N95- 13599

COMPRESSOR DISCHARGE FILM RIDING FACE SEALS

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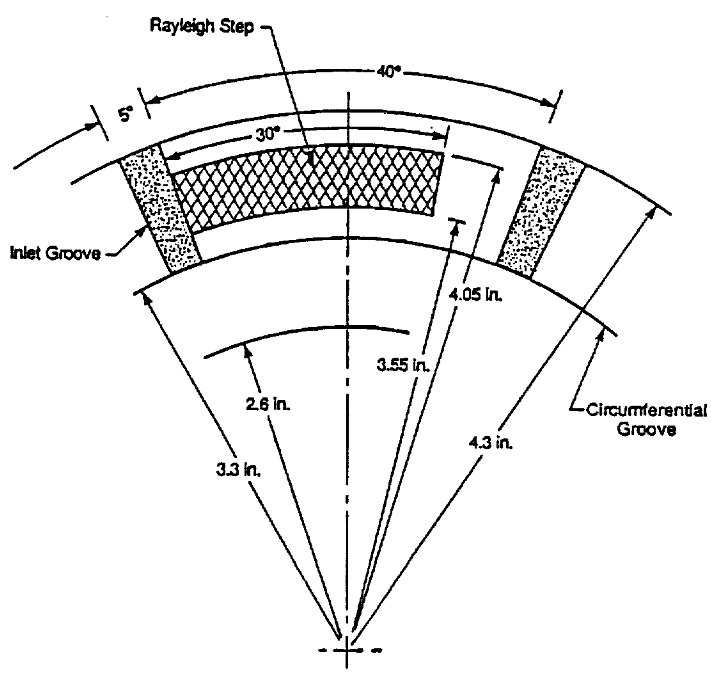
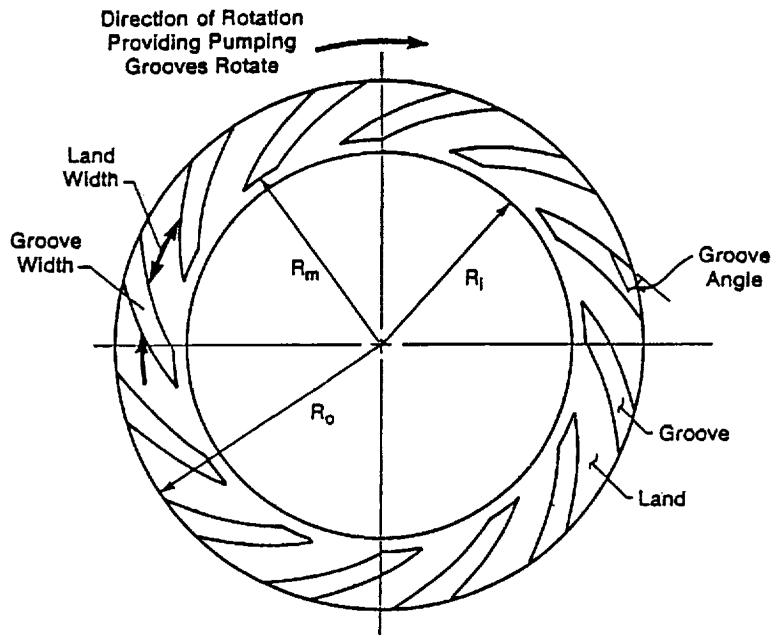
SEALS EXAMINED

1. 8 PAD RAYLEIGH - STEP
2. TAPERED SPIRAL - GROOVE
   - 3 TAPERS
3. HYDROSTATIC
   - INHERENTLY COMPENSATED
   - ORIFICE COMPENSATED WITH RECESS

