

## SEAL DEVELOPMENT FOR THE HSCT COMBUSTOR

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The combustor section of the High Speed Civil Transport (HSCT) requires high temperature seals to minimize leakage between CMC components. The temperature requirements range from 1500°F to 2100°F and the compression requirements range from 10% to 50%. Three distinctly different Nextel braided seals have been developed to seal areas such as the bulkhead heatshields and lean zone outer liner. The seals range from 0.10" dia. rope to triangular braid with 1" sides. The development of these seals is the result of a collaborative effort between Pratt & Whitney, FTS Inc., Techniweave Inc. and United Technologies Research Center.

The specific requirements in terms of temperature, sealing and compression at various combustor locations will be presented. The architectures of braided Nextel seals developed to meet these requirements will be described and microstructures will be shown. Compression and sealing data will be related to the application for the various seals. Selected seals have metal wires incorporated into the architecture to enable brazing to the metallic superstructure. The results of brazing trials on these seals will be discussed.

The combustor section of the High Speed Civil Transport (HSCT) requires high temperature seals to minimize leakage between CMC components and the metal support structure. The approach to developing seals has been to build upon the Nextel braided seal work at NASA Lewis under the direction of Bruce Steinetz. A team consisting of the following companies has been working on combustor seals during 1997: Pratt & Whitney (technical direction & brazing), United Technologies Research Center (task management and benchmark testing), FTS, Inc. (analysis & modeling), Stress Engineering Services (flow requirements), and Techniweave Inc. (seal fabrication). To date, this team has defined the basic seal requirements, obtained seals, and benchmark tested these woven seals. The development has focused on the Rich Zone-Quench-Lean Zone (RQL) combustor design with the near-term task of providing seals for a NASA RQL sector rig test.

The RQL sector rig requires three types of Nextel braided seals. First, a triangular braid seal composed of Nextel 720 will seal between the liners in the lean zone outer liner. The sealing requirements in this area are low; however, the temperature requirements are high (2400°F). The triangular braid seals experience low compression and act mainly as a heat shield for the metal support structure. Second, Nextel 720 rope seals with a diameter of 0.080" are needed along the edges of the lean transition inner liner. These seals are expected to get compressed approximately 20% and be exposed to temperatures up to 2100°F. Third, Nextel 550 rope seals with a diameter of 0.100" are required for the bulkhead heatshield, sidewalls, and in the metal retention grooves of the lean zone outer liner. These seals may experience compressions of up to 50%.

The remainder of the discussion will focus on the rope seals since they present the most significant development challenge. The rope seals must be able to balance compression requirements with permeability requirements. In other words, the seals must minimize gas leakage while being able to be compressed with low force. The 0.100" diameter rope seals in the lean zone outer liner will be compressed 70% at room temperature and to 50% at 2200°F. In addition, one side of rope seals need to be able to seal against the rough surface of the SiC/SiC composite, while the other side is bonded to the metal support structure.

Bonding of the rope seals to the metal support structure is required for assembly and positioning. This bonding is accomplished by incorporating longitudinal metal wires

along one side and brazing these wires to the support structure. Techniweave, Inc. has successfully woven Inconel 600 wire into the rope seals, and Pratt & Whitney has successfully brazed these seals to Inconel 625 panels using a vacuum furnace. The Inconel wire must be exposed on the surface of the rope seal for a good braze bond to be obtained. Techniweave also developed procedures for incorporating colored tracer fiber on the opposite side of the brazed wires to facilitate positioning for brazing.

Based on Pratt & Whitney's requirements, Techniweave has woven eleven variations of the 0.100" diameter rope seal. The rope seal consists of an inner core of unidirectional fibers and an outer region of over-braid. The unidirectional core has low permeability and the outer over-braid provides compressibility while holding the seal together. In order to produce a highly compressible weave, the unidirectional core was completely left out of rope seal #9. The various weaves were compression tested and flow tested at UTRC. The compression testing involved compressing the 0.100" diameter seal to 0.080", 0.070", 0.060" and 0.050". Three loading repetitions were performed at each compression distance, and a virgin section of braid was used at each distance. Several of the early rope seals required in excess of 900 lb per inch to be compressed 50%, which was unacceptably high for the lean zone outer liner. The hollow core rope seal (#9) required only 31 lb per inch to compress 50%, with only a 0.021" permanent set after three compression cycles.

Flow testing was performed by compressing a circular section of rope seal to the desired thickness between two metal plates. The rope seal ends were joined with RTV sealant in order to insure that the gas flow was within the rope seal. The gas flow was increased in the flow test fixture until the desired gas pressure was achieved and held (1 to 10 psi). The gas flow required to maintain a constant pressure was recorded. Using this procedure, the leakage rate as a function of gas pressure and percent compression was measured for several of the rope seals. At 2 psi and 50% compression, the hollow core rope seal #9 had a leakage rate of 0.045 SCFM / in. The analysis is in process to determine the acceptable level of leakage for the various locations in the sector rig.

# **Seal Development for the HSCT Combustor**

**HSR / EPM Program**

**Presented By: David Jarmon**

**Oct. 17, 1997**

**NASA Lewis Research Center  
Cleveland , Ohio**

# **Sealing**

## **Approach**

- Define requirements and benchmark test

## **Status**

- FTS and P&W have defined seal requirements
- Techniweave has woven 12 variations of rope seals
- P&W-EH has conducted brazing studies
- UTRC has performed compression & flow tests

## **Near-Term Future Work**

- Wear test to evaluate durability
- Identify “best” woven seals for rig test

# **Seal Effort Contributors**

**Technical Director: P&W (Martin Gibling)**

**Task Management: UTRC (David Jarmon)**

**Analysis & Modeling: FTS, Inc. (Larry Pauze)**

**Flow Requirements: Stress Eng. Serv. (Kenneth Waeber)**

**Seal Fabrication: Techniweave, Inc. (Jim Crawford)**

**Seal Brazing: P&W (Robert Schaefer)**

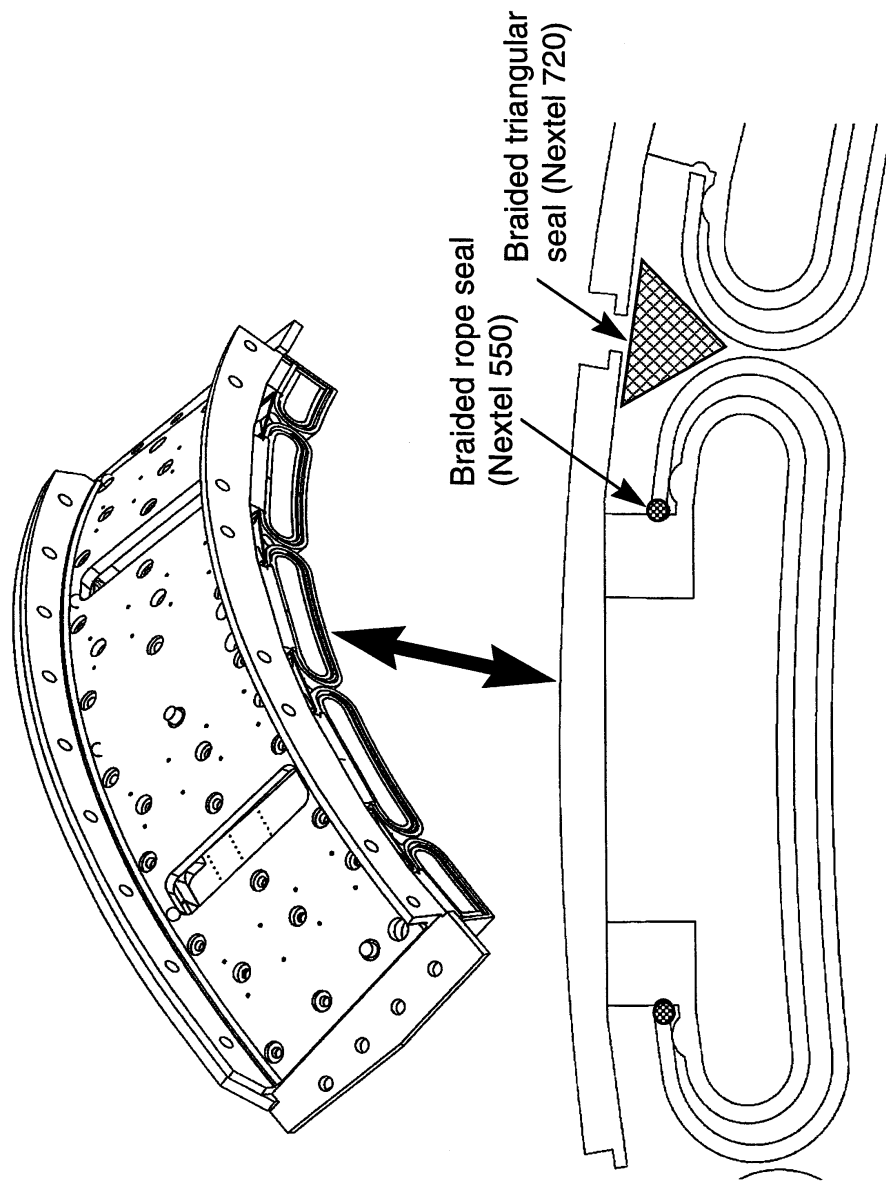
**Benchmark Testing: UTRC (David Jarmon)**

