Jet Aircraft Propulsion

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Lecture 32

Off-Design Operation Of Aircraft Jet Engines

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- A cycle is normally designed at the maximum performance requirement (Thrust / Power *and/or* Efficiency) point.
- As a result once the engine is designed, much higher performance is not possible. But lower performance schedules are quite possible.
- Each of these 'other' operating points are known as a ***off-design operating point***. The efficiency at these off-design points is always lower than the design point efficiency.

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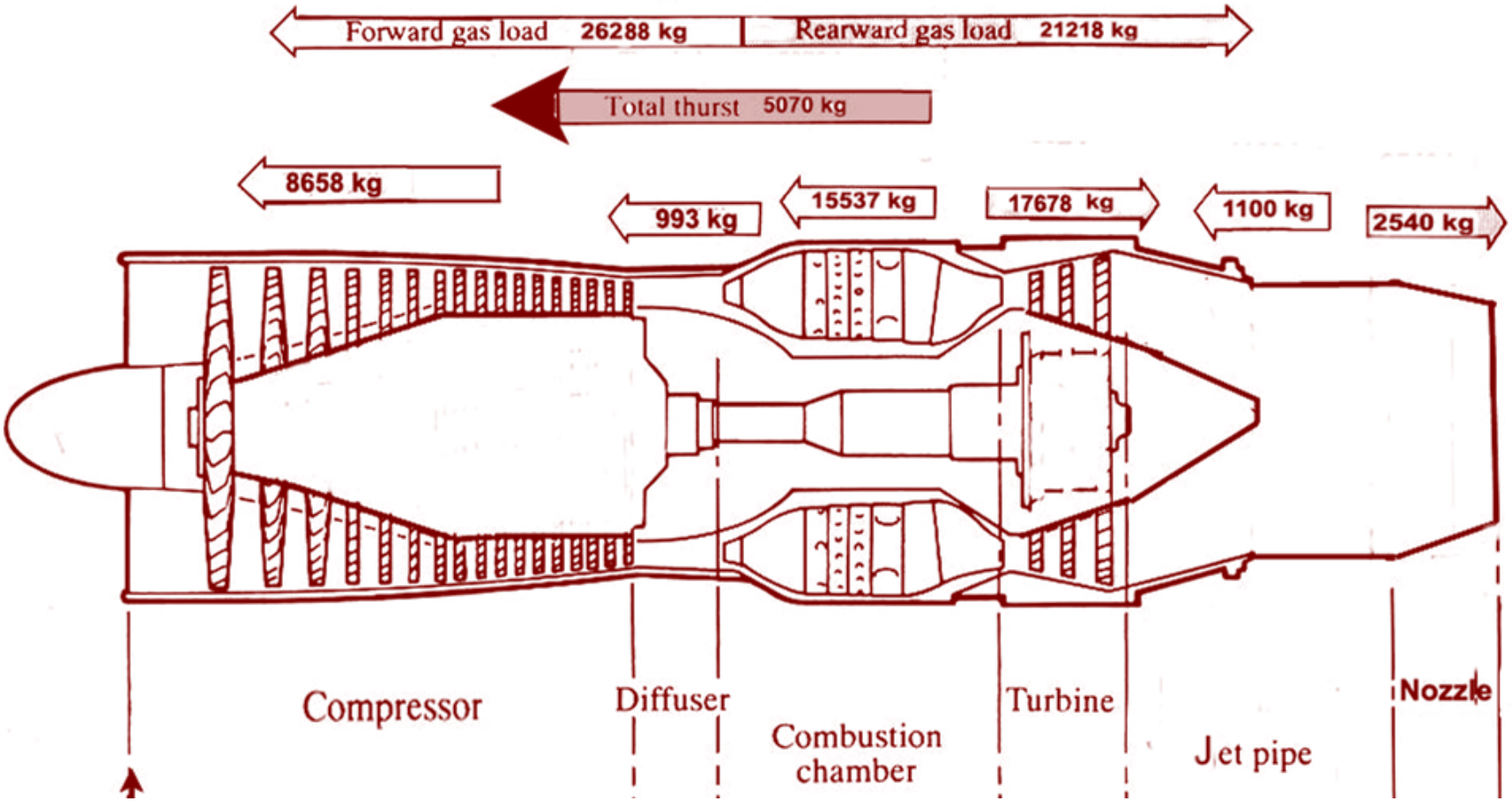
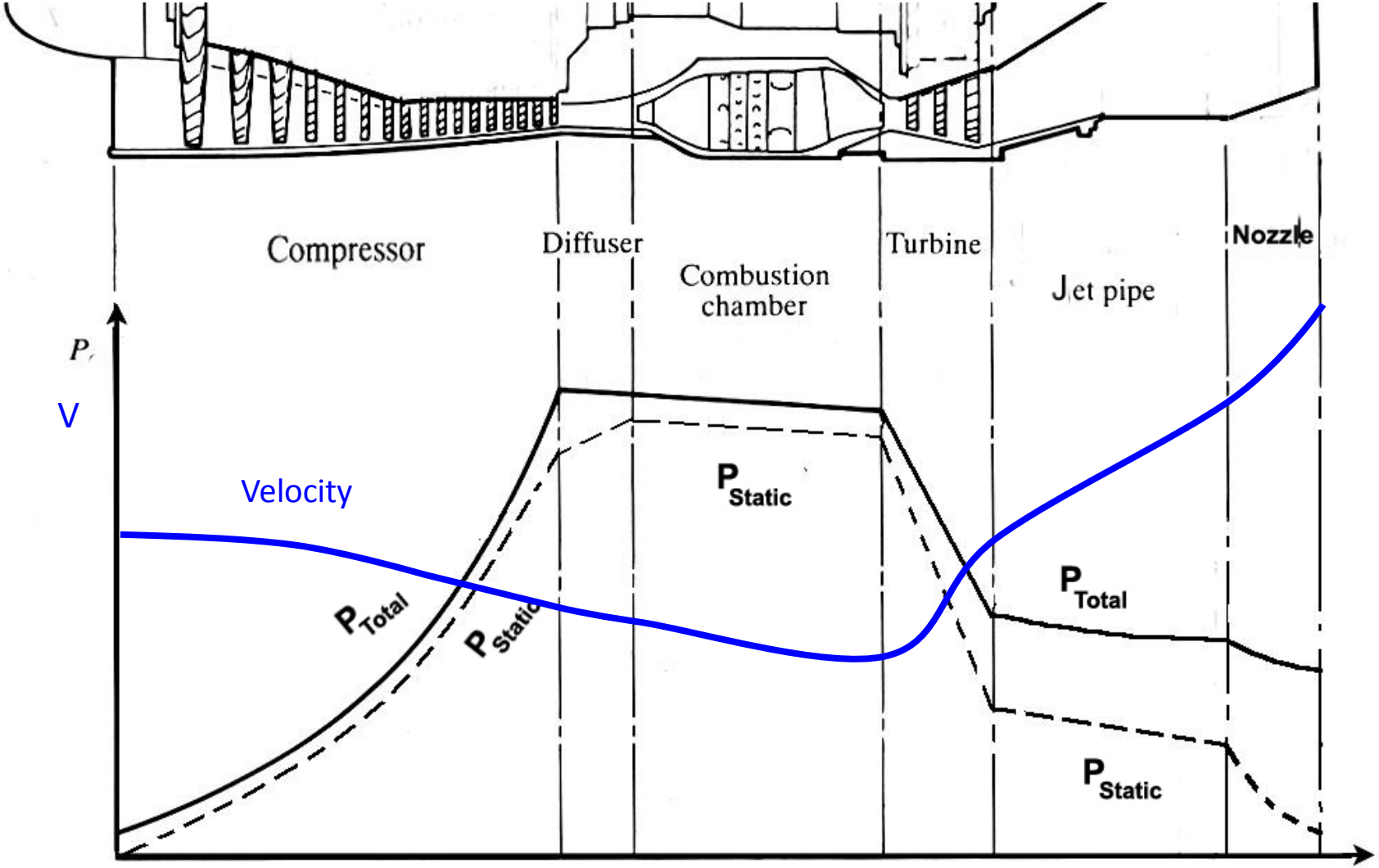
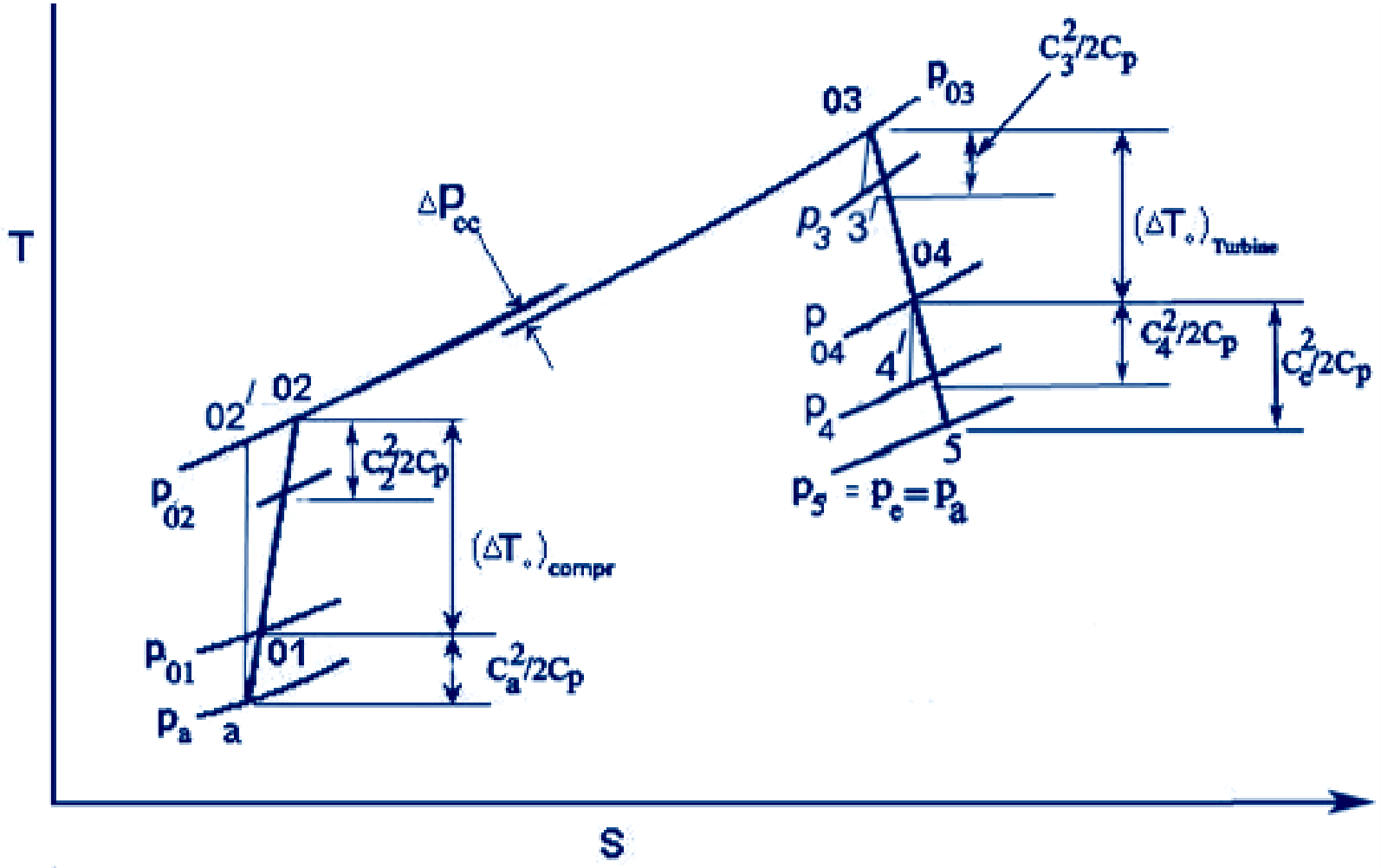
Thrust creation at design point operation



