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HYPERSONIC ENGINE SEAL DEVELOPMENT AT NASA LEWIS RESEARCH CENTER

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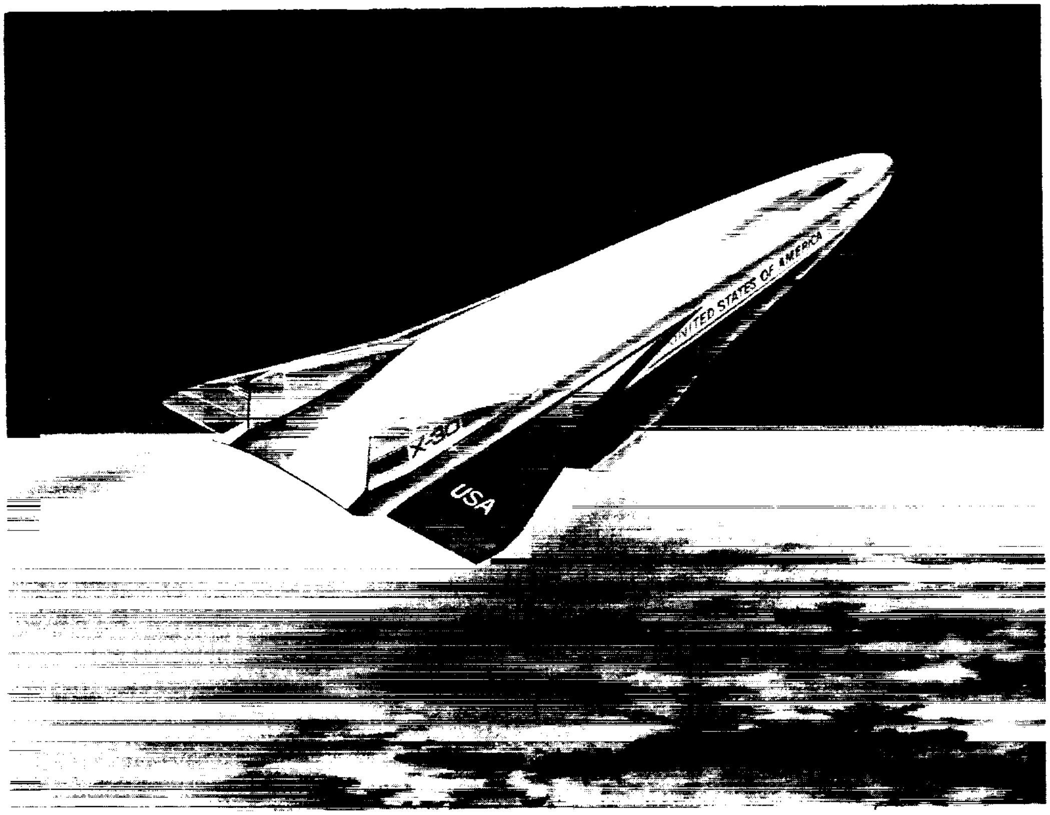
NASA Lewis Research Center is developing advanced seal concepts and sealing technology for advanced combined cycle ramjet/scramjet engines being designed for the National Aerospace Plane (NASP). Technologies are being developed for both the dynamic seals that seal the sliding interfaces between articulating engine panels and sidewalls, and for the static seals that seal the heat-exchanger to back-up structure interfaces.

