REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*

2. REPORT TYPE
Technical Papers

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Please see attached

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
1011

5e. TASK NUMBER
0046

5f. WORK UNIT NUMBER
346204

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)
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10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S NUMBER(S)
Please see attached

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

20030121 096

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Leilani Richardson
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
Unclassified	Unclassified	Unclassified	A		(661) 275-5015

TP-FY99-Ø1Ø2
ERC#E99-015

✓ Spreadsheet
✓ DTS

MEMORANDUM FOR PRR (Contractor/In-House Publication)

FROM: PROI (TI) (STINFO) 4 June1999

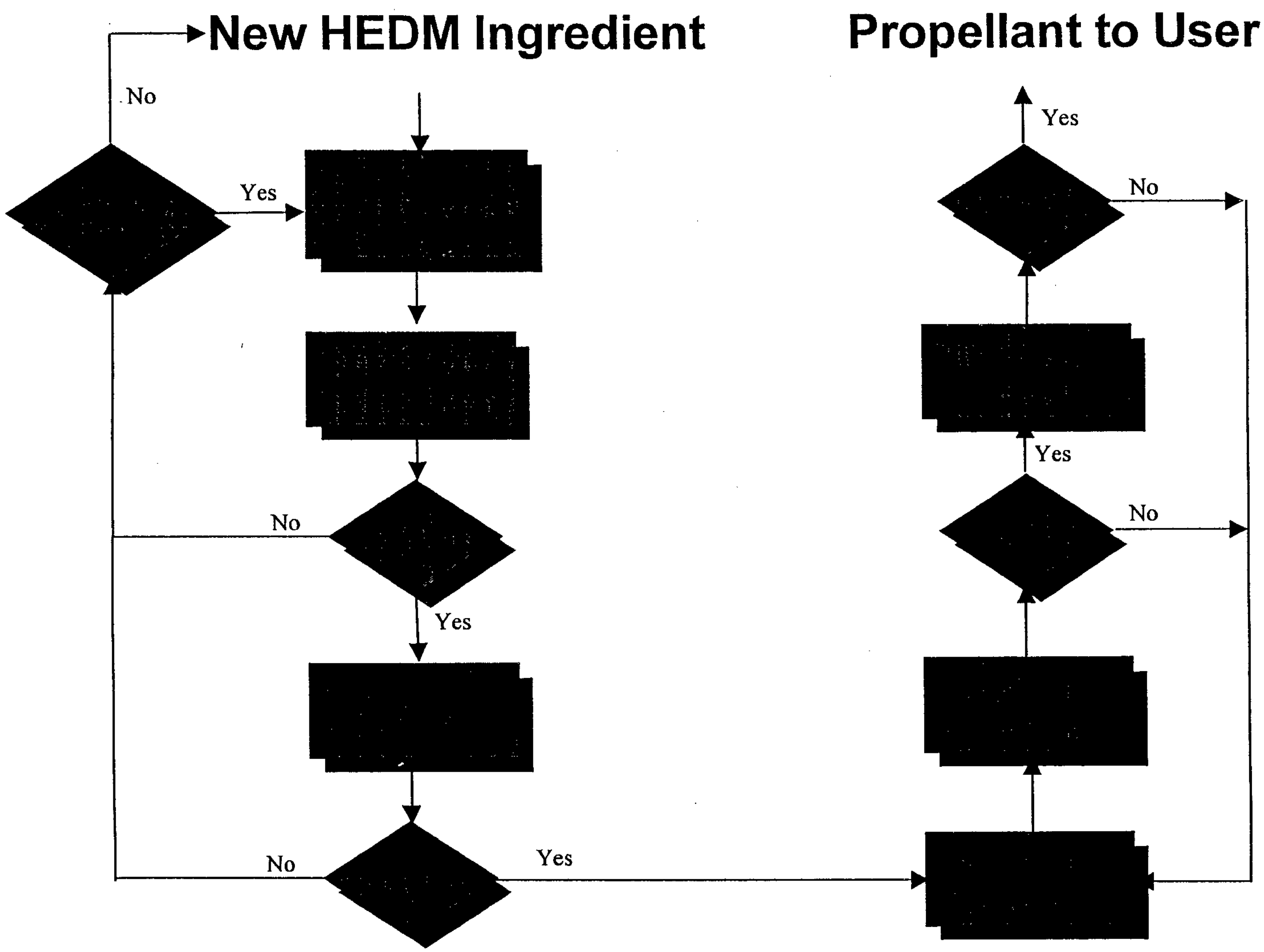
SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-FY99-0102
Brand, Hawkins..., "Laboratory Characterization of High Energy Materials"
HEDM Poster Session **(Public Release)**

