NON-CONTACTING COMPLIANT FOIL SEAL FOR GAS TURBINE ENGINE

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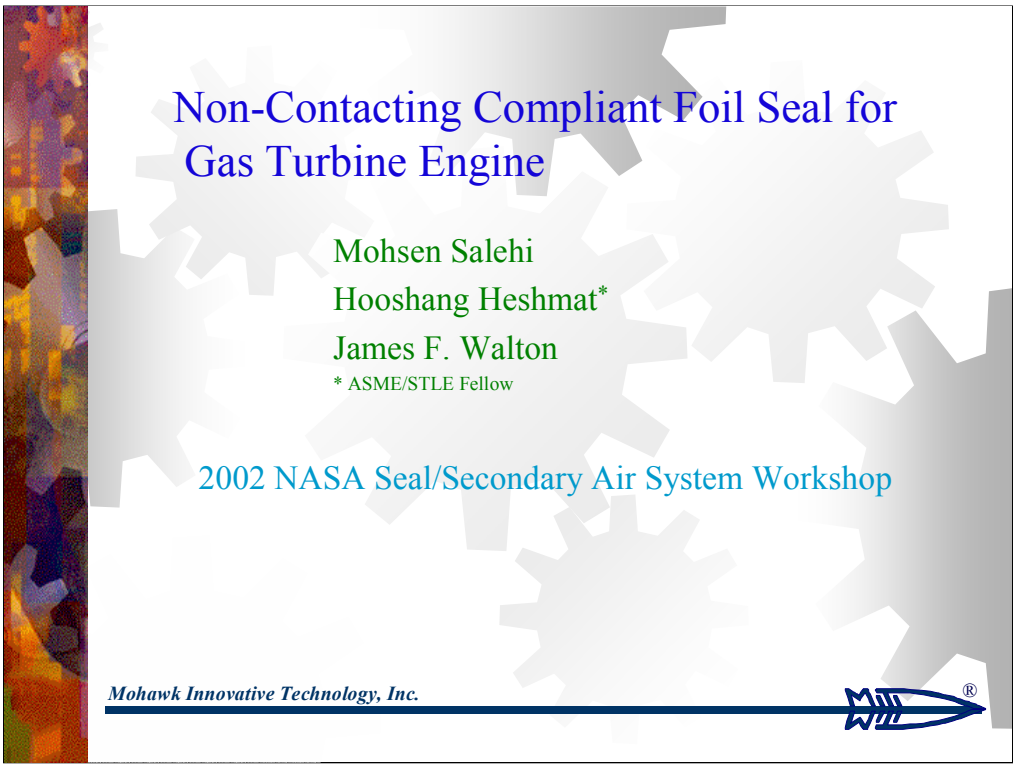

Acknowledgment

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  - Mr. Michael Tomaszewski of MiTi for his contributions to seal fabrication processes

Overview

- Objectives
- Experimental Work
- Accomplishments/Status
- Conclusions/Remarks
- Future Directions

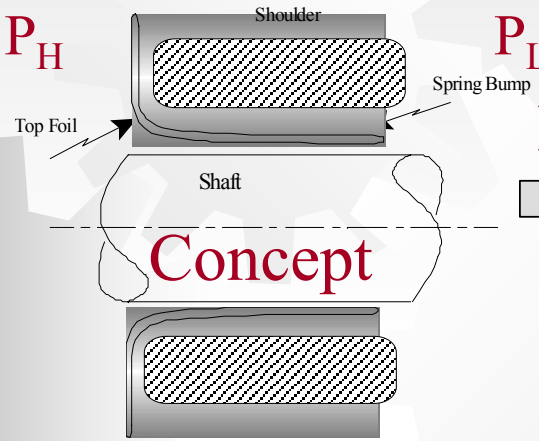
Objectives (1/2)

- Main Objective : Establish performance and scalability of the CFS by designing, building, testing and then delivering an 8.5 inch diameter seal for NASA testing.
  - Enhance current analysis to include:
    - Turbulence
    - Top foil compliance
  - Investigate manufacturing/fabrication processes
    - Examine segmented, split or other seal designs
    - Consider forming foils with different thickness
  - Modify an existing test rig to test the 6” Dia. seal at speeds to 20,000 rpm, and ΔP [0-100], temperatures to 800 °F

Objectives (Cont'd) (2/2)

