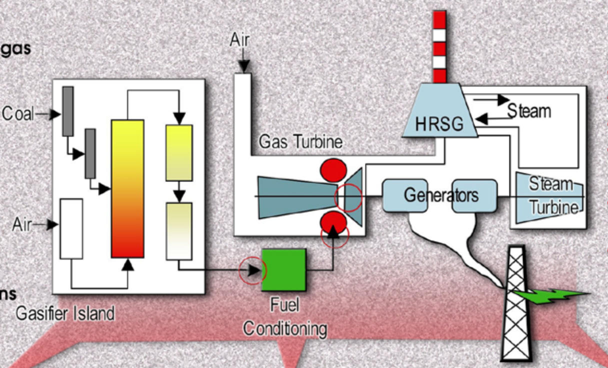
Materials Issues Associated with Gas Turbines Fired by Syngas/Hydrogen

Combined-cycle systems based on synthesis-gas (syngas)-fired gas turbines promise to be cleaner, more efficient sources of electricity than current coal-fired systems. Because syngas is derived from coal, it contains more carbon and more impurities than does natural gas, and to achieve the desired efficiency, syngas-fired systems need to operate at very high temperatures while modifying the combustion conditions to reduce carbon emissions. The DOE FE Turbine Program is researching the fuel, combustion, and materials requirements for syngas-fired turbines to ensure reliable operation while achieving these goals.

DOE's Goals for Syngas/Hydrogen-Fired Gas Turbines

Hydrogen Turbines for FutureGen
- Efficiency comparable to natural gas turbines by 2015
- NO_x emissions < 3 ppm (at 15% O_2)
- Cost < $1000/kW

Turbines and Combustors for Oxy-Fuel Rankine Cycle Systems
- System efficiency increased to ≈ 50-60% (HHV) by 2015
- Oxy-fuel combustors compatible with a range of synfuel formulations by 2015
- Oxy-fuel turbine operating temperatures of 1650-1760°C

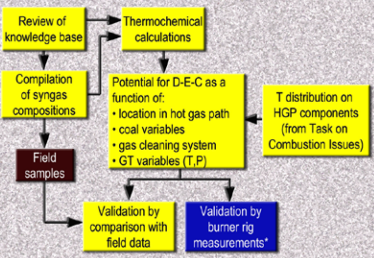


Megawatt-Scale Hydrogen Turbines
- H_2 or H_2-augmented fuels
- Highly-efficient
- Near zero-emissions (NO_x < 3 ppm)
- Power + H_2 co-production

Advanced Brayton Cycles
- High efficiency (LHV) to 65-67% equivalent (RIT to 1700°C)
- R&D targeted at modifications leading to improvements in
  - combustion
  - gas turbine
  - integrated system

Fuel Purity

Focus: Assessment of the Potential for Deposition-Erosion-Corrosion (D-E-C) When Firing Syngas



Understanding of Potential Scenarios Where D-E-C Would be Possible in the GT
- Coal-derived syngas
- Hydrogen-augmented syngas
- Hydrogen- depleted syngas
- Hydrogen
- Oxygen enhancement
- Natural gas (baseline reference)

Examining Types of Degradation Modes
- Predictions based on thermochemical analyses
- Complementary lab and field results

Exploring Possibilities of:
- quantification
- improved fuel/gas cleanup specifications

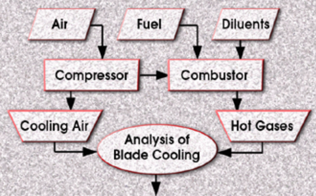
Representative Coal-Derived Syngas Composition for Oxygen-Blown Gasifier (Vol %)

H_2	43	H_2S/COS	40-100 ppm
CO	45	H_2O	0.02
CO_2	8	N_2	1.3
CH_4	0.35	Ar	Balance

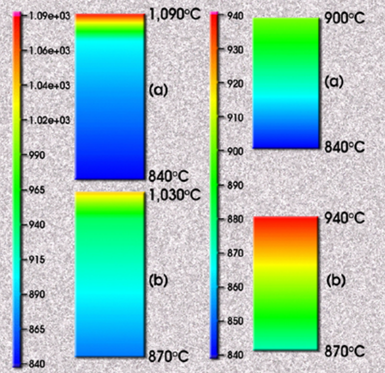
Combustion Enhancement

An Iterative Approach to Determine Effects of Fuel Composition, Combustion Conditions on:
- Component temperatures
- Cooling requirements

Flow Diagram for Modeling of Influence of Combustion Conditions on Turbine Blade Temperatures



Initial Model Calculates Appropriate Interface Temperatures as a Function of Flame Temperature, TBC Properties, etc:



Temperature profile in the TBC, BC, and blade for (a) virgin TBC, (b) after 32 kh hours of service

Temperature profile in the blade for (a) virgin TBC, (b) after 32 kh hours of service

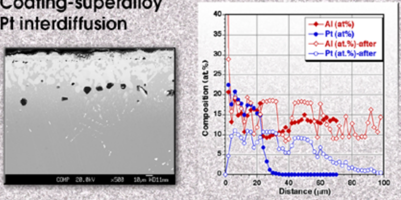
In this example, after 32 kh, degradation of TBC increases blade surface temperature from 900 to 940°C (at constant coolant flow)

Hot Gas Path Durability

Pt-Enriched γ-γ' Two-Phase TBC Bond Coatings

Compared to single-phase β-(Ni,Pt)Al coatings, γ-γ' coatings have:
- Better compatibility with the superalloy substrate
- Higher creep strength/increased fatigue resistance
- Potentially lower manufacturing costs

Research Topics for Pt-Enriched γ-γ' Coatings:
- Fabrication methods vs current coatings
- Composition vs performance
- Alloying elements from substrate
- Optimal levels of Pt and Hf
- Impurities (e.g. S) in the coating and substrate
- Coating-superalloy Pt interdiffusion



Composition of γ-γ' Coating Made by Pt Diffusion on Alloy 142: Ni-16Al-18Pt-7Cr-9Co (at.%) or Ni-5Al-43Pt-4Cr-6Co (wt.%) After 300 h at 1100°C: Ni-14Al-8Pt-6Cr-10Co (at %).

Summary of Current Work
- A Pt-enriched γ+γ' coating was applied to alloys 142 & N5 by electroplating Pt.
- Substrate Hf and S content has been shown to affect coating performance.
- Significant Pt interdiffusion occurred at 1100°C.
- New coating fabrication routes are being explored.

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