

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY)		2. REPORT TYPE Technical Papers		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE <i>Please see attached</i>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER 2302	
				5e. TASK NUMBER MIG2	
				5f. WORK UNIT NUMBER 346120	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				8. PERFORMING ORGANIZATION REPORT	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC) AFRL/PRS 5 Pollux Drive Edwards AFB CA 93524-7048				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S NUMBER(S) <i>Please see attached</i>	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
20030128 233					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <i>A</i>	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Leilani Richardson
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified			19b. TELEPHONE NUMBER (include area code) (661) 275-5015

2001-10-11
0302 MIA 2

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO)

16 Mar 2001

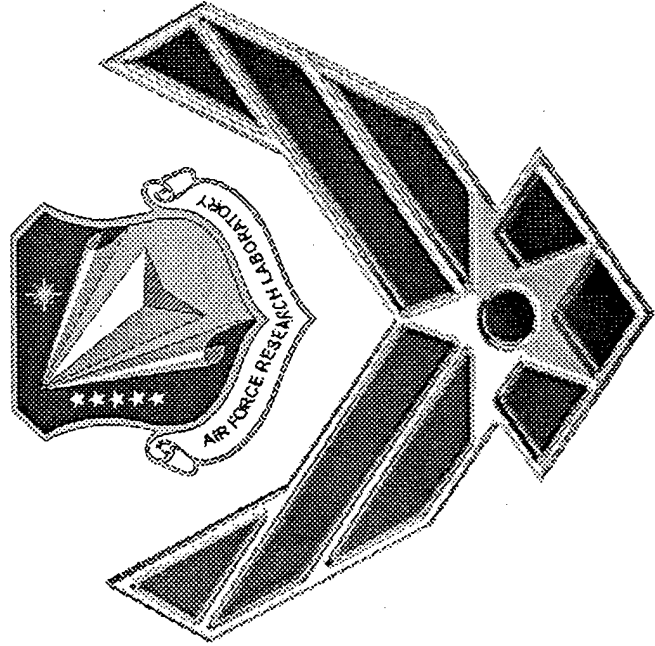
SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-053**
Miller, T.C., "Crack Growth Rates in a Propellant Under Various Conditions" (VuGraphs)

JANNAF 34th Structures & Mechanical Behavior Subcommittee Meeting
(Cocoa Beach, FL, 26-30 Mar 01) (Deadline: 26 Mar 2001)

(Statement A)

