CONTINUED EVALUATION OF THE HYBRID FLOATING BRUSH SEAL (HFBS)

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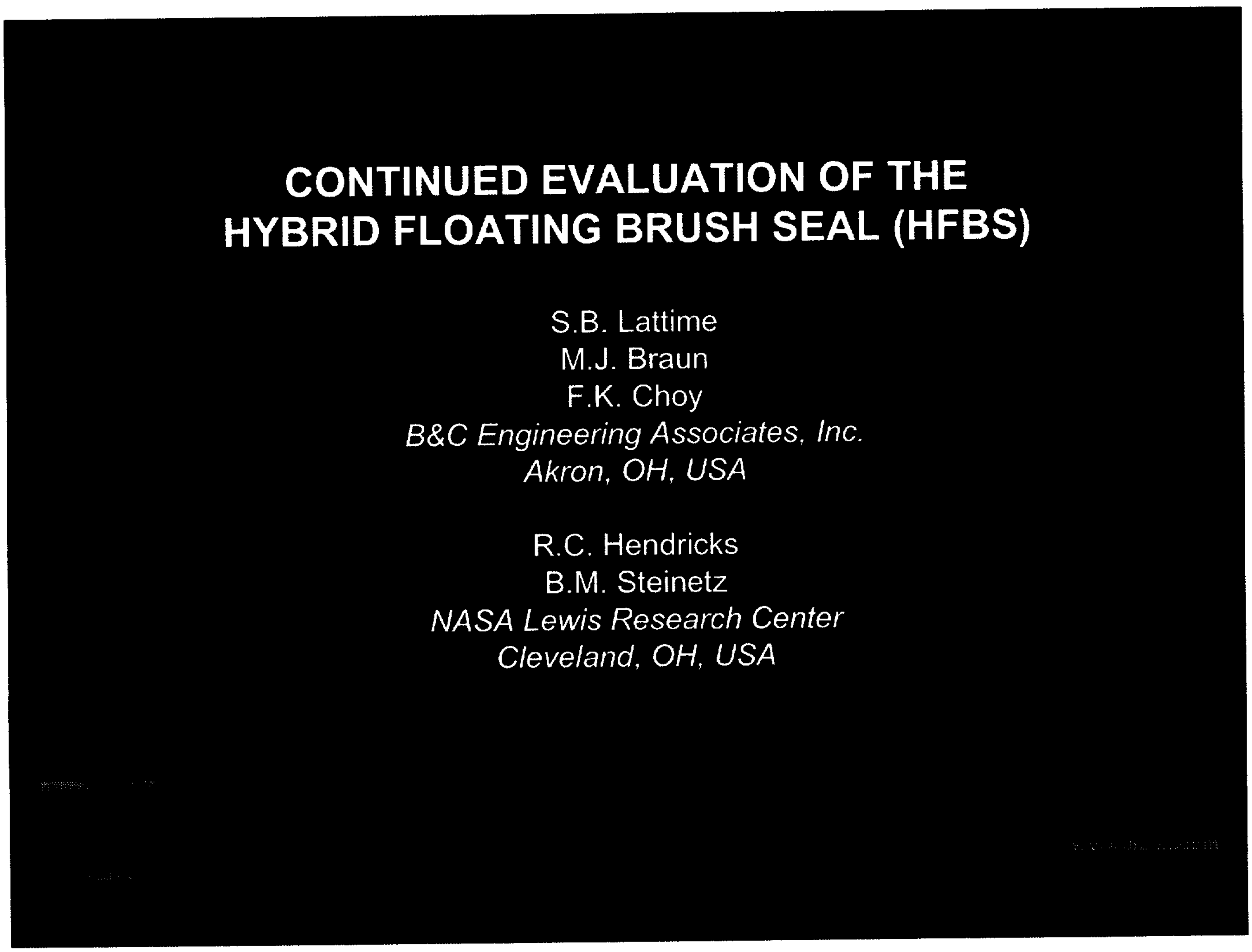


- Motivation
- HFBS Concept
- Experimental Apparatus
- Experimental Results
- Conclusions

Motivation

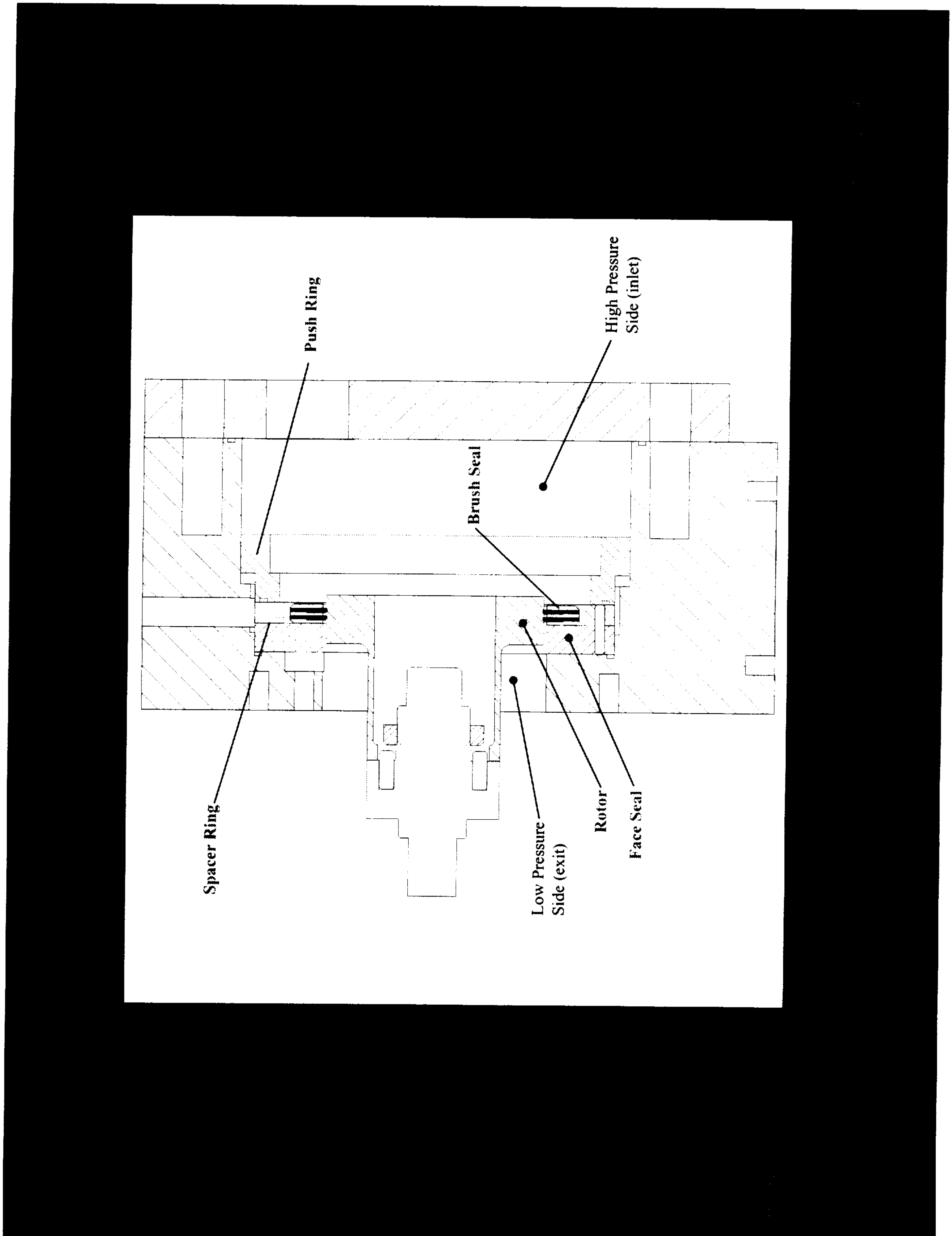
- increase thrust to weight ratio
- decrease specific fuel consumption
- eliminate wear of sealing components

