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10 HCA 95

MEMORANDUM FOR PRS (In-House Publication)

FROM: PROI (STINFO)

19 May 2001

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-VG-2001-145**
Rusty Blanski, Shawn Phillips, "Status of the Air Force Solid Rocket Motor Insulation Program"

50th Annual JANNAF Propulsion Conference
(Salt Lake City, UT, 11-13 July 2001) (Deadline: PAST DUE!)

(Statement A)

1. This request has been reviewed by the Foreign Disclosure Office for: a.) appropriateness of distribution statement, b.) military/national critical technology, c.) export controls or distribution restrictions, d.) appropriateness for release to a foreign nation, and e.) technical sensitivity and/or economic sensitivity.

Comments: _____

Signature _____ Date _____

2. This request has been reviewed by the Public Affairs Office for: a.) appropriateness for public release and/or b) possible higher headquarters review.

Comments: _____

Signature _____ Date _____

3. This request has been reviewed by the STINFO for: a.) changes if approved as amended, b) appropriateness of references, if applicable; and c.) format and completion of meeting clearance form if required

Comments: _____

Signature _____ Date _____

4. This request has been reviewed by PR for: a.) technical accuracy, b.) appropriateness for audience, c.) appropriateness of distribution statement, d.) technical sensitivity and economic sensitivity, e.) military/national critical technology, and f.) data rights and patentability

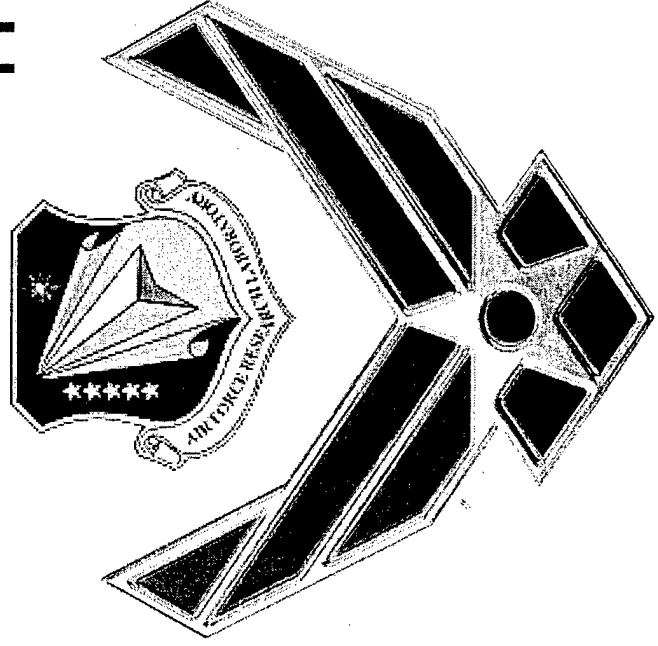
Comments: _____

APPROVED/APPROVED AS AMENDED/DISAPPROVED

PHILIP A. KESSEL Date
Technical Advisor
Space and Missile Propulsion Division

Status of the Air Force Solid Rocket Motor Insulation Program

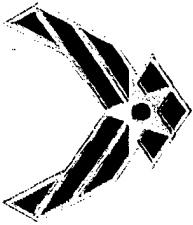
11 July 2001



Dr. Rusty Blanski

AFRL/PRSM

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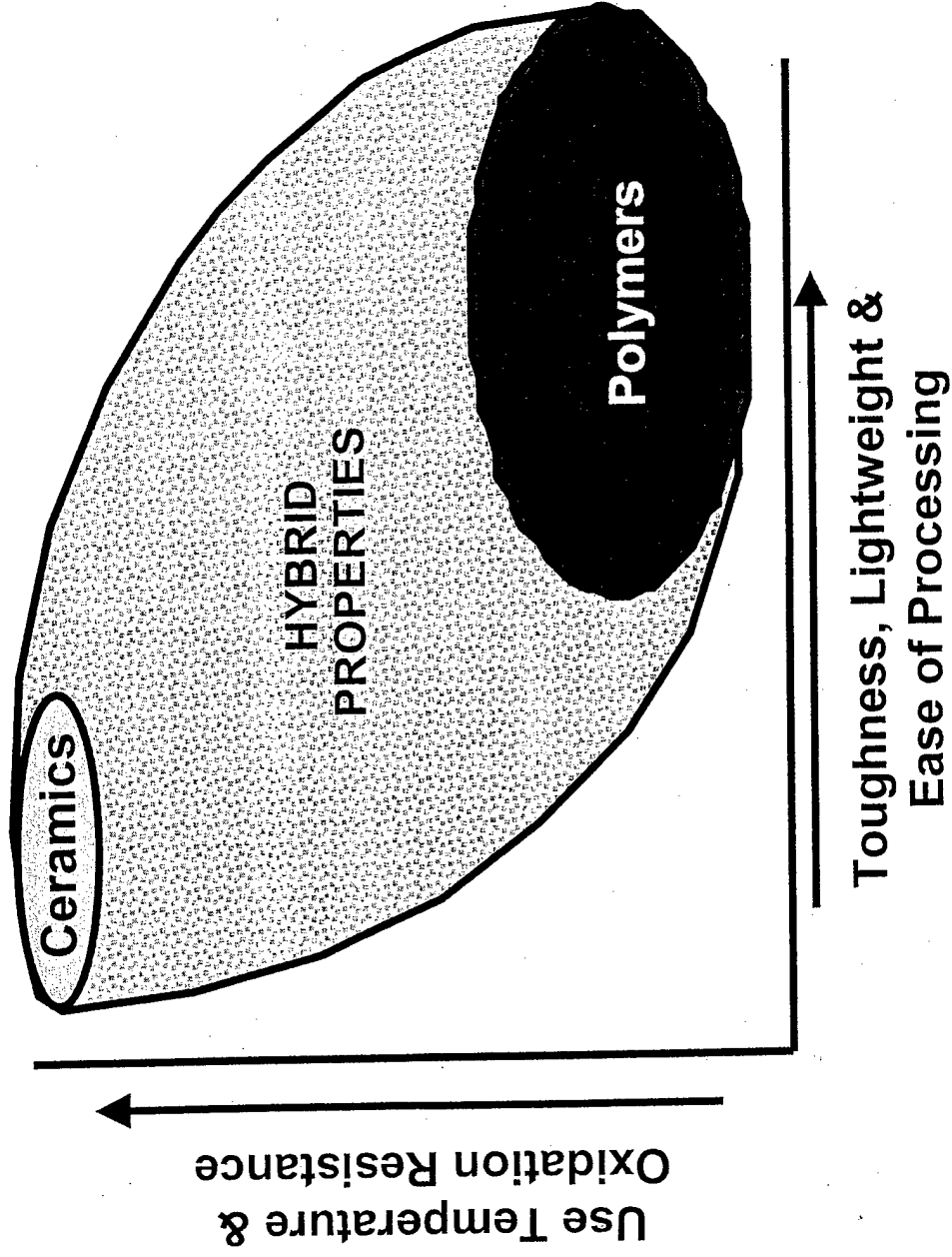
Objectives