CRACK GROWTH RATES IN A PROPELLANT UNDER VARIOUS CONDITIONS

27 Mar 01

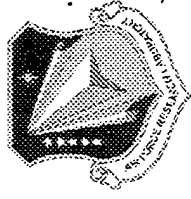


Tim Miller
Engineer

Propulsion Directorate
Air Force Research Laboratory



Introduction



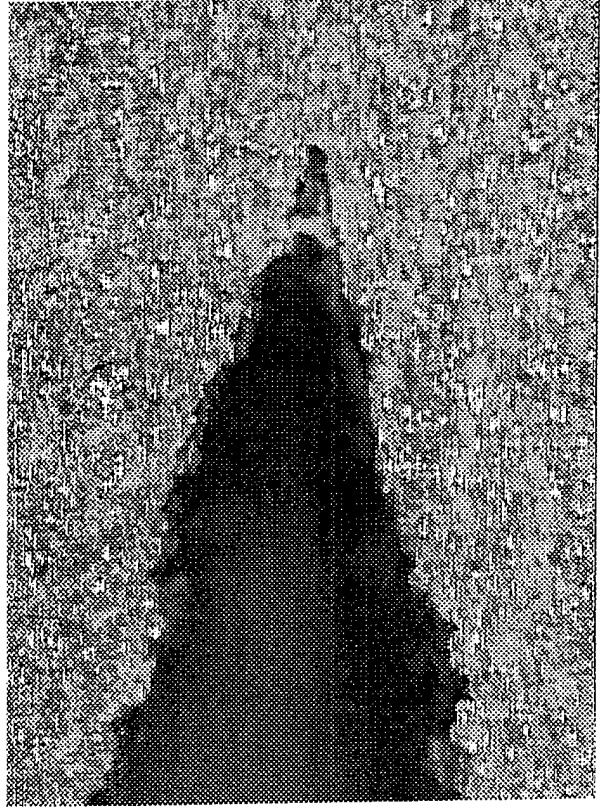
Introduction

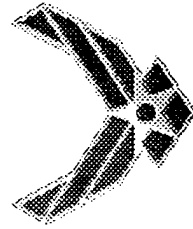
Experimental
Procedure

Results and
Discussion

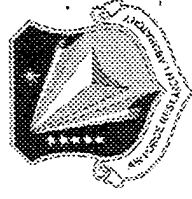
Summary and
Conclusions

- Cracks develop during manufacturing, handling, and storage of rubbery particulate composites
- During the service life, the cracks may begin to grow, but may still be subcritical because the cracks may grow slower than the burn rate of the propellant
- Results for three types of specimens are described. This is done both at ambient and 1000 psi (6895 kPa) pressure.





Complications in Propellant Fracture Analysis



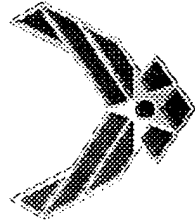
Introduction

Experimental Procedure

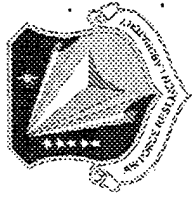
Results and Discussion

Summary and Conclusions

- Propellant has unusual properties (time dependence, large deformations, inhomogeneous microstructure) and has not been analyzed as thoroughly as more conventional materials
- Conventional experimental approaches do not always work well because of these properties
- Service conditions vary from long-term low stress conditions caused by thermal loads during storage to short-term high stress conditions caused by pressurization during launch



Experimental Procedure



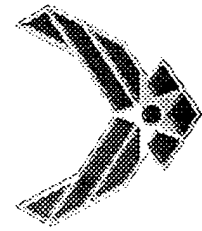
Introduction

Experimental
Procedure

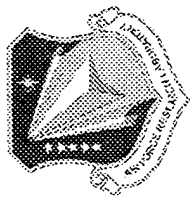
Results and
Discussion

Summary and
Conclusions

- Specimen geometries and test matrix
- Test conditions
- Equipment



Specimen Geometries and Test Matrix

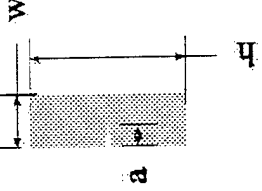
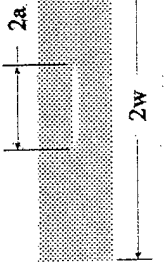
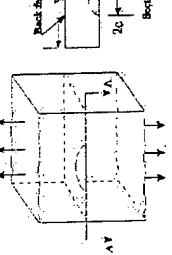


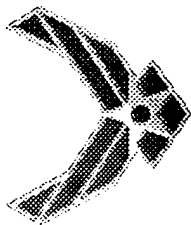
Introduction

Experimental Procedure

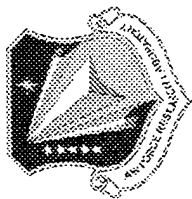
Results and Discussion

Summary and Conclusions

Specimen Type	Figure	Test Conditions
Single edge notched tension	 <p> $w = 1$ in (25.4 mm) $a = 0.1, 0.3$ in (2.54, 7.62 mm) $h = 3, 5$ in (76.2, 127 mm) thickness = 0.2, 0.5, 1.0, 1.5 in (5.08, 12.7, 25.4, 38.1 mm) </p>	Strain rate = 0.067 in/in/min, ambient pressure, 1000 psi (6895 kPa)
Biaxial stress	 <p> $2w = 8$ in (203.2 mm) $2a = 1.5$ in (38.1 mm) $h = 2$ in (50.8 mm) thickness = 0.2 in (5.08 mm) </p>	Strain rate = 0.100 in/in/min, ambient pressure
Surface cracked	 <p> $a = c = 0.4$ in (10.16 mm) $t = w = 2$ in (50.8 mm) height = 2.75 in (69.85 mm) </p>	Strain rate = 0.067 in/in/min, 1000 psi (6895 kPa) pressure



