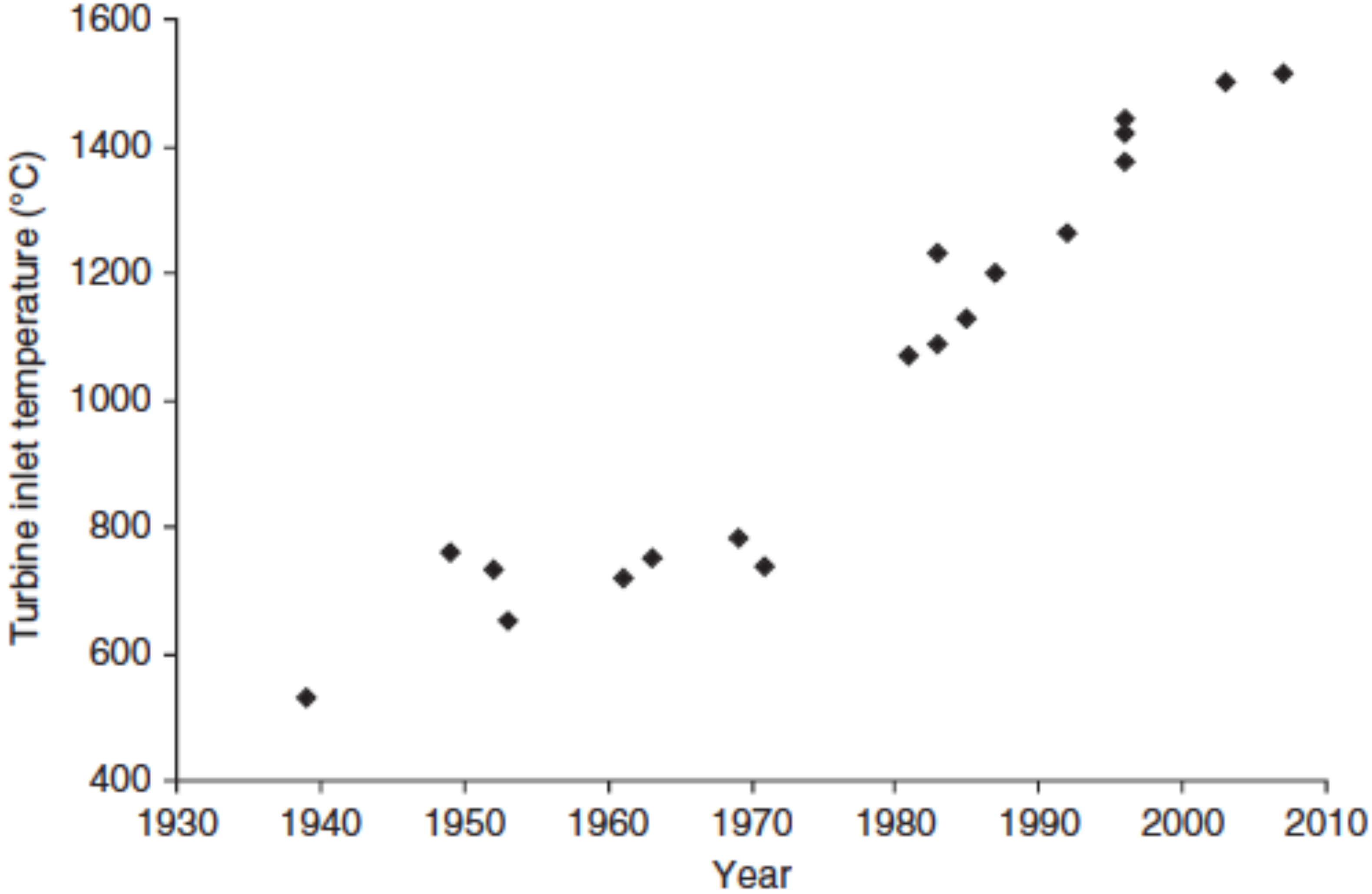
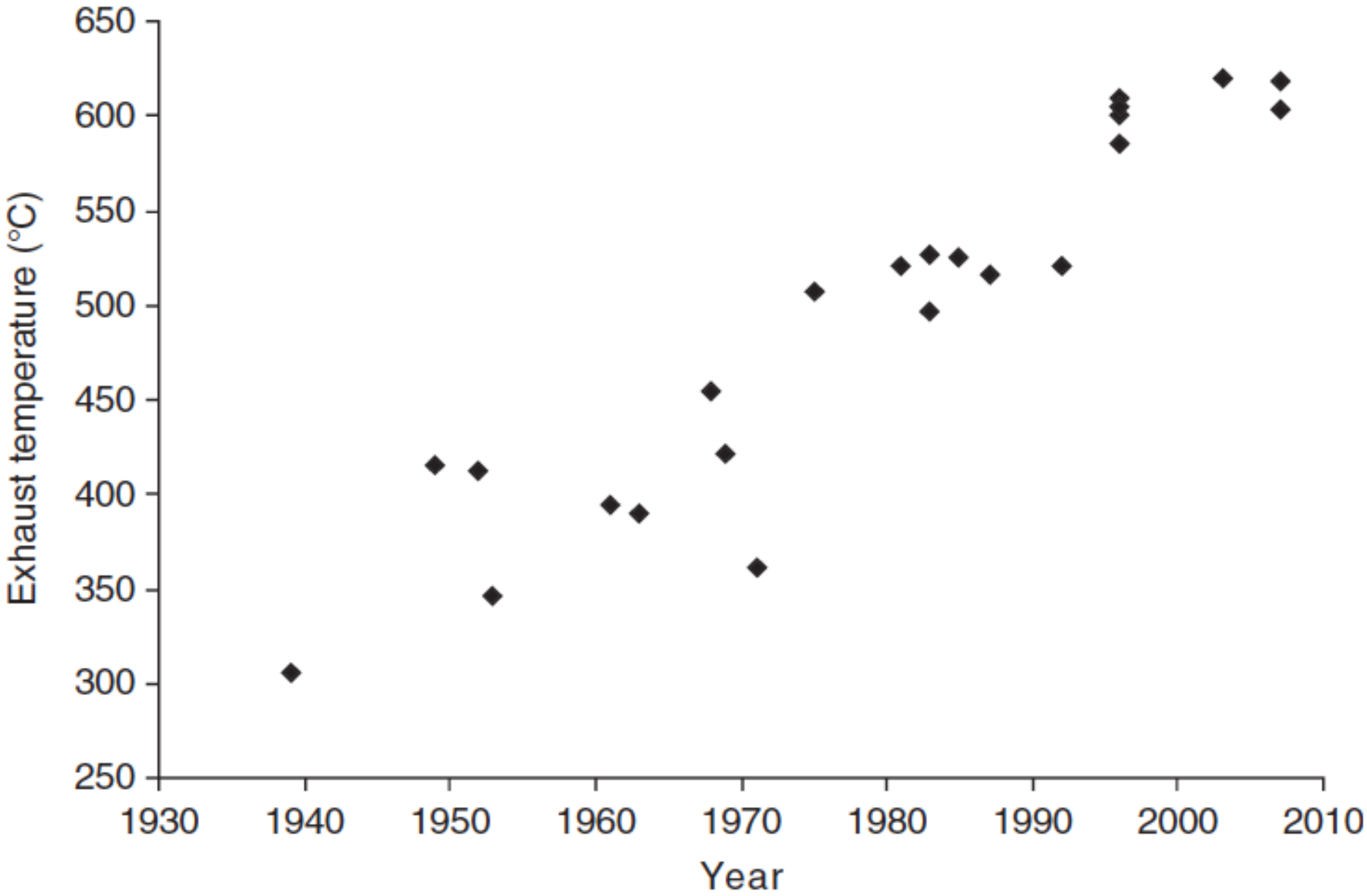
Gas turbine blade cooling