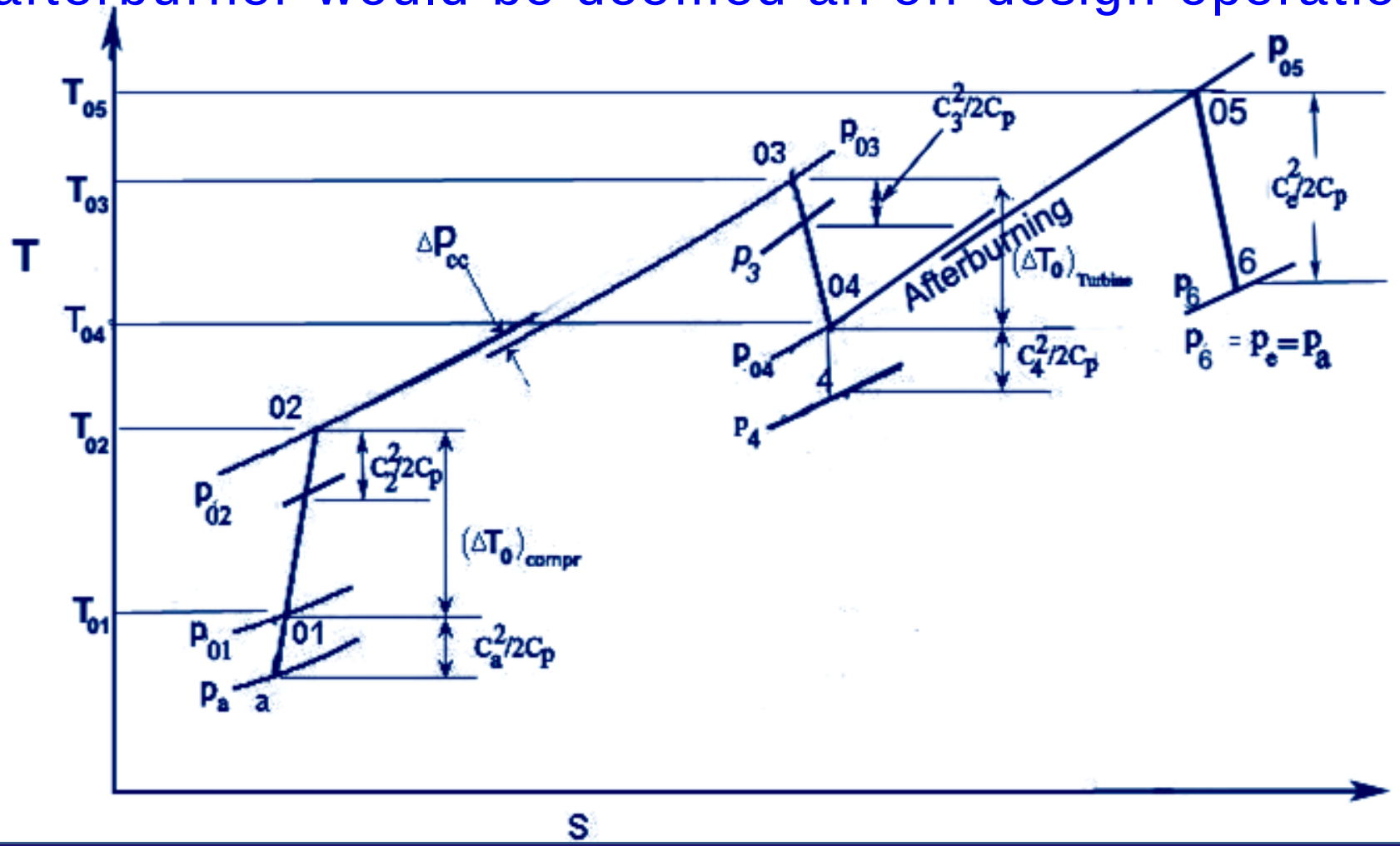

Compressor
Diffuser
Combustion chamber
Turbine
Jet pipe
Nozzle
P
V
Velocity
P Static
P Total
P Total
P Static
P Static

1) All the above positive and negative thrust values shall change with different operating conditions
2) All the above pressure , temperature and velocity values will change at different operating conditions
3) Thus all aircraft engines are effectively variable cycle engines.
4) Except the take-off (Design point) operation, all other flight operations are at engine off-design operations

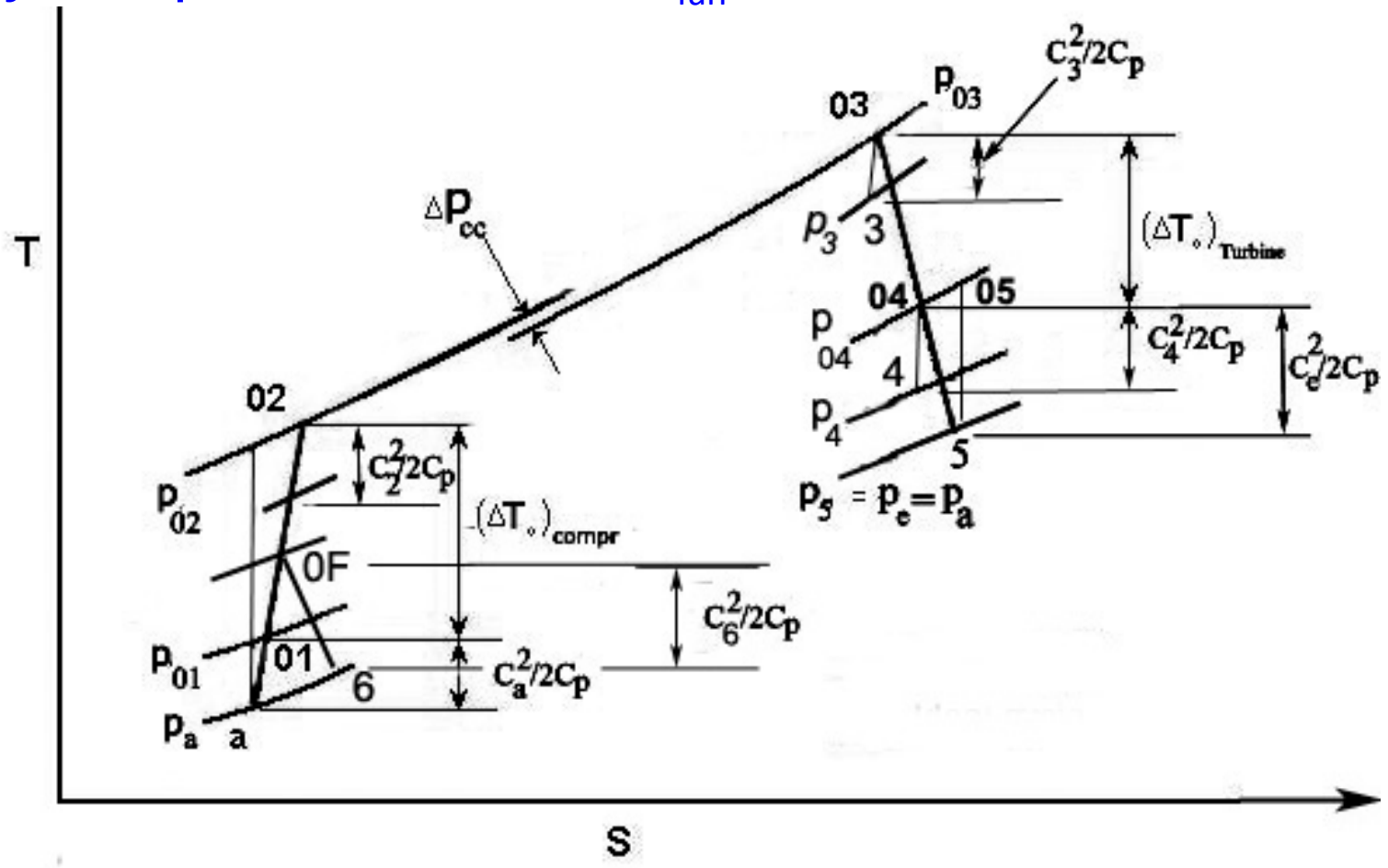
The cycle nodal points (a, 01, 02, 03, 04, 5) change during off-design operation of the engine.



