OPTIMIZATION OF TURBINE RIM SEALS

J.H. Wagner, D.E. Tew, G.M. Stetson, and J.S. Sabnis
Pratt & Whitney
West Palm Beach, Florida

ABSTRACT

Experiments are being conducted to gain an understanding of the physics of rim seal cavity ingestion in a turbine stage with the high-work, single-stage characteristics envisioned for Advanced Subsonic Transport (AST) aircraft gas turbine engines of the early 21st century. Initial experimental measurements to be presented include time-averaged turbine rim cavity and main gas path static pressure measurements for rim seal coolant to main gas path mass flow ratios between 0 and 0.02. The ultimate objective of this work is develop improved rim seal design concepts for use in modern high-work, single stage turbines in order to minimize the use of secondary coolant flow. Toward this objective the time averaged and unsteady data to be obtained in these experiments will be used to

1) Quantify the impact of the rim cavity cooling air on the ingestion process,
2) Quantify the film cooling benefits of the rim cavity purge flow in the main gas path,
3) Quantify the impact of the cooling air on turbine efficiency,
4) Develop/evaluate both 3D CFD and analytical models of the ingestion/cooling process.

AGENDA

- Motivation
- Objective
- Approach
- Description of Experiments
- Description of Model
- Initial Results
- Summary

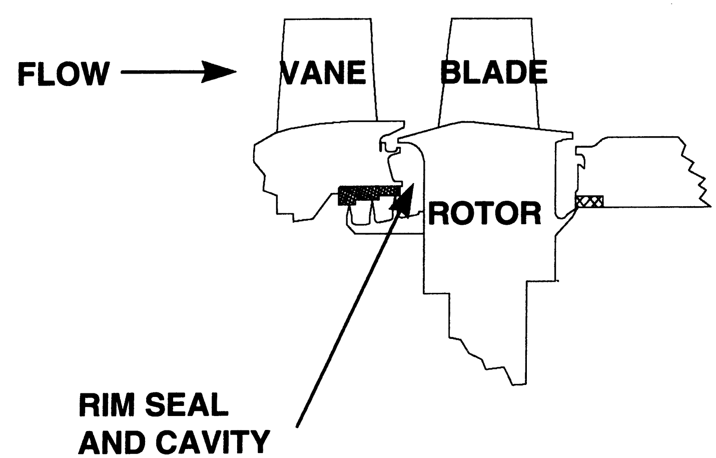
MOTIVATION

- Reduce SFC by reducing rim seal purge air required to cool cavity
  - Reduced SFC leads to
    - » Decreased DOC&I
    - » Decreased emissions

OBJECTIVE

- Reduce rim seal cooling air requirements by optimizing rim seal geometries

- Geometric parameters
  - Platform overlap
  - Radial gap
  - Overlap/gap asymmetries
  - Vane/blade spacing



APPROACH

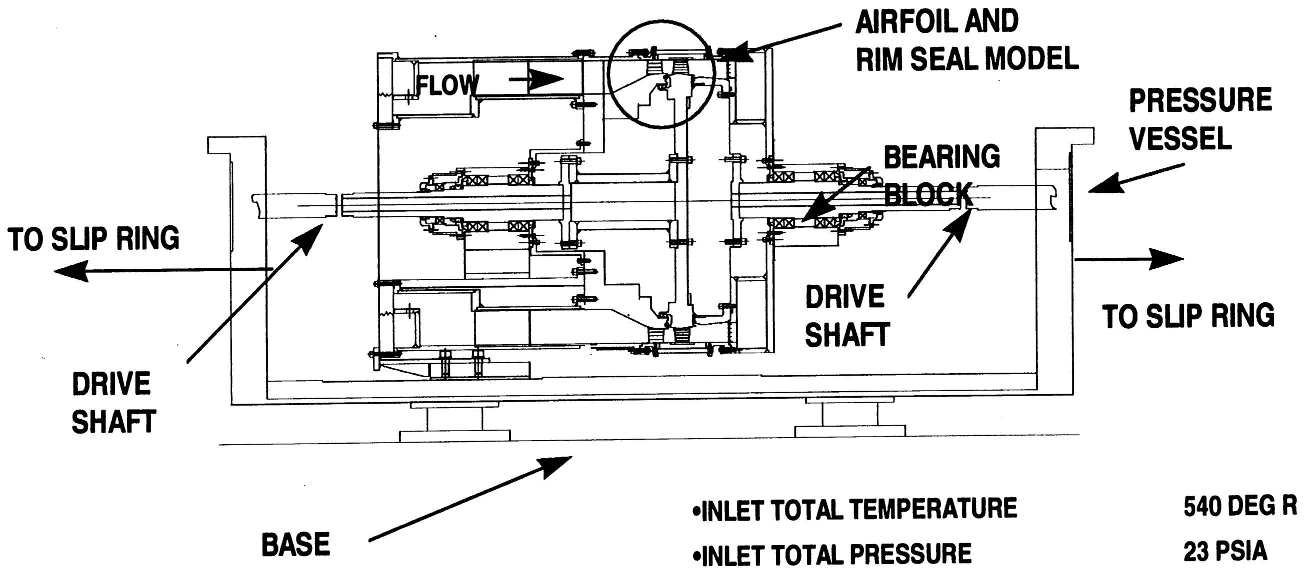
- Develop understanding of rim seal ingestion process via experiments and analytical models
  - Identify major drivers
  - Identify key design levers
- Develop optimized design
- Evaluate new design

