



Performance Analysis of Twin-Spool Water Injected Gas Turbine using Adaptive Modeling

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Performance Analysis of Twin-Spool Water injected Gas Turbines using Adaptive Modeling

§Constitution of a Performance Model

§Elements of Adaptive Modeling

§Implementation to an Engine

§Study of Gas Turbine Behavior

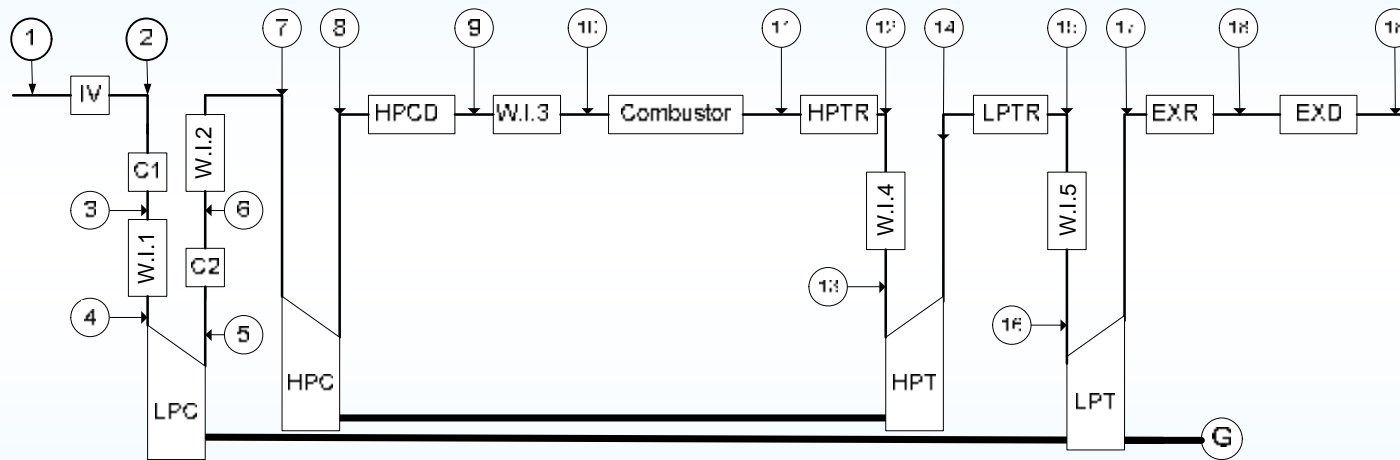
§Components Behavior

§Water Injection Effect on Engine Diagnostics

§Conclusions



Constitution of a Performance Model



Desire to represent the performance of an individual engine as accurately as possible in all situations



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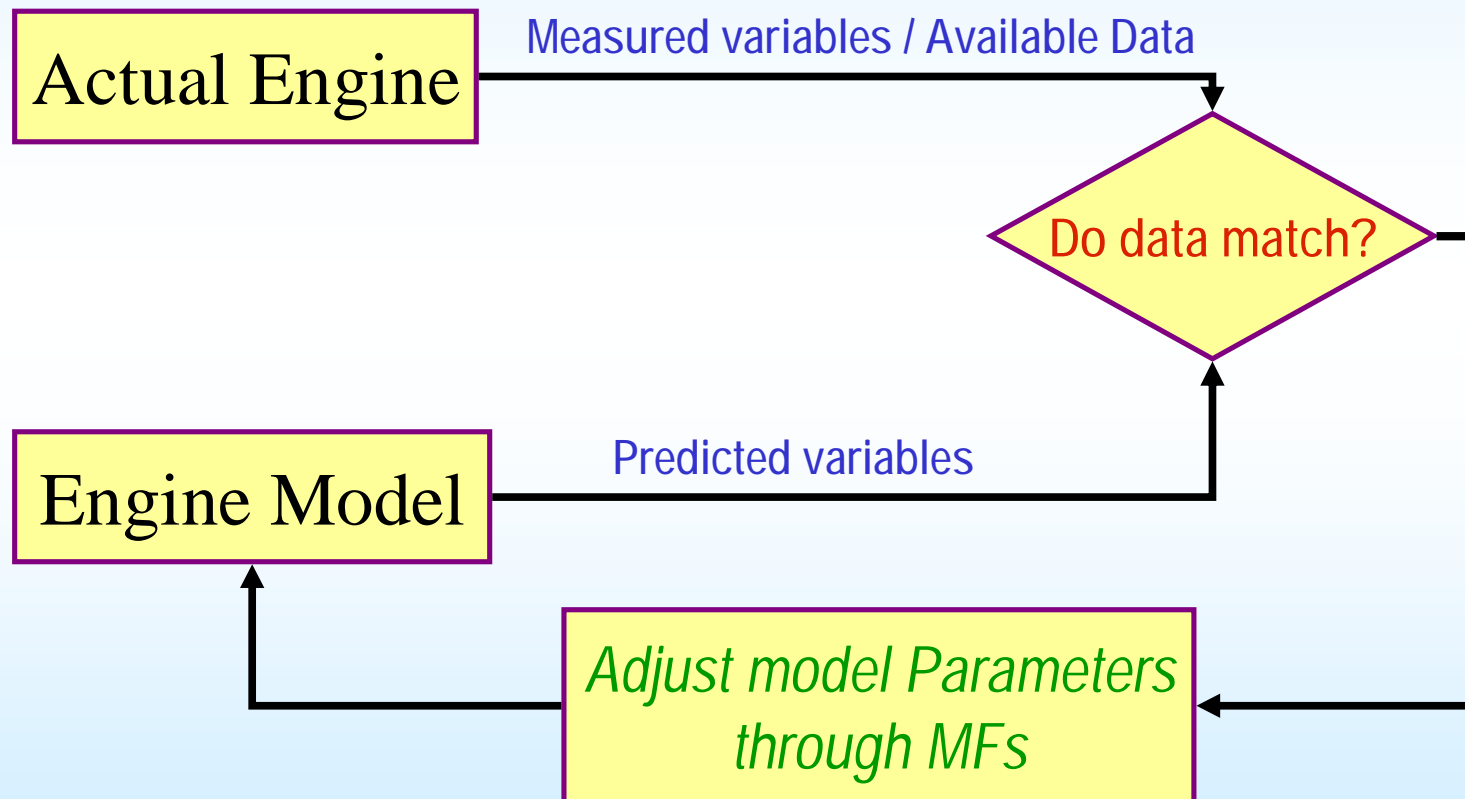
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Elements of Adaptive models