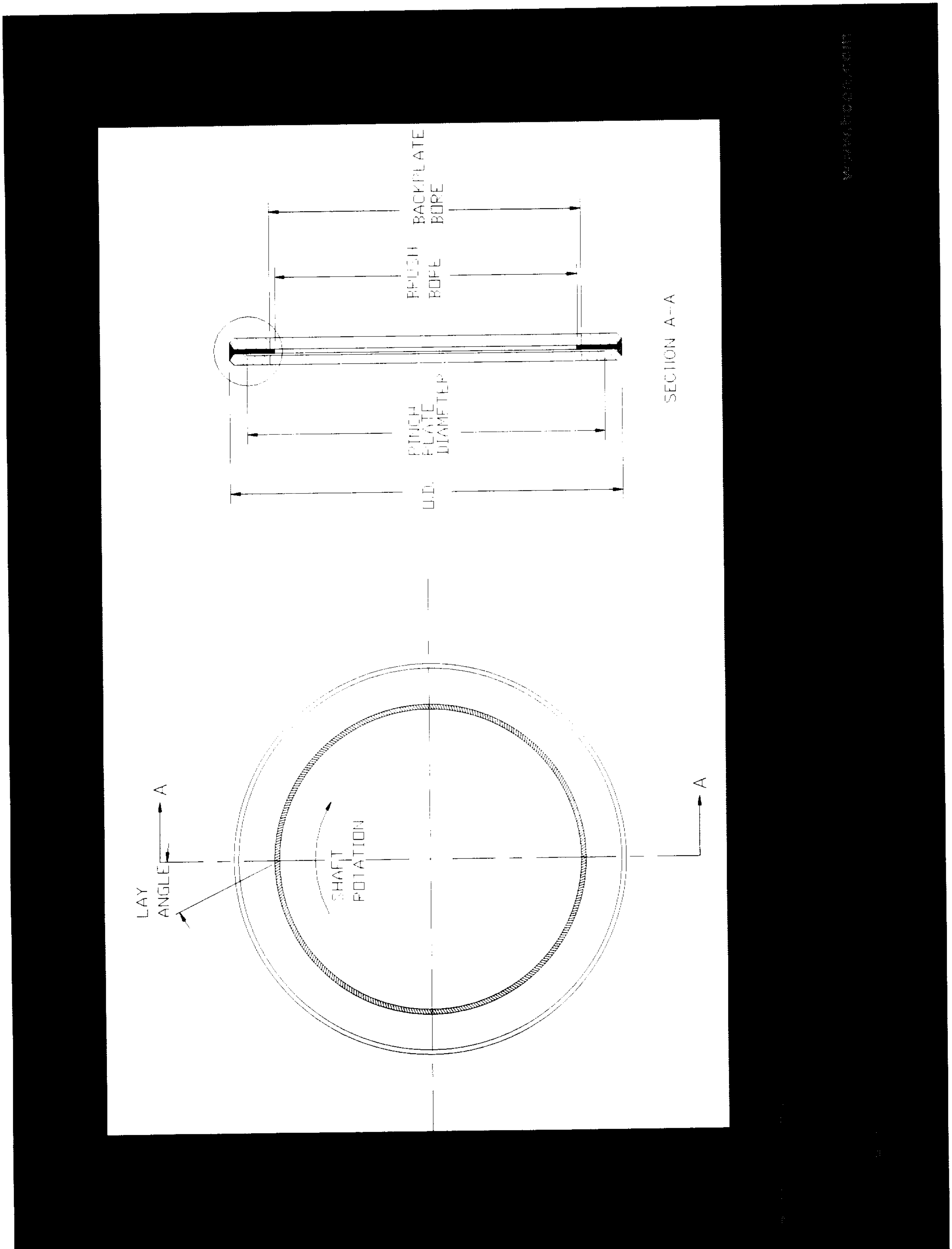
HFBS Concept

- combining seal technologies
- allowing for axial & radial shaft excursions
- eliminate interface surface speeds