DESCRIPTION OF EXPERIMENTS

- Facility
- Diagnostic Techniques

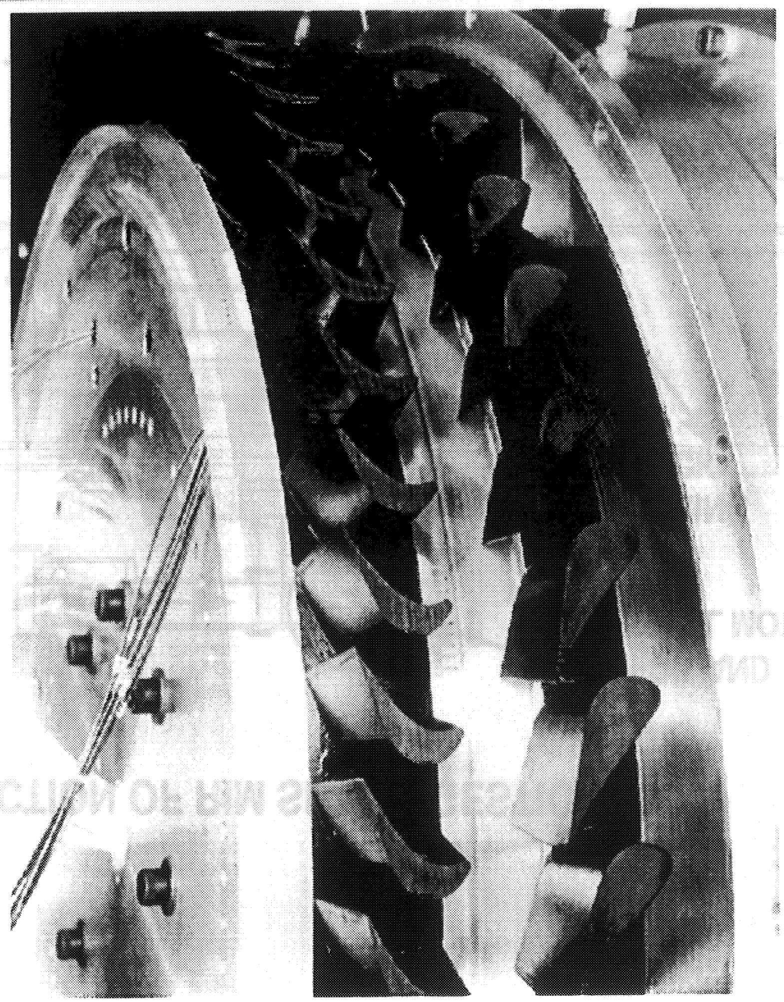
FACILITY

CROSS-SECTION OF RIM SEAL INGESTION RIG



•INLET TOTAL TEMPERATURE	540 DEG R
•INLET TOTAL PRESSURE	23 PSIA
•MASS FLOW	15 LBM/SEC
•FLOW COEFFICIENT (CX/U)	0.45
•VELOCITY TRIANGLES ARE MODELED	

