An Investigation to Develop an Insensitive Artillery Propellant: A Joint U.S.-Japan Cooperative Project

US Army RDECOM-ARDEC

&

First Research Center, TRDI,

Japan Defense Agency

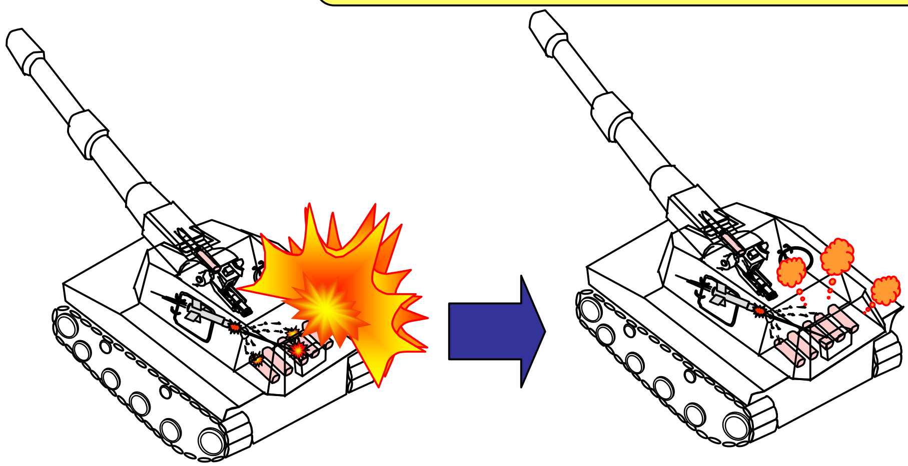
CONTENTS

1 Project Objectives

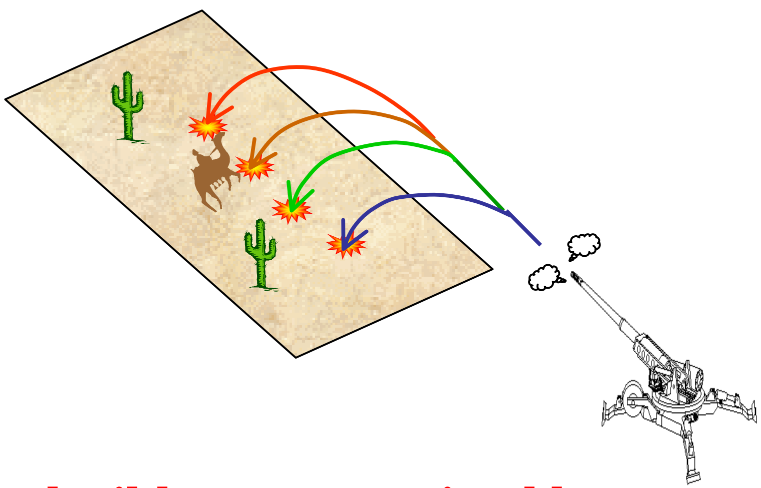
Research and exploratory development of high performance LOVA gun propellant to reduce the vulnerability, increase the energy, and maintain the reliability of propellant formulations which are applicable to future artillery charge systems

-ARDEC and First Research Center share the technologies and responsibility, pursue the common performance goals according to MOU and Management Plan.

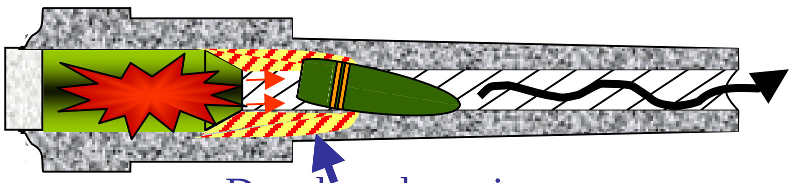
1-2 Performance Goals: Concept



Minimize the battle damage

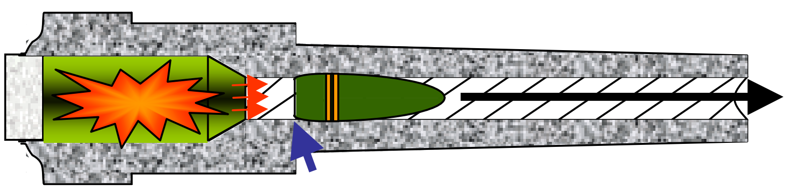


Flexible range attained by proper combustion behavior



Developed erosion

With current propellant



Reduced erosion

With propellant under study

Longer tube life with lower erosivity

1-2 Performance Goals

Compared with the reference gun propellant;

- Low Vulnerability – one rank-order safer
- High Energy – desired to be 5% higher
- Low Erosivity – 20% less gun wear
- Proper Combustion Behavior – similar burning characteristics
- Proper Aging Characteristics – better stability
- System Performance – Priority: Safety > Performance, etc.

