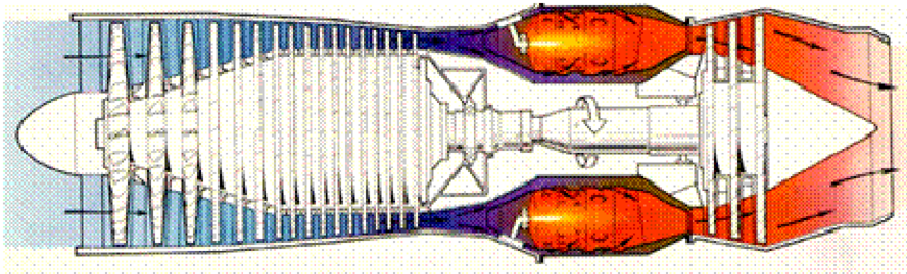
Experimental Research: Gas-Turbine Blade Cooling



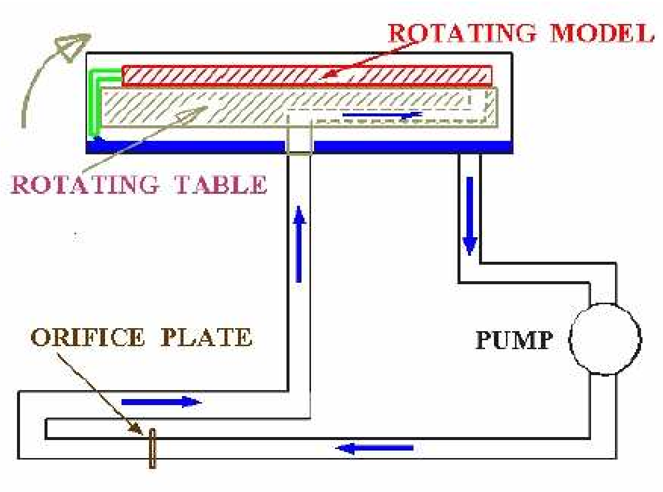
To increase the engine propulsive power and efficiency, the designer must raise the gas temperature.

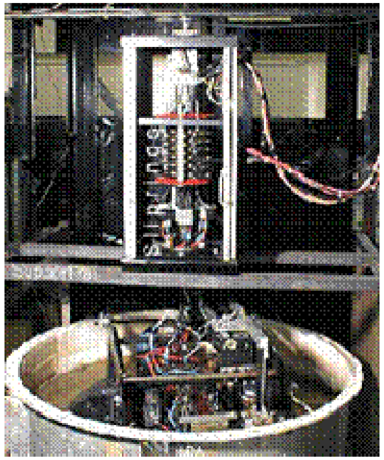
- Desired operating temperatures, above the limit of the materials used to manufacture turbine blades;
- Increase the safe temperature limit of the materials and cool turbine blades and nozzle guide vanes internally;
- The blade cooling systems include, long ribbed passages with sharp U-bends at each end, impingement cooling, pin fins etc.

The blade rotation also generates Coriolis and rotational buoyancy forces.