Trend of TIT

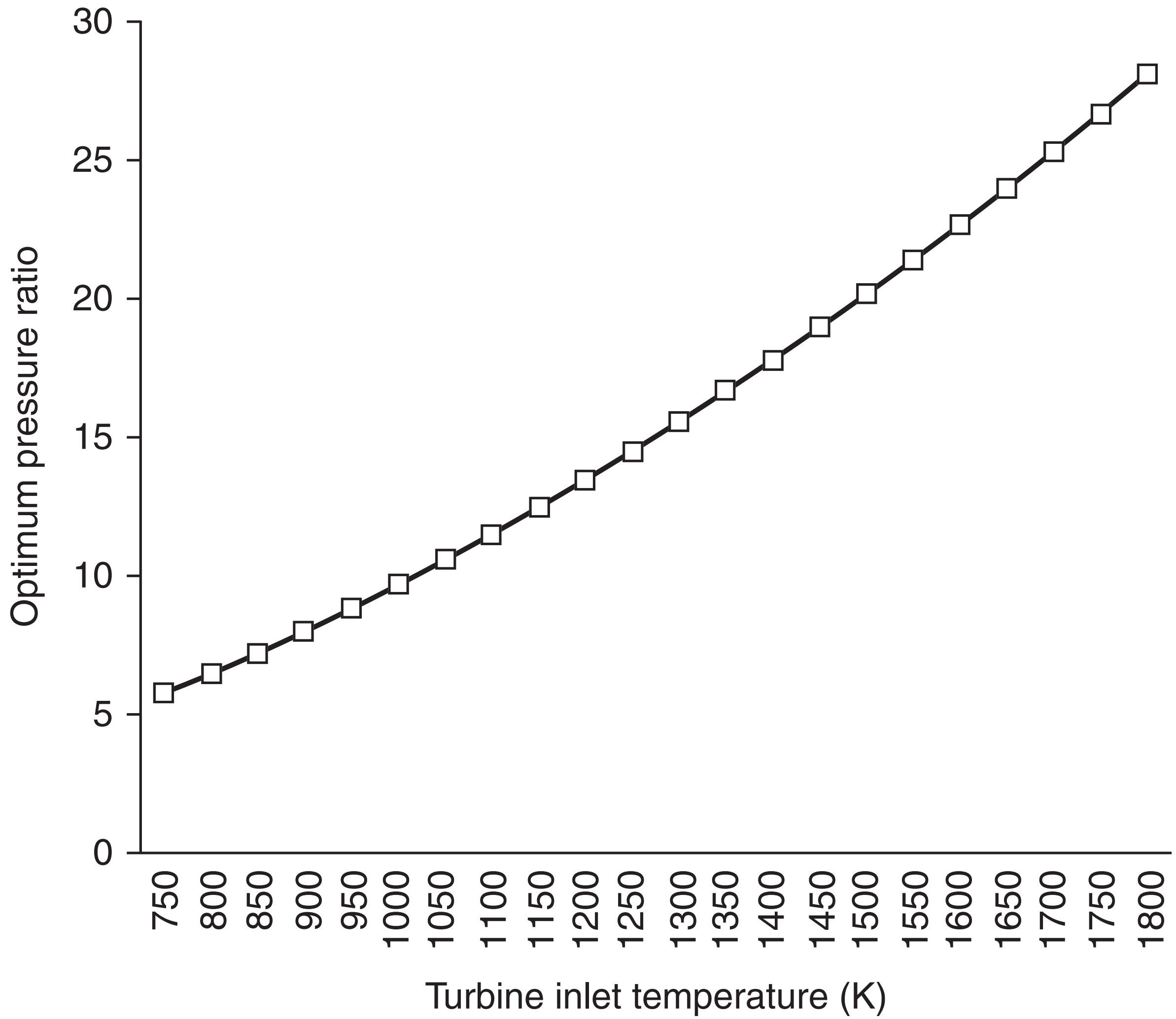


1600
1400
1200
1000
800
600
400
Turbine inlet temperature (°C)
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year