Test Conditions



Introduction

Experimental
Procedure

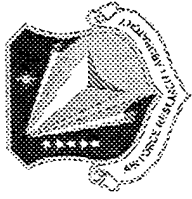
Results and
Discussion

Summary and
Conclusions

- **Ambient temperature**
- **Ambient pressure and 6895 kPa pressure (nitrogen gas)**
- **Constant strain rate tests (0.067 - 0.100 mm/mm/min)**

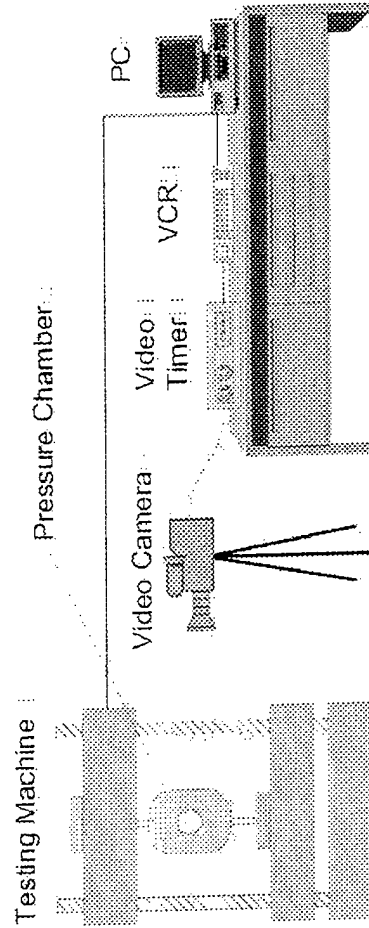
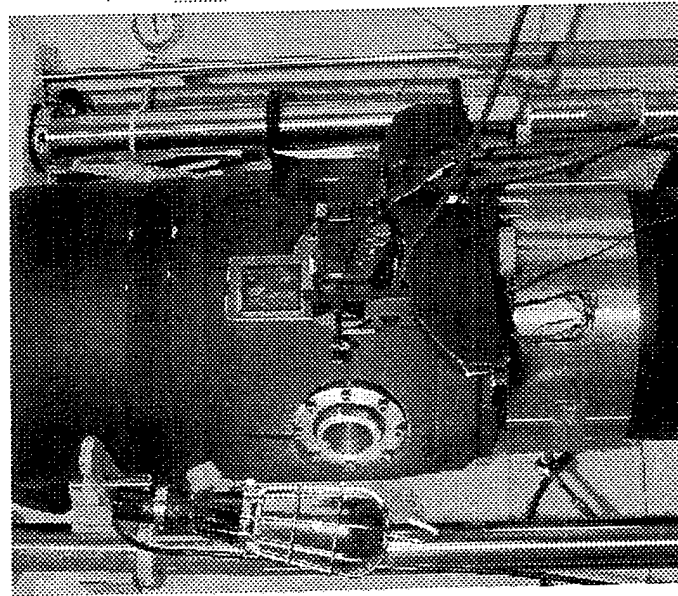


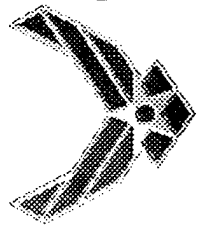
Equipment



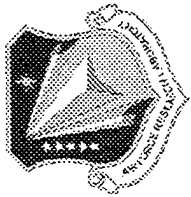
Introduction
Experimental Procedure
Results and Discussion
Summary and Conclusions