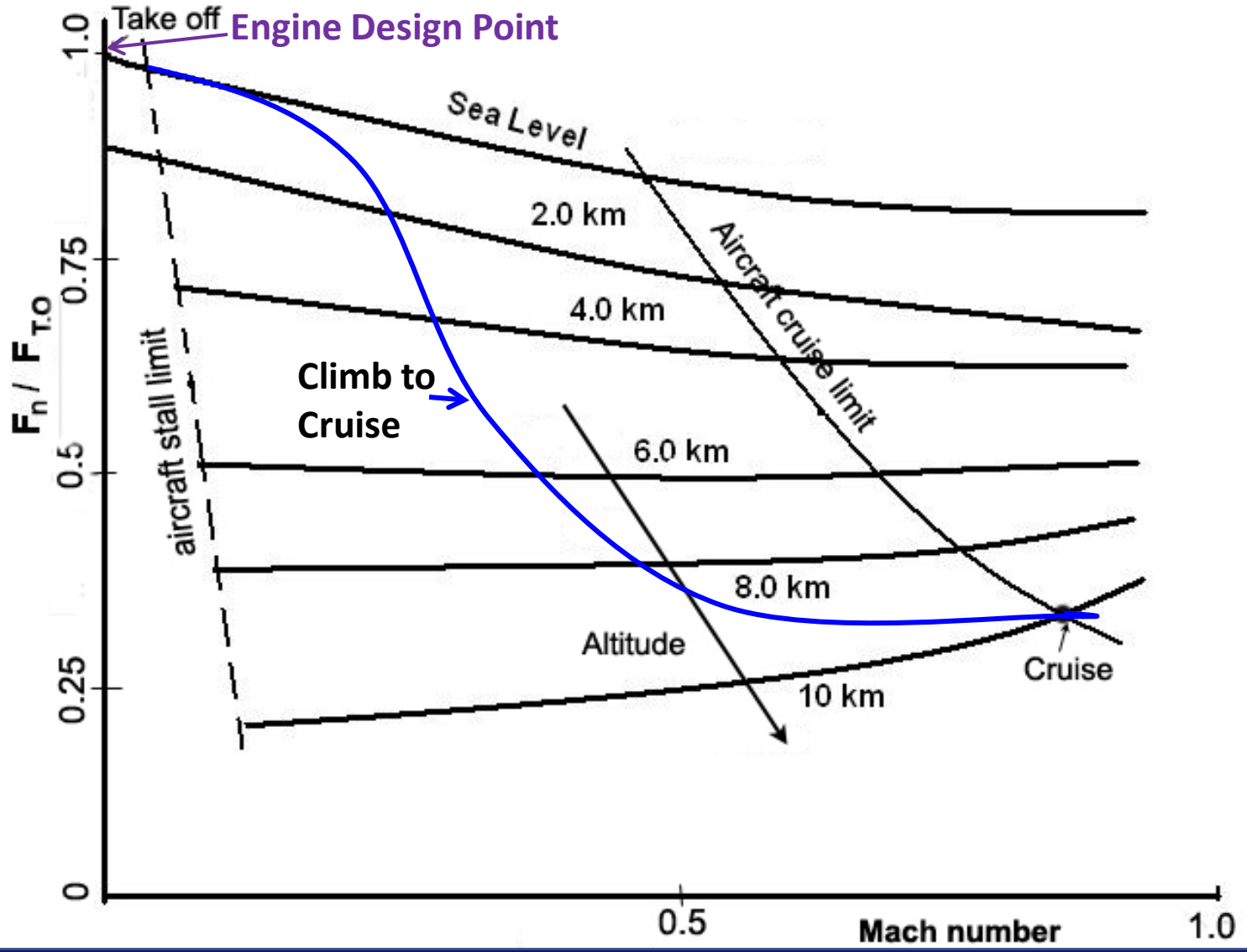
A cycle analysis may be observed for an engine with afterburner. In this case the engine operation without afterburner would be deemed an off-design operation.



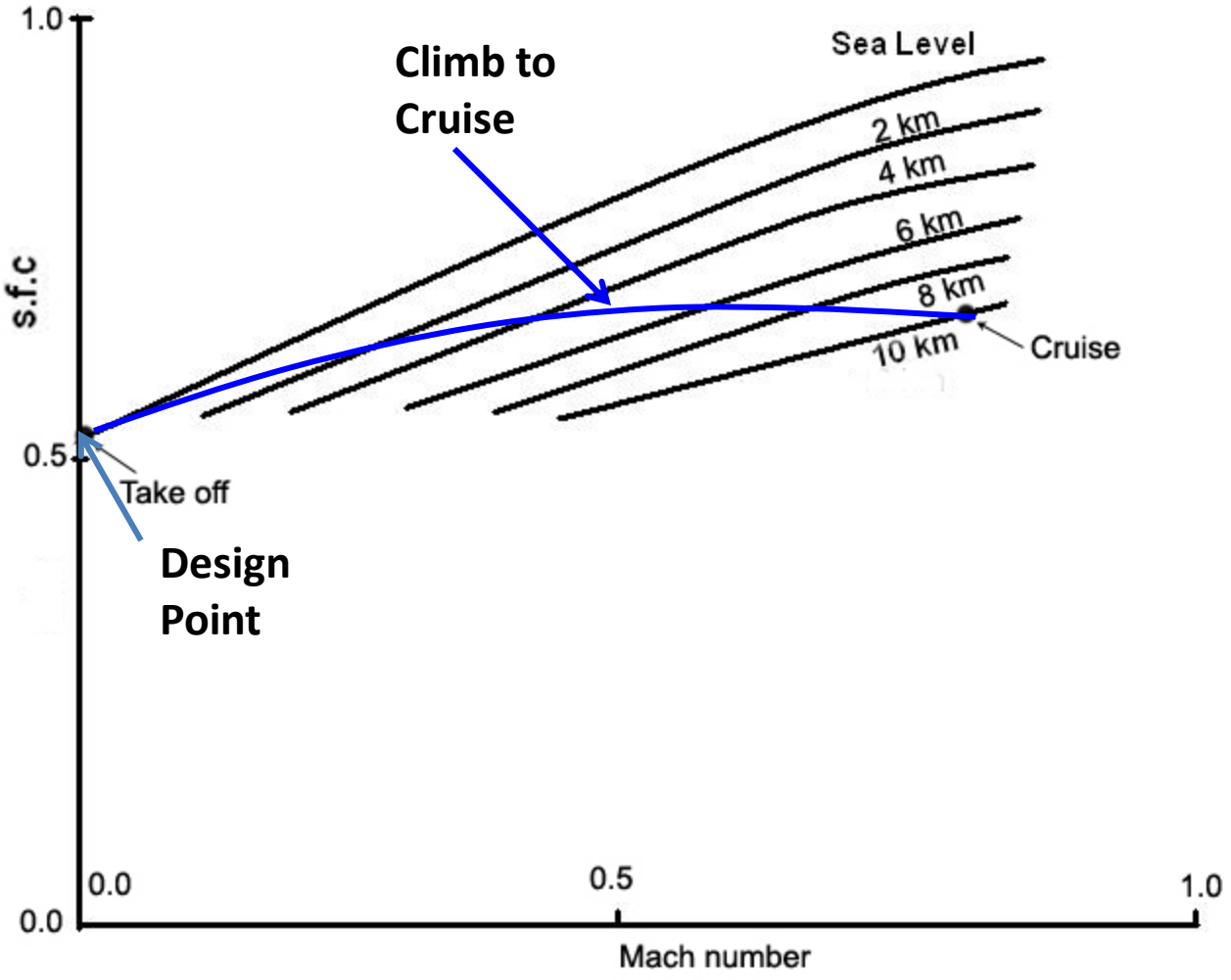
- The turbofan engine uses a Fan and are often 2-spool
- In addition to bypass ratio, B, it is necessary to specify fan pressure ratio, π_{fan}.