*Note: Nextel rope seal is based on work at NASA Lewis Research Center by Bruce Steinetz*

# RQL Nextel Braided Seals Requirements

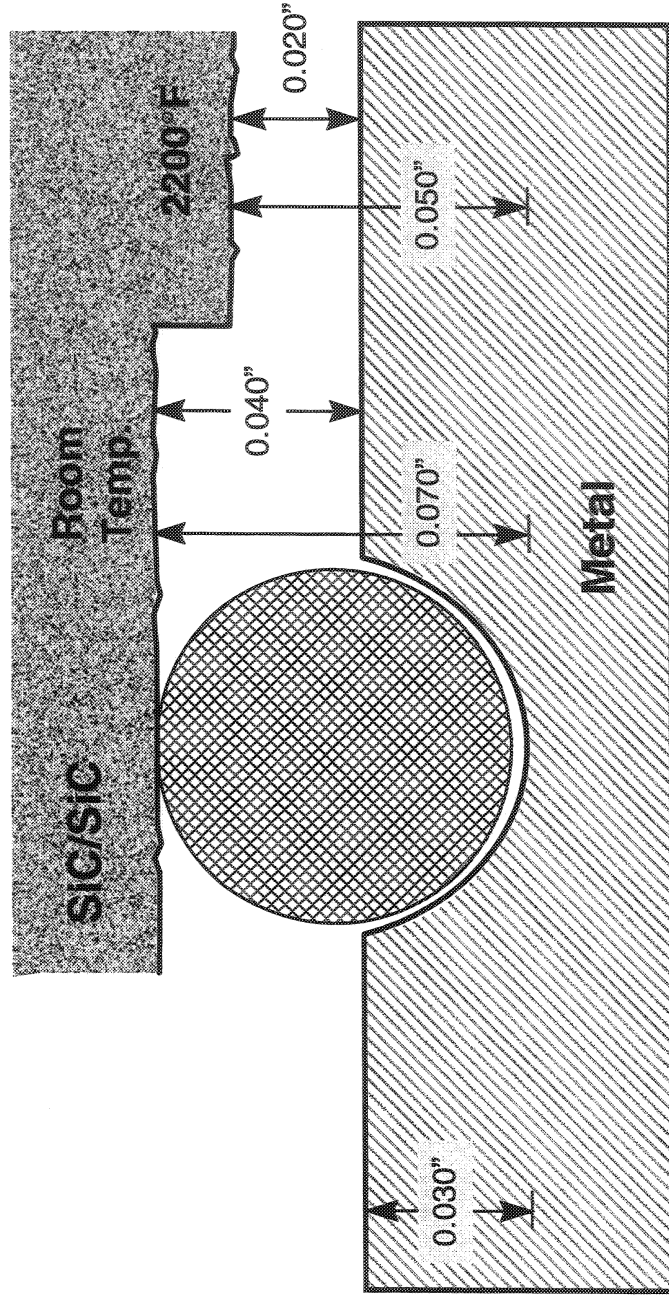
Component / Location	Shape	Mounting Surface	Temp. (F)	Thickness (inch)			Nextel Fiber	Braze Wire	Sealing Requirement
				Free Standing	Com-pressed				
Lean Transition Inner Liner: Along both edges	round	flat surface	2100	0.080	0.060		Yes	Moderate	
A) Bulkhead Heatshield: Along top edge								A) Moderate	
B) Bulkhead Heatshield: Around holes	round	flat surface	1800	0.100	0.080		Yes	B) Moderate	
C) Sidewalls: Around four edges								C) High	
Lean Zone Outer Liner: Between liners	triangular	triangular slot	2400	0.160 sq. in.	0.127 sq. in.		No	Low	
Lean Zone Outer Liner: In metal retention groove	round	groove	1500	0.100	0.080" to 0.050"		Yes	Moderate	

