UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2011/2012 Academic Session

June 2012

EKC 367 – Plant Safety
[Keselamatan Loji]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains EIGHT printed pages and TWO printed pages of Appendix before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi LAPAN muka surat yang bercetak dan DUA 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].

…2/-

Answer ALL questions.
Jawab SEMUA soalan.

1. [a] [i] What are the two factors useful as the measures of the effectiveness of safety programs?

Apakah dua faktor yang berguna sebagai ukuran keberkesanan bagi program-program keselamatan?

[ii] Describe the characteristics of an inherently safe plant.
Terangkan ciri-ciri terwujud bagi suatu loji yang selamat.

[5 marks/markah]

[b] [i] What do you understand by OSHA incidence rate?
Apakah yang anda faham dengan kadar insiden OSHA?

[ii] A chemical plant has 1500 full-time employees. In a particular year this plant had 50 reportable lost-time injuries. Compute the OSHA incidence rate based on injuries.

Sebuah loji mempunyai 1500 pekerja sepenuh masa. Pada tahun tertentu loji ini dilaporkan mempunyai 50 kecederaan hilang-masa. Kira kadar insiden OSHA berdasarkan kecederaan.

[4 marks/markah]

[c] Explain how toxicants enter into the system of biological organisms and consequently how the toxicants are eliminated.

Jelaskan bagaimana bahan toksik memasuki sistem biologi organisma dan seterusnya bagaimana bahan toksik itu disingkirkan.

[6 marks/markah]

[d] Eighty five people are tested for skin irritation 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 Table Q.1.[d].:

Lapan puluh lima orang diuji berkaitan kerengsaan kulit disebabkan dos tertentu bagi sejenis bahan. Tindakbalas direkodkan pada skala 0 hingga 10, dengan 0 menunjukkan tiada tindakbalas dan 10 menunjukkan tindakbalas yang tinggi. Jumlah bilangan individu yang mempamerkan tindakbalas tertentu diberikan dalam Jadual S.1.[d].

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

Response *Tindakbalas*	Number of affected individuals *Bilangan individu yang terkesan*
0	0
1	6
2	11
3	14
4	15
5	12
6	10
7	6
8	5
9	4
10	2

[i] Plot the normal distribution curve representing the variation of responses towards the exposure of a specific dose of that substance.

Plotkan lengkung taburan normal yang mewakili variasi tindakbalas terhadap pendedahan dos tertentu bagi bahan itu.

[6 marks/markah]

[ii] If scale 6 and scale 7 indicate skin must be medically treated, how many individuals predicted require medical treatment?

Jika skala 6 dan skala 7 menunjukkan kulit mesti dirawat secara perubatan, berapa ramaikah yang diramal memerlukan rawatan perubatan?

[2 marks/markah]

[iii] The responses obtained from different doses can be systematically used to construct a response-log dose curve. What do you understand by ED and LD?

Maklum balas yang diperolehi daripada dos yang berbeza boleh digunakan secara sistematik untuk membina lengkung maklum balas - log dos. Apakah yang anda faham dengan ED dan LD?

[2 marks/markah]

2. [a] Safety regulations were developed mainly to improve occupational conditions. What do you understand by PSM and RMP? In what sense both regulations differ?

Peraturan-peraturan keselamatan telah diwujudkan terutamanya untuk memperbaiki keadaan pekerjaan. Apakah yang kamu faham dengan PSM dan RMP? Dari segi apakah kedua-dua peraturan itu berbeza?

[2 marks/markah]

[b] An accident can be described by a sequence of three steps. Explain the steps involved in the case of a burning house with any suitable reasoning.

Kemalangan boleh digambarkan melalui suatu urutan tiga tahap. Terangkan tahap-tahap yang terlibat bagi kes sebuah rumah yang terbakar dengan sebab yang bersesuaian.