Experimental Research: Gas-Turbine Blade Cooling

Rotating Flow Experiment

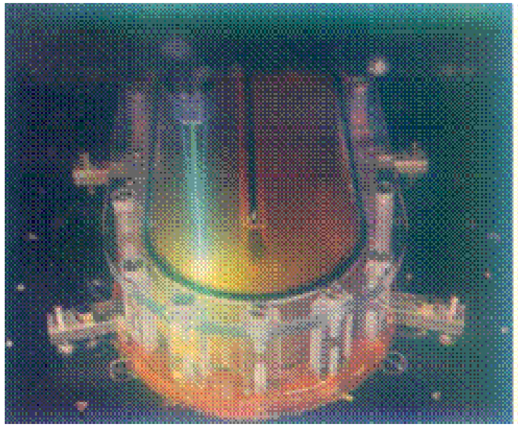


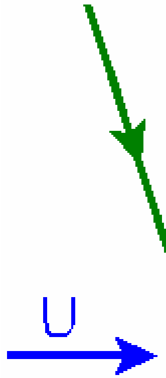


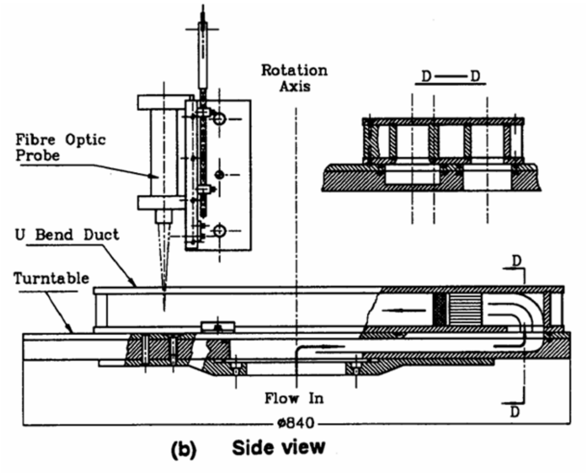
- Rotating water flow table, 1.2 m in diameter
- Experimental models 25-50 times larger than actual cooling passages
- Capable of reproducing engine Reynolds & rotation numbers

Experimental Research: Gas-Turbine Blade Cooling

Mapping of the Velocity Field



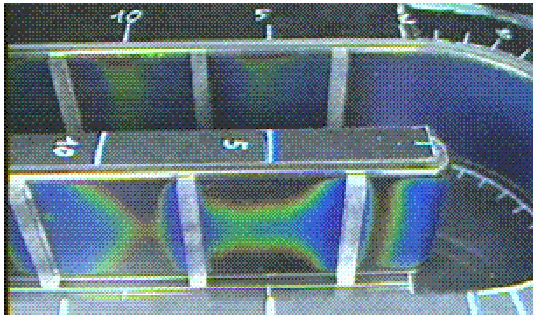




- Laser Doppler Anemometry: Measures velocity of fluid particles that move through the intersection of the two beams.
- Optical fibres take the beams above rotating experimental model.
- Velocity measurements collected within rotating passages.
- Sophisticated data-processing software

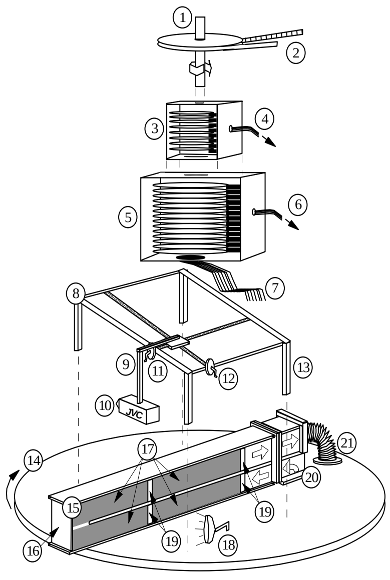
Experimental Research: Gas-Turbine Blade Cooling

Mapping of wall heat flux coefficient Liquid Crystal Technique



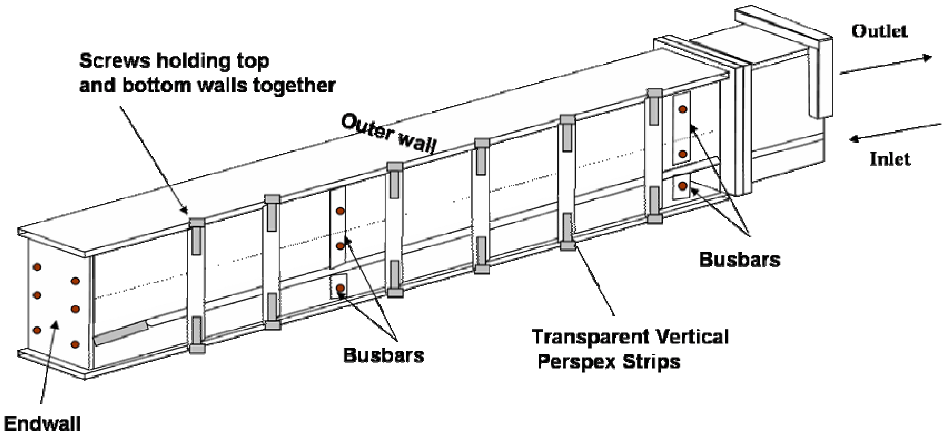
- Surface colour changes with temperature
- Surfaces electrically heated

