AERODYNAMIC PRINCIPLES FOR PROFESSIONAL PILOTS

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STANDARD ATMOSPHERE VARIABLES

AT ANY ALTITUDE:

Pressure Ratio = "Delta" = $\delta \equiv \frac{P}{P_o}$

Temperature Ratio = "Theta" = $\theta \equiv \frac{T}{T_o}$

Note: T = Absolute Temp. = $^oK = {}^oC + 273^o$

$T_o = 288^oK$

Density Ratio = "Sigma" = $\sigma \equiv \frac{\rho}{\rho_o}$

Speed of Sound = $a = a_o\sqrt{\frac{T}{T_o}} = 661.7\sqrt{\theta}$ knots

$P = \delta P_o = \delta$ (29.92"Hg)

$T = \theta T_o = \theta$ (288^oK)

$\rho = \sigma\rho_o = \sigma$ (0.0023769 slugs/ft^3)

SEA LEVEL CONDITIONS (0'):

Pressure = P_o = 29.92"Hg = 2116 psf =14.7 psi

Temperature = $T_o = 15^oC = 59^oF = 288^oK$

Density = ρ_o = .0023769 slugs/ft^3

Speed of Sound = a_o = 661.7 knots

$\delta = \theta = \sigma = 1.0$

GAS LAWS and RATIO RELATIONSHIPS

AT ANY ALTITUDE: $P = \rho RT$

WHERE P = PRESSURE ρ = DENSITY
T = ABSOLUTE TEMPERATURE
R = CONSTANT FOR A PARTICULAR GAS

AT SEA LEVEL: $P_o = \rho_o R T_o$

$$\frac{P}{P_o} = \text{PRESSURE RATIO} = \frac{\rho \cancel{R} T}{\rho_o \cancel{R} T_o} = \left(\frac{\rho}{\rho_o}\right)\left(\frac{T}{T_o}\right)$$

$$\boxed{\frac{P}{P_o} = \left(\frac{\rho}{\rho_o}\right)\left(\frac{T}{T_o}\right)}$$

PRESSURE RATIO = (DENSITY RATIO)(TEMPERATURE RATIO)

$$\delta = (\sigma)(\theta)$$

NOTE:
IF ANY TWO RATIOS ARE KNOWN, THE THIRD RATIO IS AUTOMATICALLY DETERMINED BY THE ABOVE EQUATION.

THE ICAO STANDARD ATMOSPHERE

ALTITUDE FT.	DENSITY RATIO σ	$\sqrt{\sigma}$	PRESSURE RATIO δ	TEMPER-ATURE °F	TEMPER-ATURE RATIO θ	SPEED OF SOUND a KNOTS
0	1.0000	1.0000	1.0000	59.00	1.0000	661.7
1000	0.9711	0.9854	0.9644	55.43	0.9931	659.5
2000	0.9428	0.9710	0.9298	51.87	0.9862	657.2
3000	0.9151	0.9566	0.8962	48.30	0.9794	654.9
4000	0.8881	0.9424	0.8637	44.74	0.9725	652.6
5000	0.8617	0.9283	0.8320	41.17	0.9656	650.3
6000	0.8359	0.9143	0.8014	37.60	0.9587	647.9
7000	0.8106	0.9004	0.7716	34.04	0.9519	645.6
8000	0.7860	0.8866	0.7428	30.47	0.9450	643.3
9000	0.7620	0.8729	0.7148	26.90	0.9381	640.9
10000	0.7385	0.8593	0.6877	23.34	0.9312	638.6
15000	0.6292	0.7932	0.5643	5.51	0.8969	626.7
20000	0.5328	0.7299	0.4595	-12.32	0.8625	614.6
25000	0.4481	0.6694	0.3711	-30.15	0.8281	602.2
30000	0.3741	0.6117	0.2970	-47.98	0.7937	589.5
35000	0.3099	0.5567	0.2353	-65.82	0.7594	576.6
*36089	0.2971	0.5450	0.2234	-69.70	0.7519	573.8
40000	0.2462	0.4962	0.1851	-69.70	0.7519	573.8
45000	0.1936	0.4400	0.1455	-69.70	0.7519	573.8
50000	0.1522	0.3902	0.1145	-69.70	0.7519	573.8
55000	0.1197	0.3460	0.0900	-69.70	0.7519	573.8
60000	0.0941	0.3068	0.0708	-69.70	0.7519	573.8
65000	0.0740	0.2721	0.0557	-69.70	0.7519	573.8
70000	0.0582	0.2413	0.0438	-69.70	0.7519	573.8
75000	0.0458	0.2140	0.0344	-69.70	0.7519	573.8
80000	0.0360	0.1897	0.0271	-69.70	0.7519	573.8
85000	0.0280	0.1673	0.0213	-64.80	0.7613	577.4
90000	0.0217	0.1472	0.0168	-56.57	0.7772	583.4
95000	0.0169	0.1299	0.0134	-48.34	0.7931	589.3
100000	0.0132	0.1149	0.0107	-40.11	0.8089	595.2