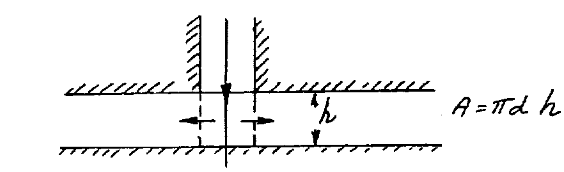
CIRCUMFERENTIAL GROOVE CONFIGURATION



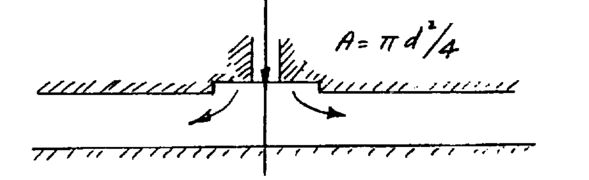
SPIRAL - GROOVE PARAMETERS



Groove Angle = α
Groove Depth = GD
Land Width/Groove Width = γ



INHERENT COMPENSATION



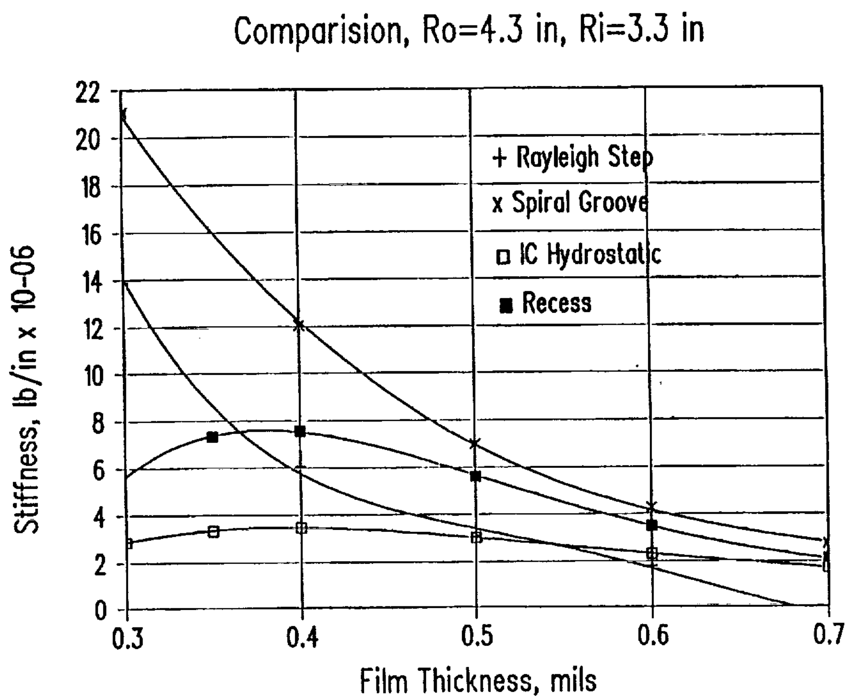
ORIFICE COMPENSATION

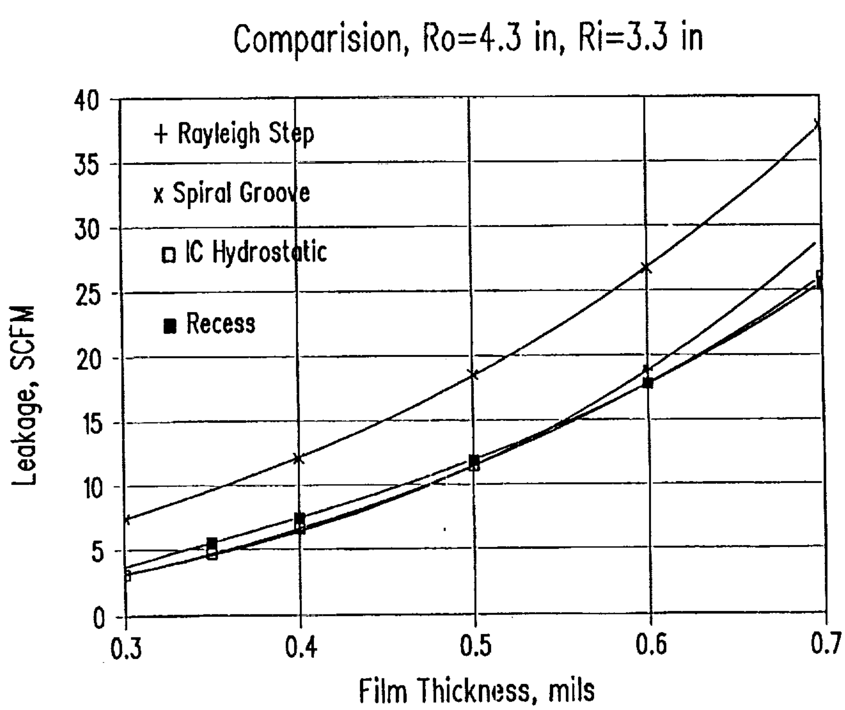
COMMON CONDITIONS

o	GAS TEMPERATURE	1200°F
o	GAS CONSTANT	247,420 IN^2/S^2-°R
o	SPECIFIC HEAT RATIO	1.342
o	VISCOSITY	5.82×10^{-9} LB-S/IN^2
o	SPEED	30,000 RPM
o	HIGH PRESSURE	650 PSIG
o	LOW PRESSURE	100 PSIG

