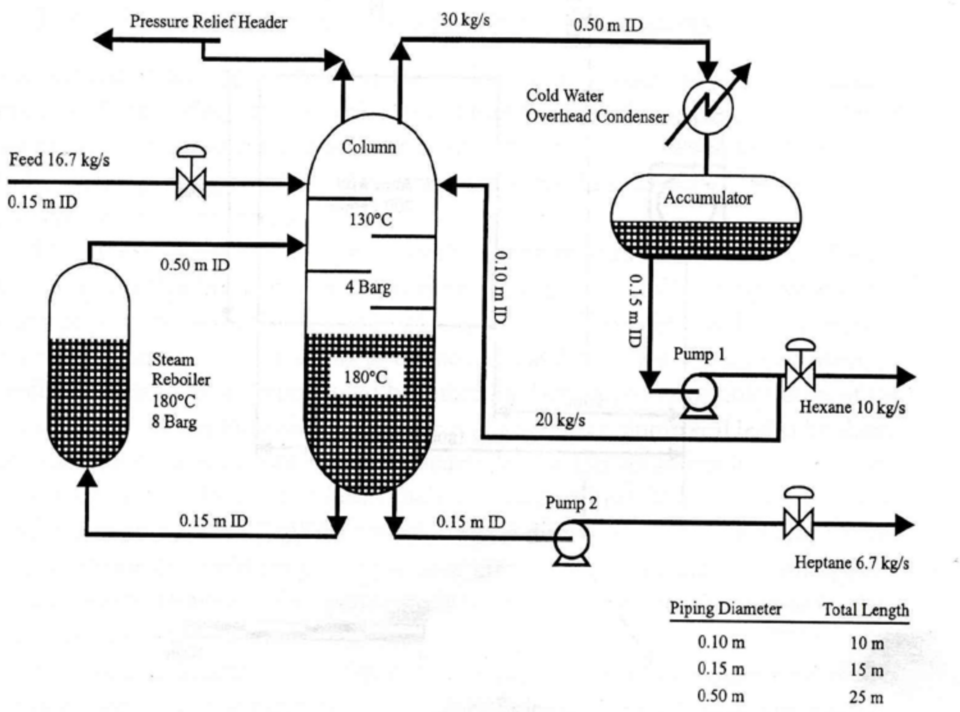

Figure Q.3.
Rajah S.3.

4. [a] Define the following terms:
Tarifkan terma-terma berikut:

[i] Individual risk
Risiko individu

[ii] Societal risk
Risiko awam

[5 marks/markah]

[b] Figure Q.4. shows the plant site layout for the distillation column system as being described in Question Q.3. This is an old plant, and to the East (80 m away), is an onsite office and warehouse complex containing 200 people (present 24 hours a day), distributed uniformly on 1 ha (100 x 100 m) of land. The remaining area around the site consists of open field.

Rajah S.4. menunjukkan bentang kawasan loji bagi sistem turus penyulingan yang dibincangkan dalam Soalan 3. Loji tersebut merupakan sebuah loji yang lama dan terdapat pejabat dan komplek gudang yang mempunyai 200 pekerja (24 jam sehari), diagihkan secara uniform pada tanah keluasan 1 hektar (100 x 100 m). Kawasan selebihnya di sekeliling tapak adalah kawasan lapang.

[i] Sketch the boundary of each outcome based on Table Q.4.[a].
Lakarkan sempadan bagi setiap hasil berdasarkan Jadual S.4.[a].

[3 marks/markah]

[ii] Construct the Event Tree Diagrams based the instantaneous and continuous releases of the hazardous material, respectively.

Bangunkan Gambarajah Pokok Peristiwa berdasarkan pembebasan bahan berbahaya secara masing-masing ketika dan berterusan.

[8 marks/markah]

[iii] Plot the individual and societal risks from the fractioning system based on the data from Tables Q.4.[b] and Q.4.[c].

Plot risiko-risiko individu dan awam bagi sistem pemecahan tersebut berdasarkan Jadual S.4.[b] dan S.4.[c].