# Lean Zone Outer Liner

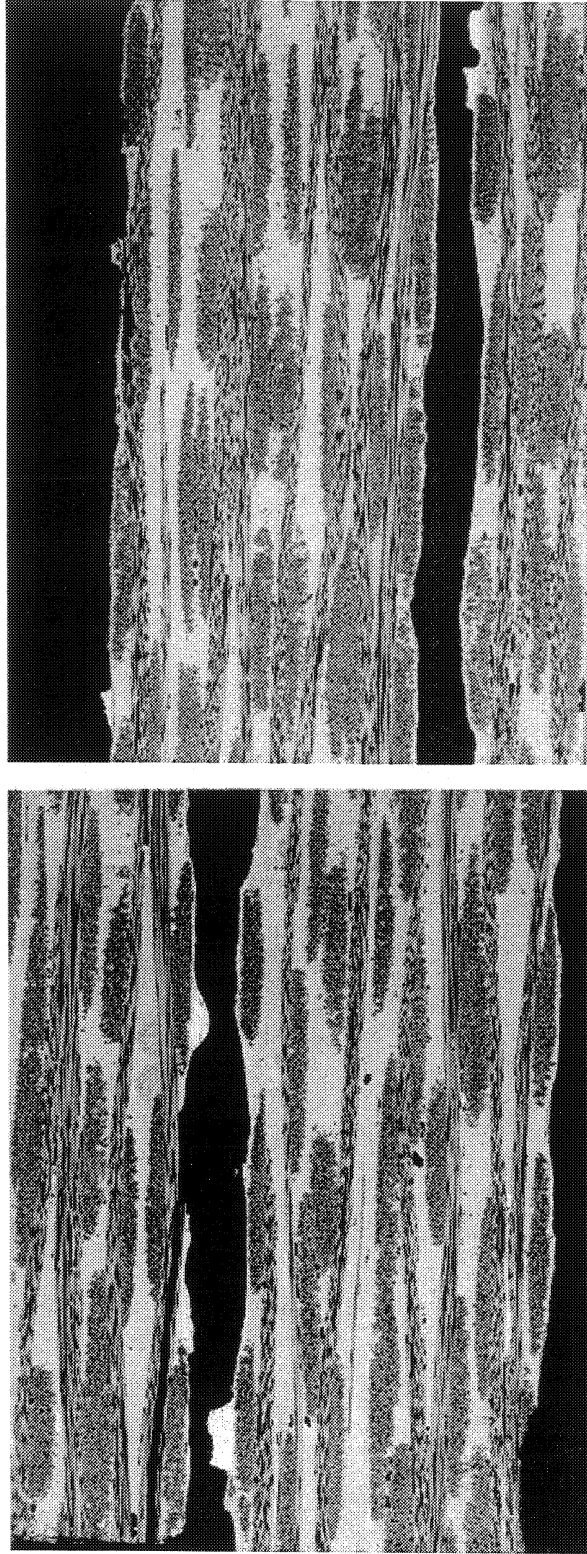




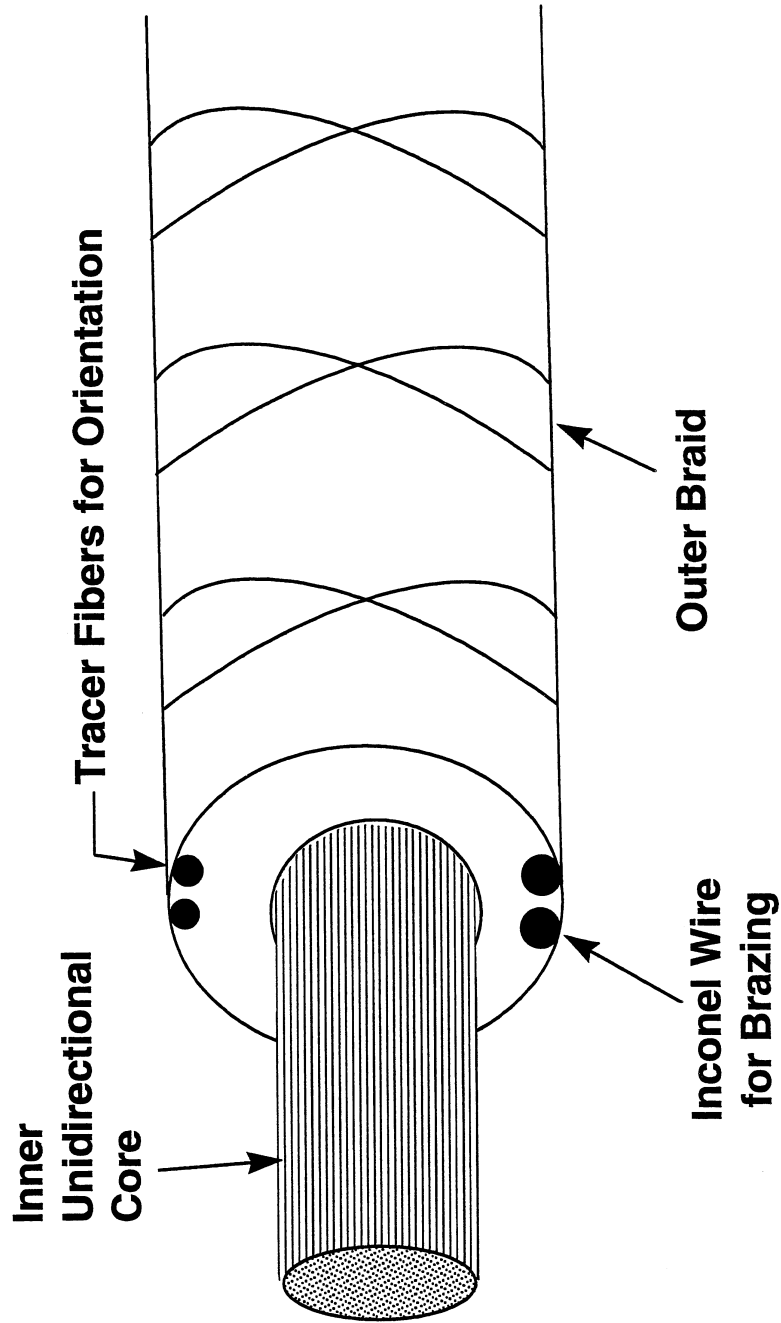
# Rope Seal in Lean Zone Outer Liner at RT & 2200°F



# Microstructure and Surface Profile of MI SiC/SiC

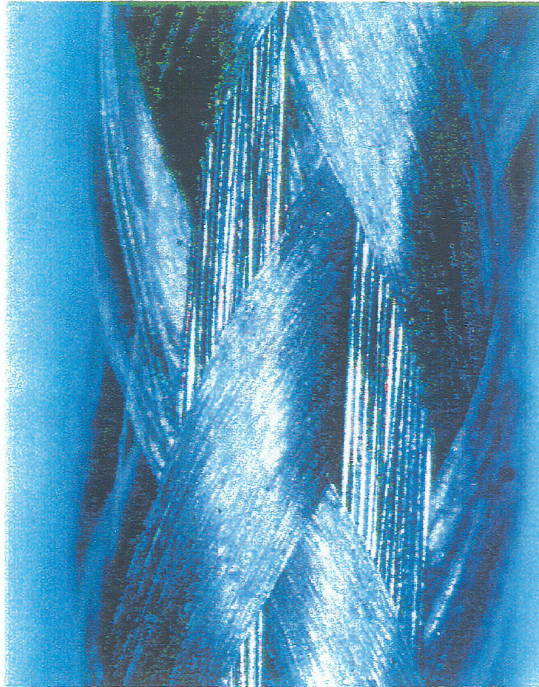


# Rope Seal Structure



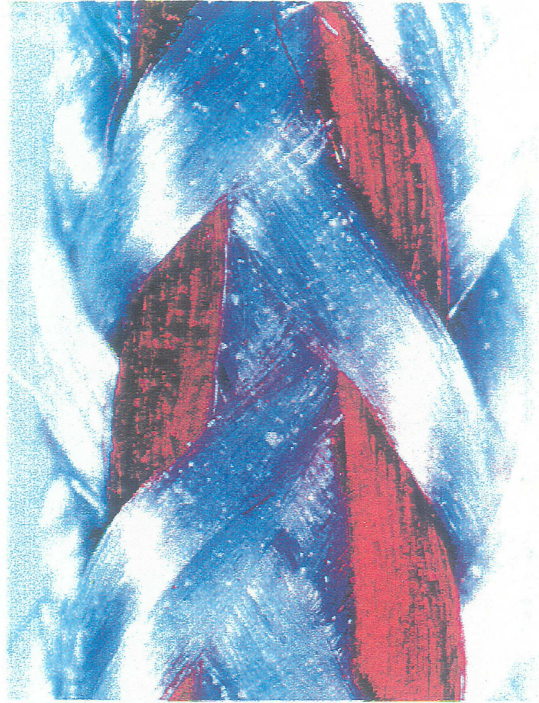
# Braid Rope Seals

**Inconel 600 Wire  
for Brazing**



**Type 12**

**Red Tracer Fibers  
for Orientation**



**Type 10**

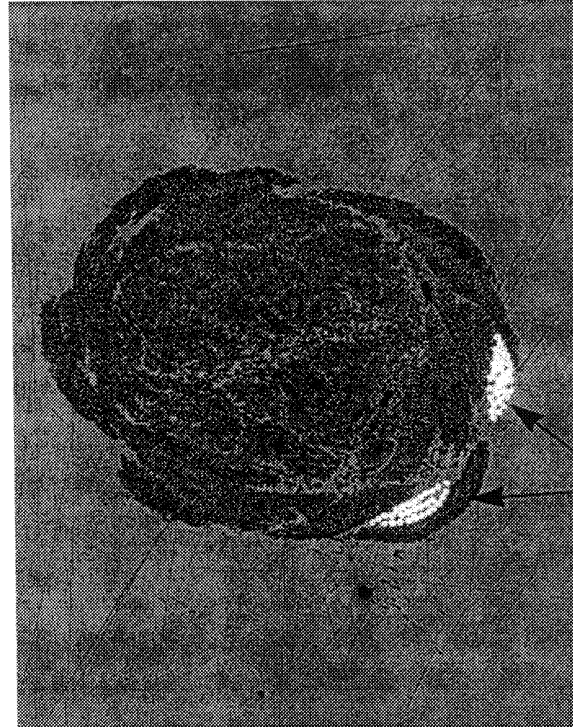
— 0.040" —  
— 1 mm —

DCJc97-24.cdr



# Braided Rope Seals

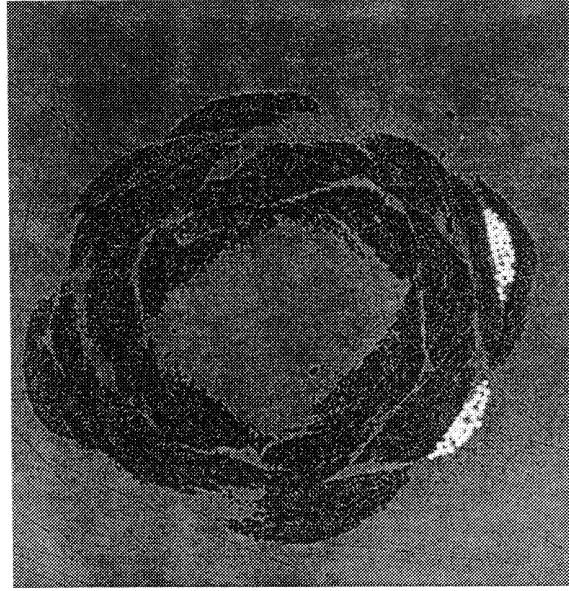
**Filled Core for  
Decreased Permeability**



