

Problem Statement

The pressure sensitive paint is a methodology implemented to measure the pressure at the surface of a testing element. Pressure measurement is traditionally conducted using pressure tabs which display several limitations such as creating perturbations on the mainstream and local measurements.

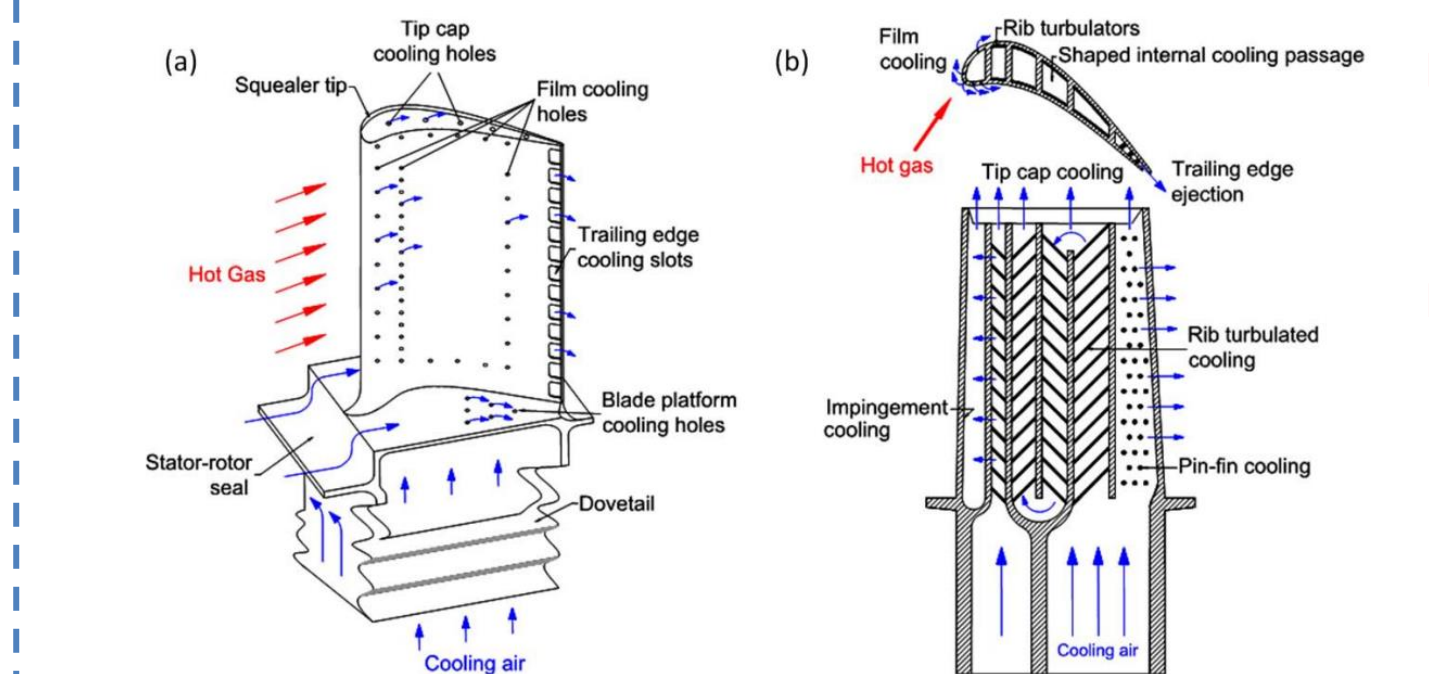
Objectives

- Measuring pressure using PSP technique from intensity
- Determine film cooling effectiveness by relating it to the partial pressure of oxygen