[12 marks/markah]

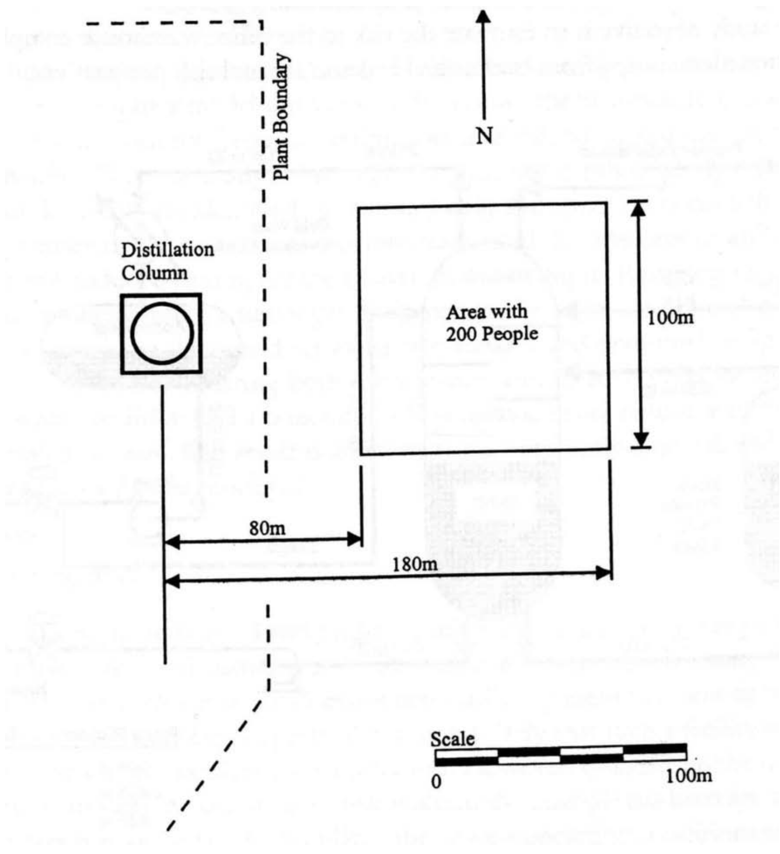

Figure Q.4.
Rajah S.4.

Table Q.4.[a]: Incident Outcomes
Jadual S.4.[a] :

1	BLEVE	Radius 135 m centered on the column
2	VCE	Radius 179 m centered 85 m from the column
3	Flash Fire (Instantaneous)	Radius of 148 m centered 85 m from the column
4	Flash Fire (Continuous)	64 degree of radius 56 m centered on a point 106 m from the column

Table Q.4.[b]:
Jadual S.4.[b].

Total Individual Risk at Discrete Distances in the East Direction[a]

Distance segment (m)	Incident outcome case that no longer impact on the total individual risk	Total individual risk (yr^{-1})
At 0 up to 63	Flash Fire (Cont.) N to S NE to SW E to W SE to NW S to N	7.39×10^{-5}
At 63 up to 75	Flash Fire (Inst.) E to W	7.38×10^{-5}
At 75 up to 94	Flash Fire (Inst.) SE to NW NE to SW	7.36×10^{-5}
At 94 up to 108	UCVE E to W	7.34×10^{-5}
At 108 up to 120	UVCE NE to SW SE to NW	7.32×10^{-5}
At 120 up to 135	Flash Fire (Inst.) N to S S to N	7.29×10^{-5}
At 135 up to 157	Flash Fire (Cont.) SW to NE NW to SE	2.63×10^{-5}
At 157 up to 162	UVCE N to S S to N	2.60×10^{-5}
At 162 up to 194	Flash Fire (Cont.) W to E	4.59×10^{-6}
At 194 up to 228	Flash Fire (Inst.) SW to NE NW to SE	3.06×10^{-6}
At 228 up to 233	UVCE SW to NE NW to SE	1.53 × 10–6
At 233 up to 264	Flash Fire (Inst.) W to E	7.65 × 10–6
>264	UVCE W to E	0

Table Q.4.[c].
Jadual S.4.[c].