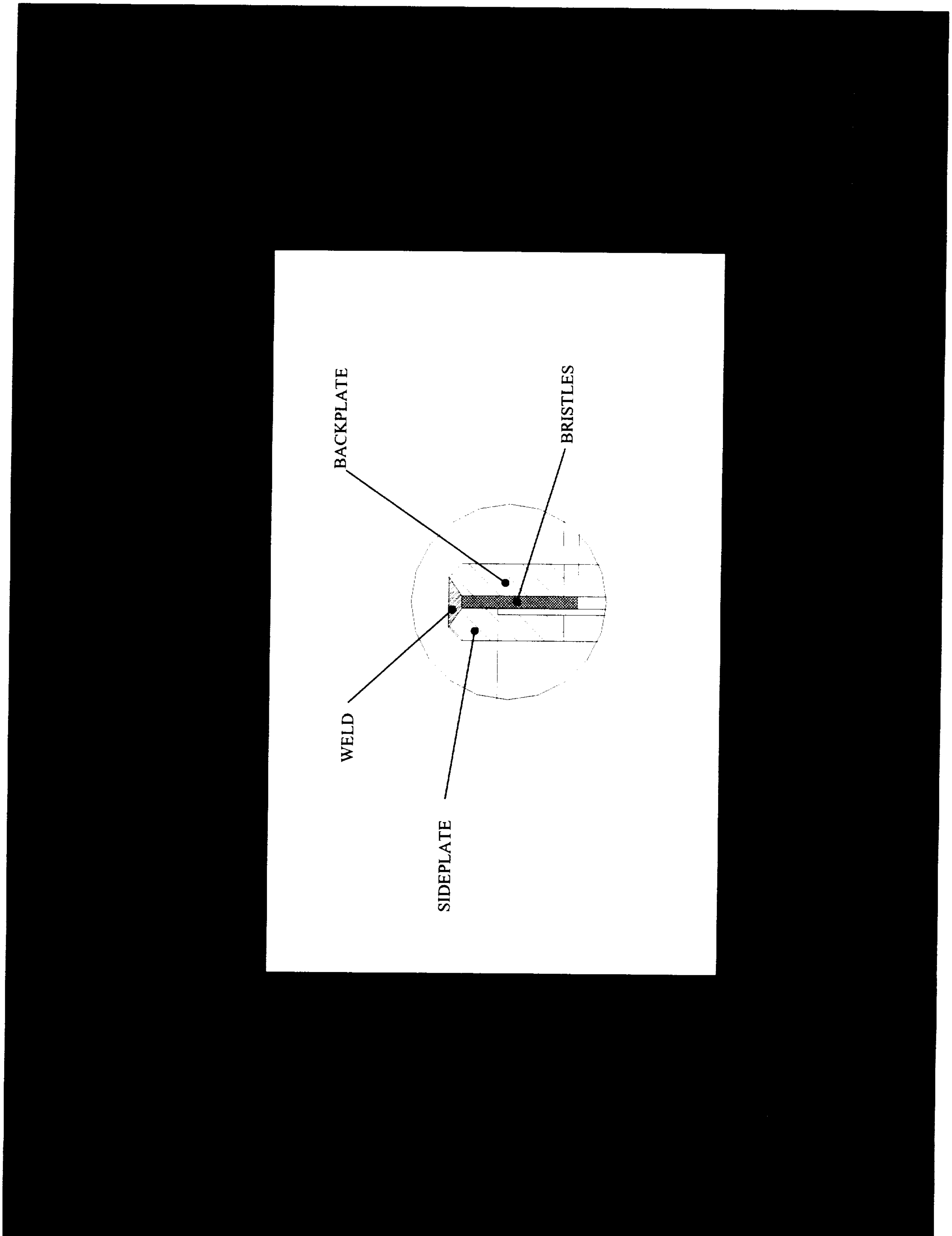
HFBS Concept

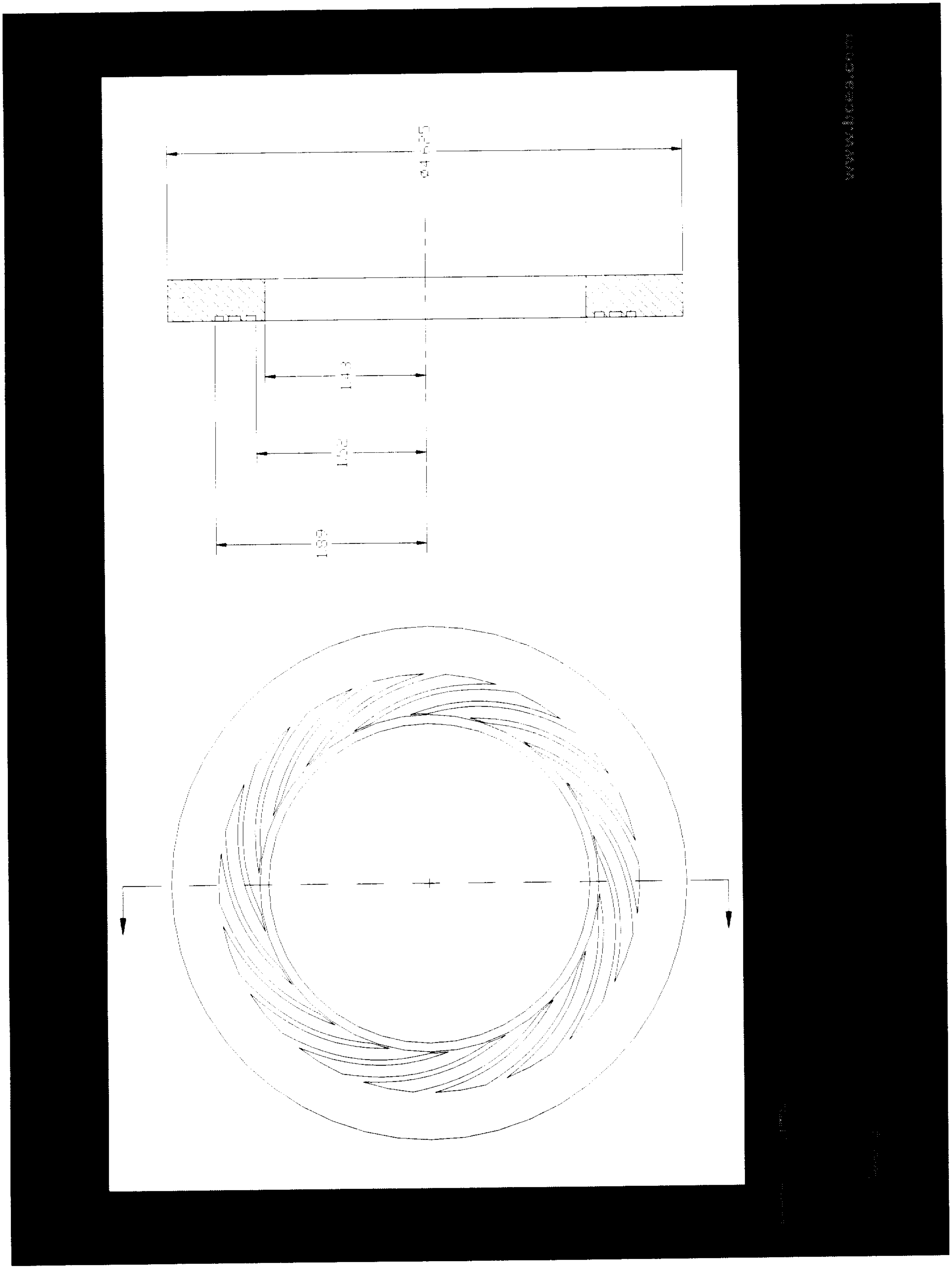
- combining seal technologies
  - brush seal
  - film riding face seal
- allowing for axial & radial shaft excursions
- eliminate interface surface speeds