[3 marks/markah]

[c] Hydrogen sulfide (H_2S) gas is stored at 25 ^oC and maintained at 8.0 atm in a tank within an environment having a local ventilation rate of 55 m^3 min^{-1}. The tank has a hole creating a gas leakage. Estimate the diameter of the hole leading to a local H_2S concentration equal to 10 ppm.

Gas hidrogen sulfida (H_2S) disimpan pada 25 ^oC dan dikekalkan pada 8.0 atm di dalam sebuah tangki dalam persekitaran yang mempunyai kadar pengalihudaraan lokal 55 m^3 min^{-1}. Tangki itu mempunyai lubang yang menyebabkan kebocoran gas. Anggarkan diameter lubang yang membawa kepada kepekatan H_2S lokal bersamaan dengan 10 ppm.

Useful data:
Ambient pressure, P = 1 atm
Non ideal mixing factor, k = 0.125
Discharge coefficient, C_o = 1

Data yang berguna:
Tekanan persekitaran, P = 1 atm
Faktor percampuran tak ideal, k *= 0,125*
Pekali luahan, C_o = 1

[12 marks/markah]

[d] A large amount of propane is released and eventually ignited, producing a vapour cloud explosion. Estimate the quantity of propane (C_3H_8) released if the blast shattered windows 500 meter from the source of the ignition.

Suatu kuantiti besar propana dibebaskan dan seterusnya dinyalakan, menghasilkan satu letupan kepulan gas. Anggarkan kuantiti propana (C_3H_8) yang dibebaskan jika letupan menyebabkan tingkap berjarak 500 meter dari sumber penyalaan berkecai.

Useful data:
Scaled distance, z_e = 33 m $kg^{-1/3}$
Heat of combustion of C_3H_8 (lower value), ΔH_c = 2043.1 kJ mol^{-1}
Energy released from TNT explosion, E_{TNT} = 4686 kJ kg^{-1}
Explosion efficiency, η = 0.05

Data yang berguna:
Jarak terskala, z_e *= 33 m $kg^{-1/3}$*
Haba pembakaran bagi C_3H_8 (nilai yang lebih rendah), ΔH_c = 2043.1 kJ mol^{-1}
Tenaga yang dibebaskan dari letupan TNT, E_{TNT} = 4686 kJ kg^{-1}
Kecekapan letupan, η *= 0.05*

[8 marks/markah]

3. [a] Explain Risk Assessment in terms of the process safety in chemical process industries.
Terangkan Penilaian Risiko dari segi keselamatan proses di industri proses kimia.

[4 marks/markah]

[b] What are the differences between Fault Tree Analysis (FTA) and Event Tree Analysis (ETA)?
Apakah perbezaan antara Analisis Pokok Kesalahan (FTA) dan Analisis Pokok Acara (ETA)?

[6 marks/markah]

[c] The storage tank system shown in Figure Q.3.[c]. is used to store process feedstock. Overfilling of storage tank is a common problem in the process industries. To prevent overfilling, the storage tank is equipped with a high-level alarm and a high-level shutdown system. The high-level shutdown system is connected to a solenoid valve that stops the flow of input stock. By using the data in Table Q.3.[c].:

Sistem tangki penyimpanan yang ditunjukkan dalam Rajah S.3.[c]. digunakan untuk menyimpan bahan mentah proses. Pengisian terlebih dalam tangki simpanan adalah masalah biasa dalam industri proses. Untuk mengelakkan pengisian terlebih, tangki penyimpanan dilengkapi dengan penggera peringkat tinggi dan sistem penutupan peringkat tinggi. Sistem penutupan peringkat tinggi disambungkan kepada sebuah injap solenoid yang menghentikan pengaliran stok masuk. Dengan menggunakan data di Jadual S.3.[c].:

Figure Q.3.[c].
Rajah S.3.[c].