- **Testing machine**
- **Pressure test chamber**
- **Videotape equipment**





Fixture Is Used to Apply Uniform Displacement Boundary Conditions

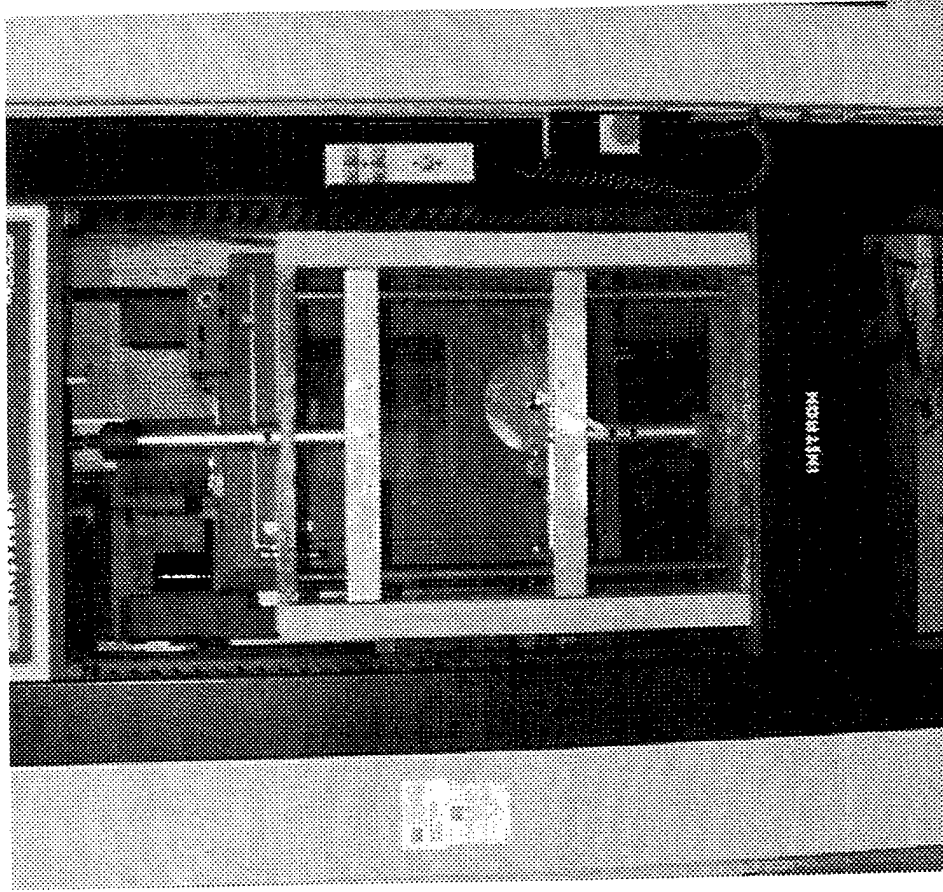


Introduction

Experimental Procedure

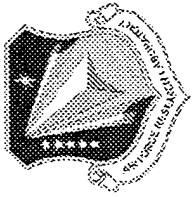
Results and Discussion

Summary and Conclusions





Flowchart for Experimental Procedure

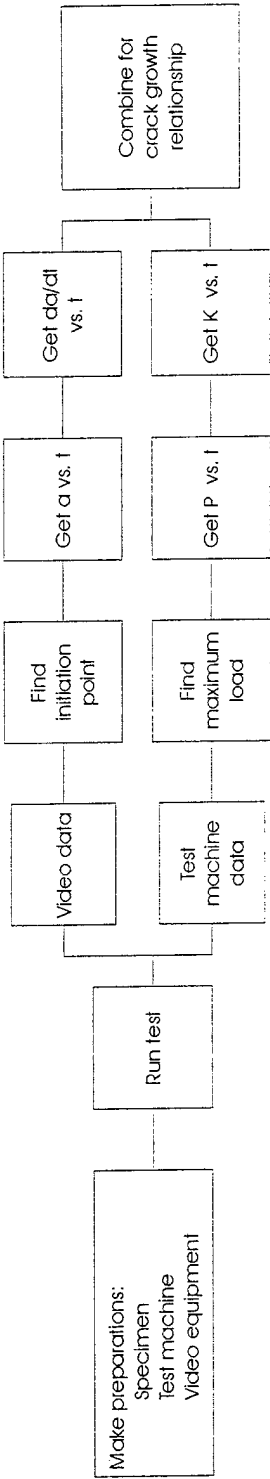


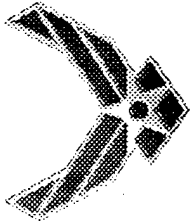
