Aviation Fuel Tank - Sample Calculations (3 Runway System)

Fuel Tank Emission = Standing Loss + Working Loss

Table 1: Information from Questionnaires [1]

Tank Type	Number of Tanks	Tank Diameter (m)	Tank Height (m)	Fuel Type	Exit Gas Velocity (m/s)	Max. fuel height (m)	Average fuel height (m)	Annual Net Throughput (m3)	Annual Throughput/Tank (m3)
Notation in AP-42		**2 * R_S**	**H_S**			**H_LX**	**H_L**		**Q**
Type A	6	39	20	Jet A-1	1.86	18.5	16	6257737	1042956.17
Type B	3	27.5	20	Jet A-1	1.86	18.5	16	3128869	1042956.33
Type C	3	34	23	Jet A-1	1.86	19	16	3128869	1042956.33
Type D	9	43.5	24.7	Jet A-1	1.86	23.6	23.6	11308365	1256485.00
Type E	1	41.5	24.7	Jet A-1	1.86	23.7	23.7	1148787	1148787.00
Type F	1	35	24.7	Jet A-1	1.86	22.9	22.9	789791	789791.00
Type G	1	33.5	23	Jet A-1	1.86	21.6	21.6	682092	682092.00

Note:
[1] Information for Tank Types A-C (Lantau) provided by AFSC Operations Limited; information for Tank Types D-G (Tuen Mun) obtained from approved EIA "Permanent Aviation Fuel Facility"

Table 2: Met Data (from PCRAMMET results)

Tank Type	Month	Day	Hour of Day	Hourly Temp (deg C)	Daily Max Temp (Deg C)	Daily Min Temp (Deg C)	Hourly Temp (deg F) [2]	Daily Max Temp (Deg R) [2]	Daily Min Temp (Deg R) [2]
Type A	01	01	24	18.2	19.9	16.6	64.76	527.82	521.88
Type B	01	01	24	18.2	19.9	16.6	64.76	527.82	521.88
Type C	01	01	24	18.2	19.9	16.6	64.76	527.82	521.88
Type D	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82
Type E	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82
Type F	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82
Type G	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82

Note:
[2] Deg F = Deg C * 1.8 + 32; Deg R = Deg C * 1.8 + 492

Table 3: Vapor Space Volume

Tank Type	Roof Outage (m) [3]	Vapour Space Outage (m) [4]	Vapour Space Outage (ft) [5]	Tank Radius (m)	Tank Radius (ft) [5]	Vapor Space Volume (ft^3) [6]
Notation in AP-42	**H_RO**	**H_VO**	**H_VO**	**R_S**	**R_S**	**V_V**
Type A	0.41	4.41	14.46	19.50	63.98	185884.57
Type B	0.29	4.29	14.06	13.75	45.11	89910.20
Type C	0.35	7.35	24.13	17.00	55.77	235795.93
Type D	0.45	1.55	5.10	21.75	71.36	81513.57
Type E	0.43	1.43	4.70	20.75	68.08	68418.36
Type F	0.36	2.16	7.10	17.50	57.41	73545.38
Type G	0.35	1.75	5.74	16.75	54.95	54439.49

Notes:
[3] Roof Outage (H_RO) = 0.0625 * R_S / 3 for cone-shaped roofs (AP-42, Ch. 7.1, Eq. 1-16,17)
[4] Vapour Space Outage (H_VO) = H_S - H_L + H_RO (AP-42, Ch. 7.1, Eq. 1-15)
[5] 1 ft = 0.3048m
[6] Vapor Space Volume (V_V)= (R_S) ^ 2 * H_VO * π (AP-42, Ch. 7.1, Eq. 1-3)

Table 4: Vapor Space Expansion Factor and Vented Vapor Saturation Factor

Tank Type	Tank paint solar absorbance [7]	Total solar insolation (Btu/(ft^2 day)) [8]	Daily Maximum Ambient Temp (deg R)	Daily Minimum Ambient Temp (deg R)	Vapor Space Expansion Factor [9]	True Vapor Pressure (psi) [10]	Vented Vapor Saturation Factor [11]
Notation in AP-42	**alpha**	**I**	**T_AX**	**T_AN**	**K_E**	**P_VA**	**K_S**
Type A	0.17	1181.41	527.82	521.88	0.01782	0.00941	0.99285
Type B	0.17	1181.41	527.82	521.88	0.01782	0.00941	0.99304
Type C	0.17	1181.41	527.82	521.88	0.01782	0.00941	0.98812
Type D	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99780
Type E	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99798
Type F	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99694
Type G	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99753

