UNIVERSITI SAINS MALAYSIA

Second Semester Examination
Academic Session 2006/2007

April 2007

EKC 367E – Plant Safety
[Keselamatan Loji]

Duration : 3 hours
[Masa : 3 jam]

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

[Sila pastikan bahawa kertas peperiksaan ini mengandungi DUA BELAS muka surat yang bercetak dan SATU muka surat Lampiran sebelum anda memulakan peperiksaan ini.]

Instruction: Answer **FOUR (4)** questions. Answer any **TWO (2)** questions from Section A. Answer any **TWO (2)** questions from Section B.

*[**Arahan:** Jawab **EMPAT** (4) soalan. Jawab mana-mana **DUA** (2) soalan dari Bahagian A. Jawab mana-mana **DUA** (2) soalan dari Bahagian B.]*

[PELAJAR DIBENARKAN MENJAWAB SEMUA SOALAN DALAM BAHASA INGGERIS ATAU BAHASA MALAYSIA ATAU KOMBINASI KEDUA-DUANYA.]

Section A : Answer any TWO questions.
Bahagian A : Jawab mana-mana DUA soalan.

1. [a] Discuss the following:

[i] OSHA incidence rate

[ii] Fatal accident rate

[iii] Fatality rate

[5 marks]

[b] [i] What is meant by an inherently safe plant?

[ii] Discuss various inherent safety techniques which are used in chemical industry

[9 marks]

[c] An industry has 2200 workers. In a particular year this industry had 50 reportable lost-time injuries and illness with a resulting 300 lost workdays. Find OSHA incidence rate based on injuries and lost workdays

[3 marks]

[d] The peak-overpressure expected due to explosion of a tank is approximated by the equation

$$\log [P/6894.8] = 4.2 - 1.8 \log [3.281\ r]$$

where P = overpressure, N/m^2
r = distance, m

The plant employs 700 people in a work area from 5 to 160m from the potential blast site. Estimate the number of fatalities due to lung hemorrhage. Probit correlation:

$Y = -77.1 + 6.91 \ln P$
Y = death from lungs hemorrhage

[8 marks]

1. [a] Bincangkan yang berikut:

[i] Kadar kemalangan OSHA

[ii] Kadar kemalangan maut

[iii] Kadar maut

[5 markah]

[b] [i] Apakah yang dimaksudkan dengan loji selamat terwujud?

[ii] Bincangkan teknik-teknik keselamatan terwujud yang digunakan dalam industri kimia

[9 markah]

[c] Sebuah industri mempunyai 2200 orang pekerja. Bagi suatu tahun tertentu, industri tersebut mempunyai 50 kes kecederaan dan kesakitan masa-hilang yang boleh dilaporkan perkara ini telah menghasilkan kehilangan 300 hari kerja. Kirakan kadar kemalangan OSHA berdasarkan kecederaan dan hari kerja yang hilang.

[3 markah]

[d] Persamaan penghampiran bagi puncak-tekanan lebihan yang dijangka berlaku akibat daripada letupan tangki ialah

$$\log [P/6894.8] = 4.2 - 1.8 \log [3.281\ r]$$

di mana P = *tekanan lebihan,* N/m^2
r = *jarak, m*

Loji tersebut mempunyai 700 orang pekerja dalam kawasan kerja 5 hingga 160 m dari tapak letupan berpotensi. Anggarkan bilangan kes maut akibat dari pendarahan paru-paru. Sekaitan probit:

$Y = -77.1 + 6.91 \ln P$
Y = *kematian dari pendarahan paru-paru*

[8 markah]

2. [a] Discuss various control techniques which are used in chemical industries to protect employee from accidents and occupational health hazards.

[6 marks]

[b] Write down the working principle of ventilation

[3 marks]

[c] Discuss the following:

[i] Local ventilation

[ii] Dilution ventilation

[6 marks]

[d] A drum contains 200 L of benzene. By mistake the lid of the drum is left opened (lid diameter 20 cm) to ambient condition. Determine:

[i] Time required to evaporate 20 lit of benzene from the drum

[ii] Concentration of benzene in ppm near the drum if the local ventilation rate is 60 m^3/min.