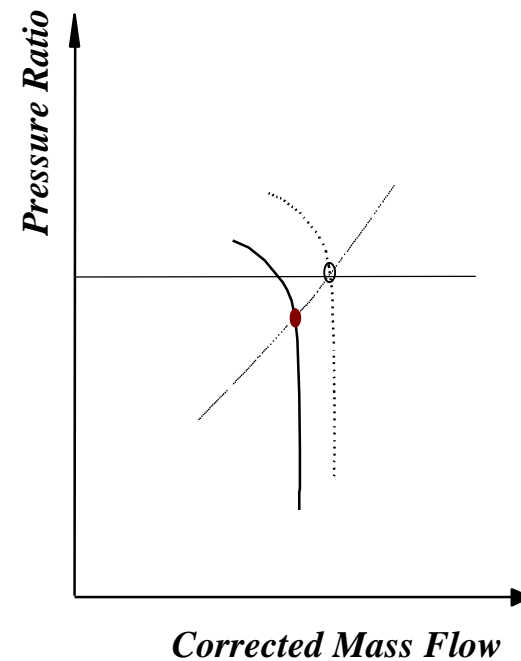


The meaning of Modification factors

$$f_k = \frac{x_{p,k}}{x_{p,ref,k}}$$

$x_{p,k}$: Actual value
for parameter

$x_{p,ref,k}$: Reference
value for
parameter



Transformation of component performance maps



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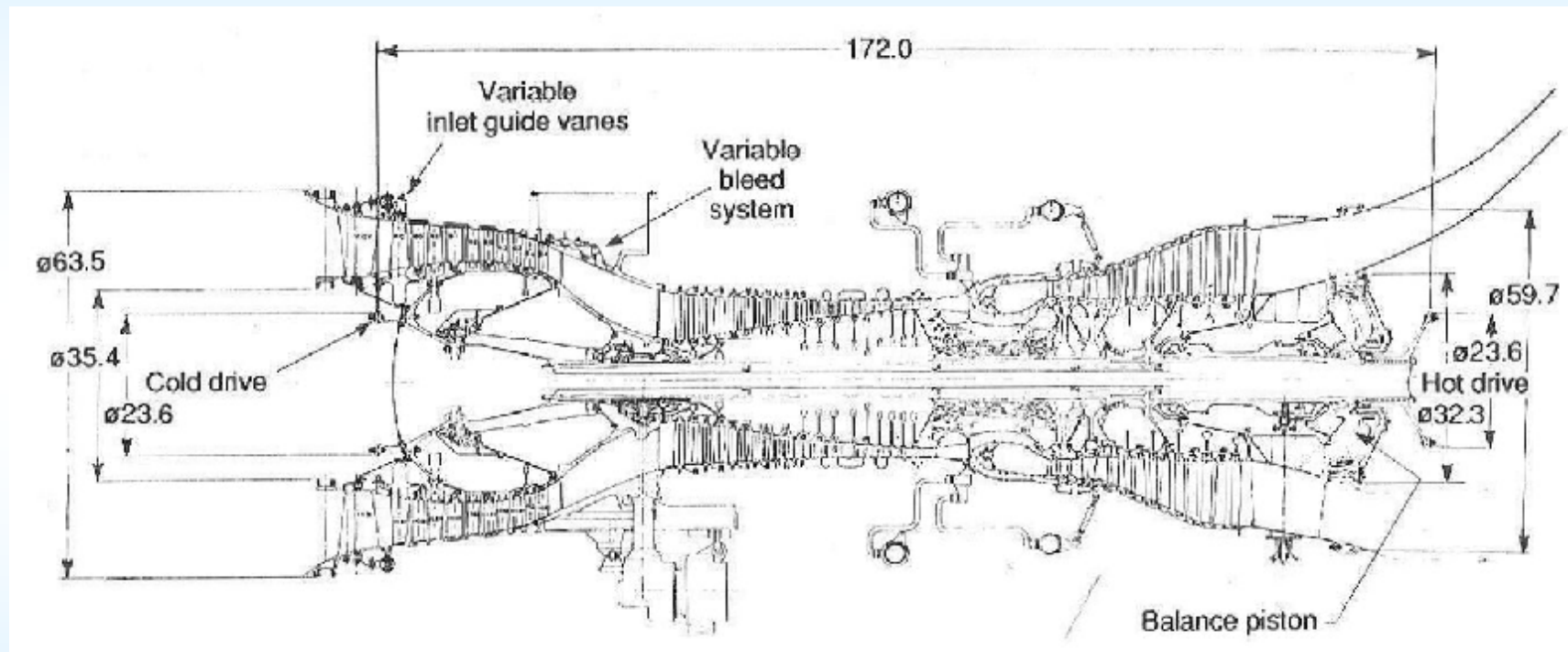
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Implementation to a selected Engine



§5 stage LPC

§2 stage air – cooled HPT

§14 stage HPC with 6 V.G.S.

