TURBINOWE SILNIKI ŚMIGŁOWE I ŚMIGŁOWCOWE
TURBOPROP AND TURBOSHAFT ENGINE

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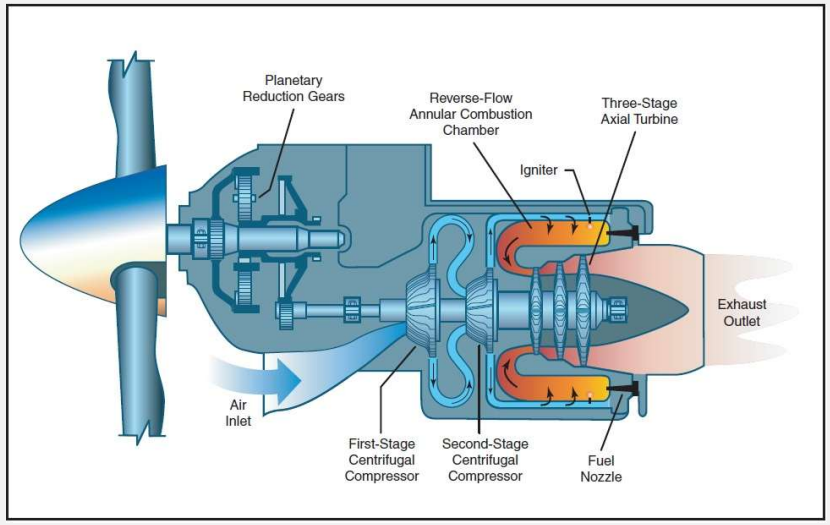
LITERATURE:

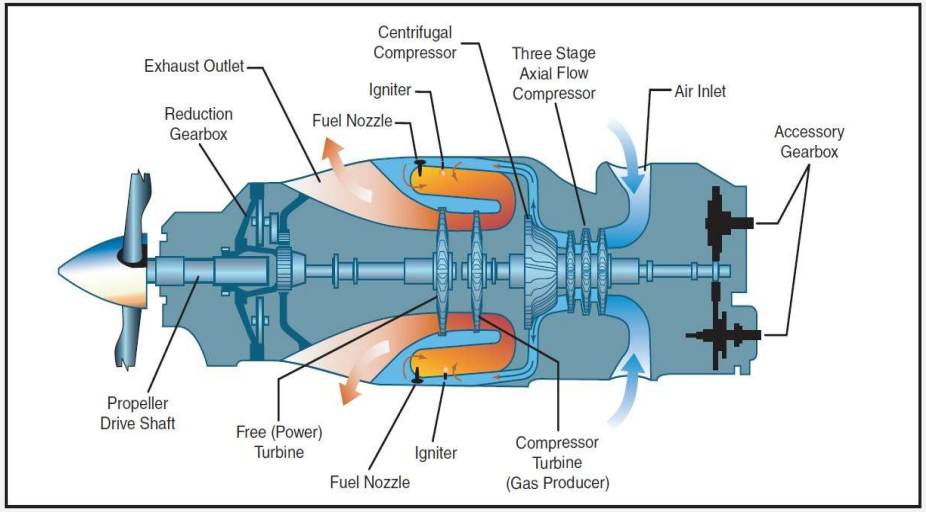
- **Gordon C. Oates, Aerothermodynamics of Gas Turbine and Rocket Propulsion, AIAA Education Series, 1997 (Chapter 7)**
- **Jack D. Mattingly, Elements of Gas Turbine Propulsion, Tata McGraw Hill Education Private Limited, 2013 (Chapter 7)**
- Jack D. Mattingly, William H. Heiser, David T. Pratt, **Aircraft Engine Design, Second Edition,** American Institute of Aeronautics and Astronautics, Inc. 2002 (**Appendix K**)

ROZWIĄZANIA KONSTRUKCYJNE TURBINOWEGO SILNIKA ŚMIGŁOWEGO



Silnik jednowirnikowy (Single spool turboprop)