- Introduction
- History of our SRM program: Early Work
- In-House efforts
- POSS in EPDM Results
- Future of the Program



Propulsion (Air Force) Technology is Limited by Material Properties

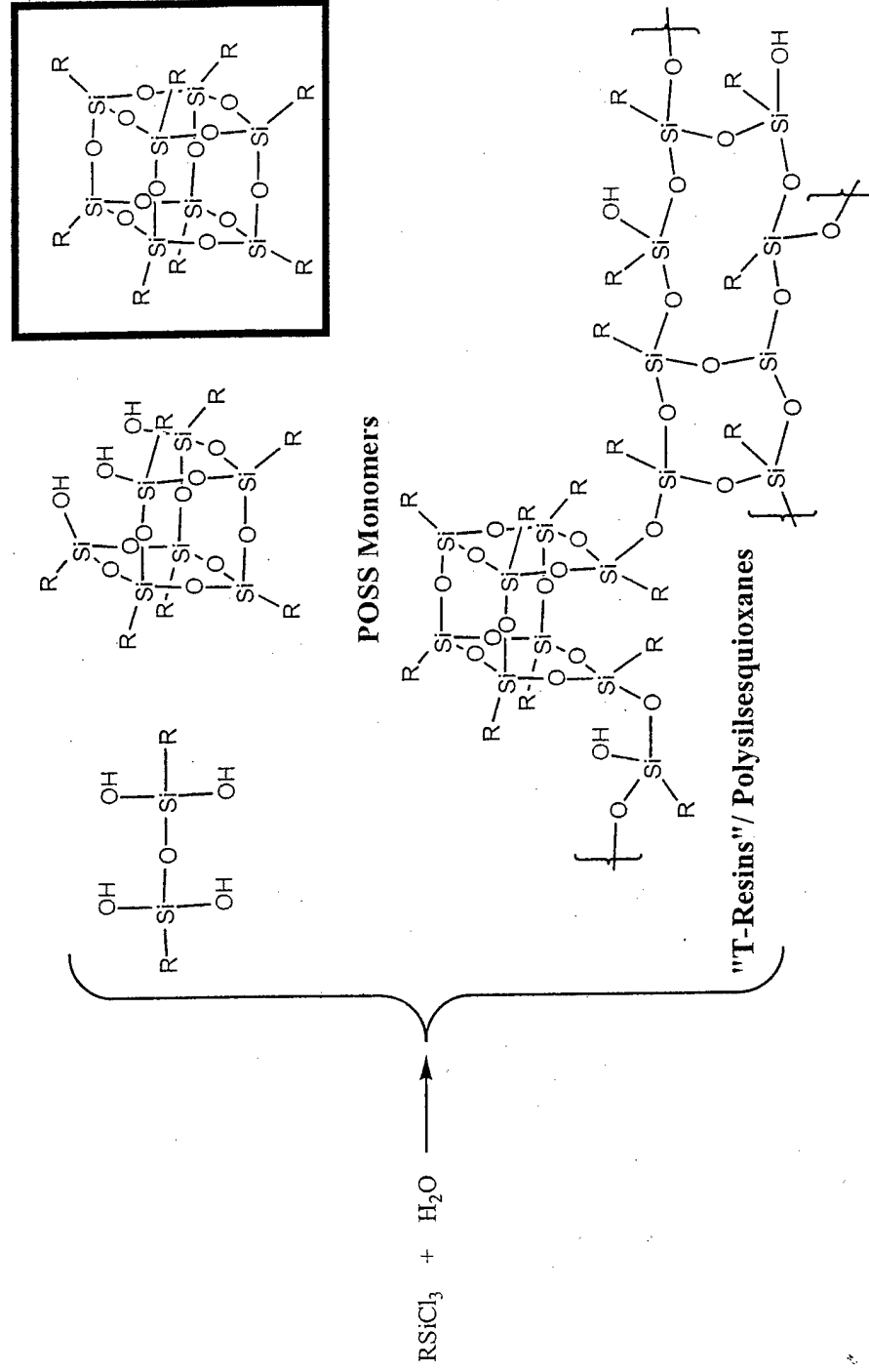


• Hybrid plastics can bridge the barrier between ceramics and polymers



POSS

Polyhedral OligoMeric Silsequioxane



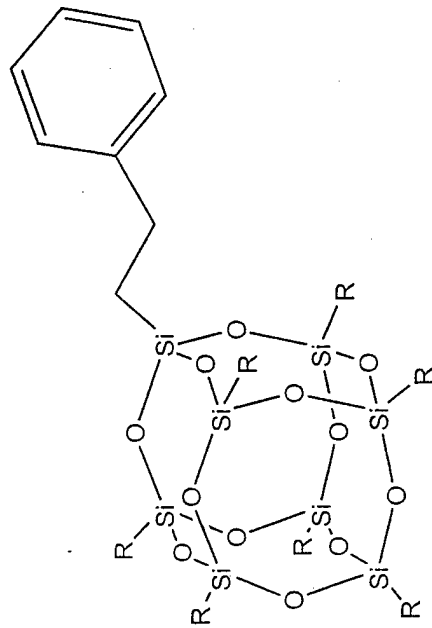
- The maximization of property enhancements in polymers results from interaction at the nano-level (Edwards AFRL/PRSM ----> POSS monomers)⁴



