
UNIVERSITI SAINS MALAYSIA

Second Semester Examination
2012/2013 Academic Session

June 2013

EKC 463 – Advanced Process Safety Engineering
[Kejuruteraan Keselamatan Proses Lanjutan]

Duration : 3 hours
[Masa : 3 jam]

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

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEMBILAN 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 digunakan.]

Answer ALL questions.

Jawab SEMUA soalan.

1. [a] What is the difference between commission and omission human errors?
Apakah perbezaan antara ralat manusia penambahan dan peninggalan.
[2 marks/markah]
- [b] What must a management do if they are serious about providing a safe and healthy work environment for employees?
Apakah yang seharusnya dilakukan oleh pihak pengurusan jika mereka serius tentang menyediakan persekitaran kerja yang selamat dan sihat bagi pekerja?
[8 marks/markah]
- [c] Apex Manufacturing Sdn. Bhd. (AMSB) produces polymer resins for commercial use. After ten years of steady, respectable growth in Malaysia market, AMSB suddenly saw its sales triple in less than six months. This rapid growth was the result of AMSB successful entry into Asian market. The growth in sales, although welcome by both management and employees, quickly overloaded and overwhelmed the company's production facility. AMSB responded by adding a second shift of production and approving unlimited overtime for highly skilled personnel. Shortly after the upturn in production, AMSB began experience a disturbing increase in accidents and injuries. Briefly discuss a theory of accident causation that might contribute to the increased in accidents and injuries in AMSB.
Apex Manufacturing Sdn. Bhd. (AMSB) menghasilkan resin polimer untuk kegunaan komersial. Selepas sepuluh tahun perkembangan yang stabil dan dihormati di pasaran Malaysia, AMSB tiba-tiba melihat jualannya meningkat tiga kali ganda dalam masa kurang daripada enam bulan. Pertumbuhan pesat ini adalah hasil daripada penceburan AMSB ke pasaran Asia. Walaupun peningkatan dalam jualan dialu-alukan oleh pihak pengurusan dan pekerja, tetapi kemudahan pengeluaran syarikat dilanda dengan pantas dan mengalami beban lebih. AMSB bertindak dengan menambahkan pengeluaran shif kedua dan membenarkan pekerja yang berkemahiran tinggi bekerja selepas waktu pejabat tanpa had. Sejurus selepas peningkatan dalam pengeluaran, AMSB mula mengalami peningkatan dalam kemalangan dan kecederaan yang merungsingkan. Bincangkan satu teori penyebab kemalangan yang mungkin menyumbang kepada peningkatan dalam kemalangan dan kecederaan dalam AMSB.
[9 marks/markah]
- [d] Valve C as shown in Figure Q.1.[d].(1) is malfunction. A technician facing a problem of replacing valve C caused he has forgotten its initial orientation.
Injap C seperti yang ditunjukkan dalam Rajah S.1.[d].(1) mengalami kerosakan. Seorang juruteknik menghadapi masalah untuk menggantikan injap C kerana beliau telah terlupa tentang orientasi awalnya.

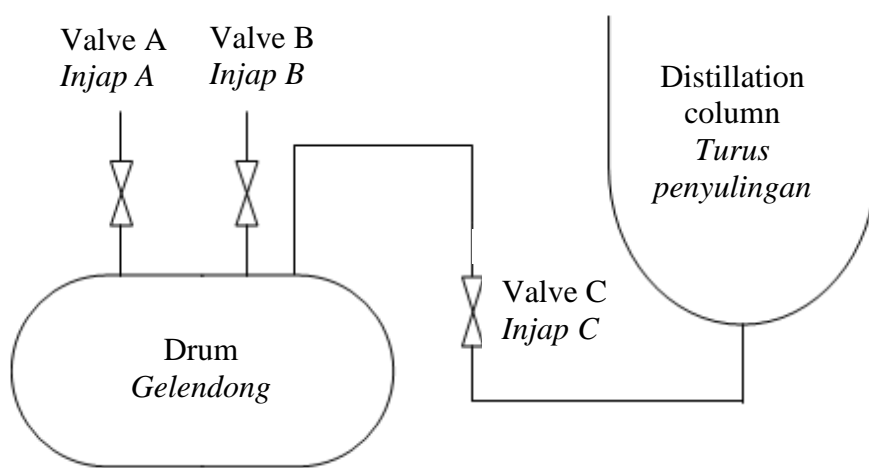


Figure Q.1.[d].(1) A distillation column connected to a drum.
Rajah S.1.[d].(1) Satu turus penyulingan yang disambungkan kepada gelendong.