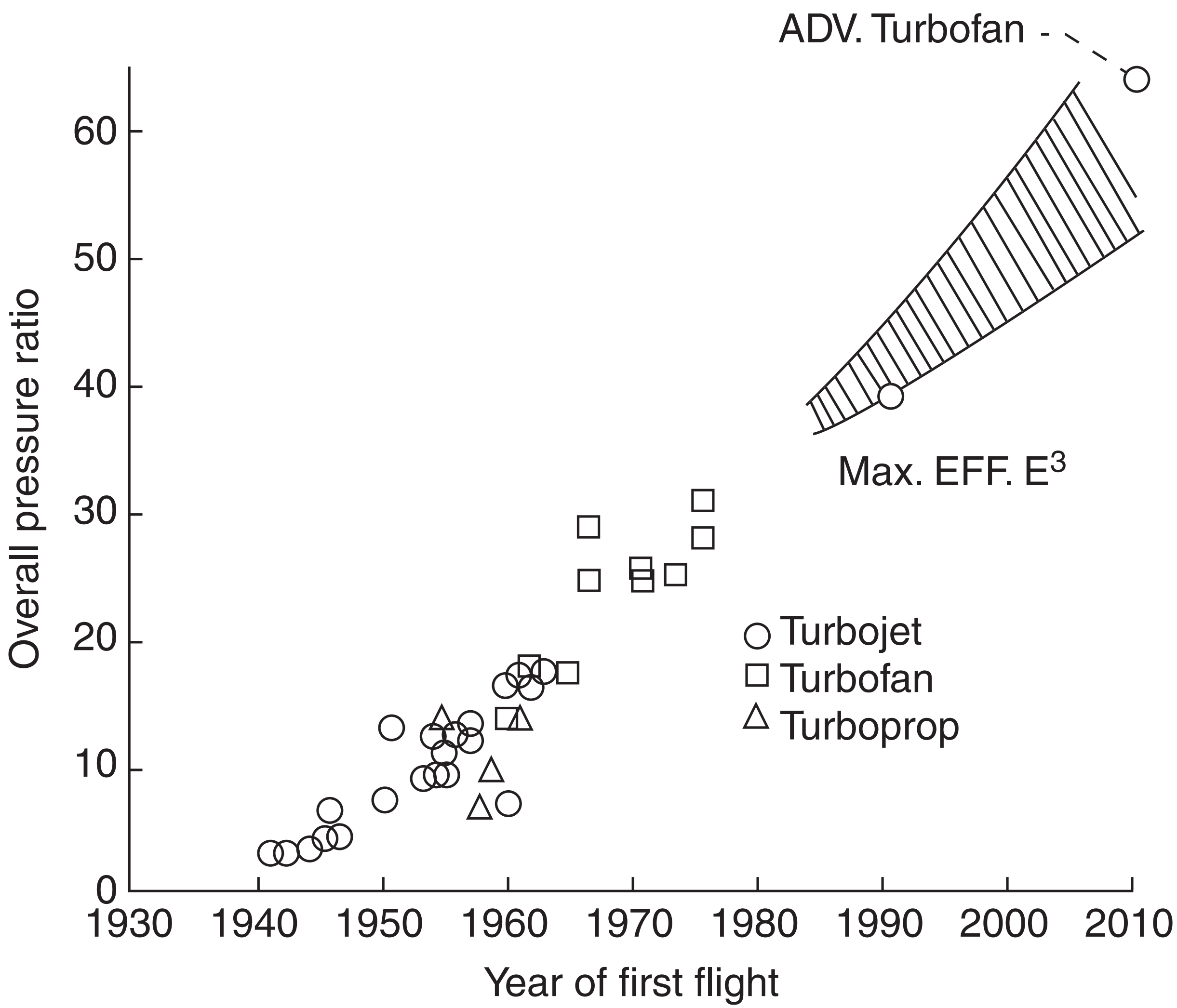
Trend of exhaust temperature



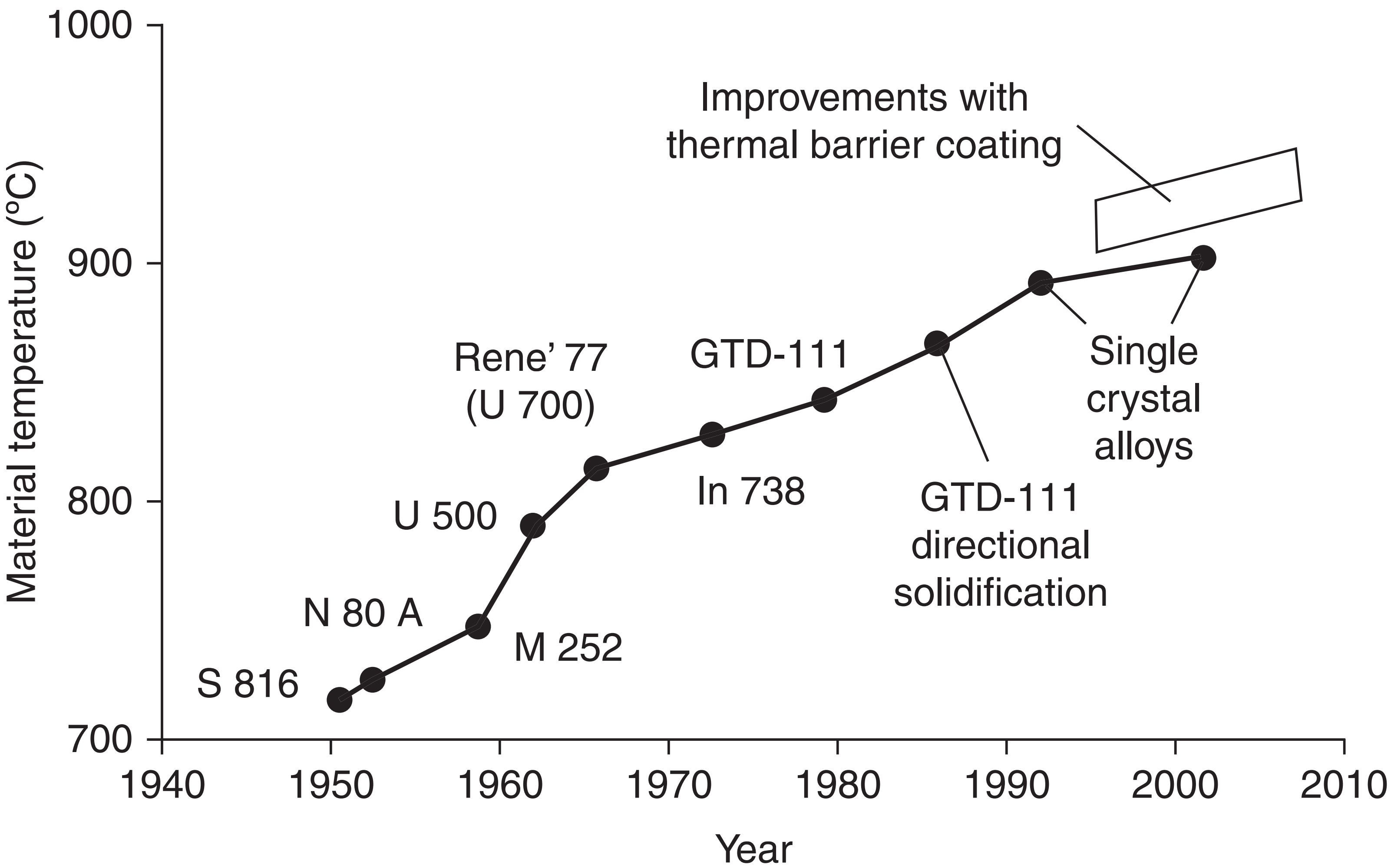
Pressure ratio at maximum power



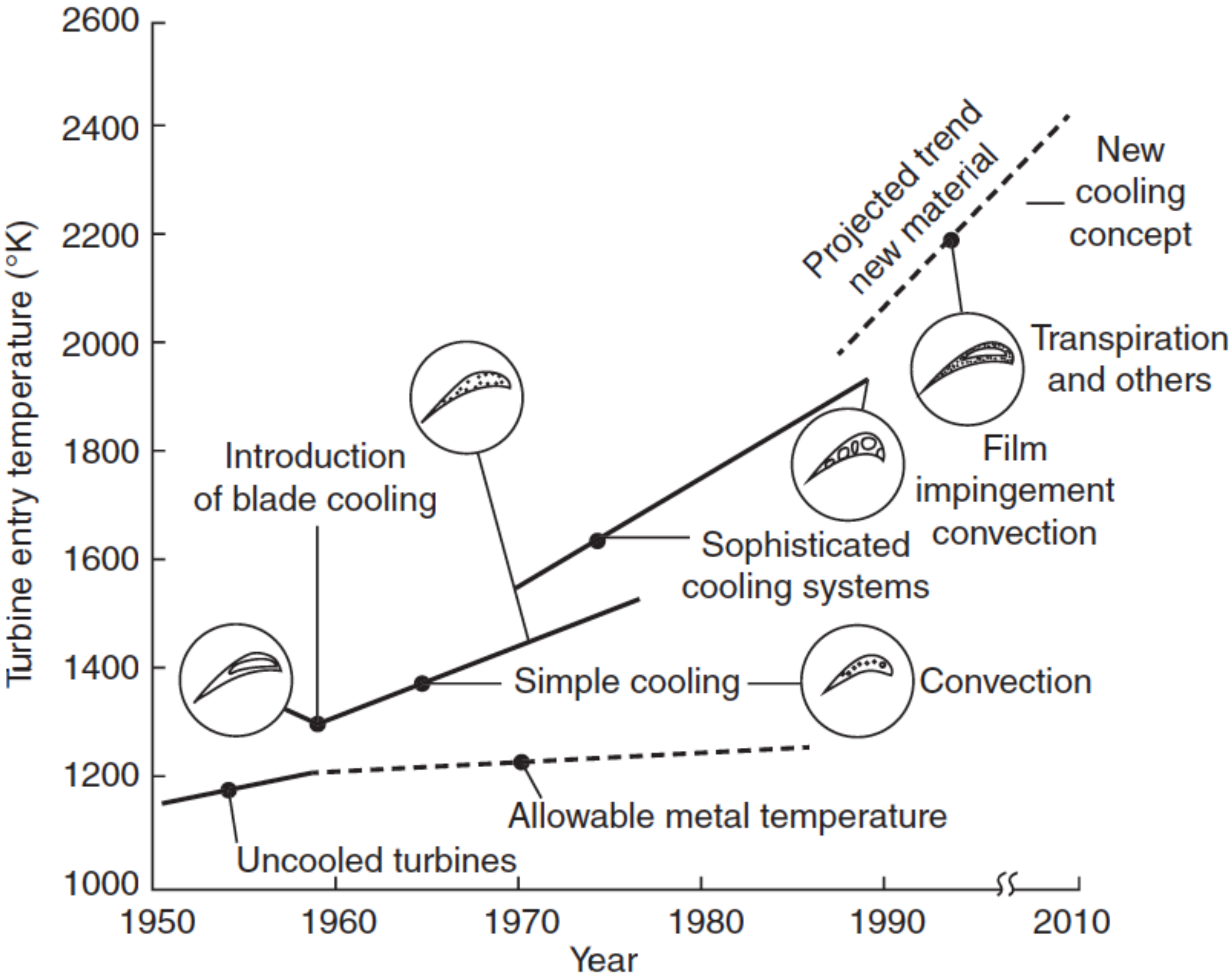
Trend of pressure ratio

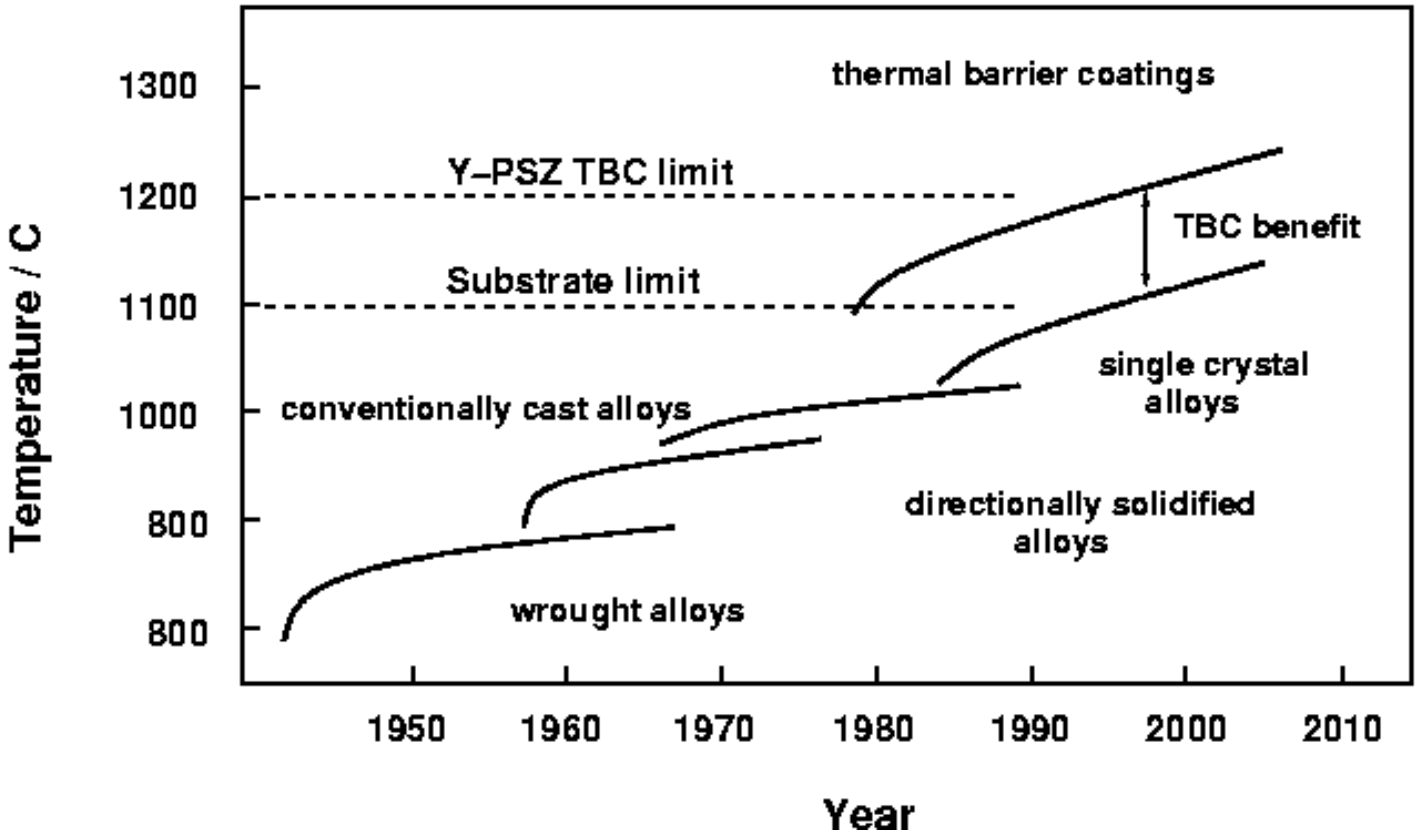


Trend of material temperature