PERFORMANCE PARAMETERS PRODUCED AS A FUNCTION OF FILM THICKNESS

- LEAKAGE
- STIFFNESS
- VISCOUS POWER LOSS
- HYDROSTATIC PRESSURE RATIO
- ALSO LOOKED AT:
  - LOAD CAPACITY
  - ADIABATIC TEMPERATURE RISE


Comparision, Ro=4.3 in, Ri=3.3 in
Stiffness, lb/in x 10-06
Film Thickness, mils
+ Rayleigh Step
x Spiral Groove
IC Hydrostatic
Recess
0
2
4
6
8
10
12
14
16
18
20
22
0.3
0.4
0.5
0.6
0.7


Comparision, Ro=4.3 in, Ri=3.3 in
Leakage, SCFM
Film Thickness, mils
+ Rayleigh Step
x Spiral Groove
IC Hydrostatic
Recess
0
5
10
15
20
25
30
35
40
0.3
0.4
0.5
0.6
0.7

CONCLUSIONS AND RECOMMENDATIONS

- o SPIRAL-GROOVE CONFIGURATION IS PREFERRED CHOICE BECAUSE OF SUPERIOR STIFFNESS.

- o SECOND CHOICE IS RAYLEIGH-STEP BECAUSE OF COMBINED HIGHER OPERATING FILM THICKNESS AND GOOD STIFFNESS AT LOW CLEARANCE.

- o RECESS HYDROSTATIC HAS REASONABLE PERFORMANCE, BUT STIFFNESS FALLS OFF AT LOW CLEARANCE. ALSO, PNEUMATIC HAMMER CHARACTERISTICS MUST BE INVESTIGATED. EXPERIENCE AT HIGH PRESSURE RATIOS IS LIMITED. AN ADVANTAGE IS THAT IT WOULD HAVE GOOD LOW SPEED PERFORMANCE. IT MAY BE A GOOD COMPRISE SECOND CHOICE, BECAUSE IT OFFERS AN ALTERNATIVE TO A STRICTLY HYDRODYNAMIC CONFIGURATION.

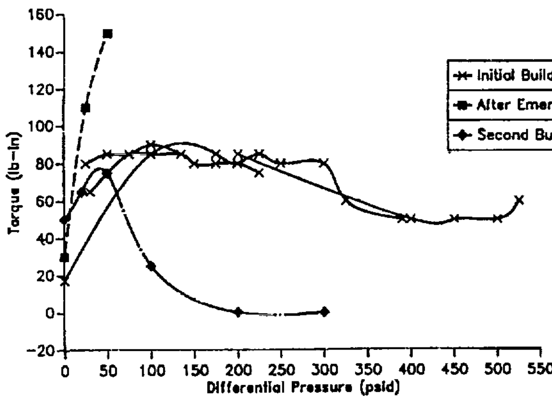
Final Design Parameters For Experimental Seals

	Spiral Groove	Rayleigh Step Pad
Mating Ring OD	7.280 - 7.285	7.280 - 7.285
Pad OD	-	7.030
Pad ID	-	6.470
SG ID	5.940	-
SG angle (deg)	19°	-
No. Grooves/Pads	15	8
Nom. Groove Depth	0.0010 - 0.0015	.002 - .004
Primary Ring OD	6.750	7.600
Primary Ring ID	5.660	5.660
Seal Balance Dia.	5.840	5.981
Secondary Seal Type	3 Ring Circumferential	Piston Ring
Materials		
Mating Ring	INCO 718 Cr2C3 wear face	INCO 718 PS212 wear face
Primary Ring	α - Silicon Carbide	α - Silicon Carbide
Secondary Seal	carbon / graphite CJPS	carbon / graphite CJPS
Housing	INCO 718	INCO 718
Springs	INCO 750-X	INCO 750-X