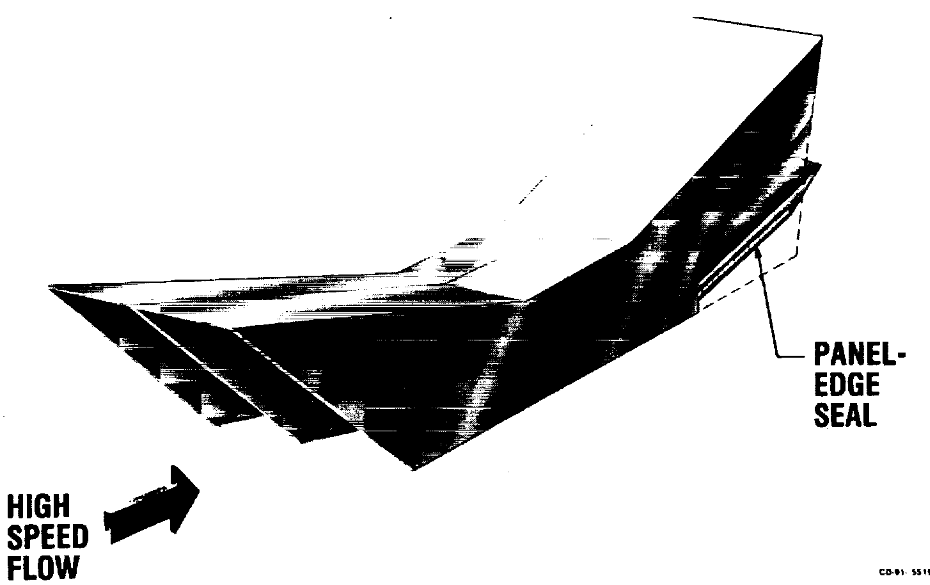
This paper will provide an overview of the candidate engine seal concepts, seal material assessments, and unique test facilities used to assess the leakage and thermal performance of the seal concepts.

Outline

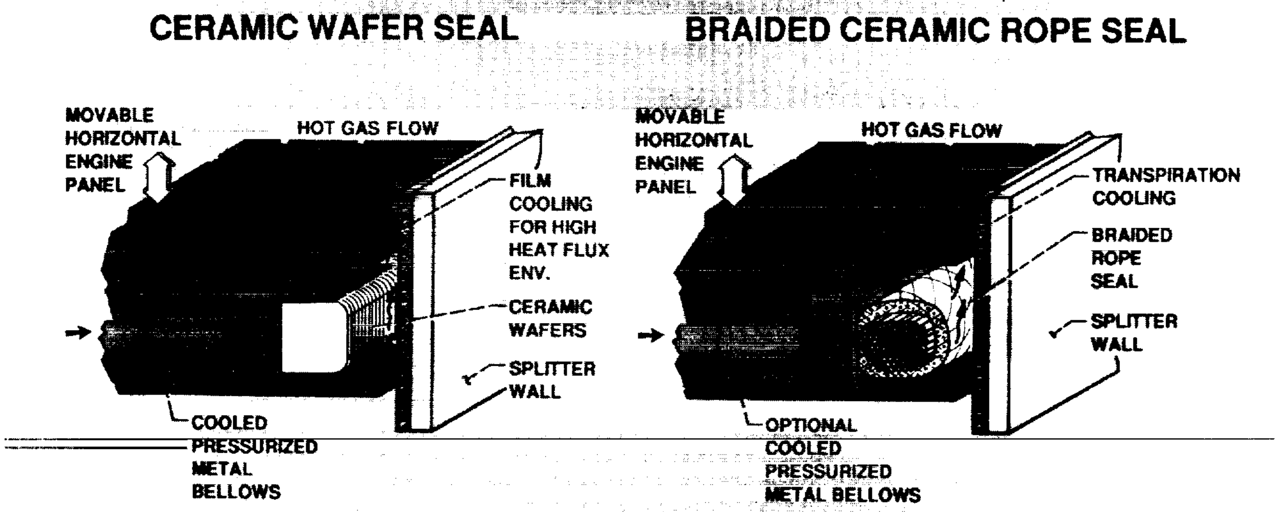
- o Introduction
- o Flow Modeling
- o High Temperature Material Friction and Wear Tests
- o High Temperature Durability/Flow Assessments
- o High Heat Flux Facility
- o Summary



HYPERSONIC ENGINE PANEL-EDGE SEAL



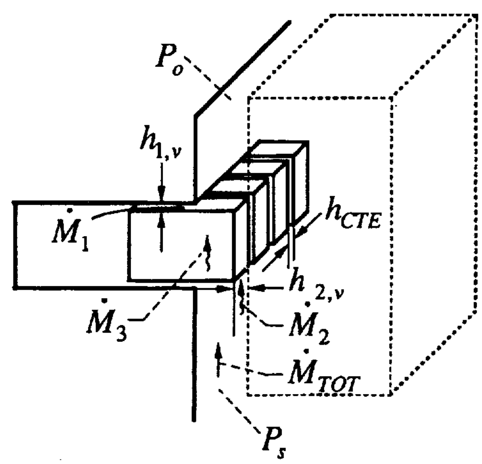
SEAL CONCEPTS UNDER DEVELOPMENT (U)