§5 stage LPT



Implementation to a selected Engine

Engine Data

§Data for the Nominal Operating Conditions

§Thermodynamic Analysis

§Create Components Initial Characteristics

Adaptation

§Initial Adaptation to Nominal Operating Conditions

§Acquire Operating Data Points

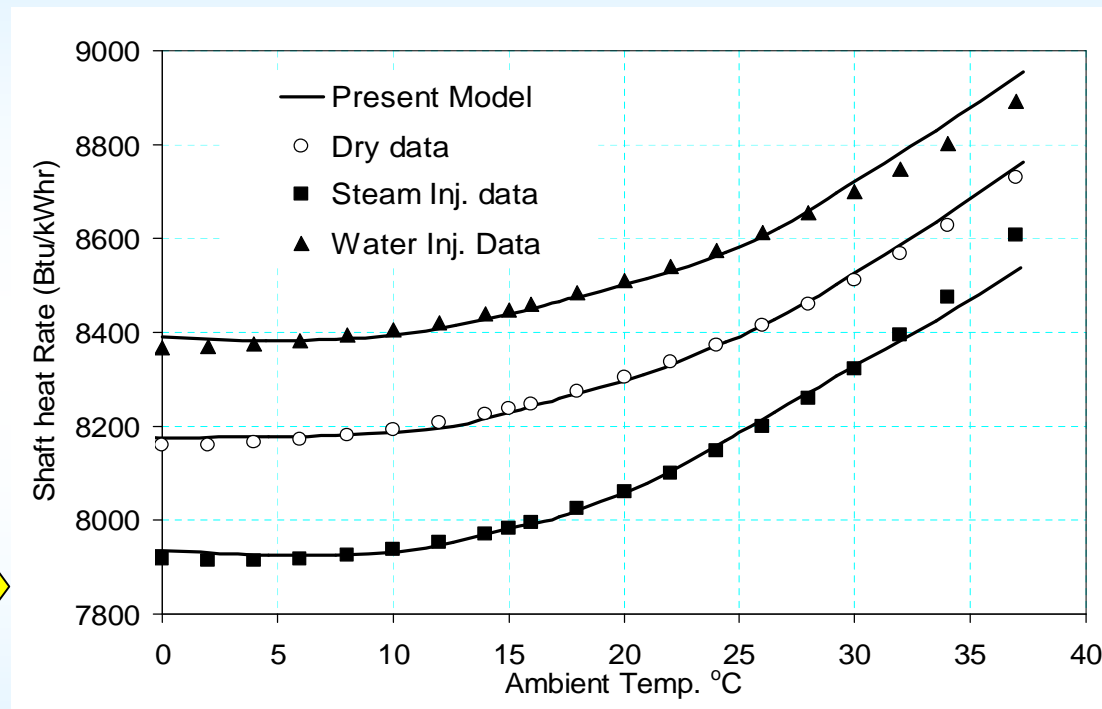
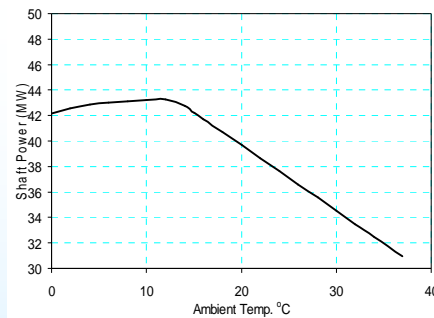
§Determination of MFs according to Available Data

§Determination of new Components Characteristics



Implementation to a selected Engine

Load Schedule





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Performance Prediction

Control Parameter

§Low Pressure Turbine Inlet Temperature

§Compressor Discharge Temperature ($T_{amb} > 15^{\circ}\text{C}$)