Societal Risk Estimation

Number of fatalities	Incident outcome case	Incident outcome case frequency (yr^{-1})	Cumulative frequency of N or more fatalities (yr^{-1})
200	2 VCE SW to NE	1.0×10^{-6}	1.5×10^{-6}
200	2 VCE NW to SE	5.1×10^{-7}	
150	2 VCE W to E	7.7×10^{-7}	1.5×10^{-6}
150	3 Flash Fire W to E	7.7×10^{-7}	
130	2 VCE S to N	1.8×10^{-7}	
130	2 VCE N to S	1.2×10^{-7}	
130	3 Flash Fire SW to NE	1.0×10^{-6}	1.8×10^{-6}
130	3 Flash Fire NW to SE	5.1×10^{-7}	
80	2 VCE NE to SW	1.2×10^{-7}	
80	2 VCE SE to NW	1.2×10^{-7}	
80	2 VCE E to W	1.2×10^{-7}	4.1×10^{-6}
80	1 BLEVE	3.8×10^{-6}	
40	5 Flash Fire W to E	2.1×10^{-5}	
40	3 Flash Fire S to N	1.8×10^{-7}	2.2×10^{-5}
40	3 Flash Fire N to S	1.2×10^{-7}	
5	5 Flash Fire SW to NE	2.9×10^{-5}	4.3×10^{-5}
5	5 Flash Fire NW to SE	1.4×10^{-5}	

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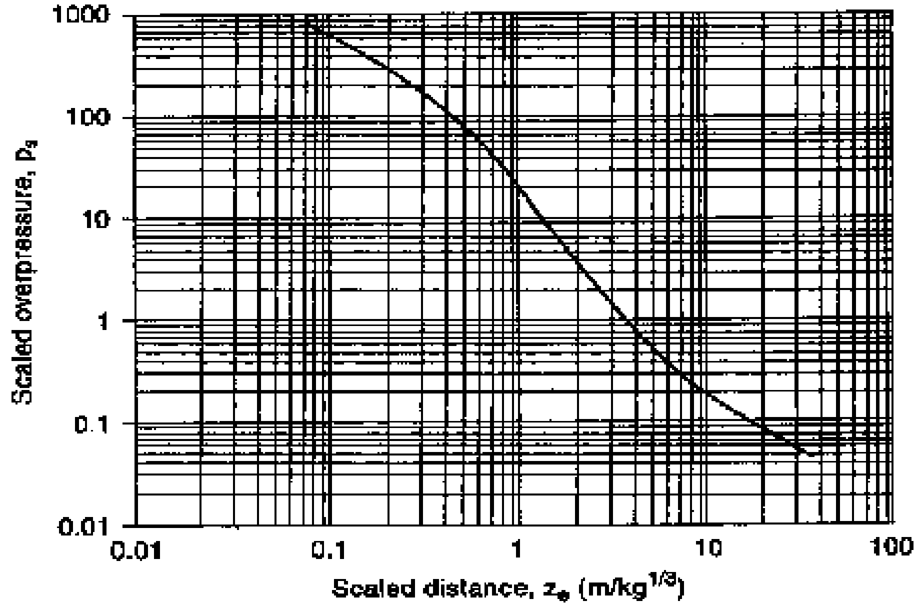
Appendix



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).

Volume Equivalents

in^3	ft^3	US gal	L	m^3
1	5.787×10^{-4}	4.329×10^{-3}	1.639×10^{-2}	1.639×10^{-5}
1728	1	7.481	28.32	2.832×10^{-2}
231	0.1337	1	3.785	3.785×10^{-3}
61.03	3.531×10^{-2}	0.2642	1	1.000×10^{-3}
6.102×10^4	35.31	264.2	1000	1

Ideal Gas Constant R_g

1.9872 cal/g-mol K
1.9872 Btu/lb-mol°R
10.731 psia ft³/lb-mol°R
8.3143 kPa m³/kg-mol K = 8.314 J/g-mol K
82.057 cm³ atm/g-mol K = 8.2057×10^{-5} m³ atm/mol K
0.082057 L atm/g-mol K = 0.082057 m³ atm/kg-mol K
21.9 (in Hg) ft³/lb-mol°R
0.7302 ft³ atm/lb-mol°R
1,545.3 ft lb_f/lb-mol°R

Gravitational Constant, g_c

32.174 ft-lb_m/lb_f-s²
1 (kg m/s²)/N
1 (g cm/s²)/dyne

Miscellaneous

1 Poise = 100 centipoise = 0.1 kg/m s = 0.1 Pa s = 0.1 N s/m²
1 N = 1 kg m/s²
1 J = 1 N m = 1 kg m²/s²
1 centipoise = 1×10^{-3} kg/m s = 2.4191 lb/ft-hr = 6.7197×10^{-4} lb/ft s