*GEOPOTENTIAL OF THE TROPOPAUSE

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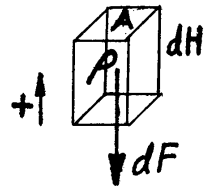
STANDARD ATMOSPHERE CALCULATIONS



$$dV = A\,dH$$
$$dm = \rho\,dV = \rho A\,dH$$
$$dW = g\,dm = -g\rho A\,dH$$
$$dF = dW = -g\rho A\,dH$$
$$\frac{dF}{A} = dP = -g\rho\,dH$$
GAS LAW: $P = \rho RT$, $\rho = \frac{P}{RT}$
$$dP = \frac{-Pg\,dH}{RT}$$

BASIC DIFFERENTIAL EQUATION:

$$\boxed{\frac{dP}{P} = \frac{-g}{RT}\,dH}$$

$$R_{AIR} = 3091.4 \ \frac{FT/SEC^2}{{}^{\circ}K/FT.}$$
$$g = 32.174 \ FT/SEC^2$$

The calculations on this and the following pages are not critical for understanding the standard atmosphere. They are used in the creation of a computer program that will calculate the standard atmospheric variables at any altitude.

IF TEMPERATURE CHANGES WITH ALTITUDE

$$T = T_1 + LR.(H)$$

$$\frac{dP}{P} = \frac{-g}{RT}dH = \frac{-g}{R}\left(\frac{dH}{T_1 + LR.(H)}\right)$$

$$\int_{P_1}^{P_2}\frac{dP}{P} = \frac{-g}{R}\int_{H_1}^{H_2}\frac{dH}{T_1 + LR(H)}$$

$$\ln P_2 - \ln P_1 = \frac{-g}{R(LR)}\left[\ln(T_1 + LR(H_2)) - \ln(T_1 + LR(H_1))\right]$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{-g}{R(LR)}\ln\left(\frac{T_1 + LR(H_2)}{T_1 + LR(H_1)}\right)$$

$$\boxed{\frac{P_2}{P_1} = \left(\frac{T_1 + LR(H_2)}{T_1 + LR(H_1)}\right)^{\frac{-g}{R(LR)}}}$$

IF TEMPERATURE IS CONSTANT WITH ALTITUDE

$$\frac{dP}{P} = \frac{-g}{RT}dH$$

$$\int_{P_1}^{P_2}\frac{dP}{P} = \frac{-g}{RT}\int_{H_1}^{H_2}dH$$

$$\ln P_2 - \ln P_1 = \frac{-g}{RT}(H_2 - H_1)$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{-g}{RT}(H_2 - H_1)$$

$$\boxed{\frac{P_2}{P_1} = e^{\frac{-g}{RT}(H_2 - H_1)}}$$