Materials and Methods

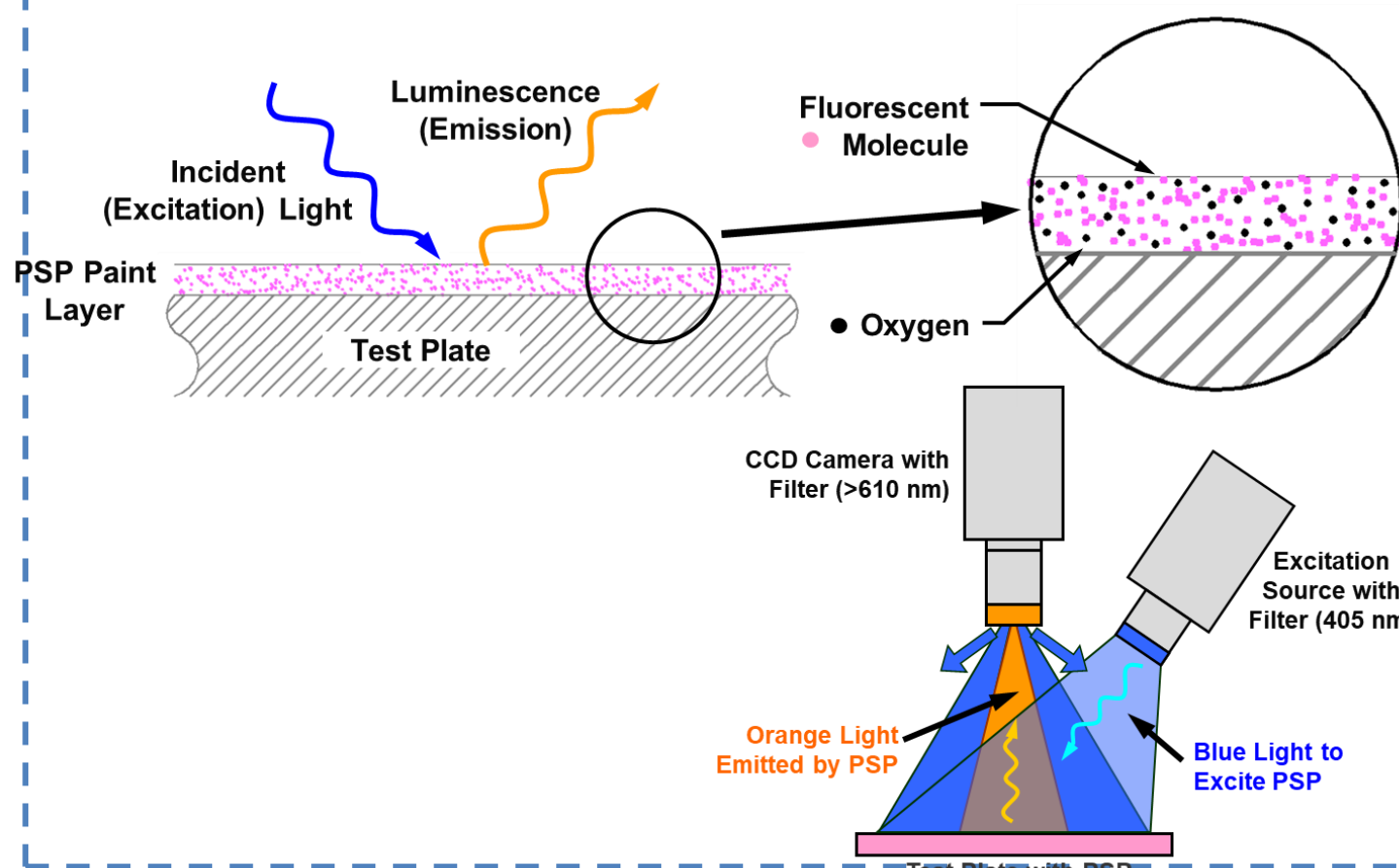
Turbine Blade Cooling Techniques

Advanced cooling technologies include blade internal cooling (Fig. b) and external cooling (Fig. a)



- Internal Cooling:**
 - Pin fin cooling
 - Rib turbulated cooling
 - Impingement cooling
- External Cooling:**
 - Film cooling and the provision of an insulating thermal barrier coating.
 - Form an insulating film reducing contact of the blade material with the hot mainstream drilling secondary fluid into internal cooling passages