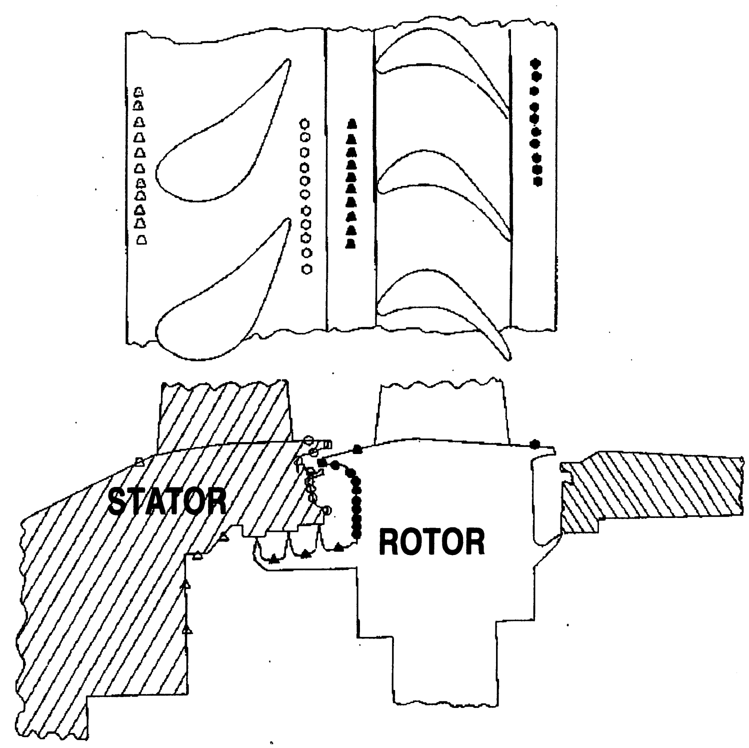
HALF-SPAN TURBINE MODEL



DIAGNOSTIC TECHNIQUES

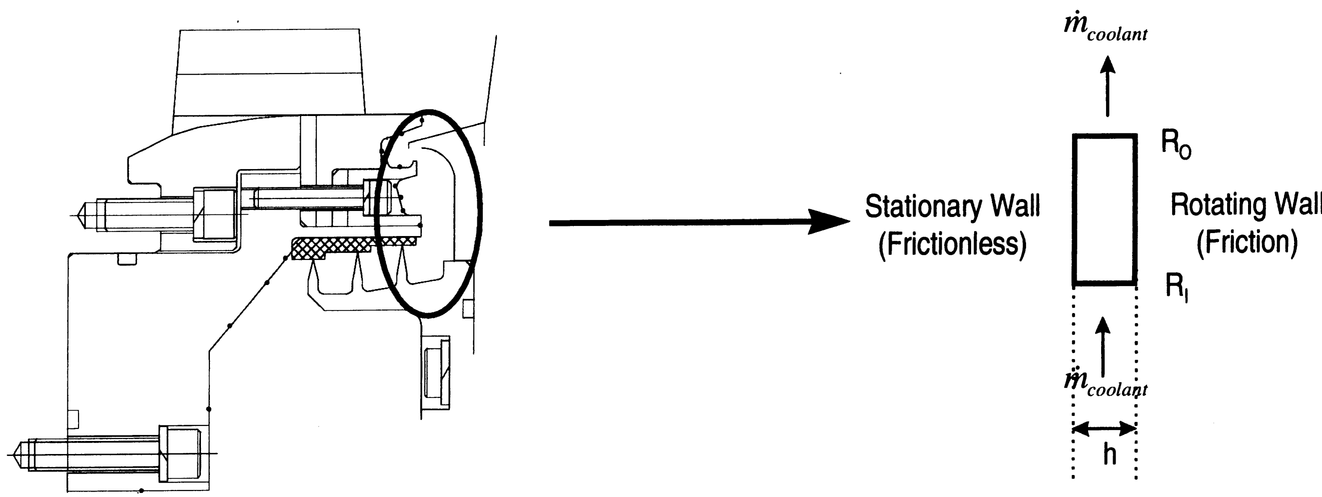
Technique	Utility
Time-Average Pressure	Evaluate CV models of cavity flow
CO_2 Concentration	Estimate cavity ingestion(temperatures) (Sc,Pr # analogies)
Unsteady Pressure	Quantify unsteadiness of cavity flow

PRESSURE TAP LOCATIONS



DESCRIPTION OF MODEL

Control Volume Approach

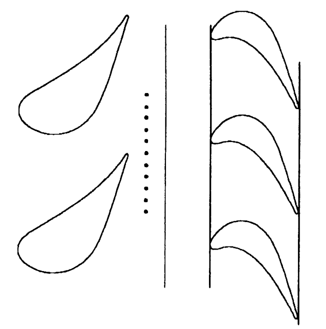


- **Given**
  - **Re, R_I / R_O, h / R_O, $\dot{m}_{coolant}$**
- **Calculate**
  - **Radial press. dist.**
  - **Radial and tang. velocity dist.**