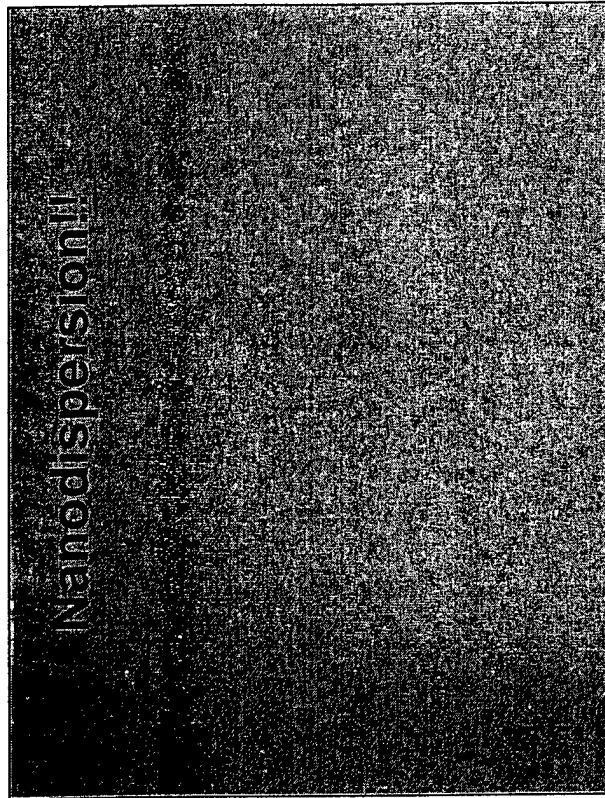
POSS-Polymer Blends

Miscibility Demonstrated

50 wt % Phenethyl₈T₈ in 2 million mol. wt. Polystyrene



R = Phenethyl



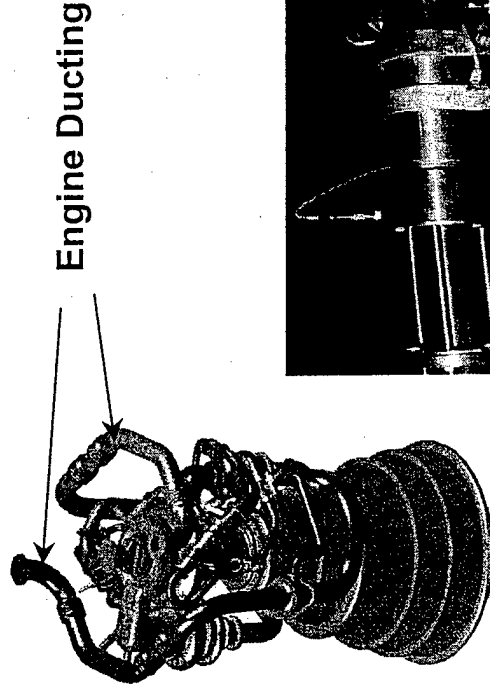
- Catalytic hydrogenation of Styryl₈T₈
- No POSS crystallites by SEM or X-ray!!



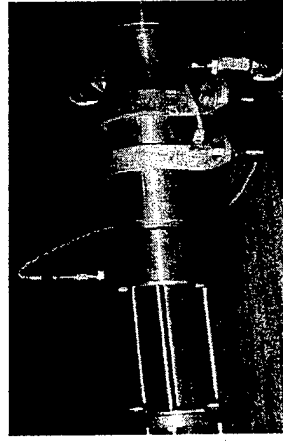
Versatility of POSS Blends and Lubricants



Liquid Rocket Engines



Polymer Tube/Case Hot Gas Burst Tester

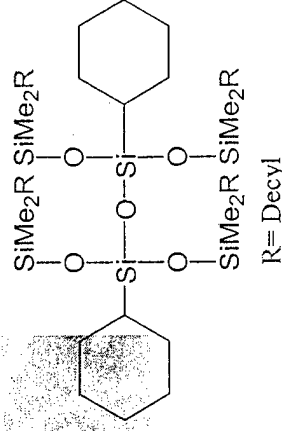
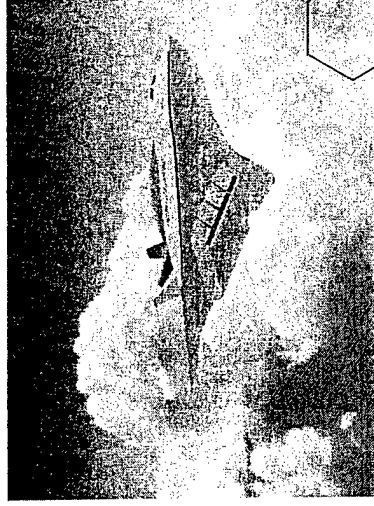


Plastic Engine Ducting (SSME)

- 80% duct weight decrease
- 15% upper stage thrust-to-weight increase

3 candidates selected, SBIR, DUS&T

Lubricants



Lubricants for Turbine Engines

- Demonstrated to be pour^{able} ^{“pourable” is one word} between -40 °C and 200 °C

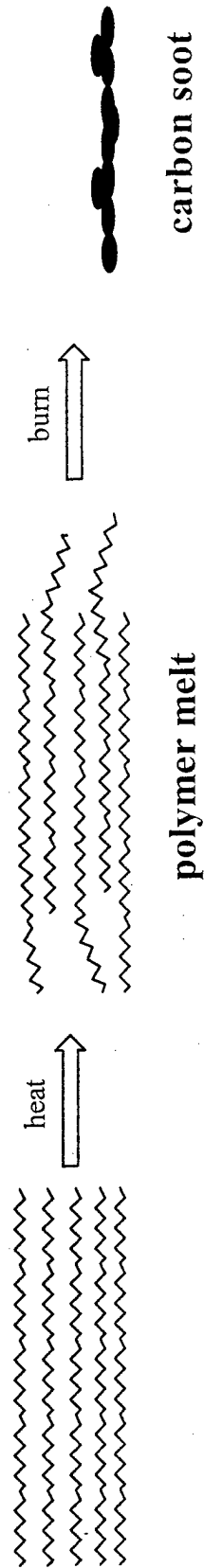
Higher Temperature Studies underway (PRTM)
6