Laboratory Characterization of High Energy Materials

A.J. Brand, T.W. Hawkins, and M.B. Mckay
AFRL, Edwards AFB, CA
I.M.K. Ismail
ERC Inc., Edwards AFB CA

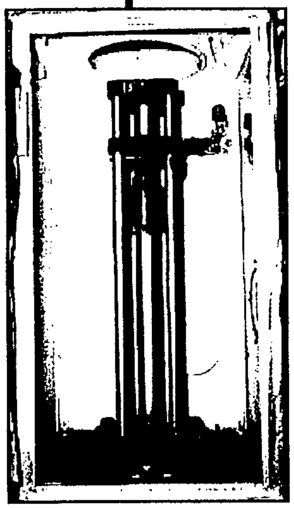
AFOSR HEDM Conference
10 June 1999

Approach to Advanced Propellant Development

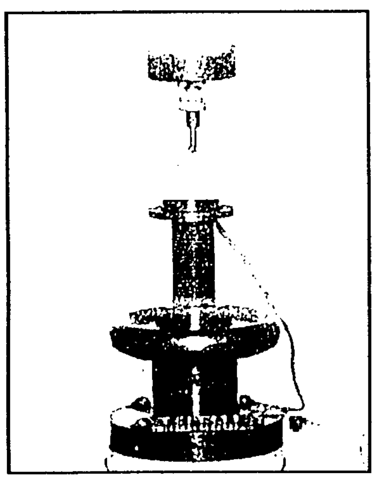


Ingredient/Propellant Testing

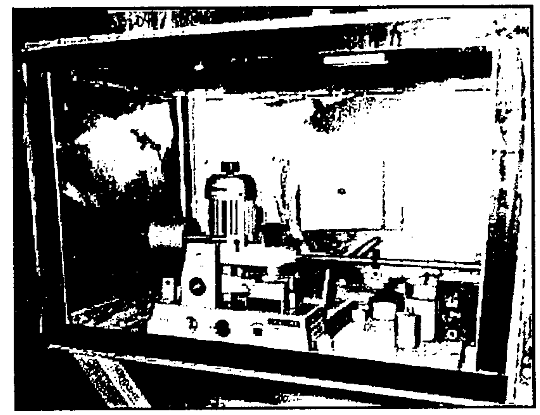
Impact



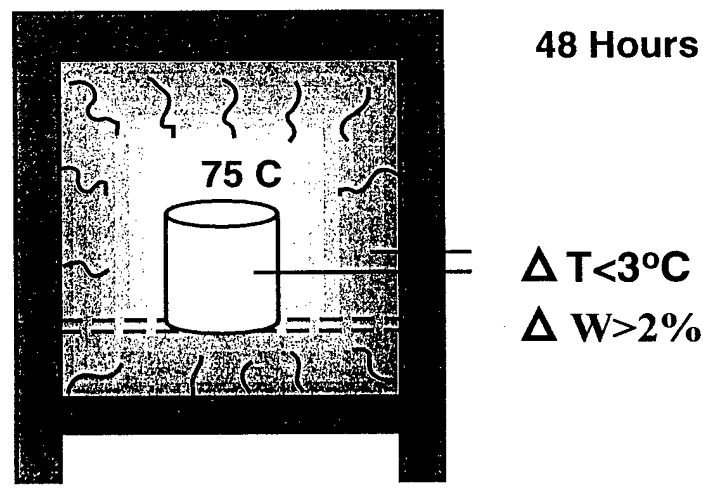
Electrostatic Discharge



Friction



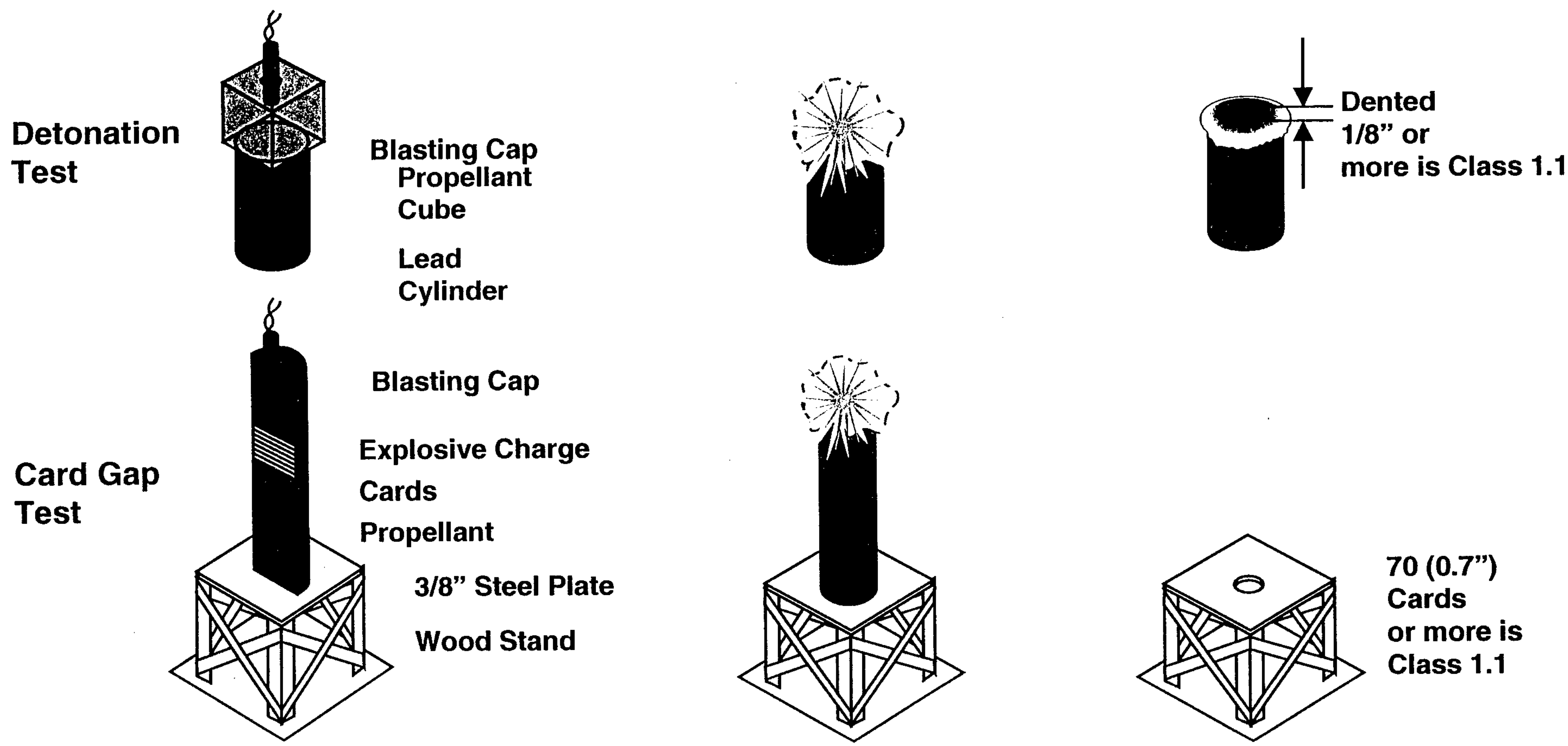
Thermal



Ingredient/Propellant Testing

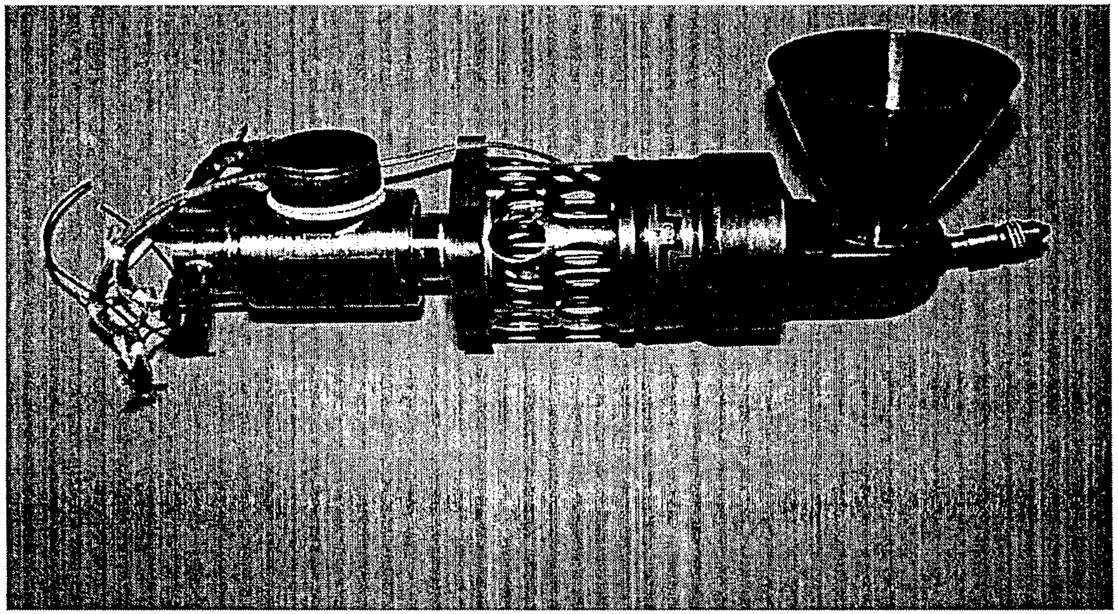
Shock to Detonation Tests

- All current solid rocket propellants are divided into two hazard classifications (1.1 or 1.3)
- Two tests are used to distinguish between Classes 1.1 and 1.3