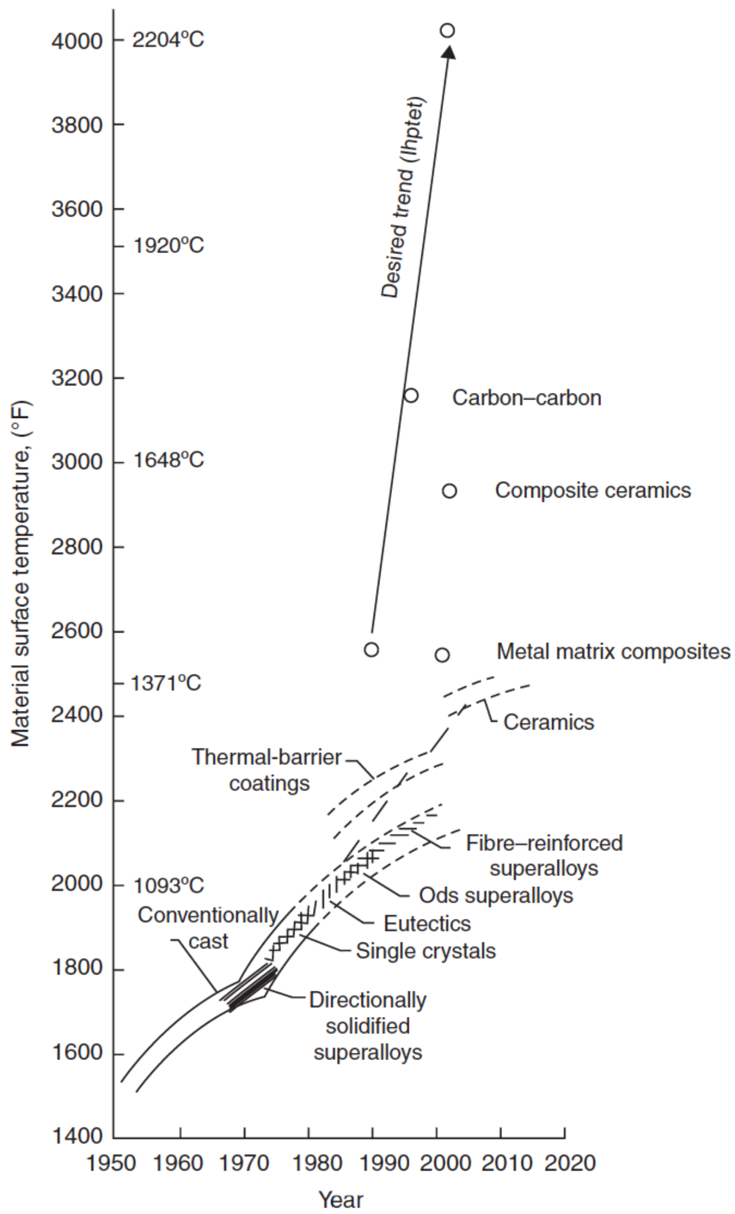


Trend of material temperature




thermal barrier coatings
Y–PSZ TBC limit
TBC benefit
Substrate limit
single crystal
alloys
conventionally cast alloys
directionally solidified
alloys
wrought alloys
Temperature / C
1300
1200
1100
1000
800
800
1950
1960
1970
1980
1990
2000
2010
Year