Data given:

Temperature = 25°C
Density of benzene = 0.88 g/cm^3
R_g (gas constant) = 82.057 (cm^3 atm)/(g-mol K)
K_{water} (mass transfer coefficent) = 0.83 cm/s
Molecular wt of benzene = 78.0

Saturation vapor pressure relation:

$$\ln P^{sat} = A - B/(C+T)$$

where P^{sat} is the saturation vapor pressure in mm Hg, T is absolute temperature in Kelvin; A,B and C are the constant given below:

A = 15.90
B = 2788.51
C = -52.36

[10 marks]

2. *[a] Bincangkan teknik-teknik kawalan yang digunakan dalam industri kimia bagi melindungi pekerja dari kemalangan dan bahaya kesihatan pekerjaan.*

[6 markah]

[b] Tuliskan prinsip kerja pengalihudaraan

[3 markah]

[c] Bincangkan yang berikut:

[i] Pengalihudaraan tempatan

[ii] Pengalihudaraan pencairan

[6 markah]

[d] *Sebuah tong mengandungi 200 L benzena. Disebabkan kesilapan, penutup tong telah dibiarkan terbuka (garispusat penutup 20 sm) kepada keadaan ambien. Tentukan:*

[i] *Masa yang diperlukan bagi menyejat 20 liter benzena dari tong*

[ii] *Kepekatan benzena (ppm) berhampiran tong jika kadar pengalihudaraan tempatan ialah 60 m^3/min.*

Data yang diberi:

Suhu = 25°C
Ketumpatan benzena = 0.88 g/sm^3
R_g (pemalar gas) = 82.057 (sm^3 atm)/(g-mol K)
K_{air} (pekali pemindahan jisim) = 0.83 sm/s
Berat molekul benzena = 78.0

Hubungan tekanan wap tepu:

$$lnP^{tepu} = A-B/(C+T)$$

di mana P^{tepu} adalah tekanan wap tepu dalam mm Hg, T adalah suhu mutlak dalam Kelvin; A,B dan C adalah pemalar-pemalar yang diberikan di bawah:

A = 15.90
B = 2788.51
C = -52.36

[10 markah]

3. [a] Write down the parameters which affect atmospheric dispersion of toxic materials.

[3 marks]

[b] Discuss on various release mitigation approaches.

[6 marks]

[c] A burning dump in a rural area emits an estimated 3 g/s of oxides of nitrogen. What is the average concentration of oxides of nitrogen from this source directly downwind at a distance of 3 km with a wind speed of 7 m/s? Assume that the dump is a point ground level source.

Useful relation:

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

σ_y (m) = $0.08x\ (1+0.0001x)^{-1/2}$
σ_z (m) = $0.06x\ (1+0.0015x)^{-1/2}$
where x is distance in meter

[7 marks]

...6/-

[d] The TLV-TWA for chlorine gas is 0.5 ppm. Chlorine gas is stored in a tank at pressure 1.5 X 10^6 N/m^2 and at temperature 27°C. Estimate the diameter of a hole in the tank leading to a local chlorine concentration equal to TLV. The local ventilation rate is 85 m^3/min. The ambient pressure is 1.013 X 10^5 N/m^2.

[9 marks]

Data given:

$C_0 = 1.0$
$\gamma_{chlorine} = 1.33$
k (non ideal mixing factor) = 0.125
$R_g = 8.314$(N m)/ (K g-mol)
$g_c = 1$ (kg m)/(s^2 N)
Molecular weight of chlorine = 70.9

Useful relation: $(Q_m)_{choked} = C_0 A P_0 \sqrt{\frac{\gamma g_c M}{R_g T_0}\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}$

$$\frac{P_{choked}}{P_0} = \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)}$$

3. *[a] Senaraikan parameter-parameter yang mempengaruhi serakan atmosfera bahan-bahan toksik.*

[3 markah]

[b] Bincangkan pendekatan pelegaan pelepasan pelbagai.

[6 markah]

[c] Sebuah tapak buangan terbakar di suatu kawasan luar bandar mengeluarkan secara anggaran 3 g/s oksida nitrogen. Apakah kepekatan purata oksida nitrogen dari sumber ini di hiliran terus angin pada jarak 3 km dengan laju angin 7 m/s? Andaikan tapak buangan tersebut adalah sumber titik aras bumi.

