RECENT PROGRESS IN AIR/OIL SEALS RESEARCH AT ALLIEDSIGNAL

M. Rifat Ullah
AlliedSignal Aerospace
Phoenix, Arizona

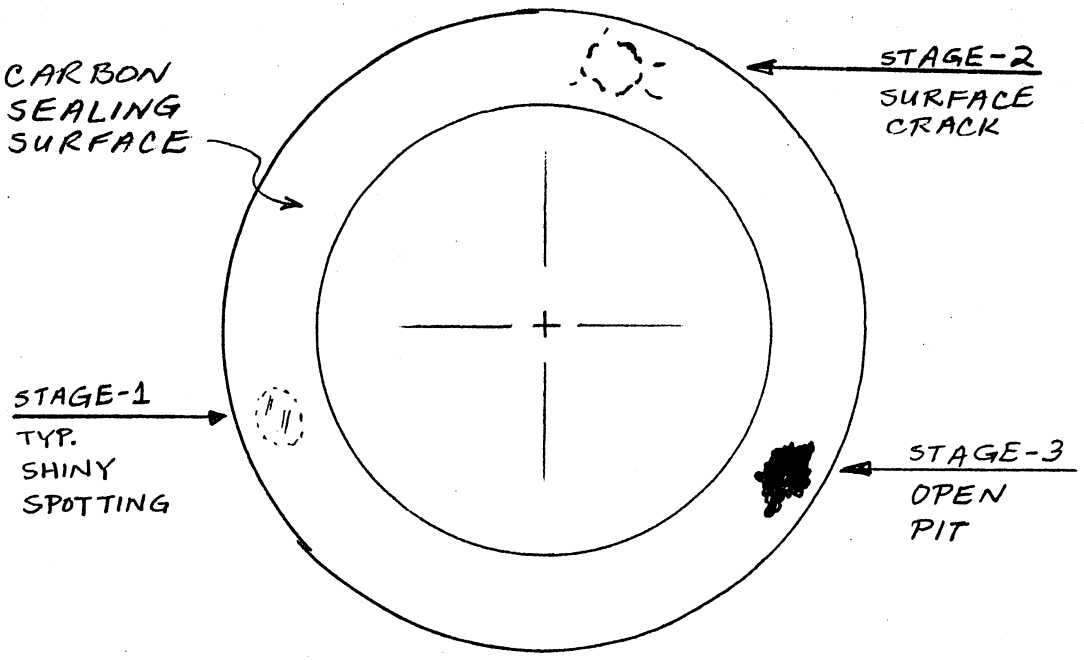
Carbon Seal Blister Prevention Research (1997-1998)

OUTLINE:

- Microstructure of Carbon-Graphite
- Modeling Current Blister Theories
- Blister Rig Development, for Repeatable Results
- Method Development: Blister Test & Damage Measurement
- "Ranking" Tests for Various Carbon-Graphites
- Measurement of Key Properties
- Correlating Blister Damage to Relevant Variables
- Results To-Date

Stages of Blistered Carbon

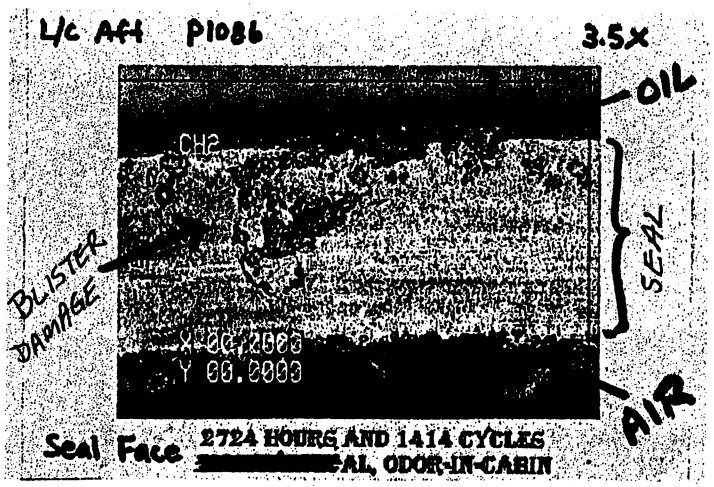
Carbon "Blisters" result in Material Removal, and can lead to Seal Leakage. They are typically Categorized into 3 Stages:

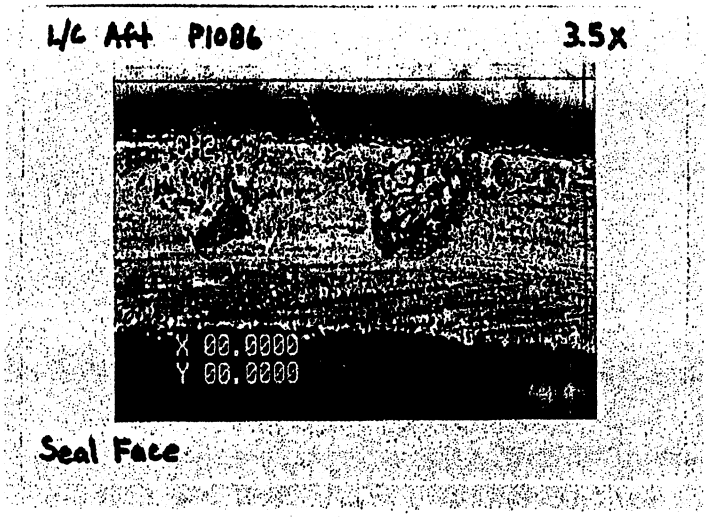


Picture of Blistered Carbon Seal

"Stages-3" Blisters from an Aircraft APU Seal …

This seal was Leaking Oil and Causing "Odor in Cabin" for a Passenger Aircraft





1997-1998 Program Objectives

(1) "Rank" Carbon-Graphites for Blister-Resistance

(2) Determine Carbon Key Properties governing Blistering

(3) Identify Blister Mechanism

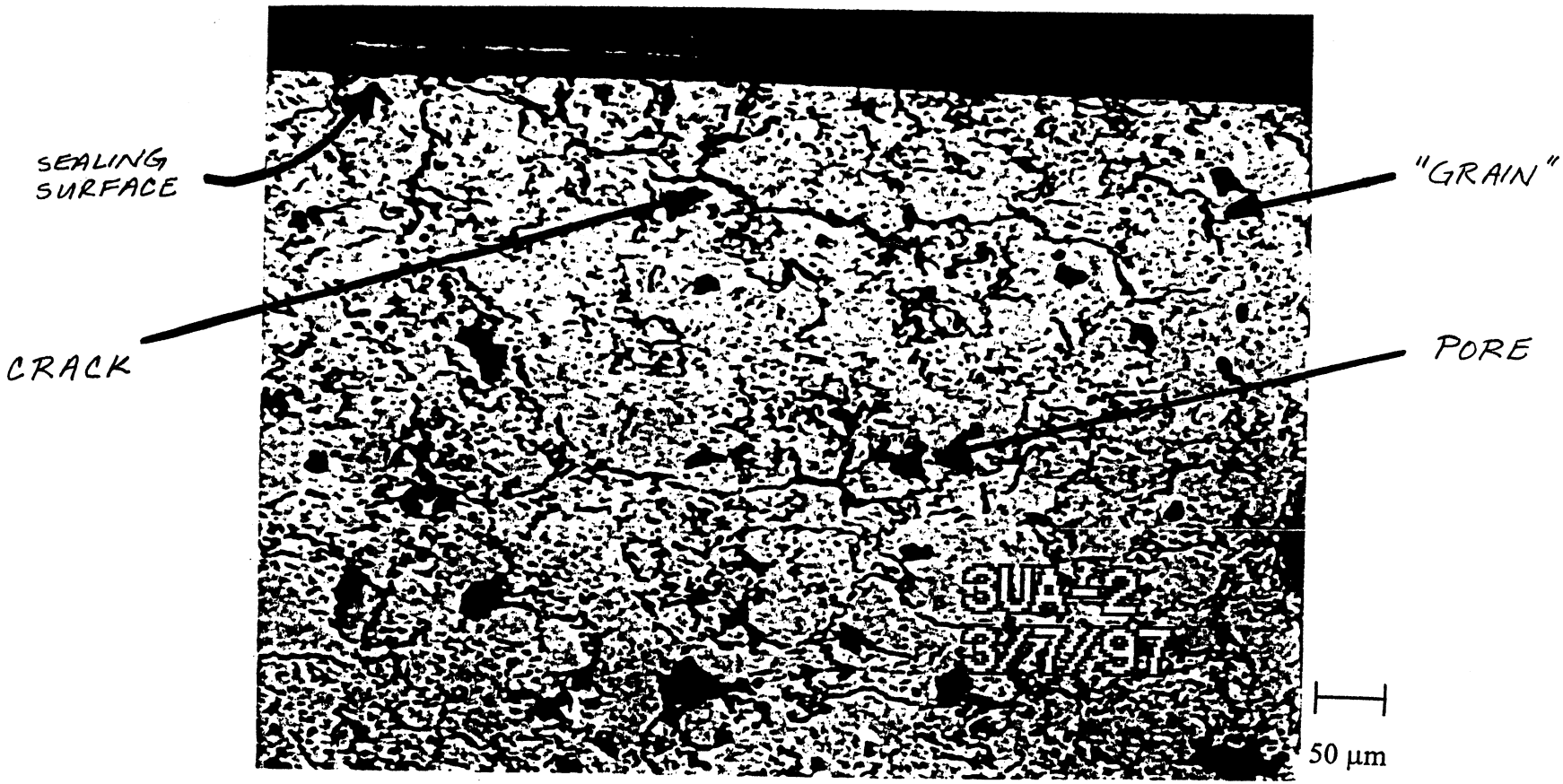
MicroStructure of Carbon-Graphite

- Carbon-Graphites have many natural "Flaws": Pores; Cracks that link the pores, etc.