Flow Modeling

Ceramic Wafer Seal Flow Modeling

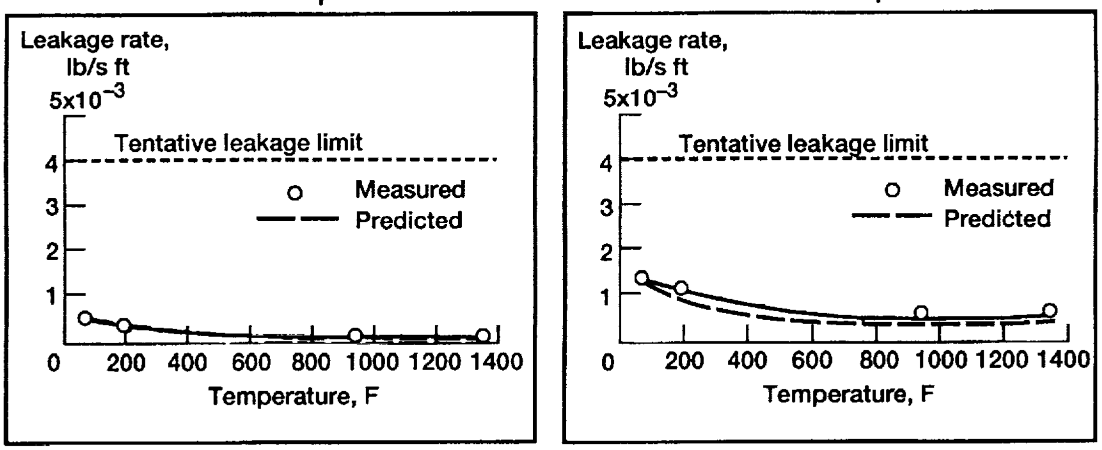
$$\dot{M}_{TOT} = \underbrace{\dot{M}_1}_{\text{Top}} + \underbrace{\dot{M}_2}_{\text{Nose}} + \underbrace{\dot{M}_3}_{\text{Between wafers}}$$



$h_{1,v}; h_{2,v}; h_{CTE}$ - Seal leakage gap heights
$H_1; H_2$ - Seal-to-wall contact dim.
L - Seal length
$P_s; P_o$ - Inlet & outlet pressures
$\mu; \rho; T$ - Gas viscosity, density, temp.
R - Gas constant

Ceramic Wafer Seal Leakage vs Temperature Comparison of Measured & Predicted

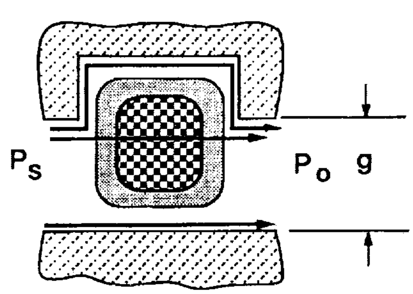
$\Delta P = 20$ psi | $\Delta P = 40$ psi

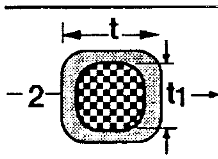


Leakage Path Flow Resistances

$$\dot{M}_{TOT} = \underbrace{\dot{M}_1}_{\text{Behind seal}} + \underbrace{\dot{M}_2}_{\text{Through seal}} + \underbrace{\dot{M}_3}_{\text{Front of seal}}$$