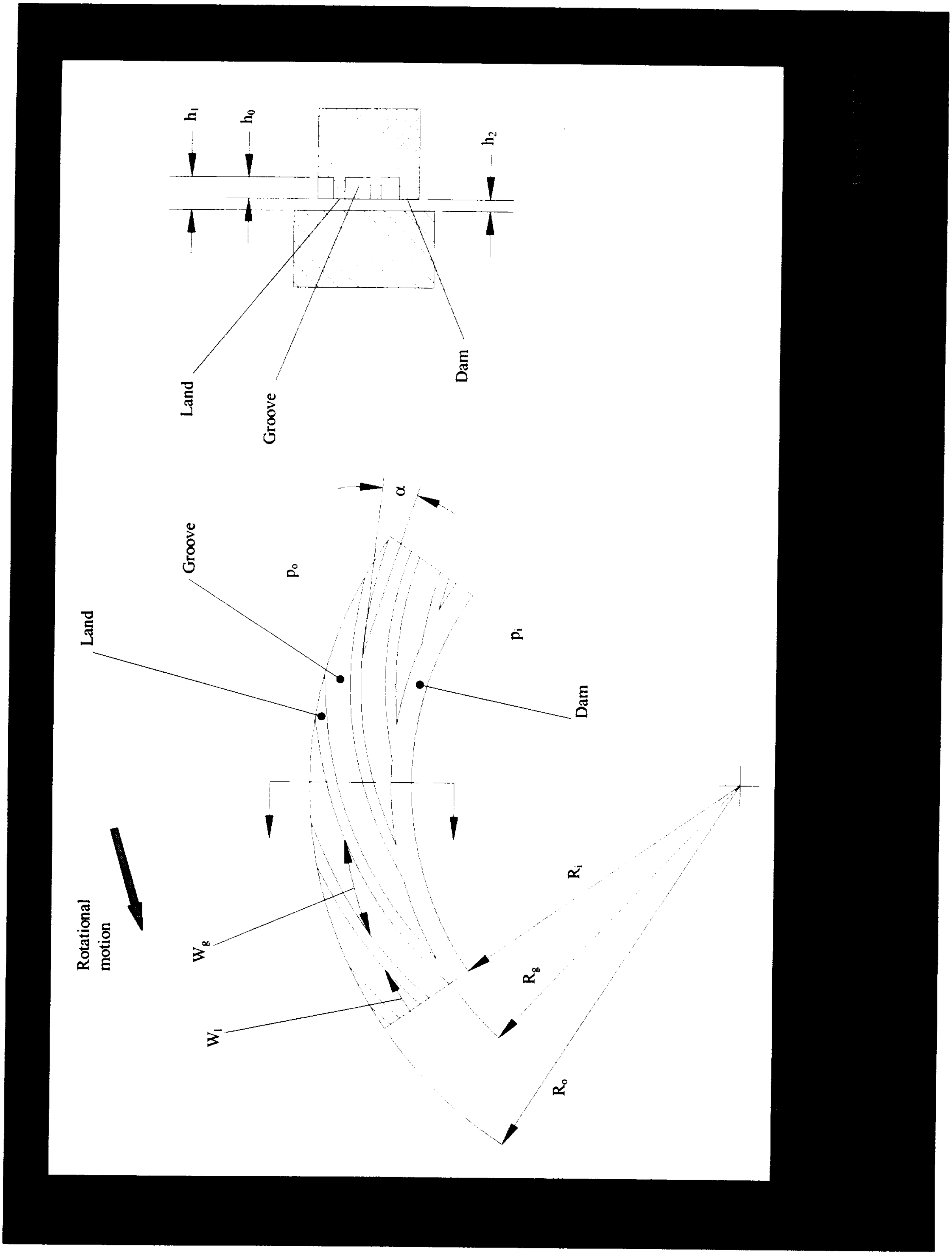

Push Ring
High Pressure
Side (inlet)
Brush Seal
Spacer Ring
Low Pressure
Side (exit)
Rotor
Face Seal



LAY
ANGLE
A
SHAFT
ROTATION
A
O.D.
PINCH
PLATE
DIAMETER
BRUSH
BORE
BACKPLATE
BORE
SECTION A-A


BACKPLATE
BRISTLES
WELD
SIDEPLATE


ø4.625
1.43
1.52
1.89
www.hcea.com


Rotational motion
Land
Groove
Dam
p_o
p_i
α
W_g
W_l
R_i
R_g
R_o
h_1
h_0
h_2
Land
Groove
Dam

HFBS Concept

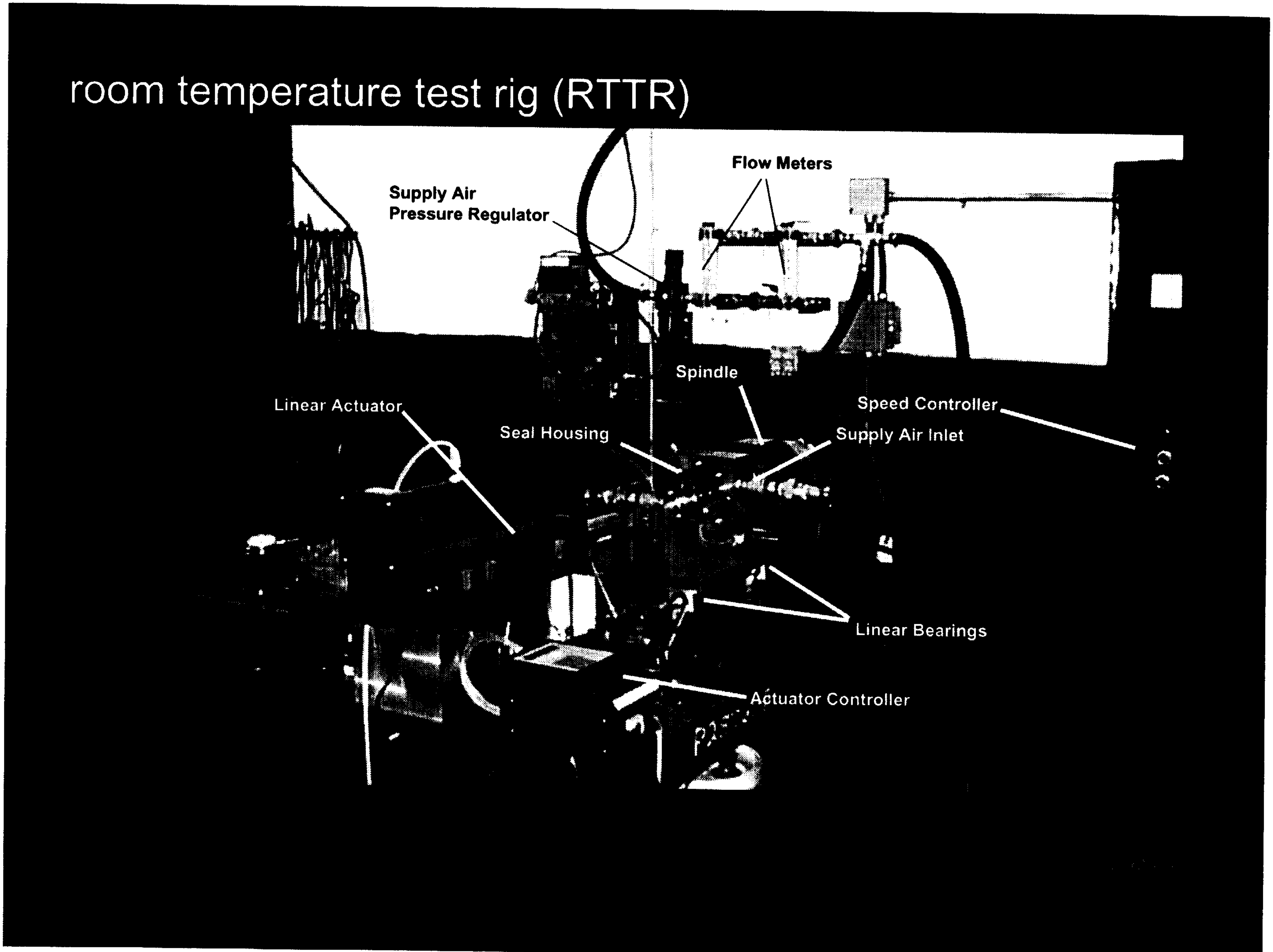
- combining seal technologies
- allowing for axial & radial shaft excursions
    - brush seal is compliant
    - brush seal “floats” on shaft
- eliminate interface surface speeds