Introduction

Experimental Procedure

Results and Discussion

Summary and Conclusions





Introduction

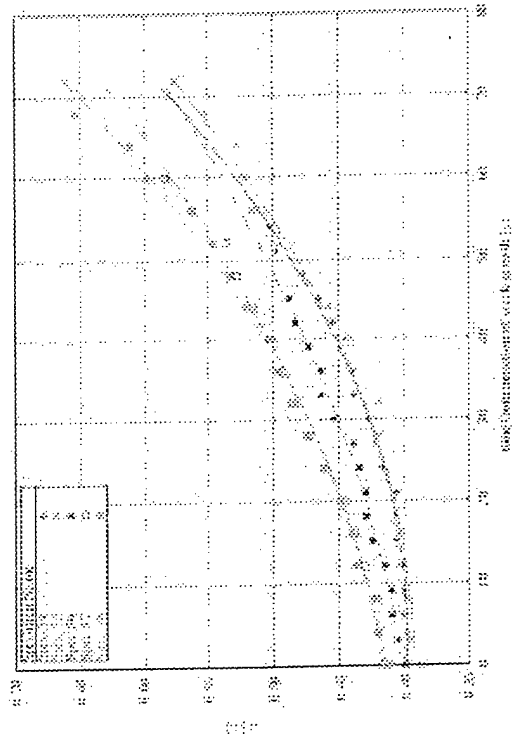
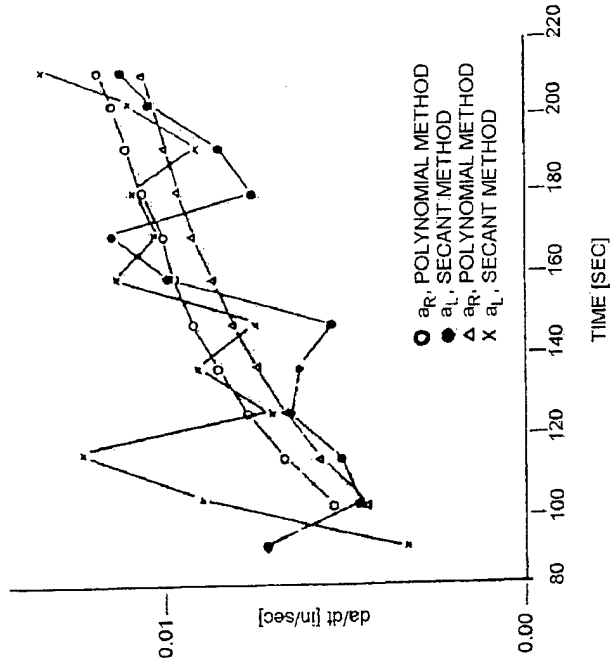
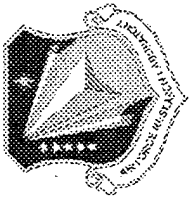
Experimental Procedure

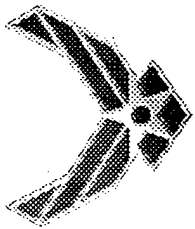
Results and Discussion

Summary and Conclusions

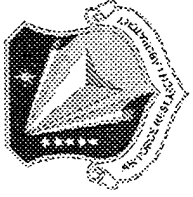
Non-smooth or irregular?