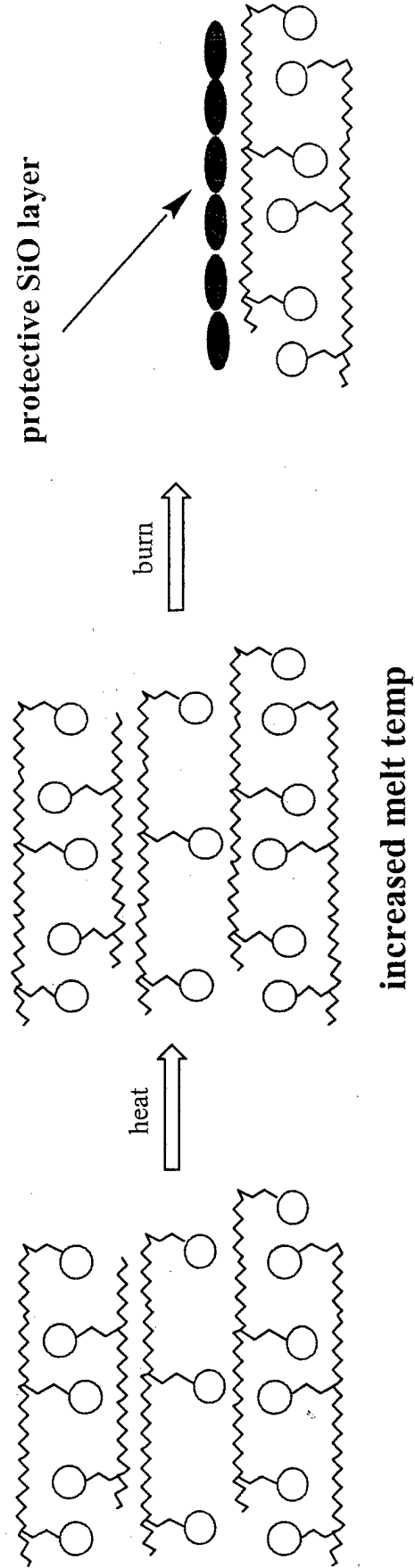
POSS for Ablative Materials

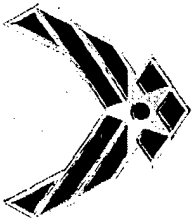


Traditional Polymer



POSS Polymer





Solid Propellant Insulation Program

POSS- Polymers



POSS-Polymer Insulation - Advantages:

- High loadings of POSS can be incorporated without embrittlement
- Si to O ratio is 1:1.5, proven to oxidize up to 1:2 (SiO₂)
- Tailorability of POSS monomers improve physical/mechanical properties
- Capabilities for Large and Small scale testing (Hybrid Plastics)

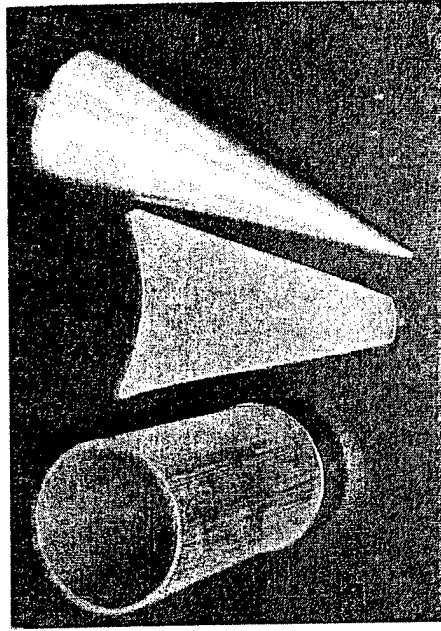
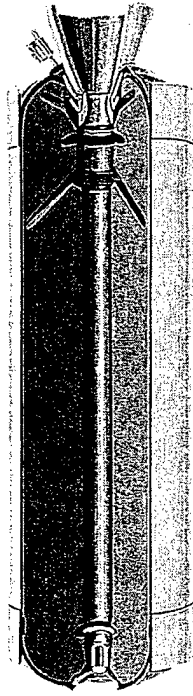


Solid Propellant Insulation Program

Project Goals 6.2 (IHPRPT)



Case Insulation



POSS-Insulation Sample

**Goal: 50% Lower Erosion of Insulation (44 % weight reduction,
7.4% booster payload increase) – Phase III IHPRPT**

Objective: Development of Ceramic Forming Polymer



Solid Propellant Insulation Program

In-House Project History

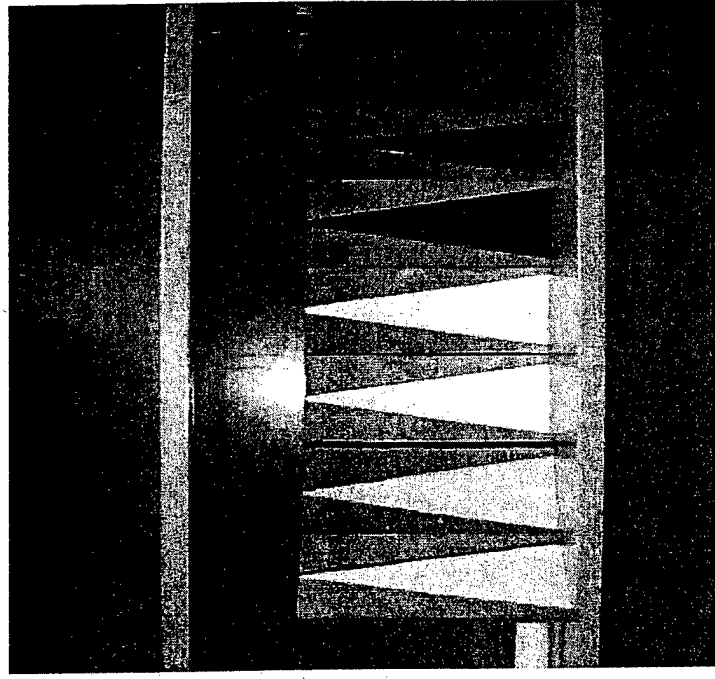


- 1992: Flame testing performed on POSS-PDMS bead polymers. Potential for SRM insulation recognized
- 1994-1998: 4" Pi-K motor testing begun. Due to equipment limitations, a two dimensional test was designed.
- 1999- present: 3-dimensional cone testing capability acquired. Polymer blending equipment and 24 ton press acquired. Firings begun.



Solid Propellant Insulation Program

In-House Project History 1994-1998



2-D pizza wedges
glued into $\frac{1}{2}$ cones

- Sample preparation was difficult: dissolve POSS and polymer in solvent, evaporate and press into wedge in small press
- Glue sample and standard into test bed ($\frac{1}{2}$ cone) and fasten together
- Samples: Pebax, BMI, Parmax, Starfire w/mat