2 Scope of Work

Task 1: Disclose specific background information

Task 2: Develop fundamental specifications of CAN-based LOVA gun propellants through exchange of ingredients and fabrication of candidates

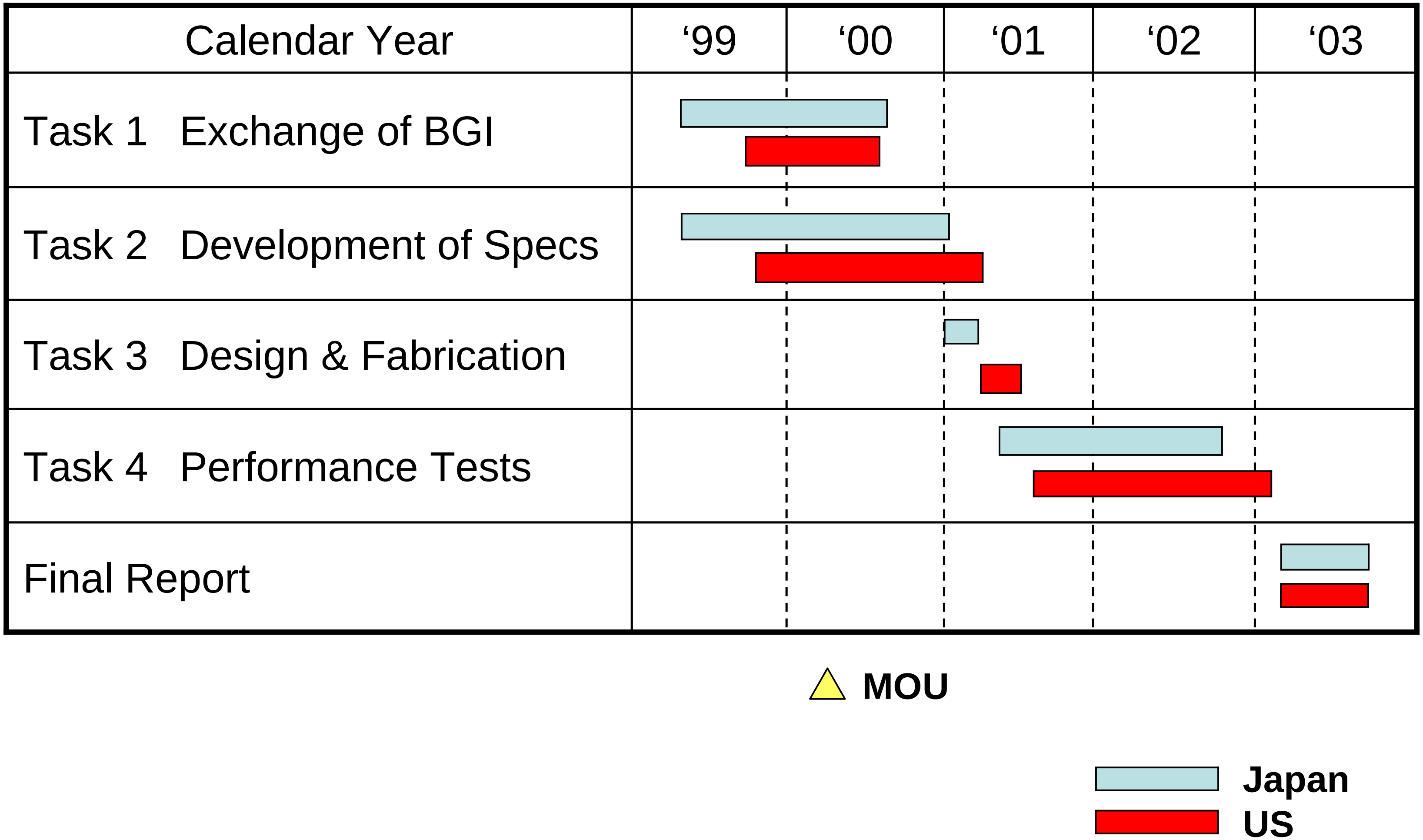
Task 3: Design and fabricate LOVA gun propellants

