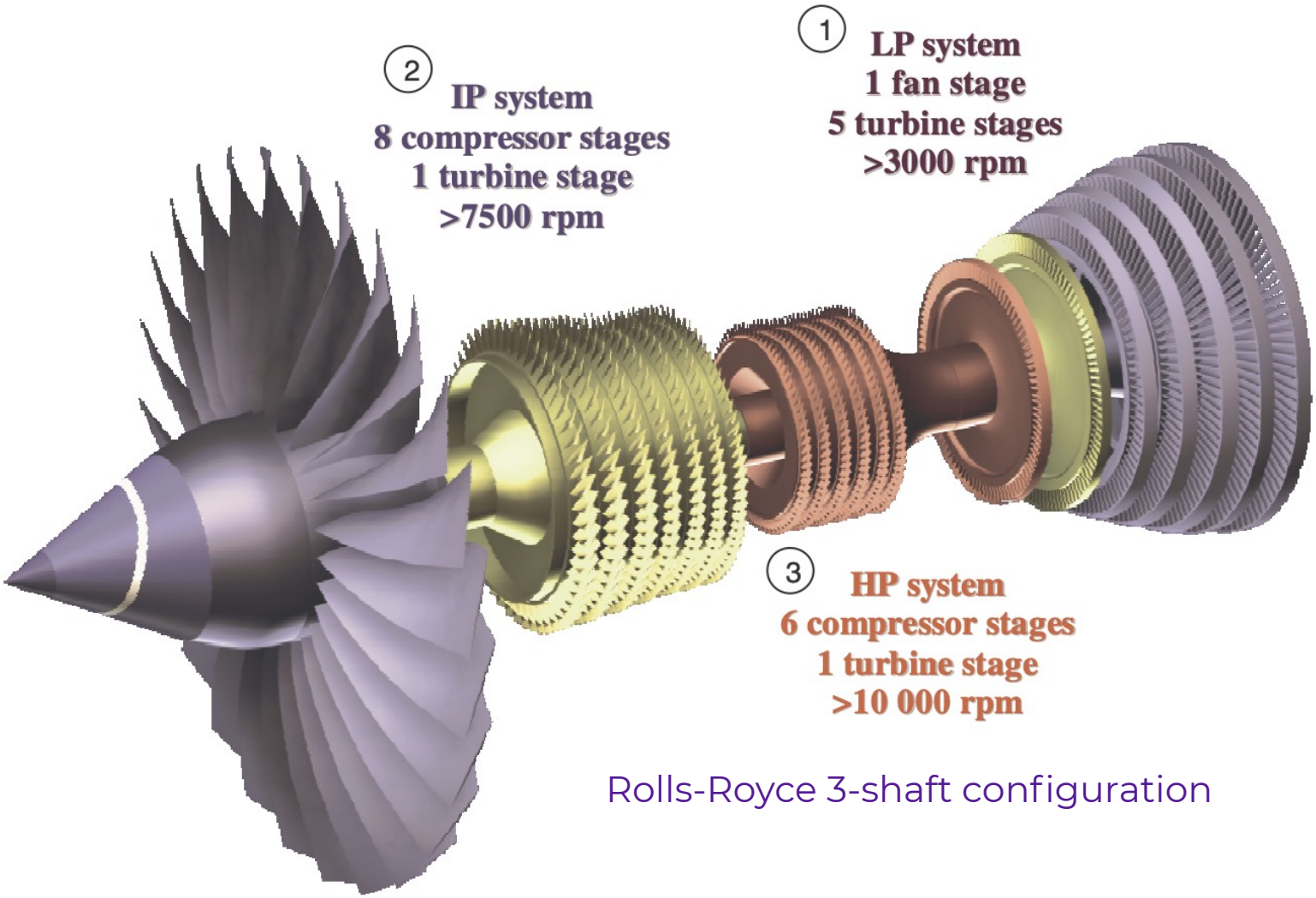
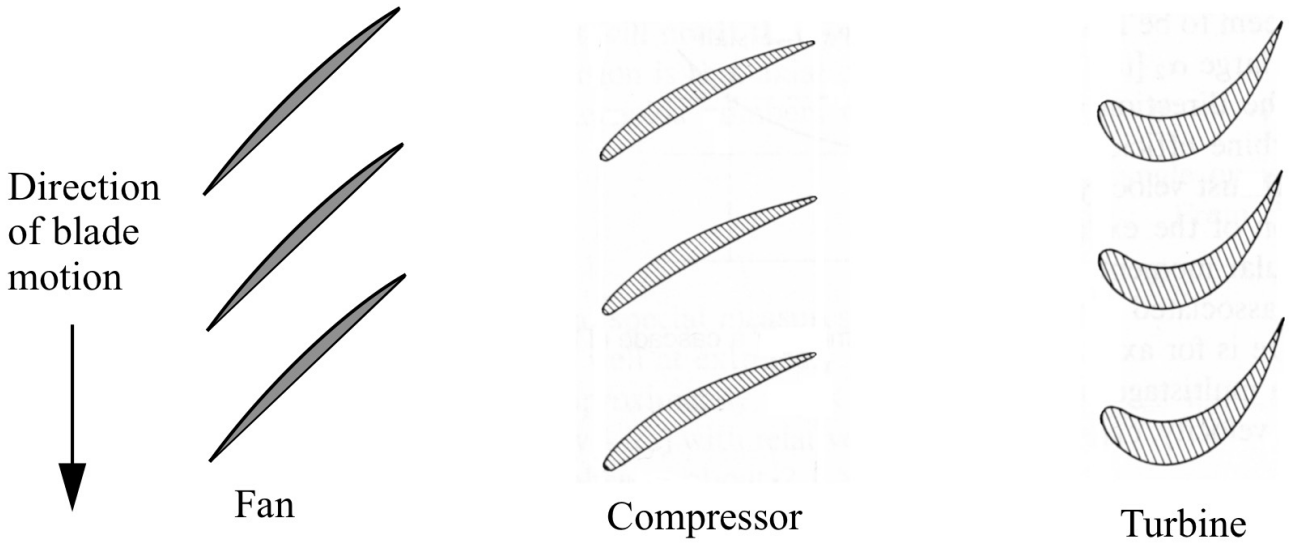
Turbines



