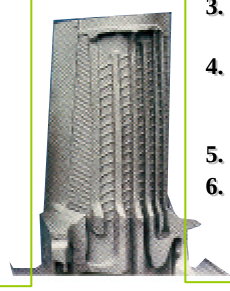
MIST/STEAM COOLING OF HIGH-TEMPERATURE GAS TURBINES

To improve the overall thermal efficiency, the inlet temperature and compressor pressure ratio are increasing for the next generation of gas turbine systems. As a result, gas turbine engines are expected to continuously operate at temperatures much higher than the allowable metal temperature of the turbine airfoils, which, in turn, makes effective cooling of the airfoils essential. Internal mist/steam blade cooling technology is developed at ECCC for future high-temperature gas turbine systems. By injecting small amount of micro-water droplets into the steam flow, the heat transfer can be significantly enhanced from 50 to 200% on average. The local enhancement can achieve up to 800%.

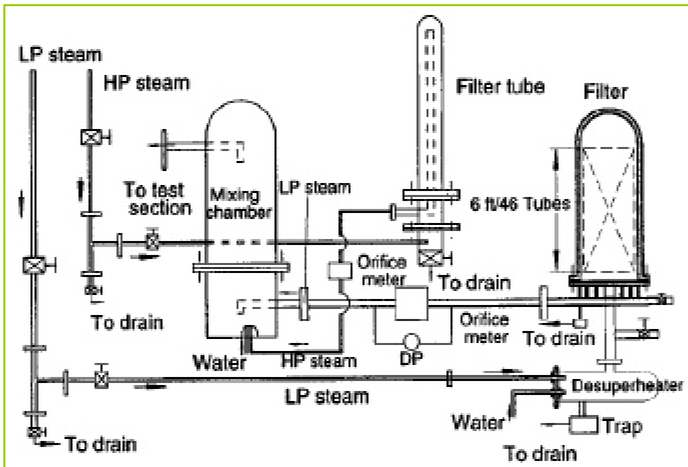
RESEARCH PROGRAM

- Measuring heat transfer enhancement with water droplets injection
- Droplet measurement by using a phase Doppler particle analyzer (PDPA)
- Simulating particle dynamics & heat transfer using computational fluid dynamics (CFD)
- Modeling of mist/steam cooling to explore its mechanism
- Projecting mist/steam cooling from lab tests to industrial prototypes

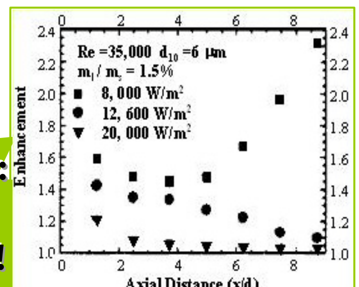


ENHANCEMENT MECHANISMS

1. Latent heat of evaporation serves as a heat sink to absorb large amounts of thermal energy;
2. Heat sink effect reduces the bulk temperature and increases its gradient near the wall;
3. Direct contact of droplets with the wall increases heat transfer via wall-to-liquid heat conduction;
4. Propulsive momentum induced by wall-to-liquid droplet vaporization accelerates the transport of energy from the wall to the core flow;
5. Steam & water have higher specific heat capacities than air;
6. Flow mixing is increased by steam-particle interactions through particle dynamics, including forces such as Saffman force, turbophoresis and evaporation force.

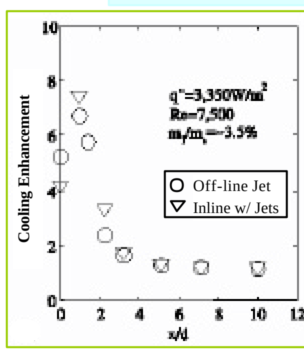


Cooling Enhancement:
-- Locally, up to 800%
-- Overall, up to 200% !

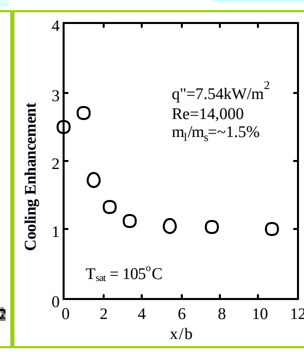


Straight Tube

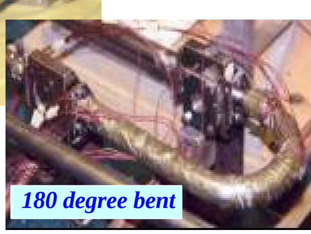
A Row of Round Jets



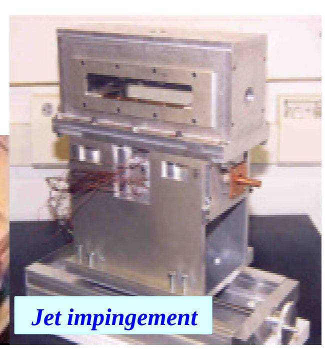
A Slot Jet



Straight Tube



180 degree bent



Jet impingement

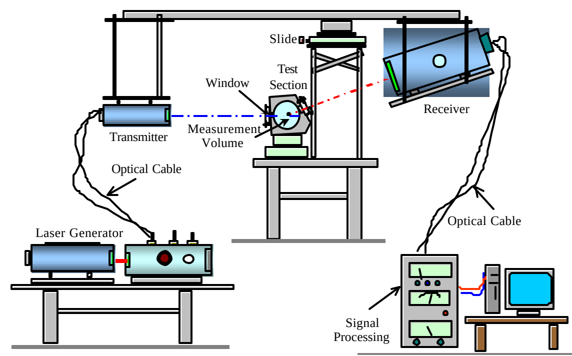
Energy Conversion & Conservation Center
UNIVERSITY OF NEW ORLEANS