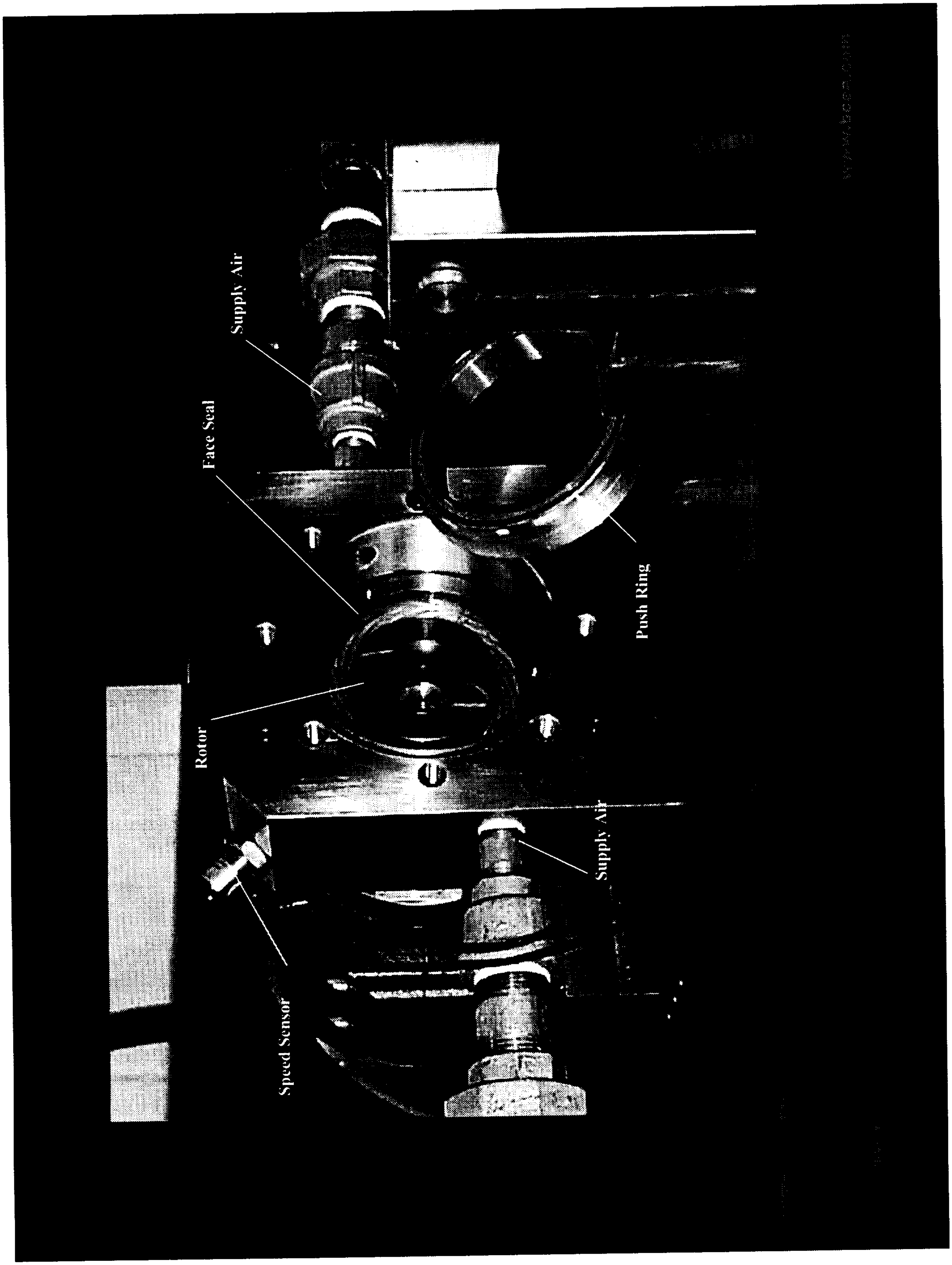
HFBS Concept

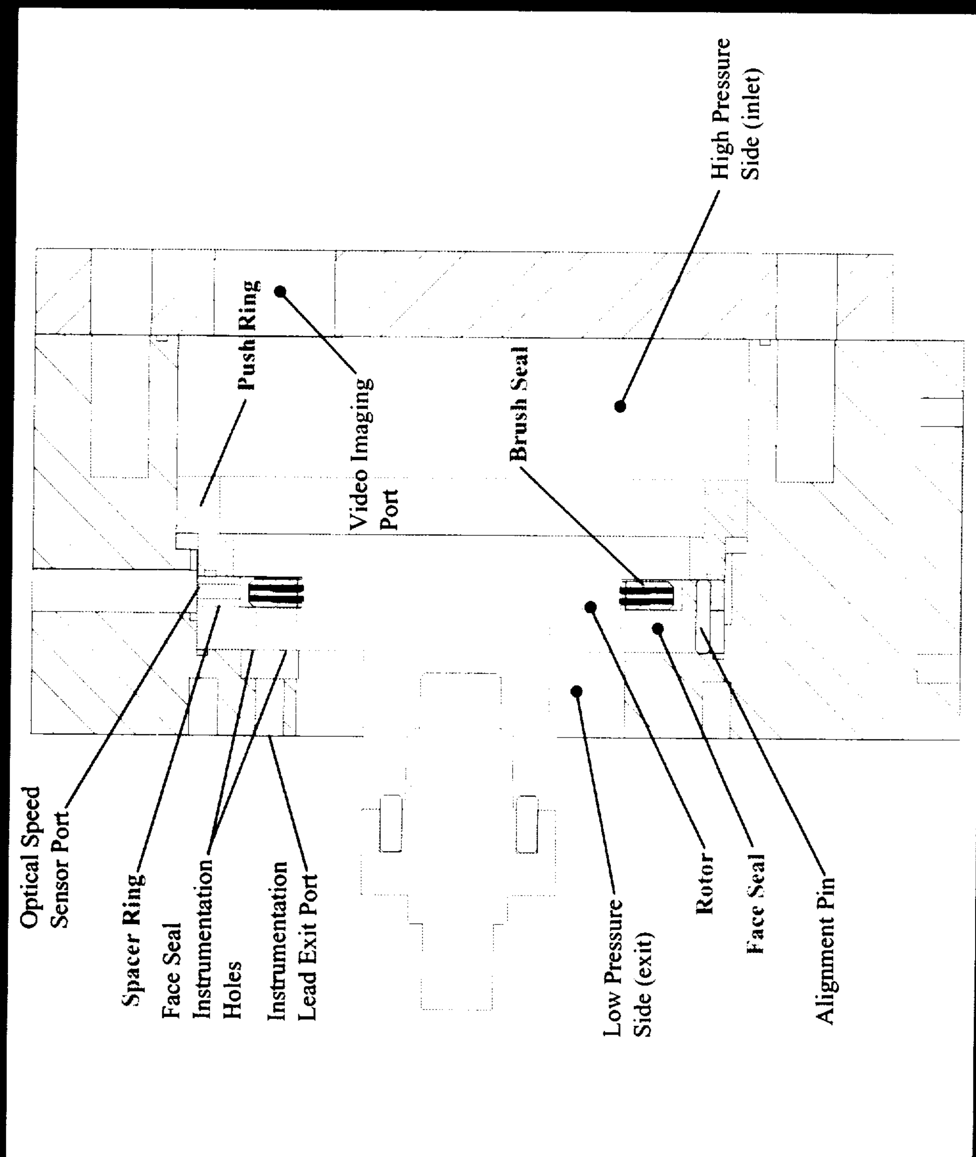
- combining seal technologies
- allowing for axial & radial shaft excursions
- eliminate interface surface speeds
    - brush seal rotates with the shaft

Experimental Apparatus

- room temperature test rig (RTTR)
- brush seals
- film riding face seal


room temperature test rig (RTTR)
Flow Meters
Supply Air
Pressure Regulator
Spindle
Speed Controller
Linear Actuator
Seal Housing
Supply Air Inlet
Linear Bearings
Actuator Controller