Notes:
[7] Tanks are assumpted to be painted in white (alpha = 0.17) (AP-42, p.7.1-12)
[8] Based on 5-year average value (2008-2012) at King's Park weather station (http://www.hko.gov.hk/wxinfo/pastwx/ywx2012.htm) (1 MJ/(m^2 day) = 86.9065 BTU/(ft^2 day))
[9] Vapor Space Expansion Factor (K_E) = 0.0018 * [0.72 * (T_AX - T_AN) + 0.028 * alpha * I] (AP-42, Ch. 7-1, Eq. 1-5)
[10] True Vapor Pressure (P_VA) = exp (0.031937 * Hourly Temperature - 6.7347), Hourly Temperature in degrees F (see Figure A and Chart B)
[11] Vented Vapor Saturation Factor (K_S) = 1 / (1 + 0.053 * P_VA * H_VO) (AP-42, Ch. 7.1, Eq. 1-20)

Table 5: Stock Vapor Density and Standing Loss

Tank Type	Molecular Weight (lb/lb-mole) [12]	Ideal Gas Constant (psi ft^3/lb-mole R) [11]	Daily Average Ambient Temp (deg F) [13]	Liquid Bulk Temp (deg R) [14]	Daily Avg. Liquid Surface Temp (deg R) [15]	Stock Vapor Density (lb/ft^3) [16]	Standing Loss per Tank (lb/yr) [17]	Standing Loss per Tank (g/hr) [18]
Notation in AP-42	**M_V**	**R**	**T_AA**	**T_B**	**T_LA**	**W_V**	**L_S**	**L_S**
Type A	130	10.731	524.85	524.87	526.45	0.000216	259.818	13.480
Type B	130	10.731	524.85	524.87	526.45	0.000216	125.695	6.522
Type C	130	10.731	524.85	524.87	526.45	0.000216	328.011	17.018
Type D	130	10.731	521.70	521.72	523.30	0.000189	98.466	5.109
Type E	130	10.731	521.70	521.72	523.30	0.000189	82.662	4.289
Type F	130	10.731	521.70	521.72	523.30	0.000189	88.764	4.605
Type G	130	10.731	521.70	521.72	523.30	0.000189	65.743	3.411

Notes:
[12] Molecular weight (M_V) value from AP-42, Table 7.1-2. R assumed to be 10.731 (AP-42, p. 7.1-16)
[13] Daily Average Ambient Temp (T_AA) = (T_AX + T_AN) / 2 (AP-42, Ch. 7.1, Eq. 1-27)
[14] Liquid Bulk Temp (T_B) = T_AA + 6 * alpha - 1 (AP-42, Ch. 7.1, Eq. 1-28)
[15] Daily Avg. Liquid Surface Temp (T_LA) = 0.44 * T_AA + 0.56 * T_B + 0.0079 * alpha * I (AP-42, Ch. 7.1, Eq. 1-26)
[16] Stock Vapor Density (W_V) = M_V * P_VA / (R * T_LA) (AP-42, Ch. 7.1, Eq. 1-21)
[17] Standing Loss (L_S) = 365 * V_V * K_E * K_S * W_V (AP-42, Ch. 7.1, Eq. 1-2)
[18] Standing Loss (g/hr) = Standing Loss (lb/yr) * 454.5 (g/lb) / 8760 (hr/yr)