Hubungan berguna:

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

$\sigma_y (m) = 0.08x\ (1 + 0.0001x)^{-1/2}$
$\sigma_z (m) = 0.06x\ (1 + 0.0015x)^{-1/2}$
di mana x adalah jarak dalam meter

[7 markah]

[d] TLV-TWA bagi gas klorin ialah 0.5 ppm. Gas klorin disimpan di dalam sebuah tangki pada tekanan 1.5 X 10^6 N/m^2 dan suhu 27°C. Anggarkan garispusat lubang dalam tangki yang menyebabkan kepekatan klorin setempat menyamai TLV. Kadar pengalihudaraan setempat ialah 85 m^3/min. Tekanan ambien ialah 1.013 X 10^5 N/m^2.

[9 markah]

...7/-

Data yang diberi:

$C_0 = 1.0$

$\gamma_{klorin} = 1.33$

k (faktor pencampuran tak unggul) = 0.125

$R_g = 8.314$*(N m)/ (K g-mol)*

$g_c = 1$ *(kg m)/(s^2 N)*

Berat molekul klorin = 70.9

Hubungan berguna: $(Q_m)_{tercekik} = C_0 A P_0 \sqrt{\frac{\gamma g_c M}{R_g T_0}\left(\frac{2}{\gamma+1}\right)^{(\gamma+1)/(\gamma-1)}}$

$$\frac{P_{tercekik}}{P_0} = \left(\frac{2}{\gamma+1}\right)^{\gamma/(\gamma-1)}$$

Section B : Answer any TWO questions.
Bahagian B : Jawab mana-mana DUA soalan.

4. [a] What do you understand by these following terms:

[i] Detonation

[ii] Deflagration

[3 marks]

[b] With a simple sketch, describe an explosion, based on BLEVE phenomenon.

[5 marks]

[c] A huge explosion occurred in one of chemical industries at an industrial park. The explosion gave rise overpressure (P_o) of 20.7 kPa at a distance of 500 m. Investigation has shown that the explosion was caused by the release of 360,190 kg of unidentified hydrocarbon A. Assuming that 4 % of the total energy released contributed to the overpressure,

[i] Estimate the molecular weight of chemical A in the unit of g/mol.

[15 marks]

[ii] Suggest what could be the chemical A based on the calculated molecular weight

[2 marks]

Data:
Energy of explosion of chemical A = 3239.3 kJ/mol
Equivalent energy of TNT = 4692.8 kJ/kg
Ambient pressure at 1 atm = 14.7 psi = 101.3 kPa

4. *[a] Apakah yang anda faham tentang terma-terma berikut:*

[i] Ledakan (Detonation)

[ii] "Deflagration"

[3 markah]

[b] Dengan lakaran ringkas, huraikan letupan berdasarkan fenomena BLEVE.

[5 markah]

[c] Suatu letupan besar berlaku pada sebuah industri kimia di sebuah taman industri. Letupan itu menghasilkan tekanan lebih (P_o) 20.7 kPa pada jarak 500 m. Hasil siasatan menunjukkan bahawa letupan itu disebabkan oleh pembebasan 360,190 kg bahan hidrokarbon A. Dengan menganggap bahawa 4 % daripada jumlah tenaga yang dibebaskan menghasilkan tekanan lebih,

[i] Anggarkan berat molekul bahawa kimia A dalam unit g/mol.

[15 markah]

[ii] Cadangkan bahan kimia A berdasarkan berat molekul tersebut

[2 markah]

Data:
Tenaga letupan bahan kimia A = 3239.3 kJ/mol
Tenaga setara TNT = 4692.8 kJ/kg
Tekanan atmosfera pada 1 atm = 14.7 psi = 101.3 kPa

5. [a] Illustrate the procedure of Hazard and Operability Study (HAZOP) by using an algorithm.