There are two possible orientations to install the valve C as shown in Figure Q.1.[d].(2).
Terdapat dua orientasi yang mungkin untuk memasang injap C seperti yang ditunjukkan dalam Rajah S.1.[d].(2).

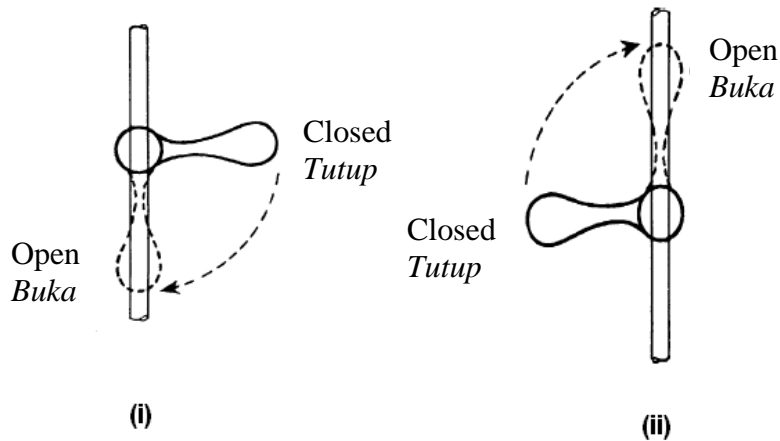


Figure Q.1.[d] (2) Two possible orientations to install valve C.
Rajah S.1.[d] (2) Dua orientasi yang mungkin untuk memasang injap C.

As a process engineer, please advice the technician the most appropriate orientation and give comments to support your answer.

Sebagai seorang jurutera proses, sila nasihati juruteknik tersebut tentang orientasi yang paling sesuai serta memberi komen untuk menyokong jawapan anda.

[6 marks/markah]

2. [a] [i] What is system life cycle?
Apakah sistem kitar hayat? [2 marks/markah]
- [ii] Briefly discuss the phases involve in system life cycle.
Bincangkan secara ringkas fasa yang terlibat dalam sistem kitar hayat. [5 marks/markah]

- [b] [i] What do you understand about equipment failure rates (EFR) and what factors could influence EFR?
Apa yang anda faham tentang kadar kegagalan peralatan (KKP) dan apakah faktor-faktor yang boleh mempengaruhi KKP? [5 marks/markah]

- [ii] A membrane pervaporation separation system for separating of organic-organic mixture is shown in Figure Q.2.[b].[ii]. The system is operated in a temperature controller environment and is free from corrosion and erosion. In general, the permeation cell will face a fouling problem after sometime. The peristaltic and vacuum pumps could have some pulsating flow problems resulted from the wear-and-tear. In addition, the external vibration environmental factor could cause a problem for the control valve and digital temperature controller. Assume that all other accessories are negligible in the failure.

Satu sistem pemisahan pervaporasi membran untuk memisahkan campuran organik-organik adalah ditunjukkan dalam Rajah S.2.[b].[ii]. Sistem tersebut beroperasi dalam persekitaran suhu terkawal dan bebas daripada kakisan dan hakisan. Secara umumnya, sel penelapan akan menghadapi masalah kotoran selepas beberapa ketika. Pam peristaltik dan vakum boleh mengalami masalah aliran denyut akibat daripada haus dan lusuh. Di samping itu, faktor getaran luaran alam sekitar boleh menyebabkan masalah pada injap kawalan dan pengawal suhu digital. Andaikan bahawa kegagalan untuk semua aksesori lain boleh diabaikan.

Given: The generic failure rate data and generic failure rate data adjustment factors as shown in Table Q.2.[b].[ii](1) and Table Q.2.[b].[ii](2), respectively.

Diberi: Data kadar kegagalan generik dan data kadar kegagalan generik faktor larasan masing-masing ditunjukkan dalam Jadual S.2.[b].[ii](1) dan Jadual S.2.[b].[ii](2).