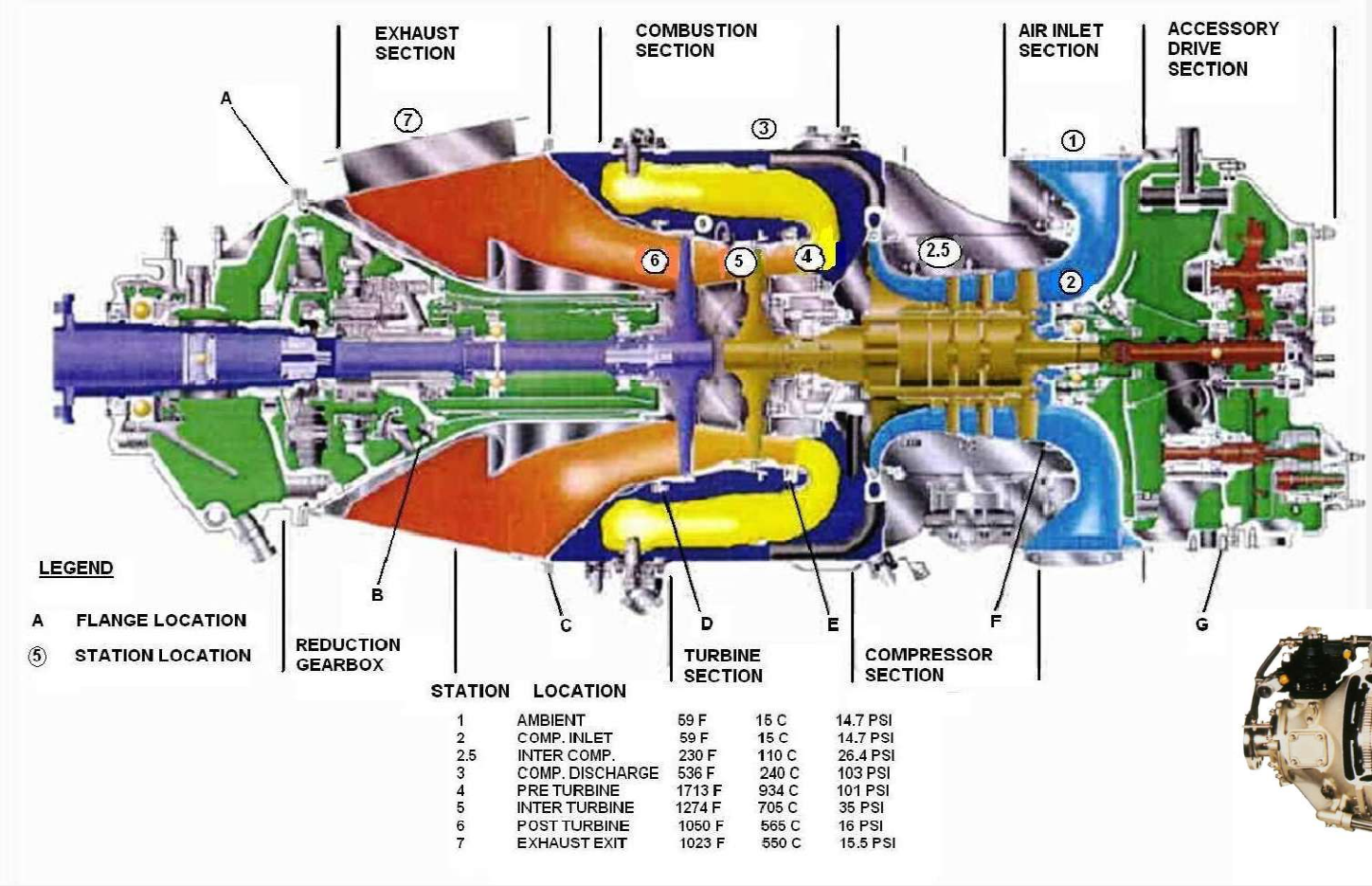
- Prosta konstrukcja – tylko jeden wał współosiowy.
- Śmigło jest napędzane poprzez przekładnię redukcyjną przez ten sam wał, który napędza sprężarkę.



Silnik z wolną turbiną (free power turbine)

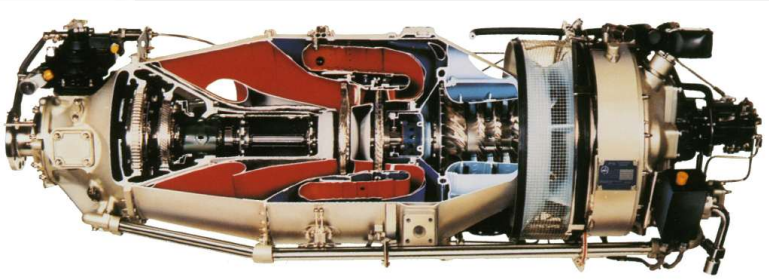
- Oferuje lepszą elastyczność i osiągi podczas szybkich zmian mocy, takich jak podczas startu i lądowania.
- Śmigło jest napędzane przez wolną turbinę za pośrednictwem oddzielnego wału, co umożliwia optymalne, wolniejsze prędkości obrotowe śmigła niezależnie od prędkości obrotowej wytwornicy spalin.

