

Improved IM Response for Future 2.75” APKWS Rockets with Composite Case Technology

Christina Davis (AMRDEC)
Tom Farabaugh, Mike Kessinger (ATK)

41st Annual Armament Systems:
Gun and Missile Systems Conference and Exhibition
Sacramento, California
March 27-31, 2006



ATK/Government CRDA Team Structure



An advanced weapon and space systems company

- **AMRDEC**

- Propulsion & Structures Labs
 - IM testing, nozzle design and spin tab testing, case design, support



- **ATK**

- Design, analysis, testing, Program support

- **HST, Inc.**

- High volume, low cost supplier

- **Program:** 2 year Cooperative Research and Development Agreement (CRDA) for Improved Rocket Motor with focus on improvement to IM response

- **Success Criteria:** Demonstrate improved IM response in the 2.75” rocket motor by incorporating a composite case with the current propellant grain.

- **Test Plan:** Static tests, Bullet Impact (.50 Cal), fragment impact (Army), Fast Cook Off



System/Motor Requirements

- No changes to launcher.
- Performance within current MK66 rocket motor specification
- Case stiffness equal to or better than current MK66 aluminum case
- Center of Gravity location same as or further aft than current MK66 motor to match flight characteristics

IM Improvement

- Demonstrated improvement in IM response compared to current MK66 motor

**CRDA Composite Case Was Designed To Be A
“Drop In” Replacement For Current Aluminum Case**

Use Non-Development Item (NDI) Composite Case Technology with Cartridge-Loaded Grain

- The NDI program was a 2.75” rocket motor effort, circa 1998, where Thiokol (now ATK-Thiokol) demonstrated composite case technology using a case-bonded propellant grain.
- The CRDA technical approach was to modify the NDI composite case design to accept the current cartridge-loaded propellant grain, with minimal changes to the rest of the rocket motor components.

Major Design Feature of the CRDA Composite Case is the Case Adapter

- Provides best attachment interface from composite case to forward bulkhead warhead attachment and aft nozzle attachment.
- Allows cartridge loading of current APKWS extruded propellant grain.

**CRDA Composite Case Adapter Configuration
Maximizes Loadable Propellant Volume**

Static Testing

- 2 motors tested at +150°F, 2 at -50°F at Radford AAP, completed July 2005
- 4 motors tested at ambient, 4 at +150°F, 4 at -50°F at AMRDEC, completed Sept. 2005