Typical requirements of an Aircraft (subsonic) schedule



Typical requirements of an aircraft schedule



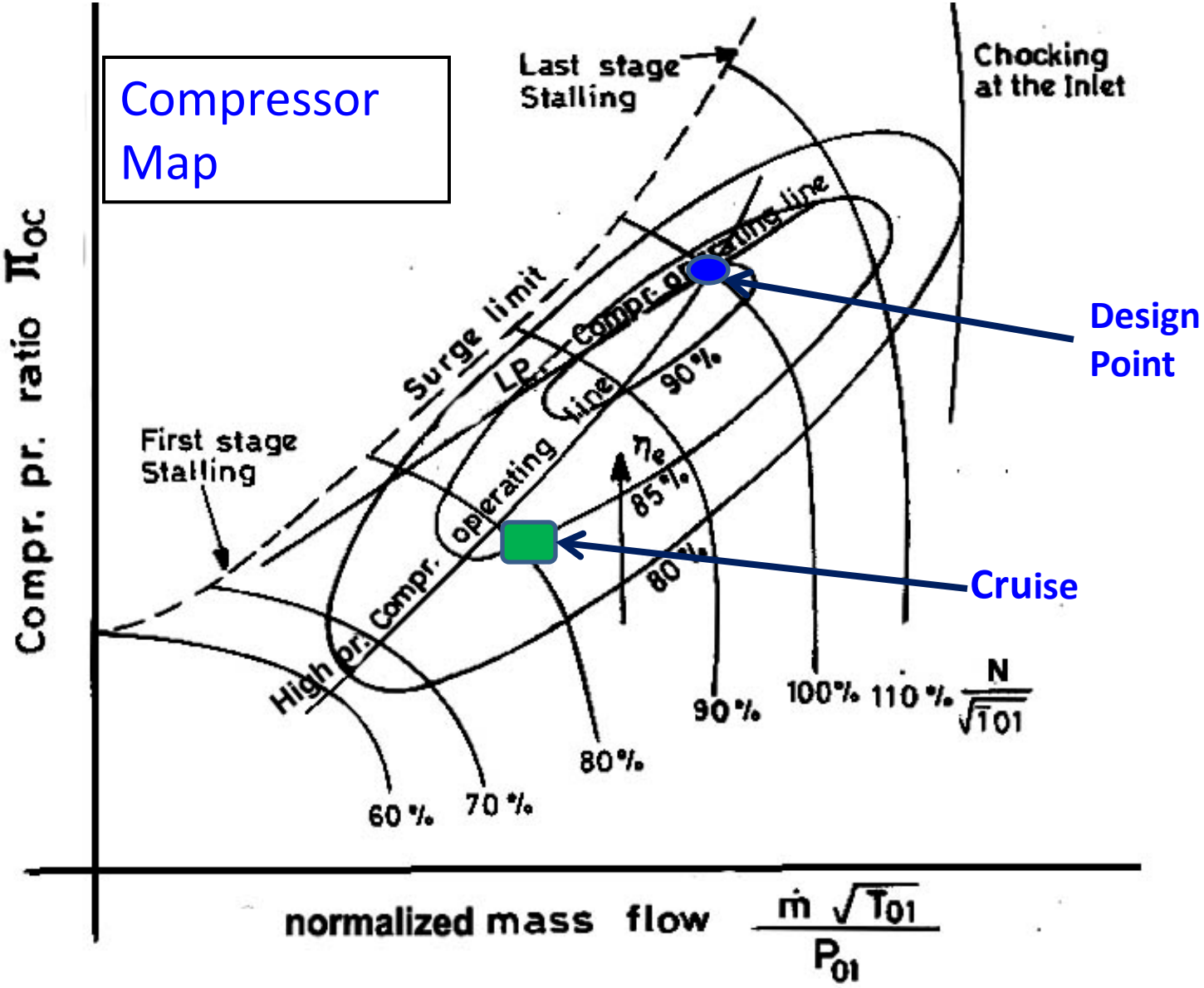
Off-design component matching needed for

1) Mass flow (normalized) matching between the components
2) Energy or Work matching between the components
3) Mechanical matching (e.g. rpm of rotating components)
4) Geometrical matching of component sizes and interfaces
5) Individual sub-component matching of compr / Turbines for onset of instability

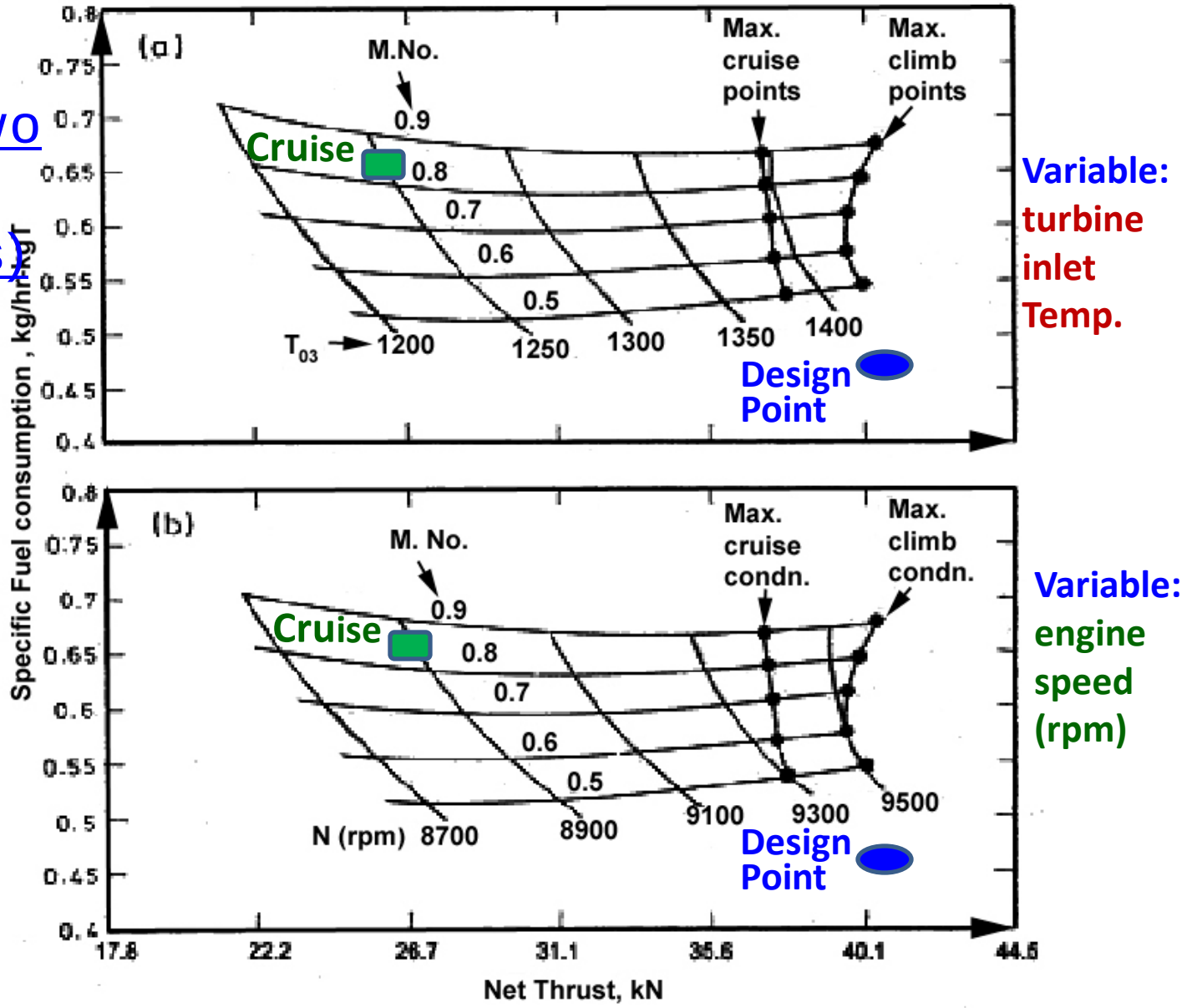
Performance of Engine at various flight segments