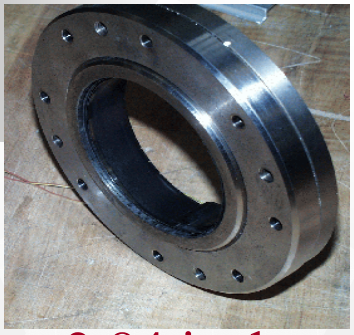
- Validate design analysis through experimental studies of 2.84" & 6" diameter seals
  - Differential Pressure
  - Speed
  - Eccentricity
  - Clearance
- Apply lessons learned to the design of the 8.5" diameter seal

Compliant Gas Foil Seal -Concept to Application

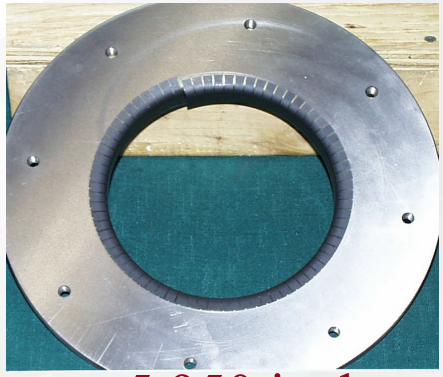


Fabrication

1.4 inch
(36 mm)



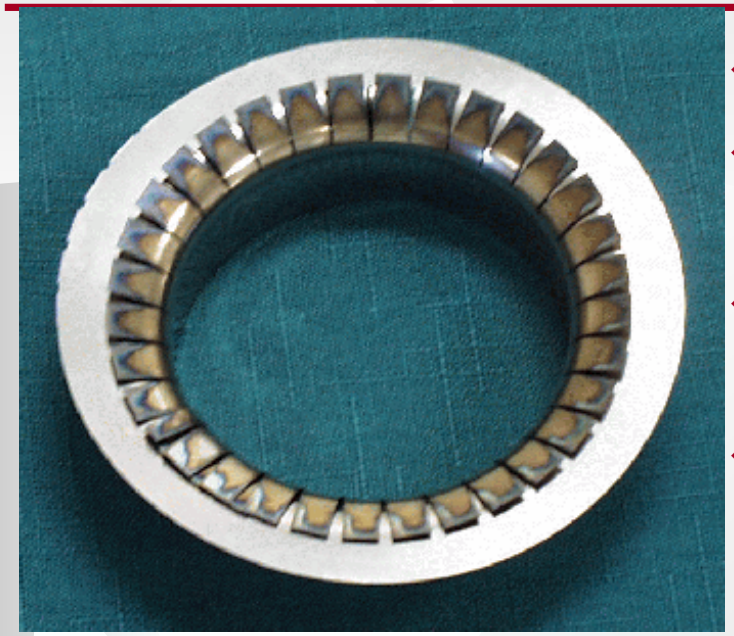
2.84 inch
(72 mm)



5.950 inch
(150 mm)

8.5 inch
(216 mm)