**Type 10**

Inconel 600 wire  
for brazing

**Hollow Core for  
Maximum Compressibility**

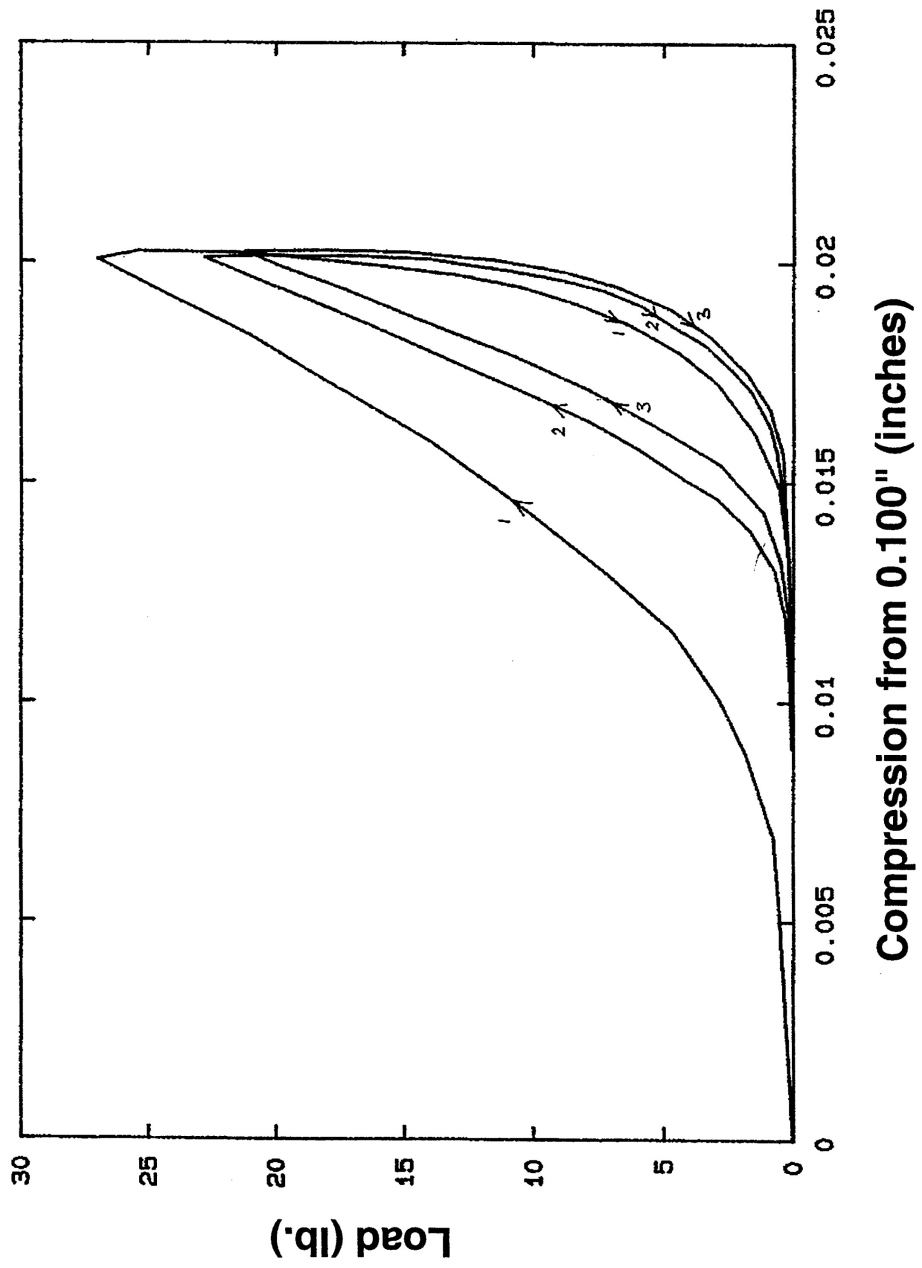


**Type 9**

0.040"  
1 mm

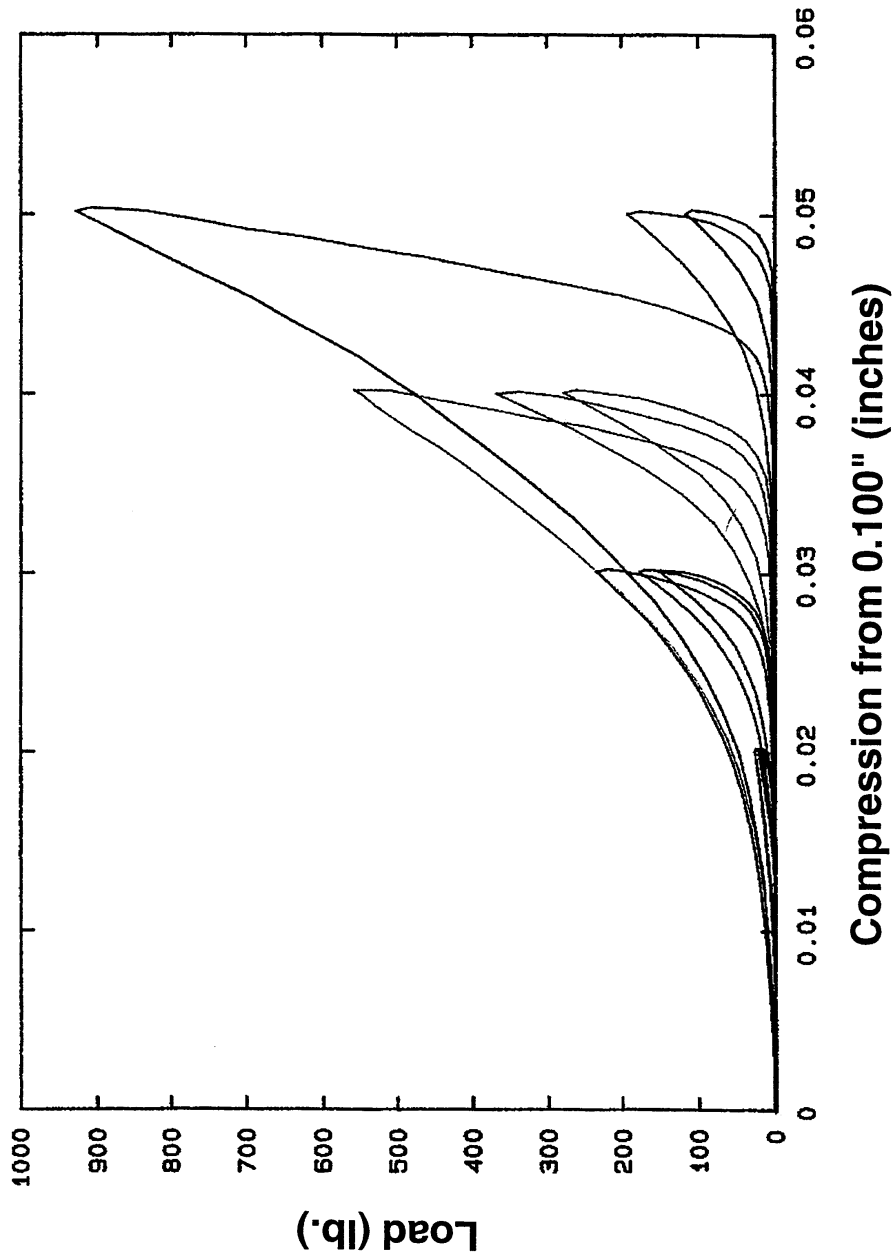
# Compression of Rope Seal No. 4 From 0.100" to 0.080"