Nonuniform Crack Growth





Results and Discussion



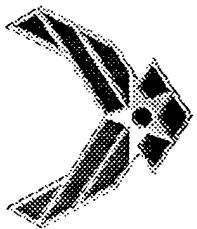
Introduction

Experimental
Procedure

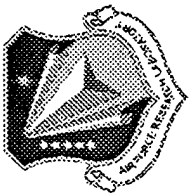
Results and
Discussion

Summary and
Conclusions

- Specimen Geometries (SENT, biaxial, surface cracked)
- Pressure Effects



Comparison of Biaxial and SENT Specimen Growth Data



Introduction

Experimental Procedure

Results and Discussion

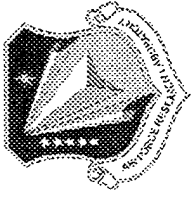
Summary and Conclusions

$$\frac{da}{dt} = C_1 K_I^{C_2} \text{ or } \log\left(\frac{da}{dt}\right) = \log(C_1) + C_2 \log(K_I)$$

Specimen type	$\log(C_1)$	C_2	$K_I = 50 \text{ psi in}^{1/2}$	$K_I = 90 \text{ psi in}^{1/2}$	$da/dt \text{ (in/sec)}$
SENT	-6.030	2.084	0.0028	0.0110	
Biaxial	-6.590	2.375	0.0032	0.0113	



SENT and Surface Cracked Specimen Comparisons



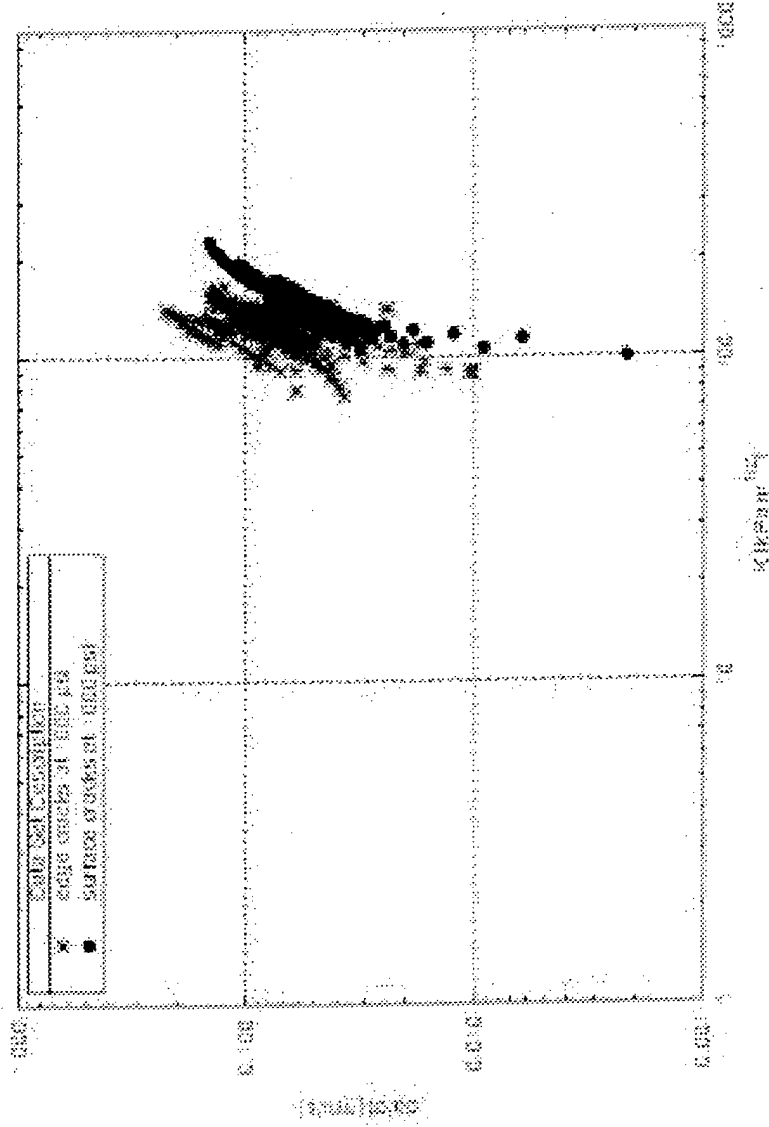
Introduction

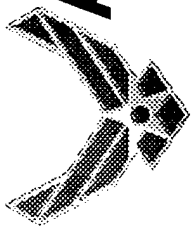
Experimental Procedure

Results and Discussion

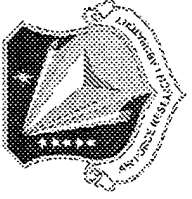
Summary and Conclusions

- Similar growth rates found for both geometries
- Implication: SENT data can be used instead of testing with surface cracked specimens