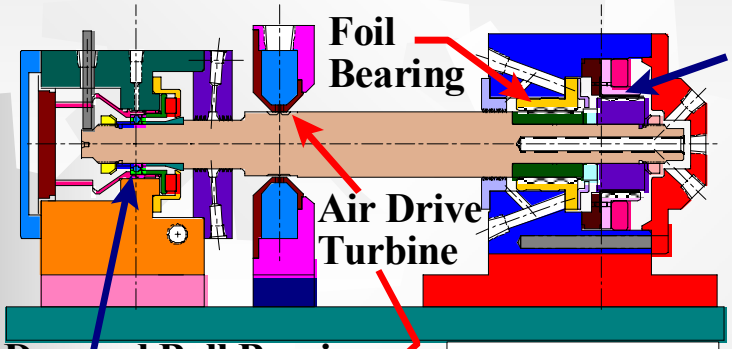
Compliant Foil Seal

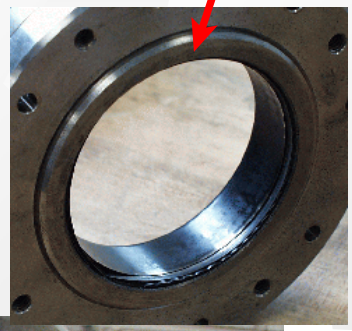


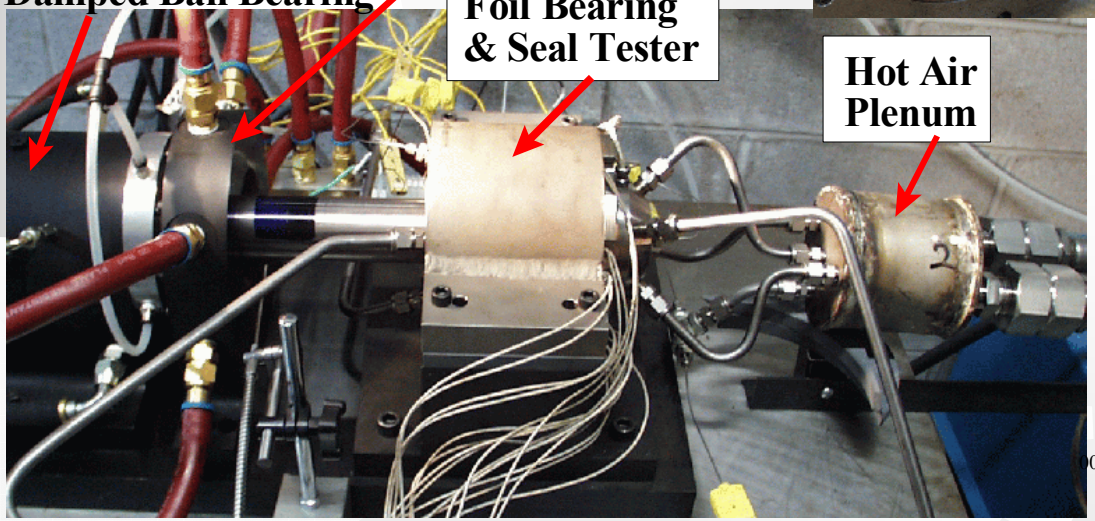
- Nickel Base Alloy for Foils
- MiTi Proprietary Coating for Smooth Lift Off
- Nickel Base Material for Journal
- Electrolized or High Temperature NASA PS304 Coated Journal

Diameter (in)	Length (in)	Radial Clearance (in)	Compliancy (in/lb)
1.40	0.65	0.0015 – 0.006	Various
2.84			
5.95			
8.50			