(3 Repetitions)

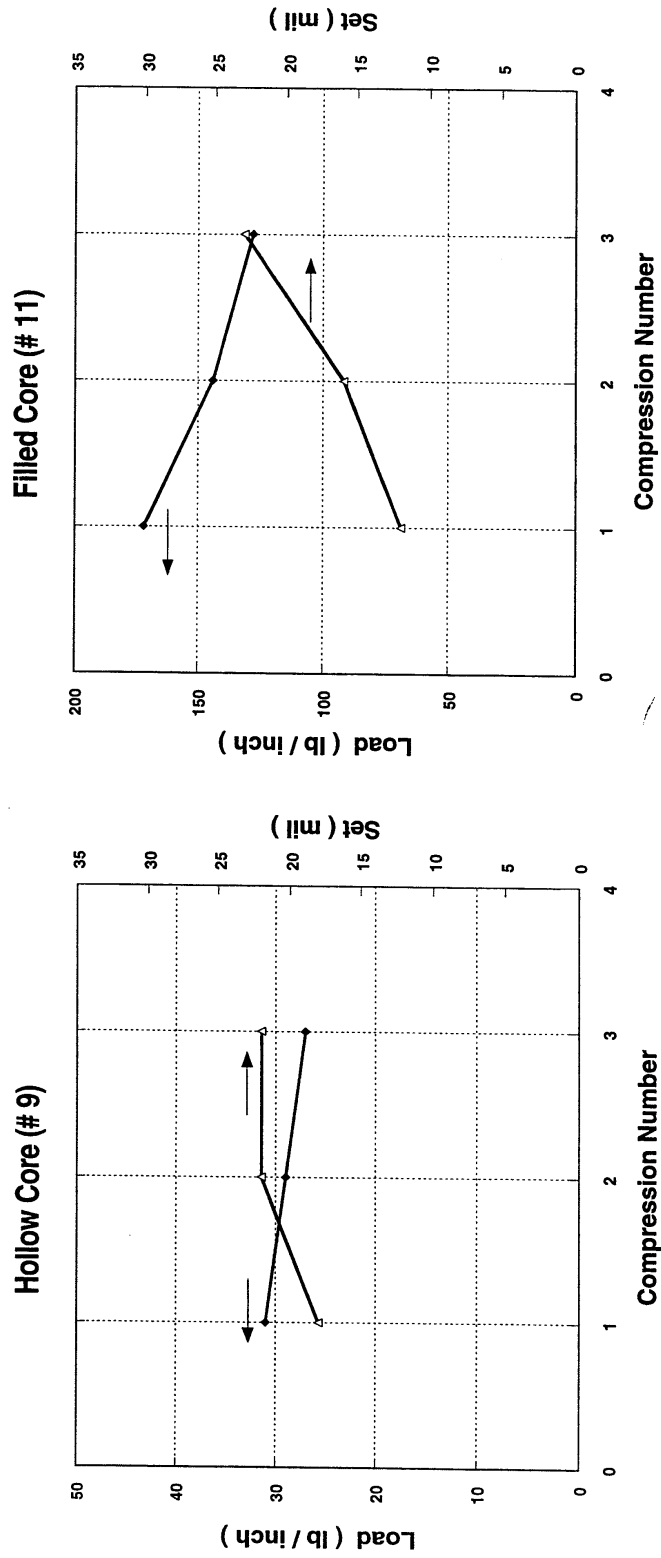


**Compression of Rope Seal No. 4 From 0.100" to 0.080", 0.070", 0.060" & 0.050"**

**(3 repetitions at each distance)**

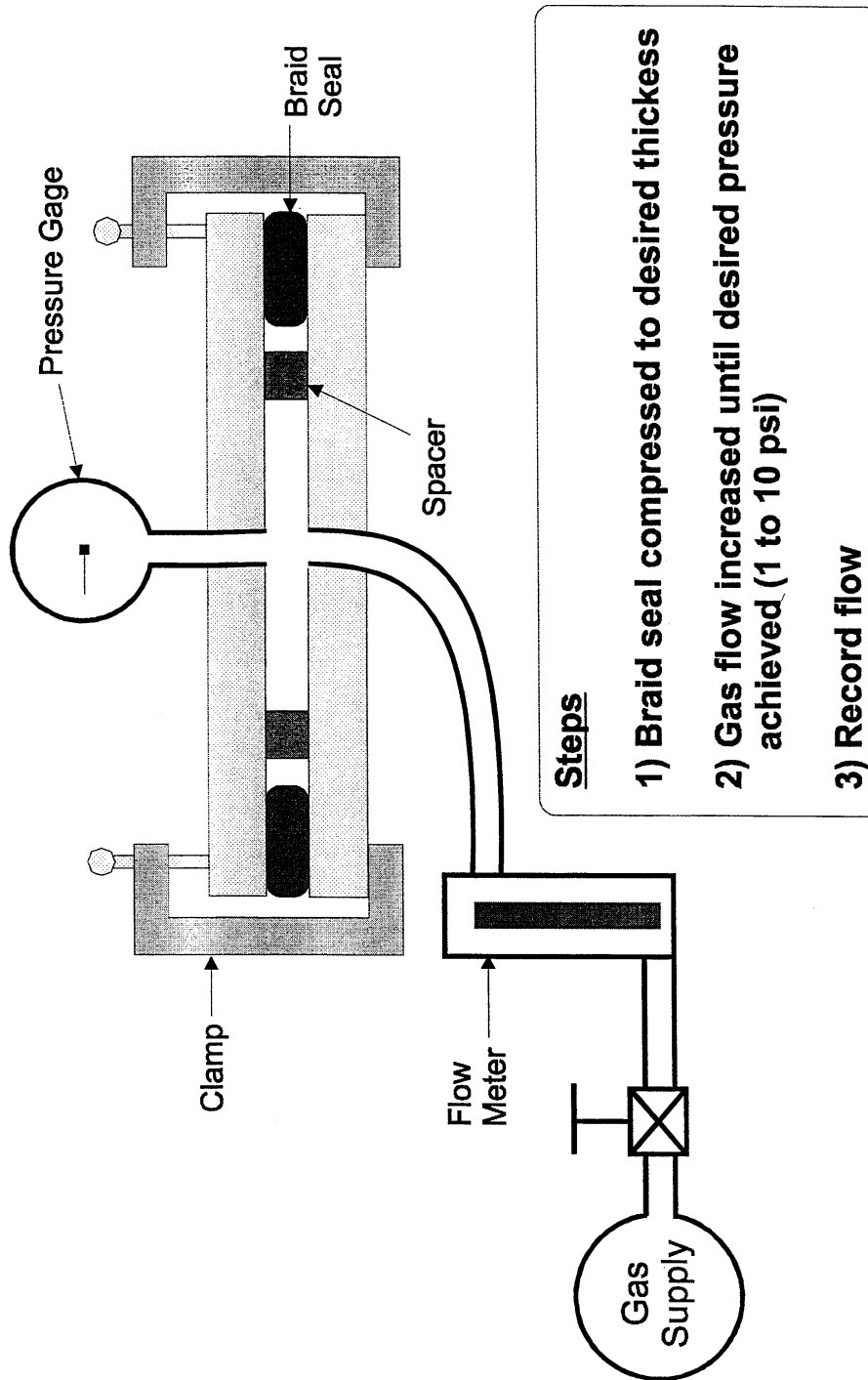