Task 4: Conduct performance tests

Final report

Note: CAN = Cellulose Acetate Nitrate

3 Project Schedule



4 Background Information Exchanged

- RDX properties – physical, chemical, toxicological
- CAN properties – physical, chemical, toxicological
- Plasticizers properties
- Gun propellant design method
- M30A1 properties – physical, chemical, transport
- Performance test procedures

5-1 Design of Prototype Propellants

Composition

Main	Binder	Plasticizer
RDX	**CAN** (Japan flag)	**P1, P2** (US flag)

↓

Grain fabrication

↓

Type A, B, C

LOVA Prototype Propellants

Composition

NQ	NC	NG

↓

Grain fabrication

↓

Reference Propellant (M30A1)

5-2 Design Approach to Prototype Propellants

ESTABLISH BASIC CONCEPT

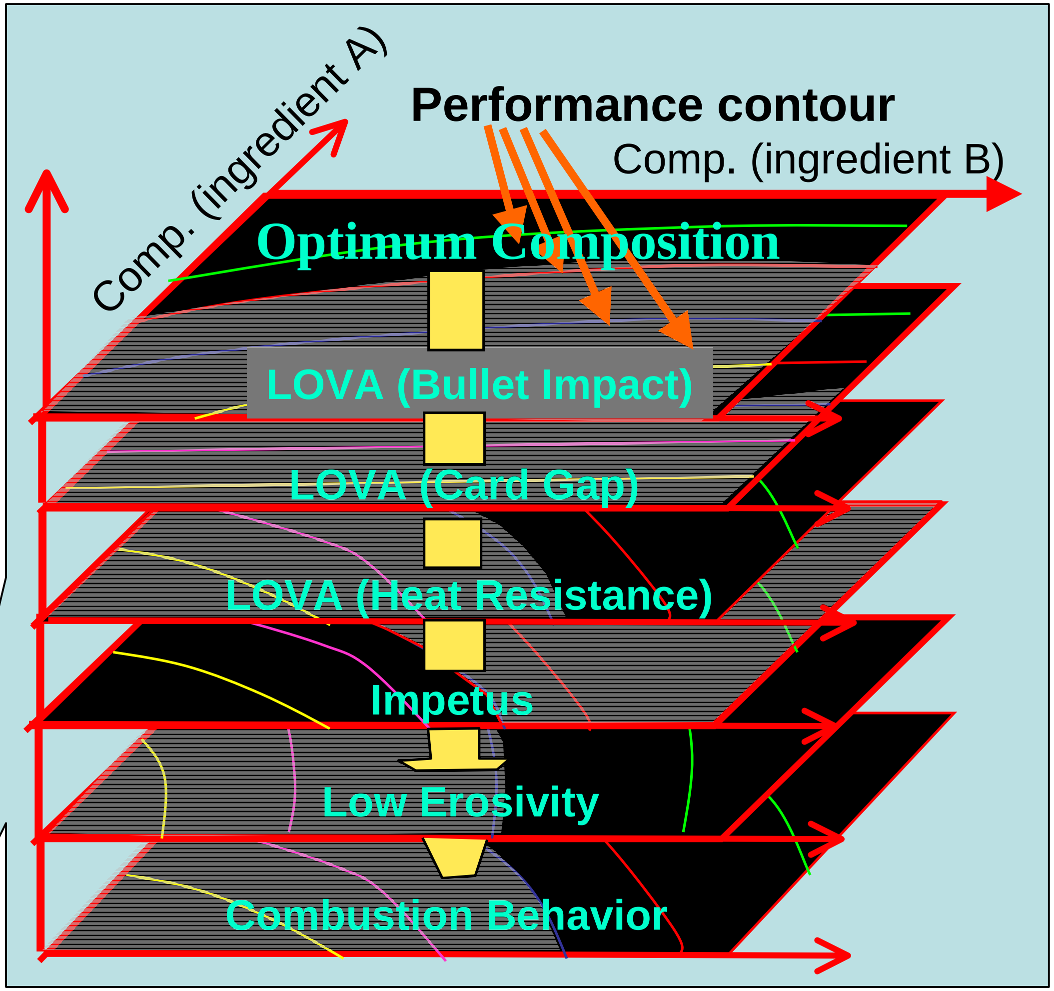
- Calculate Impetus
- Predict Erosion Behavior