Solid Propellant Insulation Program

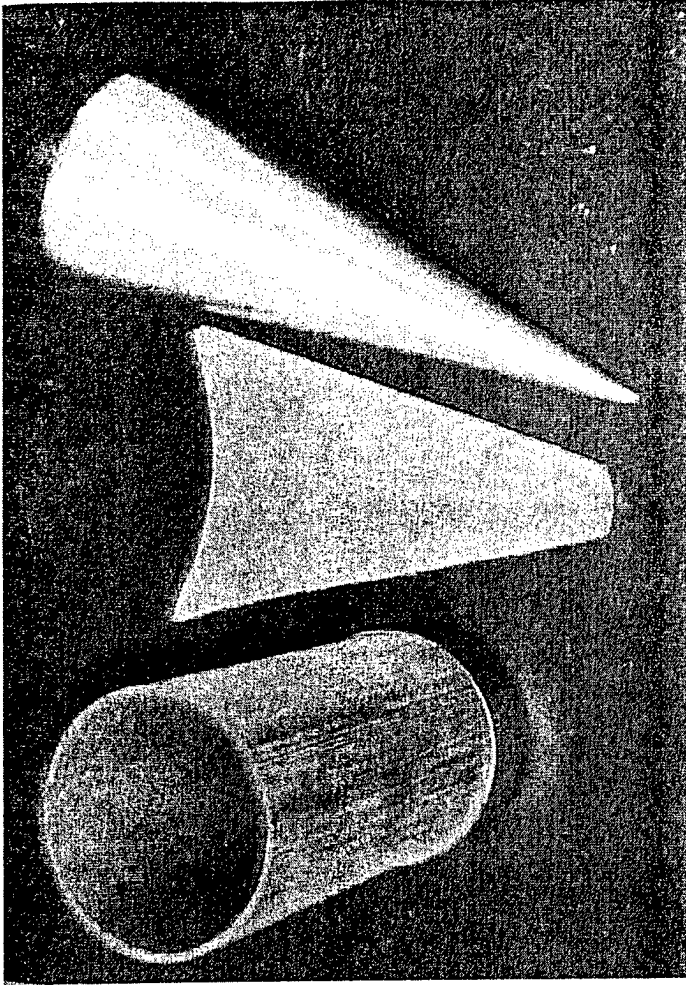
In-House Project History 1999-Present



- 3-dimensional testing capability realized

- Sample preparation was streamlined: POSS is blended into polymer with standard industrial blending equipment (Brabender Mixer) and pressed into Large Pizza wedge (24 ton Press)

- Glue sample and standard into cone



Cone, Pizza Wedge and Jig to set wedges in cone



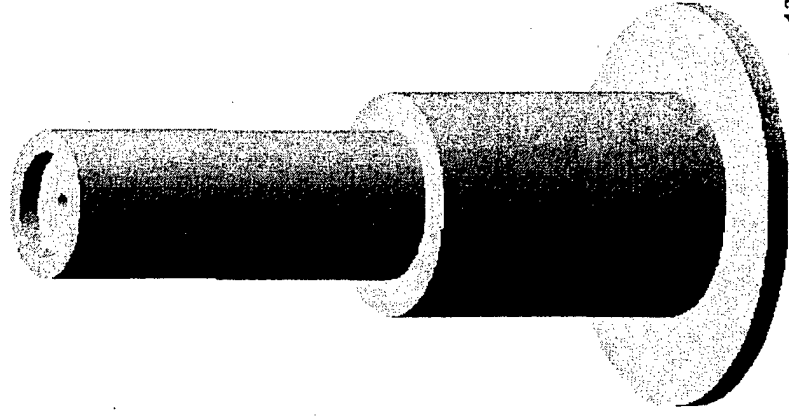
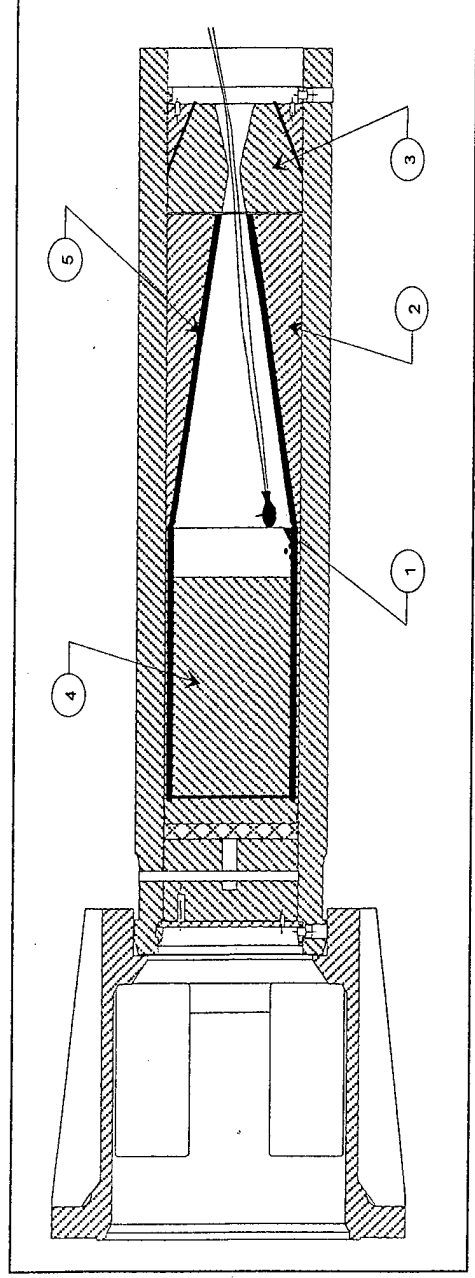
Solid Propellant Insulation Program

In-House Low Cost Screening of New Materials



Present Capabilities:

- Test facilities developed at Edwards AFRL (4" Pi-K Motor)
- Only 100 g of material needed (down from 5 Kg)
- Cost (synthesis, part fabrication, ablation test, analysis) reduced to ~1K!!
- Rapid testing of 5-6 samples per day.





In-House SRM Insulation Testing

Interdisciplinary Team Effort



Many Diverse Skills at AFRL Come Together:

- Phenolic cone Fabrication: Machine Shop
- Pi-K Motor preparation: Propellants Branch
- Pi-K Motor Cutting: Machine Shop
- Sample Cone Preparation: Polymer working Group
- Sample Firing: Propellants Branch
- Sample Analysis: Polymer Working Group (measurements) and Motors Branch (mass flux conversion)