Candidate Salt Ingredient Characterization & Safety Testing

Amine Functional Nitrate (AFN)



- AFN is a Dense, Low Melting Liquid Salt Suitable as a Monopropellant Ingredient
- AFN Meets Thermal Stability, ESD, Impact, Friction, and Detonability Requirements to Continue Development

Acceptable Monopropellant Properties

Characteristic	Objective
Density Isp [300 psi-vac; exp=50]	> 50% increase over Hydrazine
Vapor Toxicity	Does Not Exceed TLV (No SCBA in Handling)
Carbon Content	No Solid Carbon Forms in Theoretical Exhaust
Melting Point	$< 2^{O}C$
Detonability [NOL Card Gap]	Class 1.3; (Prefer 24 Cards Maximum (E_{50})
Impact Sensitivity [Drop Weight]	20 kg-cm Minimum (E_{50})
Adiabatic Compression [U-Tube Test]	No Explosive Decomposition (Pressure Ratio of 35)
Thermal Stability	< 2% by wt. Decomposition for 48 hrs at $75^{O}C$
Critical Diameter	No Propagation in Lines of < 0.75 inch Diameter

*** Reference: (1) M.B. Frankel et. al., Rocketdyne Div., Rockwell International, Technical Report, May 1979.**

AFN Propellant Development

AFN

[redacted]

Melt Point = -50 °C
Density = 1.42
DSC Exotherm = 200 °C

[redacted]

Thermal Stability = 0.24% loss/day
Impact = 38 kg-cm
Friction = 88 N
Card-Gap = 0 Cards

[redacted]

Yes

[redacted]

2 Step Synthesis
Neutralization Reaction
1 kg Quantity
Low Cost

[redacted]

Yes

[redacted]

[redacted]

Thermal Stability = <1% loss/day
Impact = 60 kg-cm
Friction = 300 N
Card-Gap = Negative @69 Cards

[redacted]

Yes

[redacted]

Efficiency = 95%
Energy-Density > Hydrazine
Melt Point < Hydrazine
Low Toxicity

[redacted]