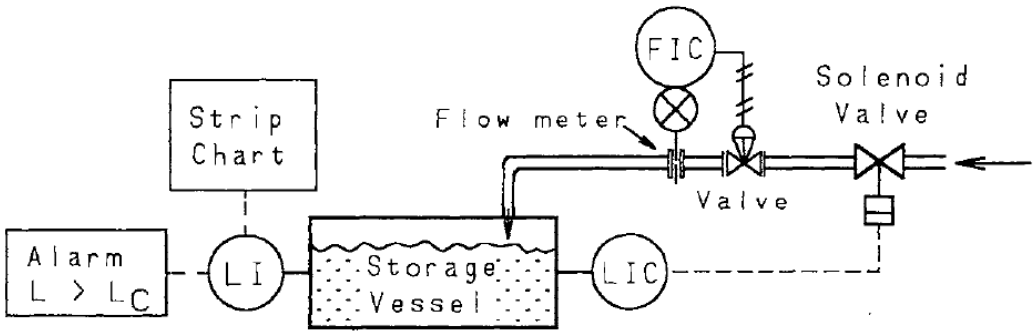

Table Q.3.[c].
Jadual S.3.[c].

System ***Sistem***	**Failures / Demand** ***Kegagalan / Permintaan***
High-level alarm *Penggera peringkat tinggi*	0.01
Operator stops flow *Pengendali menghentikan aliran*	0.1
High-level switch system *Sistem suis peringkat tinggi*	0.01

…6/-

[i] Develop an Event Tree for this system using the "failure of level indicator" as the initiating event.

Membangunkan sebuah Pokok Acara untuk sistem ini dengan menggunakan "kegagalan penunjuk tahap" sebagai acara mula.

[5 marks/markah]

[ii] Given that the level indicator fails 4 times/yr, estimate the number of overflows expected per year.

Diberi bahawa penunjuk tahap gagal 4 kali/tahun, anggarkan bilangan limpahan yang dijangka setiap tahun.

[10 marks/markah]

4. [a] What do you understand by the term HAZOP Analysis?
Apakah yang anda faham dengan istilah Analisis HAZOP?

[3 marks/markah]

[b] Explain the key elements to complete the HAZOP Analysis.
Terangkan elemen-elemen penting untuk melengkapkan Analisis HAZOP.

[7 marks/markah]

[c] A P&ID of the plant is shown in Figure Q.4.[c]. The main plant items include a distillation column (H3), gas fired hot oil furnace (H1), shell and tube heat exchanger (H2), condenser (C1), pumps, controls and pipelines (L). During operation, the contaminated waste kerosene is fed to H3 and the in-flow is controlled by flow control valve VO pre-set at the desired flow rate. The closed hot oil furnace uses a heating fluid which is heated in H1 and circulated through H2 by pump P1. The waste kerosene is boiled in H2. Temperature indicator and controller TIC on H3 controls the piped natural gas feed valve V1 to the burner in H1, to maintain the set temperature in H3. The residues in H3 are maintained at the required level by the pump P3 and valve V12 which is controlled by the level indicator and controller LIC. The kerosene vapours in H3 are condensed in C1, a water-cooled shell and tube heat exchanger. A vent is provided to release any non-condensables. Level in refined product receiver T1 is maintained by LIC and V10. Product pump P2 transfers product to holding tank (not shown) for distribution to customers by tanker. The “Hot oil furnace, Hot oil circulation pump and Pipeline” and “Distillation column” are served as two description nodes. Perform HAZOP analysis on the node by using the following guidewords:

Suatu P&ID loji ditunjukkan dalam Rajah S.4.[c]. Barangan utama kilang termasuk turus penyulingan (H3), minyak relau panas menggunakan gas (H1), kelompang dan tiub penukar haba (H2), pemeluwap (C1), pam-pam, kawalan dan talian paip (L). Semasa operasi, sisa tercemar minyak tanah adalah disuapkan ke dalam H3 dan aliran masuk dikawal oleh injap kawalan aliran VO pra-ditetapkan pada kadar aliran yang dikehendaki. Relau minyak panas tertutup menggunakan bendalir pemanasan yang dipanaskan di dalam H1 dan diedarkan melalui H2 oleh pam P1. Sisa minyak tanah dididihkan dalam H2. Penunjuk suhu dan pengawal TIC pada H3 mengawal injap paip V1 gas suapan asli ke pembakar di H1, untuk mengekalkan suhu yang ditetapkan dalam H3. Sisa di H3 dikekalkan pada paras yang dikehendaki oleh pam P3 dan injap V12 yang dikawal oleh penunjuk tahap dan pengawal LIC.