IMPACT OF COOLANT ON CAVITY C_p DISTRIBUTION

- **OBJECTIVE**
  - Assess impact of coolant on cavity time-average C_p distributions

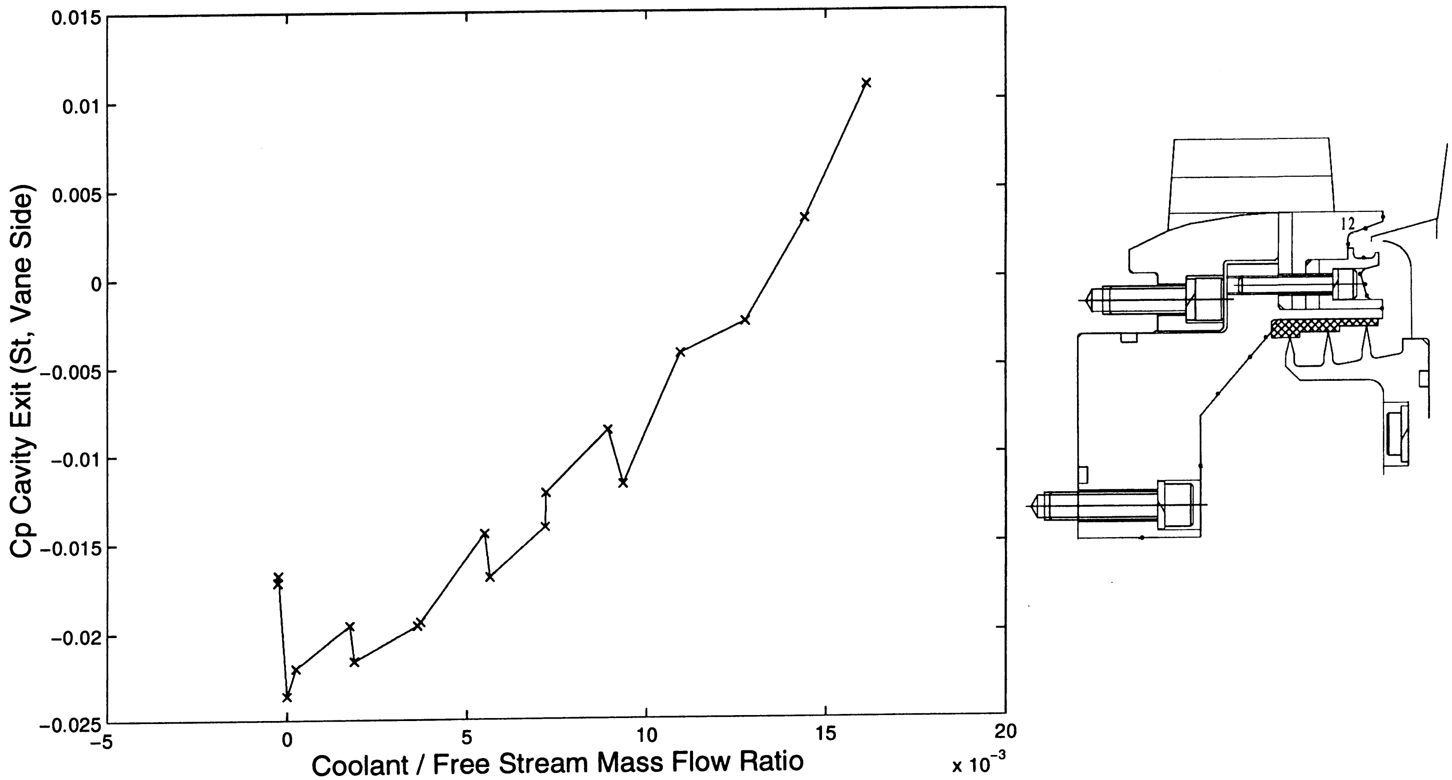
$$C_p \equiv \frac{p - \overline{p}_v}{Pt_{in} - \overline{p}_v}$$



- **APPROACH**
  - Vary coolant to free stream mass flow ratio
  - Hold flow coefficient and wheel speed constant
- **CAVEATS**
  - Flow coefficient not constant(+/- 5% variation)
  - Full uncertainty analysis not yet performed