Yes

Propellant Submitted to User

Monopropellant Chemical/Physical Characteristics

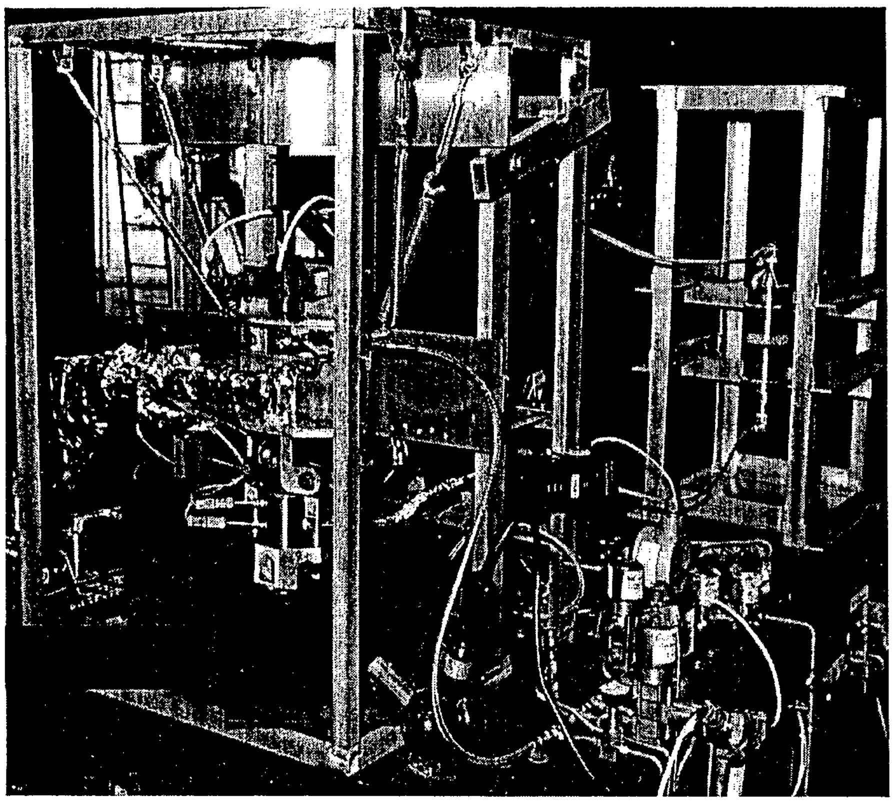
Properties	AFN1	AFN2	HAN-Based	Hydrazine
Density, g/cc	1.43	1.46	1.34	1.01
Viscosity, cp	8.6	23.1	7.4	0.97
Chamber Temp. (Theoretical), K	2070	2083	1369	883
Carbon Content of Exhaust; (b)	none	none	none	none
Impact Sensitivity*, kg-cm (5 negatives)	>200	60	>200	>200
Friction Sensitivity, N (5 negatives)	318	300	>371	>371
NOL Card Gap (at 69 Cards)	negative	negative	negative	negative
Thermal Stability, %wt loss/48hr,75°C	< 0.5	1.96	5.1%	(< 0.1)
Melt Point, C	5 (c)	<-22	-39	1

a: Theoretical, calculated with 300 psi chamber pressure, exhaust to vacuum, 50/1 expansion
b: as soot or solid carbon (by theoretical computation)
c: by DSC; melt transition was broad, melt peak reported
*: For reference, n-propylnitrate had an impact sensitivity of 8 kg-cm

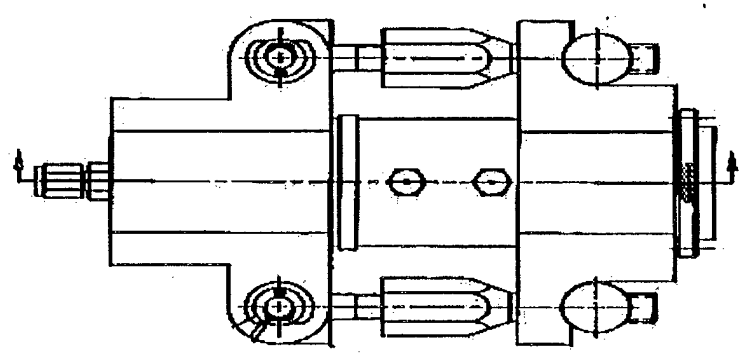
AFN-Based Propellants Display Acceptable Safety/Sensitivity Properties For Continued Development