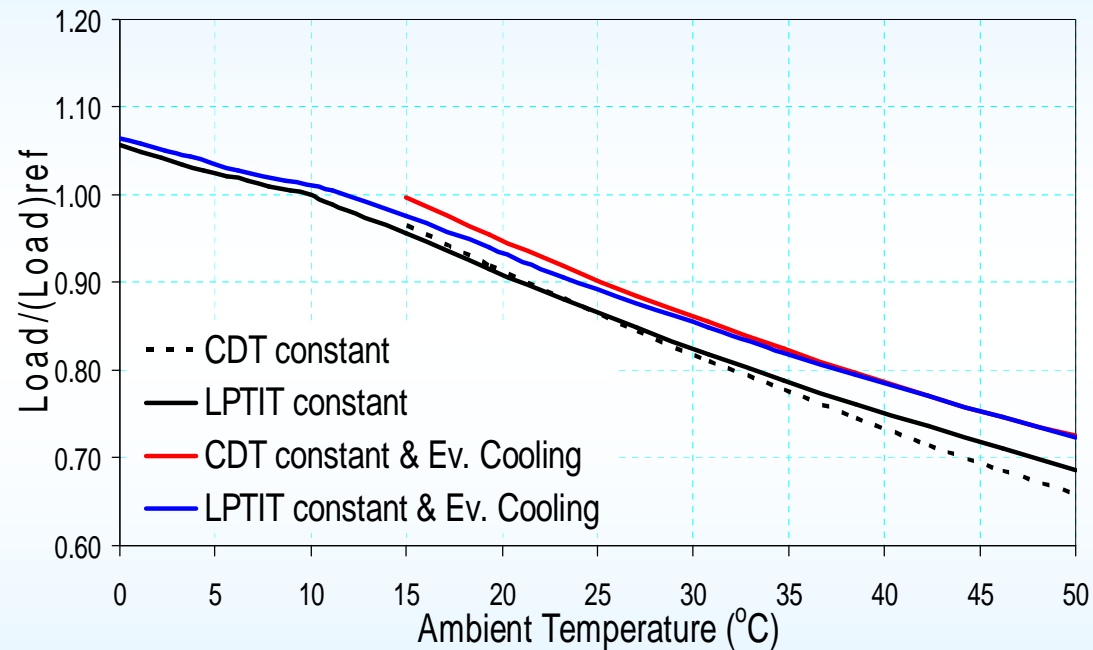
Test Cases

§Evaporative Cooling via Water Injection

§Intercooling via Water Injection



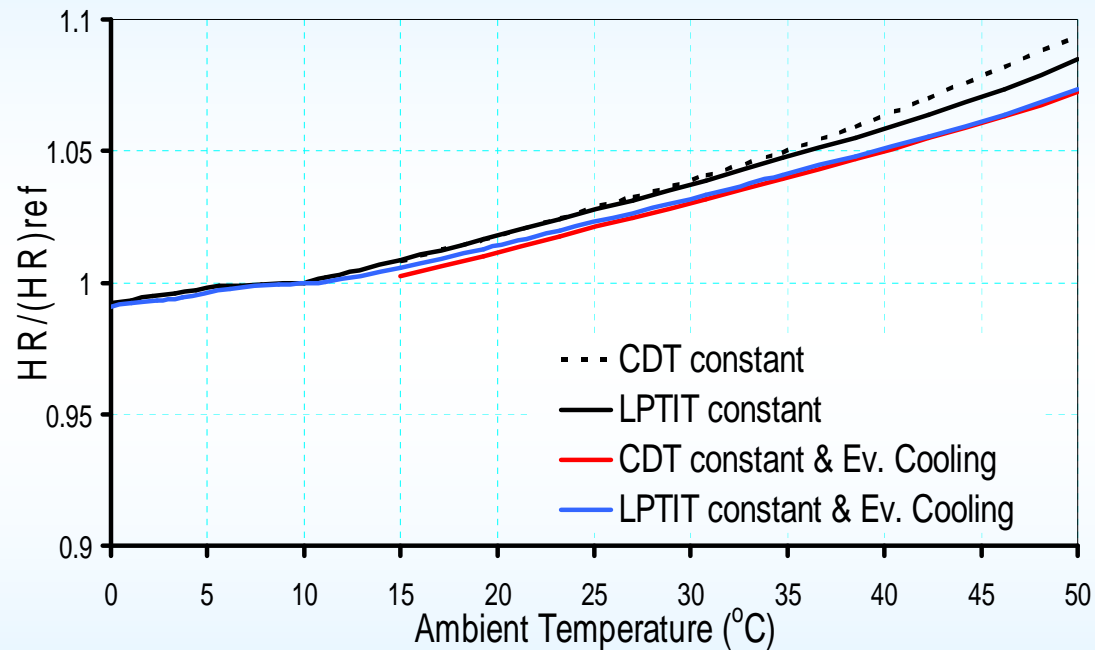
Evaporative Cooling



Operation with constant CDT results in a Slight Higher Gain in Load



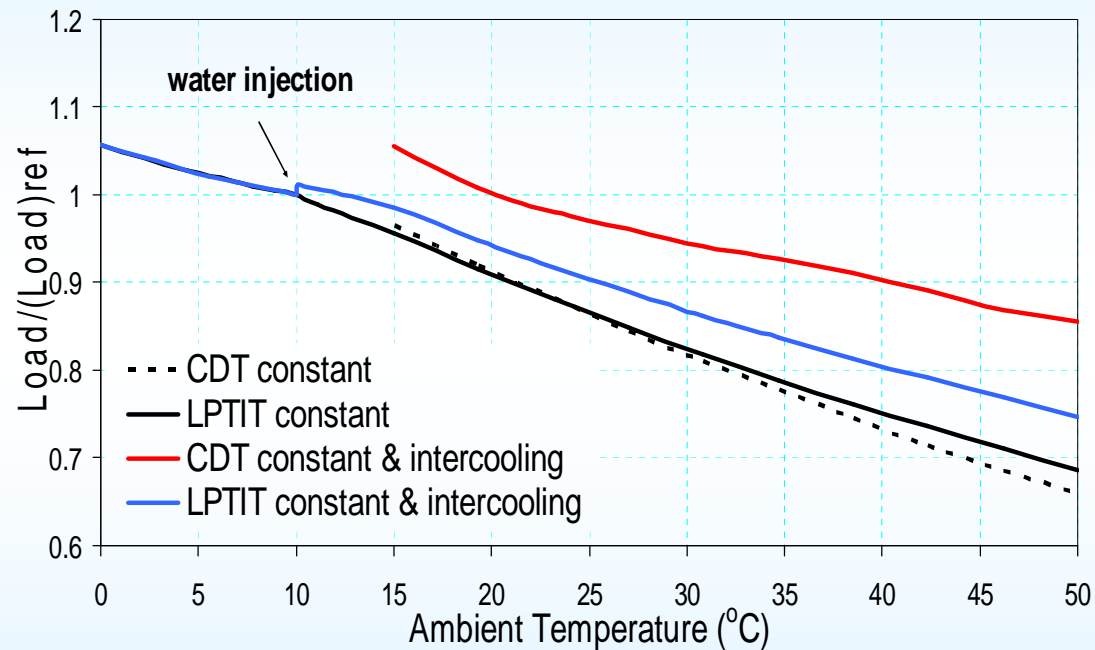
Evaporative Cooling



Operation with constant CDT results in a Slight Higher Gain in Thermal Efficiency