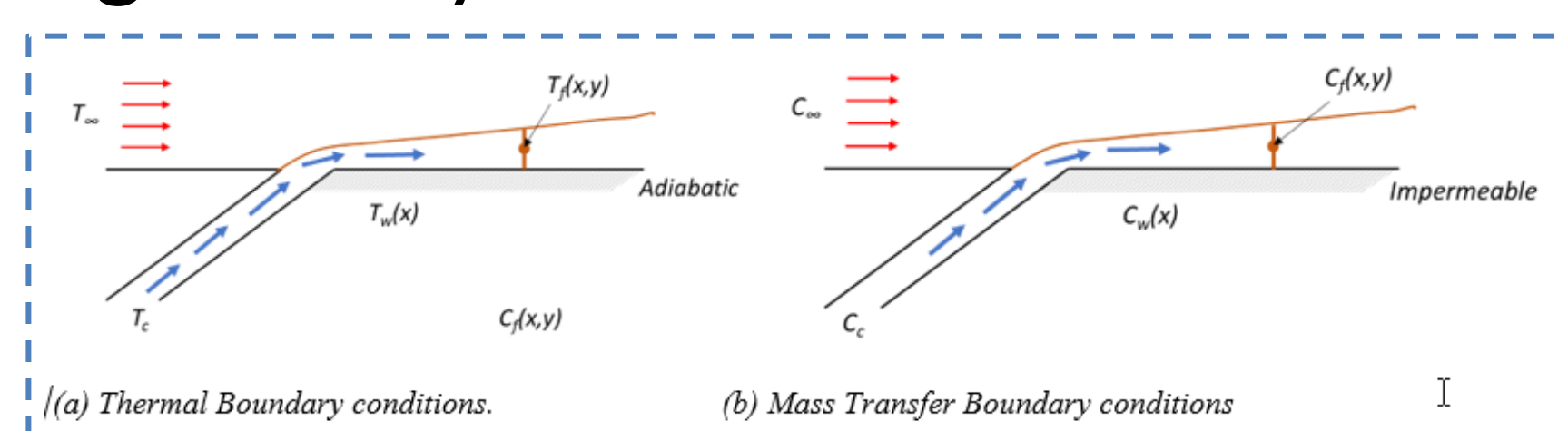
PSP Test Description



- Photo-luminescent molecules and an oxygen-permeable polymer binder, both dissolved in a solvent
- Excited by a LED light source with a wavelength of 400 nm
- Luminescent molecules in the paint emit photons at a wavelength around 650 nm