PT6 – PRZYKŁAD SILNIKA TURBINOWEGO ŚMIOGŁOWEGO Z WOLNĄ TURBINĄ

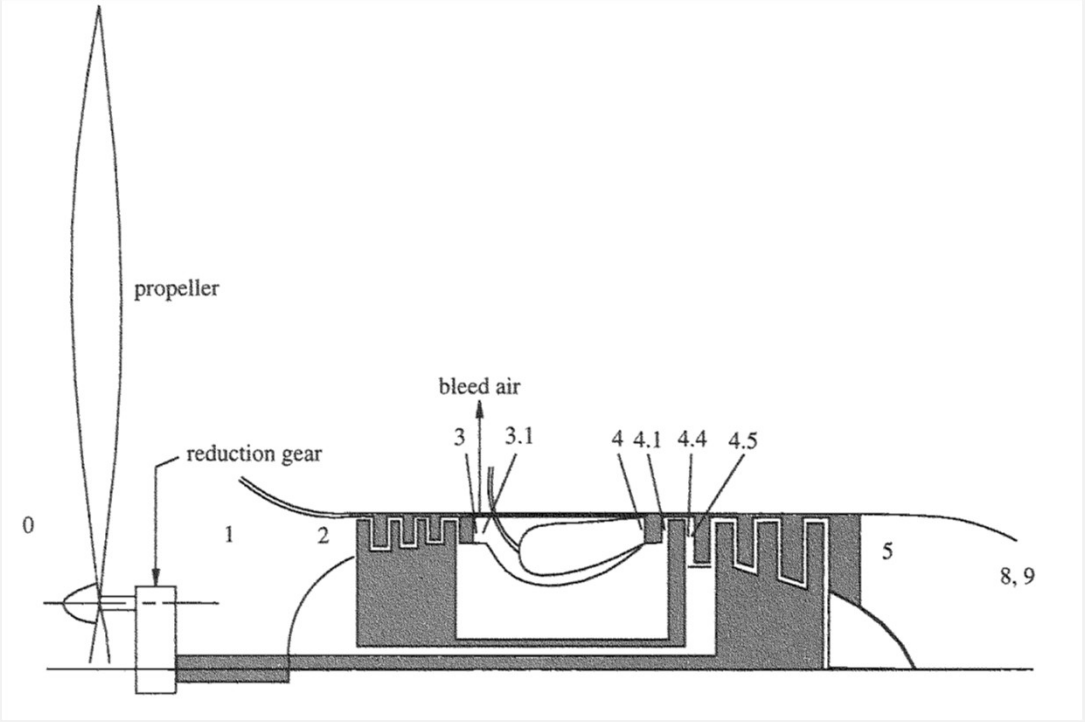


STATION	LOCATION			
1	AMBIENT	59 F	15 C	14.7 PSI
2	COMP. INLET	59 F	15 C	14.7 PSI
2.5	INTER COMP.	230 F	110 C	26.4 PSI
3	COMP. DISCHARGE	536 F	240 C	103 PSI
4	PRE TURBINE	1713 F	934 C	101 PSI
5	INTER TURBINE	1274 F	705 C	35 PSI
6	POST TURBINE	1050 F	565 C	16 PSI
7	EXHAUST EXIT	1023 F	550 C	15.5 PSI

PT 6 A/B



FREE POWER TURBINE TURBOPROP



Power of the power turbine

$$P_{PT} = \dot{m}_{45} Cp_T (T_{t45} - T_{t5})$$

Power transmitted to the propeller: Shaft Power

$$P_{SP} = \eta_m \eta_G P_{PT} = \eta_m \eta_G \dot{m}_{45}\, Cp_T (T_{t45} - T_{t5})$$

η_m - mechanical efficiency

η_G - gear efficiency

Propeller thrust

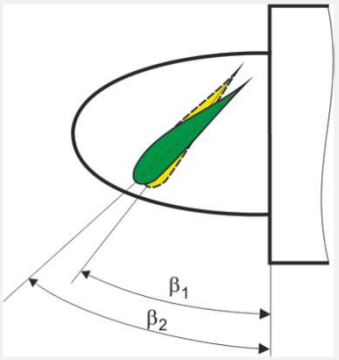
$For\ V_0 > 0$ $\quad T_{PR} = \dfrac{\eta_{PR} P_{PR}}{V_0}$ $\quad \eta_{PR}$ - propeller efficiency

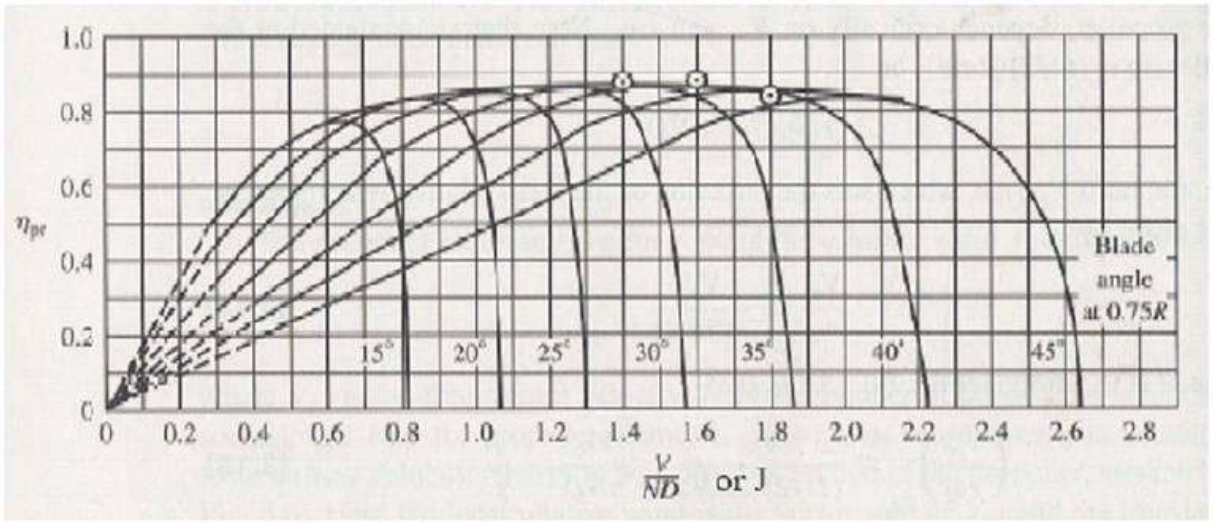
$For\ V_0 = 0$ $\quad T_{PR} = B_{PR} P_{PR}$ $\quad B_{PR}$ - propeller thrust to power ratio