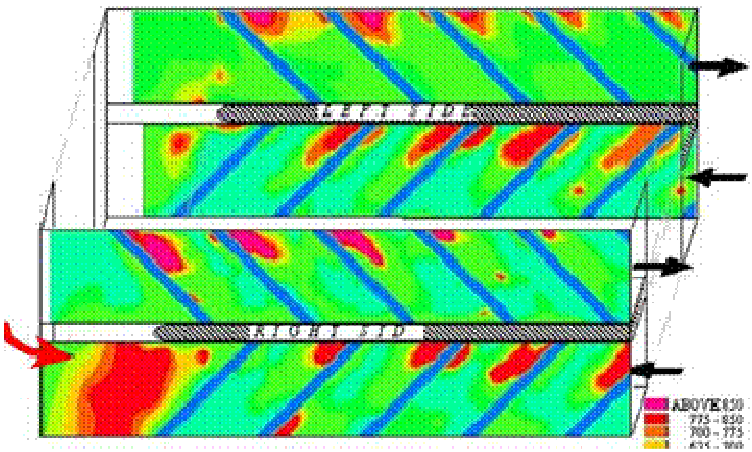
- Knowledge of heating rate results in calculation of heat flux coefficient along colour contours
- Use of power slip rings and rotating cameras allow application of method to rotating flows
- Image processing software converts images to contours of dimensionless wall heat transfer rates.