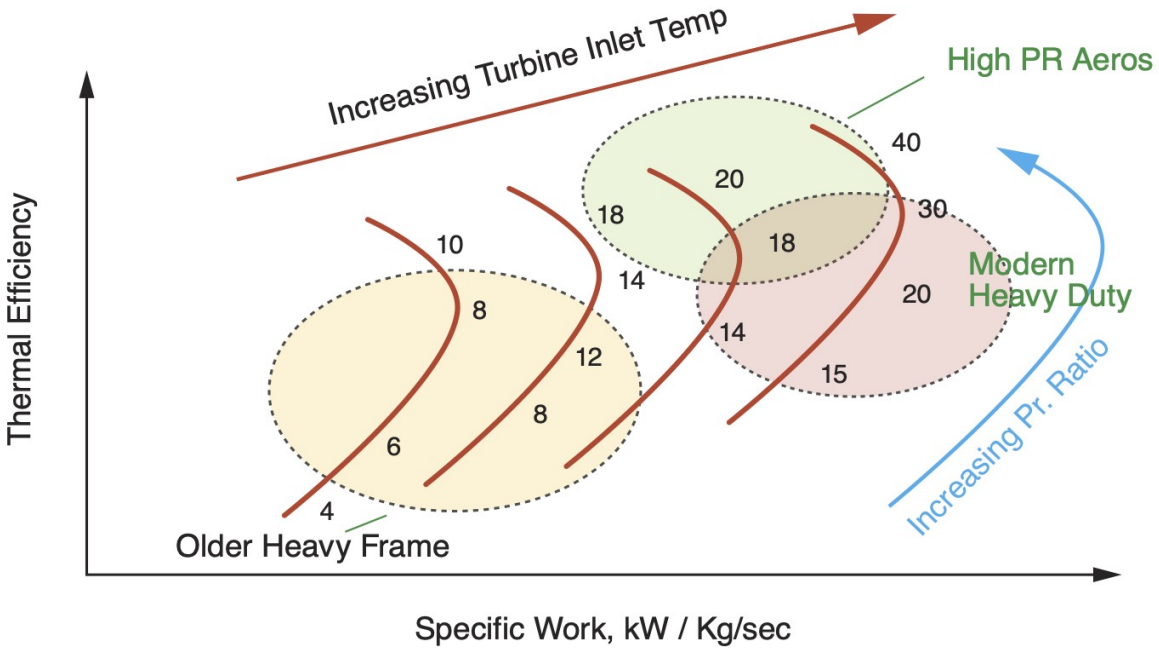
Rolls-Royce 3-shaft configuration

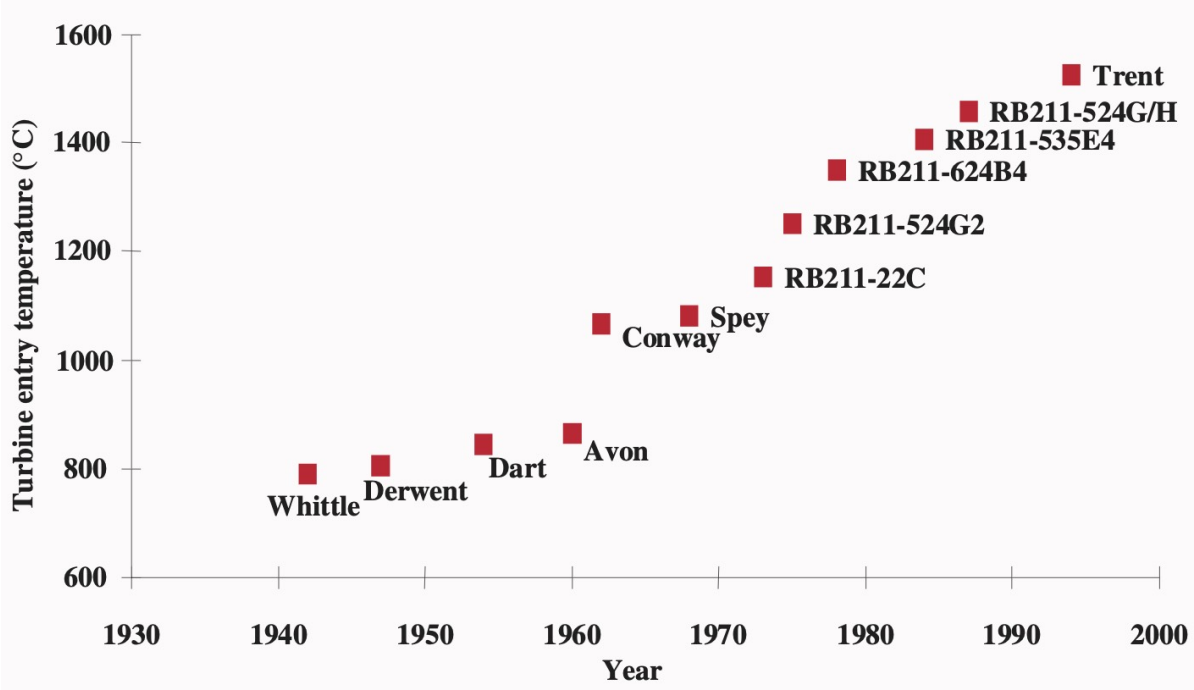
Comparison of blade shapes of the turbomachinery