Supply Air
Face Seal
Rotor
Push Ring
Supply Air
Speed Sensor


Optical Speed Sensor Port
Spacer Ring
Face Seal Instrumentation Holes
Instrumentation Lead Exit Port
Low Pressure Side (exit)
Rotor
Face Seal
Alignment Pin
Push Ring
Video Imaging Port
Brush Seal
High Pressure Side (inlet)

brush seals

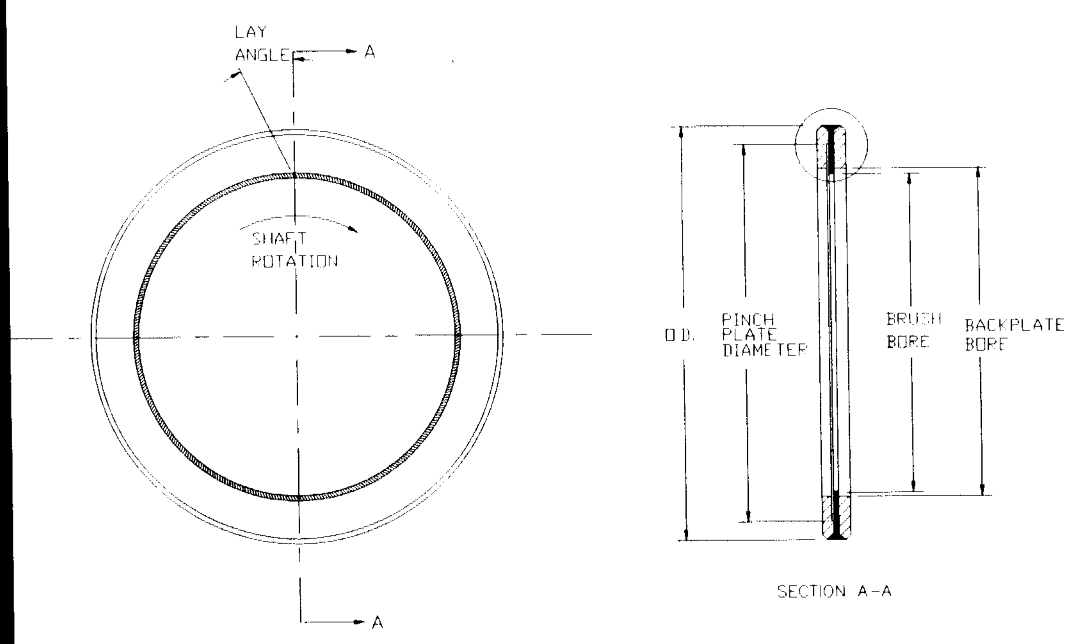


Figure 3: Single Brush Seal

The design of a brush seal for the HFBS is significantly different from that of a stationary brush seal.

Stationary brush seals

- focus is largely on tribo-pairing the materials of the brush and the moving rotor
- reduce the wear at the interface of the two components

HFBS

- prevent the bristles from lifting off the shaft, due to centrifugal forces
- eliminate relative velocities between the two components

Bristle Liftoff Model

The design process of the brush seal involved parametric calculations using the geometric characteristics and material properties of the bristles.

The calculations allowed the determination of the highest rotational speed at which the bristles would begin to lift off the rotor for a given bristle geometry. These properties included:

a) free length of the bristles

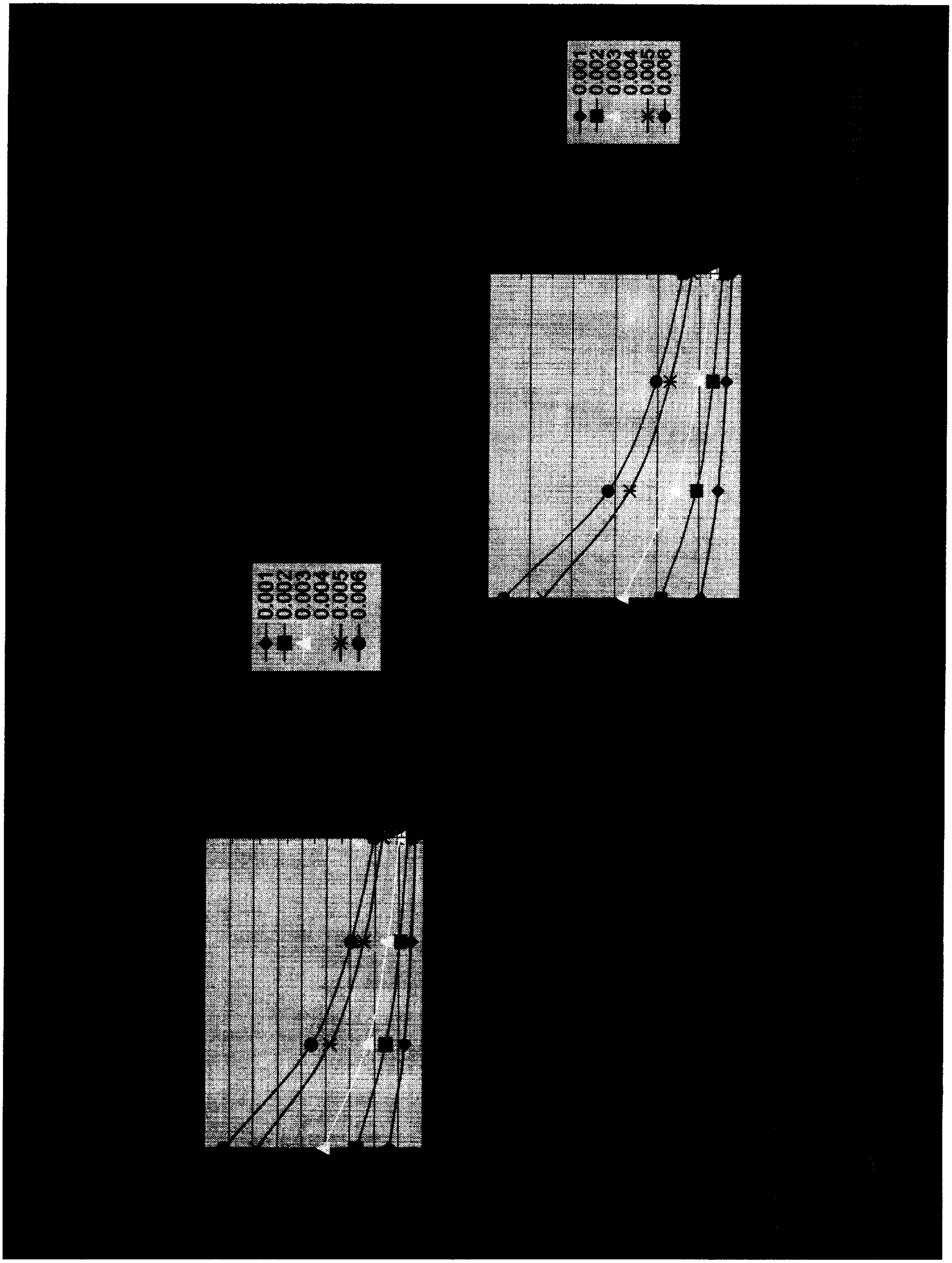
b) bristle material

c) diameter of the bristles

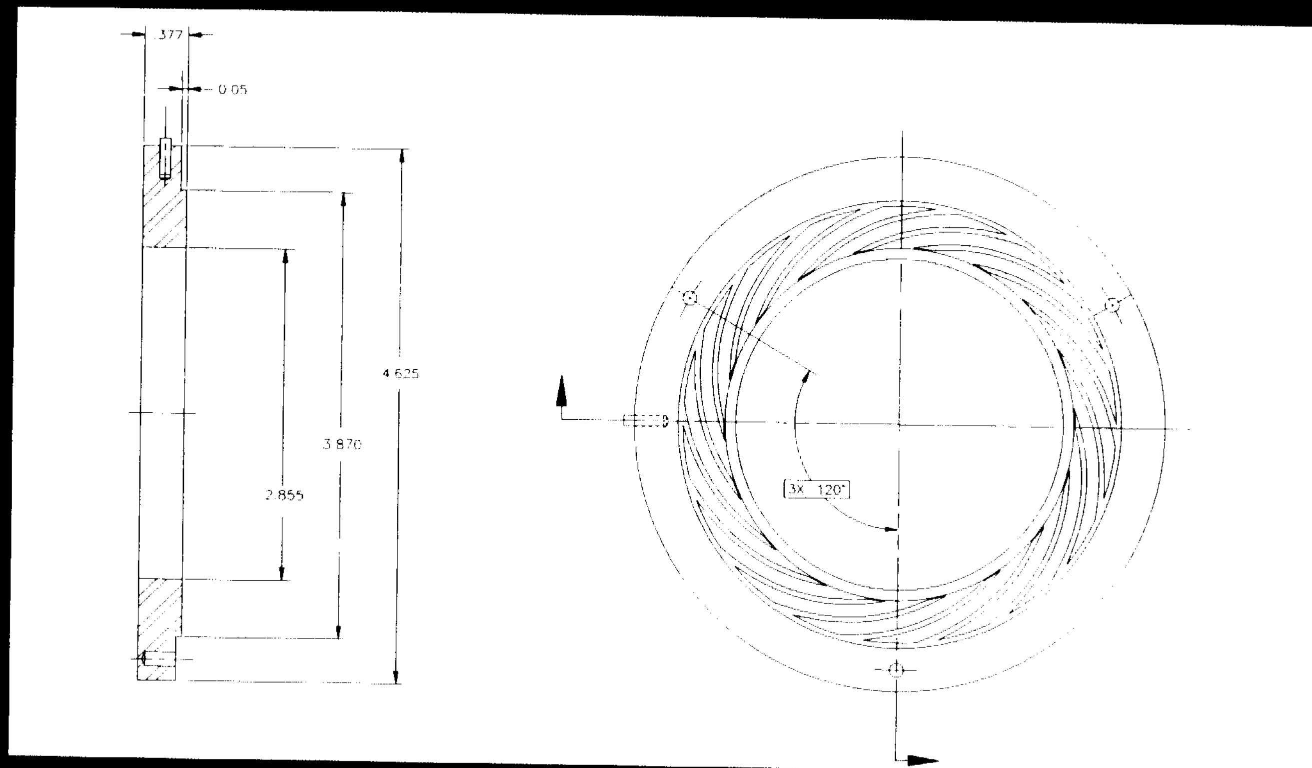
d) lay angle of the bristles

e) bristle pre-load

f) bending stress of the bristles


0.001
0.002
0.003
0.004
0.005
0.006
0.001
0.002
0.003
0.004
0.005
0.006

film riding face seal



Experimental Results

- leakage performance
- axial shaft movement
- shaft radial runout

leakage performance

Sealing performance shall be expressed in terms of a leakage flow factor ϕ.

The flow factor is defined as:

$$\phi = m(Tave)/(PuD)$$

where:

m = mass flow rate of air (pps)
Tave = average upstream air temperature (°R)
Pu = average upstream air pressure (psia)
D = shaft outer diameter (in)

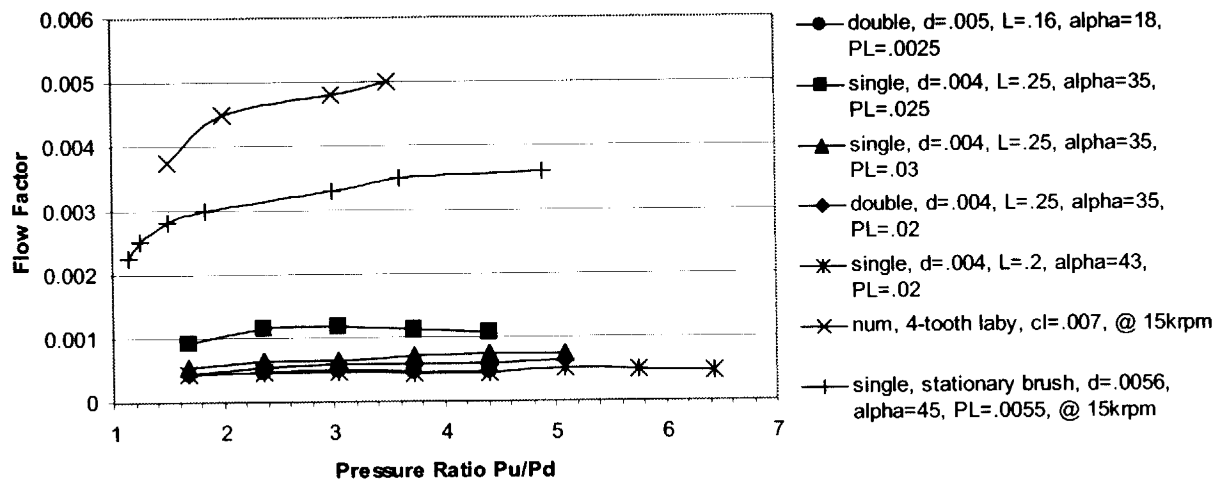


Figure 6: Leakage Performance @ 16krpm (197fps)

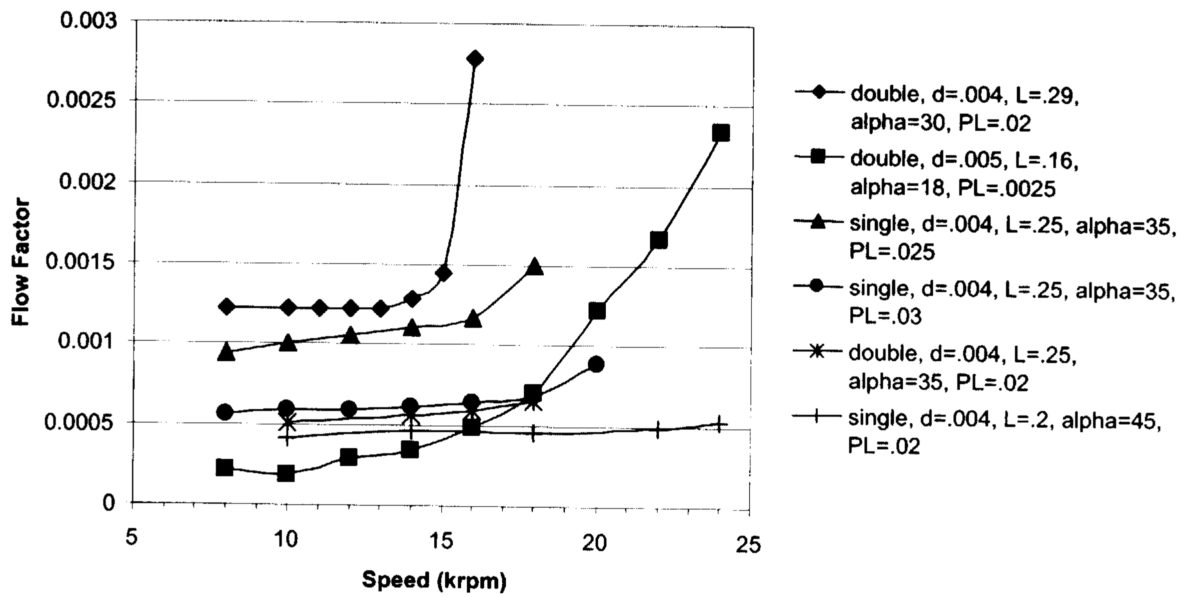


Figure 7: Leakage Performance @ P_u/P_d=3.04 (10krpm=123fps)