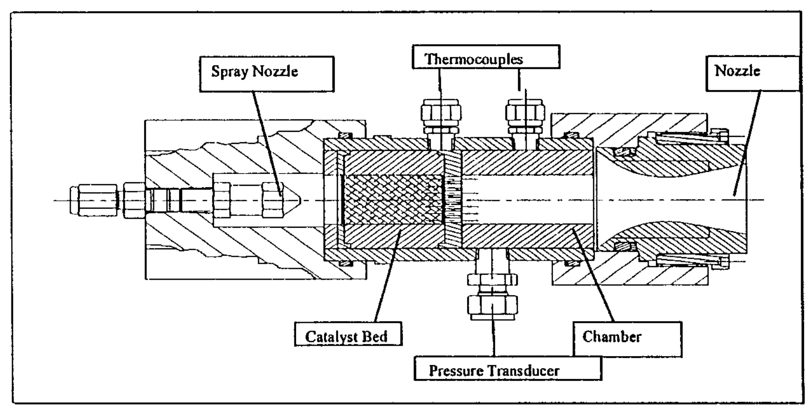
Monopropellant Thruster Testing

Monopropellant Thrust Stand



15 lbf Modular Thruster





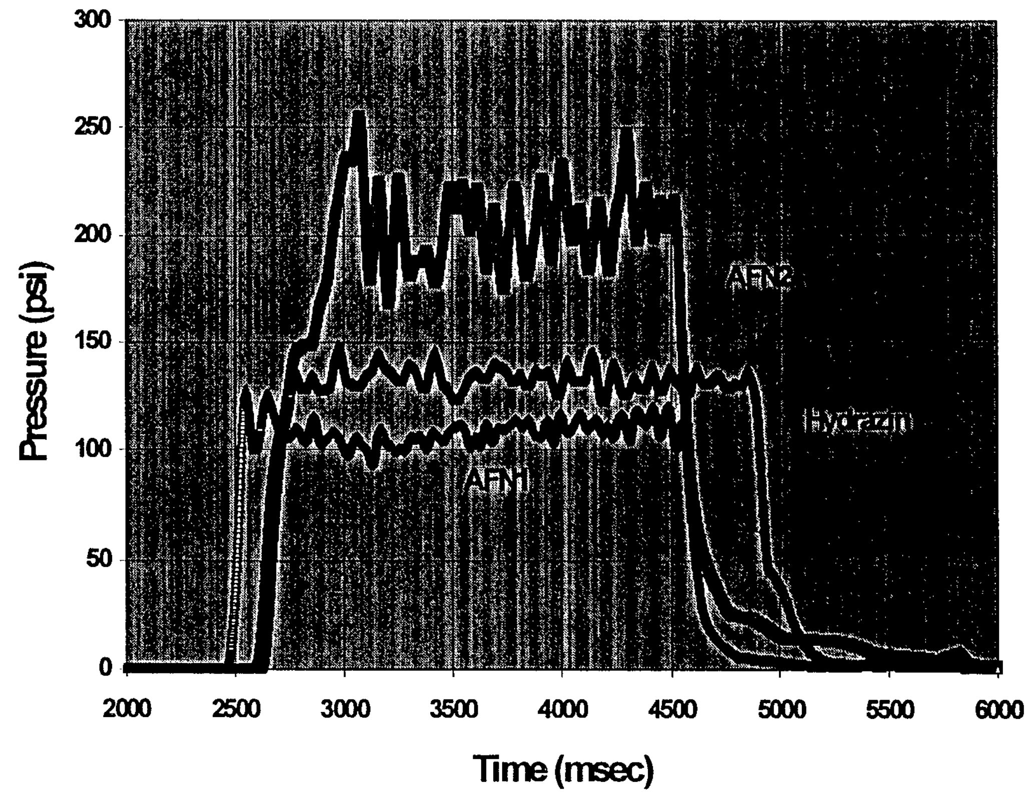
AFRL Fabricated Thruster and Initiated Testing
at National Hover Test Facility in 1998

Monopropellant Thruster Testing

Monoprops	%Efficiency
Hydrazine	96
AFN1	85*
AFN2	95

* Compromised Seal Caused Leaking of Exhaust and Poor Performance

Monopropellant Test Firings



Toxicology of AFN

Toxicology

PROPERTY	AFN	HAN (13M)	HYDRAZINE
LD50 (rat), mg/kg	367	325	60
Dermal Irritation	Slight	Moderate	Corrosive
Genotoxicity (Ames)	3 Negative/ 2 Positive	Negative	Positive

Vapor Toxicity (TVDL)

AFN   no detection <1ppb   (TLV for Hydrazine is 0.01ppm)

<u>AFN Evaluation</u>:

- **Negligible Vapor Pressure**
- **6X Less Oral Toxicity than Hydrazine**
- **Very Low Dermal Irritation**
- **Genotoxicity (Bacterial) in 2 of 5 Strains**

Laboratory Characterization of High Energy Materials

Conclusions

- AFN Has Demonstrated Acceptable Properties to Further Propellant Development
  - Displayed Good Stability (Thermal, Friction, Impact and Detonability)
  - Low Melt Point is Suitable for Monopropellant Applications
  - Extremely Low Toxic Vapor Concentrations
- AFN-Based Propellant Has Been Evaluated to Indicate Additional Development is Warranted
  - High Performance Demonstrated in Thruster Testbed
  - Acceptable Safety Properties
  - Low Toxic Vapor Concentrations
- Propellant Submitted to Industry for Evaluation