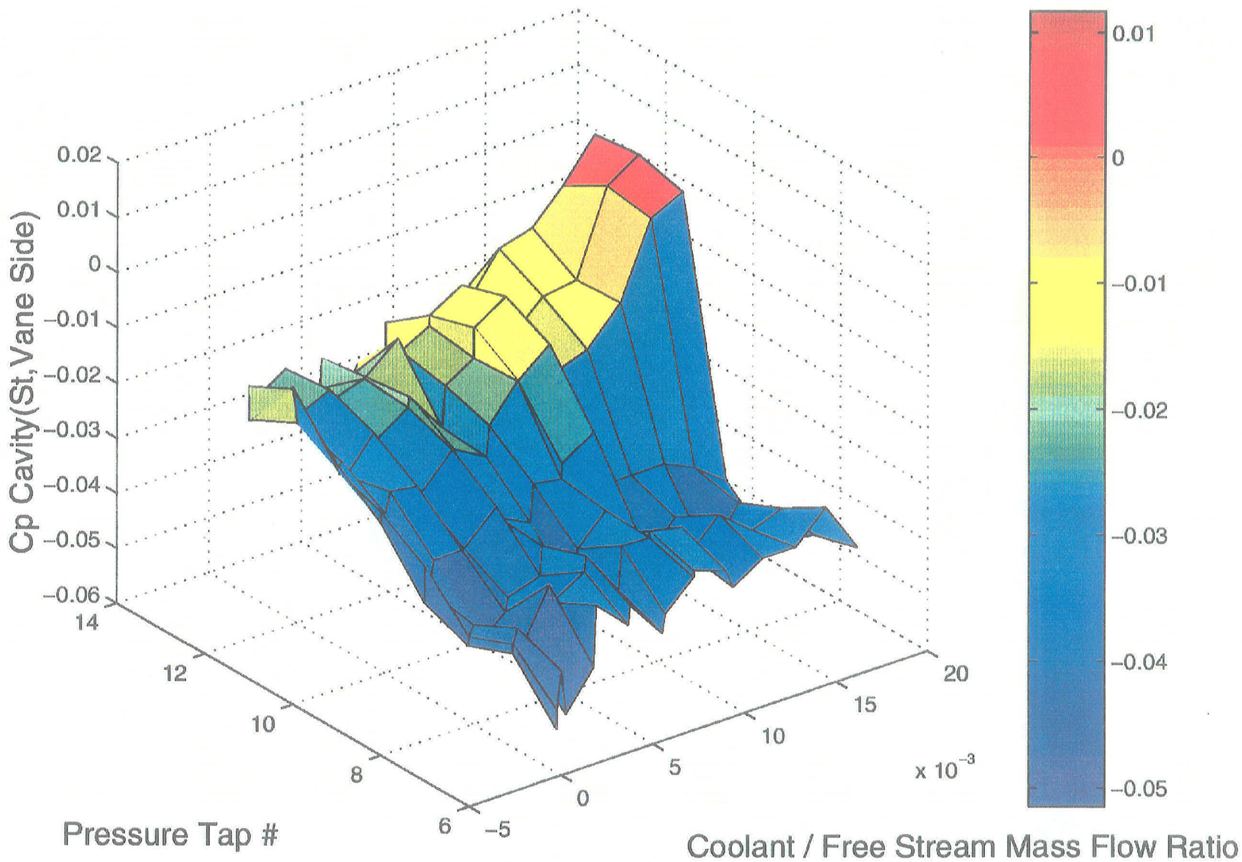
IMPACT OF COOLANT ON CAVITY Cp (DATA)

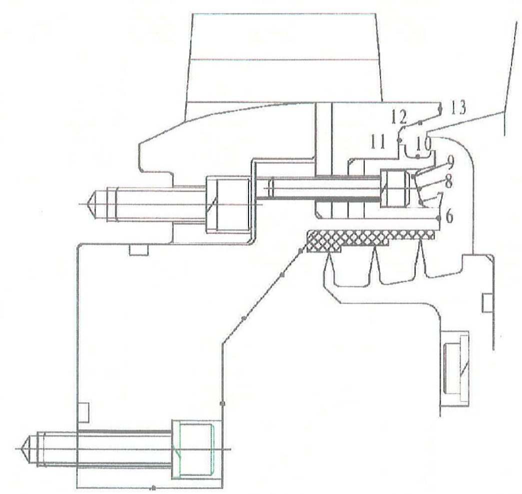
- **Vane Side Cavity Exit (Tap #12)**



IMPACT OF COOLANT ON CAVITY Cp (DATA)