Mist/Steam Cooling of High-Temperature Gas Turbines

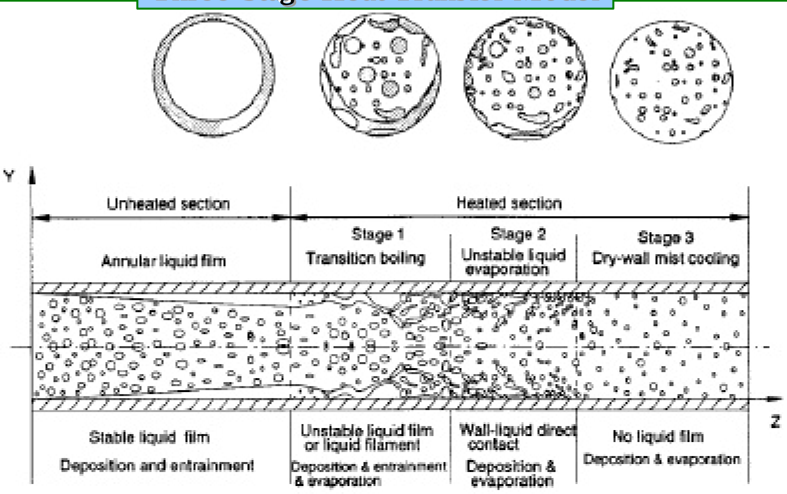
Test Cases & Enhancement Brief

Test Cases	Mist Mass Fraction	Enchantment Average / Max
Straight Tube	5%	~100% / 200%
180° Tube Bent	5%	~200% / 800%
Slot Jet w/ Flat Target	1.5%	~200% / 400%
Slot Jet w/ Curved Target	0.5%	~ 50% / 200%
Circular Jet w/ Flat Target	0.75~3.5%	~200% / 600%

PDPA (Phase Doppler Particle Analyzer) System

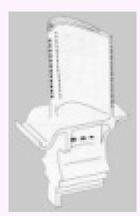


Three-Stage Heat Transfer Model

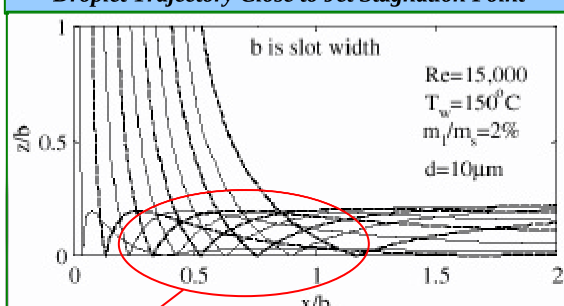


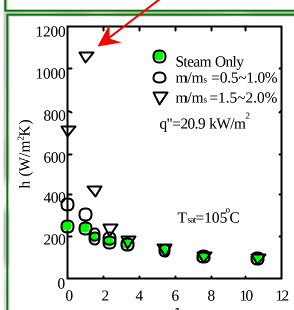
Future Study

- Mist/steam heat transfer at high pressure
- Mist/steam heat transfer at high temperature
- Mist/steam heat transfer with rotation
- Mist/steam cooling in prototypes
- Mist/air cooling
- Droplet dynamics in confined and rotating channels



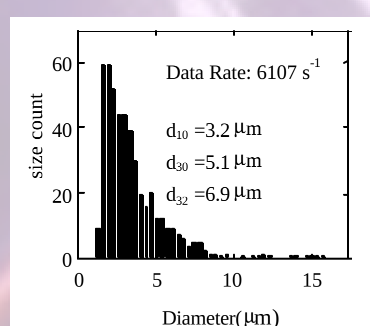
Droplet Trajectory Close to Jet Stagnation Point

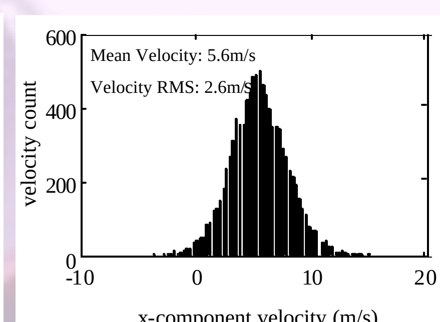




Rebounding and re-impact plus streamline splitting make the peak heat transfer coefficient off-axis.

Typical droplet size distribution at test section inlet in mist/steam experiments





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