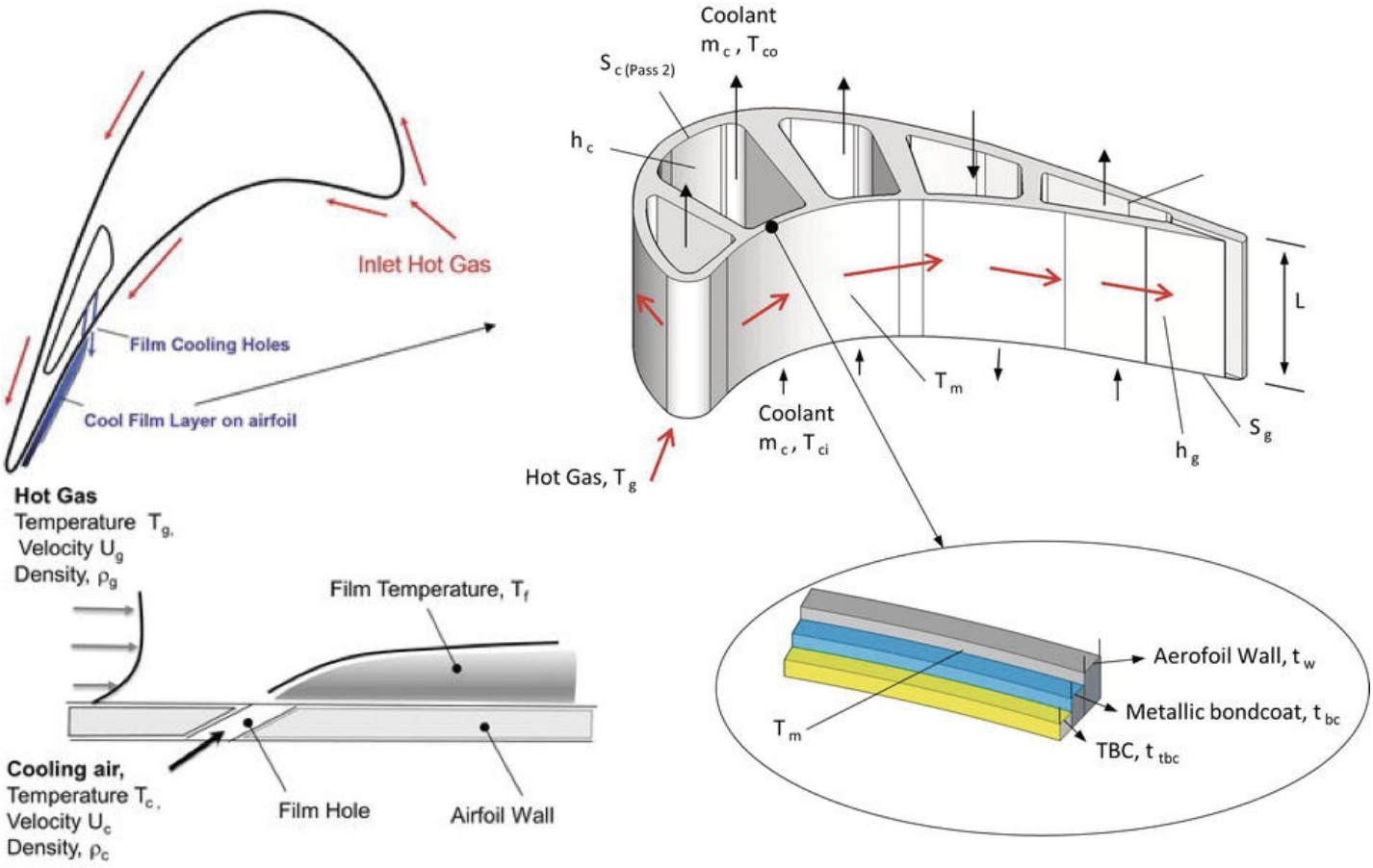
Temperature seen by compressor and turbine blades

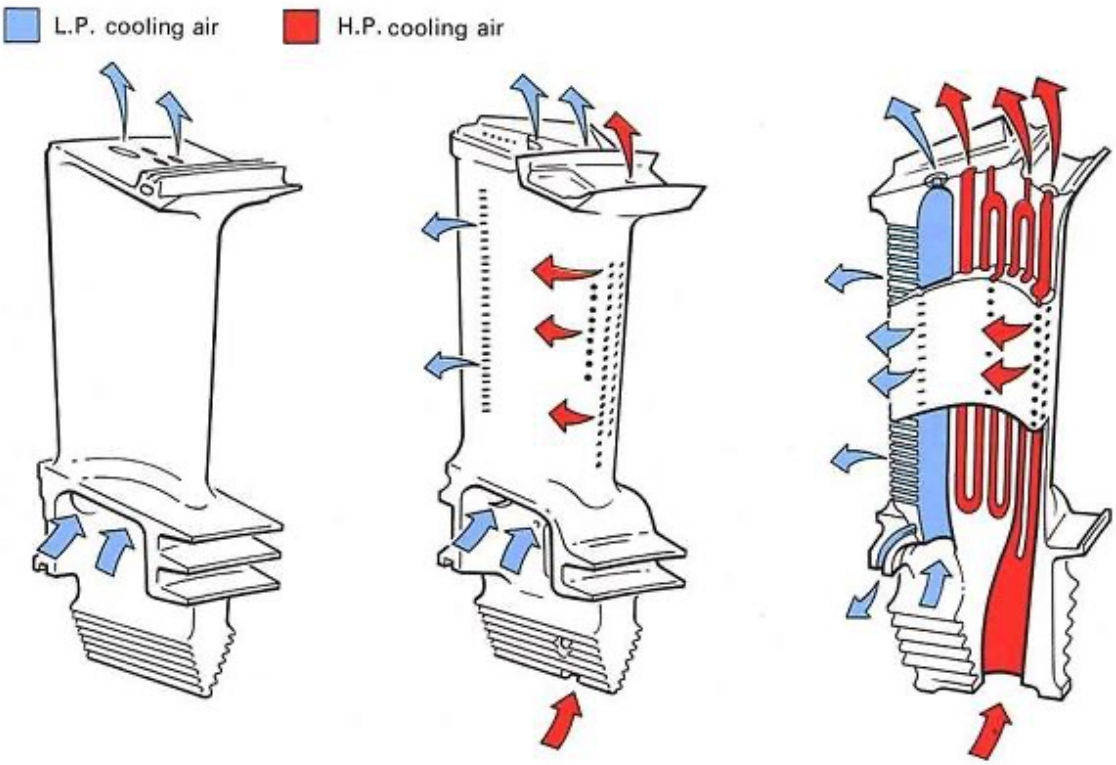
Power (MW_e)	<5	5–15	15–50	50–150	>150
Pressure (bar)	6–12	12–15 (20)	12–15 (>20/35)	12–15 (>20)	15–25 (>25/35)
Temperature (°C) (compressor exit)	270–380	350–450 (500)	350–450 (500)	350–450 (500)	400–480 (550)
Temperature (°C) (turbine entry)	700–1100	850–1150	1100–1230	1150–1280	1230–1280 (1400)
Temperature (°C) (turbine exit)	350–550	400–500	450–550	500–600	550–600 (640)