PRELIMINARY SCREENING TEST

- Update impetus calculation and Erosion Behavior
- Calculate correlations between LOVA compositions and: Bullet Impact Response, Card Gap, etc

ESTABLISH CORRELATIONS

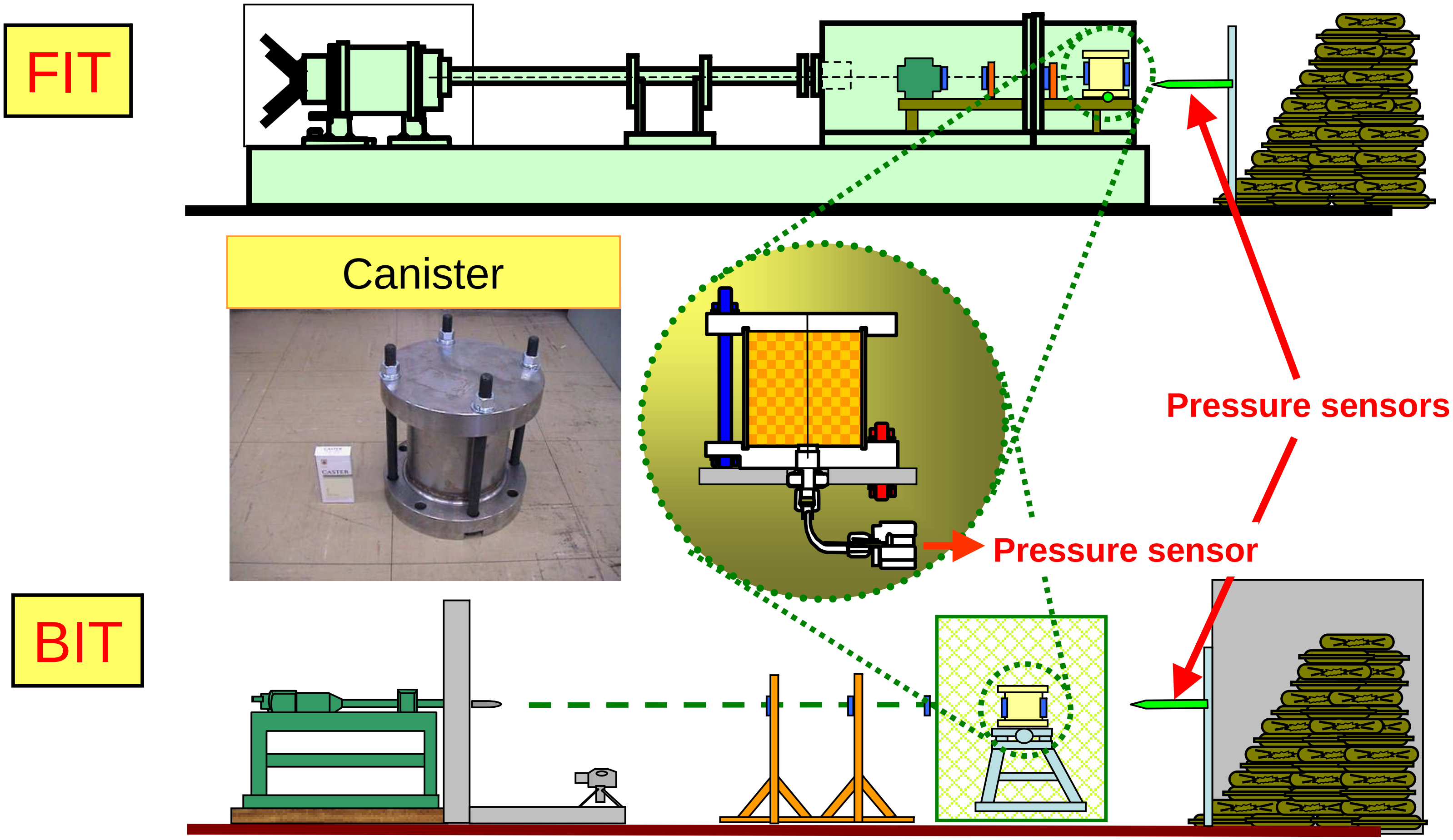
FIND BEST COMPOSITIONS



6-1 Outline of Performance Tests

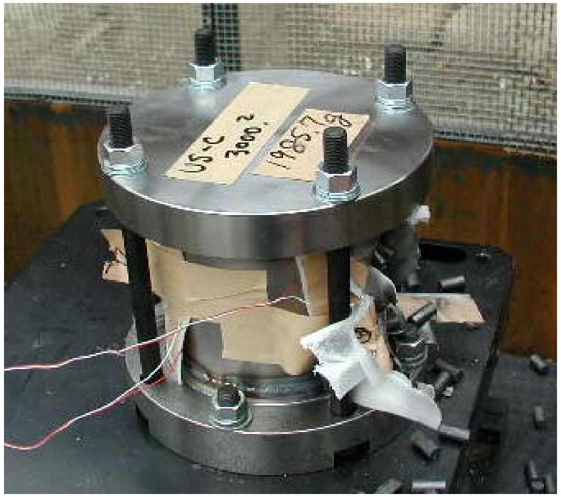
Category	Itemized Tests	Places
LOVA	Fast Cook-off Shaped Charge Jet Impact Fragment Impact Bullet Impact	ARDEC & Shimokita Test Center, Japan