# Rope Seal Compression Load and Set Compression Cycle at 50% Compression

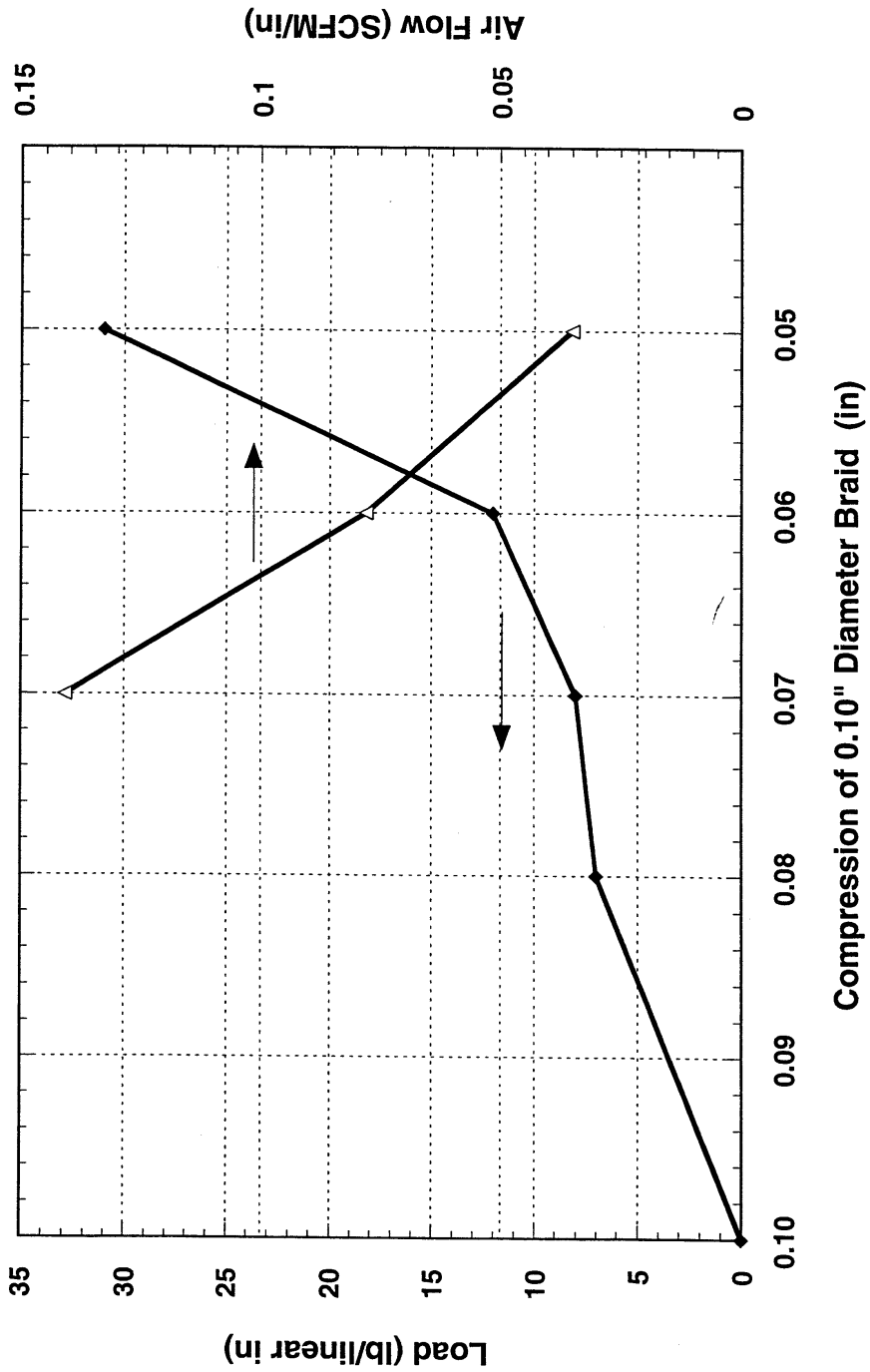




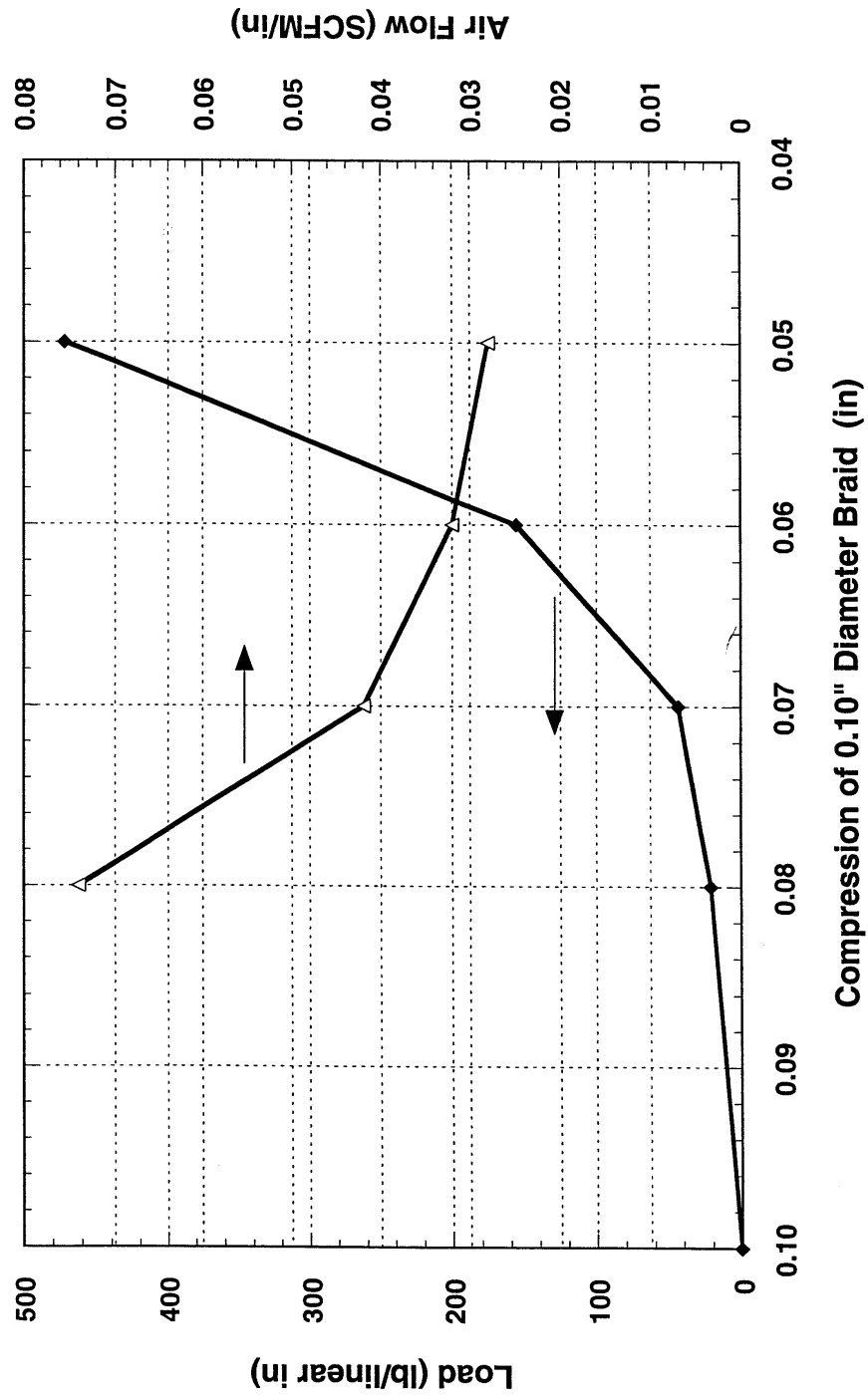
# Braid Seal Flow Test Rig



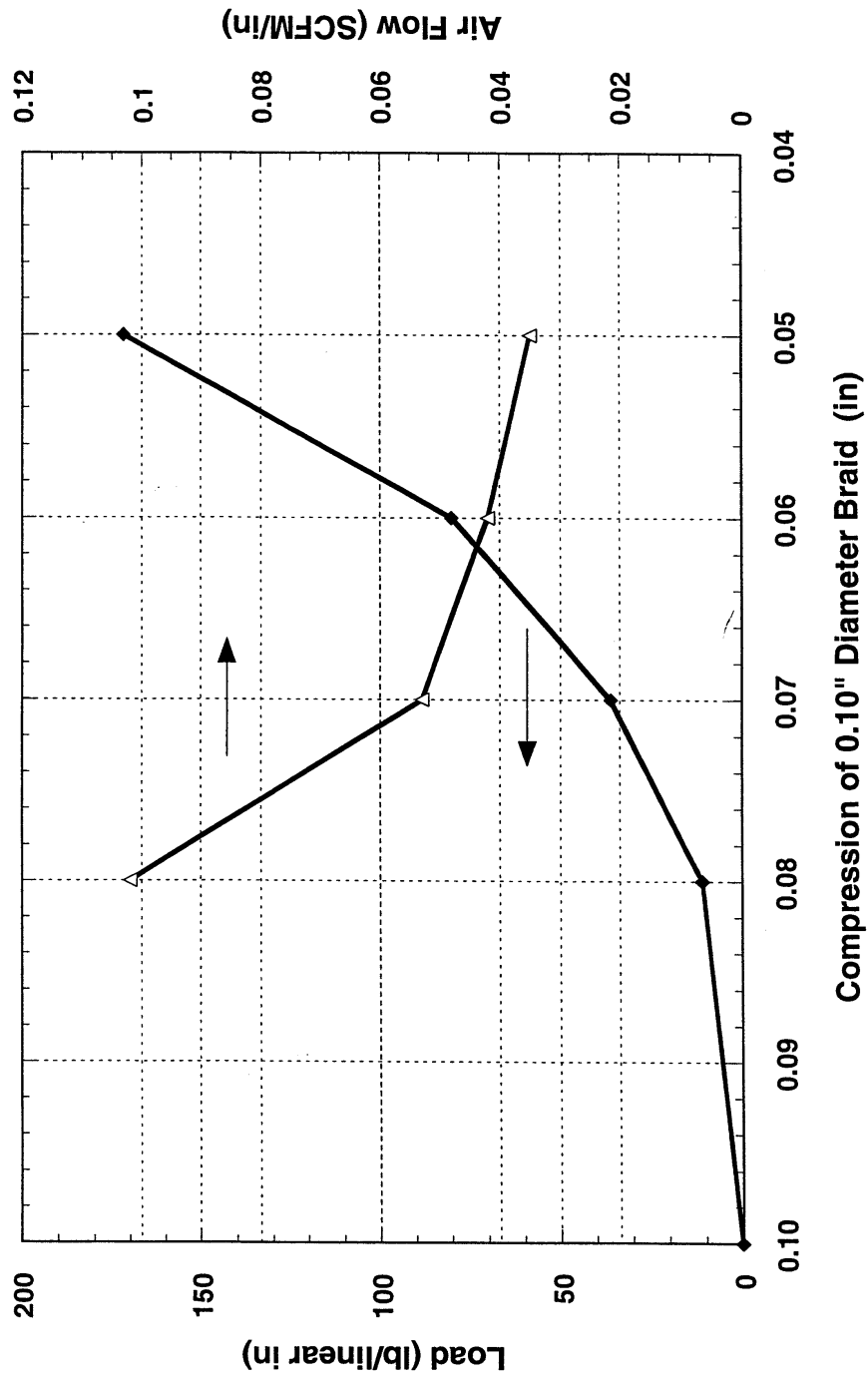