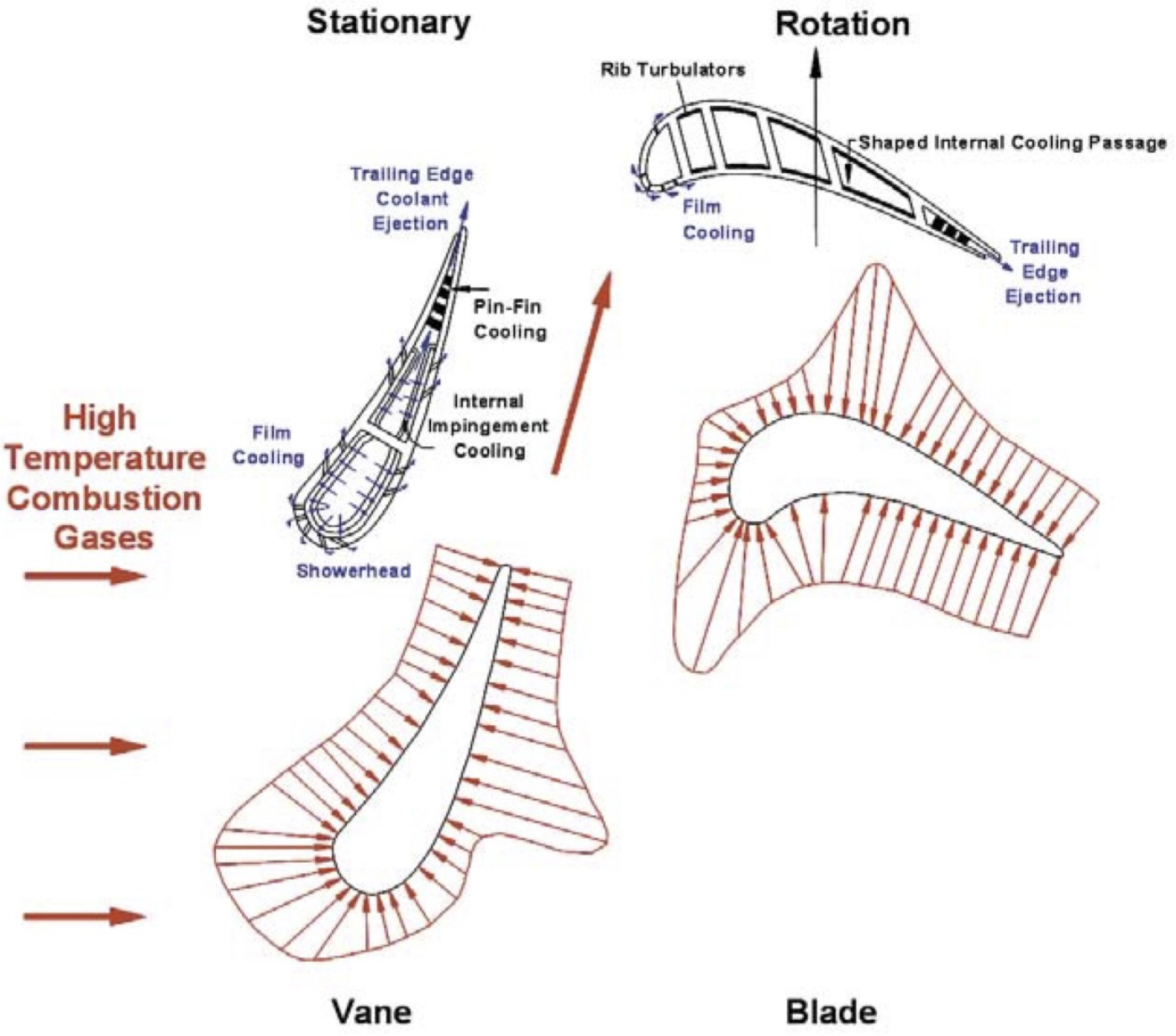


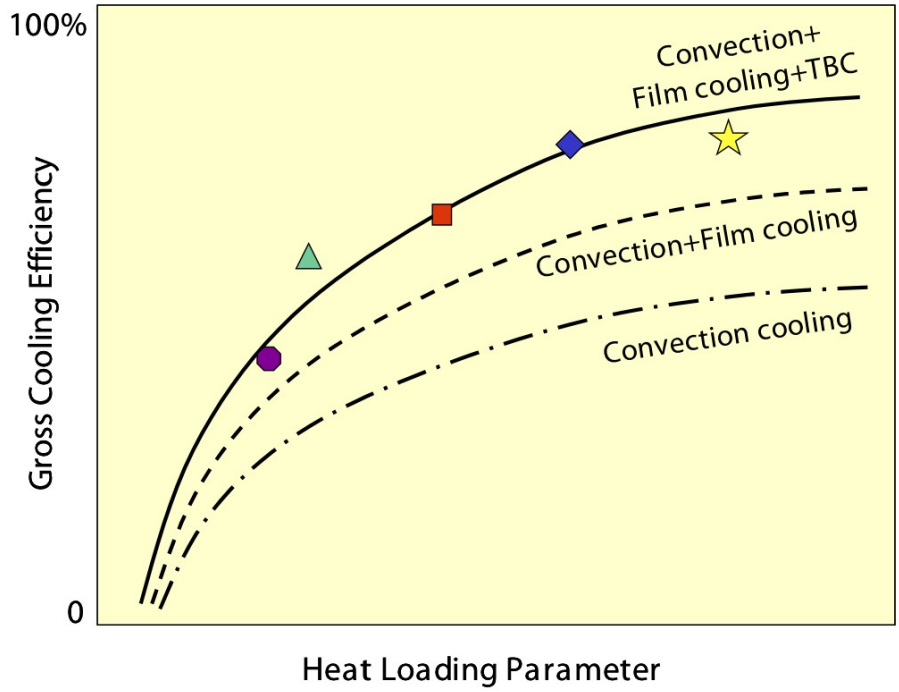


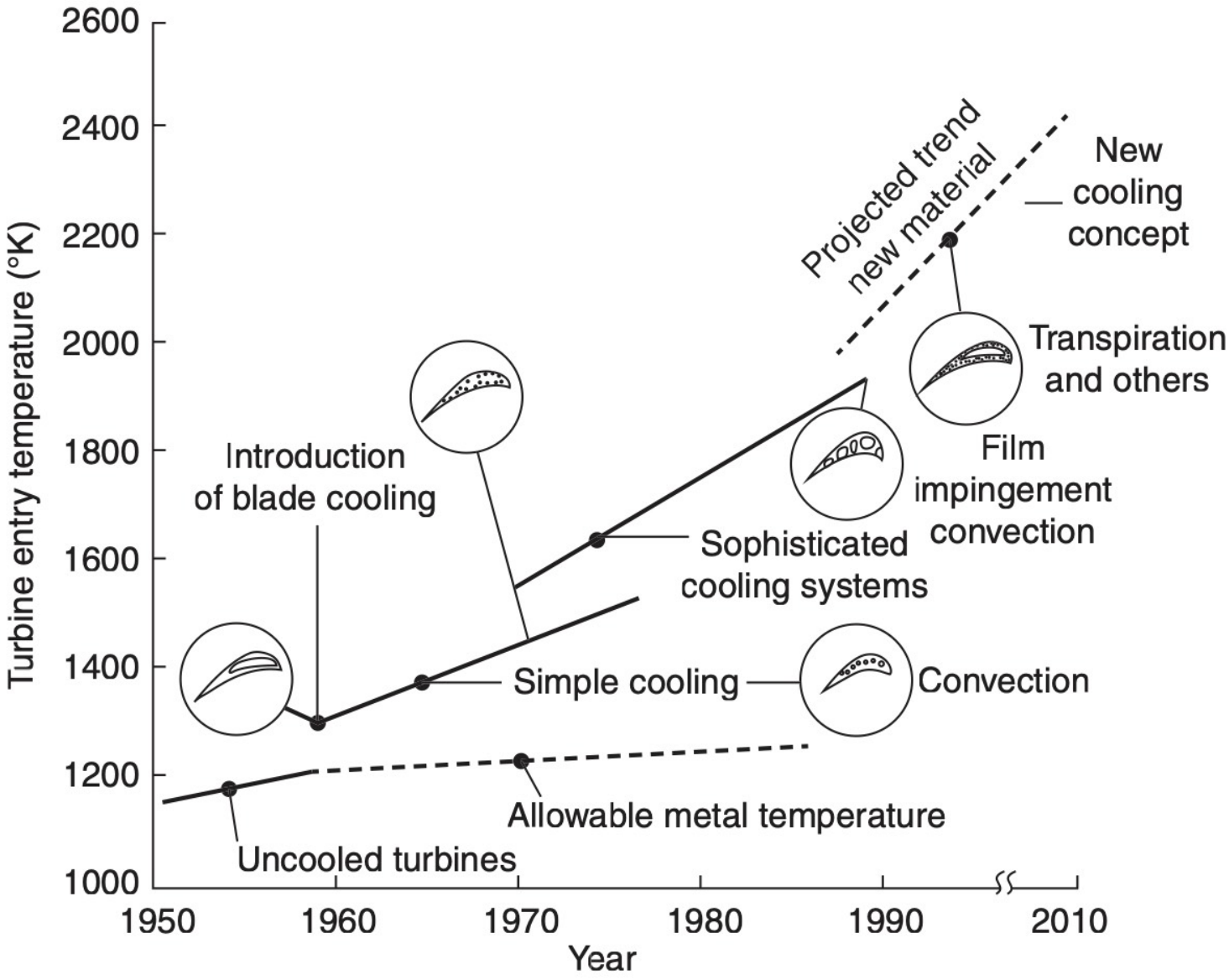
Turbine blade cooling approaches