[5 marks]

[b] Figure Q.5 shows plantwide control for a CSTR in which the species A reacts to form B in an exothermic reaction. The reactor effluent is fed to a flash vessel, where heavier product B is concentrated in the liquid stream, and unreacted A is discarded in the vapour stream. Perform HAZOP analysis to the system using the following deviations:

[i] No cooling flow

[ii] More cooling flow

[iii] High temperature in CSTR

[iv] High level in CSTR

[v] No Agitation

[20 marks]

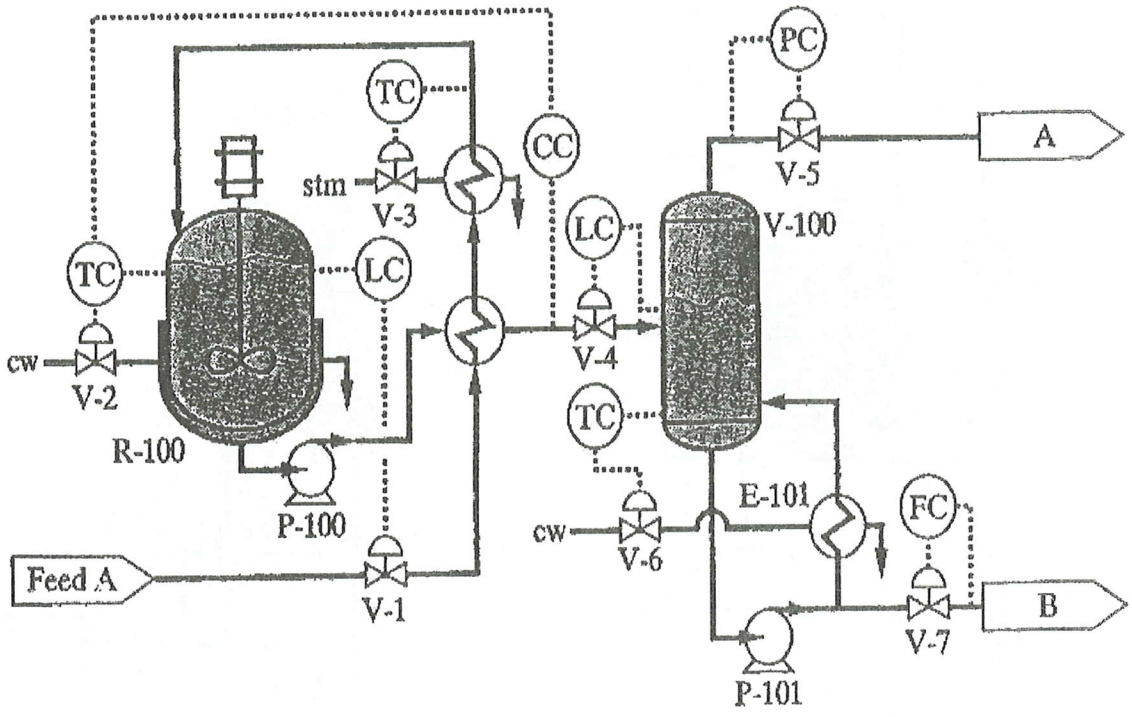

Figure Q.5

5. [a] *Huraikan prosedur Penganalisaan Pengoperasian dan Bahaya (HAZOP) dengan mengguna sebuah algoritma.*

[5 markah]

[b] *Rajah S.5 menunjukkan kawalan lebar loji bagi sebuah CSTR di mana spesis A bertindakbalas untuk menghasilkan B dalam suatu tindakbalas eksotermik. Hasil reaktor disuapkan ke sebuah tangki kilat di mana produk B yang lebih berat dipekatkan di dalam aliran cecair, manakala bahan A yang tidak bertindakbalas dikeluarkan dalam aliran wap. Lakarkan analisa HAZOP kepada sistem tersebut dengan menggunakan sisihan-sisihan:*

[i] Tiada aliran penyejuk

[ii] Lebihan aliran penyejuk

[iii] Suhu tinggi dalam CSTR

[iv] Arus tinggi dalam CSTR

[v] Tiada pengadukan

[20 markah]