PROPELLER EFFICIENCY

Ciąg śmigła

$$K = \eta_{PR} \frac{P}{V_H}$$

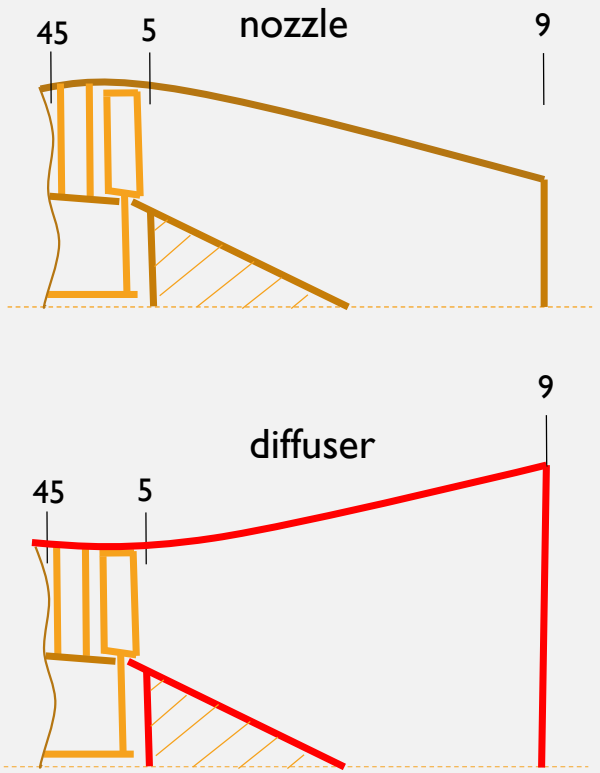


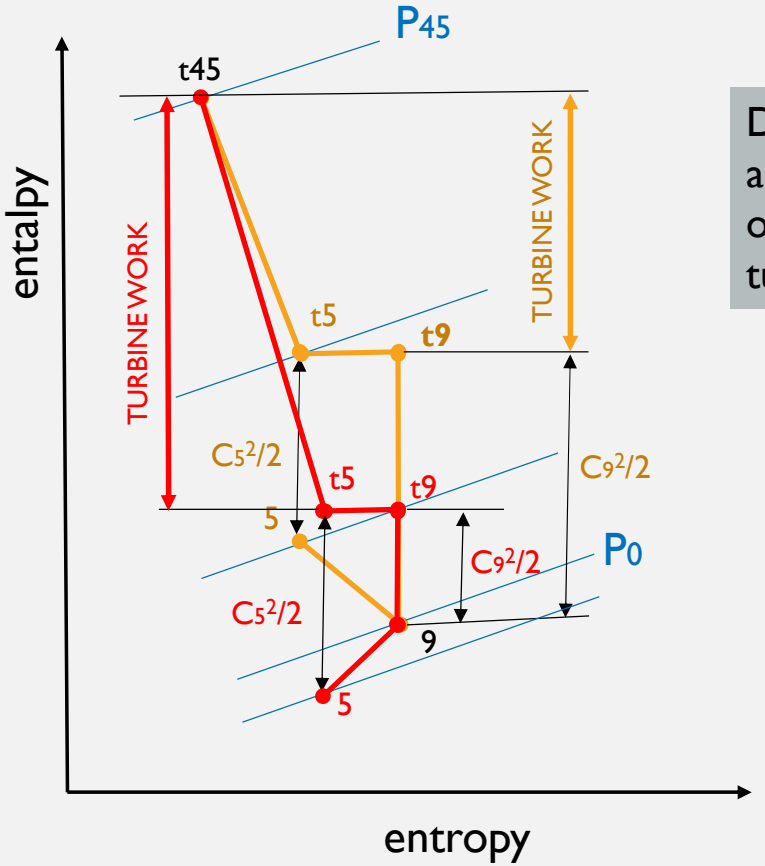


Each curve is for a different pitch angle, β

Changing the propeller pitch angle for varying flight speeds allows its propulsion properties to be used more efficiently.

