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COMPRESSIBILITY COEFFICIENT

INTRODUCTION

The ratio of the mean airflow rate through the fan to the airflow rate at fan air density; the ratio of the fan total pressure that would be developed with an incompressible fluid to the fan total pressure that is developed with a compressible fluid, i.e., air, the test gas.
The compressibility coefficient is a thermodynamic factor that must be applied to determine fan total efficiency from fan airflow rate, fan total pressure, and fan input power.

Note: Where the fan total efficiency is less than or equal to (γ-1)/γ, assume $K_P = 1$.

English (IP) Units of Measure:

$$x = \frac{P_t}{P_{t1} + 13.595(p_b)}$$

$$z = \left(\frac{\gamma - 1}{\gamma}\right)\left(\frac{6343.3\left(\frac{H}{Q}\right)}{P_{t1} + 13.595(p_b)}\right)$$

$$K_p = \left(\frac{\ln(1+x)}{x}\right)\left(\frac{z}{\ln(1+z)}\right)$$

Metric (SI) Units of Measure:

$$x = \frac{P_t}{P_{t1} + p_b}$$

$$z = \left(\frac{\gamma - 1}{\gamma}\right)\left(\frac{1000\left(\frac{H}{Q}\right)}{P_{t1} + p_b}\right)$$

$$K_p = \left(\frac{\ln(1+x)}{x}\right)\left(\frac{z}{\ln(1+z)}\right)$$

THE FAN COMPRESSIBILITY RATIO (K_P/K_{PC}) IS CALCULATED AS FOLLOWS:

English (IP) Units of Measure:

$$\frac{z}{z_c} = \frac{13.595p_{bc} + P_{t1c}}{13.595p_b + P_{t1}} \times \frac{\rho}{\rho_c} \times \left(\frac{N}{N_c}\right)^2 \times \left(\frac{D}{D_c}\right)^2 \times \frac{\gamma_c}{\gamma_c - 1} \times \frac{\gamma - 1}{\gamma}$$

$$z_c = \frac{z}{z/z_c}$$

$$\ln(1 + x_c) = \ln(1 + x)\left(\frac{\ln(1 + z_c)}{\ln(1 + z)}\right)\left(\frac{\gamma - 1}{\gamma}\right)\left(\frac{\gamma_c}{\gamma_c - 1}\right)$$

$$x_c = e^{\ln(1+x_c)} - 1$$

$$\frac{K_p}{K_{pc}} = \left(\frac{z}{z_c}\right)\left(\frac{x_c}{x}\right)\left(\frac{\gamma}{\gamma - 1}\right)\left(\frac{\gamma_c - 1}{\gamma_c}\right)$$

Metric (SI) Units of Measure:

$$\frac{z}{z_c} = \left(\frac{p_{bc} + P_{t1c}}{p_b + P_{t1}}\right)\left(\frac{\rho}{\rho_c}\right)\left(\frac{N}{N_c}\right)^2\left(\frac{D}{D_c}\right)^2\left(\frac{\gamma_c}{\gamma_c - 1}\right)\left(\frac{\gamma - 1}{\gamma}\right)$$

$$z_c = \frac{z}{z/z_c}$$

$$\ln(1 + x_c) = \ln(1 + x)\left(\frac{\ln(1 + z_c)}{\ln(1 + z)}\right)\left(\frac{\gamma - 1}{\gamma}\right)\left(\frac{\gamma_c}{\gamma_c - 1}\right)$$

$$x_c = e^{\ln(1+x_c)} - 1$$

$$\frac{K_p}{K_{pc}} = \left(\frac{z}{z_c}\right)\left(\frac{x_c}{x}\right)\left(\frac{\gamma}{\gamma - 1}\right)\left(\frac{\gamma_c - 1}{\gamma_c}\right)$$

CALCULATE CONVERTED (FULL SIZE) FAN PERFORMANCE FROM BASELINE (MODEL) VALUES PER:

$$Q_c = Q \times (D_c/D)^3 \times (N_c/N) \times (K_p/K_{pc})$$

$$P_{tc} = P_t \times (D_c/D)^2 \times (N_c/N)^2 \times (\rho_c/\rho) \times (K_p/K_{pc})$$

$$P_{vc} = P_v \times (D_c/D)^2 \times (N_c/N)^2 \times (\rho_c/\rho)$$

$$P_{sc} = P_{tc} - P_{vc}$$

$$H_c = H \times (D_c/D)^5 \times (N_c/N)^3 \times (\rho_c/\rho) \times (K_p/K_{pc})$$

$$\eta_{sc} = \eta_{tc} \times (P_{sc}/P_{tc})$$

$$\eta_{tc} = \eta_t$$

Where:

D_c = full size impeller diameter

D = model fan impeller diameter

P_{tc} = full size fan total pressure

P_t = model fan total pressure

P_{sc} = full size fan static pressure

P_s = model fan static pressure

P_{vc} = full size fan velocity pressure

P_v = model fan velocity pressure

Q_c = full size fan airflow rate

Q = model fan airflow rate

N_c = full size fan rotational speed

N = model fan rotational speed

ρ_c = full size fan air density

ρ = model fan air density

H_c = full size fan power

H = model fan power

K_{pc} = full size fan compressibility coefficient

K_p = model fan compressibility coefficient

η_{tc} = full size fan total efficiency

η_{sc} = full size fan static efficiency

Units:

Symbol	Description	English (IP) Unit	Metric (SI) Unit
Subscript C	Denotes corrected value	N/A	N/A
D	Diameter	inches	mm
H	Fan power	hp	kW
K_P	Compressibility coefficient	Dimensionless	Dimensionless
N	Rotational speed	rpm	rpm
P_s	Fan static pressure	in. wg	Pa
P_t	Fan total pressure	in. wg	Pa
P_{t1}	Total pressure at inlet plane	in. wg	Pa
P_V	Fan velocity pressure	in. wg	Pa
Q	Fan airflow rate	ft3 /min	m3 /s
γ	Specific heat ratio	Dimensionless	Dimensionless
ρ	Fan air density	lbm/ft3	kg/m3
P_b	Barometric pressure	In. Hg	Pa
η_t	Fan total efficiency	Per unit	Per unit
η_S	Fan static efficiency	Per unit	Per unit