Ambient Vs. Pressurized Conditions



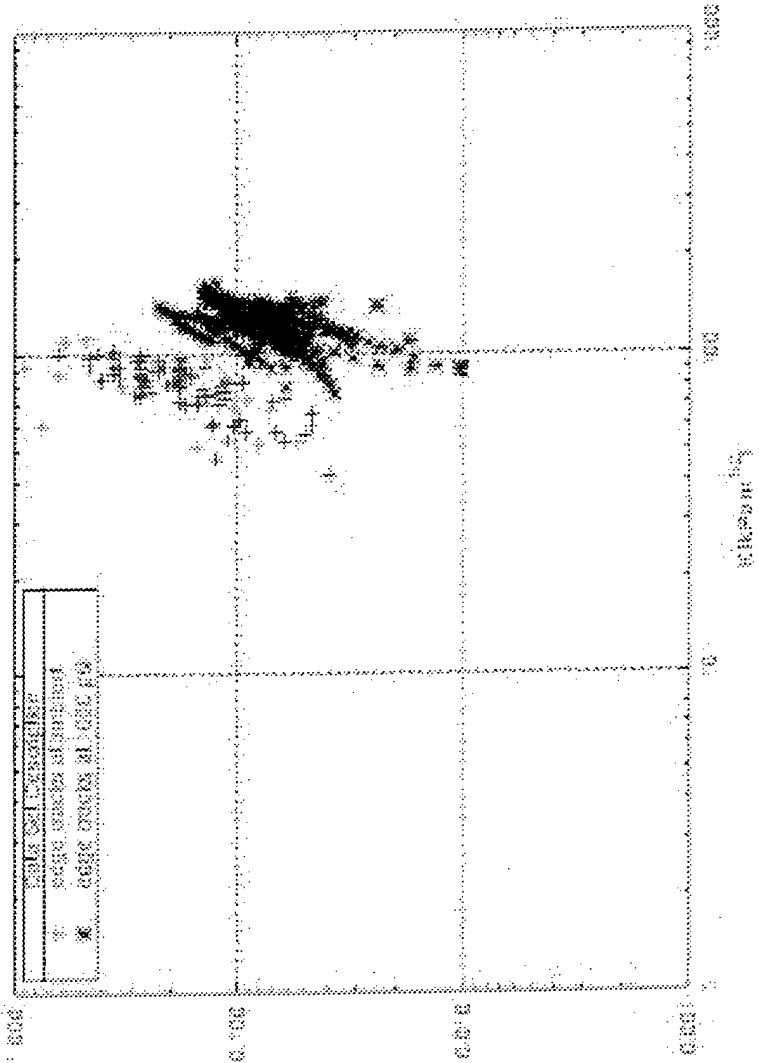
Introduction

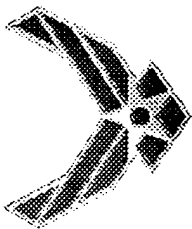
Experimental Procedure

Results and Discussion

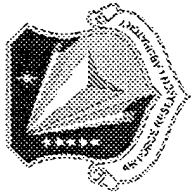
Summary and Conclusions

- Pressure causes crack growth to slow
- Microstructural explanation
- Implication: ambient data may be overly conservative for