Film Cooling Effectiveness

Film cooling two-layer Model & Mass Transfer analogy



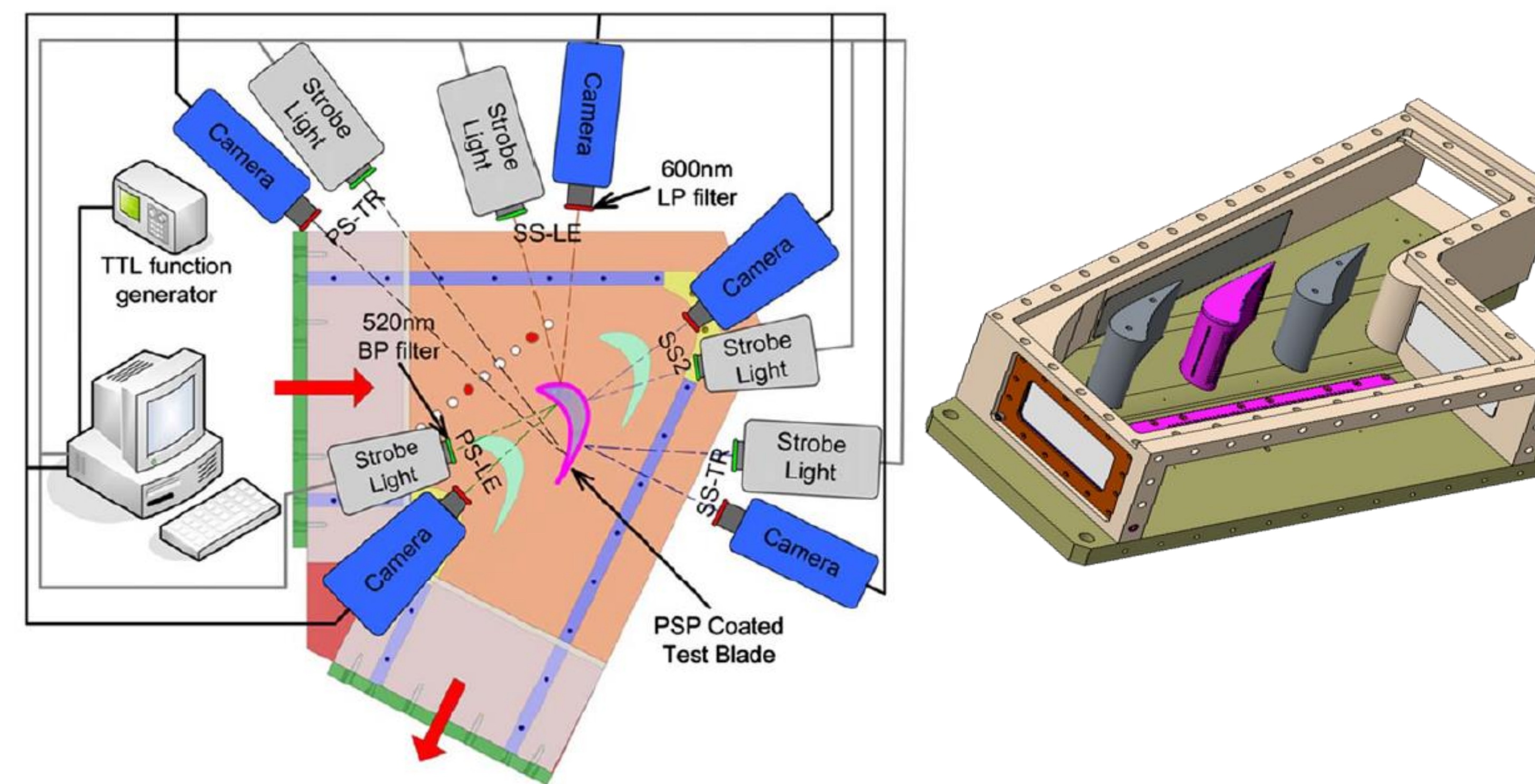
Film cooling effectiveness Calculation

$$\eta = \frac{T_f - T_\infty}{T_c - T_\infty} \approx \frac{T_{aw} - T_\infty}{T_c - T_\infty} \quad \eta \approx \frac{C_w - C_\infty}{C_c - C_\infty} = \frac{C_{O_2,fg} - C_{O_2,air}}{C_{O_2,c} - C_{O_2,air}} = 1 - \frac{C_{O_2,fg}}{C_{O_2,air}}$$

$$\eta = 1 - \frac{C_{O_2,fg}}{C_{O_2,air}} = 1 - \frac{1}{\left(1 + \left(\frac{P_{O_2,air}/P_{O_2,R}}{P_{O_2,fg}/P_{O_2,R}} - 1\right) \frac{W_{fg}}{W_{air}}\right)}$$

PSP Testing Procedure

Cascade Film Cooling Setup



Black Image

- Switch Off excitation LED light
- Capture image in Dark Room
- Determine the background noise intensity

Reference Image

- Turn ON excitation LED light
- Capture image Without mainstream
- Determine the intensity