Flight segment	Engine Speed (% of n_{max})	Thrust (% of Max)	SFC (% of Design)
Take-off (design)	100	100	100
Climb	98 - 95	95-90	98
Cruise	95 - 85	85-70%	95 - 110

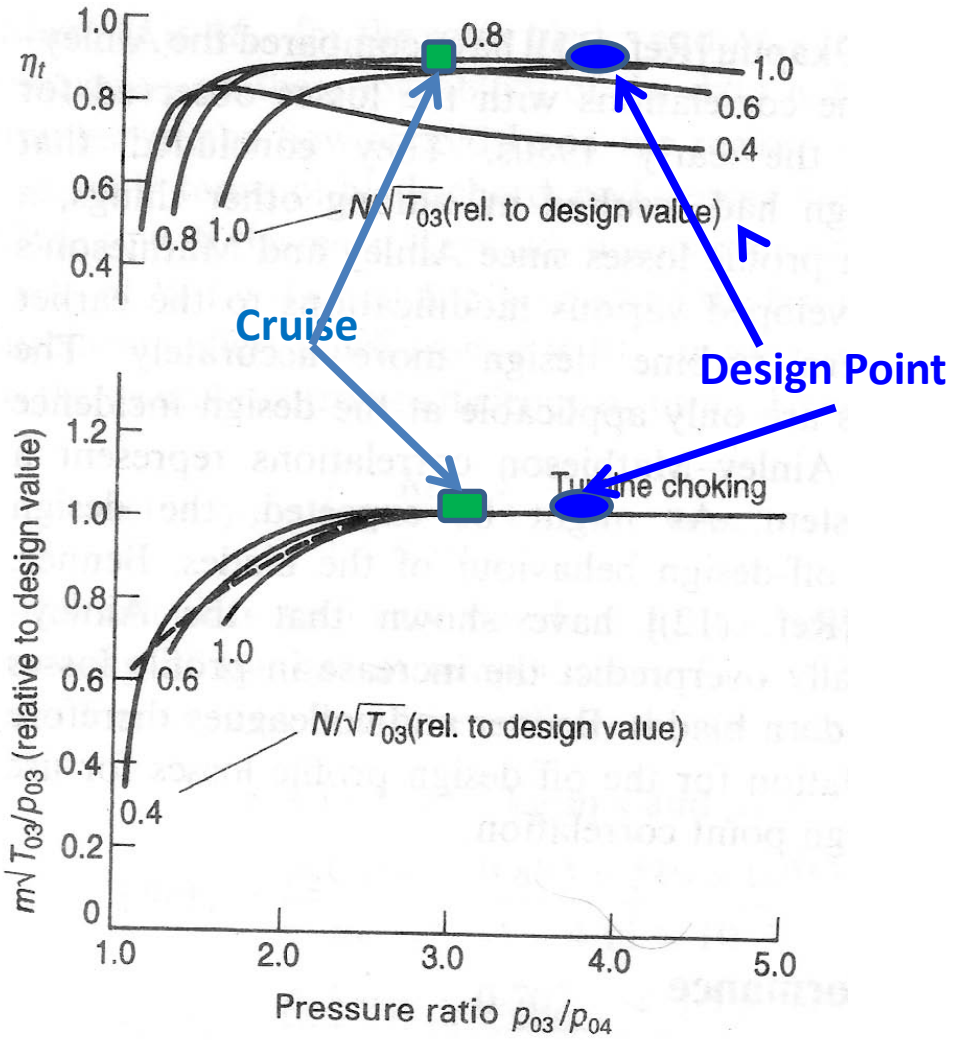
Compressor Map



Engine Map (two engine controls)