Desired trend of material temperature



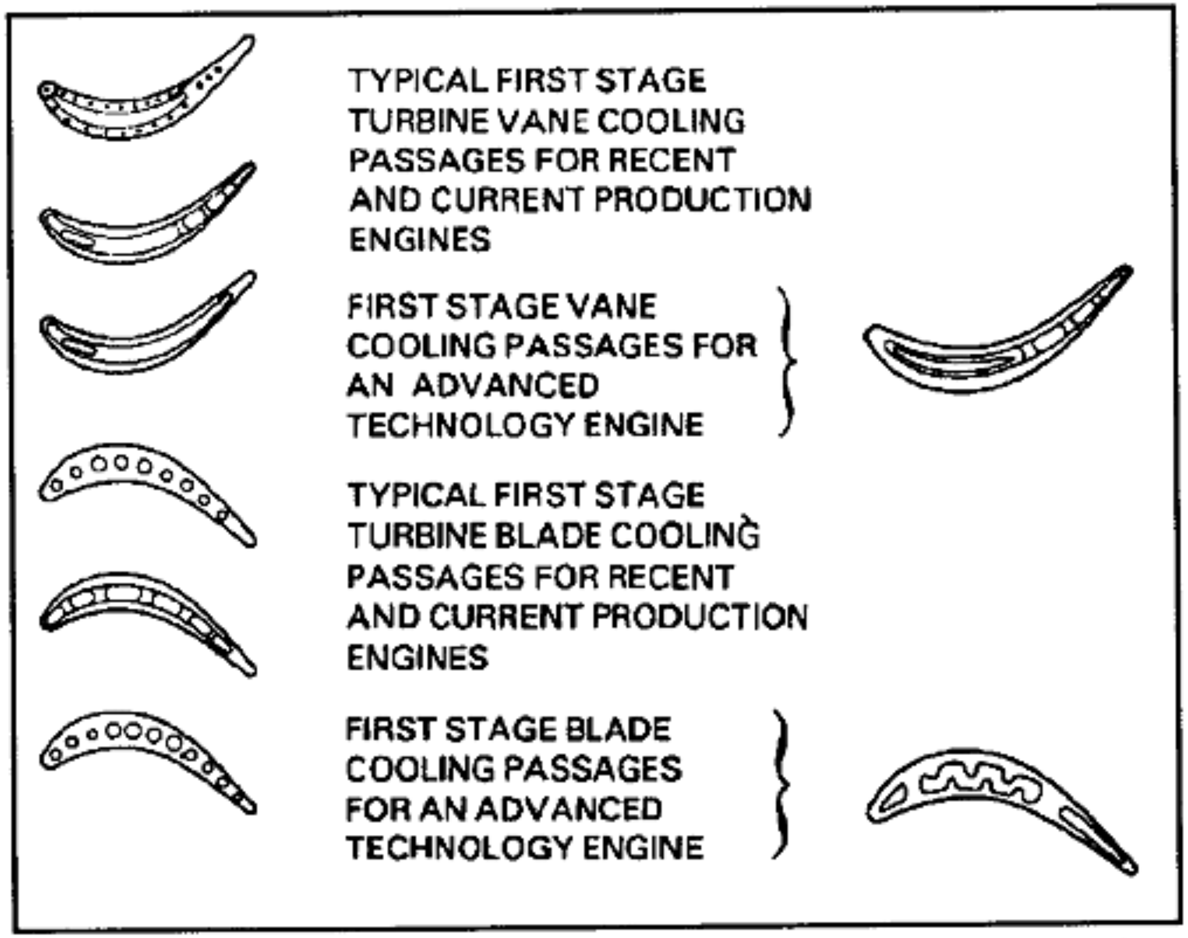
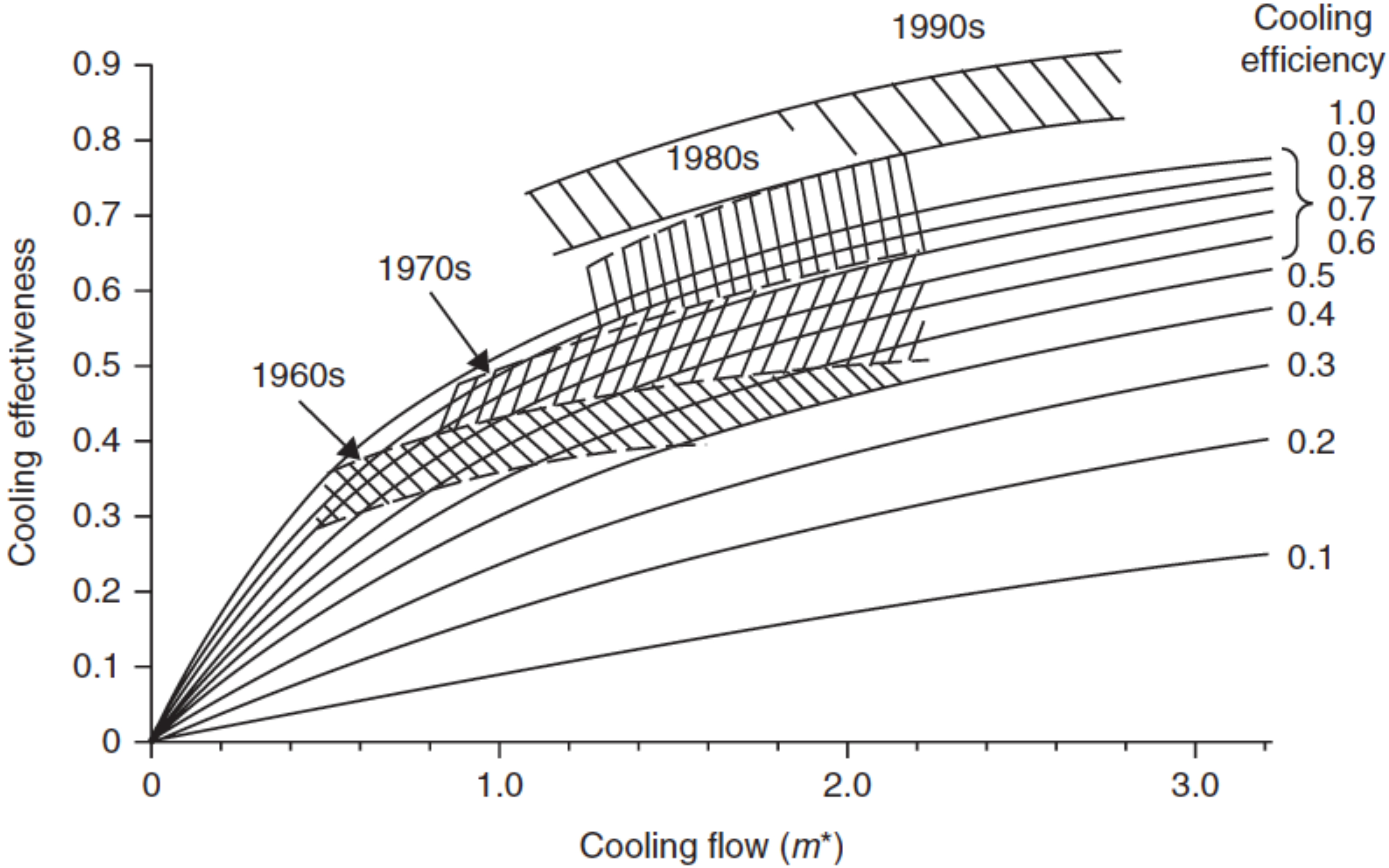


Figure 3-19. Examples of Typical Transpiration-Cooling Blades

Cooling effectiveness and efficiency



Cooling effectiveness and efficiency

- Cooling effectiveness is defined as:

$$\Phi = \frac{\left(T_m - T_{hg}\right)}{\left(T_c - T_{hg}\right)}$$

- Cooling efficiency is defined as:

$$\eta_{cool} = \frac{\left(T_{c,out} - T_{c,in}\right)}{\left(T_m - T_{c,in}\right)}$$

- The heat load parameter or mass flow function is defined as:

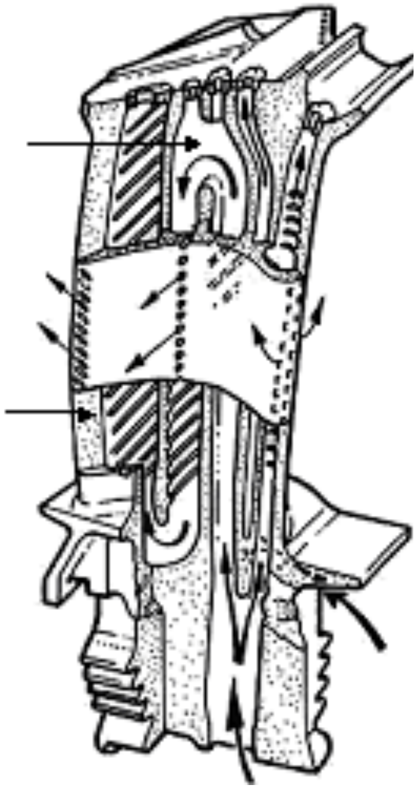
$$m^{*} = \frac{c_{p,c} \cdot m_c}{A_{hg} \cdot h_{hg}}$$

Film cooling effectiveness

- The film cooling effectiveness is defined as:

$$\eta_{film} = \frac{\left(T_{film} - T_{hg}\right)}{\left(T_c - T_{hg}\right)}$$

- If the film temperature is at the cooling air temperature the effectiveness is 1. When the film temperature is the same as the hot gas temperature the effectiveness is 0.
- This parameter defines how much the film is mixed with hot gas and changes along the blade