- Analysis of Blistered Seals focused on Sub-surface and Surface Cracking associated with each Blister

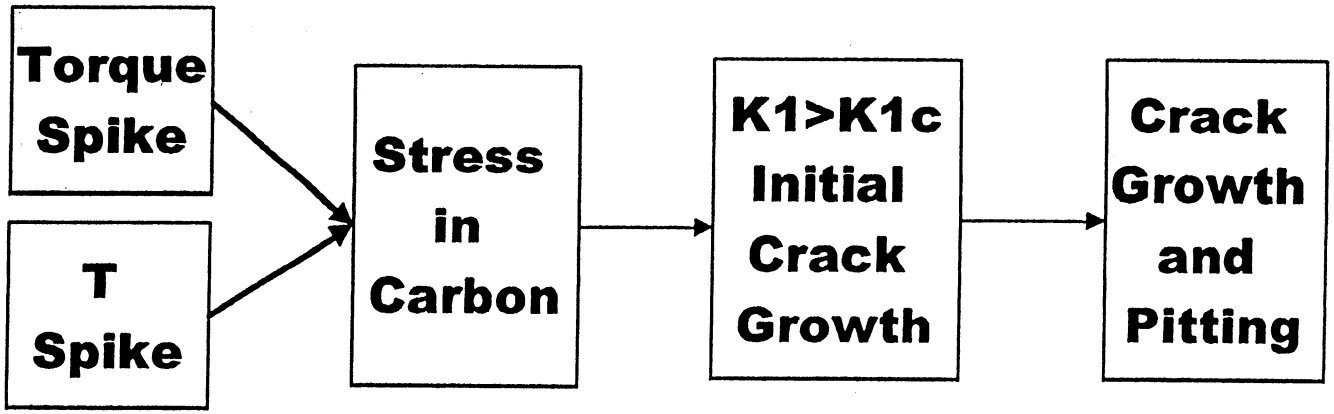
➨ **Found that "Fracture Toughness" is important to forming Blisters ... Specifically, Short Crack Toughness**

Example of MicroStructure of Carbon-Graphite



CROSS SECTION (Used Seal)

A Likely Blister Generation Process



Modeling Blister Theories

- **Hypothesis #1:** Crack Driving Force due to transient Temperature Rise … from Unrelieved Oil Expansion inside Carbon

- **Hypothesis #2:** Crack Driving Force due to transient Torque Spike … e.g. Transient Contact; Impactive Shear from Frozen Oil, etc.

AlliedSignal "Blister Rig" & "Test Method"

Objective: Produce Measurable Blisters ... "Repeatably"

Test Method:

- 1" Diameter Face Seal (Air on ID, Oil on OD)
- Air-side at Ambient conditions
- Oil-side "Flooded" with Very Cold Oil (typ -80F)
- High Face Load; Coated Seal Rotor
- Seal Chilled to -40F, then Accel from 0-to-64,000 rpm in 12 seconds
- Shutdown 10 seconds after Full-speed is reached
- Repeat Cycles (Cyclic operation produces Blisters)
- Run Specified Number of Cycles
- Measure Blisters

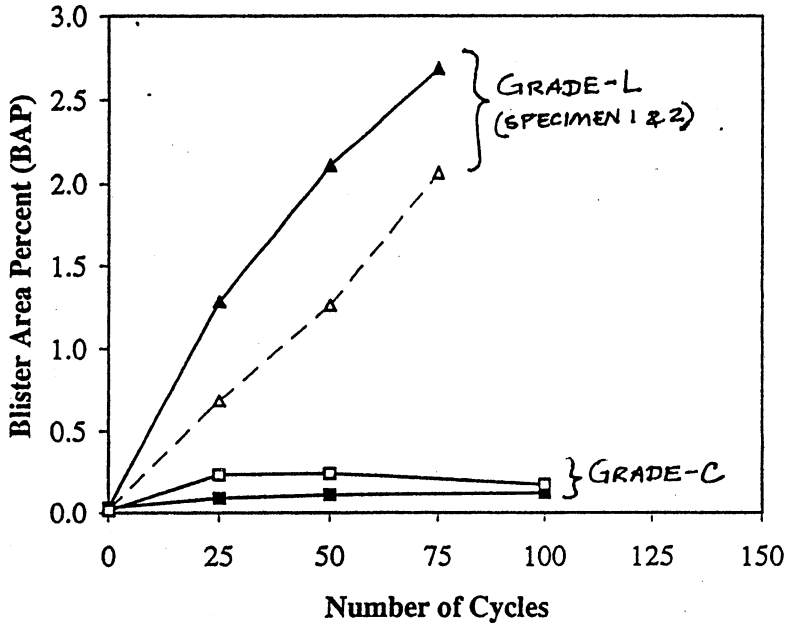
AlliedSignal "Blister Measurement" Method