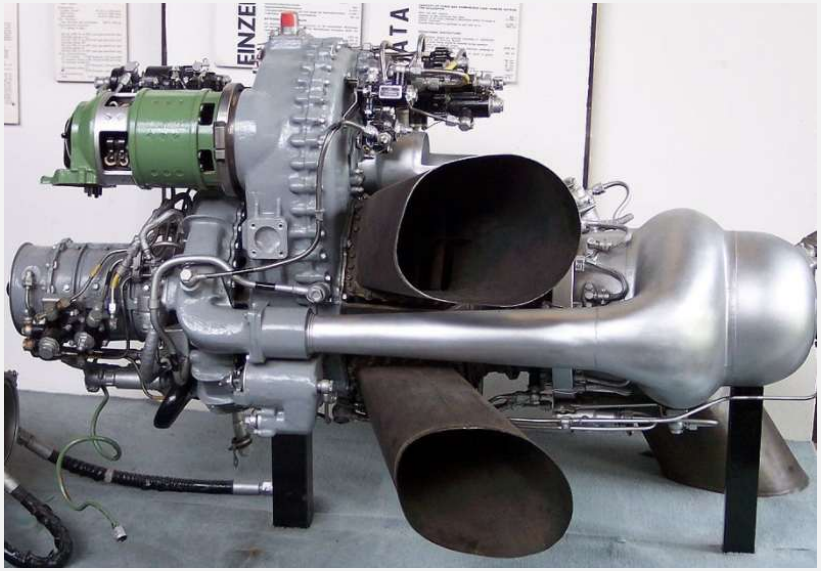
INCREASING POWER OF THE TURBINE THROUGH THE ENGINE EXHAUST



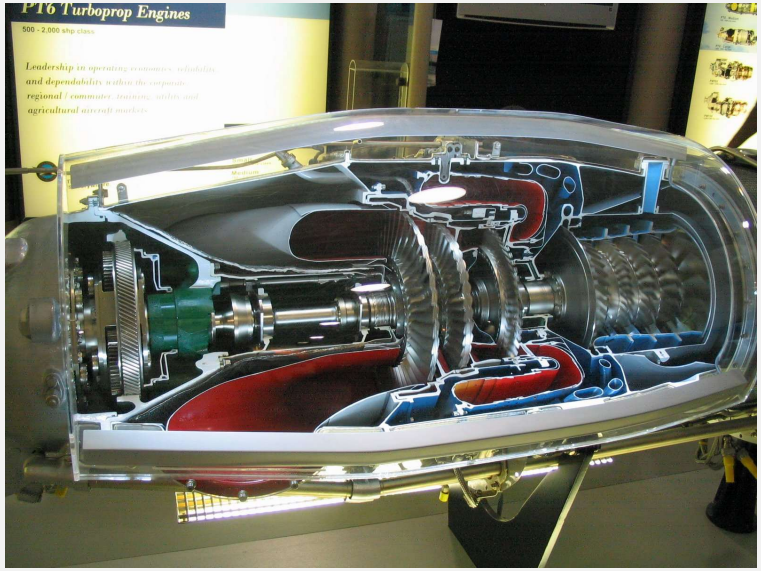


Diffuser in the turboprop and the turboshaft engine outlet allow to increase turbine power

TYPICAL TURBOPROP AND TURBOSHAFT ENGINE EXHAUST

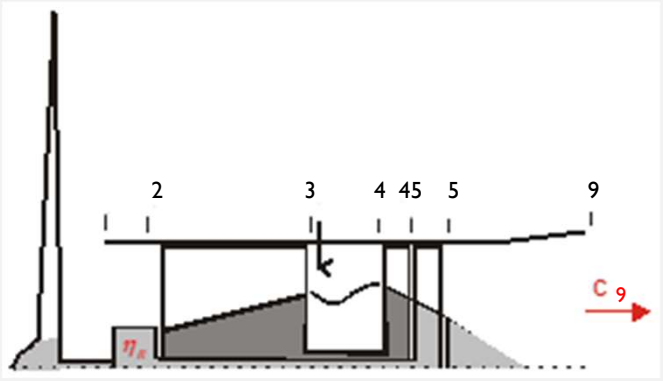


GTD 350



PT6

POWER TURBINE CALCULATION



Parameters to section 45 are calculated as for classical turbojet engine.
Engine outlet flow speed is assumed (outlet diffuser c_9=180-240 m/s 0,3-0,4 Ma)
Static pressure in diffuser outlet is equal ambient pressure P9=P0

$$P_{t5} = \frac{P_{t9}}{\pi_D} = \frac{P_9\left(1 + \frac{k_t - 1}{2} M_9{}^2\right)^{\frac{k_t}{k_t - 1}}}{\pi_D}$$

π_D - pressure losses in diffuser

$\pi_{PT} = \frac{P_{t45}}{P_{t5}}$ - power turbine pressure ratio

$$W_{PT} = Cp_T(T_{t45} - T_{t5}) = Cp_T T_{t45}\left(1 - \frac{T_{t5}}{T_{t45}}\right)$$

PT power: $P_{PT} = m_{45} W_{PT}$

Higher pressure ratio of the power turbine generate higher work and power of this component

Polytropic efficiency of PT: $T_{t5}/T_{t45} = (P_{t5}/P_{t45})^{\frac{e_{PT}(k_t - 1)}{k_t}}$

Isentropic efficiency of PT: $T_{t5}/T_{t45} = 1 - \eta_T\left(1 - (P_{t5}/P_{t45})^{\frac{k_t - 1}{k_t}}\right)$

SPECIFIC FUEL CONSUMPTION AND SPECIFIC POWER

Specific fuel consumption SFC / for power $$SFC = \frac{\dot{m}_f}{P_{SP}} = \frac{f}{\eta_m \eta_G (1+f) Cp_T (T_{t45} - T_{t5})}$$

/ for thrust $$SFC = \frac{\dot{m}_f}{T}$$

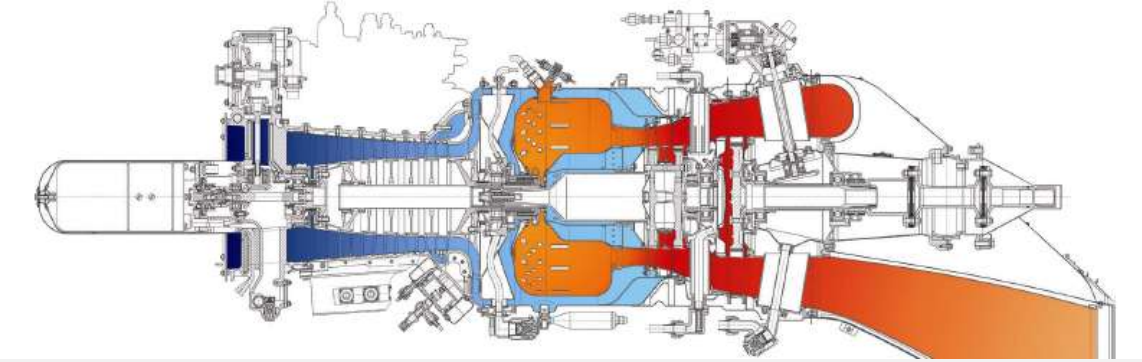
Specific Power: $$SP = \frac{P_{SP}}{\dot{m}_0} = \eta_m \eta_G (1+f) Cp_T (T_{t45} - T_{t5})$$

