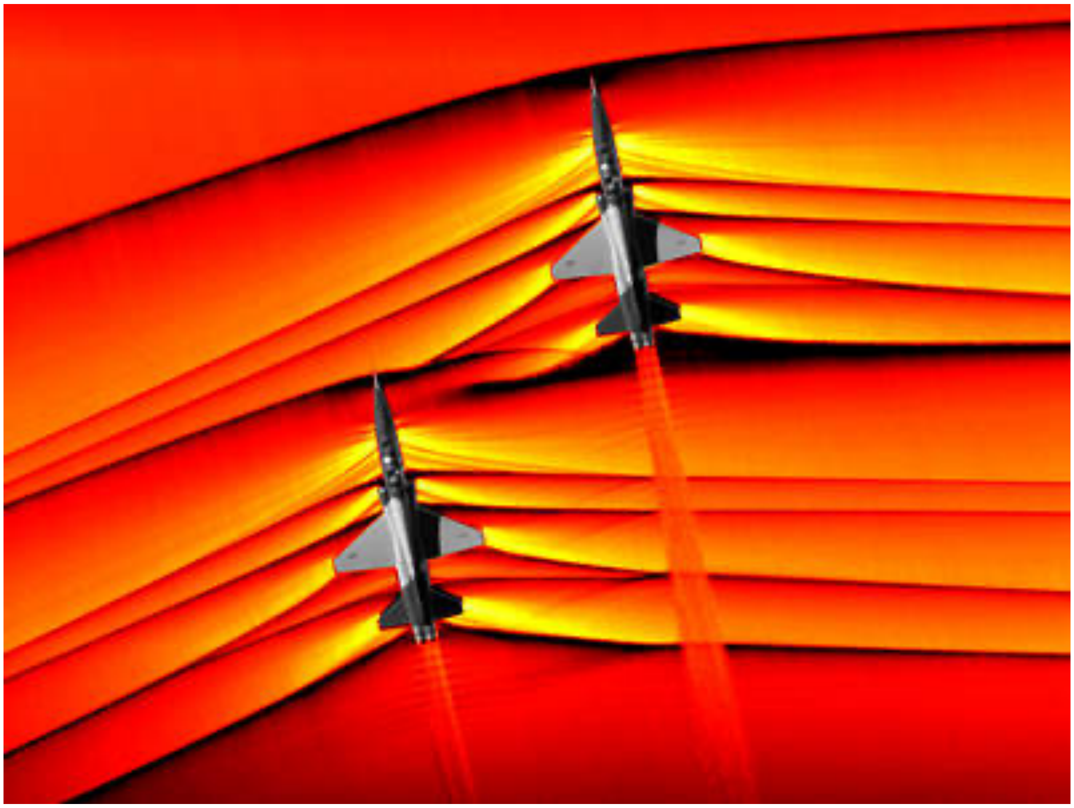

Entropy change for an ideal gas

(Visit https://www.nasa.gov/centers/armstrong/multimedia/imagegallery/Schlieren/index.html for more shock wave photos)

From the *T-ds* relations

$Tds = du + pdv$ and $Tds = dh - vdp$

For an ideal gas

$pv = RT$ => $vdp + pdv = RdT$ and $du = c_v(T)dT$ and $dh = c_p(T)dT$

Temp. [K]	h [kJ/kg]	u [kJ/kg]	s° [kJ/kg/K]	p_r	v_r
200	200.0	142.5	1.309	0.3363	1707.0
210	210.0	149.7	1.352	0.3987	1512.0
220	220.0	156.8	1.395	0.4690	1346.0
230	230.0	164.0	1.437	0.5477	1205.0
240	240.0	171.1	1.479	0.6355	1084.0
250	250.0	178.3	1.520	0.7329	979.0
260	260.0	185.4	1.559	0.8405	887.8
270	270.0	192.6	1.597	0.9590	808.0
280	280.1	199.8	1.633	1.0889	738.0

For the Ideal Gas model

- $pv = RT$ where $R = \bar{R}_u/M$ and $\bar{R}_u$ =8.314 kJ/(kmol.K) and M is the molecular weight. For example, M_{air} = 28.98 kg/kmol => R_{air} = 0.287 kJ/(kg.K)
- $c_p = c_v + R$ and $k \equiv \frac{c_p}{c_v}$
- $c_v = c_v(T)$, $c_p = c_p(T)$, $u = u(T)$, $h = h(T)$, $s = s(T, p)$
- $u(T_2) - u(T_1) = \int_{T_1}^{T_2} c_v(T)dT$ (find $u(T)$ in Ideal Gas Tables (IGTs))
- $h(T_2) - h(T_1) = \int_{T_1}^{T_2} c_p(T)dT$ (find $h(T)$ in IGTs)
- $s(T_2, p_2) - s(T_1, p_1) = s^0(T_2) - s^0(T_1) - Rln\left(\frac{p_2}{p_1}\right)$ (find $s^0(T)$ in IGTs)
    - *If the process is isentropic, i.e., $s_2 = s_1$, then,*
        - $s^0(T_2) - s^0(T_1) = Rln\left(\frac{p_2}{p_1}\right)$ (find $s^0(T)$ in IGTs)
        - $\frac{p_2}{p_1} = \frac{p_r(T_2)}{p_r(T_1)}$ (find $p_r(T)$ in IGTs)
        - $\frac{v_2}{v_1} = \frac{v_r(T_2)}{v_r(T_1)}$ (find $v_r(T)$ in IGTs)

- If the temperature range isn't too large, then it's reasonable to assume c_v, $c_p \approx$ constants (i.e., a perfect gas assumption) and,
    - $u(T_2) - u(T_1) \approx c_v(T_2 - T_1)$,
    - $h(T_2) - h(T_1) \approx c_p(T_2 - T_1)$
    - $s(T_2, v_2) - s(T_1, v_1) \approx c_v ln\left(\frac{T_2}{T_1}\right) + Rln\left(\frac{v_2}{v_1}\right)$
    - $s(T_2, p_2) - s(T_1, p_1) \approx c_p ln\left(\frac{T_2}{T_1}\right) - Rln\left(\frac{p_2}{p_1}\right)$
    - *If the process is isentropic, i.e., $s_2 = s_1$, then,*
        - $\frac{v_2}{v_1} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{1-k}}$ $\quad \frac{p_2}{p_1} = \left(\frac{T_2}{T_1}\right)^{\frac{k}{k-1}}$ $\quad \frac{p_2}{p_1} = \left(\frac{v_2}{v_1}\right)^{-k}$