Use Equation Q.2.[b].[ii]., Table Q.2.[b].[ii](1) and Table Q.2.[b].[ii](2) to calculate an adjusted failure rate for that system.

Gunakan Persamaan S.2.[b].[ii]., Jadual S.2.[b].[ii](1) dan Jadual S.2.[b].[ii](2) untuk mengira kadar kegagalan pelarasan bagi sistem tersebut.

$$\lambda_A = \lambda_B \prod_{i=1}^n f_i$$

Equation Q.2.[b].[ii].
Persamaan S.2.[b].[ii].

where λ_A = adjusted equipment failure rate
 λ_B = generic equipment failure rate
 f_i = adjustment factor i ($i = 1$ to 10)
 n = number of adjustment factors that apply

di mana λ_A = kadar kegagalan peralatan larasan
 λ_B = kadar kegagalan peralatan generik
 f_i = faktor pelarasan i ($i = 1$ hingga 10)
 n = bilangan faktor pelarasan yang terlibat

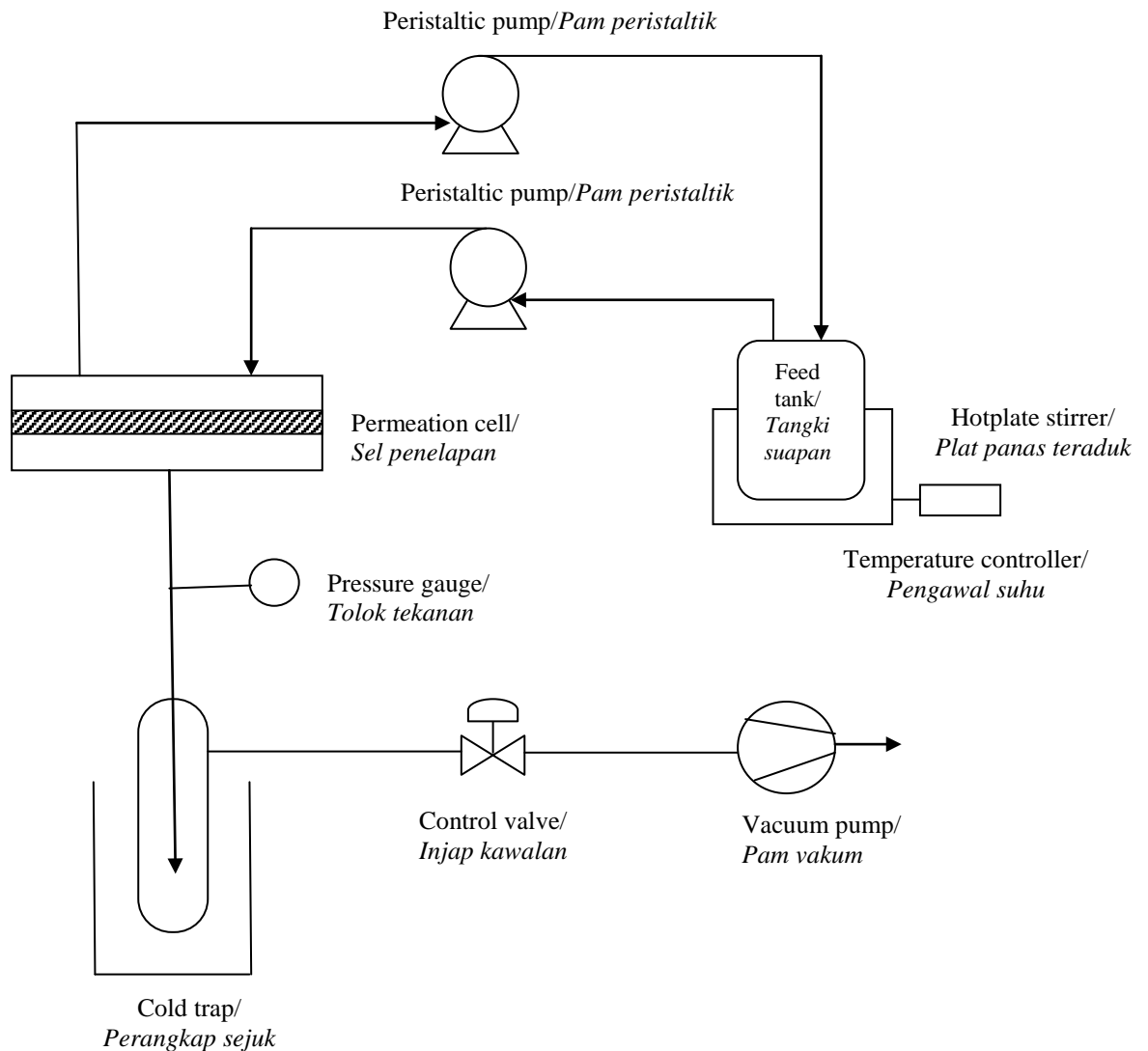


Figure Q.2.[b].[ii]. A membrane pervaporation separation system
Rajah S.2.[b].[ii]. Satu sistem pemisahan pervaporasi membran

Table Q.2.[b].[ii].(1) Generic failure rate data
Jadual S.2.[b].[ii](1) Data kadar kegagalan generik

	Confidence Level (f/yr) Aras Keyakinan (g/th)		
	Lower <i>Bawah</i>	Mean <i>Min</i>	Upper <i>Atas</i>
Peristaltic pump <i>Pam peristaltik</i>	0.001	0.05	0.01
Vacuum pump <i>Pam vakum</i>	0.001	0.002	0.005
Permeation cell <i>Sel penelapan</i>	0.01	0.05	0.1
Control valve <i>Injap kawalan</i>	0.0006	0.001	0.004
Digital temperature controller <i>Pengawal suhu digital</i>	0.0008	0.001	0.006

Table Q.2.[b].[ii].(2): Generic Failure Rate Data Adjustment Factors
Jadual S.2.[b].[ii].(2): Data kadar kegagalan generik faktor-faktor palarasan

Equipment failure rate influences <i>Pengaruh kadar kegagalan peralatan</i>	Adjustment factor [f_i in Equation Q.2.[b].] <i>Faktor palarasan [f_i dalam Persamaan S.2.[b].]</i>	