Figure A

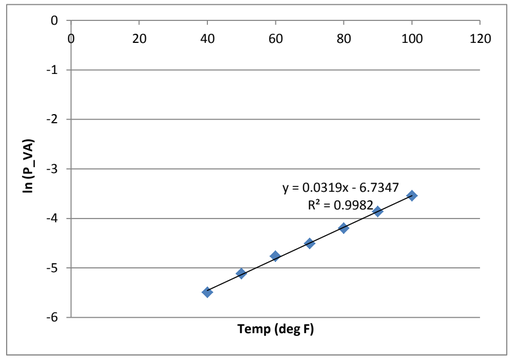
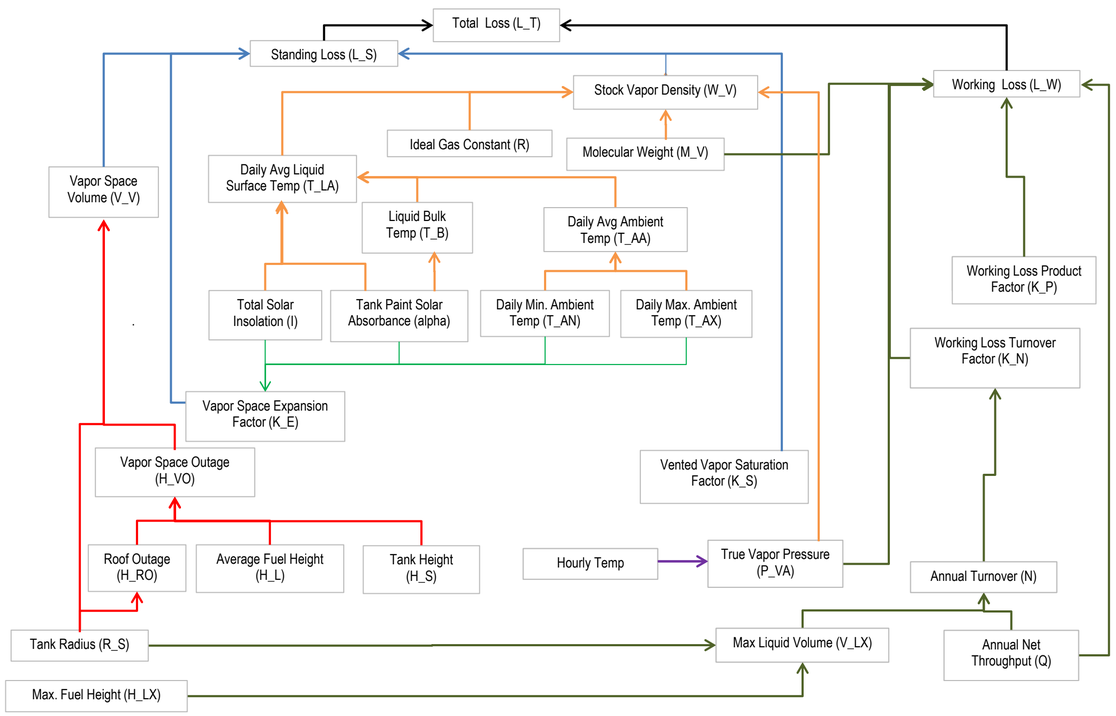


Chart B

Temperature (deg F)	True Vapour Pressure (P_VA)	ln(P_VA)
40	0.0041	-5.4968
50	0.006	-5.1160
60	0.0085	-4.7677
70	0.011	-4.5099
90	0.021	-3.8632
100	0.029	-3.5405

Reference: AP-42, Ch. 7.1, Table 7.1-2

Figure C Relationship between Input (AP-42 Notation in Brackets)



Aviation Fuel Tank - Sample Calculations (3 Runway System)

Table 6: Working Loss

Tank Type	Annual Net Throughput per Tank (bbl) [19]	Maximum Liquid Volume (m^3) [20]	Maximum Liquid Volume (ft^3) [20]	Annual Turnover [21]	Working Loss Turnover Factor [22]	Working Loss Product Factor [23]	Working Loss per Tank(lb/yr) [24]	Working Loss per Tank(g/hr) [25]
Notation in AP-42	**Q**	**V_LX**	**V_LX**	**N**	**K_N**	**K_P**	**L_W**	**L_W**
Type A	6559885.32	22099.93	780451.5291	47.19	0.8024	1	6436.228	333.934
Type B	6559886.37	10988.21	388045.0157	94.90	0.4828	1	3872.272	200.907
Type C	6559886.37	17250.49	609195.1378	60.45	0.6629	1	5317.251	275.878
Type D	7902918.42	35073.60	1238612.647	35.82	1.0000	1	8369.467	434.238
Type E	7225529.91	32057.85	1132112.362	35.83	1.0000	1	7652.089	397.018
Type F	4967551.42	22032.38	778066.2267	35.84	1.0000	1	5260.811	272.950
Type G	4290156.61	19038.52	672339.0847	35.82	1.0000	1	4543.426	235.729