Source Model

$$\frac{P_2-P_1}{\rho}+\frac{g}{g_c}\left(z_2-z_1\right)+\frac{1}{2g_c}\left(v_2^2-v_1^2\right)+\sum e_f+\frac{W_s}{\dot{m}}=0$$

$$e_f=K_f\left(\frac{v^2}{2g_c}\right)$$

$$K_f=\frac{K_1}{N_{RE}}+K_\infty\left(1+\frac{1}{ID_{inches}}\right)$$

$$\dot{m}=AC_D\sqrt{2\rho g_c\left(P_1-P_2\right)}$$

$$\dot{m}=\rho vA=\rho AC_D\sqrt{2\left(\frac{g_cP_g}{\rho}+gh_L\right)}$$

$$Q_m=C_oAP_o\sqrt{\left(\frac{2g_cM}{R_gT_o}\frac{\gamma}{\gamma-1}\right)\left[\left(\frac{P}{P_o}\right)^{2/\gamma}-\left(\frac{P}{P_o}\right)^{(\gamma+1)/\gamma}\right]}$$

$$\frac{P_{choked}}{P_o}=\left(\frac{2}{\gamma-1}\right)^{\gamma/(\gamma-1)}$$

$$(Q_m)_{choked}=C_oAP_o\sqrt{\left(\frac{g_cM}{R_gT_o}\right)\left[\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}\right]}$$

Dispersion Models

$$\langle C\rangle_{\max}=\frac{\dot{m}}{\pi\sigma_y\sigma_z u}$$

$$\langle C\rangle_{ppm}=\frac{\dot{m}}{\pi\sigma_y\sigma_z u}\left[\frac{RT}{MP}\times10^6\right]$$

$$\sigma_y=\exp\left[4.23+0.9222\ln\left(\frac{x}{1000}\right)-0.0087\left[\ln\left(\frac{x}{1000}\right)\right]^2\right]$$

$$\sigma_x=\exp\left[3.414+0.7371\ln\left(\frac{x}{1000}\right)-0.0316\left[\ln\left(\frac{x}{1000}\right)\right]^2\right]$$

Equations related to Fire Modeling

Pool Fires:

$$\dot{y}_{\max}=1.27\times10^{-6}\frac{\Delta H_c}{\Delta H^*}$$

$$\Delta H^*=\Delta H_v+\int_{T_a}^{T_{BP}}C_p\,dT$$

$$m_B=1\times10^{-3}\frac{\Delta H_c}{\Delta H^*}$$

$$D_{\max}=2\sqrt{\frac{\dot{V}_L}{\pi\dot{y}}}$$

$$\frac{H}{D}=42\left(\frac{m_B}{\rho_a\sqrt{gD}}\right)^{0.61}$$

$$E_{av}=E_me^{-SD}+E_s\left(1-e^{-SD}\right)$$

$$F_P=\frac{1}{4\pi x^2}$$

$$\tau_a=2.02\left(P_WX_S\right)^{-0.09}$$

$$E_r=\tau_aQ_rF_P=\tau_a\eta m_B\Delta H_cAF_P$$

Jet Fires:

$$\frac{L}{d_j}=\frac{5.3}{C_T}\sqrt{\frac{T_f/T_j\left[C_T+\left(1-C_T\right)\frac{M_a}{M_f}\right]}{\alpha_T}}$$

$$E_r=\tau_aQ_rF_p=\tau_a\eta\dot{m}\Delta H_cF_P$$

Equations related to Explosion Modeling

TNT Model

$$W=\frac{\eta ME_c}{E_{TNT}}$$

$$Z_e=\frac{R}{M_{TNT}}$$

$$P_S=\frac{P_o}{P_a}$$

TNO Model

$$\bar{R}=\frac{R}{\left(E/P_o\right)^{1/3}}$$

$$P_s=\Delta\bar{P}_s.P_o$$

$$t_+=\bar{t}_+\left[\frac{\left(E/P_o\right)^{1/3}}{c_o}\right]$$

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

Pressure psig	Pressure 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).