# Load and Flow Data as a Function of Compression for Hollow Core Nextel Rope Seal No. 9 at 2 psi Gas Pressure



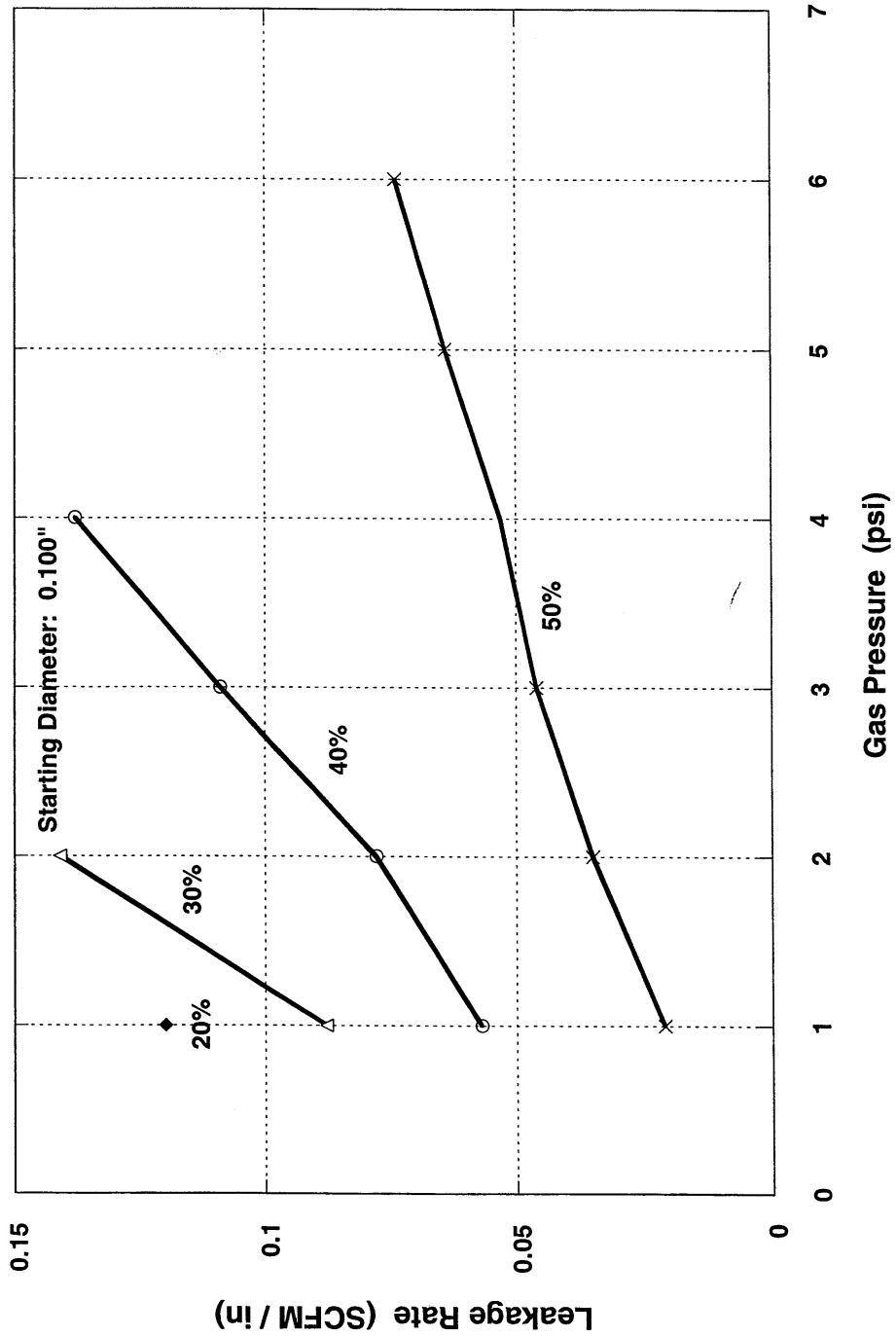
# Load and Flow Data as a Function of Compression for Filled Core Nextel Rope Seal No. 10 at 2 psi Gas Pressure