Air Image

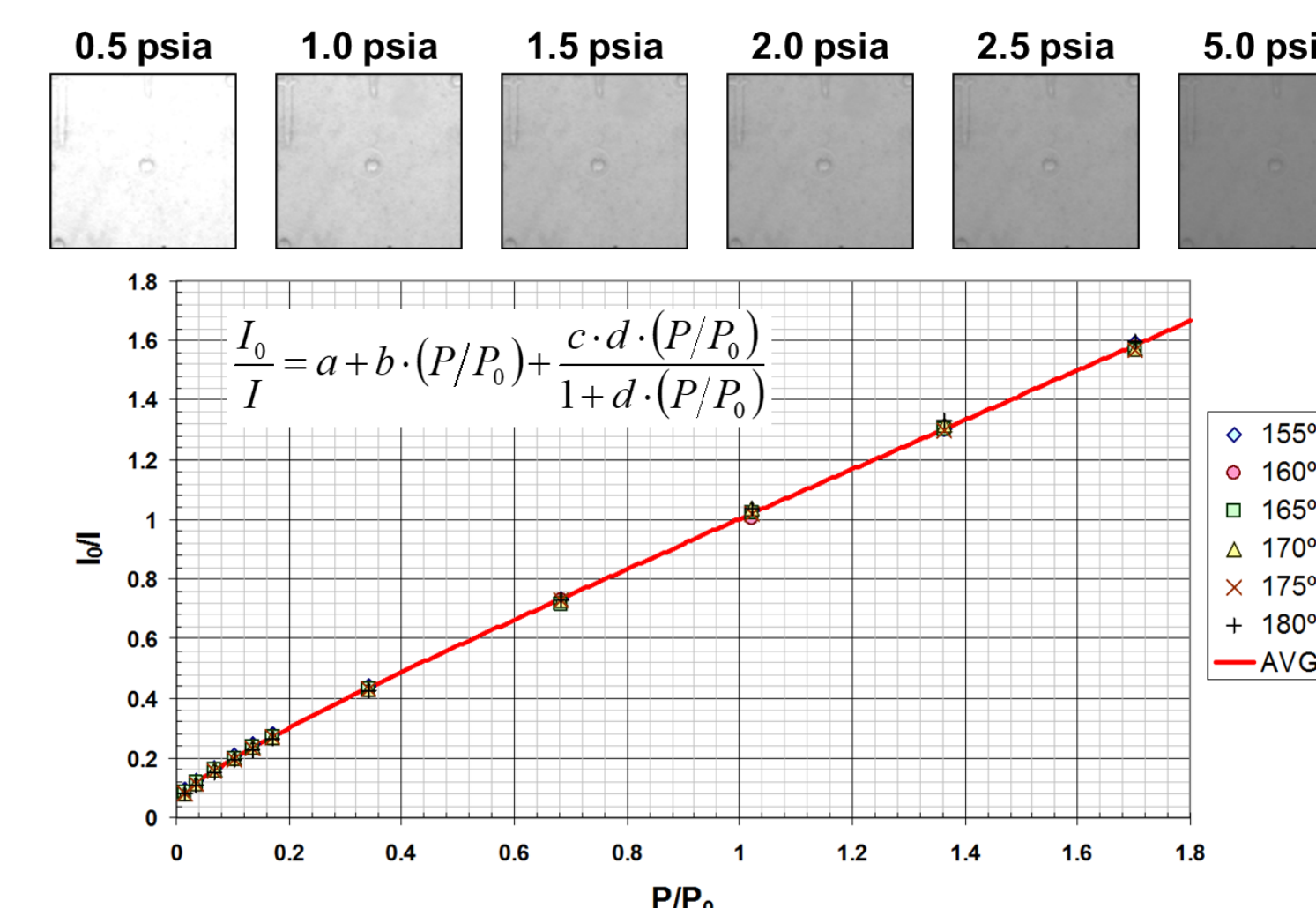
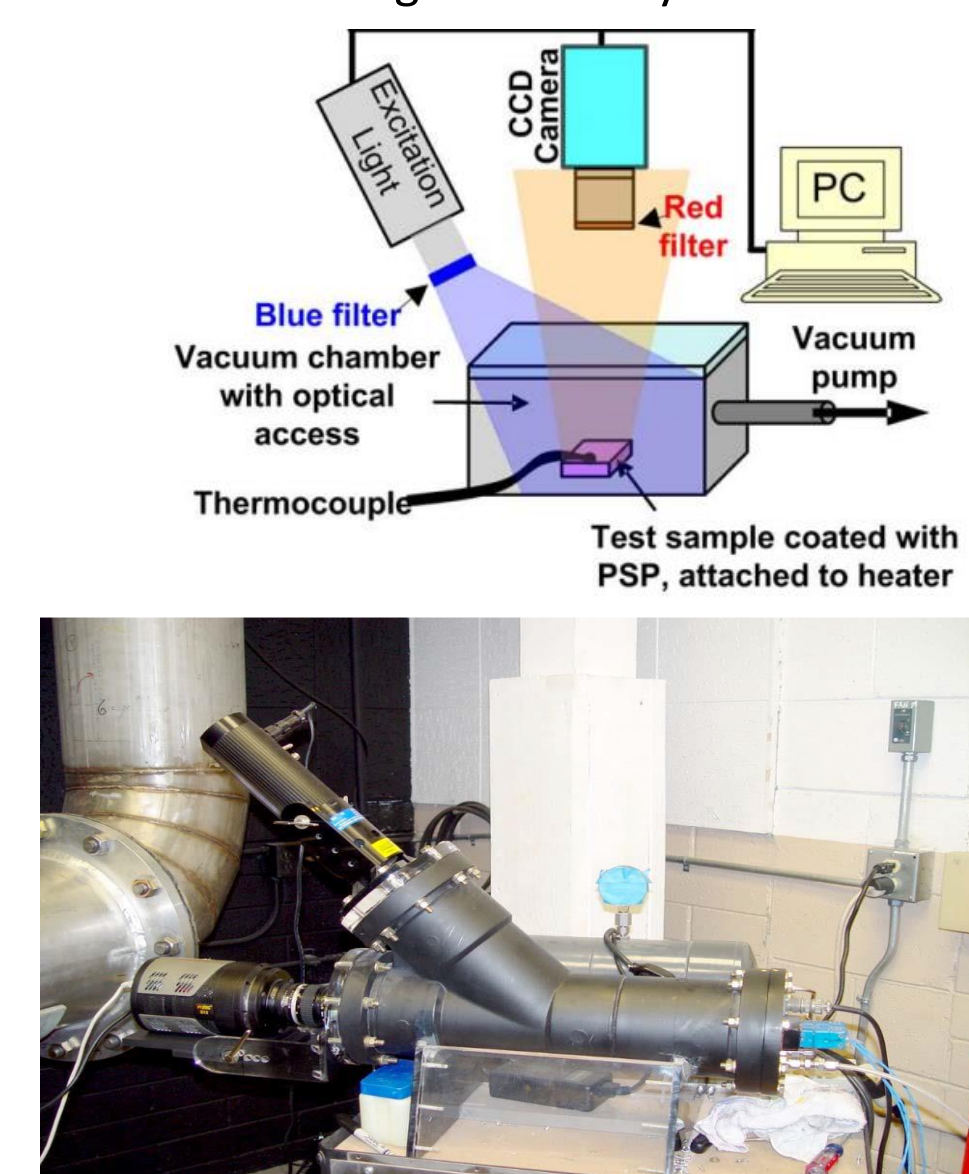
- Establish mainstream and Air blowing ratio
- Capture image of Air as coolant
- Determine the intensity of Air

