CALCULATING COMPRESSOR EFFICIENCY

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Isentropic Efficiency ($\eta$)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

where

- $T_1$ = Inlet temp (CTIM)
- $T_{2a}$ = Compressor Disch. Temp (CTD)
- $T_{2i}$ = Isentropic CTD (calculated)
Isentropic Efficiency ($\eta$)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

where

$T_1$ = Inlet temp (CTIM)

$T_{2a}$ = Compressor Disch. Temp (CTD)

$T_{2i}$ = Isentropic CTD (calculated)
IMPORTANT NOTE!!!!

You **must** use **absolute** values for the calculations. Use Rankine and Kelvin instead of Fahrenheit and Celsius, and PSIA instead of PSIG.
Calculating $T_{2i}$

$$T_{2i} = T_1 \times \left[ \frac{P_2}{P_1} \right]^{0.28571}$$

where

$T_1$ = Inlet temp (CTIM)

$P_1$ = Compressor Inlet Pressure

$P_2$ = Compressor Disch. Pressure (CPD)
EXAMPLE 1

Given

\[ T_1 = 70 \text{ F} \quad (+ 460) = 530 \text{ R} \]
\[ T_2 = 680 \text{ F} \quad (+ 460) = 1140 \text{ R} \]
\[ P_1 = -0.2 \text{ psig} \quad (+ 14.7) = 14.5 \text{ psia} \]
\[ P_2 = 160 \text{ psig} \quad (+ 14.7) = 174.7 \text{ psia} \]
Calculate $T_{2i}$

$$T_{2i} = T_1 \times \left[ \frac{P_2}{P_1} \right]^{0.28571}$$

$$T_{2i} = 530 \text{ R} \times (174.7 / 14.5)^{0.28571}$$

$$T_{2i} = 1079.2 \text{ R} \ (619.2 \text{ F})$$
Isentropic Efficiency ($\eta$)

$$\eta = \frac{T_{2i} - T_1}{T_{2a} - T_1}$$

$$\eta = \frac{1079.2 - 530}{1140 - 530}$$

$$\eta = \frac{549.2}{610}$$

$$\eta = 0.900 = 90.0\%$$
EXAMPLE 2

Given

\[ T_1 = 70 \text{ F} \quad (+ 460) = 530 \text{ R} \]
\[ T_2 = 687 \text{ F} \quad (+ 460) = 1147 \text{ R} \]
\[ P_1 = -0.2 \text{ psig} \quad (+ 14.7) = 14.5 \text{ psia} \]
\[ P_2 = 160 \text{ psig} \quad (+ 14.7) = 174.7 \text{ psia} \]
Isentropic Efficiency ($\eta$)

\[ \eta = \frac{T_{2i} - T_1}{T_{2a} - T_1} \]

\[ \eta = \frac{(1079.2 - 530)}{(1147 - 530)} \]

\[ \eta = \frac{549.2}{617} \]

\[ \eta = 0.8901 = 89.0\% \]
COMPRESSOR WORK \((w_c)\)

\[ Wc = \text{mass flow} \times c_p \times (T_2 - T_1) \]

Mass flow = 1,000,000 lb/hr

\(c_p = 0.24 \text{ BTU/LB F} \) (specific heat of air)

Divide by 3,412,141 to convert results to MW
COMPRESSOR WORK ($w_c$)

$W_c = \text{mass flow} \times c_p \times (T_{2i} - T_1)$

$Wc_i = 1,000,000 \times 0.24 \times (1079.2 - 530)$

$\frac{3,412,141}{3,412,141}$

$Wc_i = 38.6 \text{ MW}$ @ 100% efficiency
COMPRESSOR WORK ($w_c$)

\[ W_c = \text{mass flow} \times c_p \times (T_{2a} - T_1) \]

\[ W_{c_a} = 1,000,000 \times 0.24 \times (1140 - 530) \]

\[ W_{c_a} = 42.9 \text{ MW} \quad @ \ 90\% \text{ efficiency} \]
COMPRESSION WORK ($w_c$)

\[
W_c = \text{mass flow} \times c_p \times (T_{2a} - T_1)
\]

\[
W_{c_a} = 1,000,000 \times 0.24 \times (1147 - 530)
\]

\[
3,412,141
\]

\[
W_{c_a} = 43.4 \text{ MW} \quad @ \quad 89\% \text{ efficiency}
\]
90% = 42.9 MW
89% = 43.4 MW
1% = 0.5 MW
Case 1 – Clean
T1 = 70 F  \quad T2 = 680 F  \quad (619.2 F \text{ if } 100\%)  \quad CPD = 160 \text{ psig}
Comp \eta = 90\%  \quad \text{Air Flow} = 1,000,000 \text{ #/hr}  \quad \text{comp. work} = 42.9 \text{ MW}

Case 2a – Dirty
T1 = 70 F  \quad T2 = 687 F  \quad (619.2 F \text{ if } 100\%)  \quad CPD = 160 \text{ psig}
Comp \eta = 89\%  \quad \text{Air Flow} = 1,000,000 \text{ #/hr}  \quad \text{comp. work} = 43.4 \text{ MW}
Case 1 – Clean
T1 = 70 F  
T2 = 680 F  (619.2 F if 100%)  
CPD = 160 psig  
Comp η = 90%  
Air Flow = 1,000,000 #/hr  
com. work = 42.9 MW

Case 2a – Dirty
T1 = 70 F  
T2 = 687 F  (619.2 F if 100%)  
CPD = 160 psig  
Comp η = 89%  
Air Flow = 1,000,000 #/hr  
com. work = 43.4 MW

Case 2b – Dirty
T1 = 70 F  
T2 = 687 F  (615.7 F if 100%)  
CPD = 158 psig  
Comp η = 88.4%  
Air Flow = 995,000 #/hr  
com. work = 43.2 MW
From my experience,

A 1% loss in compressor efficiency actually results in a loss of generator output by about 1 MW. Half a MW loss due to the increased work required by the compressor, and another half MW loss due to reduced air flow from aerodynamic degradation.
THE MORAL OF THE STORY

KEEP YOUR COMPRESSOR CLEAN!!
QUESTIONS?