	Instruments <i>Alatan</i>	Valves <i>Injap</i>
Process medium factors <i>Faktor-faktor bahantara proses</i>		
Corrosion/ <i>Kakistan</i>	1.07	1.14
Erosion/ <i>Hakistan</i>	1.14	1.28
Fouling, plugging/ <i>Kotoran, palam</i>	1.07	1.14
Pulsating flow/ <i>Aliran denyut</i>	1.14	1.07
Temperature extremes/ <i>Suhu keterlaluan</i>	1.07	1.07
External environmental factors <i>Faktor-faktor persekitaran luar</i>		
Vibration/ <i>Getaran</i>	1.42	1.21
Corrosive atmosphere/ <i>Atmosfera mengakis</i>	1.21	1.21
Dirty atmosphere/ <i>Atmosfera kotor</i>	1.07	1.07
High temperature and/or humidity <i>Suhu tinggi dan/atau kelembapan</i>	1.07	1.07
Location factors <i>Faktor-faktor lokasi</i>		
Exposed mechanical damage/ <i>Kegagalan mekanikal terdedah</i>	1.07	1.07
Inaccessible for inspection/ <i>Tidak boleh diakses untuk pemeriksaan</i>	1.07	1.07

[13 marks/markah]

...7/-

3. [a] Outline the framework for the Quantitative Risk Analysis that is usually carried out in Safety Engineering.

Garis kasarkan rangka kerja bagi analisa risiko kuantitatif yang kerap dijalankan dalam Kejuruteraan Keselamatan.

[8 marks/markah]

- [b] A pool fire incident has occurred due to the leakage of an unknown hydrocarbon. The hydrocarbon liquid escaped from a leak at a volumetric rate of $0.5 \text{ m}^3\text{s}^{-1}$. A circular dike with a 20 m diameter contained the leak. The consequence analysis indicated that the radiation intensity of the pool fire was 20.0 kW/m^2 being experienced by a worker who stood 150 m away from the source. Estimate the heat of combustion of the liquid by using your preferred radiation model. State why you prefer the model you choosed.