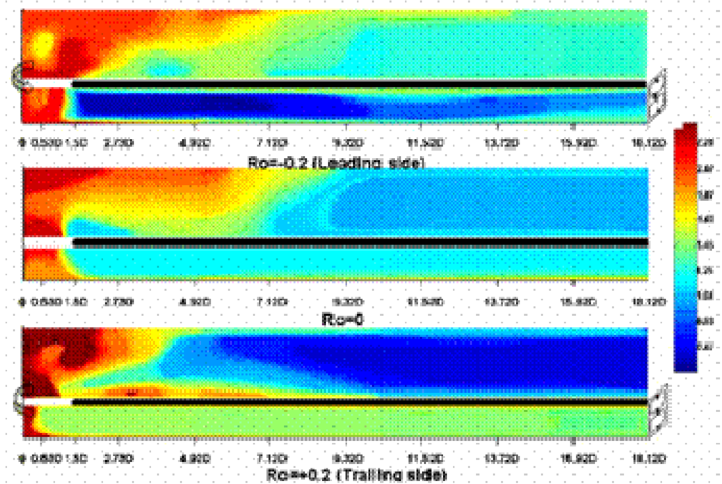


Experimental Research: Gas-Turbine Blade Cooling

Effects of Rotation on Nusselt Number



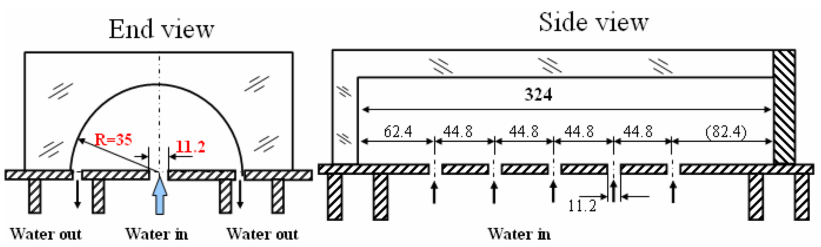




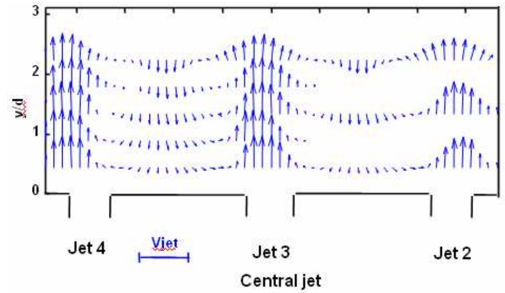
Comparison of normalised local Nusselt number between rotating and stationary conditions, for Ro=0.2, for water (Pr=5.8) and at Re=36,000