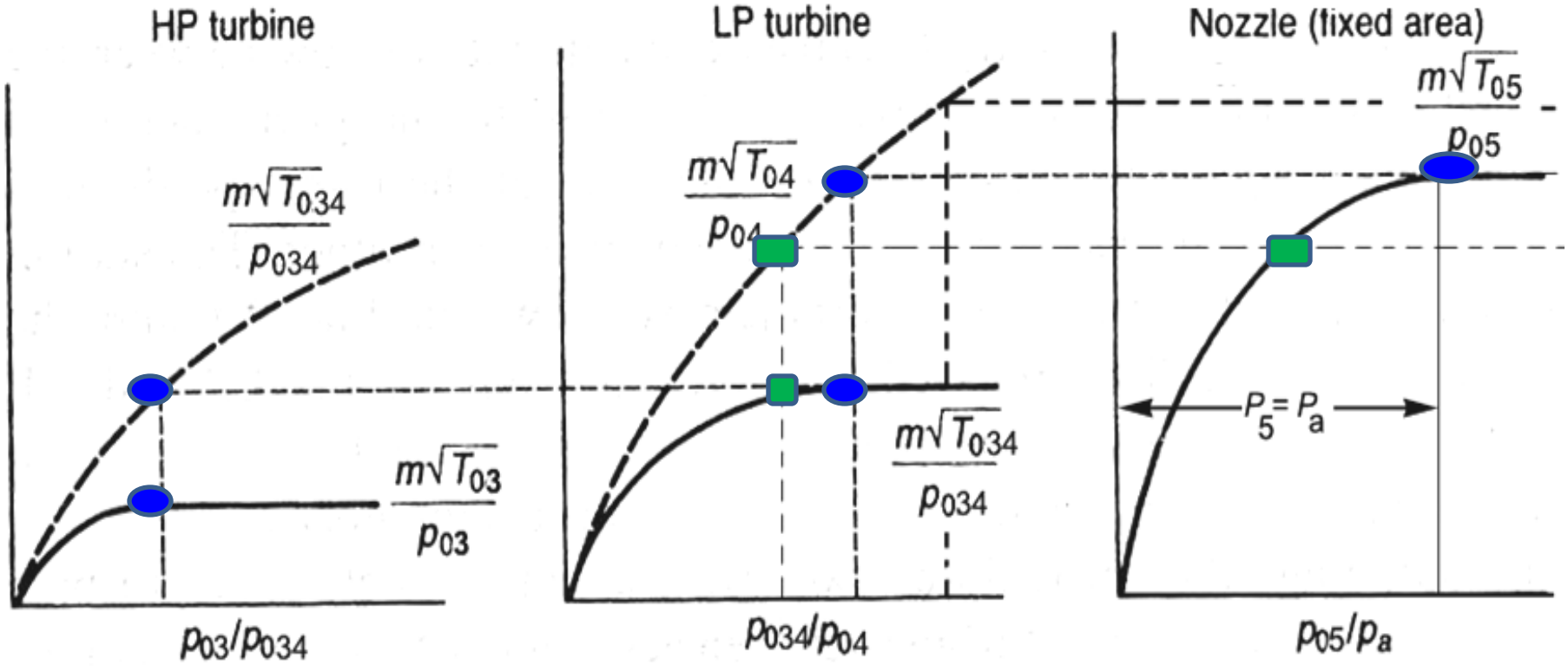


Turbine Map showing Design point and the other operating points

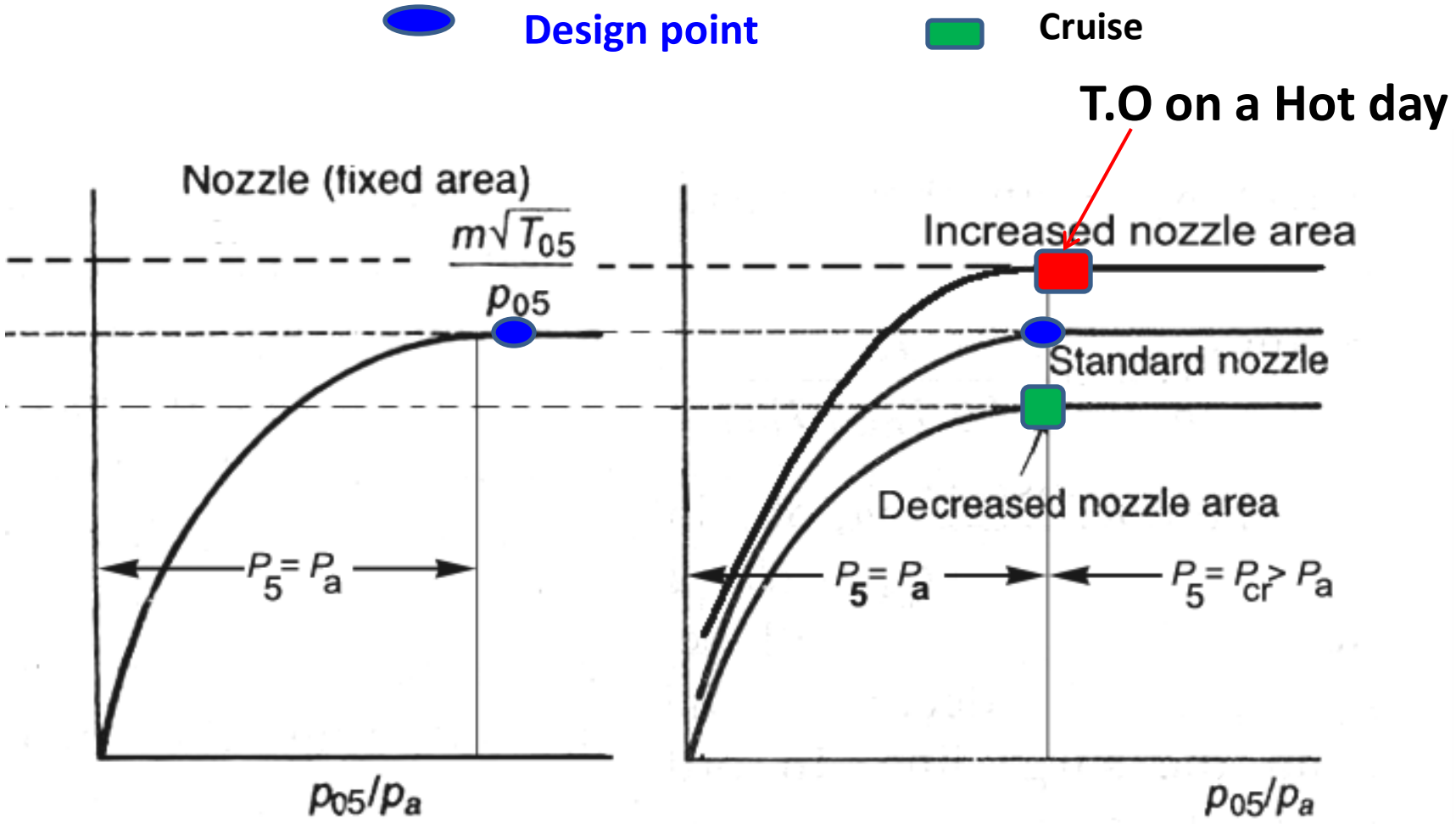


Turbine characteristics

Design point Cruise



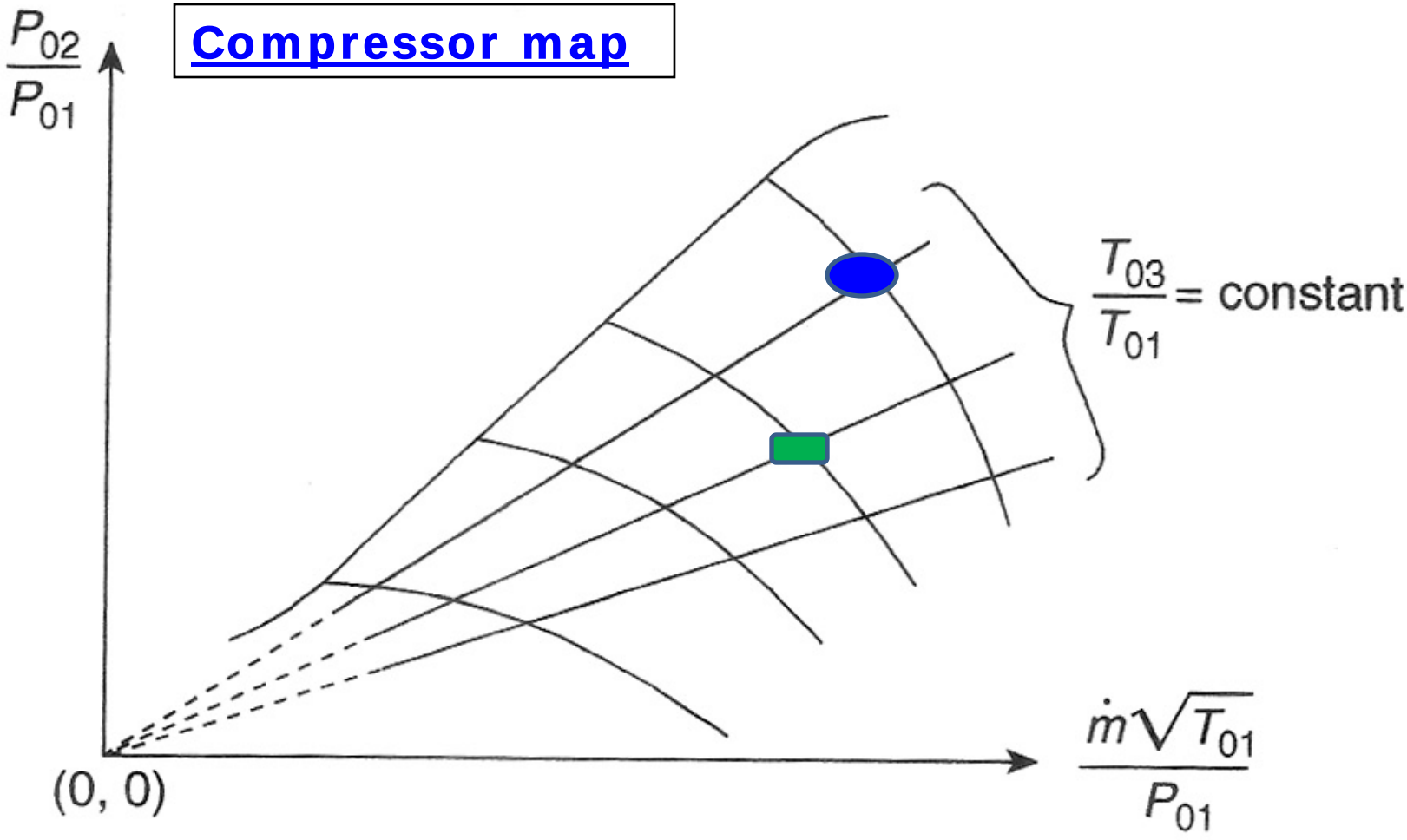
Design point matching of Turbine and Nozzle



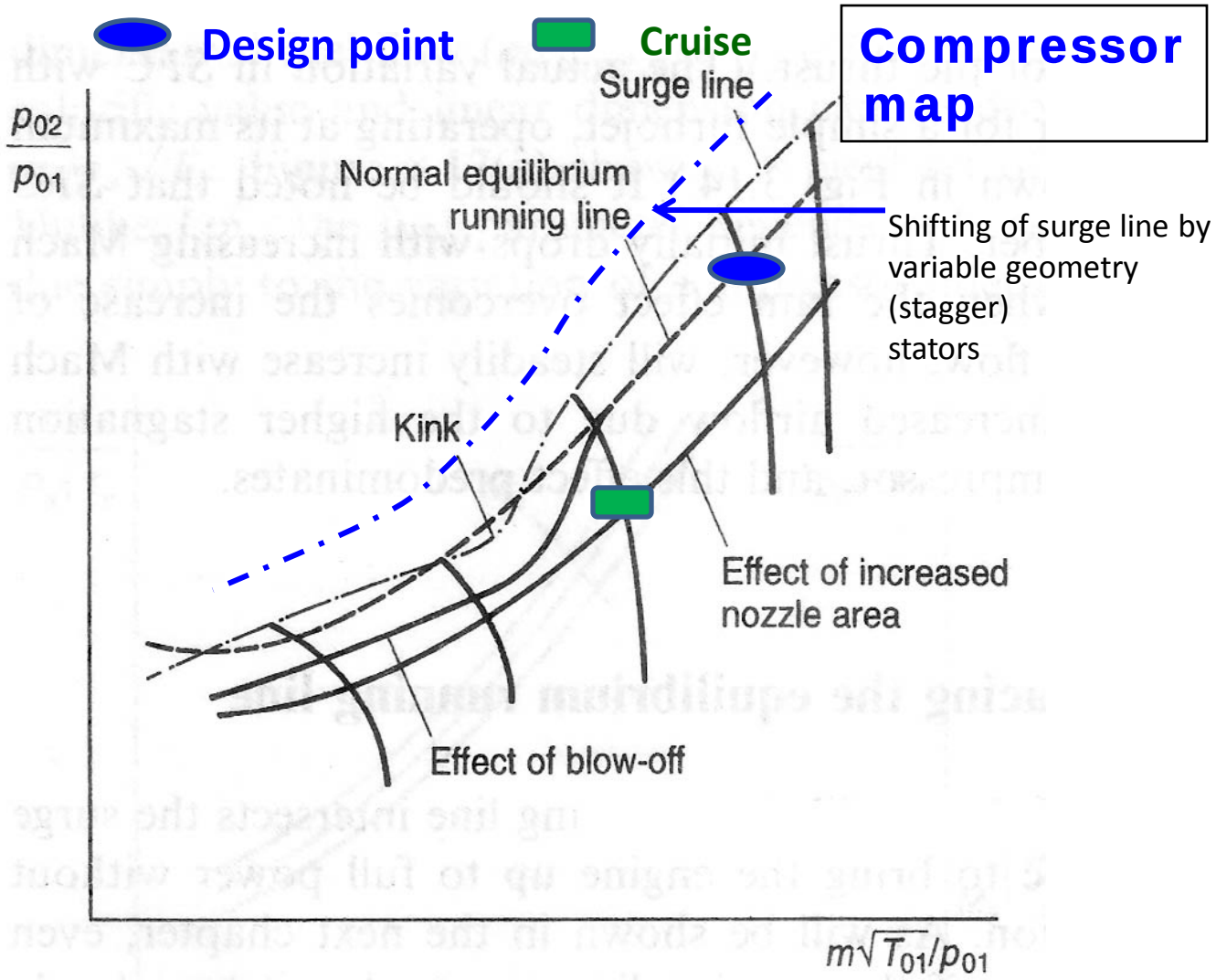
Variable geometry nozzle at off-design operation

Design point Cruise

Compressor map



Constant turbine inlet temperature on the compressor map.



compressor control at off-design operation

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Component Matching Procedure

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