Notes:
[19] 1 bbl = 0.15899m^3 (http://www.lloydminsterheavyoil.com/whatisscience.htm)
[20] Maximum Liquid Volume (V_LX) = R_S ^ 2 * H_LX * π (AP-42, Ch. 7.1, Eq. 1-31)
[21] Annual Turnover (N) = 5.614 * Q / V_LX (AP-42, Ch. 7.1, Eq. 1-30)
[22] If N ≦ 36, K_N = 1; otherwise K_N = (180 + N) / (6 * N) (AP-42, Ch. 7.1, Eq. 1-29)
[23] Working Loss Product Factor (K_P) is 1 for all organic fluids other than crude oil (AP-42, Ch. 7.1, Eq. 1-29)
[24] Working Loss (L_W) = 0.001 * M_V * P_VA * Q * K_N * K_P (AP-42, Ch. 7.1, Eq. 1-29)
[25] Working Loss (g/hr) = Standing Loss (lb/yr) * 454.5 (g/lb) / 8760 (hr/yr)

Table 7: Total Loss

Tank Type	Standing Loss per Tank (g/hr)	Working Loss per Tank (g/hr)	Total Loss per Tank (g/hr) [26, 27]
Notation in AP-42	**L_S**	**L_W**	**L_T**
Type A	13.48	333.93	347.41
Type B	6.52	200.91	207.43
Type C	17.02	275.88	292.90
Type D	5.11	434.24	439.35
Type E	4.29	397.02	401.31
Type F	4.61	272.95	277.55
Type G	3.41	235.73	239.14

Note:
[26] Total Loss (L_T) = L_S + L_W (AP-42, Ch. 7.1, Eq. 1-1)
[27] Loss from tank is assumed in the form of VOC, as jet fuel has VOC content of 100% (http://cfpub.epa.gov/si/speciate/ehpa_speciate_browse_details.cfm?ptype=G&pnumber=0100)

Aviation Fuel Tank - Sample Calculations (2 Runway System)

Fuel Tank Emission = Standing Loss + Working Loss

Table 1: Information from Questionnaires [1]

Tank Type	Number of Tanks	Tank Diameter (m)	Tank Height (m)	Fuel Type	Exit Gas Velocity (m/s)	Max. fuel height (m)	Average fuel height (m)	Annual Net Throughput (m3)	Annual Throughput/Tank (m3)
Notation in AP-42		**2 * R_S**	**H_S**			**H_LX**	**H_L**		**Q**
Type A	6	39	20	Jet A-1	1.86	18.5	16	4168363	694727.17
Type B	3	27.5	20	Jet A-1	1.86	18.5	16	2084181	694727.00
Type C	3	34	23	Jet A-1	1.86	19	16	2084181	694727.00
Type D	9	43.5	24.7	Jet A-1	1.86	23.6	23.6	11308365	1256485.00
Type E	1	41.5	24.7	Jet A-1	1.86	23.7	23.7	1148787	1148787.00
Type F	1	35	24.7	Jet A-1	1.86	22.9	22.9	789791	789791.00
Type G	1	33.5	23	Jet A-1	1.86	21.6	21.6	682092	682092.00

Note:
[1] Information for Tank Types A-C (Lantau) provided by AFSC Operations Limited; information for Tank Types D-G (Tuen Mun) obtained from approved EIA "Permanent Aviation Fuel Facility"

Table 2: Met Data (from PCRAMMET results)

Tank Type	Month	Day	Hour of Day	Hourly Temp (deg C)	Daily Max Temp (Deg C)	Daily Min Temp (Deg C)	Hourly Temp (deg F) [2]	Daily Max Temp (Deg R) [2]	Daily Min Temp (Deg R) [2]
Type A	01	01	24	18.2	19.9	16.6	64.76	527.82	521.88
Type B	01	01	24	18.2	19.9	16.6	64.76	527.82	521.88
Type C	01	01	24	18.2	19.9	16.6	64.76	527.82	521.88
Type D	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82
Type E	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82
Type F	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82
Type G	01	01	24	15.7	18.1	14.9	60.26	524.58	518.82