Experimental Research: Gas-Turbine Blade Cooling

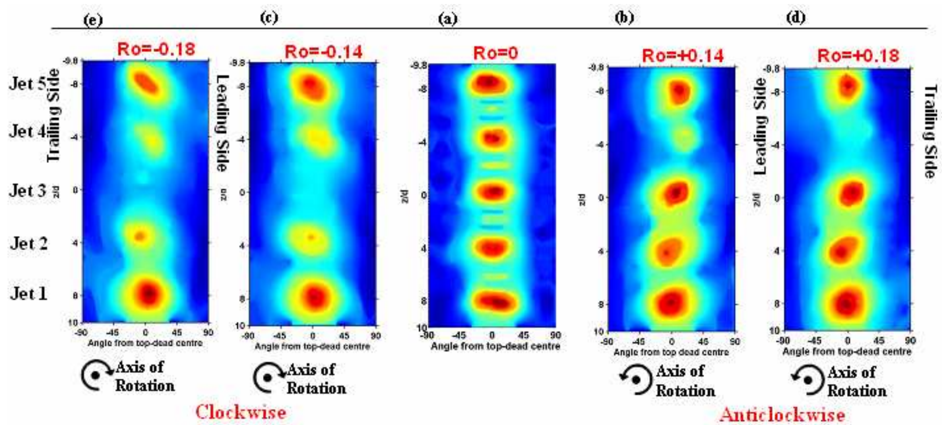
Impingement Cooling



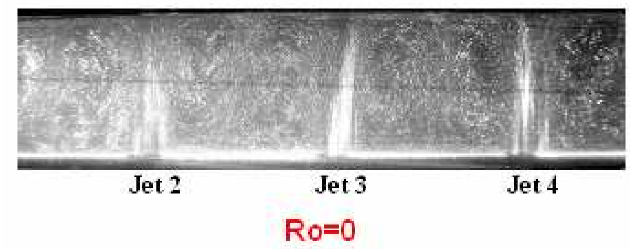
Experimental Model



Laser Doppler Measurements



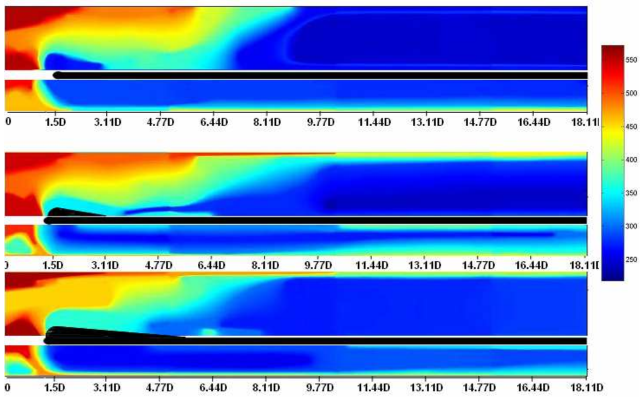
Nusselt Number Contours

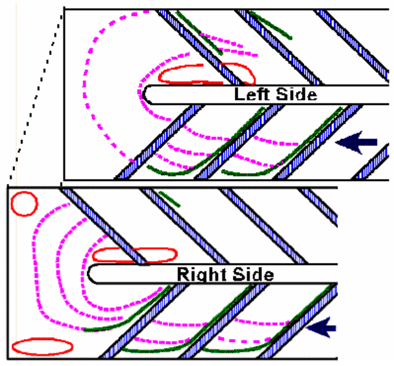


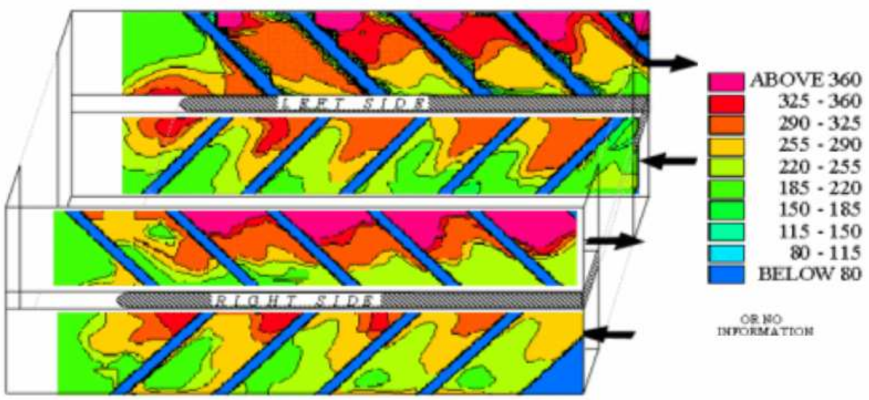
Flow Visualisation Images

Experimental Research: Gas-Turbine Blade Cooling

Exploration of Shape Optimisation

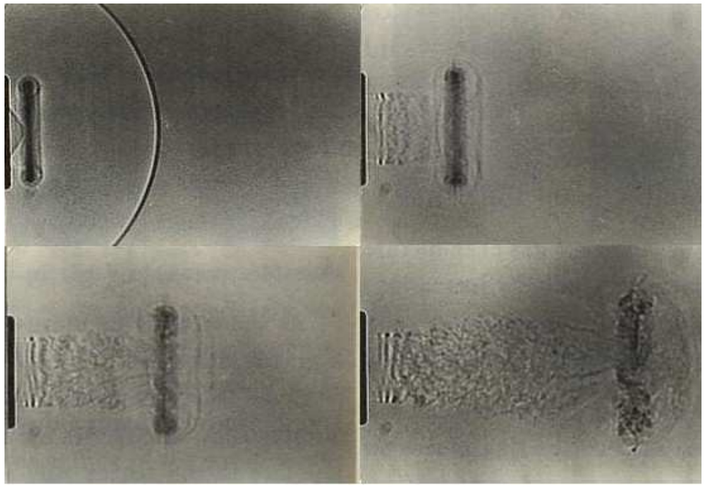


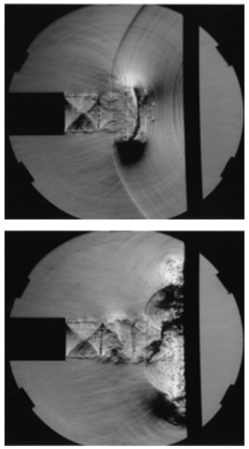




Propagation of a compressible vortex

Study of compressible vortex rings is of fundamental importance in the understanding compressible turbulence and in a variety of aerospace and military applications.