Coolant Image

- Establish blowing ratio of foreign gas
- Capture image of flowing foreign gas
- Determine the intensity of fg

PSP Calibration

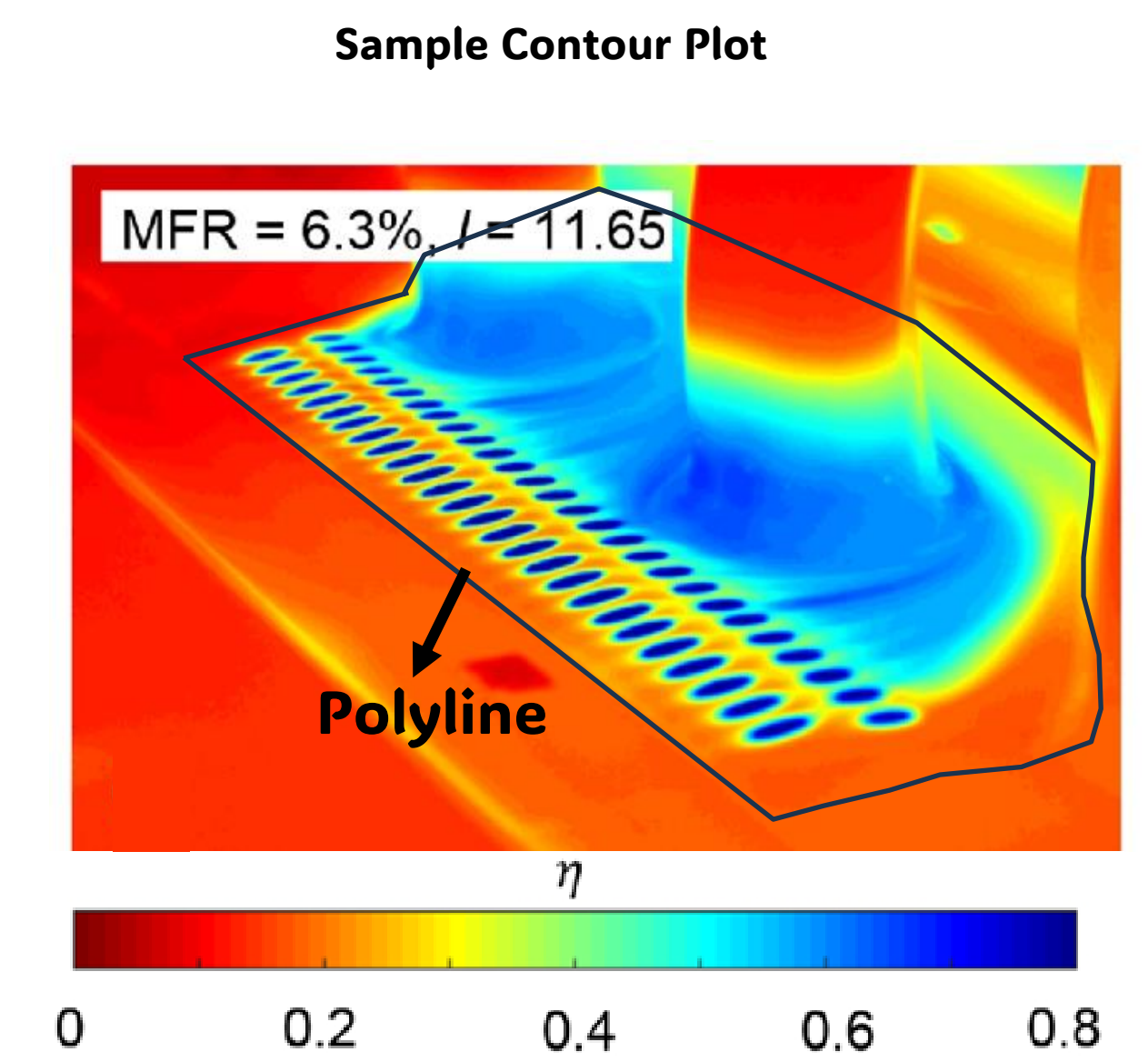
Calibration Parameters are obtained by curve fitting the data generated by the calibration setup