Suatu insiden kebakaran berkalam telah berlaku disebabkan pembebasan suatu hidrokarbon yang tidak diketahui. Cecair hidrokarbon tersebut terbebas daripada satu kebocoran pada kadar isipadu $0.5 \text{ m}^3\text{s}^{-1}$. Sebuah penakung berdiameter 20 m menakung cecair tersebut. Analisa kesan mendapati intensiti radiasi kebakaran tersebut adalah 20.0 kW/m^2 dirasai oleh seorang pekerja yang berdiri 150 m daripada punca kebakaran. Anggarkan haba pembakaran bagi cecair tersebut dengan menggunakan model radiasi pilihan anda. Nyatakan mengapa anda memilih model tersebut.

Data:

Heat of vaporization of the liquid	400	kJ/kg
Boiling point of the liquid	370	K
Ambient temperature	298	K
Liquid density	750	kg/m ³
Heat capacity of liquid (constant)	3.0	kJ/kg-K

Data:

<i>Haba pengewapan cecair</i>	400	kJ/kg
<i>Takat didih cecair</i>	370	K
<i>Suhu ambien</i>	298	K
<i>Ketumpatan cecair</i>	750	kg/m ³
<i>Kapasiti haba cecair (malar)</i>	3.0	kJ/kg-K

[17 marks/markah]

4. One of the most important unit operation equipment in chemical process industries is a reactor. Failure of any reactor may result in chemical spillage as well as fire and explosion when dealing with hazardous chemicals. Figure Q.4.[a] and Q.4.[b]. illustrate a typical control in a reactor and fault tree diagram, respectively.

Reaktor merupakan salah satu unit operasi yang penting dalam industri pemprosesan kimia. Kegagalan pada sesuatu reaktor boleh mengakibatkan tumpahan bahan kimia termasuklah kebakaran dan letupan apabila melibatkan bahan kimia berbahaya. Rajah S.4.[a]. dan S.4.[b]. masing-masing menunjukkan contoh kawalan pada suatu reaktor dan gambarajah pokok kegagalan.

- [a] Based on the Figure Q.4.[a]. and Q.4.[b]. explain how shutdown system of the reactor operate.

Berdasarkan Rajah S.4.[a]. dan S.4.[b]., terangkan bagaimana sistem penutupan reaktor itu beroperasi.

[7 marks/markah]

- [b] Determine the combination of possible minimal cut set based on the given Fault Tree Diagram.

Tentukan kombinasi set potongan minima berdasarkan Gambarajah Pokok Kegagalan yang diberi.

[8 marks/markah]

- [c] Calculate the probability of the top event based on the both minimal cut set and gate to gate method. Data given in Table Q.4.

Kirakan kebarangkalian bagi peristiwa teratas berdasarkan kedua-dua kaedah set potongan minima dan get ke get. Data diberikan dalam Jadual S.4.

[10 marks/markah]

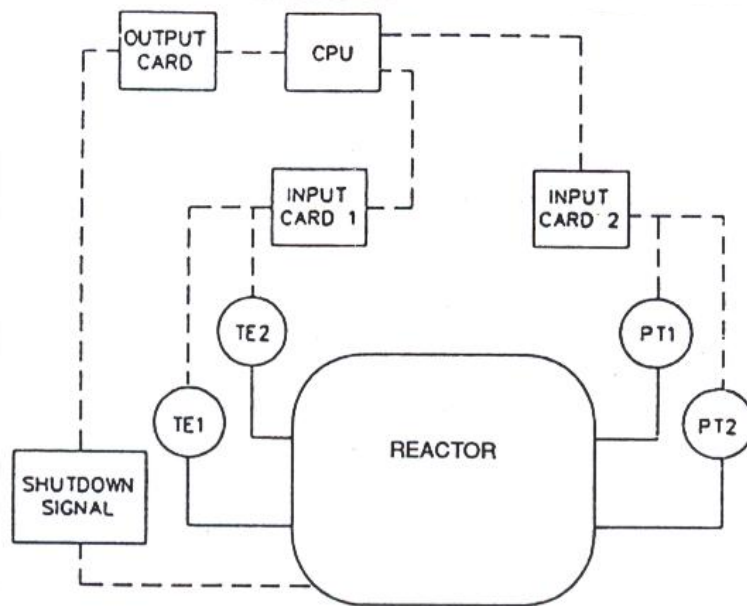


Figure Q.4.[a].
Rajah S.4.[a].