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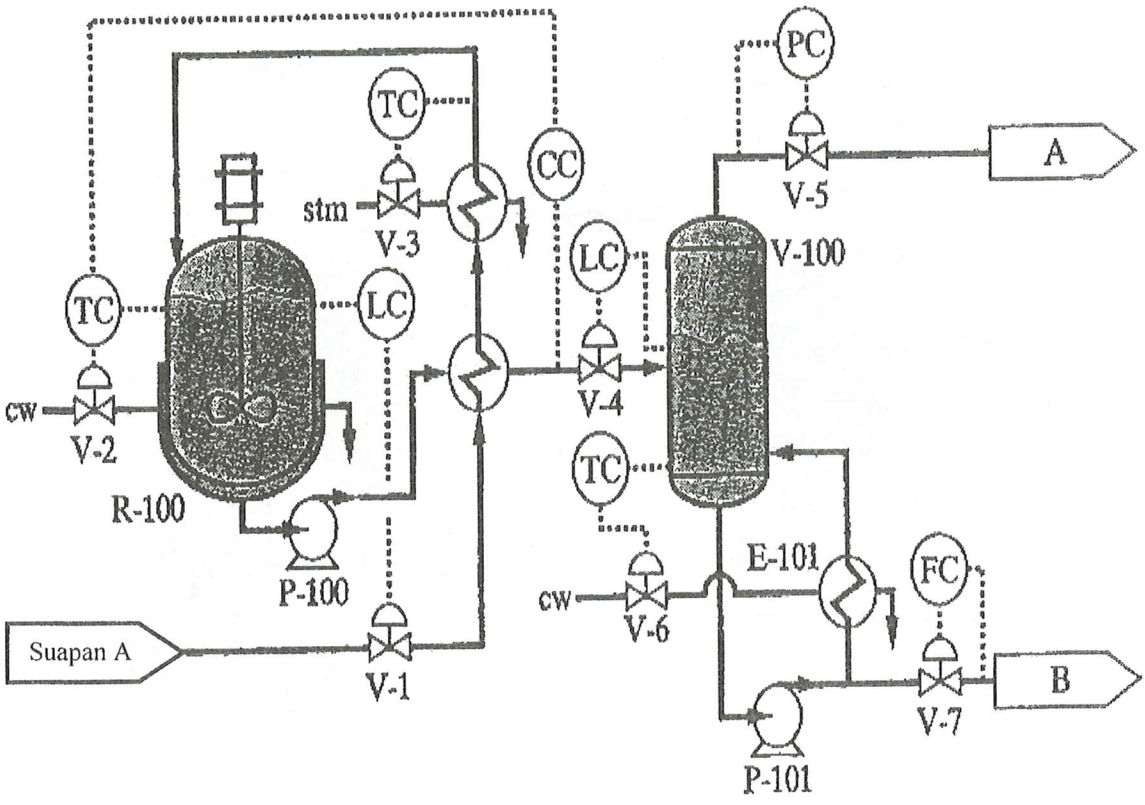


Rajah S.5

6. [a] What is Fault Tree Analysis (FTA)? Give the advantages and disadvantages of FTA

[5 marks]

[b] Figure Q.6 shows a schematic diagram of a gas-fired furnace that is commonly used for a process heating. The hot combustion gases pass through a heat exchanger to heat fresh air for space heating. The gas flow is controlled by an electric solenoid valve connected to a thermostat. The gas is ignited by a pilot light flame. A high temperature switch shuts off all gas in the event of high temperature.

[i] Construct a Fault Tree Diagram for the top event of "Excessive Heating"

[15 marks]

[ii] Suggest ways to prevent combustible gas entering the furnace, heat exchanger and chimney in case if the failure of the pilot light

[5 marks]