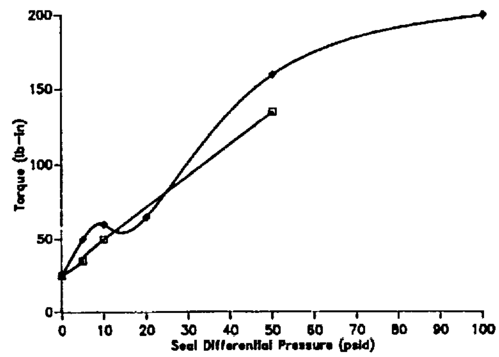
Control of both Circumferential & Radial Face Flatness Effects Seal Performance

Performance is Reflected in Breakaway Torque Measurements

Spiral Groove Seals

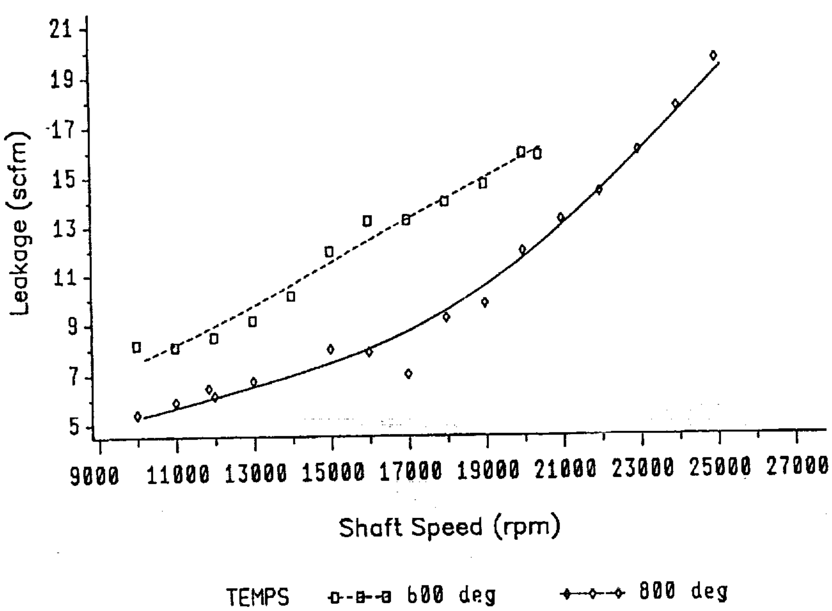


Rayleigh Step Pad Seal



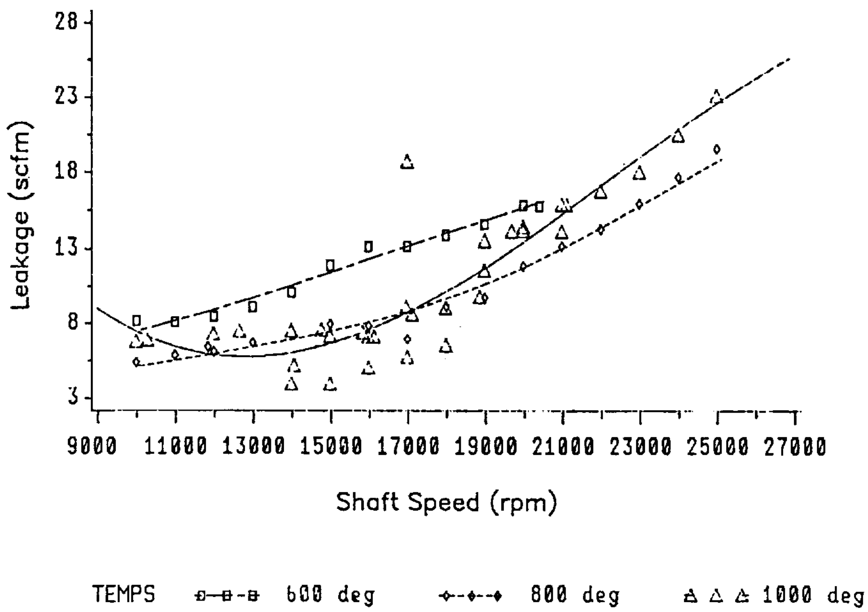
Test Results for Spiral Groove Seal

400 psid Test Results



Test Results for Spiral Groove Seal

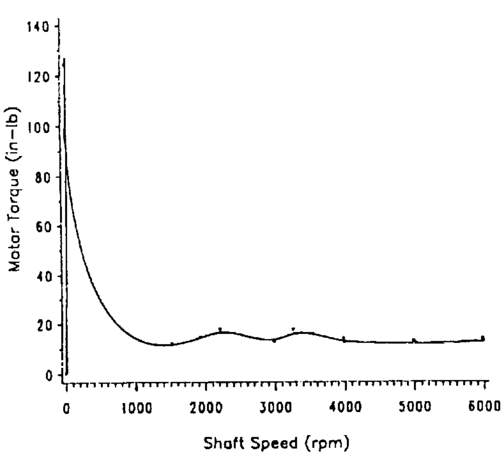
400 psid Test Results

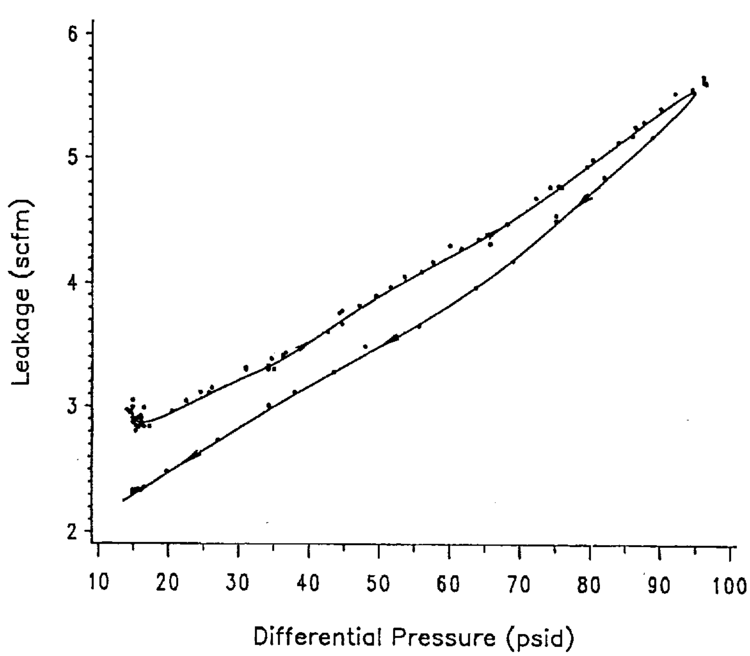


Test Results for Rayleigh Step Pad Seal

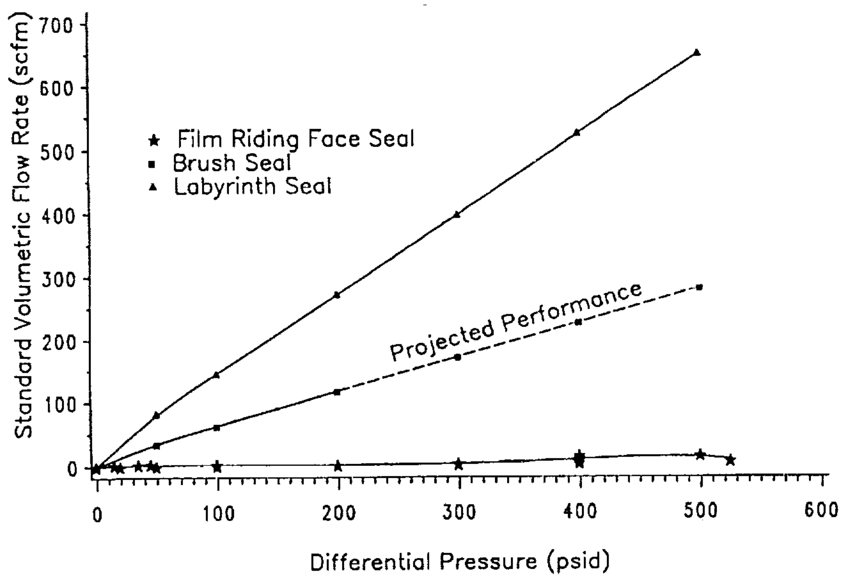
20000 rpm Test Results

Seal Starting Characteristics





Low Leakage of FRFS will provide substantial reduction in cycle specific fuel consumption:



- **1.5% relative to Labyrinth seal system**
- **0.5% relative to Projected multi-stage brush seal**

Conclusions

- Both seals operated as designed after lift-off had been acheived
- No particular reason to favor either the spiral groove, or Rayleigh step pad design over the other
- Windage may need to be addressed in engine design
- Measured seal leakage very close to design goal of 10 scfm
- Hydrodynamic seals can operate succesfully at either low, or high ΔP
- Seal face taper has strong effect on seal performance
- Analytical design methodology has been proven