Note:
[2] Deg F = Deg C * 1.8 + 32; Deg R = Deg C * 1.8 + 492

Table 3: Vapor Space Volume

Tank Type	Roof Outage (m) [3]	Vapour Space Outage (m) [4]	Vapour Space Outage (ft) [5]	Tank Radius (m)	Tank Radius (ft) [5]	Vapor Space Volume (ft^3) [6]
Notation in AP-42	**H_RO**	**H_VO**	**H_VO**	**R_S**	**R_S**	**V_V**
Type A	0.41	4.41	14.46	19.50	63.98	185884.57
Type B	0.29	4.29	14.06	13.75	45.11	89910.20
Type C	0.35	7.35	24.13	17.00	55.77	235795.93
Type D	0.45	1.55	5.10	21.75	71.36	81513.57
Type E	0.43	1.43	4.70	20.75	68.08	68418.36
Type F	0.36	2.16	7.10	17.50	57.41	73545.38
Type G	0.35	1.75	5.74	16.75	54.95	54439.49

Notes:
[3] Roof Outage (H_RO) = 0.0625 * R_S / 3 for cone-shaped roofs (AP-42, Ch. 7.1, Eq. 1-16,17)
[4] Vapour Space Outage (H_VO) = H_S - H_L + H_RO (AP-42, Ch. 7.1, Eq. 1-15)
[5] 1 ft = 0.3048m
[6] Vapor Space Volume (V_V)= (R_S) ^ 2 * H_VO * π (AP-42, Ch. 7.1, Eq. 1-3)

Table 4: Vapor Space Expansion Factor and Vented Vapor Saturation Factor

Tank Type	Tank paint solar absorbance [7]	Total solar insolation (Btu/(ft^2 day)) [8]	Daily Maximum Ambient Temp (deg R)	Daily Minimum Ambient Temp (deg R)	Vapor Space Expansion Factor [9]	True Vapor Pressure (psi) [10]	Vented Vapor Saturation Factor [11]
Notation in AP-42	**alpha**	**I**	**T_AX**	**T_AN**	**K_E**	**P_VA**	**K_S**
Type A	0.17	1181.41	527.82	521.88	0.01782	0.00941	0.99285
Type B	0.17	1181.41	527.82	521.88	0.01782	0.00941	0.99304
Type C	0.17	1181.41	527.82	521.88	0.01782	0.00941	0.98812
Type D	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99780
Type E	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99798
Type F	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99694
Type G	0.17	1181.41	524.58	518.82	0.01759	0.00815	0.99753

Notes:
[7] Tanks are assumpted to be painted in white (alpha = 0.17) (AP-42, p.7.1-12)
[8] Based on 5-year average value (2008-2012) at King's Park weather station (http://www.hko.gov.hk/wxinfo/pastwx/ywx2012.htm) (1 MJ/(m^2 day) = 86.9065 BTU/(ft^2 day))
[9] Vapor Space Expansion Factor (K_E) = 0.0018 * [0.72 * (T_AX - T_AN) + 0.028 * alpha * I] (AP-42, Ch. 7-1, Eq. 1-5)
[10] True Vapor Pressure (P_VA) = exp (0.031937 * Hourly Temperature - 6.7347), Hourly Temperature in degrees F (see Figure A and Chart B)
[11] Vented Vapor Saturation Factor (K_S) = 1 / (1 + 0.053 * P_VA * H_VO) (AP-42, Ch. 7.1, Eq. 1-20)

Table 5: Stock Vapor Density and Standing Loss

Tank Type	Molecular Weight (lb/lb-mole) [12]	Ideal Gas Constant (psi ft^3/lb-mole R) [11]	Daily Average Ambient Temp (deg F) [13]	Liquid Bulk Temp (deg R) [14]	Daily Avg. Liquid Surface Temp (deg R) [15]	Stock Vapor Density (lb/ft^3) [16]	Standing Loss per Tank (lb/yr) [17]	Standing Loss per Tank (g/hr) [18]
Notation in AP-42	**M_V**	**R**	**T_AA**	**T_B**	**T_LA**	**W_V**	**L_S**	**L_S**
Type A	130	10.731	524.85	524.87	526.45	0.000216	259.818	13.480
Type B	130	10.731	524.85	524.87	526.45	0.000216	125.695	6.522
Type C	130	10.731	524.85	524.87	526.45	0.000216	328.011	17.018
Type D	130	10.731	521.70	521.72	523.30	0.000189	98.466	5.109
Type E	130	10.731	521.70	521.72	523.30	0.000189	82.662	4.289
Type F	130	10.731	521.70	521.72	523.30	0.000189	88.764	4.605
Type G	130	10.731	521.70	521.72	523.30	0.000189	65.743	3.411