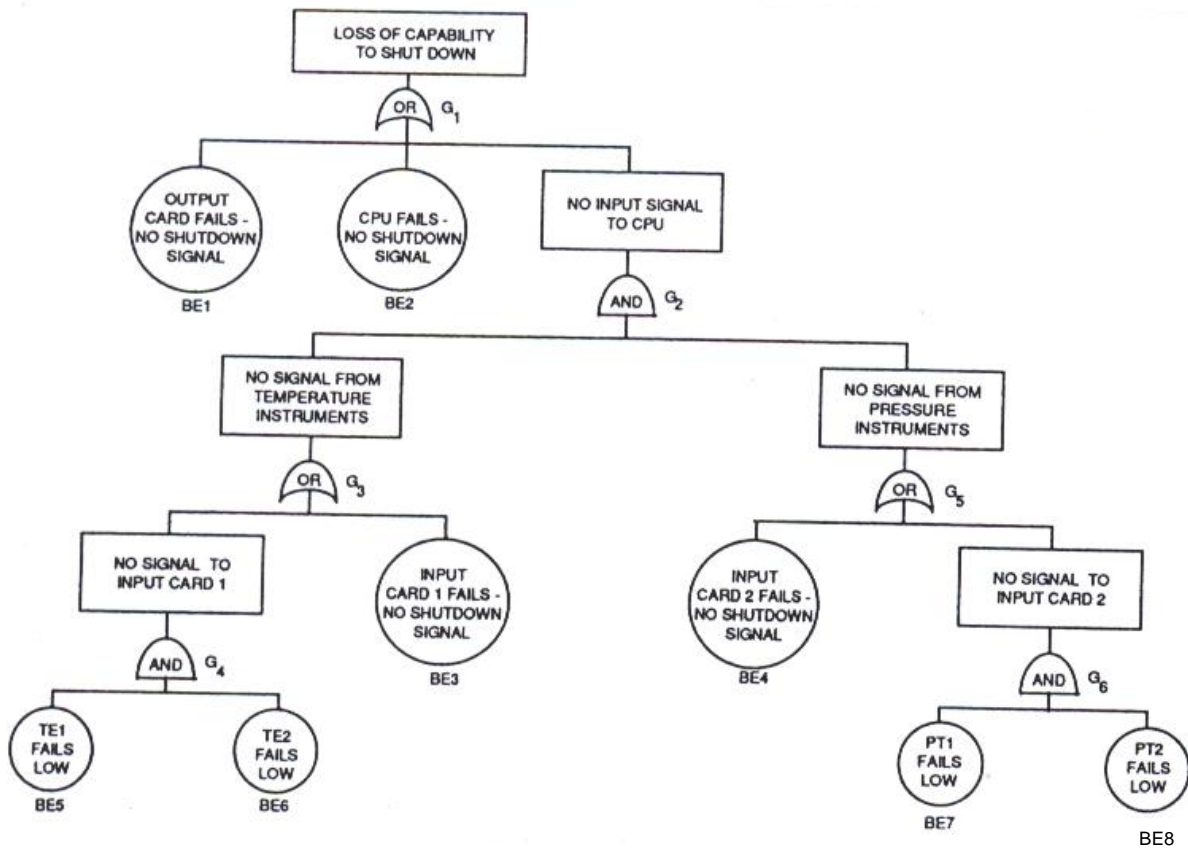


Figure Q.4.[b].
Rajah S.4.[b].

Table Q.4.: Failure Rate For Basic Event
Jadual S.4.: Kadar Kegagalan Bagi Peristiwa Asas

Basic event	Description	Failure rate λ (hr ⁻¹)	Restoration time τ (hr)
BE1	Output card fails—no shutdown signal	1.3×10^{-6}	1
BE2	CPU fails—no shutdown signal	1.0×10^{-4}	1
BE3	Input Card 1 fails—no shutdown signal	1.3×10^{-6}	24
BE4	Input Card 2 fails—no shutdown signal	1.3×10^{-6}	24
BE5	TE-1 fails low	4.6×10^{-7}	16
BE6	TE-2 fails low	4.6×10^{-7}	16
BE7	PT-1 fails low	2.2×10^{-7}	16
BE8	PT-2 fails low	2.2×10^{-7}	16