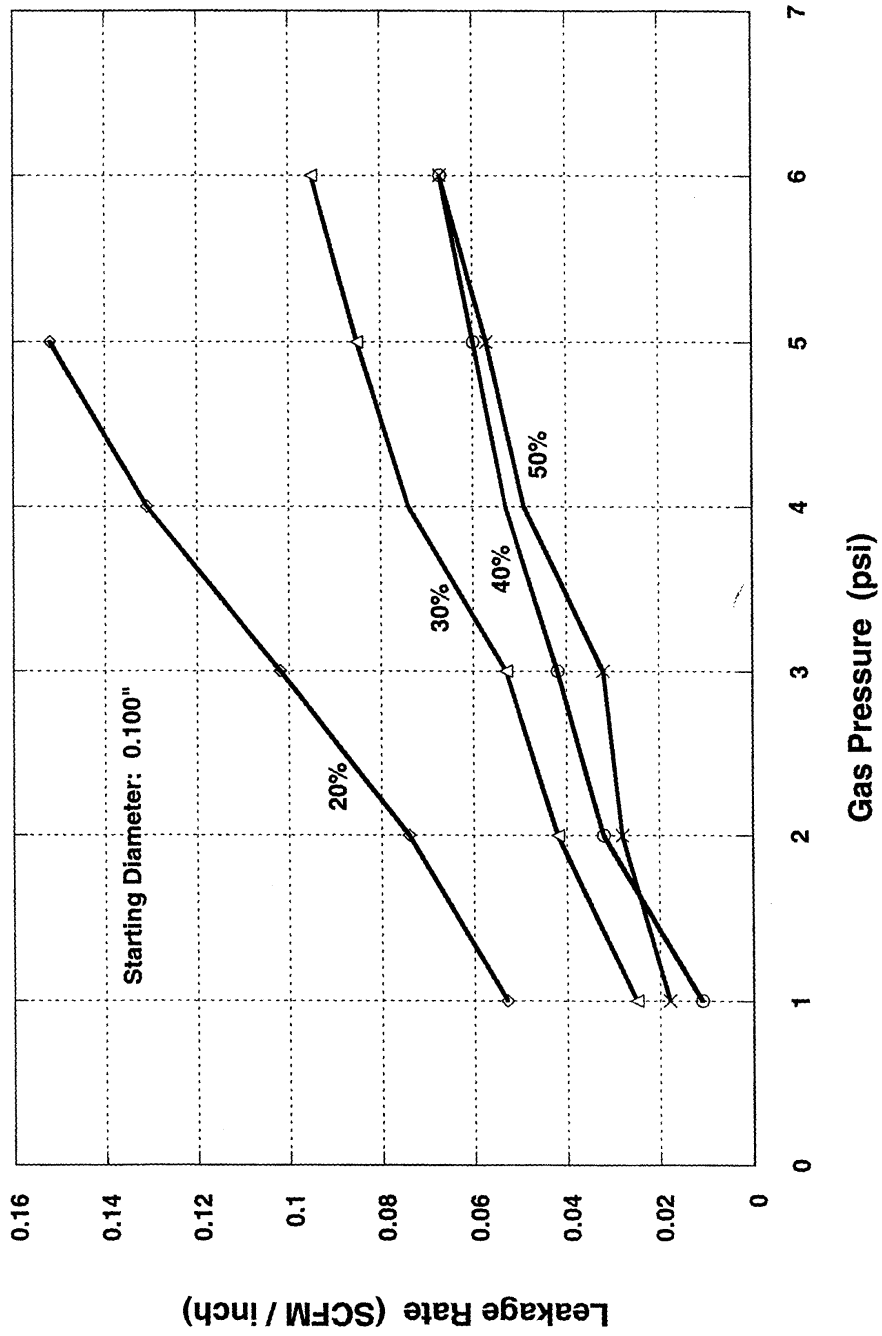
# Load and Flow Data as a Function of Compression for Filled Core Nextel Rope Seal No. 11 at 2 psi Gas Pressure



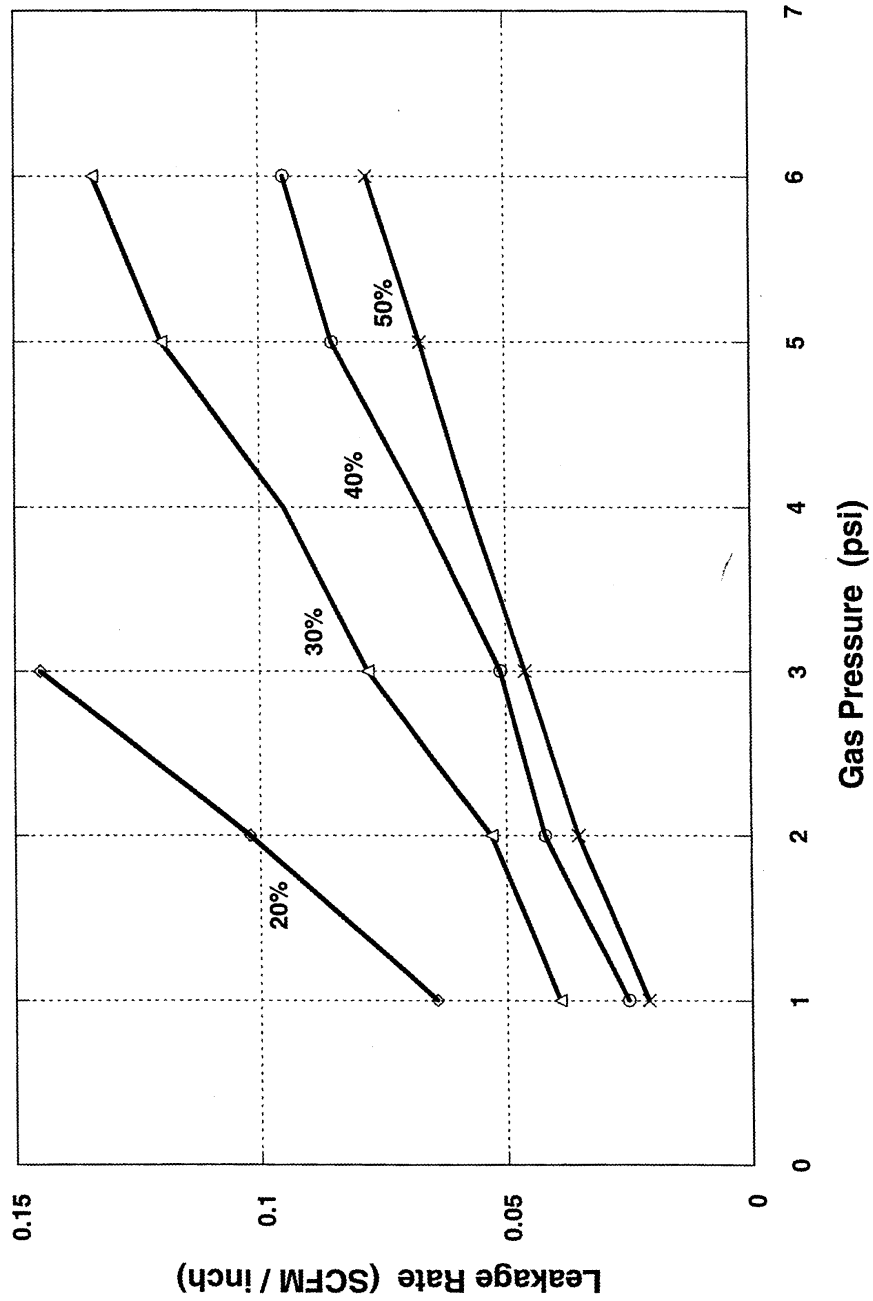
# Leakage Rate as a Function of Gas Pressure and % Compression for Hollow Core Nextel Rope Seal No. 9



# Leakage Rate as a Function of Gas Pressure and % Compression for Filled Core Nextel Rope Seal No. 10



# Leakage Rate as a Function of Gas Pressure and % Compression for Filled Core Nextel Rope Seal No. 11



## **Summary**

- **Seal requirements defined by P&W and FTS**
- **Triangular braid composed of Nextel 720 woven for the lean zone outer liner seals on sector rig**
- **12 variations of rope seals woven (Nextel 550 and 720); compression and flow tests performed on these braids; 4 selected for sector rig**
- **Highly compressible Nextel rope seal developed by Techniweave; only 31 lb./linear in. required to compress 50%**
- **Longitudinal metal wires successfully braided into rope seals by Techniweave and seals successfully brazed to Inconel panel by P&W**