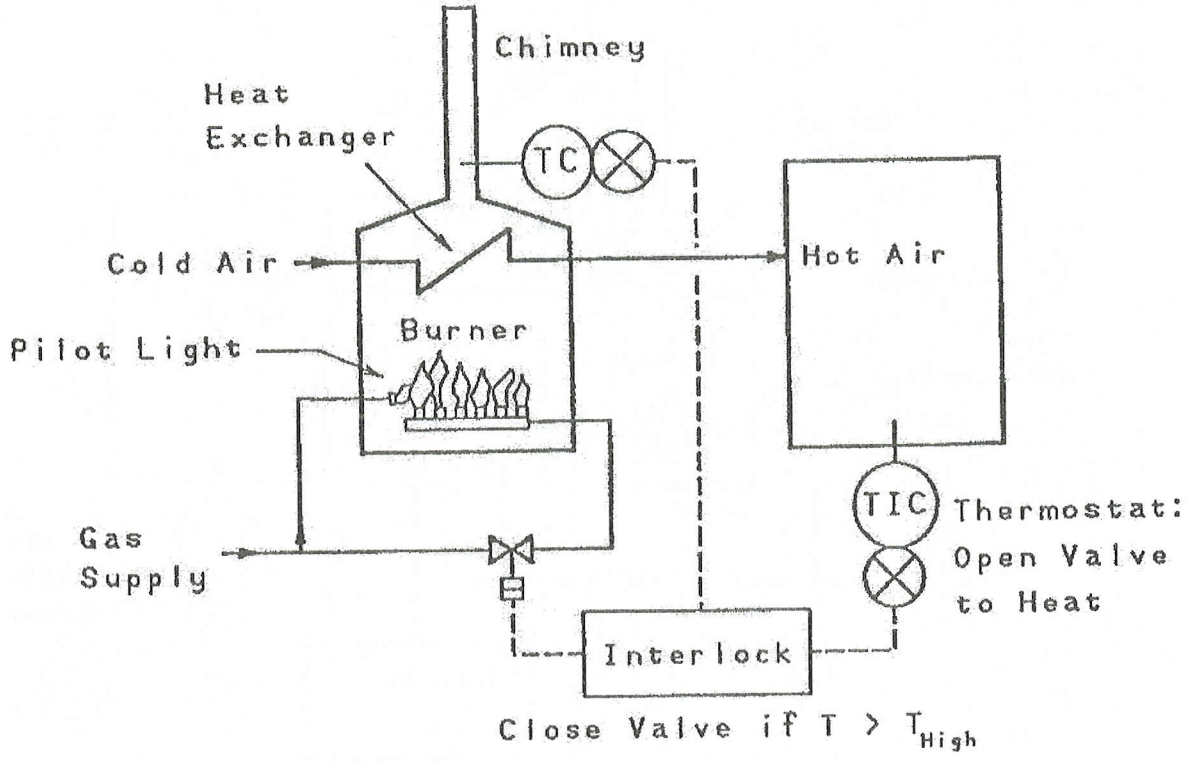


Figure Q.6

6. [a] *Apakah Analisis Pokok Kegagalan (FTA)? Berikan kebaikan dan keburukannya*

[5 markah]

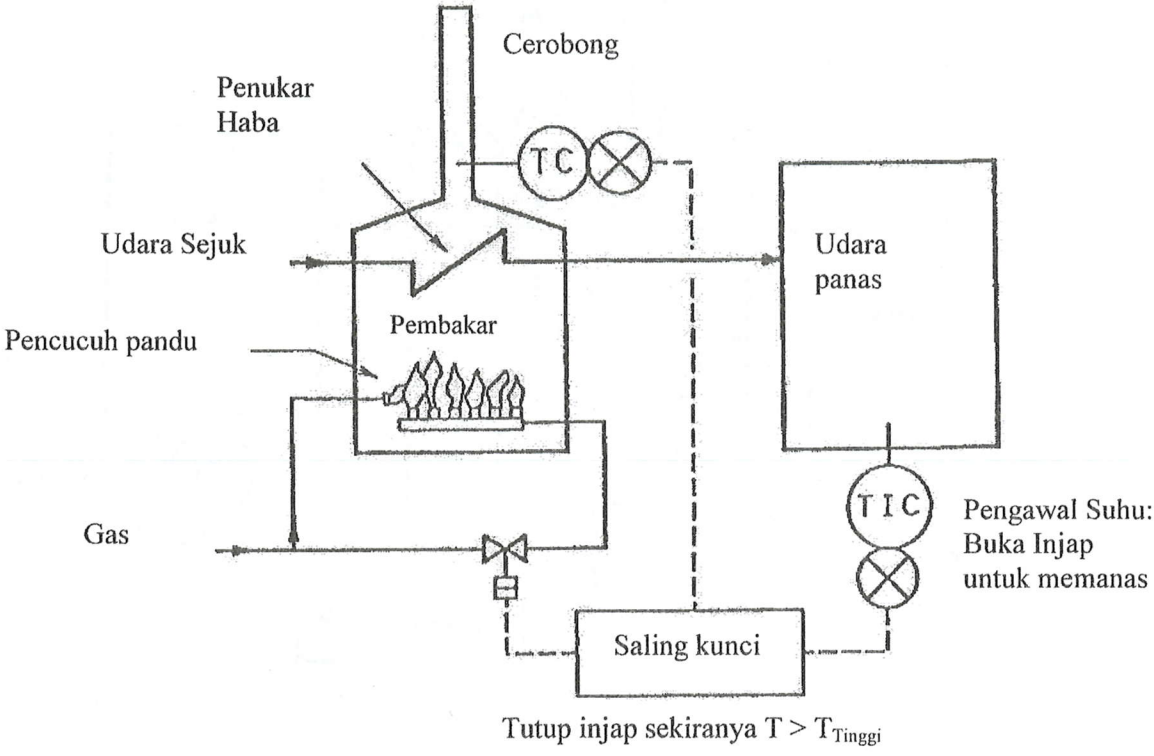
[b] *Rajah S.6 menunjukkan gambarajah skema satu kebuk pembakaran gas yang selalu digunakan bagi proses pemanasan. Gas-gas pembakaran yang panas akan melalui sebuah penukar haba untuk memanaskan udara bagi pemanasan ruang. Aliran gas dikawal oleh sebuah injap solenoid elektrik yang disambungkan kepadanya sebuah pengawal suhu. Gas tersebut dicucuhkan dengan menggunakan sebuah pencucuh pandu. Suis suhu tinggi akan menutupkan aliran gas sekiranya berlaku suhu tinggi.*