Rope Seal Flow Paths



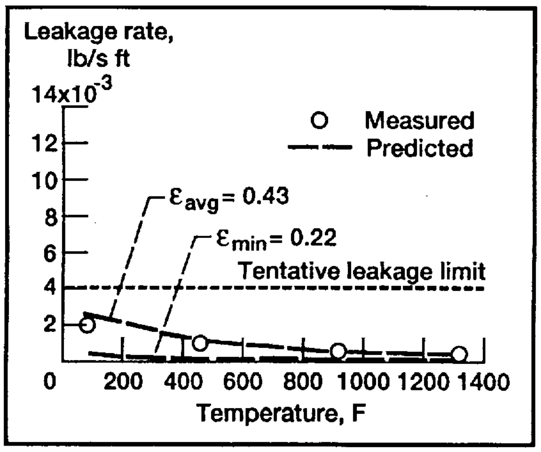
	Flow Path	Flow Resistance
$\dot{M}_1$	1	$R_1 = 9K\dfrac{t}{y_o^3}$
$\dot{M}_2$		$R_2 = 300K\dfrac{tL}{A_c}\dfrac{(1-\varepsilon_{avg})^2}{\varepsilon_{avg}^3(\phi D_{f,avg})^2}$
$\dot{M}_3$	3	$R_3 = 3K\dfrac{t}{y_o^3}$

Where: $\phi D_{f,avg}$ = Characteristic length

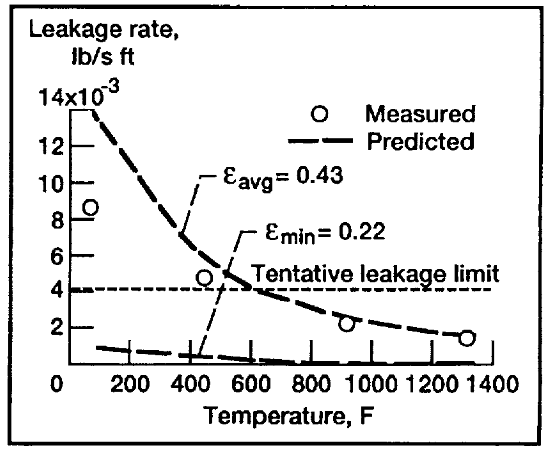
$$\varepsilon_{avg} = 1 - \frac{A_y N_c + A_y N_s / \cos\theta}{t^2}$$

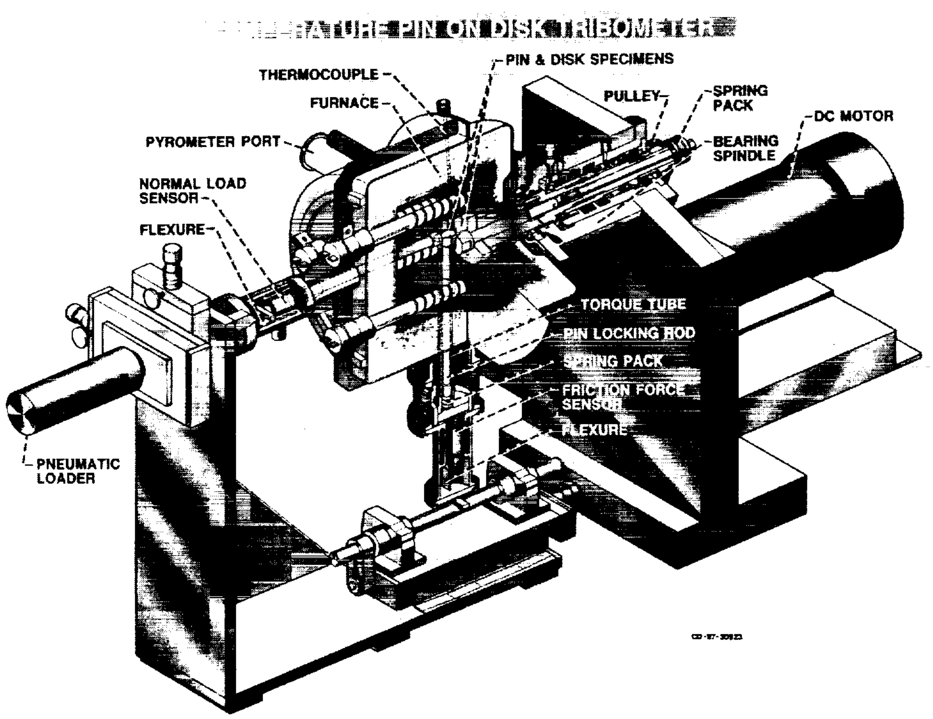
Braided Ceramic Rope Seal Leakage vs Temperature
Comparison of Measured and Predicted