Spceific Thrust: $$ST = \frac{T}{\dot{m}_0}$$

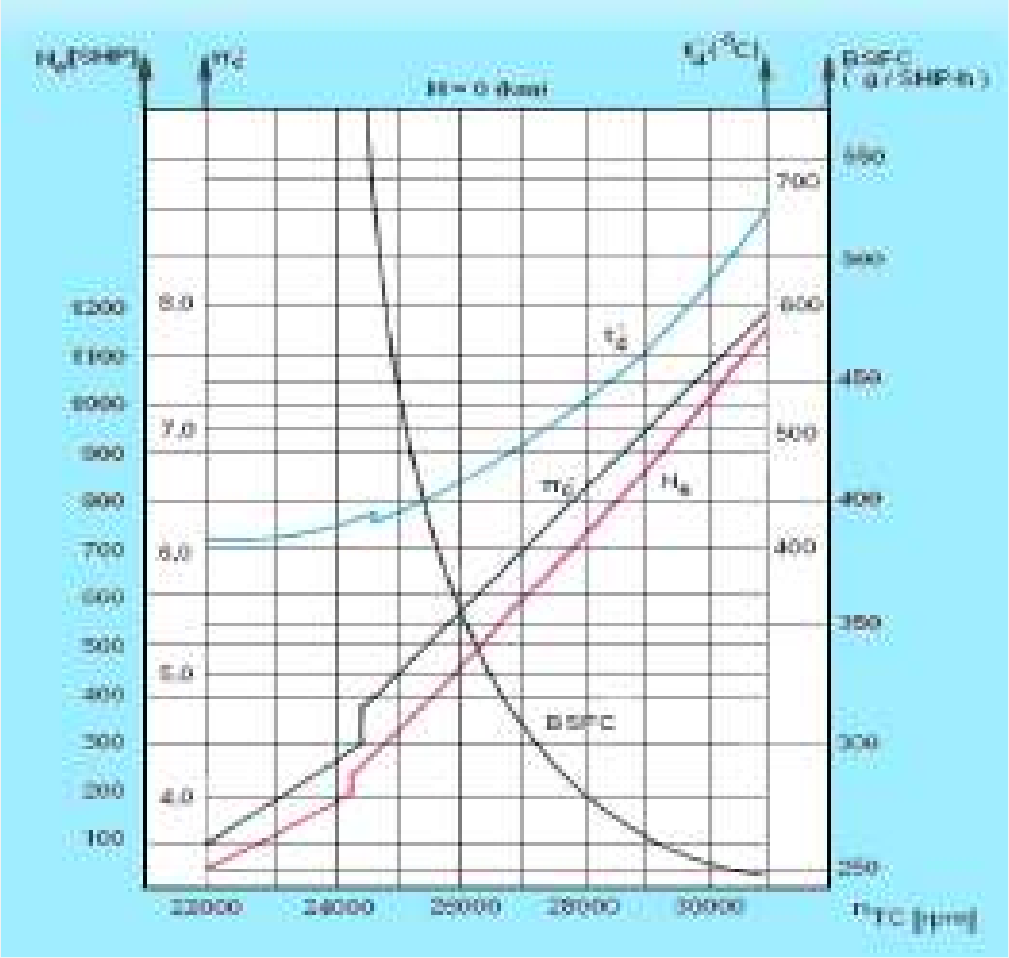
PORÓWNANIE OSIĄGÓW SILNIKÓW

	Specific thrust/ power [daN*s/kg]	SFC [kg/daN/h]
Turbojet engine	50-70	0,8-1,1
Turbojet engine AB on	80-110	1,7-2,2
Turbofan mixed stream engine	50-75	0,6-0,8
Turbofan mixed stream engine AB on	75-110	1,9-2,5
High bypass ratio turbofan engine	25-60	0,3-0,7
Turboprop/turboshaft engine	160-300 [kW*s/kg] 240-450 [daN*s/kg]	0,22-0,35 [kg/kW/h] 0,15-0,25[kg/daN/h]