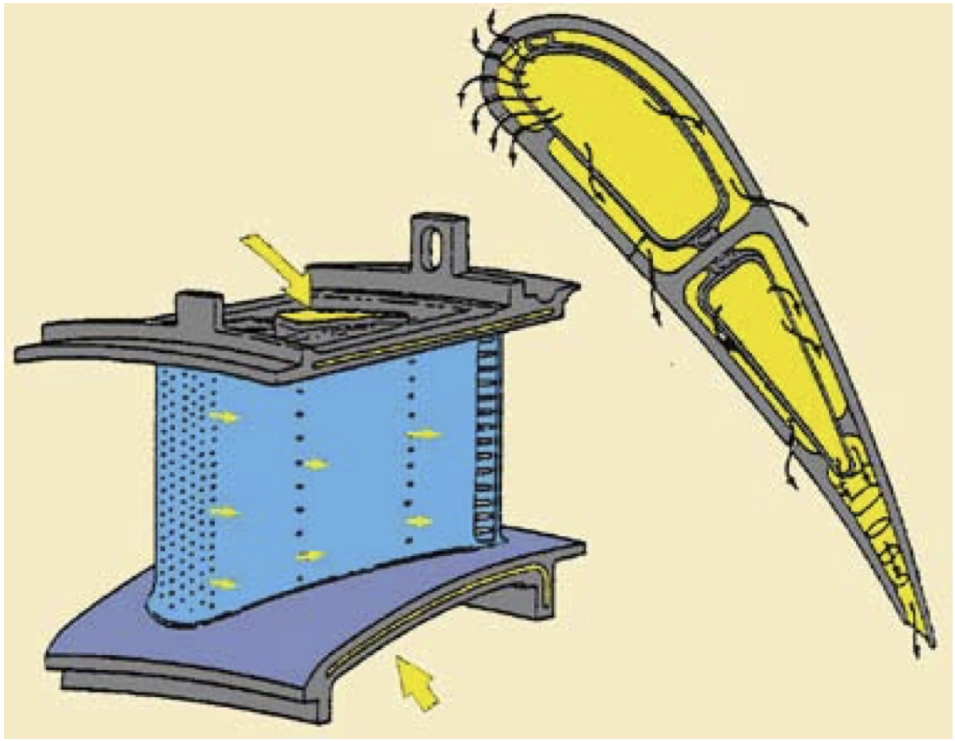


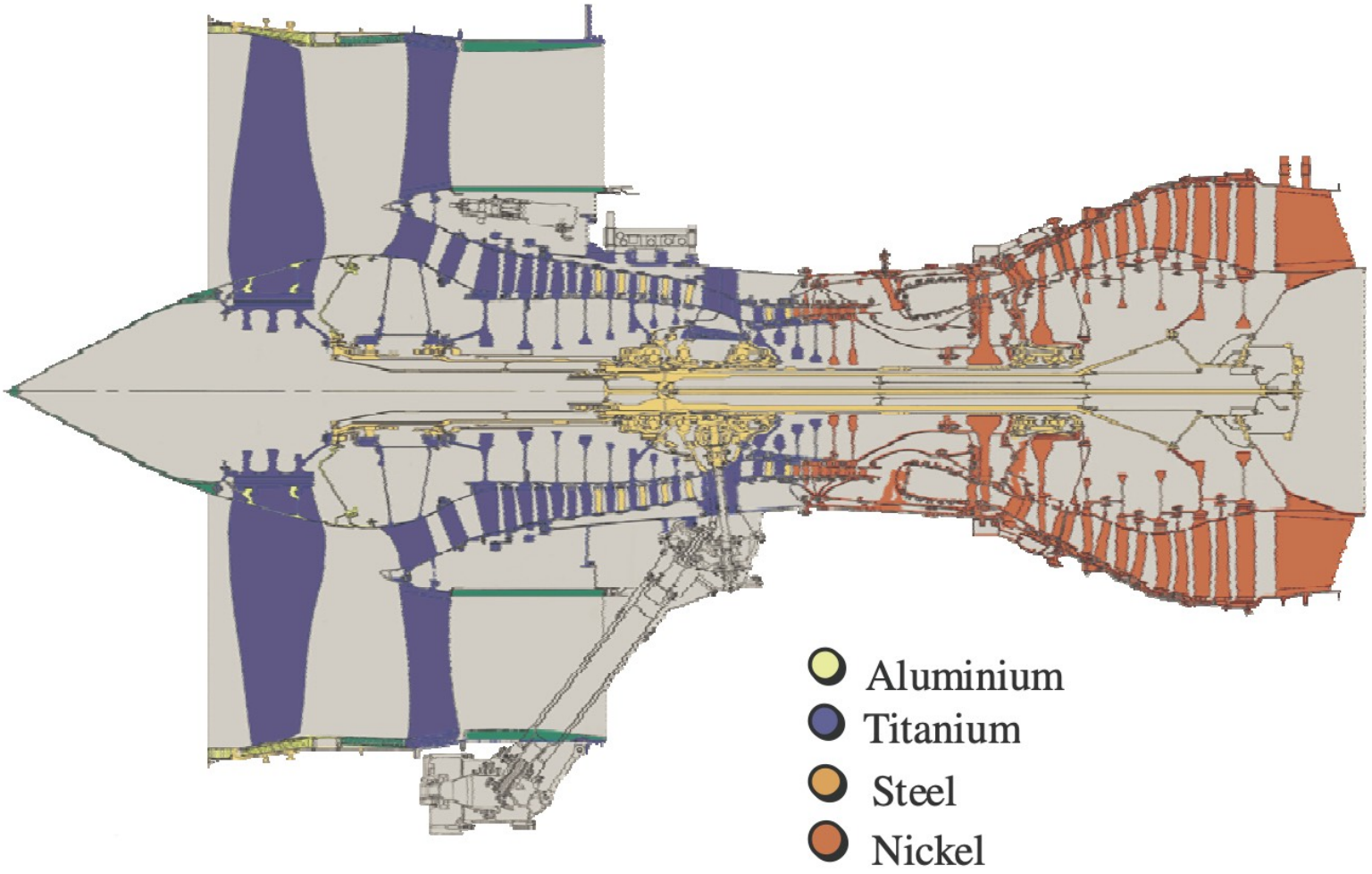


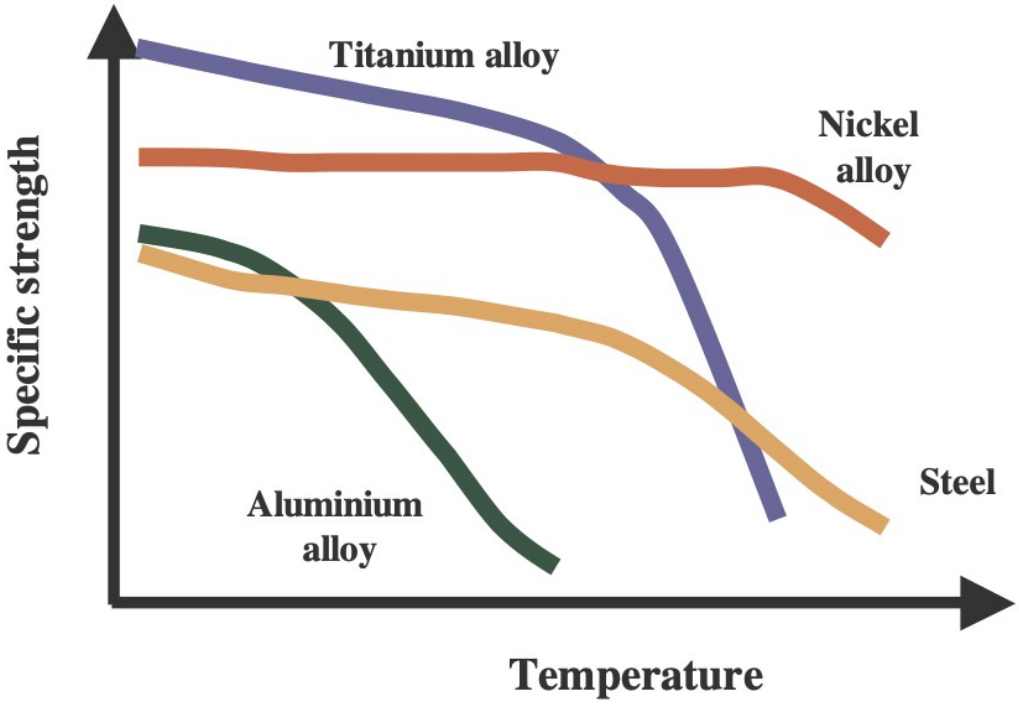

Stationary
Rotation
Rib Turbulators
Shaped Internal Cooling Passage
Trailing Edge Coolant Ejection
Film Cooling
Trailing Edge Ejection
Pin-Fin Cooling
Internal Impingement Cooling
Film Cooling
High Temperature Combustion Gases
Showerhead
Vane
Blade