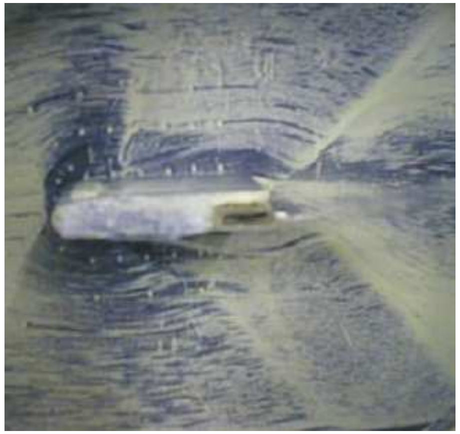


Compressible vortex ring instability and interaction with generic bodies

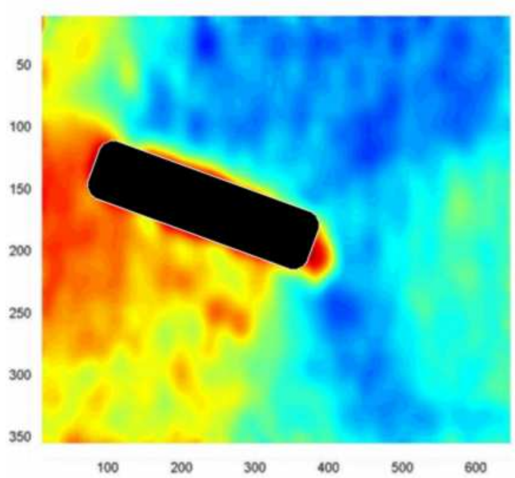
Experimental Research: Aerospace

Global pressure map: Junction Flows

Transonic glancing interaction between a flat plate and a blunt fin.



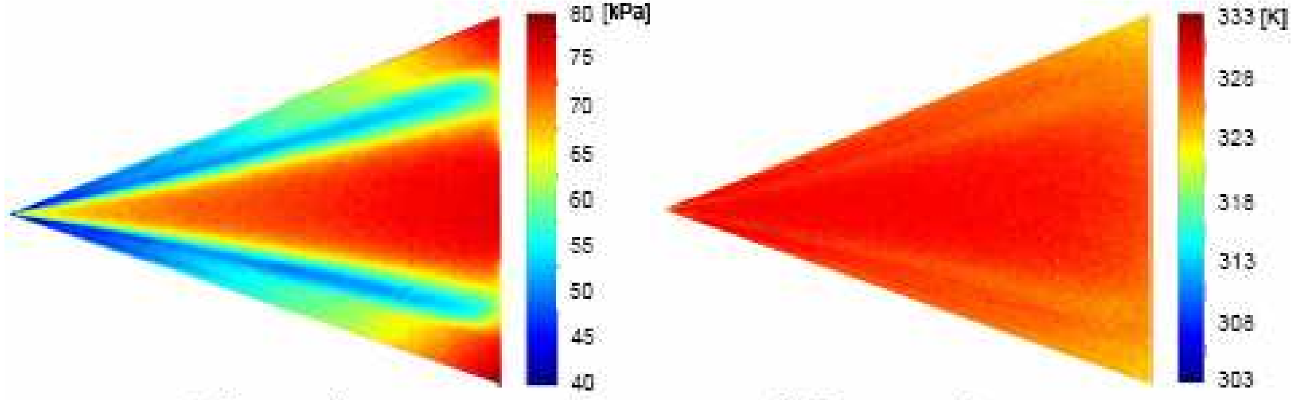
Oil flow mapping



Pressure Sensitive Paint

Experimental Research: Aerospace

Low Speed Delta Wing Surface flow mapping

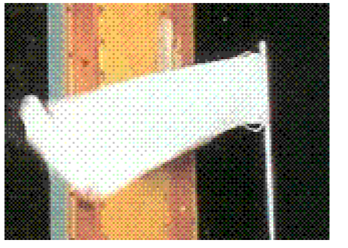


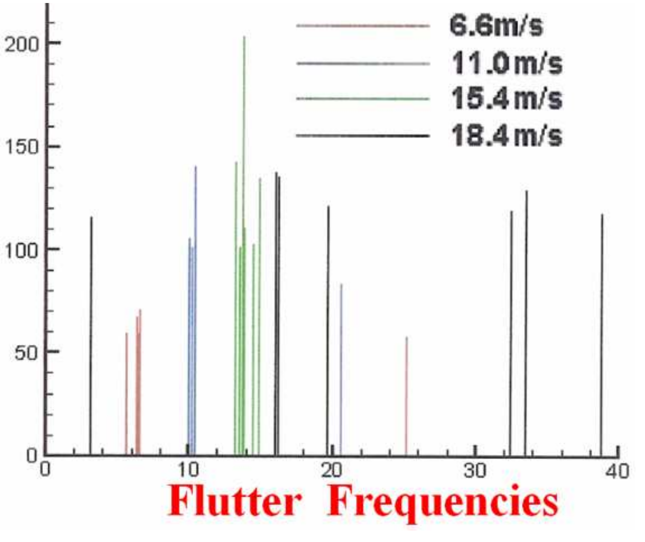
(a) Pressure image (b) Temperature image