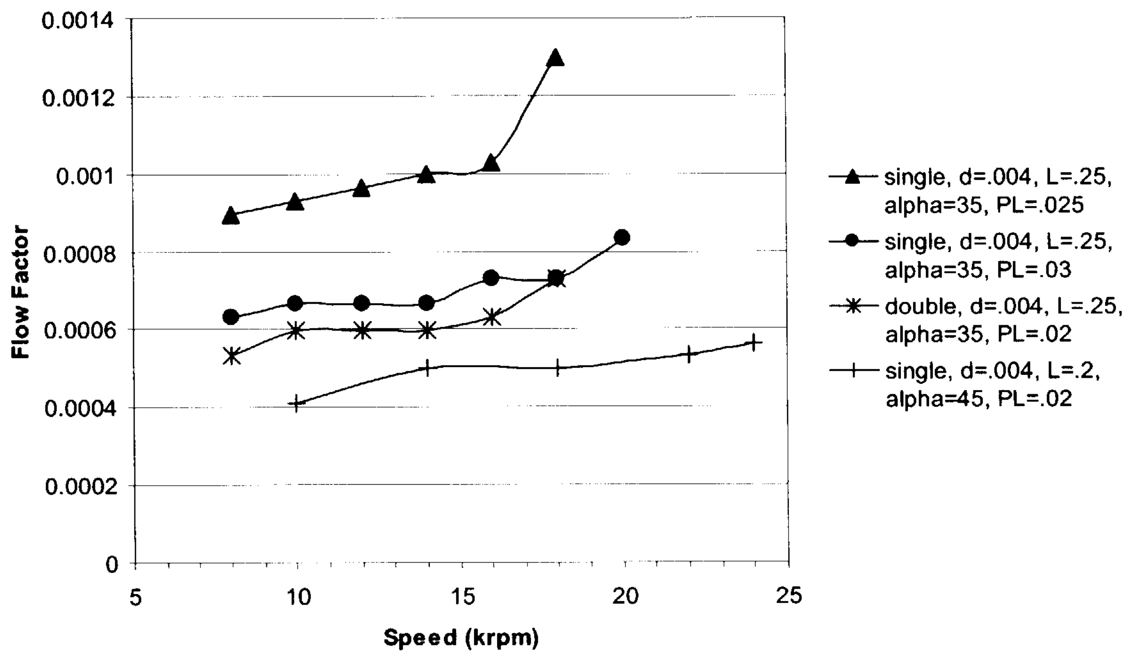
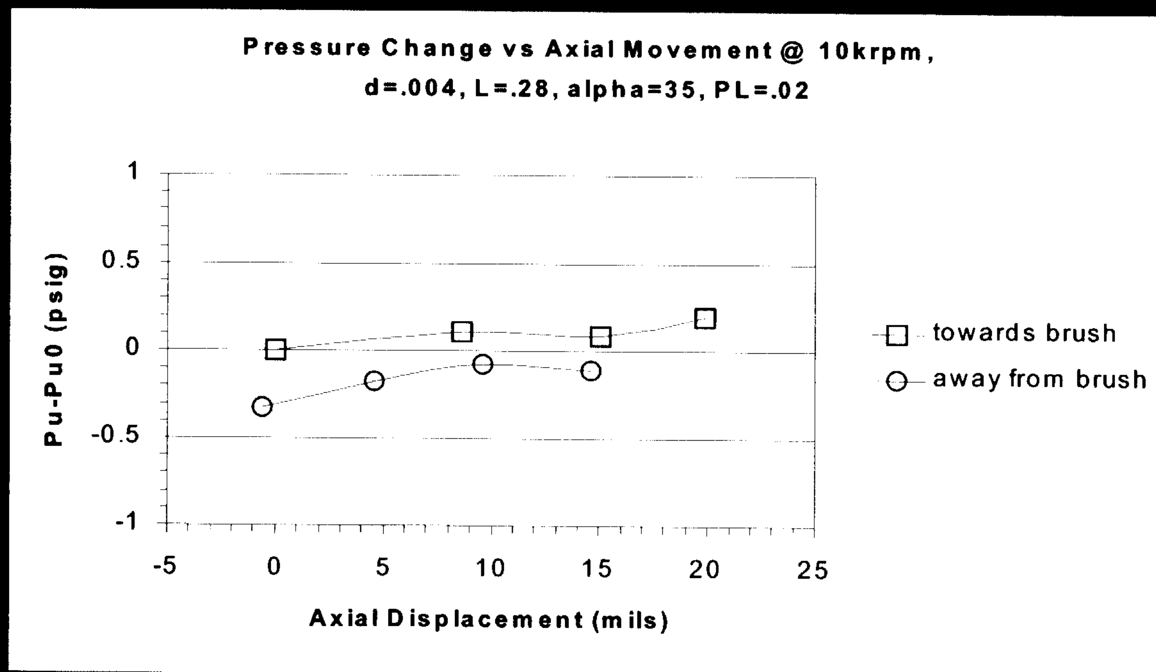


Figure 8: Leakage Performance @ P_u/P_d =5.1 (10krpm=123fps)

axial shaft movement



shaft radial runout

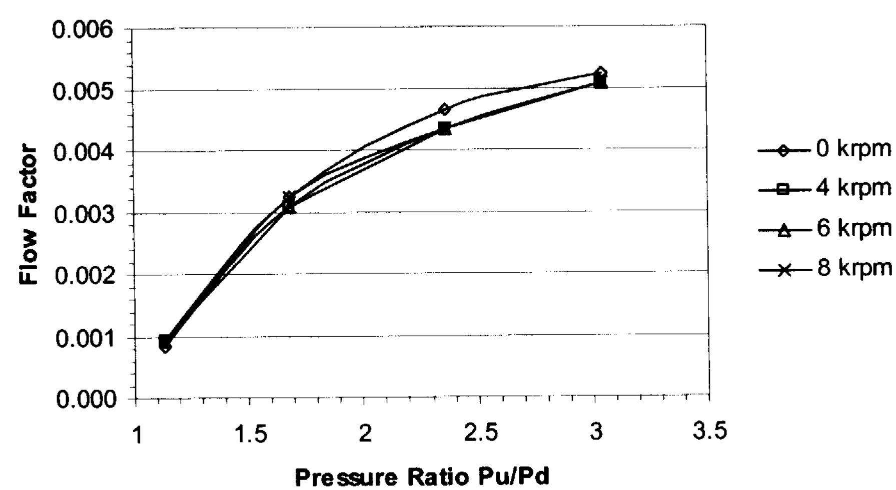


Figure 10: Seal Performance with 7mil radial runout, d=.004, L=.28, alpha=35, PL=.02 (10krpm=123fps)

Conclusions

- verified functionality and improved sealing performance of the HFBS at relatively high operational speeds

- leakage performance acceptable for gas turbine applications

- possibility of drastically improving engine efficiency with increased sealing performance

- experimentally tested/proved the theory of the “floating” brush seal by sealing around a rotating shaft during axial motion between the shaft and seal as well as sealing a rotating shaft with a large radial runout

- capable of providing improved sealing performance with the elimination of interface wear that exists in the current "standard" brush seal technology