Gas Turbine Simulator & Seal Tester







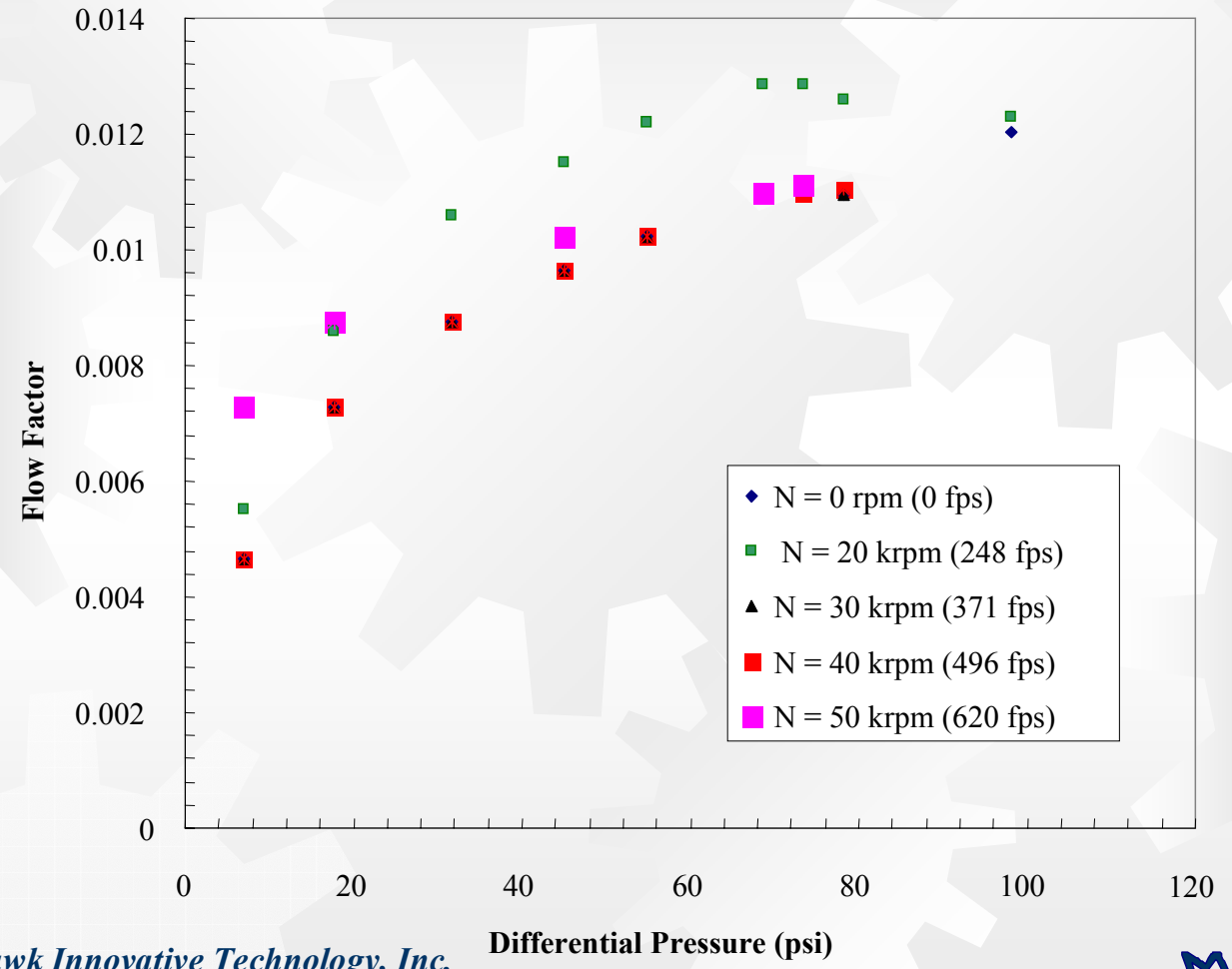
72 mm Diameter

56,000 rpm

(694 ft/sec)