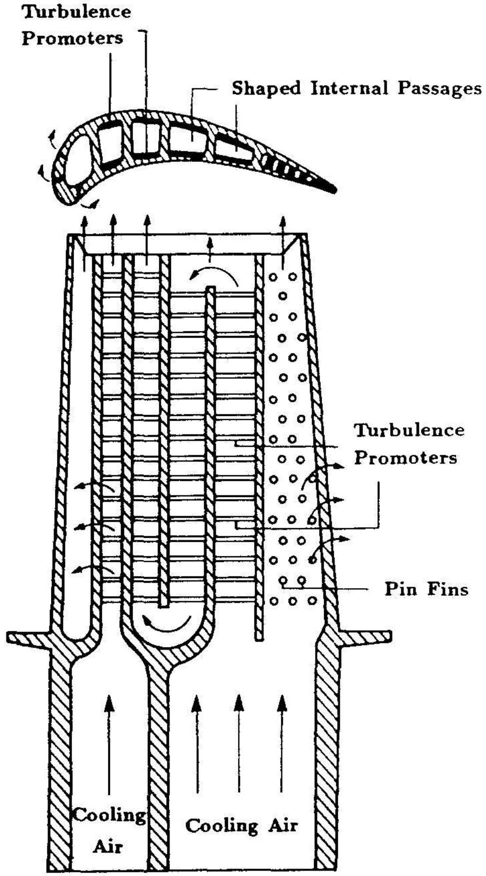


Fig. 1 Cooling concepts of a modern multipass turbine blade

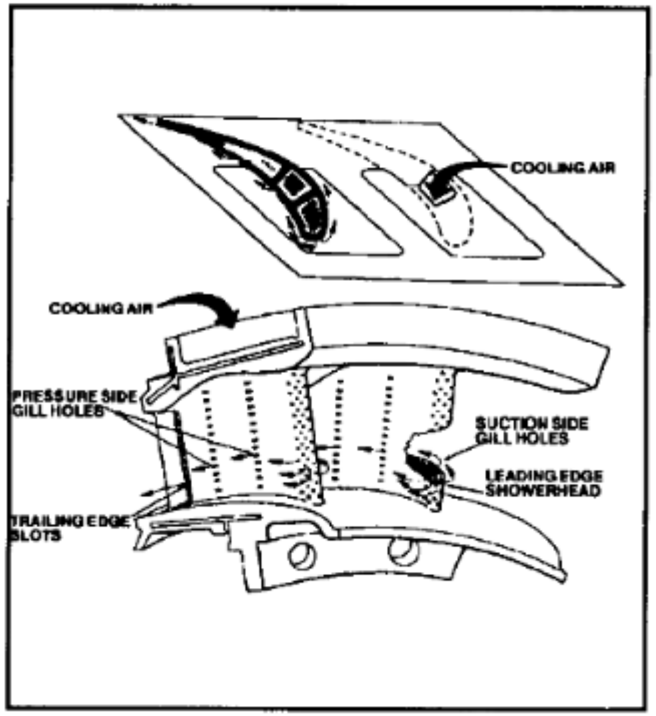
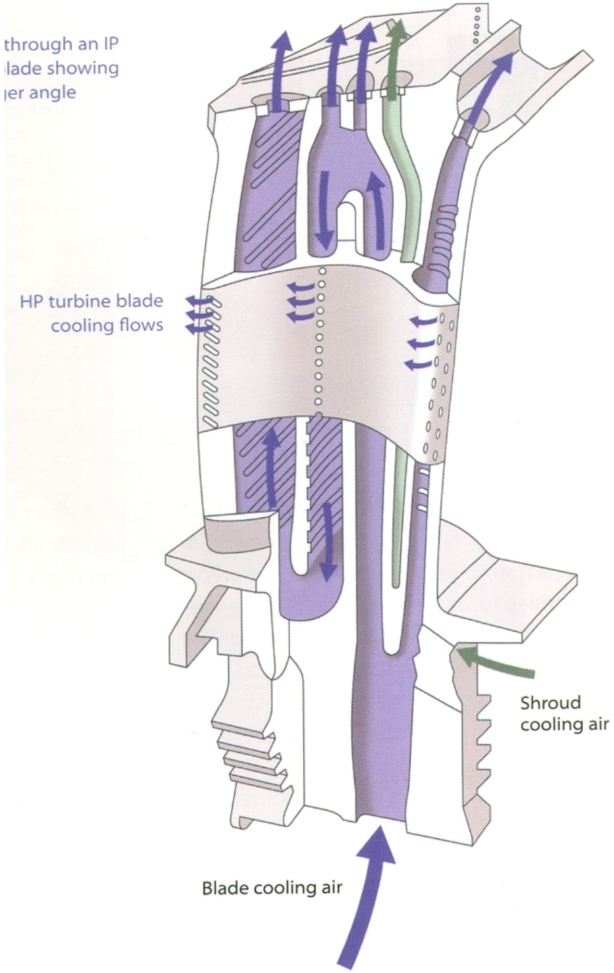
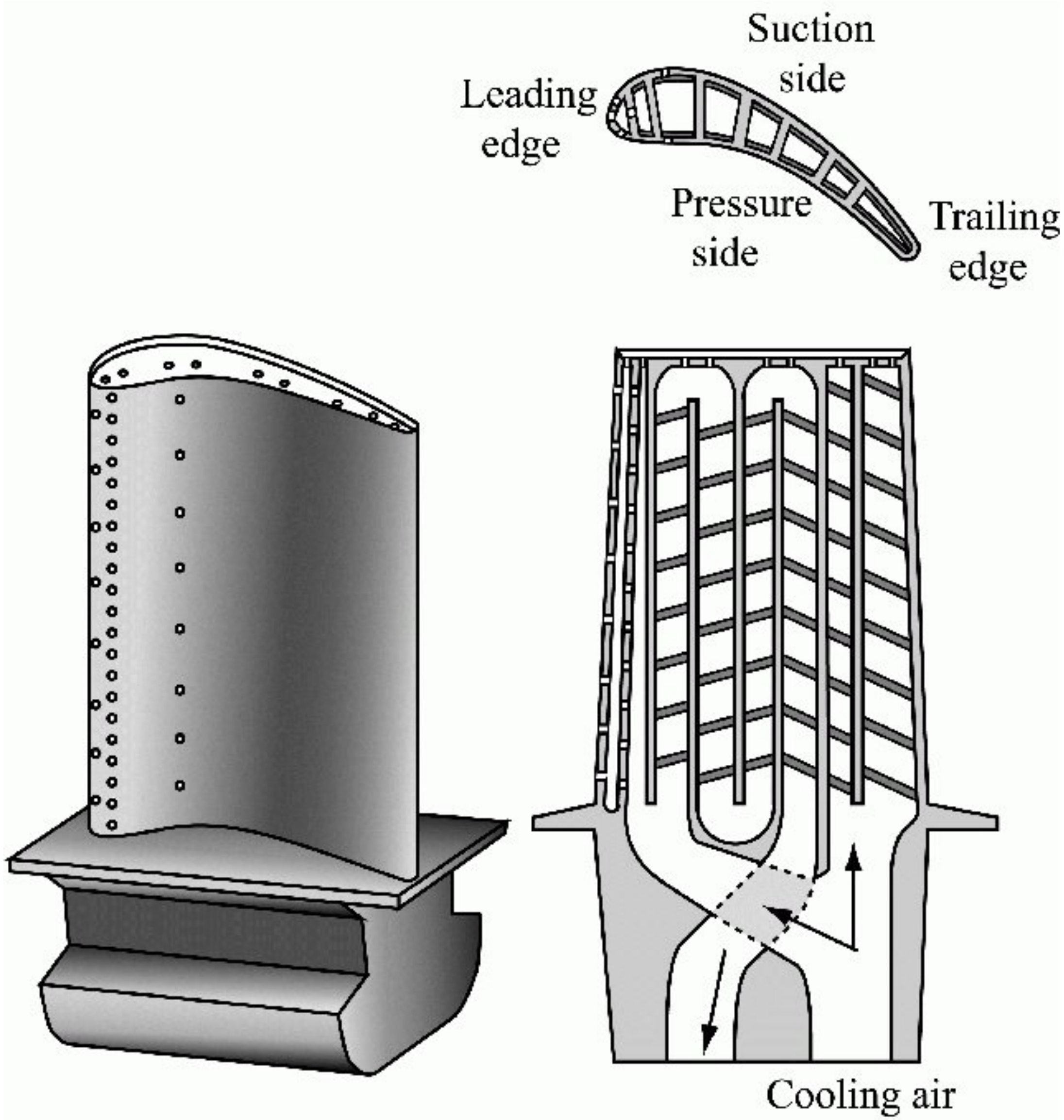
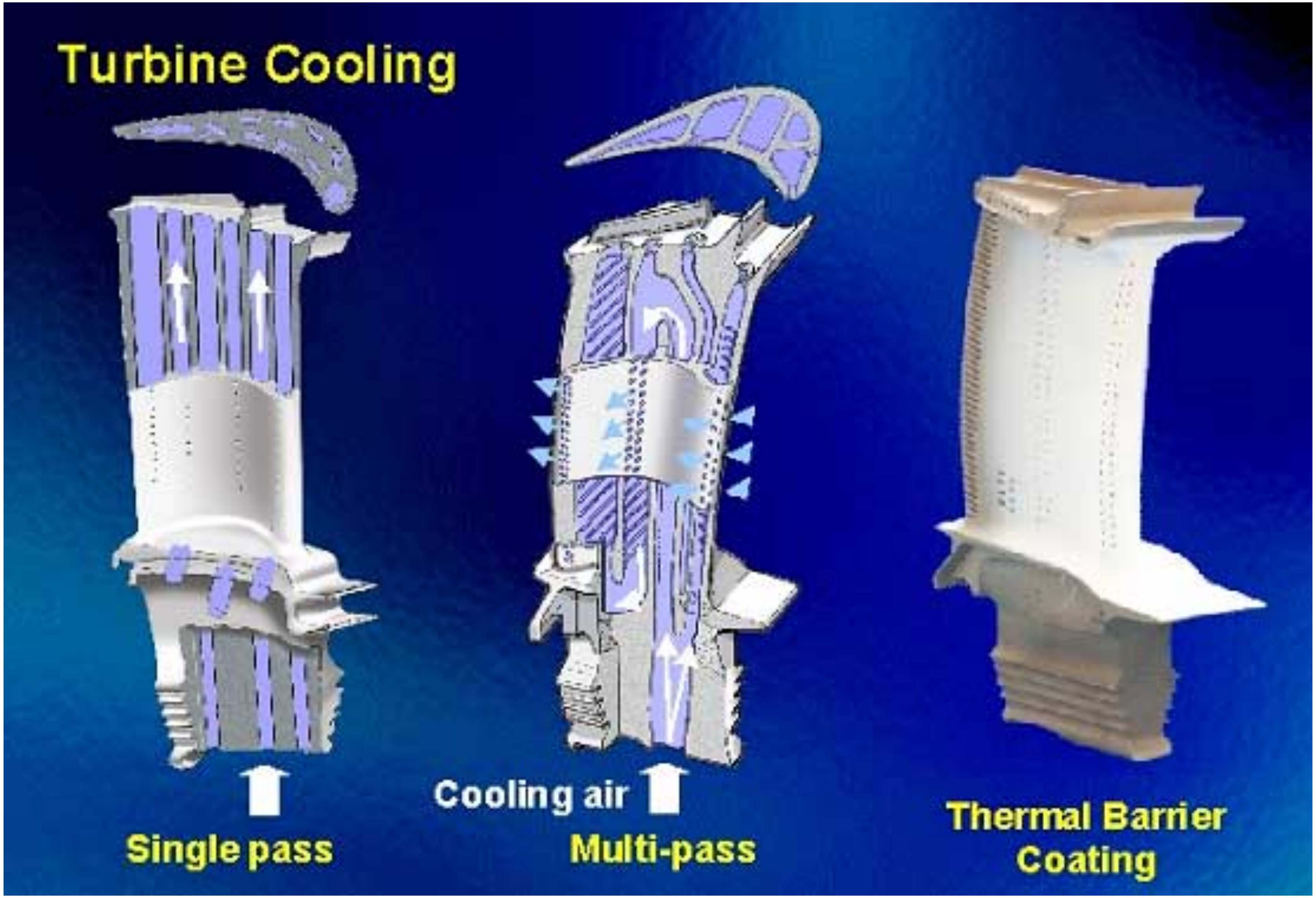