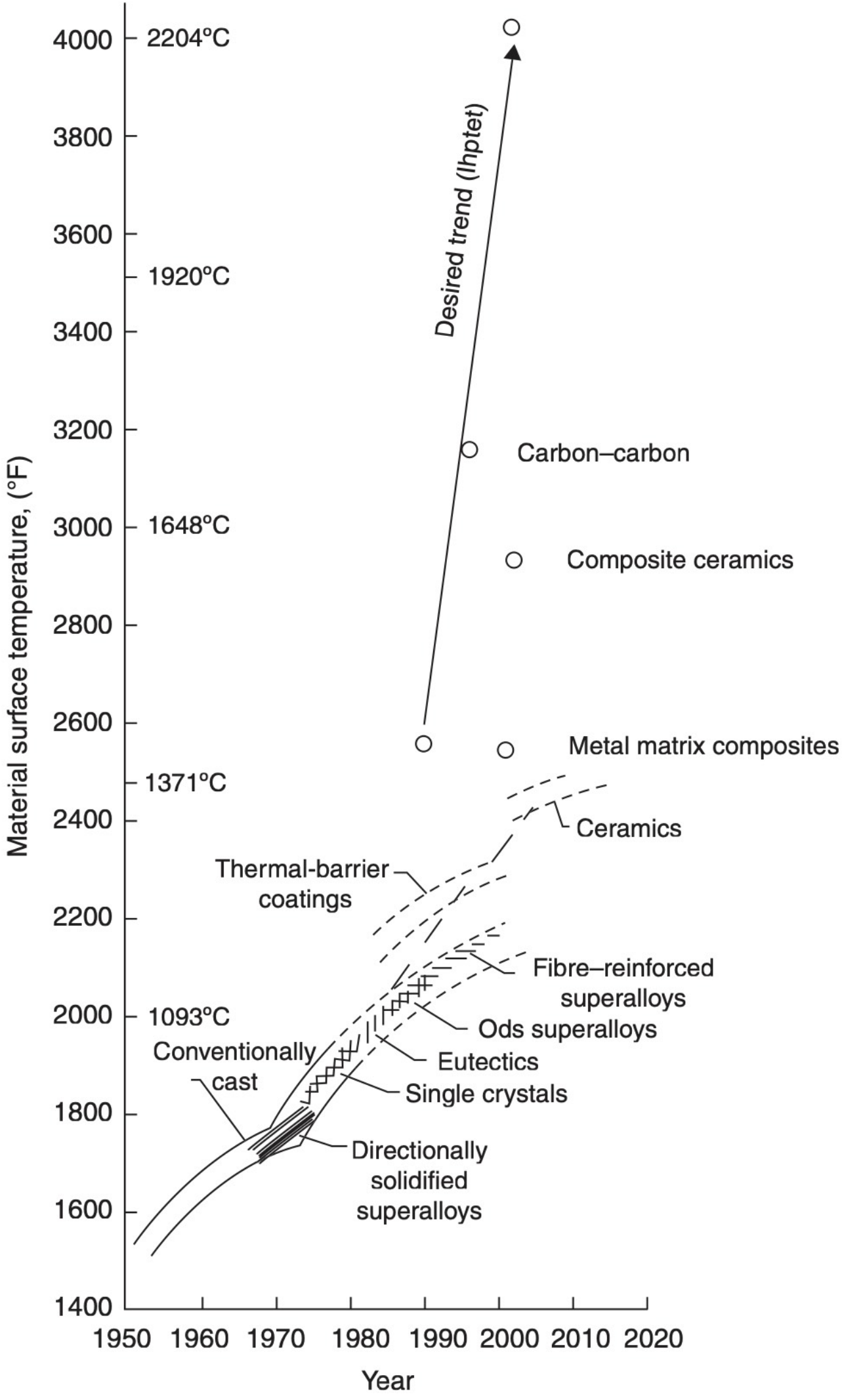

100%
0
Gross Cooling Efficiency
Convection+ Film cooling+TBC
Convection+Film cooling
Convection cooling
Heat Loading Parameter


Turbine entry temperature (°K)
2600
2400
2200
2000
1800
1600
1400
1200
1000
1950
1960
1970
1980
1990
2010
Year
Projected trend new material
New cooling concept
Transpiration and others
Film impingement convection
Introduction of blade cooling
Sophisticated cooling systems
Simple cooling
Convection
Allowable metal temperature
Uncooled turbines