Appendix

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

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 ⁻³
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^oR
- 10.731 psia ft³/lb-mol^oR
- 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^oR
- 0.7302 ft³ atm/lb-mol^oR
- 1.545.3 ft lb/lb-mol^oR

Gravitational Constant, g_c

- 32.174 ft-lb_w/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	Dispersion Models
$\frac{P_2 - P_1}{\rho} + \frac{g}{g_c}(z_2 - z_1) + \frac{1}{2g_c}(v_2^2 - v_1^2) + \sum e_f + \frac{W_s}{\dot{m}} = 0$ $e_f = K_f \left(\frac{v^2}{2g_c} \right)$ $K_f = \frac{K_1}{N_{RE}} + K_\infty \left(1 + \frac{1}{ID_{inches}} \right)$ $\dot{m} = AC_D \sqrt{2\rho g_c (P_1 - P_2)}$ $\dot{m} = \rho v A = \rho AC_D \sqrt{2 \left(\frac{g_c P_g}{\rho} + gh_L \right)}$ $Q_m = C_o A P_o \sqrt{\left(\frac{2g_c M}{R_g T_o} \frac{\gamma}{\gamma - 1} \right) \left[\left(\frac{P}{P_o} \right)^{2/\gamma} - \left(\frac{P}{P_o} \right)^{(\gamma+1)/\gamma} \right]}$ $\frac{P_{choked}}{P_o} = \left(\frac{2}{\gamma + 1} \right)^{\gamma/(\gamma-1)}$ $(Q_m)_{choked} = C_o A P_o \sqrt{\left(\frac{g_c M}{R_g T_o} \right) \left[\left(\frac{2}{\gamma + 1} \right)^{(\gamma+1)/(\gamma-1)} \right]}$	$\langle C \rangle_{max} = \frac{\dot{m}}{\pi \sigma_y \sigma_z u}$ $\langle C \rangle_{ppm} = \frac{\dot{m}}{\pi \sigma_y \sigma_z u} \left[\frac{RT}{MP} \times 10^6 \right]$ $\sigma_y = \exp \left[4.23 + 0.9222 \ln \left(\frac{x}{1000} \right) - 0.0087 \left[\ln \left(\frac{x}{1000} \right) \right]^2 \right]$ $\sigma_x = \exp \left[3.414 + 0.7371 \ln \left(\frac{x}{1000} \right) - 0.0316 \left[\ln \left(\frac{x}{1000} \right) \right]^2 \right]$
Equations related to Fire Modeling	Equations related to Explosion Modeling
<p>Pool Fires:</p> $\dot{y}_{max} = 1.27 \times 10^{-6} \frac{\Delta H_c}{\Delta H^*}$ $\Delta H^* = \Delta H_v + \int_{T_a}^{T_{BP}} C_p dT$ $m_B = 1 \times 10^{-3} \frac{\Delta H_c}{\Delta H^*}$ $D_{max} = 2 \sqrt{\frac{V_L}{\pi y}}$ $\frac{H}{D} = 42 \left(\frac{m_B}{\rho_a \sqrt{gD}} \right)^{0.61}$ $E_{av} = E_m e^{-SD} + E_s (1 - e^{-SD})$ $F_P = \frac{1}{4\pi x^2}$ $\tau_a = 2.02 (P_w X_s)^{-0.09}$ $E_r = \tau_a Q_r F_P = \tau_a \eta m_B \Delta H_c A F_P$ <p>Jet Fires:</p> $\frac{L}{d_j} = \frac{5.3}{C_T} \sqrt{\frac{T_f / T_j \left[C_T + (1 - C_T) \frac{M_a}{M_f} \right]}{\alpha_T}}$ $E_r = \tau_a Q_r F_P = \tau_a \eta \dot{m} \Delta H_c F_P$	<p>TNT Model</p> $W = \frac{\eta M E_c}{E_{TNT}}$ $Z_e = \frac{R}{M_{TNT}}$ $P_s = \frac{P_o}{P_a}$ <p>TNO Model</p> $\bar{R} = \frac{R}{(E/P_o)^{1/3}}$ $P_s = \Delta \bar{P}_s \cdot P_o$ $t_+ = t_+ \left[\frac{(E/P_o)^{1/3}}{c_o} \right]$