Notes:
[12] Molecular weight (M_V) value from AP-42, Table 7.1-2. R assumed to be 10.731 (AP-42, p. 7.1-16)
[13] Daily Average Ambient Temp (T_AA) = (T_AX + T_AN) / 2 (AP-42, Ch. 7.1, Eq. 1-27)
[14] Liquid Bulk Temp (T_B) = T_AA + 6 * alpha - 1 (AP-42, Ch. 7.1, Eq. 1-28)
[15] Daily Avg. Liquid Surface Temp (T_LA) = 0.44 * T_AA + 0.56 * T_B + 0.0079 * alpha * I (AP-42, Ch. 7.1, Eq. 1-26)
[16] Stock Vapor Density (W_V) = M_V * P_VA / (R * T_LA) (AP-42, Ch. 7.1, Eq. 1-21)
[17] Standing Loss (L_S) = 365 * V_V * K_E * K_S * W_V (AP-42, Ch. 7.1, Eq. 1-2)
[18] Standing Loss (g/hr) = Standing Loss (lb/yr) * 454.5 (g/lb) / 8760 (hr/yr)

Figure A

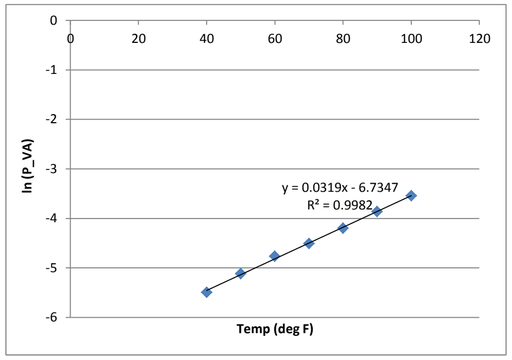
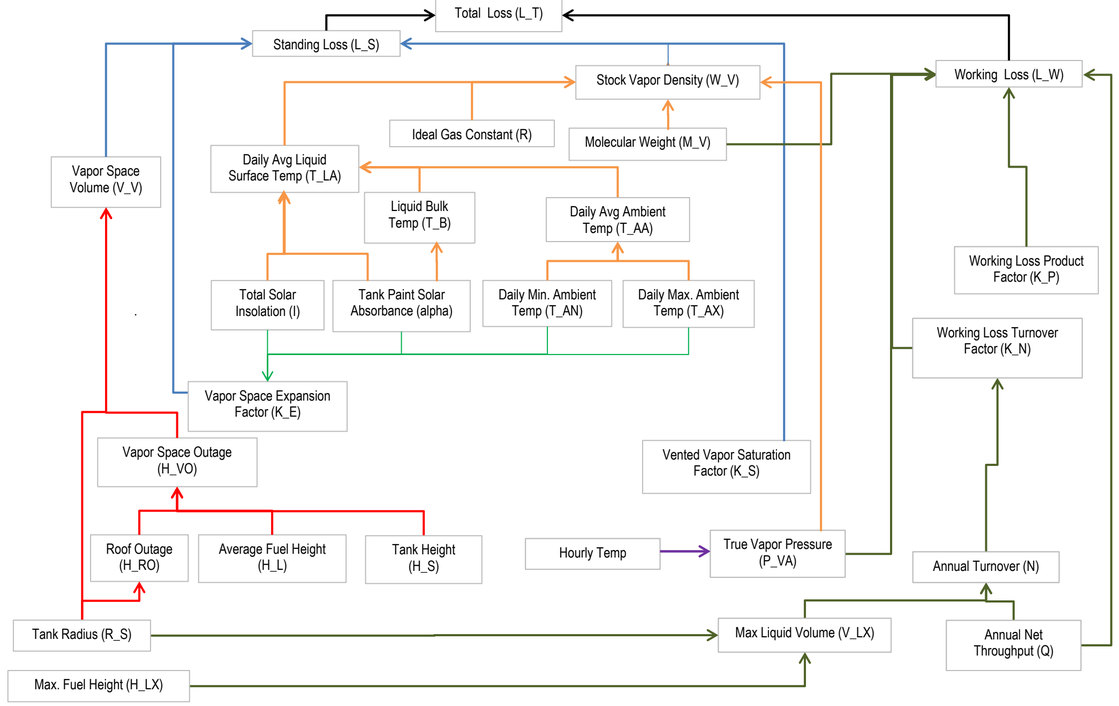