$\Delta P = 10$ psi



$\Delta P = 35$ psi

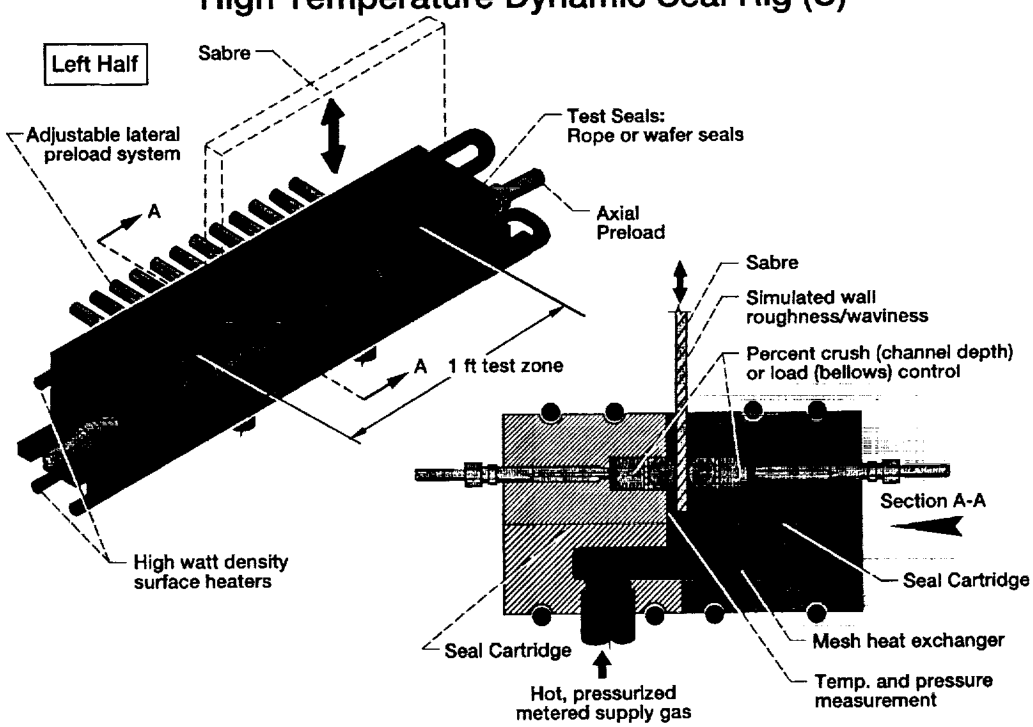


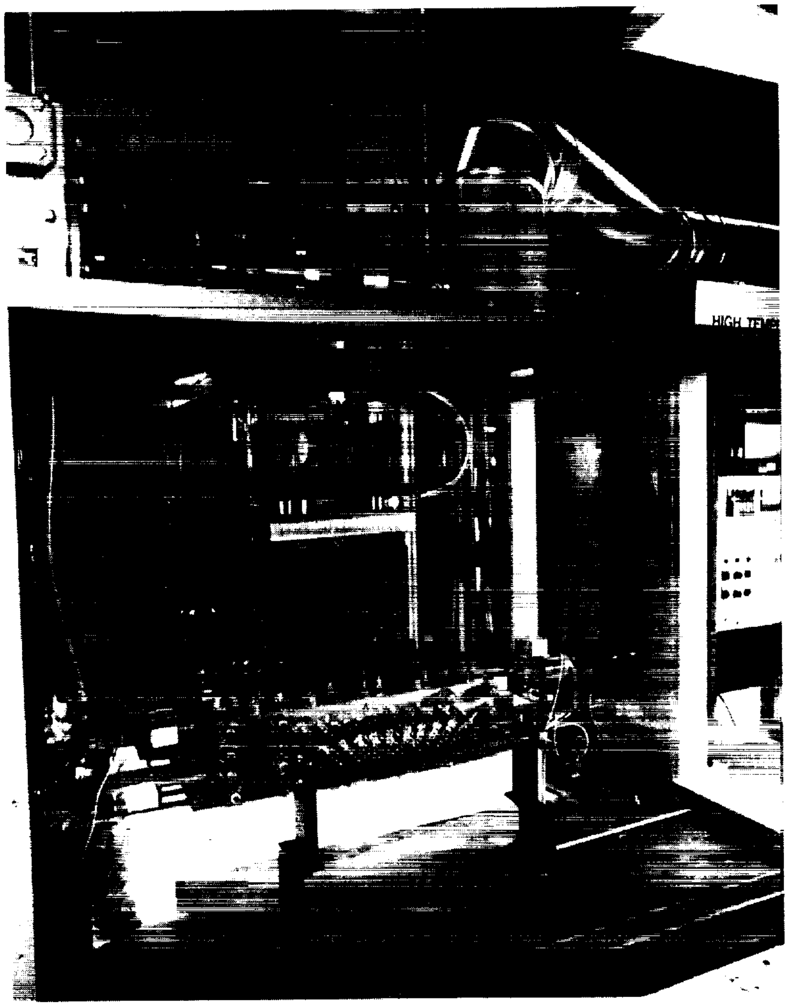


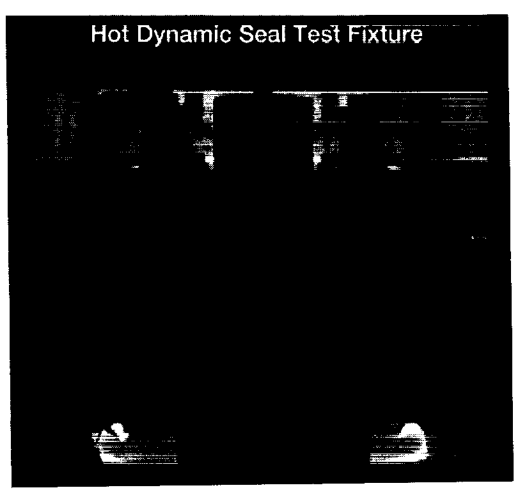
High Temperature

Solid Seal Durability/Flow Studies

High Temperature Dynamic Seal Rig (U)