Wap minyak tanah di H3 dimeluwapkan di C1, kelompang yang disejukkan oleh air dan tiub penukar haba. Satu bolong telah diperuntukkan untuk melepaskan apa-apa yang tidak dapat dimeluwapkan. Tahap dalam penerima produk tapisan T1 dikekalkan oleh pengawal LIC dan V10. Pam produk P2 memindahkan produk ke tangki simpanan (tidak ditunjukkan) untuk diedarkan kepada pelanggan melalui kapal. "Relau minyak panas, Pam peredaran minyak panas dan Talian Paip" dan "Turus penyulingan" adalah dianggap sebagai dua keterangan nod. Laksanakan analisis HAZOP pada nod berkenaan dengan menggunakan kata-tunjuk berikut:

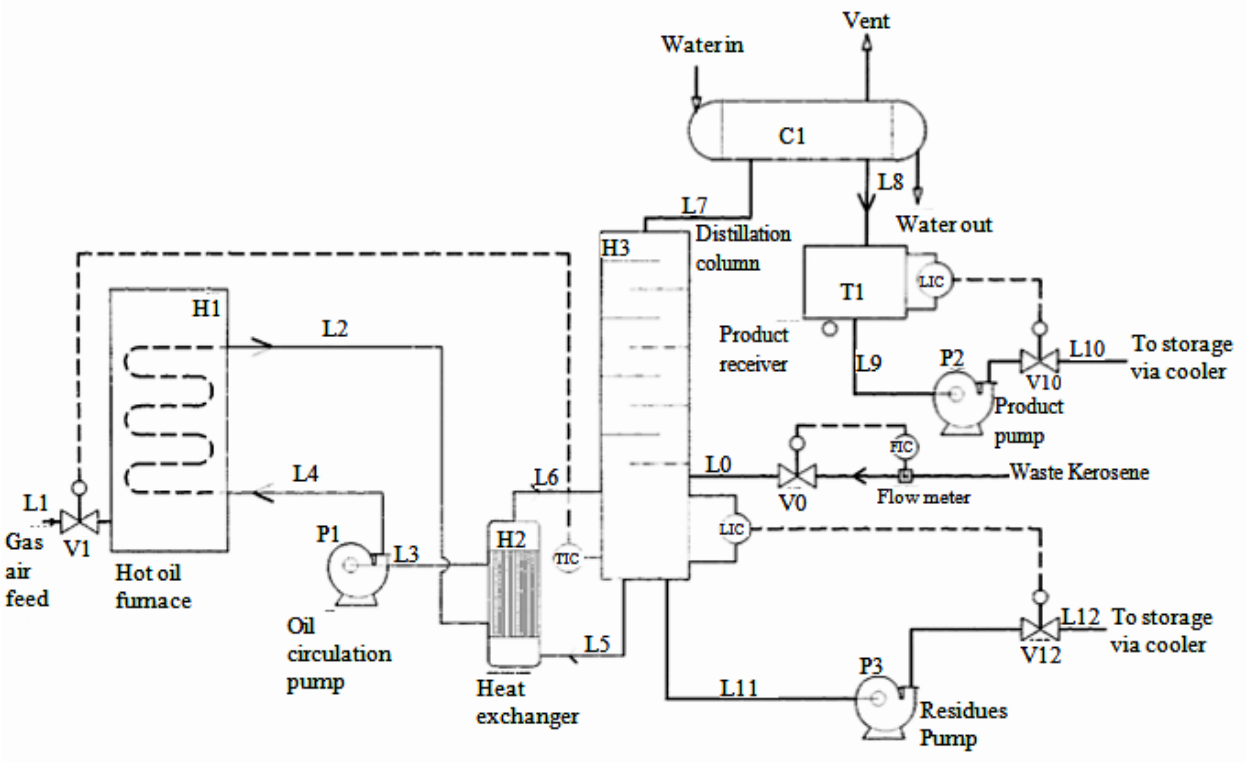

Figure Q.4.[c].
Rajah S.4.[c].

Node description: “Hot oil furnace, hot oil circulation pump and pipelines”
Keterangan nod: "Relau minyak panas, pam peredaran minyak panas dan Pepaip"

[i] High Temperature
Suhu Tinggi

[ii] High Pressure
Tekanan Tinggi

[iii] Low Flow
Aliran Rendah

Node description: “Distillation column”
Keterangan nod: "Turus penyulingan"

[iv] High Pressure
Tekanan Tinggi

[v] High Level
Tahap Tinggi

[15 marks/markah]

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Appendix

Heat Capacity Ratios γ for Selected Gases[1]

Gas	Chemical formula or symbol	Approximate molecular weight (M)	Heat capacity ratio $\gamma = C_p/C_v$
Acetylene	C_2H_2	26.0	1.30
Air	–	29.0	1.40
Ammonia	NH_3	17.0	1.32
Argon	Ar	39.9	1.67
Butane	C_4H_{10}	58.1	1.11