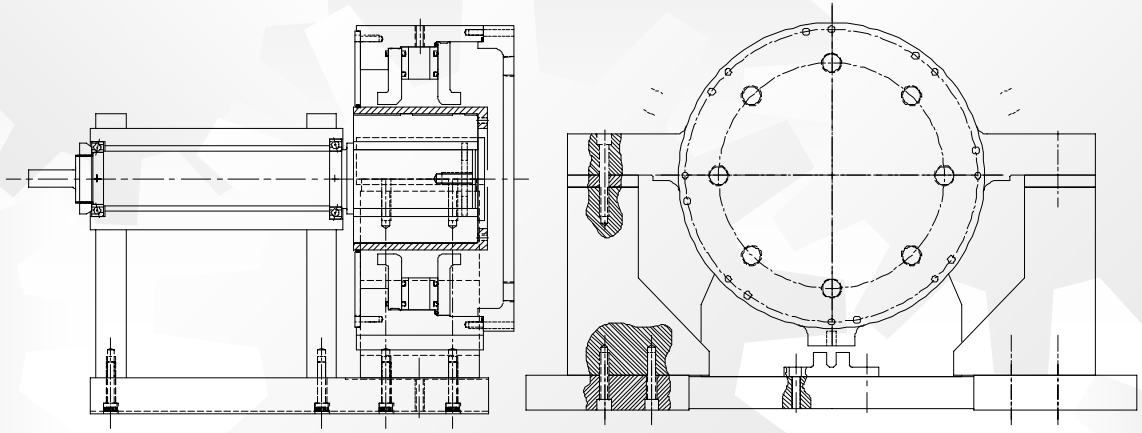
1100° F

Flow Rate for 72 mm (2.84 inch) Seal

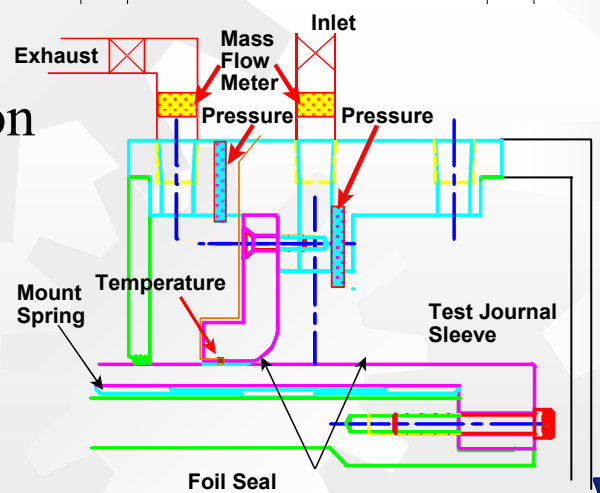


Subcomponent Test Rig for 6 in Seal

Used for both static test and dynamic tests