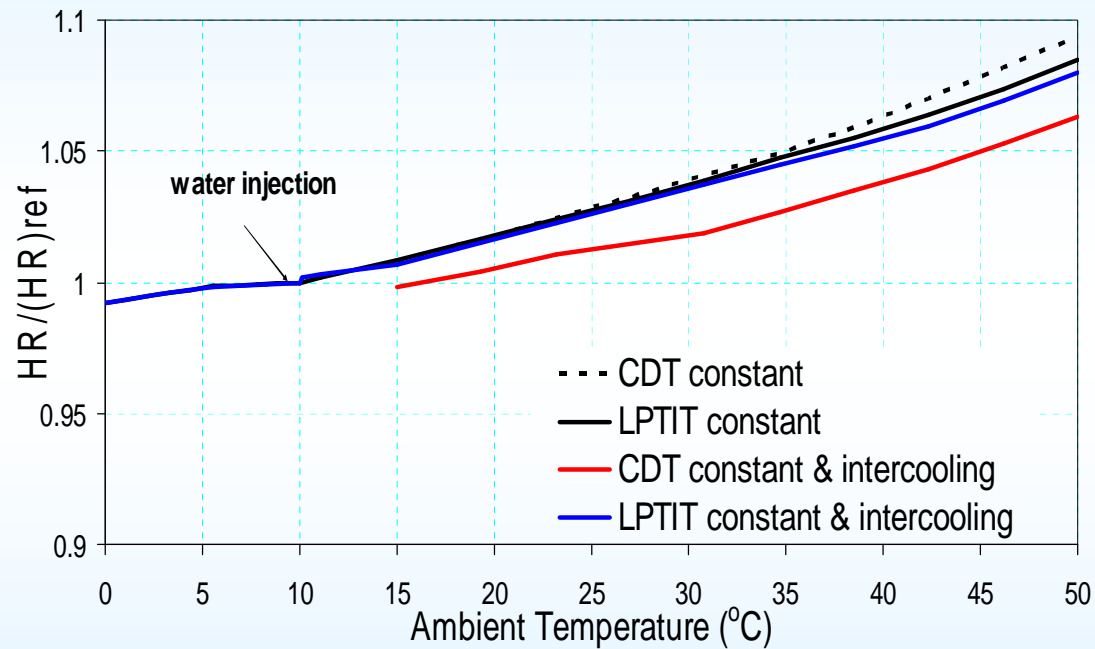
Intercooling



For High Ambient Temperature operation with constant CDT results in an Important Load Gain



Intercooling



For High Ambient Temperature operation with constant CDT results in Higher Gain



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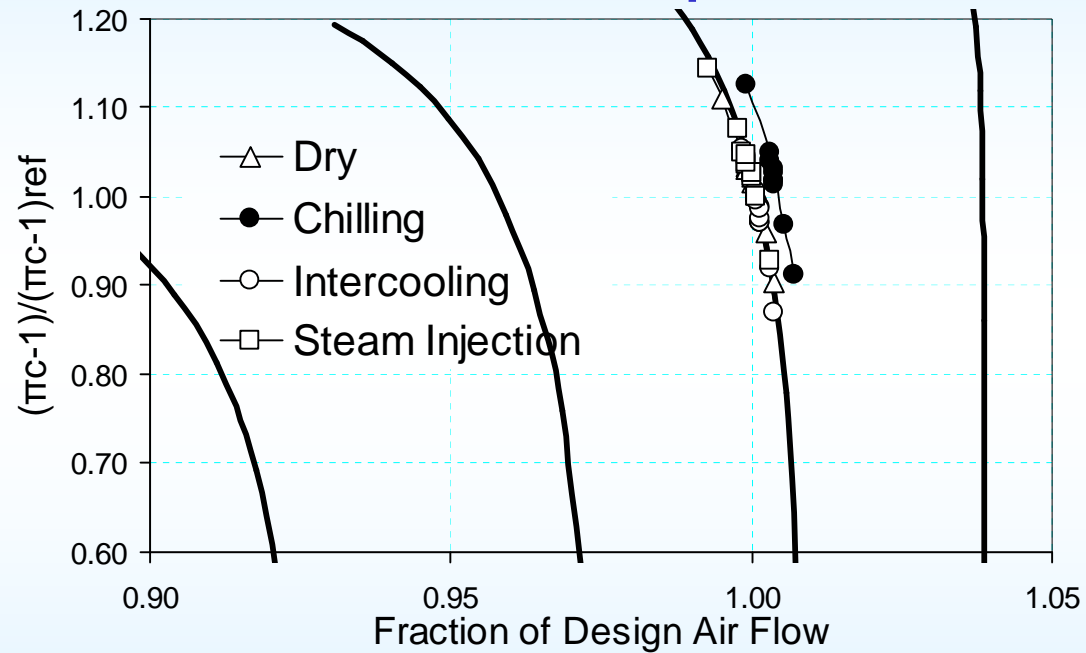
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Component Behavior