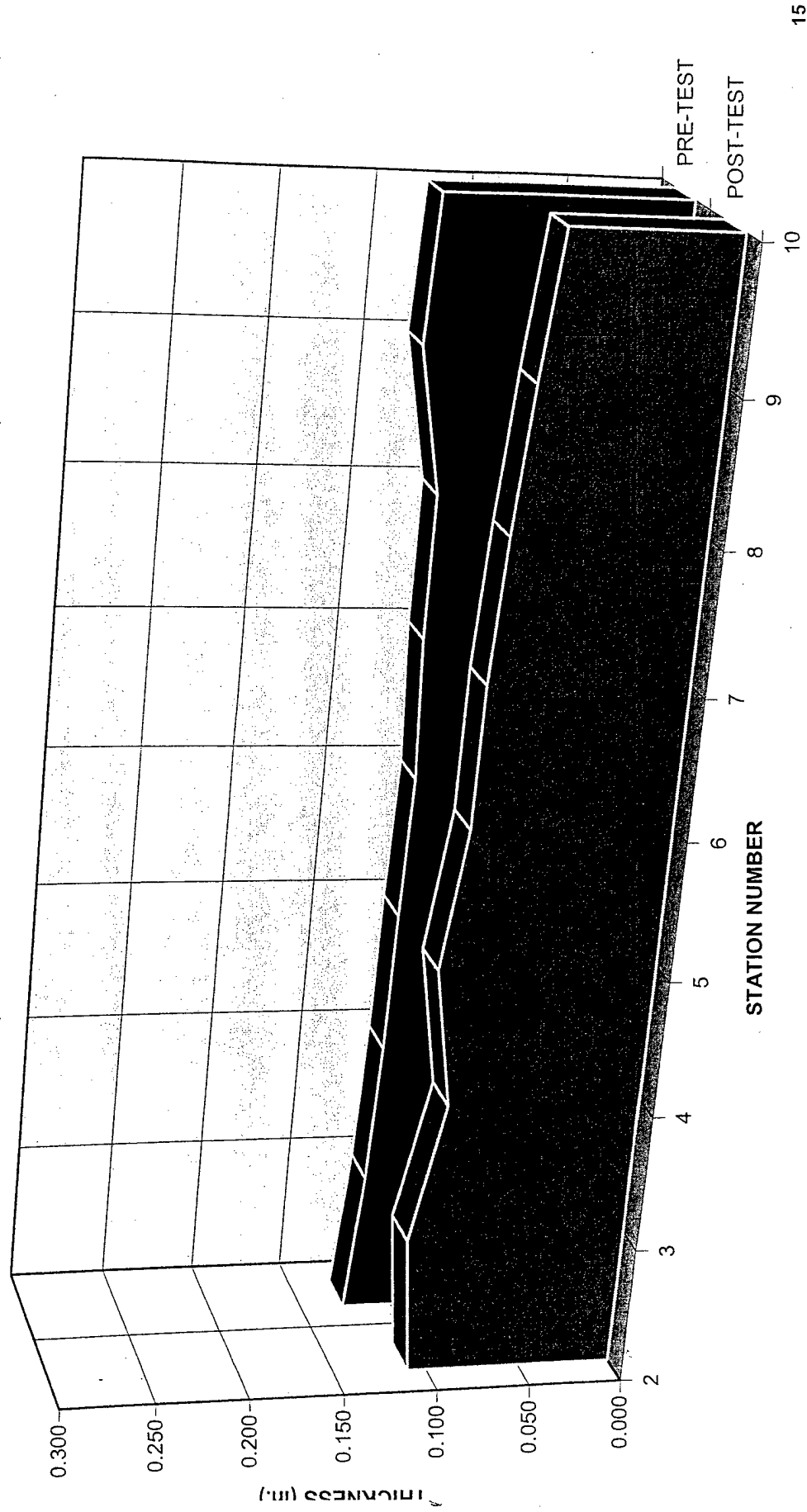


In-House SRM Insulation Testing

Low Cost Screening of New Materials



CHAR-063 ABLATION (S10 - EPDM / Kevlar STANDARD)



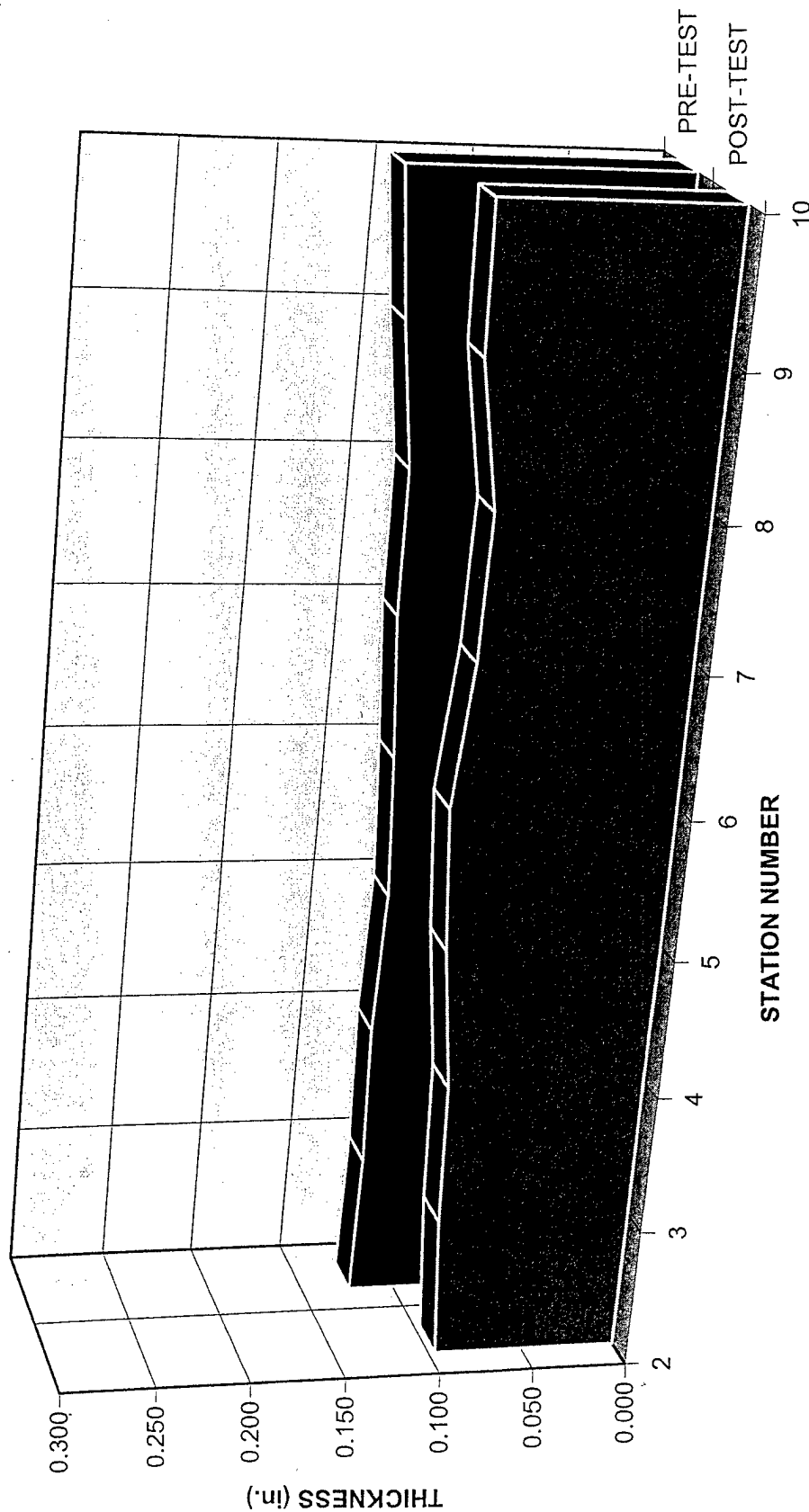


In-House SRM Insulation Testing

Low Cost Screening of New Materials



CHAR-063 ABLATION (T10 - EPDM/V₈T₈)