Test Setup

- Standard AMRDEC 2.75" rocket static test fixture

Instrumentation

- High-speed video
- Thrust gauge
- Torque gauge
- Outer case thermocouples

CRDA Composite Case Motors Performed as Expected and Met MK66 Specifications

Static Test – CRDA Motor Test Video

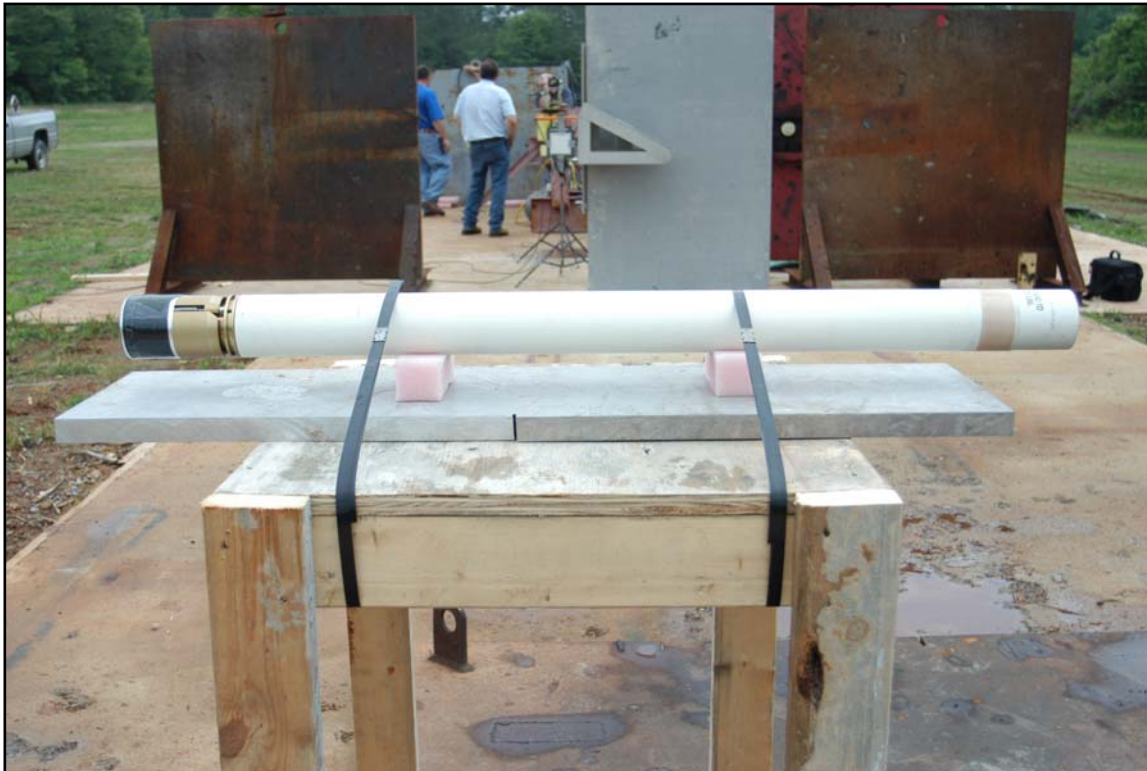


An advanced weapon and space systems company



Bullet Impact Testing

- 2 CRDA Composite Case Motors + 2 MK66 Mod 2 Motors w/Aluminum Case



Test Setup

- .50 Cal AP bullet at 2700 ft/s
- Rocket w/o warhead
- Target center of rocket motor
- Test unit lightly secured with band straps & foam blocks, but free to move after impact

Instrumentation

- High-speed video
- Chronograph for bullet velocity
- Blast over-pressure gauges

CRDA Motors Exhibited Same Response (Non-Propulsive Burning) as MK66 Mod 2 Motors

IM Bullet Impact – MK66 Mod 2 Test Video



An advanced weapon and space systems company



No Picture

IM Bullet Impact – CRDA Composite Test Video



An advanced weapon and space systems company



No Picture

Fragment Impact Testing

- 2 CRDA Composite Case Motors + 2 MK66 Mod 2 Motors w/Aluminum Case



Test Setup

- Army test specification; 18.6 gm conical steel frag at 6000 ft/s
- Rocket w/o warhead
- Target Center of Rocket Motor
- Test unit lightly secured with band straps & foam blocks, but free to move after impact

Instrumentation

- High Speed Video
- Fragment velocity screen
- Blast over -pressure gauges

CRDA Motors Exhibited A Smaller Debris Field Than the MK66 Mod 2 Motors.

IM Fragment Impact – MK66 Mod 2 Test Video



An advanced weapon and space systems company



IM Fragment Impact – CRDA Motor Test Video



An advanced weapon and space systems company



IM Fragment Impact - Test Results



An advanced weapon and space systems company

Parameter	Test 1 MK66	Test 2 MK66	Test 1 CRDA	Test 2 CRDA
Rocket Forward End Distance Traveled (ft)	300	210	165	120
Rocket Aft End Distance Traveled (ft)	19	28	15	19
Approx. Number of Small Metal Fragments Outside 50 ft Radius	6	8	0	0
Location of Largest Burned Propellant Piece (ft)	40	120	---	20
Total Mass of Unburned Propellant Pieces (gms)	1530	241	128	140
Approx. Number of Unburned Propellant Pieces Outside 50 ft Radius	2	3	1	0



**CRDA Composite Case Motors Exhibited
Less Severe Reaction Than MK66 Mod 2 Motors**

Fast Cook Off Testing

- 2 CRDA Composite Case Motors + 2 MK66 Mod 2 Motors w/Aluminum Case



Test Setup

- Two rockets in pit at same time, w/o warheads
- Separated by steel barrier
- Test units lightly secured with band straps & foam blocks, but free to move after impact
- Placed 3 feet above fuel level on metal grate
- 2000 gallons of JP-8 fuel with 30 gallons of gasoline