Low Pressure Compressor

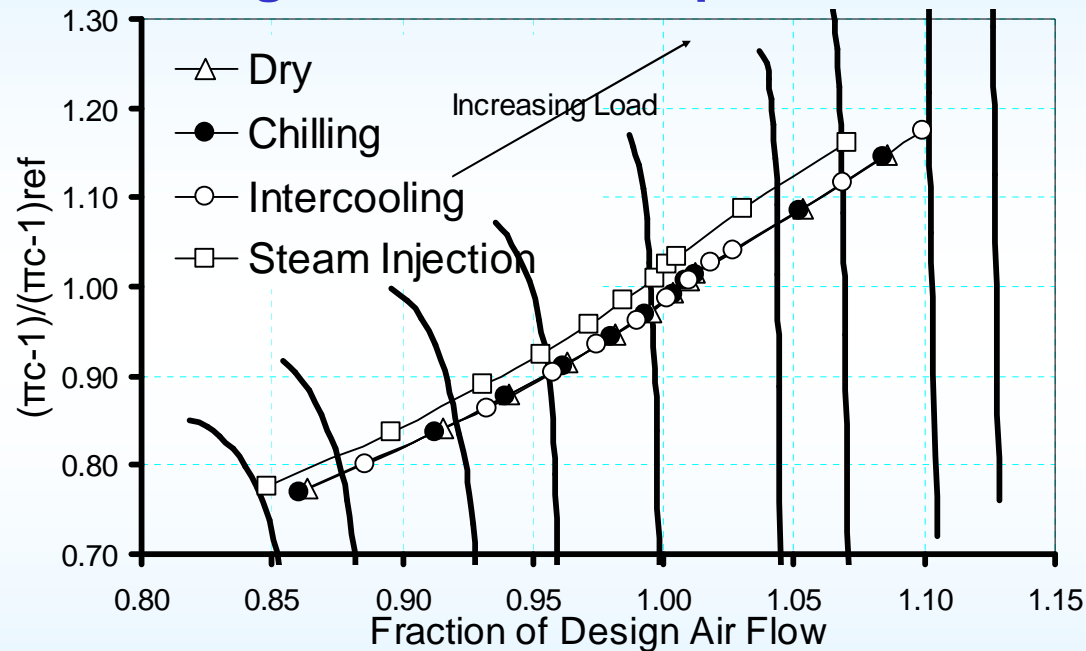


$T_{amb} = 15^{\circ}C$, Load varies from 30 to 50 MW



Component Behavior

High Pressure Compressor

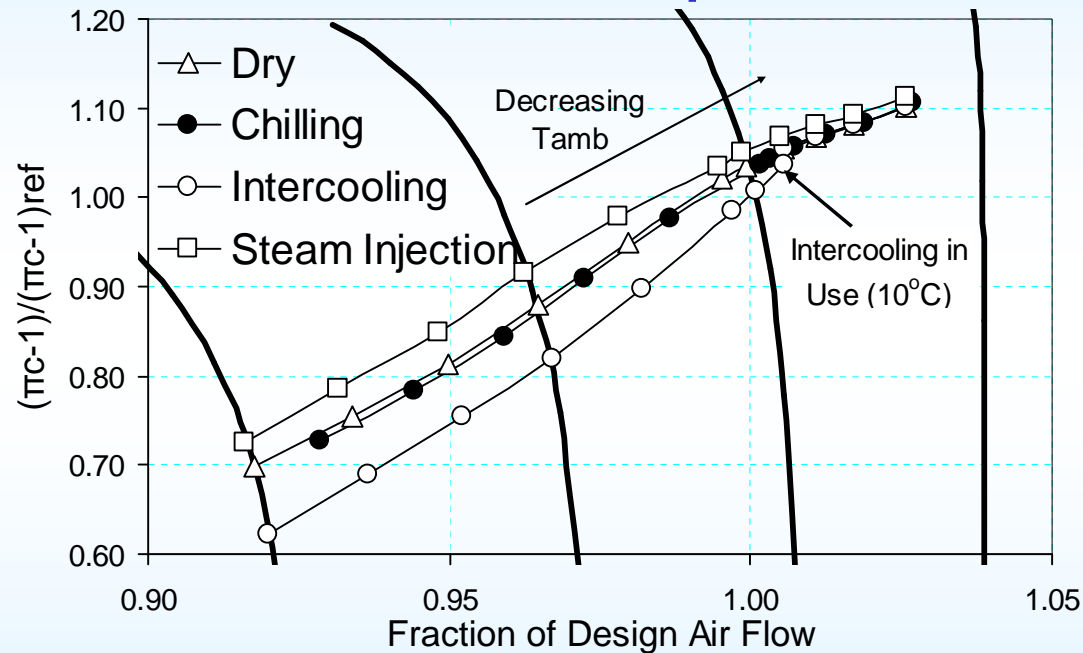


$T_{amb} = 15^\circ\text{C}$, Load varies from 30 to 50 MW



Component Behavior

Low Pressure Compressor

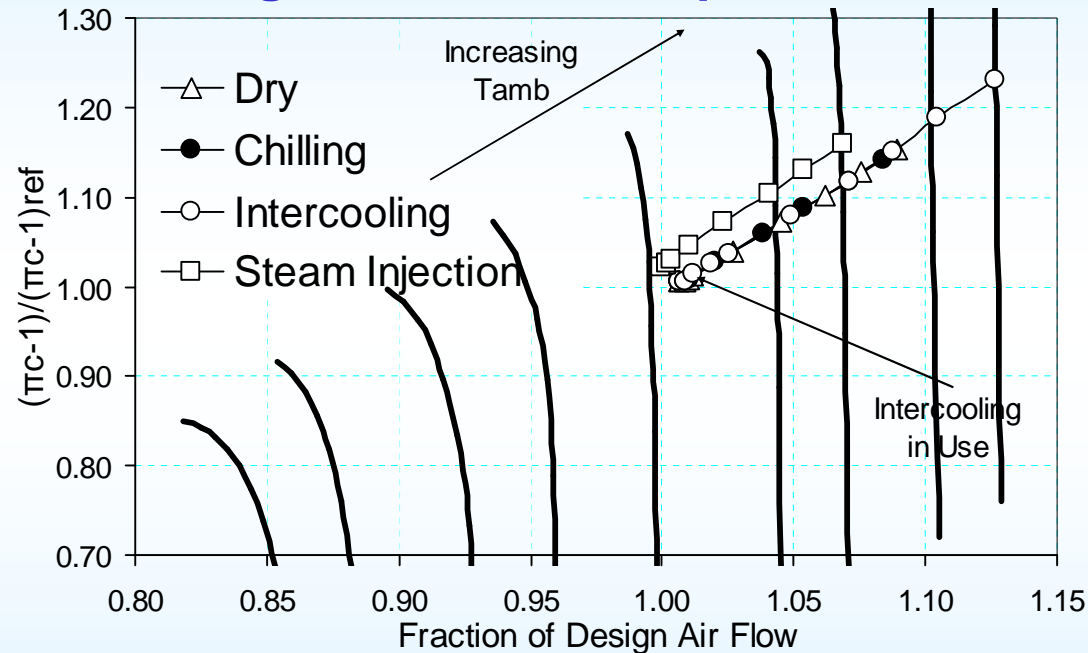


Load = 45MW, T_{amb} varies from -10 to 50 °C