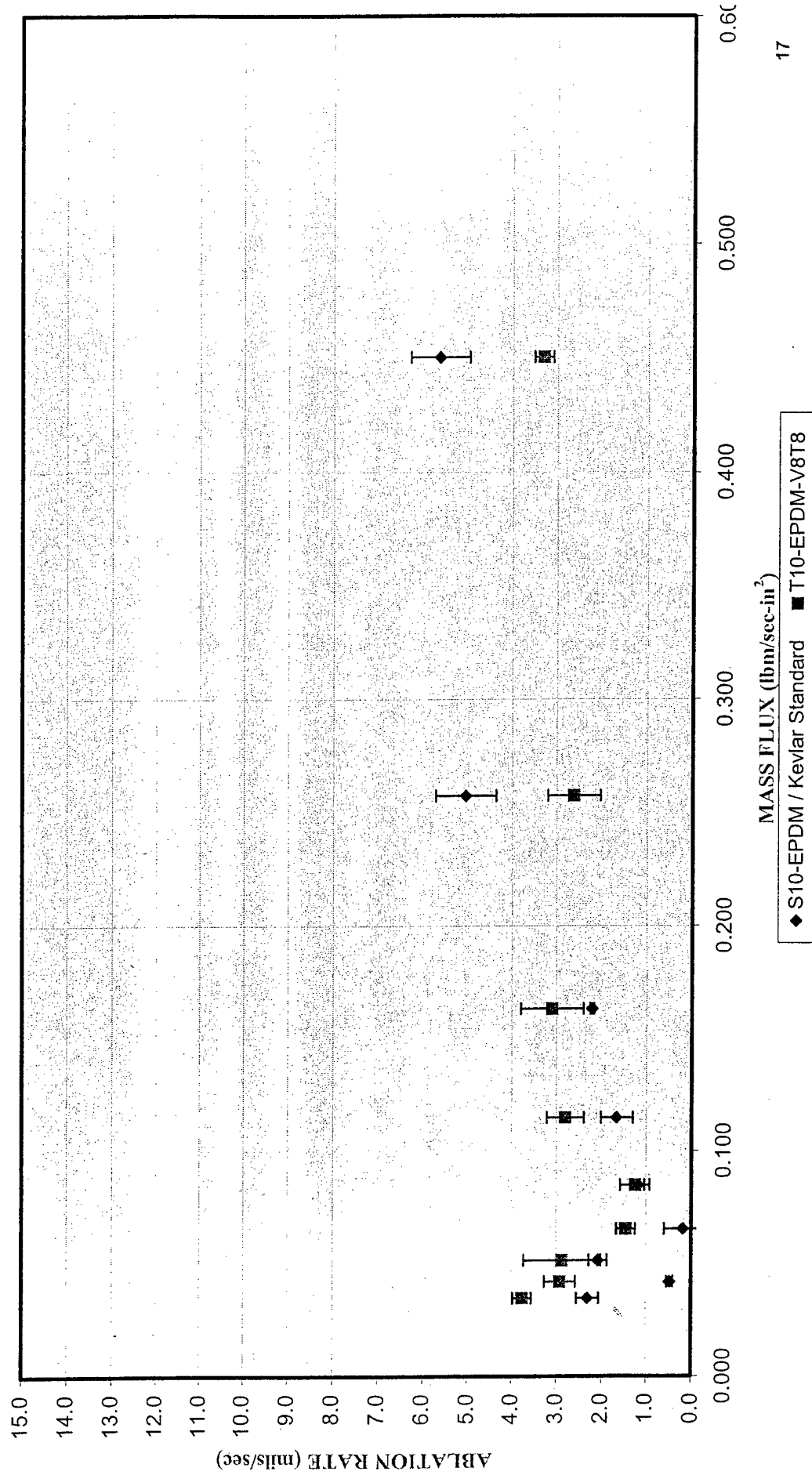
In-House SRM Insulation Testing

Ablation Rate Decreased when Using POSS



CHAR-063 ABLATION RATE

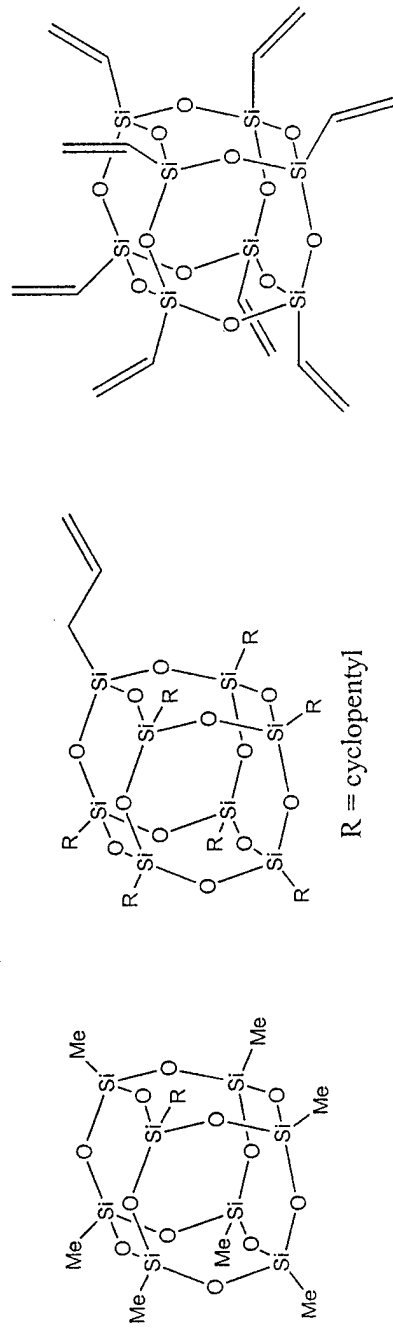
EPDM-Kevlar STANDARD (S10) / EPDM-V₈T₈ (T10)