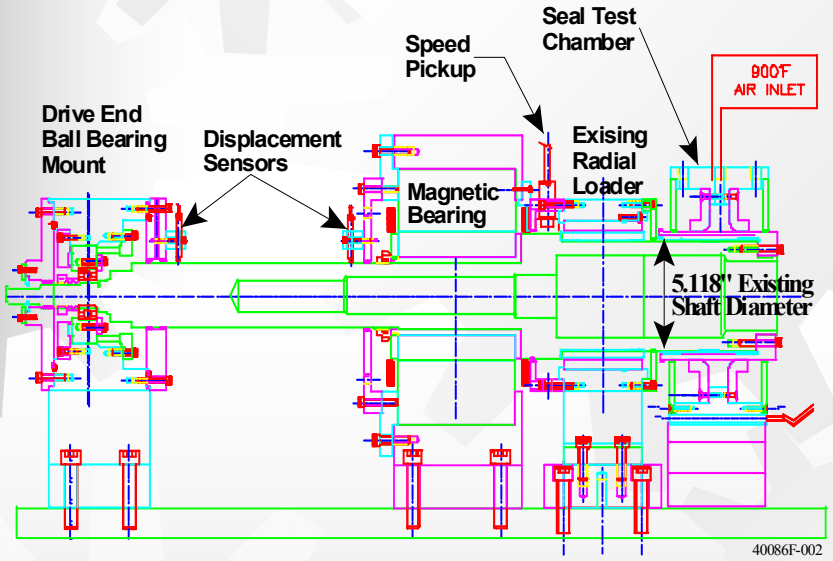


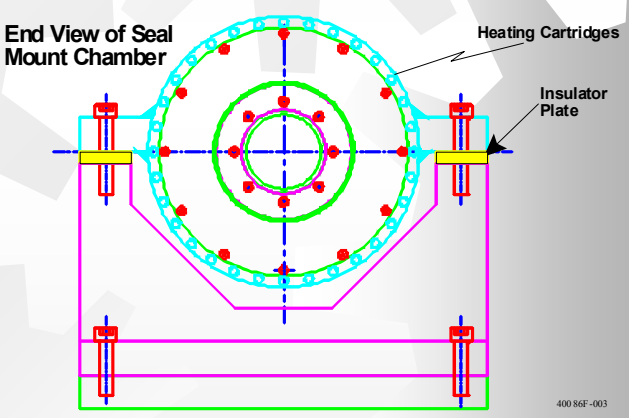
Seal housing top cross section



Layout of High-Speed Seal Tester

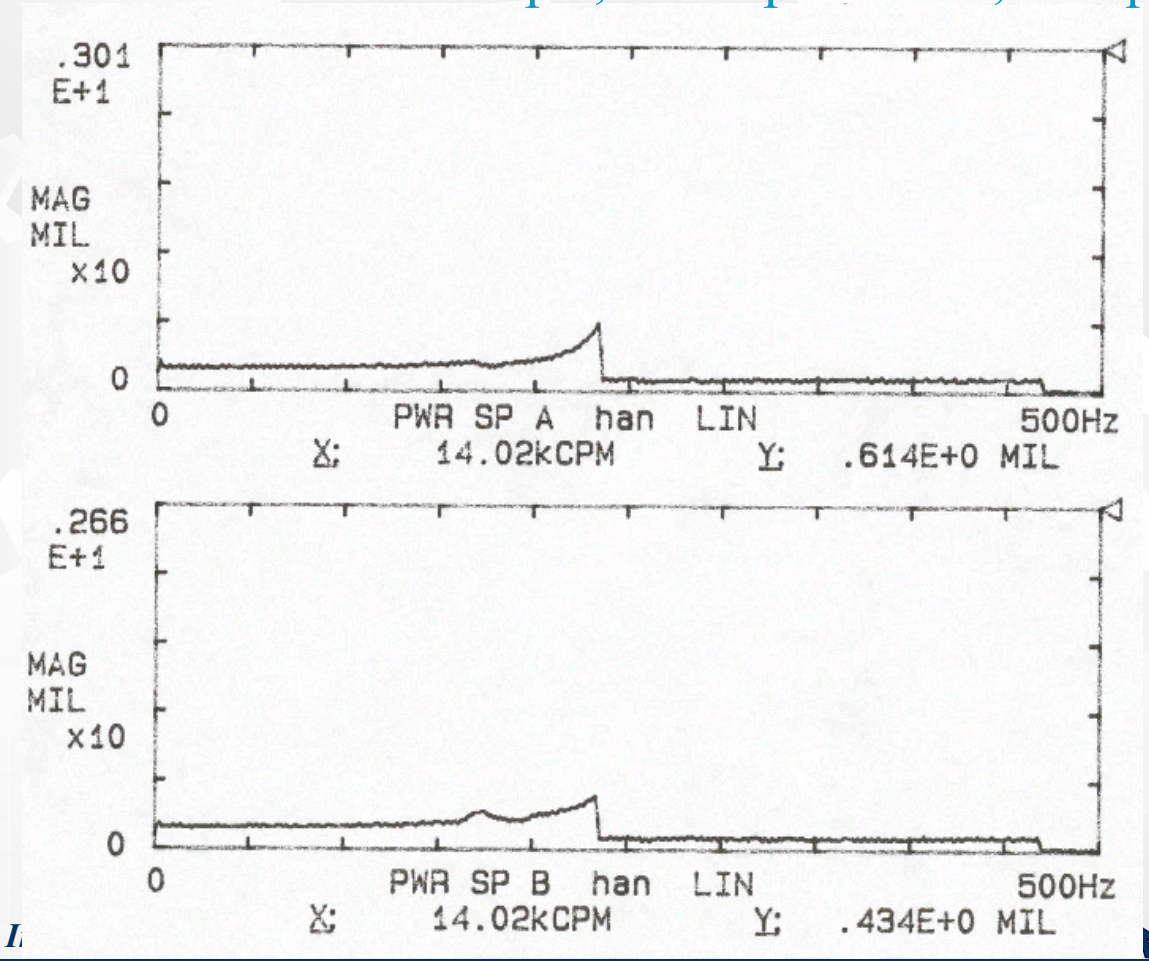
- Designed for 20,000 rpm, 900F, 6" Diameter