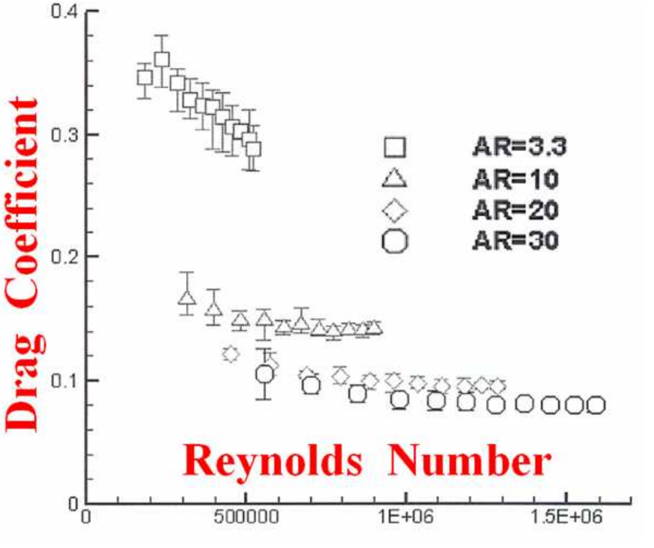
Pressure and temperature images: Leeward side, M= 0.2, angle of attack= 20 deg