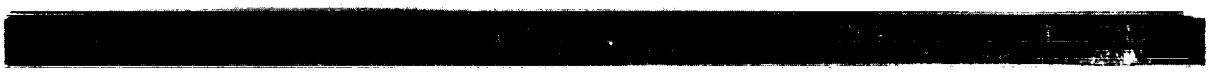

Hot Dynamic Seal Test Fixture

SOLID SEAL DURABILITY TEST

Hot Dynamic Seal Rig

Haynes 25 (2 mil wire) Hybrid seal <u>after</u> hot durability cycling

SEAL - HY3 - 1



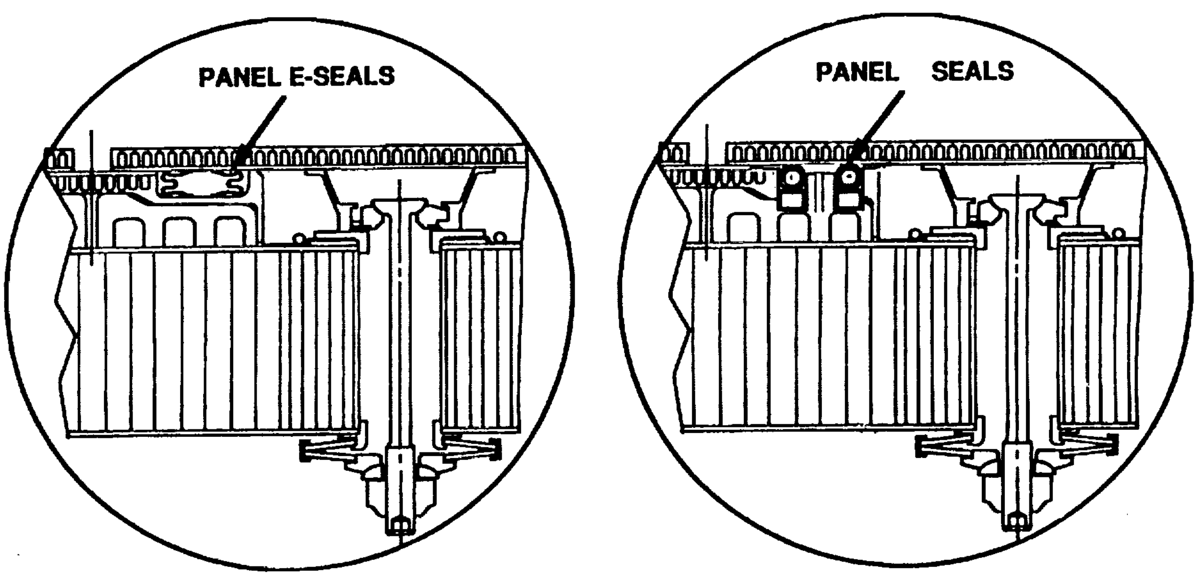
SEAL - HY3 - 2

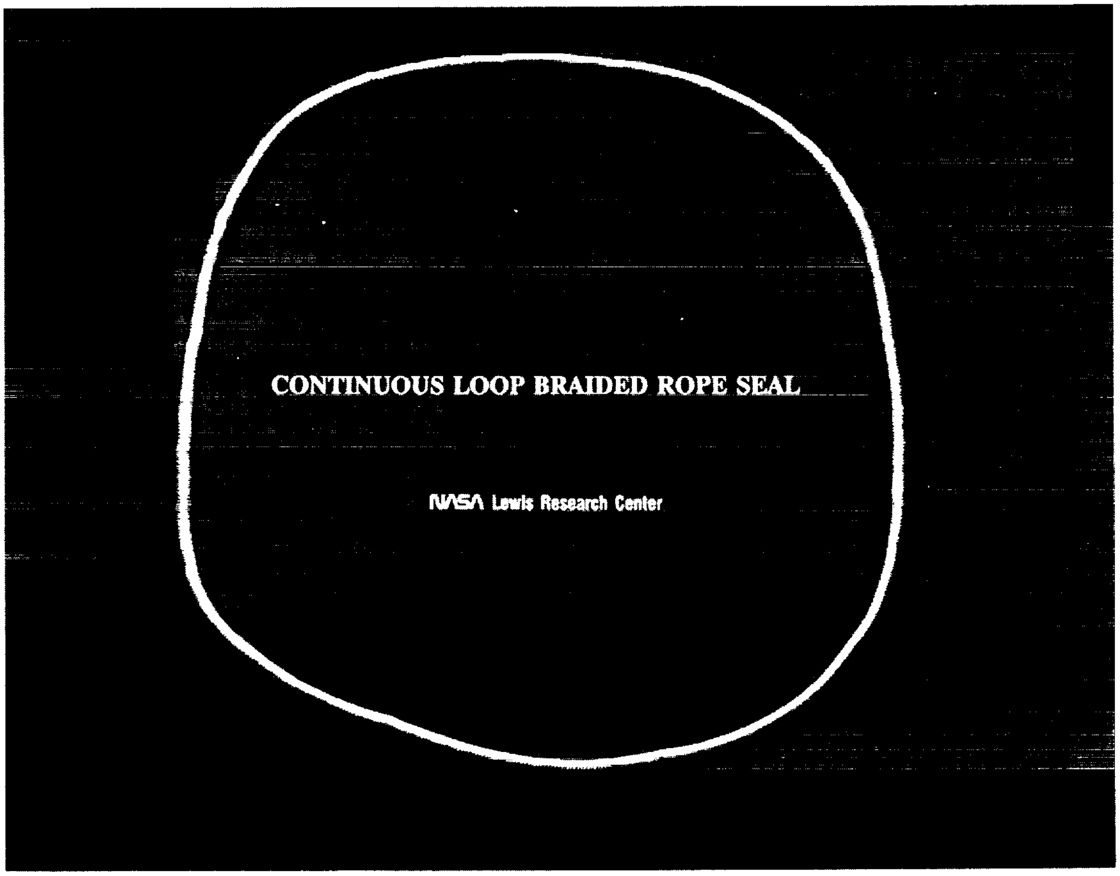
<u>CONDITIONS</u>:

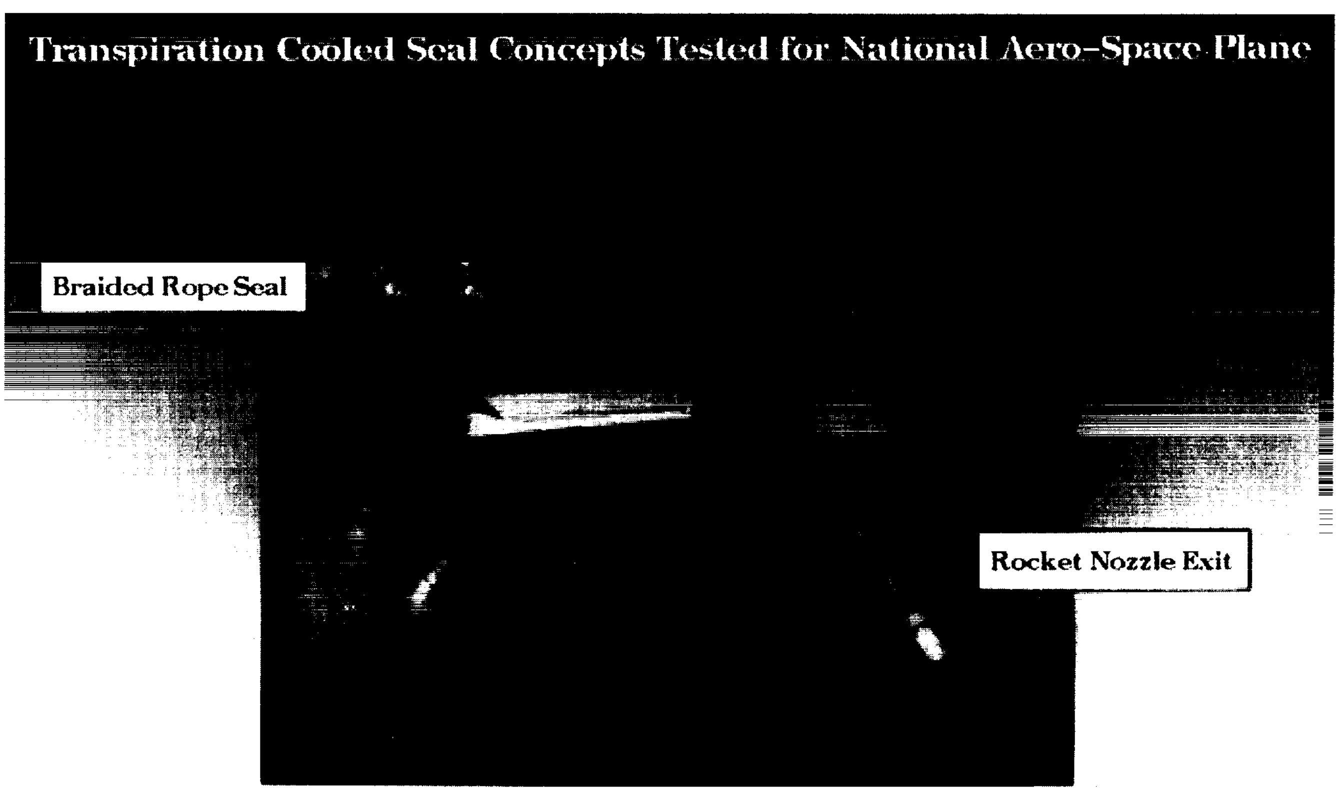
SEAL ARCH:	HY3(32.8%)-NX312(600/8)-4400/94.8%-H25(172/50)-24x1/10/80' (12.00")
SEAL GAP:	0.030 inches
PRELOAD:	Active (20 psi contact pressure)

Coolant Panel Braided Ceramic Rope Seal

Potential Alternate to Metal Seal







CRL-22 Hot Gas Facility

Summary

- o Hypersonic engines pose unique dynamic seal challenges:
  - \+ Prevent leakage of combustible hydrogen/oxygen mixtures
  - \+ Seal highly distorted sidewalls during sliding
  - \+ Operate hot requiring minimum coolant
  - \+ Resist mechanical abrasion and supersonic-flow erosion

- o NASA Lewis has developed unique test capabilities for evaluating the seal/material performance under engine simulated conditions:
  - \+ Materials/Lubricant Friction Apparatus
  - \+ High Temperature Dynamic Seal Rig
  - \+ High Heat Flux Facility

- o NASA Lewis developed hybrid seal meets the dynamic engine seal life requirements at temperatures $\geq$1500 F.