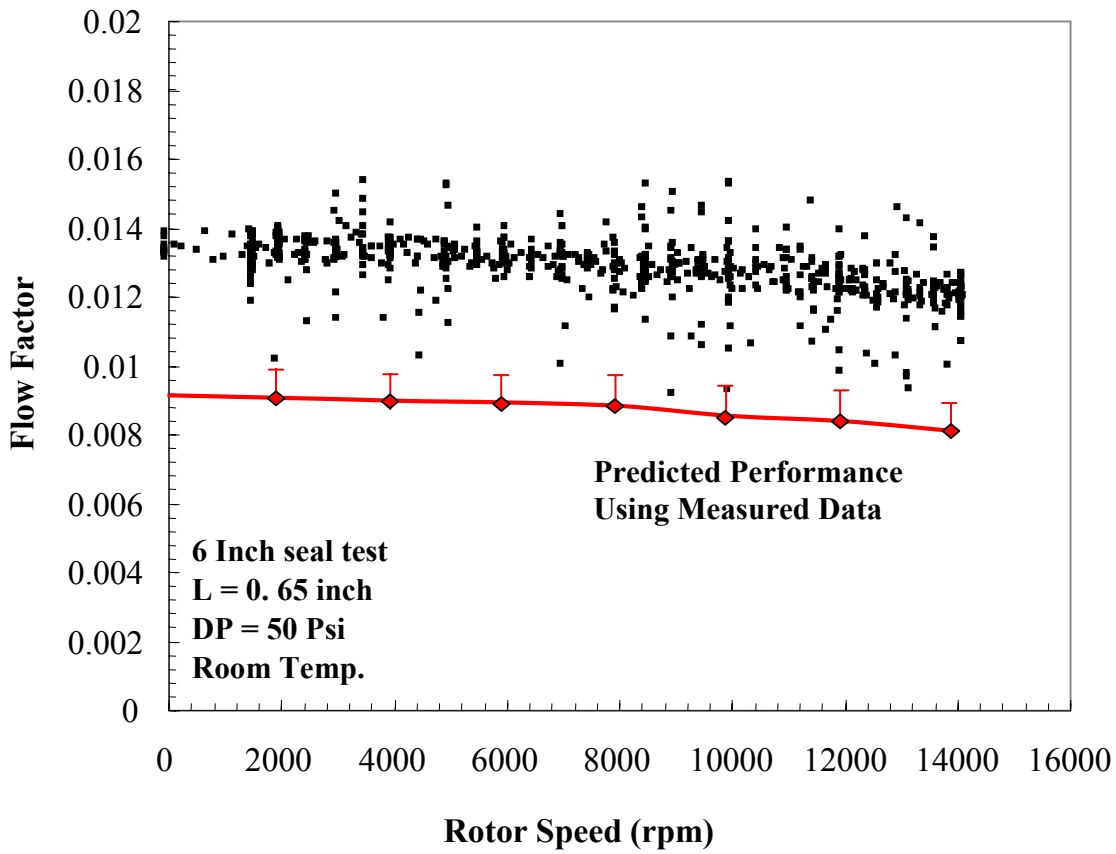


Dynamic Test

6 inch seal test at ΔP = 50 psi, Max speed = 14,000 rpm

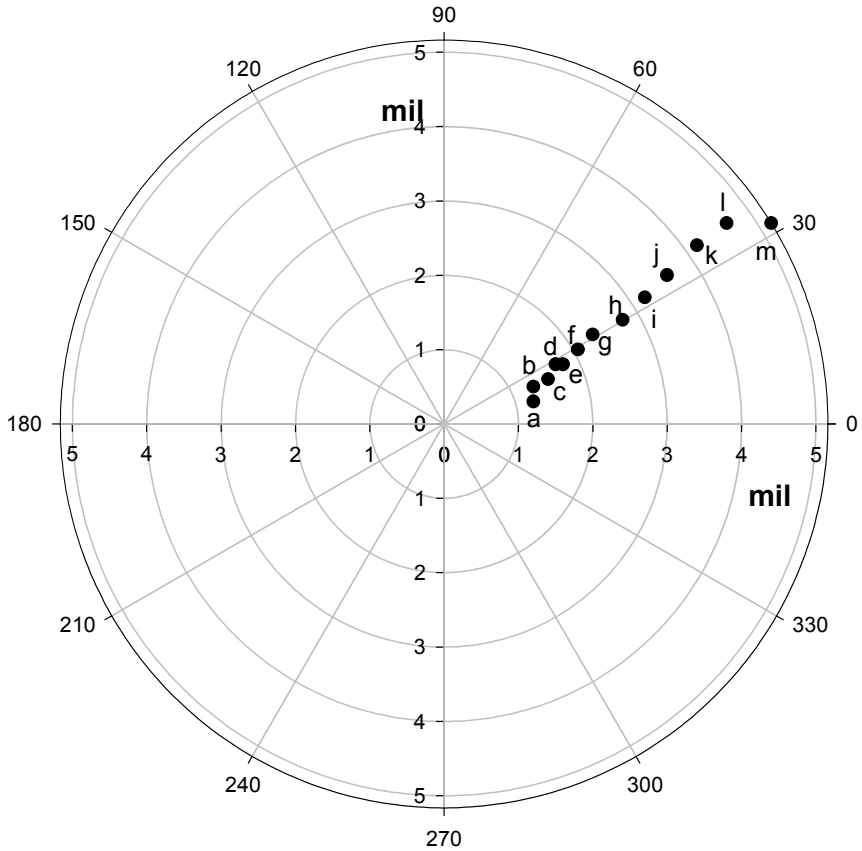


Leakage Flow Experimental Result



Seal Non-Contact Operation

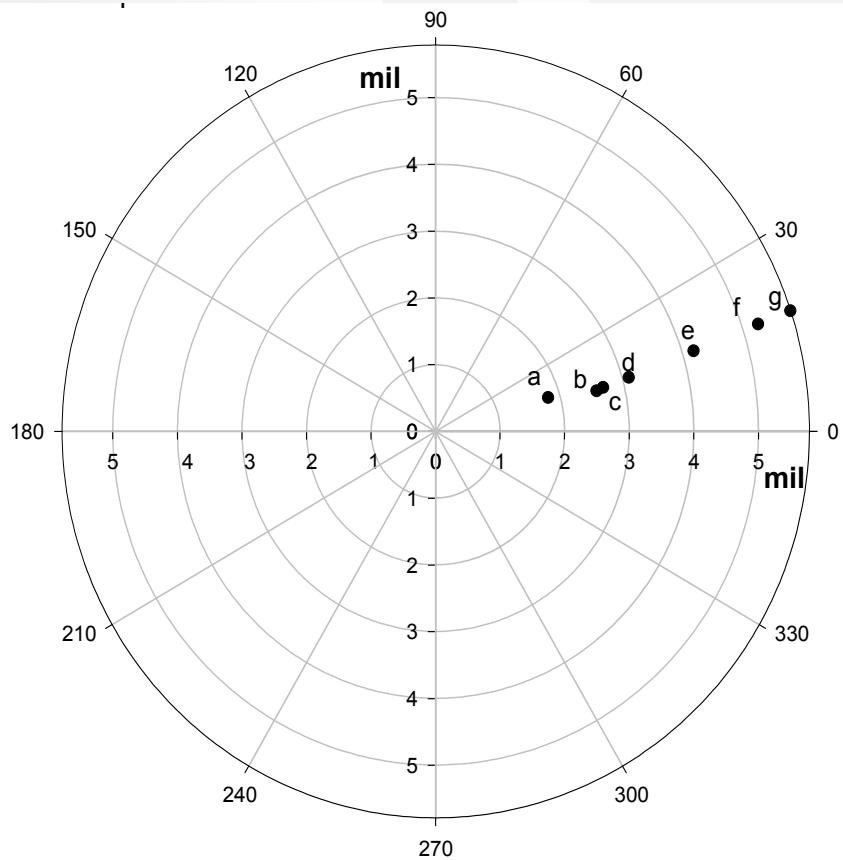
6 inch seal Rotor Motion at ΔP = 50 psi, and Various Speeds



Speed (rpm)	Temperature (ºF)
a = 2000	74
b = 3000	75
c = 4,000	77
d = 5,000	76
e = 6,000	77
f = 7,000	
g = 8,000	75
h = 9,000	
i = 10,000	76
j = 11,000	
k = 12,000	75
l = 13,000	
m = 14,000	76

Seal Non-Contact Operation

6 inch seal Rotor Motion at ΔP = 80 psi, and Various Speeds



Speed (rpm)	Temperature (°F)
a = 1500	72
b = 3000	73
c = 4,000	76
d = 5,000	75
e = 6,000	75
f = 7,000	
g = 8,000	74

Accomplishments

D = 5.95 inch (150 mm), L = 0.65 inch (16.5 mm), L/D = 0.1

- Rotor speed up to 14,000 RPM (364 fps)
- Non-contact Operation at Minimum Speed of 1000 RPM
- Eccentric Rotor Operation up to 0.006 inch at Speeds to 14,000 rpm
- Differential Pressure of up to 90 psi tested for 6” Seal
- Flow Factor of 0.01-0.014 at the highest DP and excursion of 0.006 inch

Conclusions/Remarks

- A non-contact compliant foil seal has been successfully demonstrated at sizes to 6” diameter
- Differential pressure to 90 Psi tested statically, and 80 psi dynamically.
- Dynamic tests revealed consistent leakage over speed range tested
- Seal non-contact capability including for rotor eccentric operation was verified

Future Directions

(1/2)

- Additional research to improve the performance of the seal.
  - The appropriate range of structural compliance for the elements supporting the seal surface, (i.e., to optimize both hydrodynamic performance and rotor excursion potential)
  - Geometry optimization (e.g. clearance and length)
  - Formation of the flange/face section; and other design and fabrication issues. Some of the parameters are as following

Design Parameters to be Optimized

- **Bump Foil thickness (times No. of layers)**
- **Bump height, length, and pitch**
- **Thickness of Top, Stiffener, Shim Foils**
- **Seal Length, diameter, clearance, preload**
- **Bump foil coating**
- **……..**

Future Directions (2/2)

- Static and dynamic performance evaluation of the large seal (8.5 inch ID) at NASA and prior to testing in engine
- Flow visualization study in order to identify the flow passages in a seal
- Highly Instrumented Testing
  - Film Pressures
  - Film Temperatures
  - Film Height (Rotor-Foil Gap)