Component Behavior

High Pressure Compressor

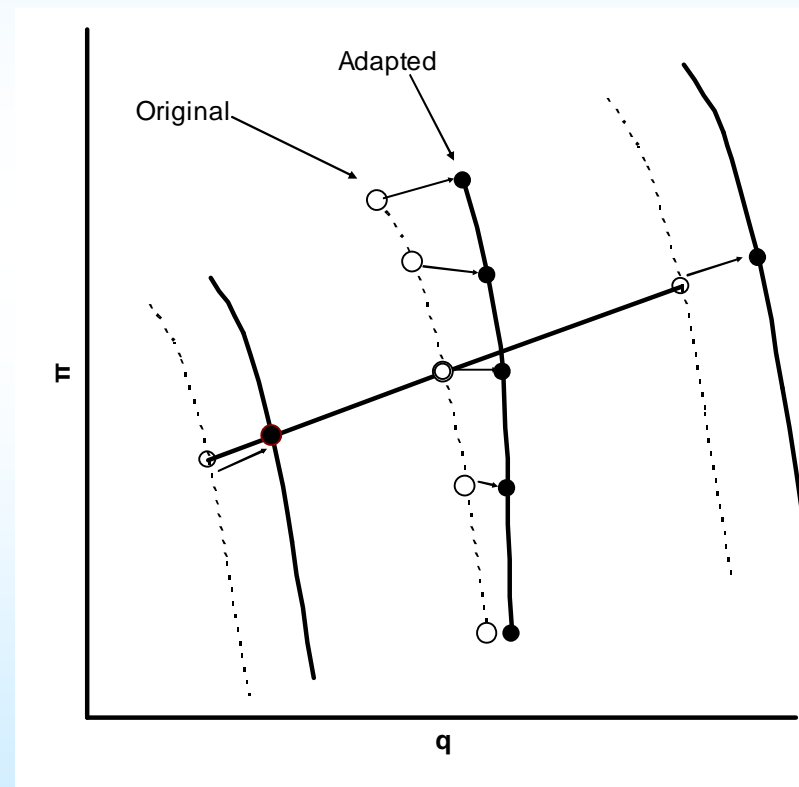


Load = 45MW, T_{amb} varies from -10 to 50 °C



Component Behavior

Additional Information obtained for operation with Water Injection





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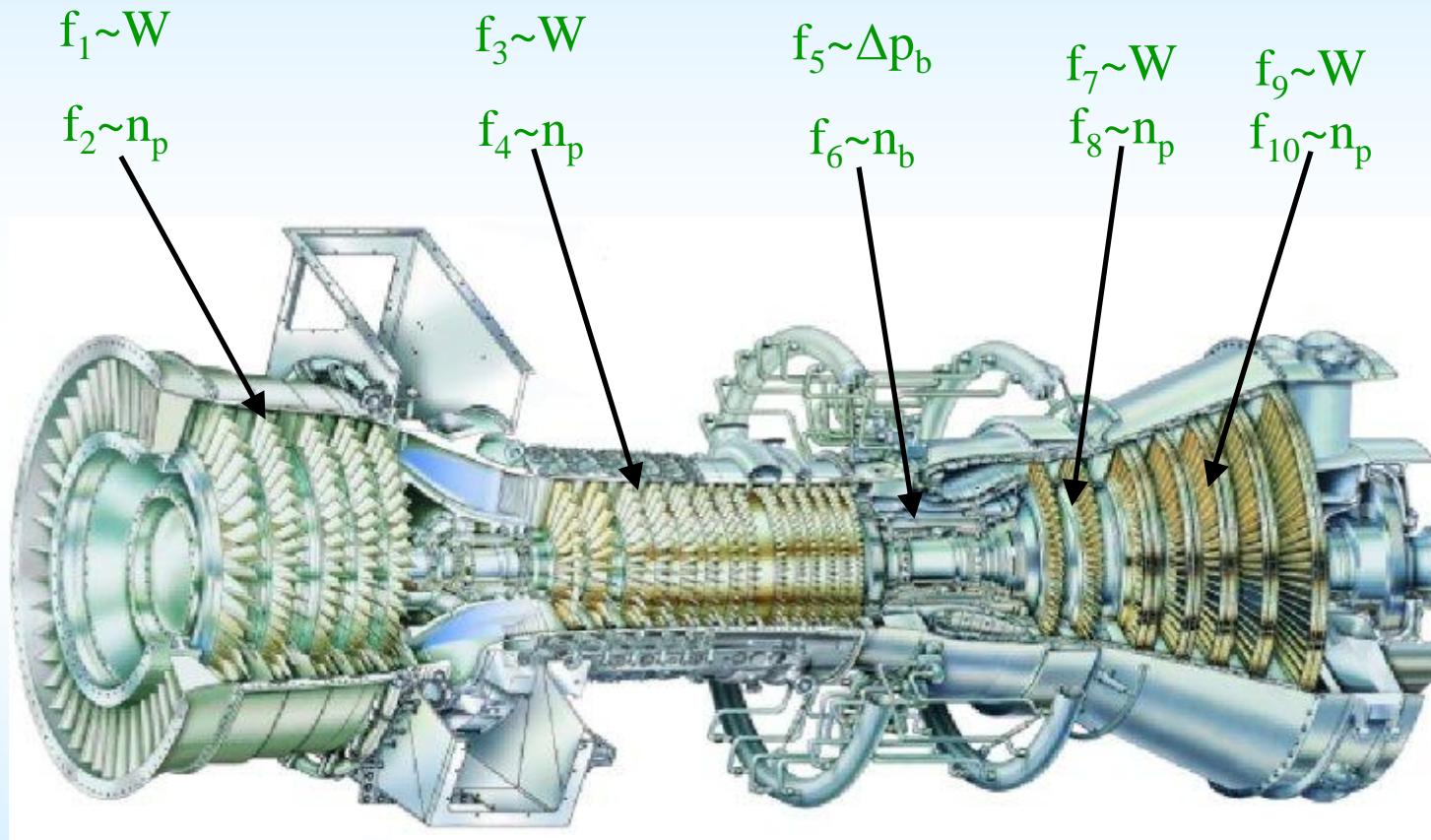
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Engine Diagnostics