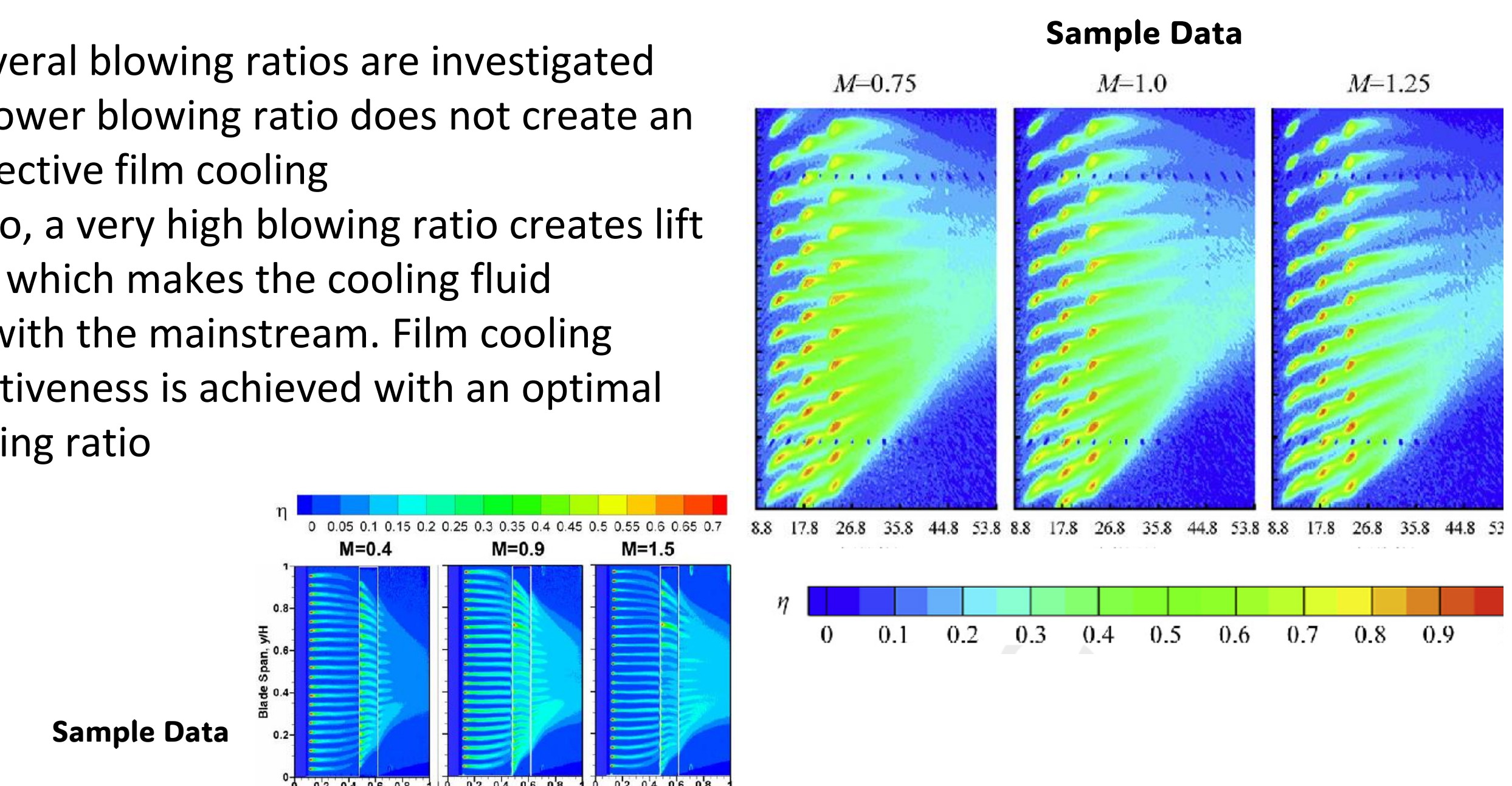
Results & Discussion

Data Reduction – Tecplot 360

- Tecplot 360 is a Computational Fluid Dynamics (CFD) and numerical simulation software package used in post-processing simulation results
- The reduced data is processed by creating a polyline to get rid of the noise surrounding the testing section of concern (i.e., Blade).
- Data cleaning using a Matlab code.
- Visualize data using a contour display mode from TECPLOT 360.
- Plot exported as a TIFF image.



- Several blowing ratios are investigated
- A lower blowing ratio does not create an effective film cooling
- Also, a very high blowing ratio creates lift off which makes the cooling fluid mix with the mainstream. Film cooling effectiveness is achieved with an optimal Blowing ratio



Outcomes

- Film cooling effectiveness data processing was elaborated
- Data cleaned and contour plots generated to assess film cooling effectiveness
- PSP procedure documented into Engineering Design Memo (EDM)
- step-by-step interactive instructional document for film cooling effectiveness data processing elaborated

Acknowledgements

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