[i] *Bangunkan gambarajah Pokok Kegagalan bagi peristiwa atas "Pemanasan Berlebihan"*

[15 markah]

[ii] *Cadangkan dua cara untuk mengelakkan kemasukan gas mudahbakar di dalam kebuk pembakaran, penukar haba dan cerobong sekiranya berlaku kegagalan pencucuh pandu*

[5 markah]



Rajah S.6

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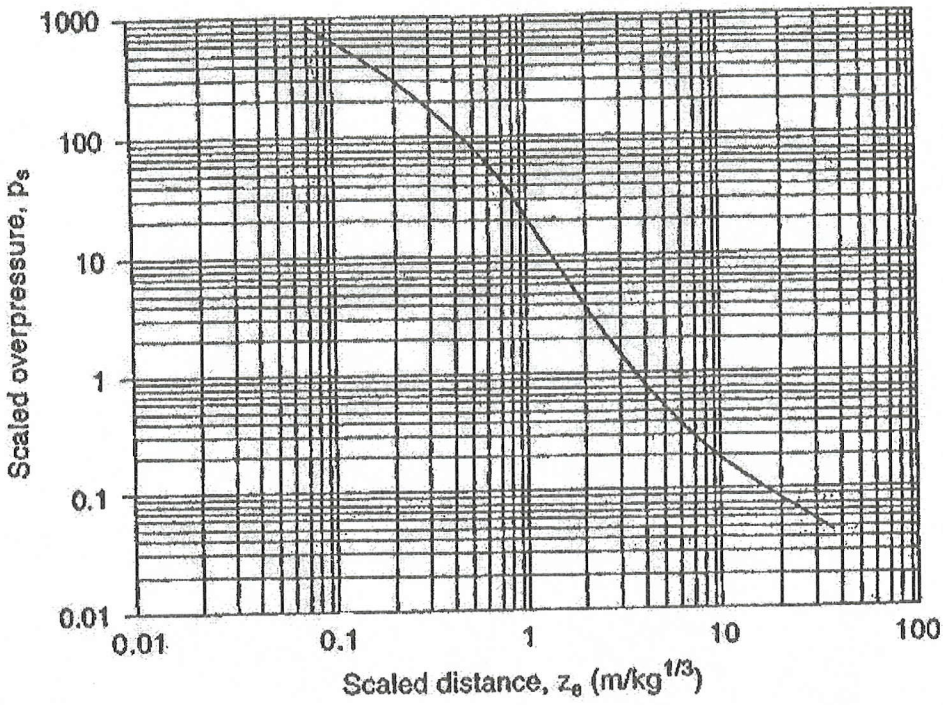

Correlation between scaled distance and explosion peak side-on overpressure for a TNT explosion occurring on a flat surface. Source: G. F. Kinney and K. J. Graham, *Explosive Shocks in Air* (Berlin: Springer-Verlag, 1985).

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