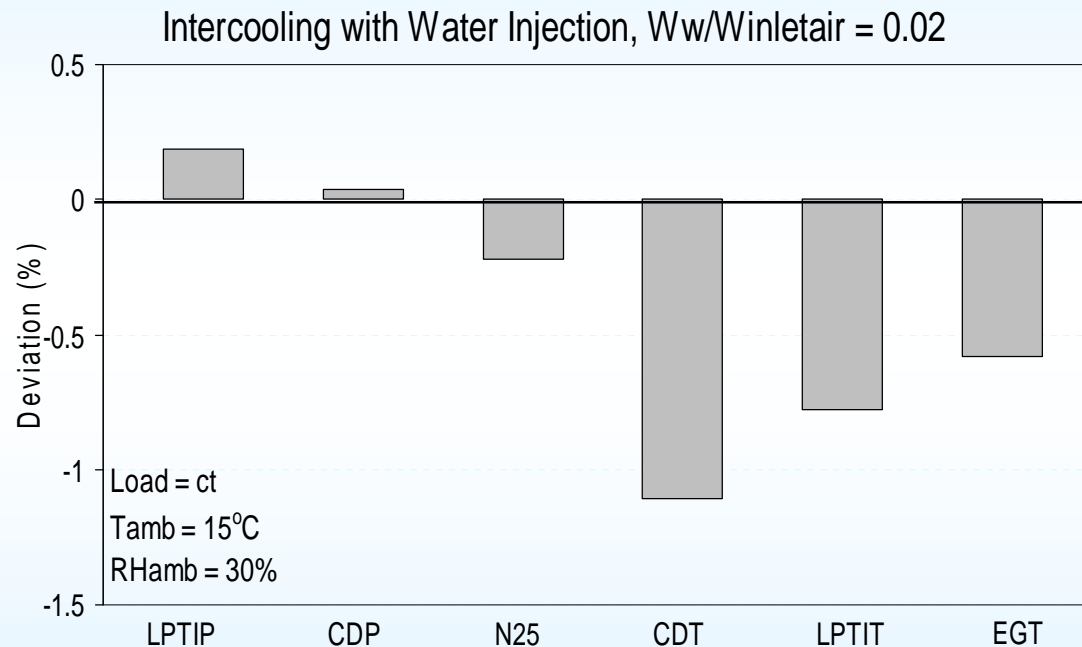


Pictorial view of MF on engine components



Engine Diagnostics

Measurement Deviation



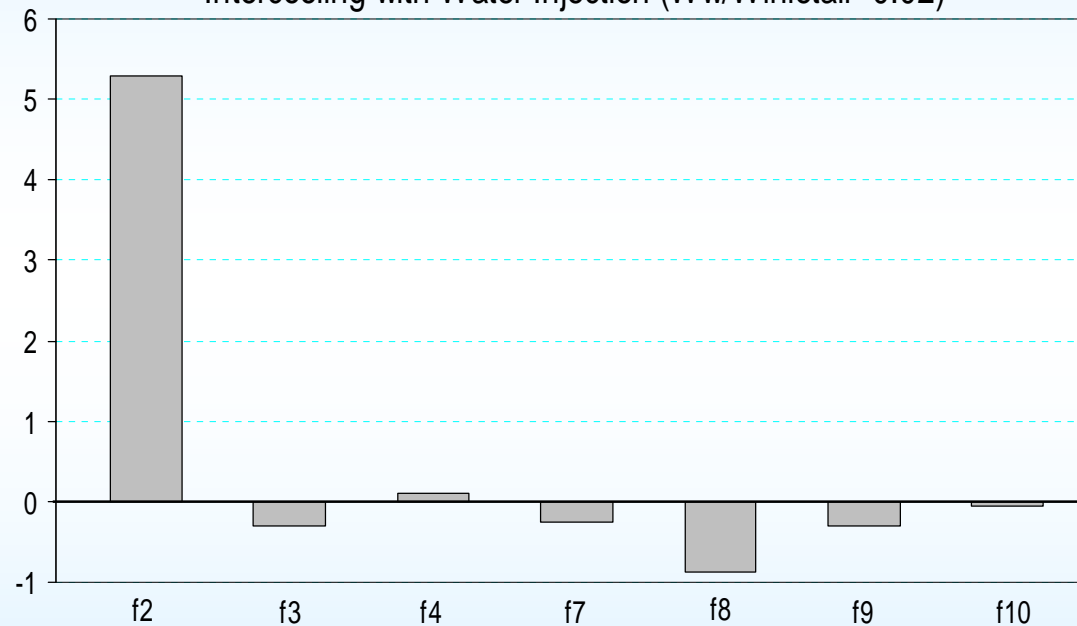
Monitoring Techniques based on Direct Observation of Measured Quantities may lead to erroneous conclusion if Water Injection is not taken into account



Engine Diagnostics

Health Indices Deviation

Intercooling with Water Injection ($W_w/W_{inletair}=0.02$)



Monitoring Techniques based on Health Parameters may lead to erroneous conclusion if Water Injection is not taken into account



Conclusions

- Using appropriate procedure it is possible to estimate the engine performance even if limited information is available
- The structure of the model gives the ability of modeling water injection at various station and using different parameters as control variables.
- Data from water Injection gives additional information for determination of component characteristics
- Water Injection must be modeled for accurate diagnosis