PZL 10W PERFORMANCE

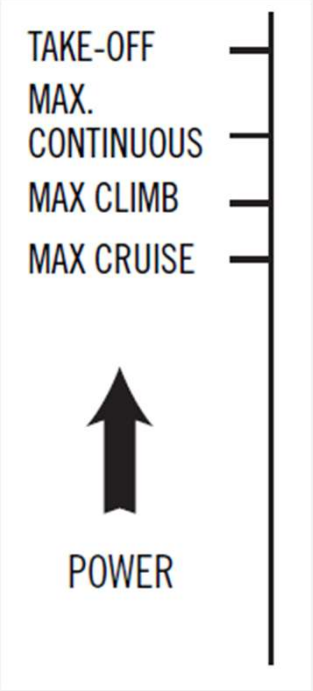


SW-3 Sokół



CHARAKTERYSTYKI OPERACYJNE SILNIKÓW TURBOŚMIGŁOWYCH

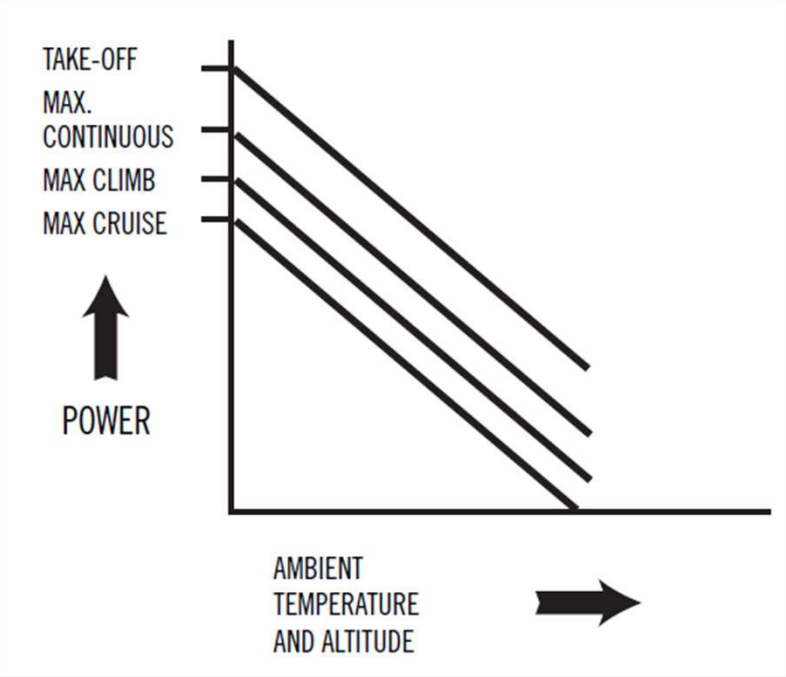
- **Take-off rating** to maksymalna moc certyfikowana do **startu** i jest ona ograniczona czasowo do pięciu minut.
- **Maximum continuous rating** to certyfikowane ustawienie mocy przeznaczone wyłącznie do użycia w sytuacjach awaryjnych w locie, zazwyczaj w zastosowaniach dwusilnikowych, gdy jeden silnik nie działa **(is inoperative)**.
- **Maximum climb** oraz **maximum cruise ratings** to maksymalne moce zatwierdzone do pracy odpowiednio na wznoszeniu i przelocie.



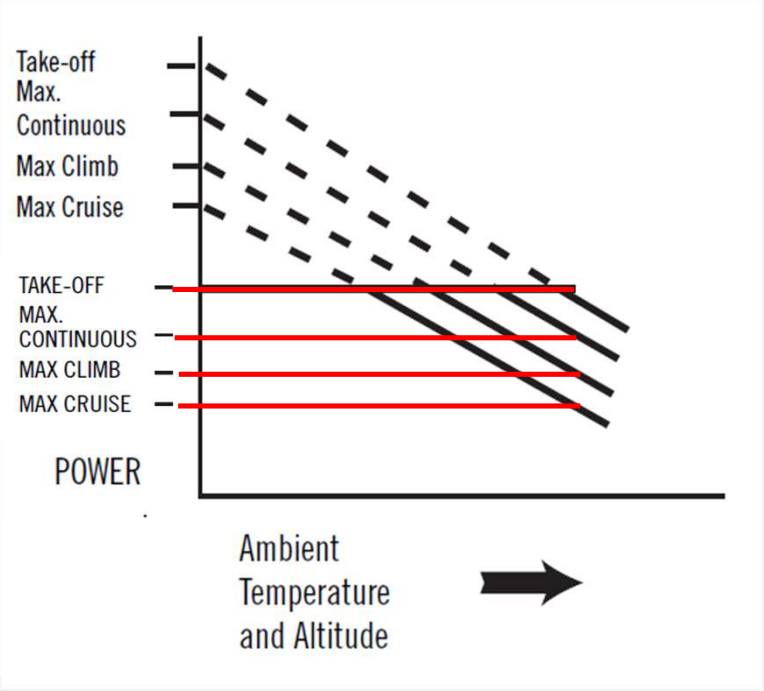
RJ1

WPŁYW WYSOKOŚCI I TEMPERATURY OTOCZENIA NA MOC SILNIKA

Moc silnika z wysokością
i temperaturą otoczenia



Stała moc silnika z wysokością
„flat rate power”