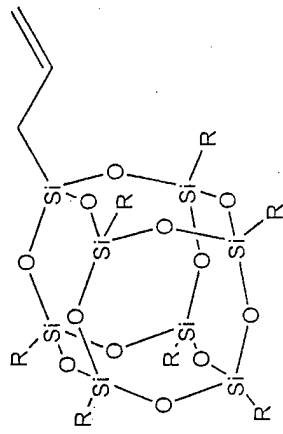
SRM Insulation Testing Program

Comparisons of POSS in EPDM

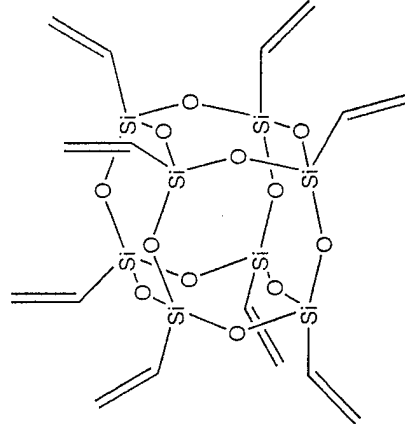


At 50 wt% loadings relative to a proprietary baseline material

Hardness:	15%↑	no change	17%↑
Tensile:	5%↓	27%↓	1%↓
Elongation:	no change	no change	no change
Viscosity:	35%↓	21%↓	36%↓
Density:	15%↑	3%↓	12%↑



R = cyclopentyl

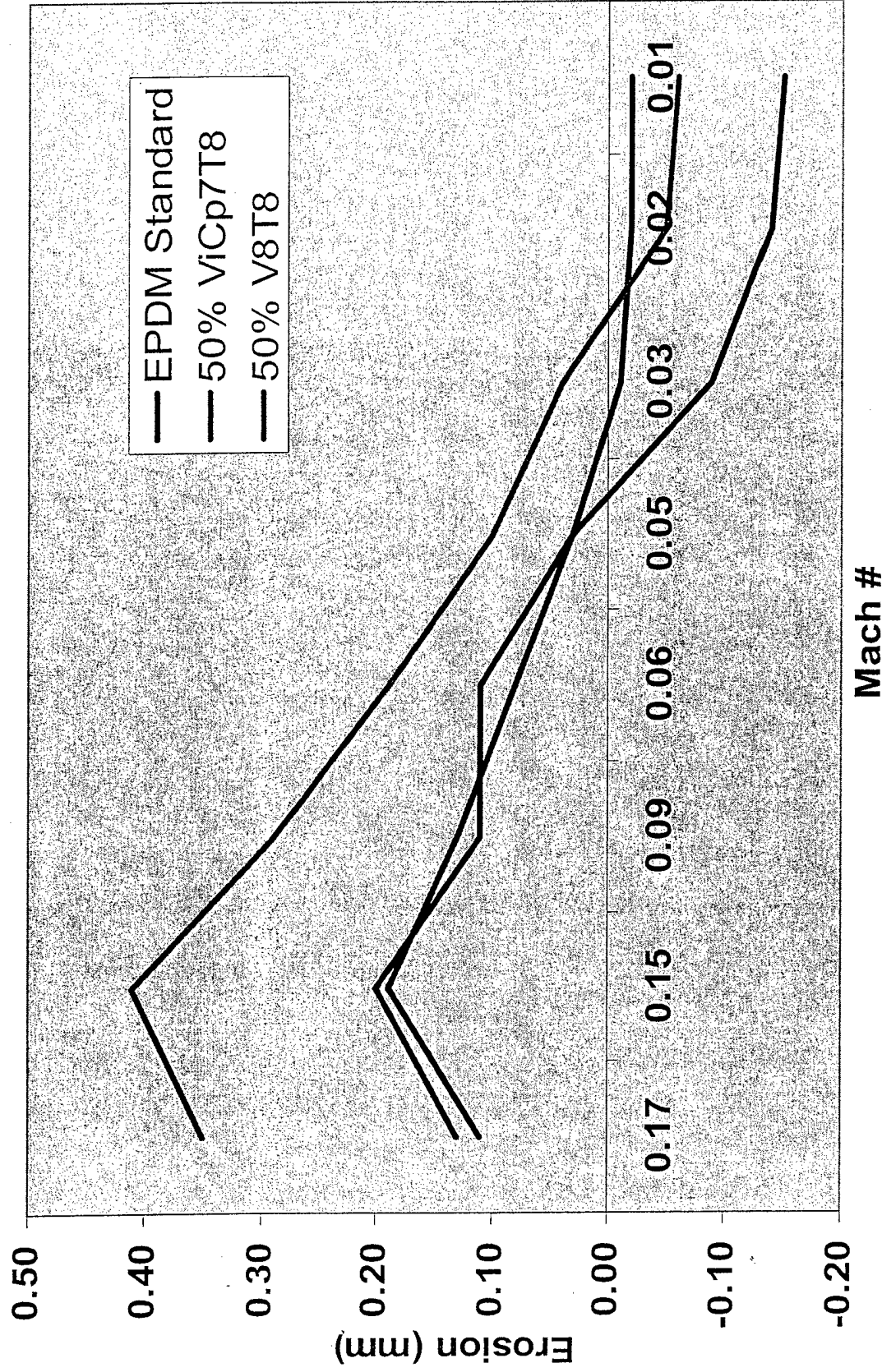


- A) Insulation containing POSS monomers**
- B) Convergent Cone**
- C) Convergent Cone + Insulation**



SRM Insulation Testing Program

Convergent Cone SRM Insulation Tests



Negative numbers represent formation of structural char



SRM Insulation Project

What Comes Next?



- More detailed physical testing of insulation
- Multiple sample cone tests
- 50 Firings Planned for FY '02



SRM Insulation Project

Multiple sample/cone



- Presently we are running the tests with two wedges in the cone: a standard and a test sample
- After the test, the cone is cut in half and measurements are taken
- It may be possible to glue in four samples/cone and still get accurate data (3 samples/1 standard)
- Working out the Logistics of multiple samples and Initial Testing is underway
- Payoff- TRIPLING OF SAMPLE OUTPUT



SRM Insulation Project

Future testing



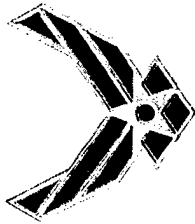
- **Thermal Property testing**
 - - density
 - - specific heat
 - - thermal conductivity
- **SEM analysis before and after**
- **Char analysis (elemental analysis)**



Conclusions



- We have all the equipment we need for the rapid testing of Solid Rocket Motor insulation
- Initial Testing in the In-House Pi-K motor tests are promising
- Initial Testing with our Partner on a larger scale also looks promising
- Plans for Future Work (multiple samples, physical testing, sample firings) are underway



In-House SRM Insulation Testing

Acknowledgements



- Mr. Hieu Nguyen (Firing Engineer; Sample Analysis)
- Dr. Tom Hawkins and Greg Warmouth (Motor Firings)
- Mr. Phil Counts (Machine Shop)
- Mr. Pat Ruth (Sample Preparation, measurement)
- Dr. ^{Dr. S.}Steve Svejda and Shawn Phillips (Moral Support)

Dr. S.