Combination of Data

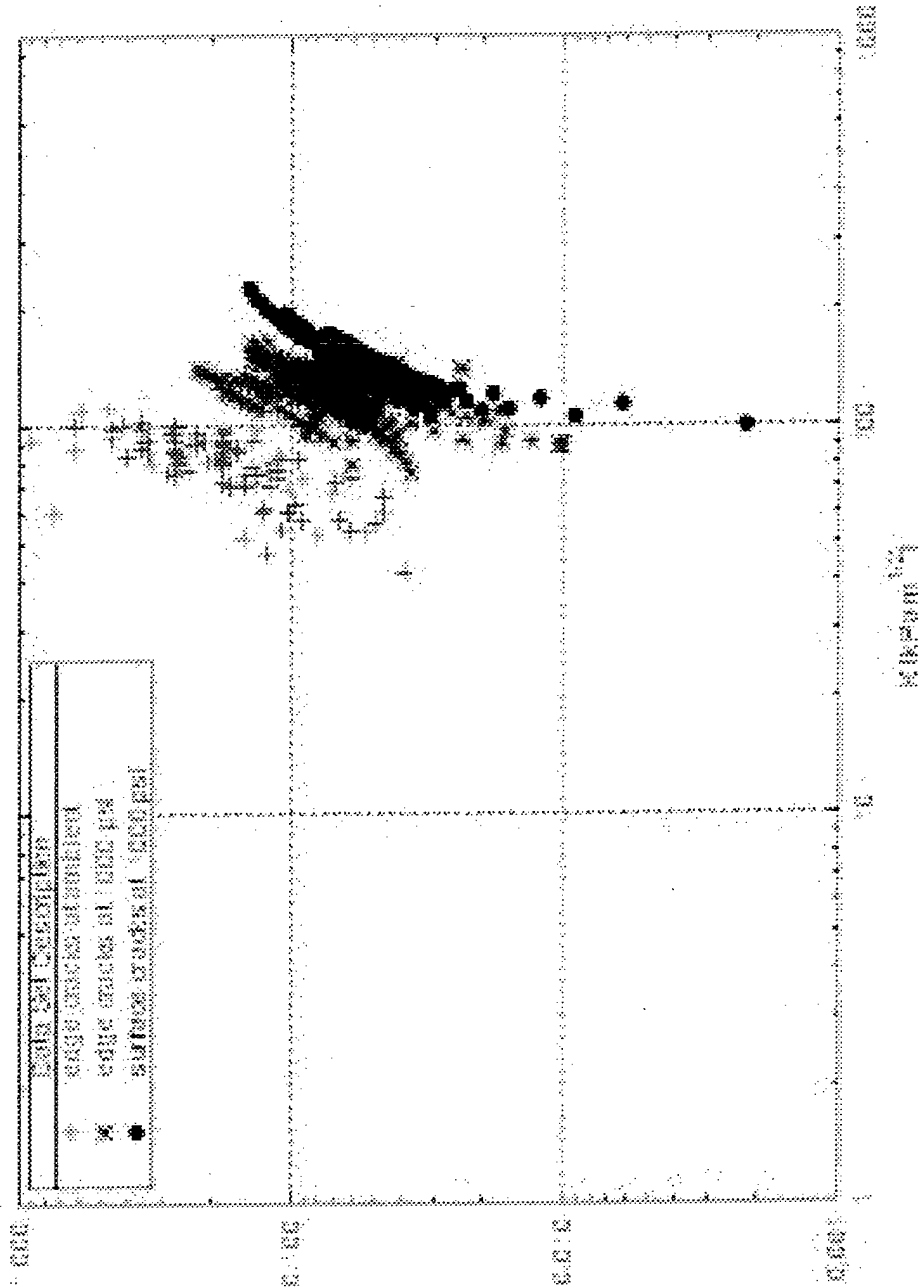


Introduction

Experimental
Procedure

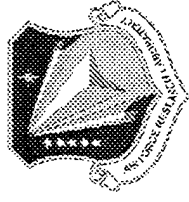
Results and
Discussion

Summary and
Conclusions





Summary and Conclusions



Introduction

Experimental
Procedure

Results and
Discussion

Summary and
Conclusions

- **Summary:** this work has investigated the effect of pressure on fracture behavior of a rubbery particulate composite, and has compared the results for different crack geometries and different pressure conditions. Pressure delays the onset of crack growth and slows the subsequent growth rate. The results for the specimen geometries tested (both at ambient and 1000 psi (6895 kPa) pressure) show good agreement.
- **Conclusions:**
 - Good agreement between biaxial, SENT, and surface cracked specimens
 - Pressure inhibits the start of crack growth and slows the subsequent crack growth
 - Pressurized test data should be used to test for pressurized service conditions