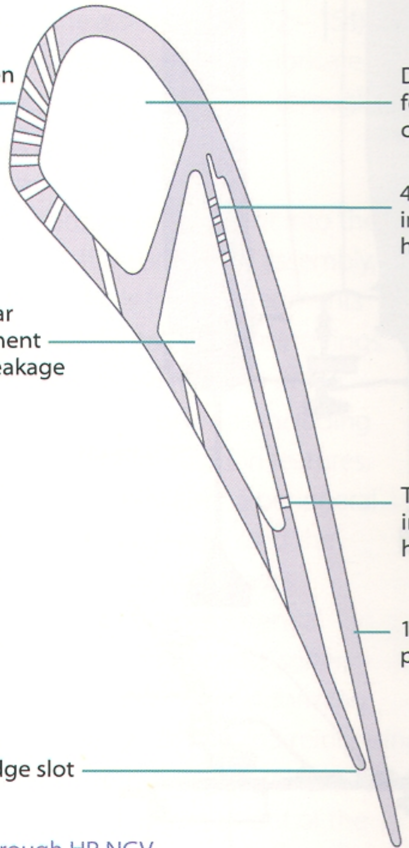
Figure 3-18. Turbine Nozzle Cooling


through an IP
lade showing
jer angle
HP turbine blade
cooling flows
Shroud
cooling air
Blade cooling air

