# Practice problems # 2 (18th Feb 2020)

**3.1** The total pressures and temperatures of the gas in an afterburning turbojet engine are shown (J57 "B" from Pratt & Whitney, 1988). The mass flow rates for the air and fuel are also indicated at two engine settings, the Maximum Power and the Military Power. Use the numbers specified in this engine to calculate

**(a)** the fuel-to-air ratio $f$ in the primary burner and the afterburner, at both power settings

**(b)** the low- and high-pressure spool compressor pressure ratios and the turbine pressure ratio (note that these remain constant with the two power settings)

**(c)** the exhaust velocity $V_9$ for both power settings by assuming the specified thrust is based on the nozzle gross thrust (because of sea level static) and *neglecting any pressure thrust* at the nozzle exit

**(d)** the thermal efficiency of this engine for both power settings (at the sea level static operation), assuming the fuel heating value is 18,600 BTU/lbm and $c_p = 0.24$ BTU/lbm·°R. Explain the lower thermal efficiency of the Maximum power setting

**(e)** the thrust specific fuel consumption in lbm/h/lbf in both power settings

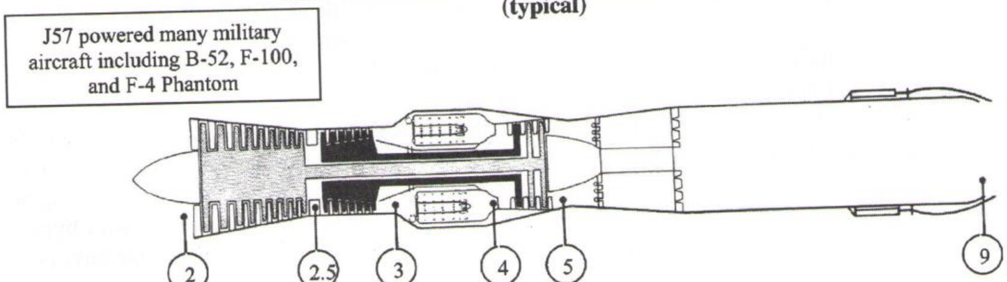
**(f)** the Carnot efficiency of a corresponding engine, i.e., operating at the same temperature limits, in both settings

**(g)** the comparision of percent thrust increase to percent fuel flow rate increase when we turn the afterburner on

**(h)** that why is it that we don't get proportional thrust increase with fuel flow increase (when it is introduced in the afterburner), i.e., doubling the fuel flow in the engine (through afterburner use) does not double the thrust

**3.2** The total pressures and temperatures of the gas are specified for a turbofan engine with separate exhaust streams (JT3D-3B from Pratt & Whitney, 1974). The mass flow rates

**J57 "B" Series afterburning military turbojet sea level static internal pressures and temperatures (typical)**




| Station | 2 | 2.5 | 3 | 4 | 5 | | 9 |
|---|---|---|---|---|---|---|---|
| $P_t$ (psia) | 14.7 | 54.0 | 167.0 | 158.0 | 36.0 | Maximum (A/B) | 31.9 |
| $T_t$ (°F) | 59° | 330° | 660° | 1570° | 1013° | | 2540° |
| $P_t$ (psia) | 14.7 | 54.0 | 167.0 | 158.0 | 36.0 | Military | 33.0 |
| $T_t$ (°F) | 59° | 330° | 660° | 1570° | 1013° | | 1013° |

Notes:

(1) Data for staions 1 through 7 also applies to a J57 "B" series nonafterburining turbojet

(2) Airflow: maximum $w_a = 172$ lb/s
Military $w_a = 164$ lb/s

(3) Fuel flow: maximum $w_f = 33{,}650$ lb/h
Military $w_f = 8{,}520$ lb/h

(4) Thrust: maximum $F_a = 16{,}000$ lb
Military $F_a = 10{,}200$ lb

**3.10** A ramjet is flying at Mach 2.0 at an altitude where $T_0 = -50°\text{C}$ and the engine airflow rate is $10\,\text{kg/s}$. If the exhaust Mach number of the ramjet is equal to the flight Mach number, i.e., $M_9 = M_0$, with perfectly expanded nozzle and $T_{t9} = 2500\,\text{K}$, calculate

**(a)** the engine ram drag $D_{\text{ram}}$ in kN

**(b)** the nozzle gross thrust $F_{\text{g}}$ in kN

**(c)** the engine net thrust $F_{\text{n}}$ in kN

**(d)** the engine propulsive efficiency $\eta_{\text{p}}$

Assume gas properties remain the same throughout the engine, i.e., assume $\gamma = 1.4$ and $c_p = 1004\,\text{J/kg}\cdot\text{K}$. Also, assume that the fuel flow rate is 4% of airflow rate.

**3.11** A turbojet-powered aircraft cruises at $V_0 = 300\,\text{m/s}$ while the engine produces an exhaust speed of $600\,\text{m/s}$. The air mass flow rate is $100\,\text{kg/s}$ and the fuel mass flow rate is $2.5\,\text{kg/s}$. The fuel heating value is $Q_{\text{R}} = 42,000\,\text{kJ/kg}$. Assuming that the nozzle is perfectly expanded, calculate:

**(a)** engine ram drag in kN

**(b)** engine gross thrust in kN

**(c)** engine net thrust in kN

**(d)** engine thrust-specific fuel consumption (TSFC) in mg/s/kN

**(e)** engine thermal efficiency

**(f)** engine propulsive efficiency

**(g)** aircraft range $R$ for $L/D$ of 10 and the $W_{\text{i}}/W_{\text{f}}$ of 1.25

**(h)** if this aircraft make it across the Atlantic Ocean?