Carbon dioxide	CO_2	44.0	1.30
Carbon monoxide	CO	28.0	1.40
Chlorine	Cl	70.9	1.33
Ethane	C_2H_6	30.0	1.22
Ethylene	C_2H_4	28.0	1.22
Helium	He	4.0	1.66
Hydrogen chloride	HCl	36.5	1.41
Hydrogen	H_2	2.0	1.41
Hydrogen sulfide	H_2S	34.1	1.30
Methane	CH_4	16.0	1.32
Methyl chloride	CH_3Cl	50.5	1.20
Natural gas	–	19.5	1.27
Nitric oxide	NO	30.0	1.40
Nitrogen	N_2	28.0	1.41
Nitrous oxide	N_2O	44.0	1.31
Oxygen	O_2	32.0	1.40
Propane	C_3H_8	44.1	1.15
Propene (propylene)	C_3H_6	42.1	1.14
Sulfur dioxide	SO_2	64.1	1.26

[1]Crane Co., *Flow of Fluids Through Valves, Fittings, and Pipes,* Technical Paper 410 (New York: Crane Co., 1986).

Constants

Universal gas constant, $R = 8.314$ Nm mol^{-1} K^{-1}

Gravitational constant (conversion factor), $g_c = 1.0$ kg ms^{-2} N^{-1}

Unit Conversion

1 atm = 101300 N m^{-2}

…2/-

Formulae

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}$$

$$\mu = \frac{\sum_{i=1}^{n} x_i f(x_i)}{\sum_{i=1}^{n} f(x_i)}$$

$$\sigma^2 = \frac{\sum_{i=1}^{n} (x_i - \mu)^2 f(x_i)}{\sum_{i=1}^{n} f(x_i)}$$

$$C_{\text{ppm}} = \frac{Q_m RT}{kQ_v PM} \times 10^6$$

$$\frac{P_{\text{Choked}}}{P_o} = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}}$$

$$(Q_m)_{\text{Choked}} = C_o A P_o \sqrt{\left(\frac{\gamma g_c M}{RT_o}\right)\left(\frac{2}{\gamma + 1}\right)^{\frac{(\gamma+1)}{(\gamma-1)}}}$$

$$z_e = \frac{r}{m_{TNT}^{\frac{1}{3}}}$$

$$m_{TNT} = \frac{\eta m \Delta H_c}{E_{TNT}}$$