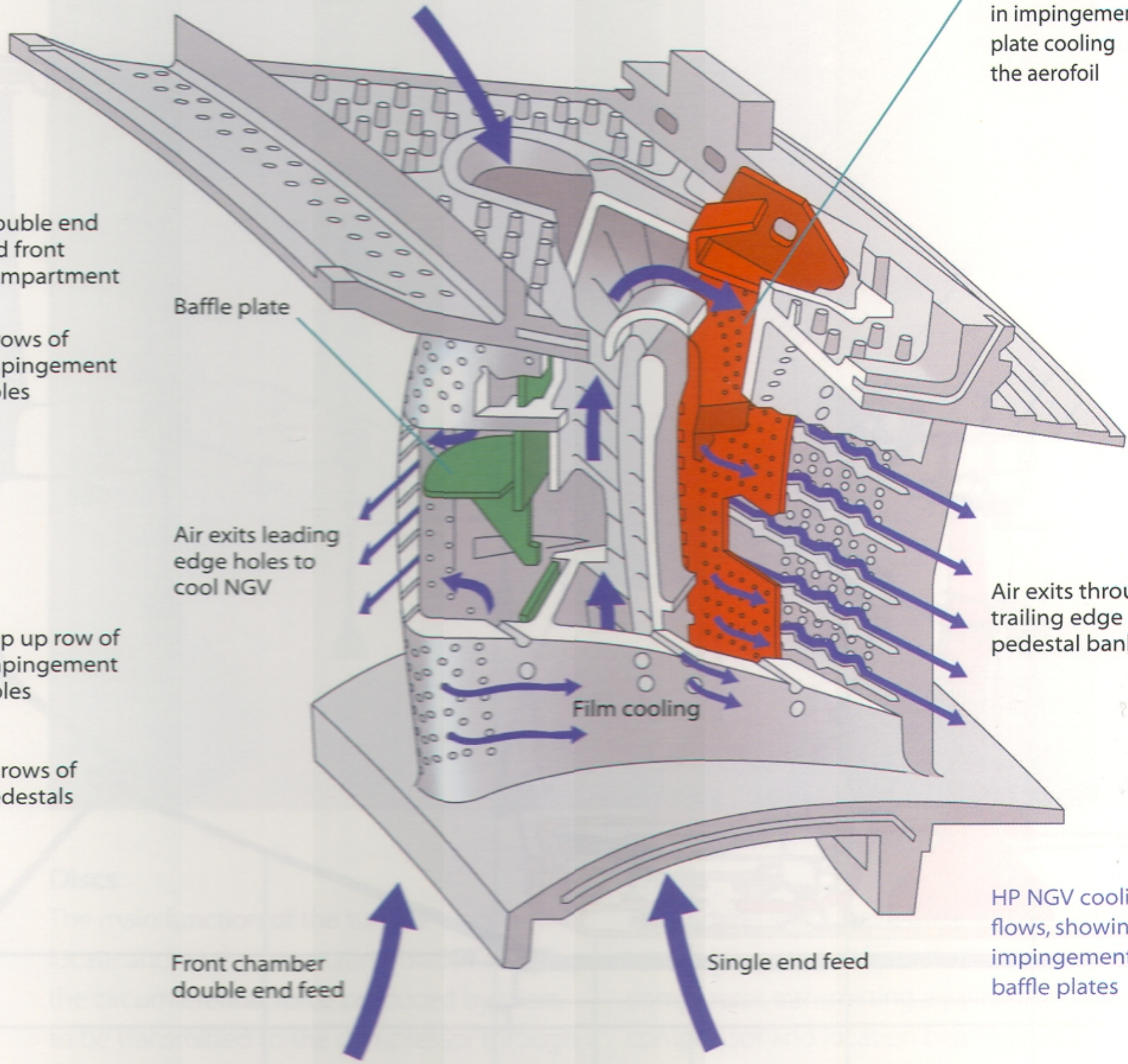

Suction
side
Leading
edge
Pressure
side
Trailing
edge
Cooling air



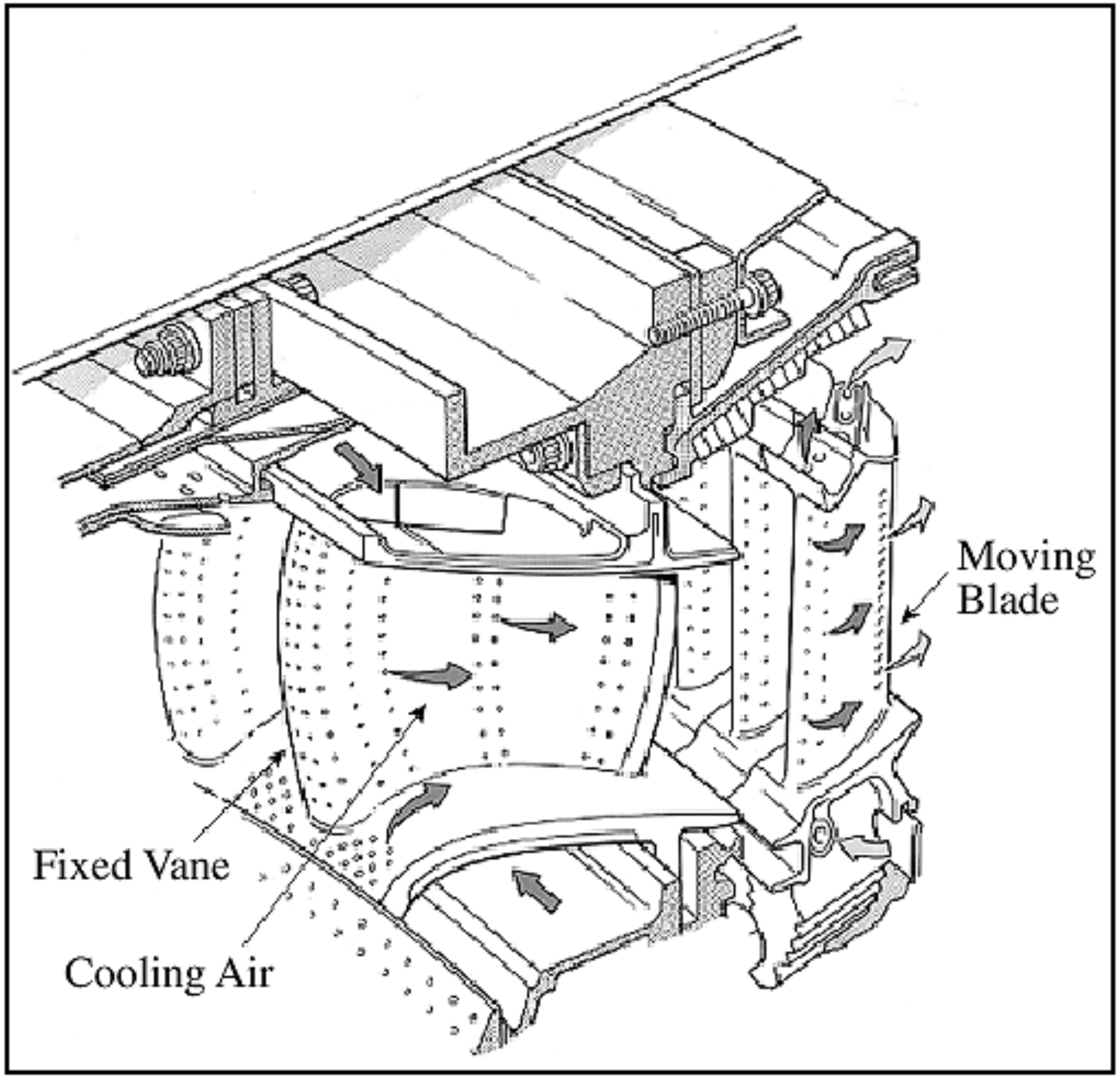
Turbine Cooling
Cooling air
Single pass
Multi-pass
Thermal Barrier
Coating

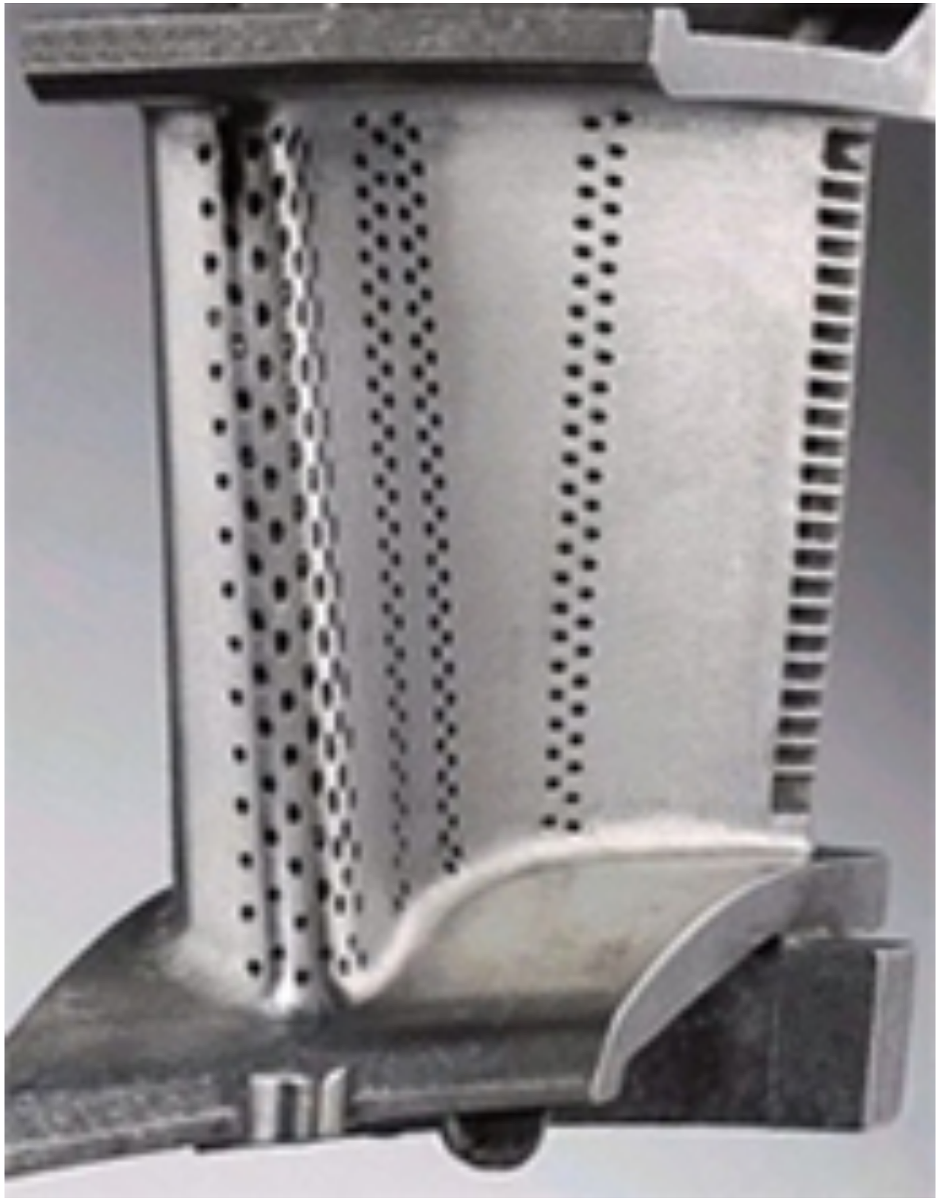


Section through HP NGV



HP NGV cooling flows, showing impingement and baffle plates


Moving
Blade
Fixed Vane
Cooling Air



Major features of an HP turbine blad[e]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