Turbofan with Separate Hot and Cold Nozzles: Thrust and SFC

Thrust, SFC, nozzle velocities and areas of a two-spool turbofan from bypass ratio, fan and overall pressure ratio and turbine inlet temperature.

Input parameters

Unit system: SI

Parameter	Value	Unit
Ambient pressure	0.22700	bar
Ambient temperature	-56.500	°C
Flight Mach number	0.83000	
Overall pressure ratio	40.000	
Fan pressure ratio	1.6000	
Bypass ratio (cold/hot flow)	8.0000	
Turbine inlet temperature	1,226.8	°C
Fan and compressor polytropic efficiency	91.000	%
Turbine polytropic efficiency	90.000	%
Intake isentropic efficiency	93.000	%
Propelling nozzle efficiency (each)	97.000	%
Mechanical efficiency (each spool)	99.000	%
Combustion efficiency	99.500	%
Combustion pressure loss	5.0000	%
Total air flow	200.00	kg/s
Air specific heat	1.0050	kJ/(kg·K)
Air ratio of specific heats	1.4000	
Gas specific heat	1.1480	kJ/(kg·K)
Gas ratio of specific heats	1.3333	
Gas constant (air and gas)	0.28700	kJ/(kg·K)
Fuel net calorific value	43,100	kJ/kg
Fuel H/C atom ratio (kerosene about 1.92, methane 4)	1.9200	

Calculated results

Parameter	Value	Unit
Fan delivery temperature	285.68	K
Compressor delivery temperature	784.86	K
Compressor delivery pressure	13.844	bar
Cold (bypass) flow	177.78	kg/s
Hot (core) flow	22.222	kg/s
Cold jet velocity	309.28	m/s
Cold thrust	19.578	kN
Cold nozzle area	1.3720	m^2

Parameter	Value	Unit
HP turbine exit temperature	1,058.6	K
LP turbine exit temperature	746.66	K
LP turbine exit pressure	0.59219	bar
Hot jet velocity	494.88	m/s
Hot thrust	7.8237	kN
Hot nozzle area	0.26342	m²
Total thrust	27.402	kN
Fuel/air ratio (core)	0.021042	
Fuel flow	1,683.4	kg/h
Specific fuel consumption	0.061434	kg/(N·h)
Specific thrust (per total flow)	137.01	N·s/kg

Notes for this case

- Cold nozzle choked, hot nozzle choked.
- Nozzle areas use the static temperature after the actual (not isentropic) expansion.2 table uses the isentropic value, so its areas are about 0.8 % smaller.

Formula and method

$$T_{05} = T_{04} - \frac{c_{pa}(T_{03} - T_{02})}{\eta_m c_{pg}}, \quad T_{06} = T_{05} - \frac{(B+1)c_{pa}(T_{02} - T_{01})}{\eta_m c_{pg}}$$

$$F = \dot{m}_c(C_8 - C_a) + \dot{m}_h(C_7 - C_a) + \sum A(p - p_a), \quad SFC = \frac{f\dot{m}_h}{F}$$

Variables

p_a	Ambient pressure	Pa
T_a	Ambient temperature	K
M	Flight Mach number	-
r_o	Overall pressure ratio	-
r_f	Fan pressure ratio	-
B	Bypass ratio (cold/hot flow)	-
T_{04}	Turbine inlet temperature	K
$\eta_{\infty c}$	Fan and compressor polytropic efficiency	-
$\eta_{\infty t}$	Turbine polytropic efficiency	-
η_i	Intake isentropic efficiency	-
η_j	Propelling nozzle efficiency (each)	-
η_m	Mechanical efficiency (each spool)	-
η_b	Combustion efficiency	-
$\Delta p_b/p_{03}$	Combustion pressure loss	-
$\dot{m}$	Total air flow	kg/s
c_{pa}	Air specific heat	J/(kg·K)
γ_a	Air ratio of specific heats	-
c_{pg}	Gas specific heat	J/(kg·K)
γ_g	Gas ratio of specific heats	-

R	Gas constant (air and gas)	J/(kg·K)
Q_{net}	Fuel net calorific value	J/kg
y	Fuel H/C atom ratio (kerosene about 1.92, methane 4)	-
T_{02}	Fan delivery temperature	K
T_{03}	Compressor delivery temperature	K
p_{03}	Compressor delivery pressure	Pa
$\dot{m}_c$	Cold (bypass) flow	kg/s
$\dot{m}_h$	Hot (core) flow	kg/s
C_8	Cold jet velocity	m/s
F_c	Cold thrust	N
A_8	Cold nozzle area	m²
T_{05}	HP turbine exit temperature	K
T_{06}	LP turbine exit temperature	K
p_{06}	LP turbine exit pressure	Pa
C_7	Hot jet velocity	m/s
F_h	Hot thrust	N
A_7	Hot nozzle area	m²
F	Total thrust	N
f	Fuel/air ratio (core)	-
$\dot{m}_f$	Fuel flow	kg/s
SFC	Specific fuel consumption	kg/(N·s)
$F/\dot{m}$	Specific thrust (per total flow)	m/s

Method and standards

Textbook separate-stream turbofan design-point calculation.

Assumptions and limits

- Separate convergent nozzles; constant c_p and γ; no bleeds or power off-takes.

Report details

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Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/boilers-power-plant/gas-turbines-combined-cycle/turbofan-separate-streams

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Reopens the calculator with the inputs of this report.