- Method is Simple, and avoids "subjectivity"
- With Optical Microscope & Digital Micrometer, Measure Stage-3 Blisters (open pits), using Elliptical Area Approximation
- Locations also Recorded

<u>Define:</u> "Blister Area Percent", $\mathbf{BAP = (\Sigma A_{Blister,i})/A_{nose}}$

Test Method was Found "Repeatable" for a Range of Carbons

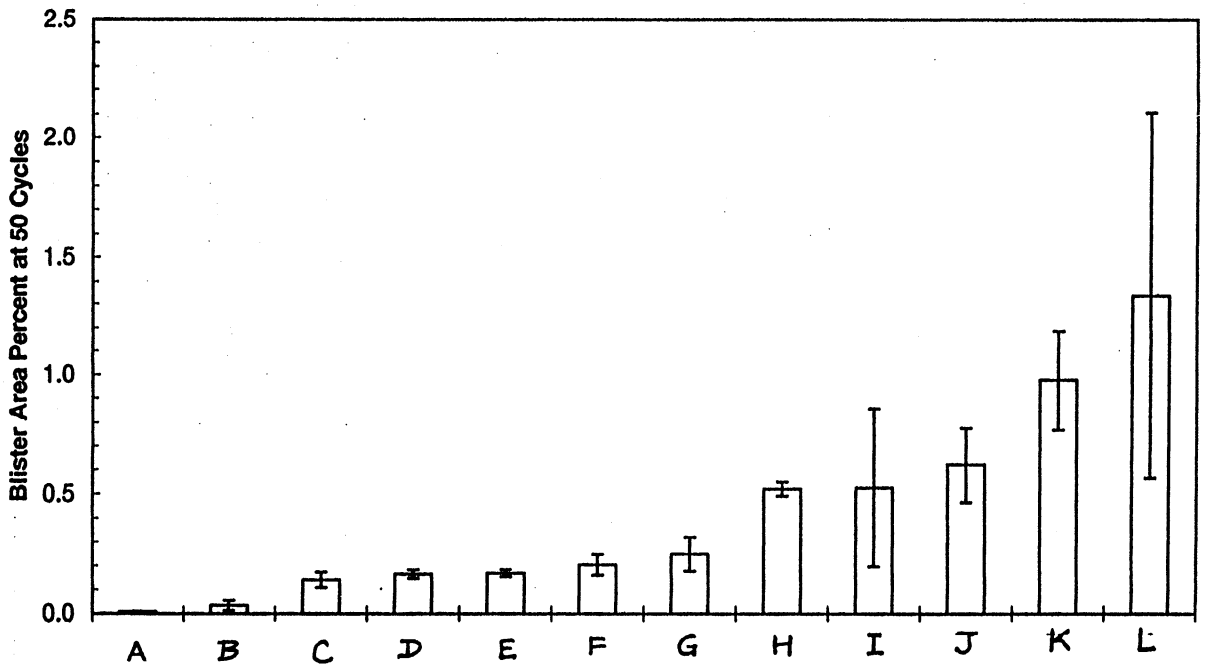
Blister-Resistant versus Blister-Prone Carbons were tested



Selected Carbon-Graphites were "Ranked" for Blistering Tendencies

Candidate Selection based on:

Grain Size & Uniformity; Impregnants; Toughness; Permeability; Experience; Vendors; etc.



Interim Conclusions

- **AlliedSignal has Demonstrated a Test Method to "Repeatably" Produce and Measure Blisters in the Lab**
- **Carbon-Graphite Microstructures Give Clues to Blistering Tendencies ... Specifically, "Finer-Grain" Carbons appear to be more Blister Resistant**
- **"Short Crack Toughness" Test Developed at AlliedSignal appears to Identify more "Blister Resistant" Carbons**
- **In Highly Controlled Tests: Some Carbons are Blister-Prone, While Other Carbons Show a High Degree of Blister-Resistance**

Results from this Study have already shown Success in Preventing Blistering in Actual Engine Seals

"The MESSAGE"

- **AlliedSignal has Tested Blister-Resistance "Repeatably". We will use this internally to Identify & Use Existing Blister-Resistant Carbons. But more Carbons are needed to Meet Various Sealing Demands, So ...**

- **AlliedSignal Wants to Encourage Carbon Companies and Seal Companies to Utilize AlliedSignal's Study and Perform their Own Studies, and Produce more Blister-Resistant Seals**