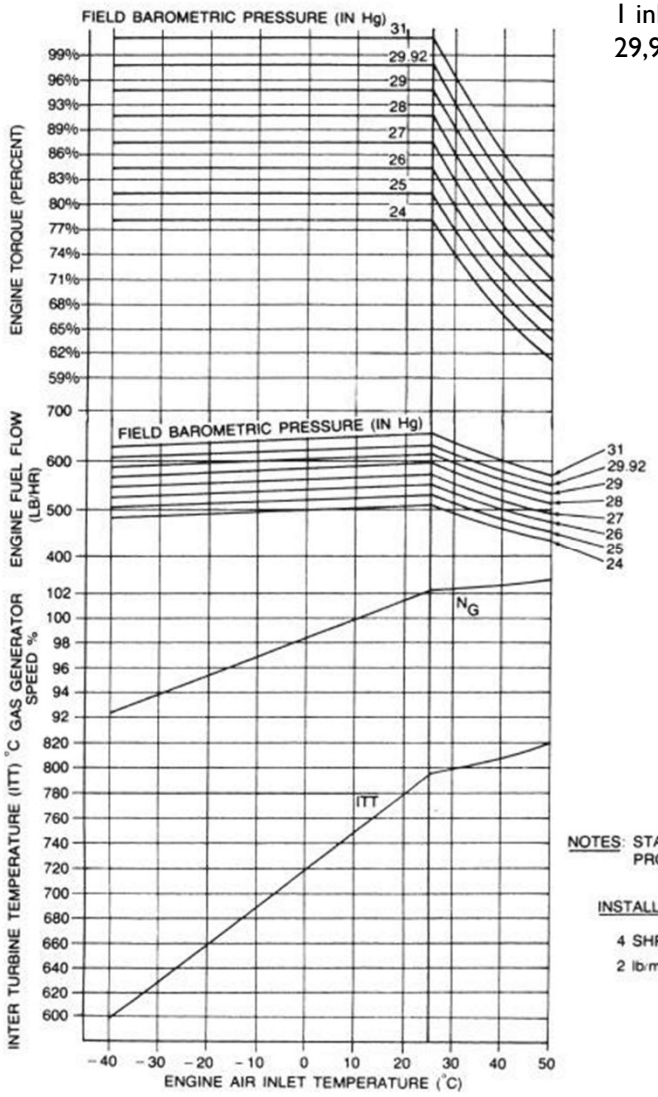


Slajd 14

RJ1 Robert Jakubowski; 21.01.2026

PT6 CHARAKTERYSTYKI

1 inHg = 3386,39 Pa
29,92 inHg – 101325Pa



NOTES: STATIC INSTALLED
PROP RPM = 1700 RPM

INSTALLATION ASSUMES

4 SHP_{EX}
2 lb/min P_3 BLEED

Pratt & Whitney Canada
A United Technologies Company

OPERATING LIMITS

PT6A-61

Power Setting	SHP	Torque		Max ITT	Ng		NP	Oil Pressure	Oil Temp.
		lb-ft	psig	°C	RPM	%	RPM	PSI	°C
Take-off/Max Cont.	850	2230	72.95	800	39000	104	2000	90 - 135	0 – 110
Max. Cruise	850	2230	72.95	800	39000	104	2000	90 - 135	10 – 104
Normal Cruise	850	2230	72.95	775	39000	104	2000	90 - 135	0 - 99
Max Climb	850	2230	72.95	775	39000	104	2000	90 - 135	0 – 104
Min. Idle	-	-	-	715	19000	51	-	60 (min)	-40 - 110
Starting	-	-	-	1000	-	-	-	200 (max)	-40 (min)
Transient	-	2750	89.73	850	39000	104	2250	40 – 200	0 - 110
Max. Reverse	800	-	-	760	-	-	-	90 - 135	0 - 99

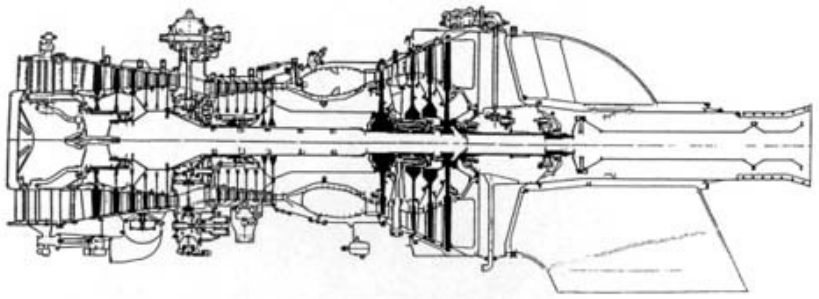
PT6A-64

Power Setting	SHP	Torque		Max ITT	Ng		NP	Oil Pressure	Oil Temp.
		lb-ft	psig	°C	RPM	%	RPM	PSI	°C
Take-off	700	2230	72.95	800	39000	104	2000(90.7%)	100 - 135	0 – 110
Max. Continuous	700	2230	72.95	800	39000	104	2000	100 - 135	0 – 104
MaxClimb/Cruise	700	2230	72.95	785	39000	104	2000	100 - 135	10 – 104
Min. Idle	-	-	-	715	19000	51	-	60 (min)	-40 - 110
Starting	-	-	-	1000	-	-	-	200 (max)	-40 (min)
Transient	-	2750	89.96	870	39000	104	2205(100%)	40 – 200	-40 - 110
Max. Reverse	700	-	-	760	-	-	1900	100 - 135	0 – 104

LOTAREV D-136 3-SPOOL TURBOSHAFT

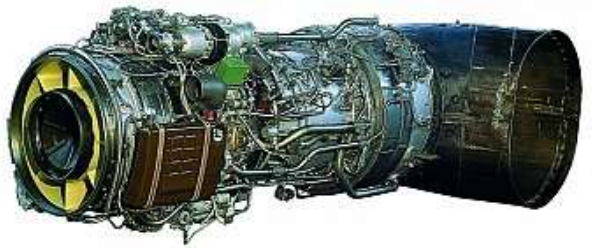
seria 1

Maximum takeoff power conditions (SLS, ISA)	
Power, shp (kW)	11400 (8382)
Specific fuel consumption, kg/hp•h (kg/kW•h)	0.194 (0.263)
Cruise power conditions (H=4600 m, M_{fl}=0,13; ISA)	
Power, shp (kW)	6100 (4486)
Specific fuel consumption, kg/hp•h (kg/kW•h)	0.230 (0.312)
Dry weight, kg	1077



seria 2

Emergency power rating (H=0, M=0, ISA+15°C):	
Power rating, hp (kW)	12500 (9190)
Maximum takeoff power rating (H=0, M_{fl}=0, ISA):	
Power rating (at t_{AMB}=30°C), hp (kW)	11650 (8560)
Specific fuel consumption, kg/hp·h (kg/kW·h)	0.198 (0.269)
Dry weight, kg	1100



- **Compressor:** 7-stage subsonic high-pressure (HP) compressor, 6-stage transonic low-pressure (LP) compressor
- **Combustors:** Annular combustion chamber, 24 fuel nozzles, 2 igniters
- **Turbine:** 1-stage HP turbine @ 14,170 rpm, 1-stage LP turbine @ 10,950 rpm, 2-stage free-power turbine @ 8,300 rpm (±300 rpm)

THANKS FOR YOUR ATENTION

Questions and Comments ?

1. …….
2. …….
3. …….