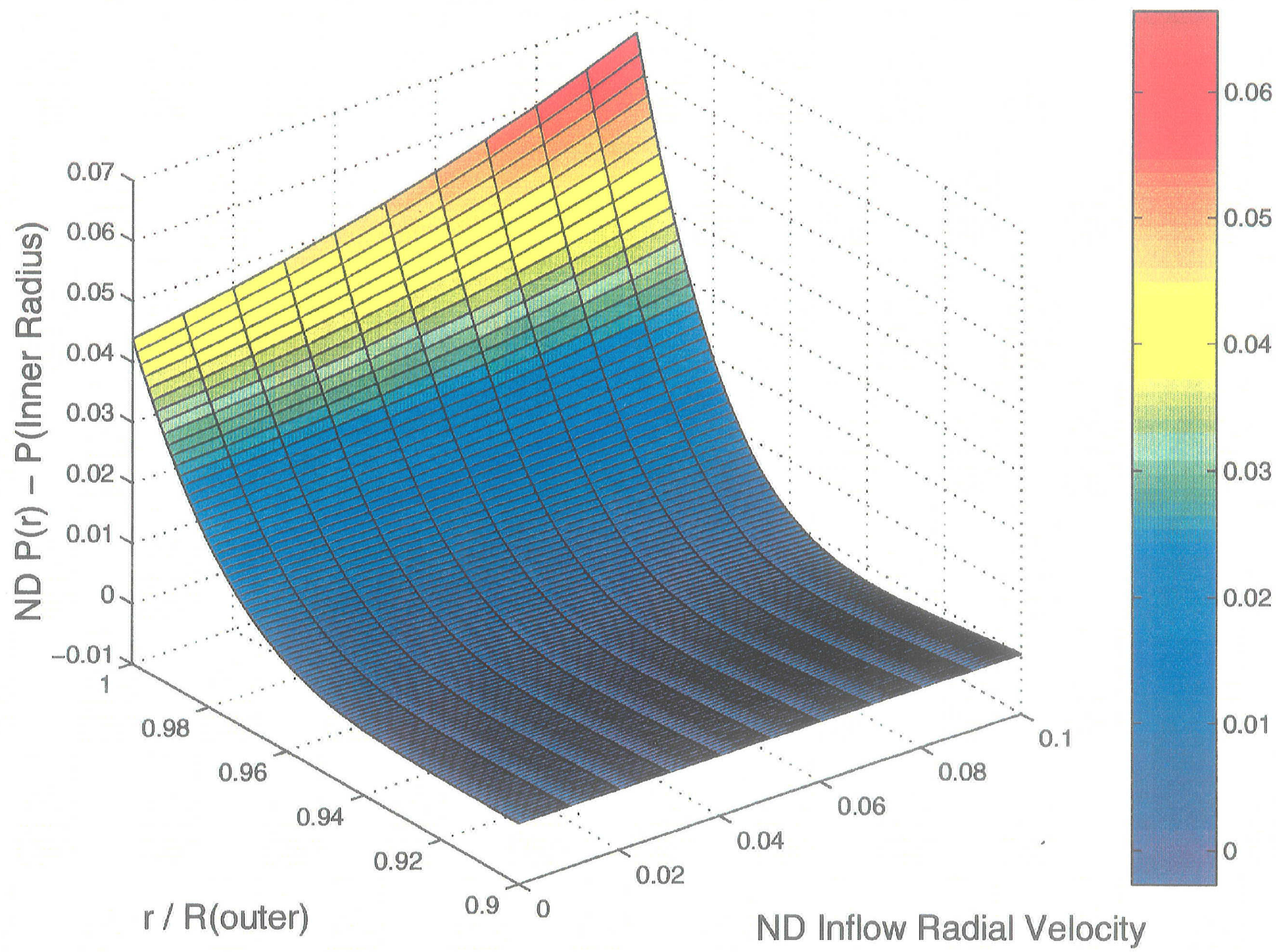
- Vane Side of Cavity





IMPACT OF COOLANT ON CAVITY PRESSURE DIST. (MODEL)

Ri = 0.9, h = 0.1, Re = 10



SUMMARY

- Experiments and modeling efforts directed toward reduction of rim seal purge air by optimizing rim seal geometry

- Approach
  1) Understand physics of ingestion process via experiments
  2) Develop control volume models(design tools)
  3) Design optmized rim seal
  4) Evaluate optimized design in experiments

- Experiments underway

- Initial modeling results encouraging