Experimental Research: Fluid-Solid Interactions

Flags, Streamers, Loops, Tapes and Parachutes





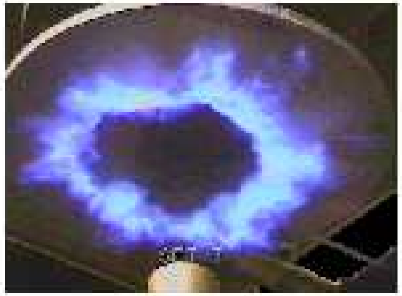


Experimental Research: Combustion

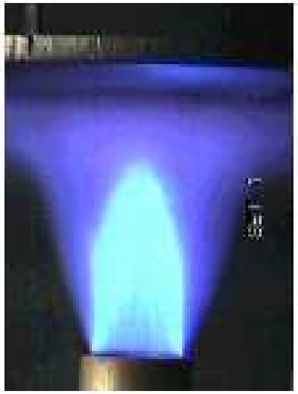
Impinging Flame Investigations

Blown ring

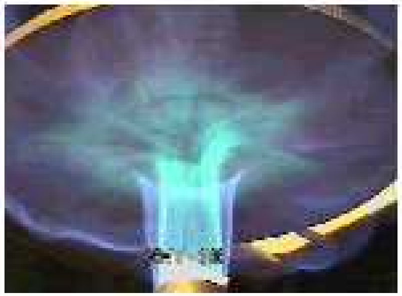
Disc



Ring



Conic

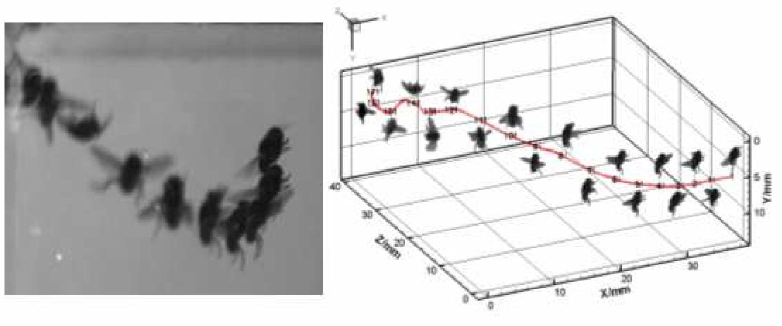


Cool Central Core

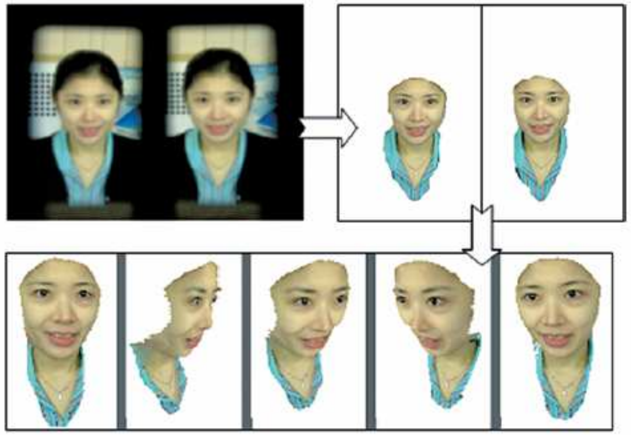
Detached Conic

Experimental Research: Combustion

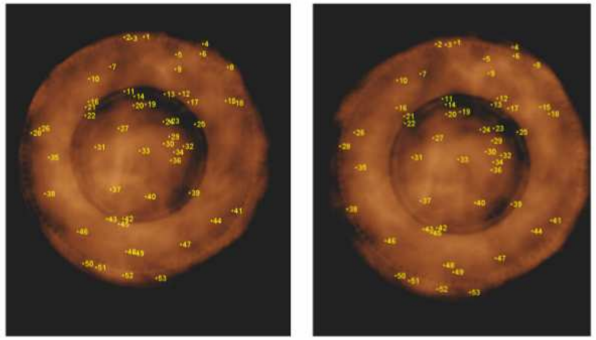
3-Dimensional Imaging



Flight Path of a Fly



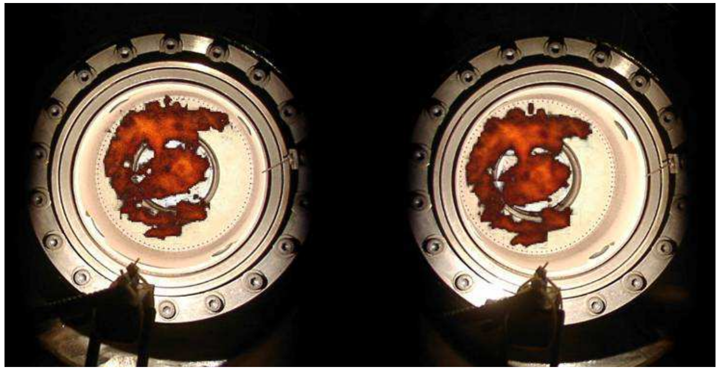
Human Face

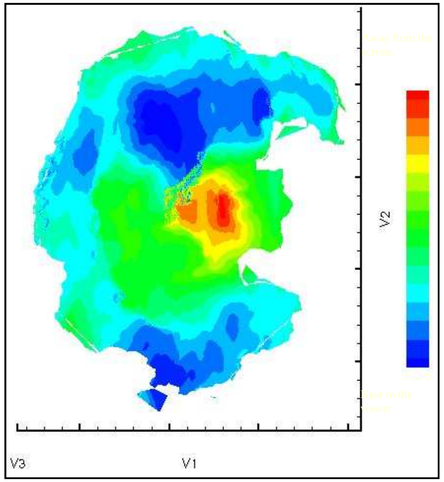


Industrial Gas Turbine Combustor

Experimental Research: Combustion

Stereo-Imaging of Combustion





Original Images

Digital Re-Construction