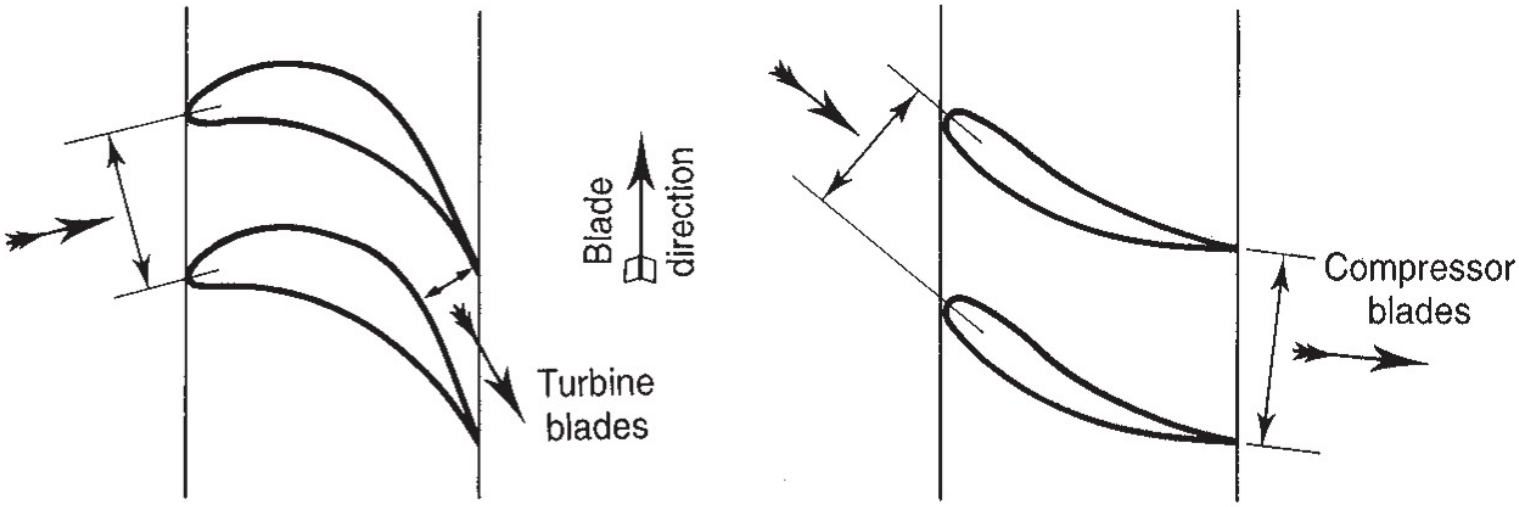



Aluminium
Titanium
Steel
Nickel

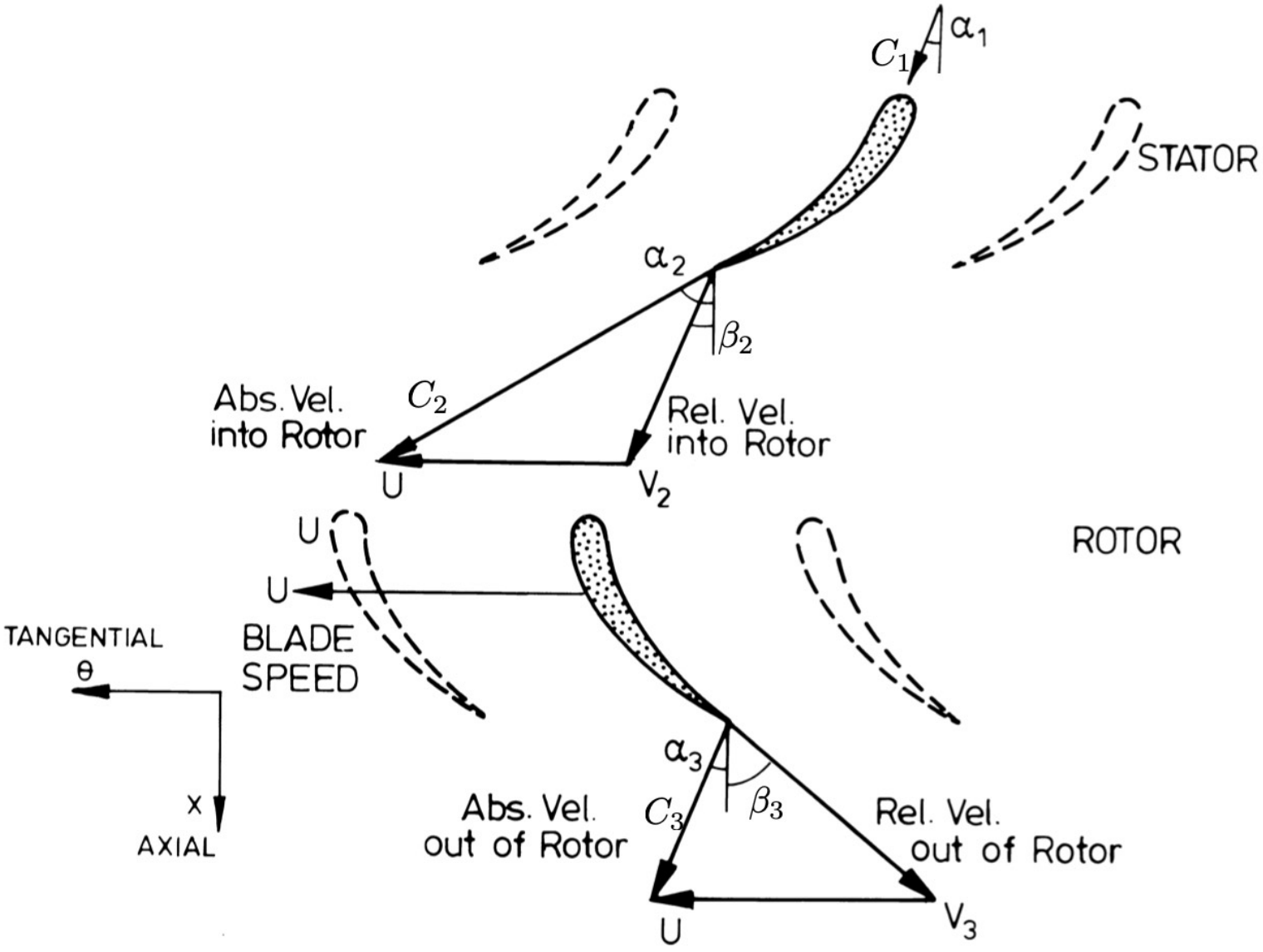

Titanium alloy
Nickel alloy
Steel
Aluminium alloy
Specific strength
Temperature


Material surface temperature, (°F)
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
2204°C
1920°C
1648°C
1371°C
1093°C
1950
1960
1970
1980
1990
2000
2010
2020
Year
Desired trend (lhptet)
Carbon–carbon
Composite ceramics
Metal matrix composites
Ceramics
Thermal-barrier coatings
Fibre–reinforced superalloys
Ods superalloys
Eutectics
Single crystals
Conventionally cast
Directionally solidified superalloys

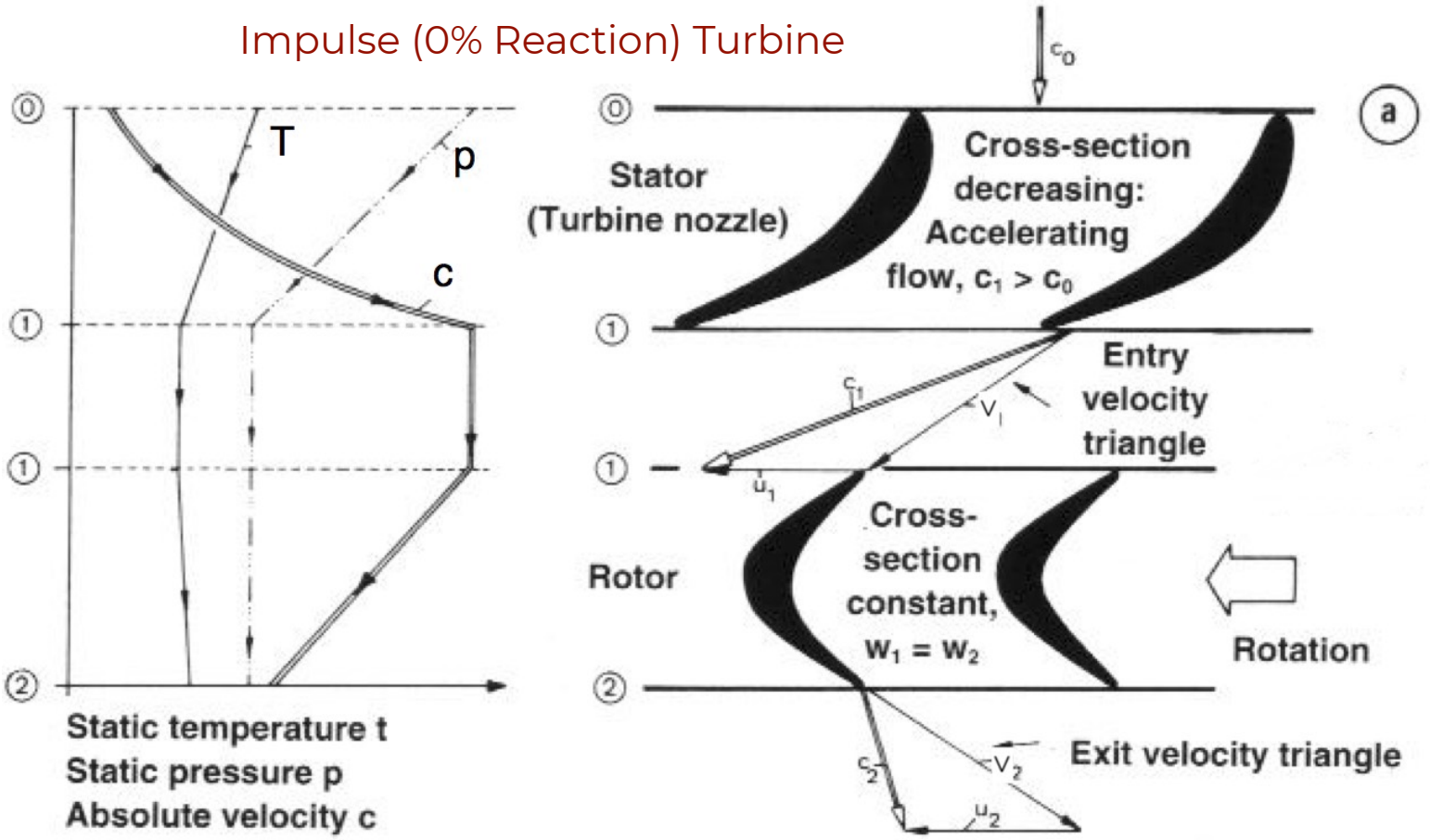
Comparison of flow path in compressors and turbines



Velocity Triangles for a turbine stage



Impulse (0% Reaction) Turbine



(50%) Reaction Turbine