Chart B

Temperature (deg F)	True Vapour Pressure (P_VA)	ln(P_VA)
40	0.0041	-5.4968
50	0.006	-5.1160
60	0.0085	-4.7677
70	0.011	-4.5099
90	0.021	-3.8632
100	0.029	-3.5405

Reference: AP-42, Ch. 7.1, Table 7.1-2

Figure C Relationship between Input (AP-42 Notation in Brackets)



Aviation Fuel Tank - Sample Calculations (2 Runway System)

Table 6: Working Loss

Tank Type	Annual Net Throughput per Tank (bbl) [19]	Maximum Liquid Volume (m^3) [20]	Maximum Liquid Volume (ft^3) [20]	Annual Turnover [21]	Working Loss Turnover Factor [22]	Working Loss Product Factor [23]	Working Loss per Tank(lb/yr) [24]	Working Loss per Tank(g/hr) [25]
Notation in AP-42	**Q**	**V_LX**	**V_LX**	**N**	**K_N**	**K_P**	**L_W**	**L_W**
Type A	4369628.07	22099.93	780451.5291	31.43	1.0000	1	5342.814	277.204
Type B	4369627.02	10988.21	388045.0157	63.22	0.6412	1	3425.927	177.749
Type C	4369627.02	17250.49	609195.1378	40.27	0.9117	1	4870.907	252.720
Type D	7902918.42	35073.60	1238612.647	35.82	1.0000	1	8369.467	434.238
Type E	7225529.91	32057.85	1132112.362	35.83	1.0000	1	7652.089	397.018
Type F	4967551.42	22032.38	778066.2267	35.84	1.0000	1	5260.811	272.950
Type G	4290156.61	19038.52	672339.0847	35.82	1.0000	1	4543.426	235.729

Notes:
[19] 1 bbl = 0.15899m^3 (http://www.lloydminsterheavyoil.com/whatisscience.htm)
[20] Maximum Liquid Volume (V_LX) = R_S ^ 2 * H_LX * π (AP-42, Ch. 7.1, Eq. 1-31)
[21] Annual Turnover (N) = 5.614 * Q / V_LX (AP-42, Ch. 7.1, Eq. 1-30)
[22] If N ≦ 36, K_N = 1; otherwise K_N = (180 + N) / (6 * N) (AP-42, Ch. 7.1, Eq. 1-29)
[23] Working Loss Product Factor (K_P) is 1 for all organic fluids other than crude oil (AP-42, Ch. 7.1, Eq. 1-29)
[24] Working Loss (L_W) = 0.001 * M_V * P_VA * Q * K_N * K_P (AP-42, Ch. 7.1, Eq. 1-29)
[25] Working Loss (g/hr) = Standing Loss (lb/yr) * 454.5 (g/lb) / 8760 (hr/yr)

Table 7: Total Loss

Tank Type	Standing Loss per Tank (g/hr)	Working Loss per Tank (g/hr)	Total Loss per Tank (g/hr) [26, 27]
Notation in AP-42	**L_S**	**L_W**	**L_T**
Type A	13.48	277.20	290.68
Type B	6.52	177.75	184.27
Type C	17.02	252.72	269.74
Type D	5.11	434.24	439.35
Type E	4.29	397.02	401.31
Type F	4.61	272.95	277.55
Type G	3.41	235.73	239.14

Note:
[26] Total Loss (L_T) = L_S + L_W (AP-42, Ch. 7.1, Eq. 1-1)
[27] Loss from tank is assumed in the form of VOC, as jet fuel has VOC content of 100% (http://cfpub.epa.gov/si/speciate/ehpa_speciate_browse_details.cfm?ptype=G&pnumber=0100)