Instrumentation

- High Speed Video
- Thermocouples

**Fast Cook Off Testing Performed
at Redstone Technical Test Center**

IM Fast Cook Off Test – MK66 Mod 2 Video



An advanced weapon and space systems company



IM Fast Cook Off Test – CRDA Composite Video



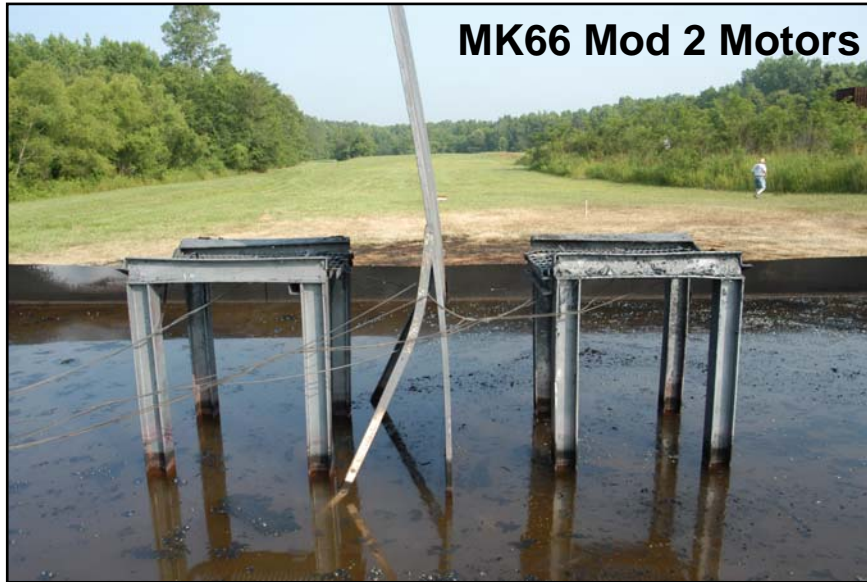
An advanced weapon and space systems company



IM Fast Cook Off Test - Results



An advanced weapon and space systems company



Parameter	Test 1 MK66	Test 2 MK66	Test 1 CRDA	Test 2 CRDA
Estimated Time to Motor Ignition (sec)	83	85	73	67
Approximate Temperature at Ignition (°F)	1200	1300	1300	1400
Location of Largest Burned Propellant Piece (ft)	120	54	In pit	Next to pit

CRDA Composite Case Motors Were Contained Within the 50ft Radius Requirement

Preliminary IM Testing – Results & Summary



An advanced weapon and space systems company

Test Type	MK66 Aluminum	CRDA Composite
Bullet Impact (.50 Cal)	V	V
Frag Impact (Army)	III - IV	IV*
Fast Cook Off	IV	V

CRDA Composite Case Motors...

- meet MK66 ballistic performance requirements
- demonstrate less severe reactions than MK66 Mod 2 for (Army) fragment impact tests and Fast Cook Off tests
- match MK66 Mod 2 IM response for bullet impact (.50 Cal) test

CRDA Composite Case Motors Exhibit Improved IM Response for Fragment Impact and Fast Cook Off

The authors would like to thank the following people for their support during this effort. Without their dedication, valuable experience and technical expertise, this effort would not have been possible.

- **AMRDEC** – B. Nourse, Dr. J. Lilley, M. Morrison, R. Esslinger, S. Hudson and J. Webb.
- **ATK** - W. Farley, M. Quesenberry, R. Evans, J. Orahod, C. Zisette, W. Worrell, J. Yu, A. Parrish, G. Pratt, R. Summers, M. Conklin, L. Austin, T. Levison, B. Hollaway, J. Berg, P. Corwell, K. Hartman, T. White, R. Murri, L. Bracken and D. Weeks.
- **HST, Inc.** – T. Boretto, C. Robinson, N. Wamsley, A. Santos, A. Gutierrez, J. Encarnacion and S. Garcia.