Energy	Impetus Muzzle Velocity	
Combustion	Pressure Exponent Temperature Sensitivity	
Erosivity	Erosion Bomb	ARDEC & Tsuchiura Test Center, Japan
Aging	NO_x Evolution Rate Microcalorimatric Chemiluminescence Remaining Virgin Stabilizer (SIP)	

6-2 Fragment/Bullet Impact Tests

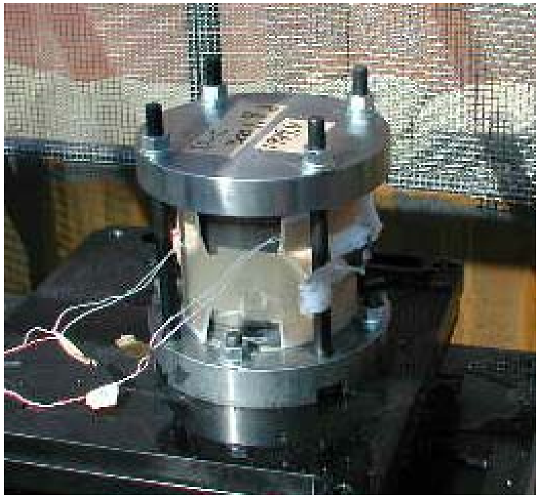


6-2 Bullet Impact Test Results

Reference (M30A1)
Explosion ~ Deflagration



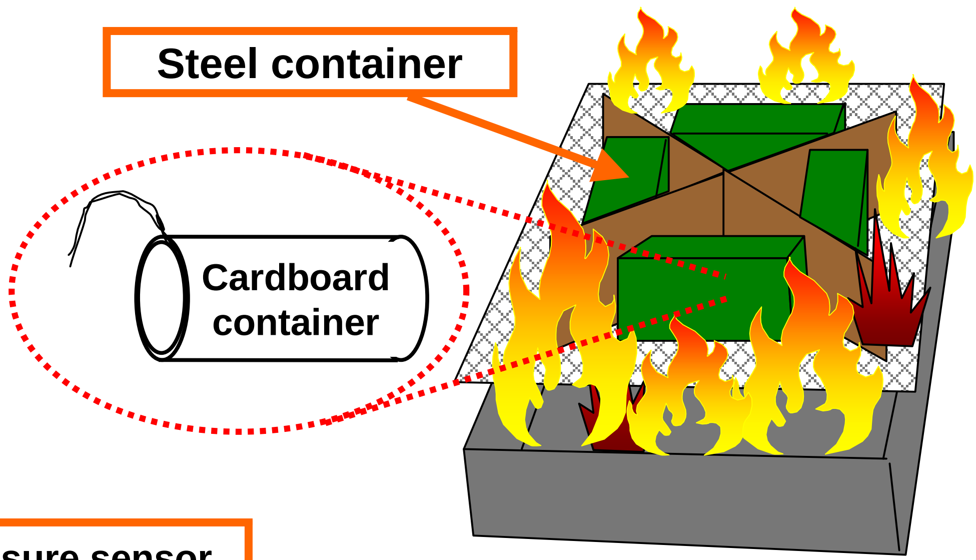
LOVA (US-C)
> Burning



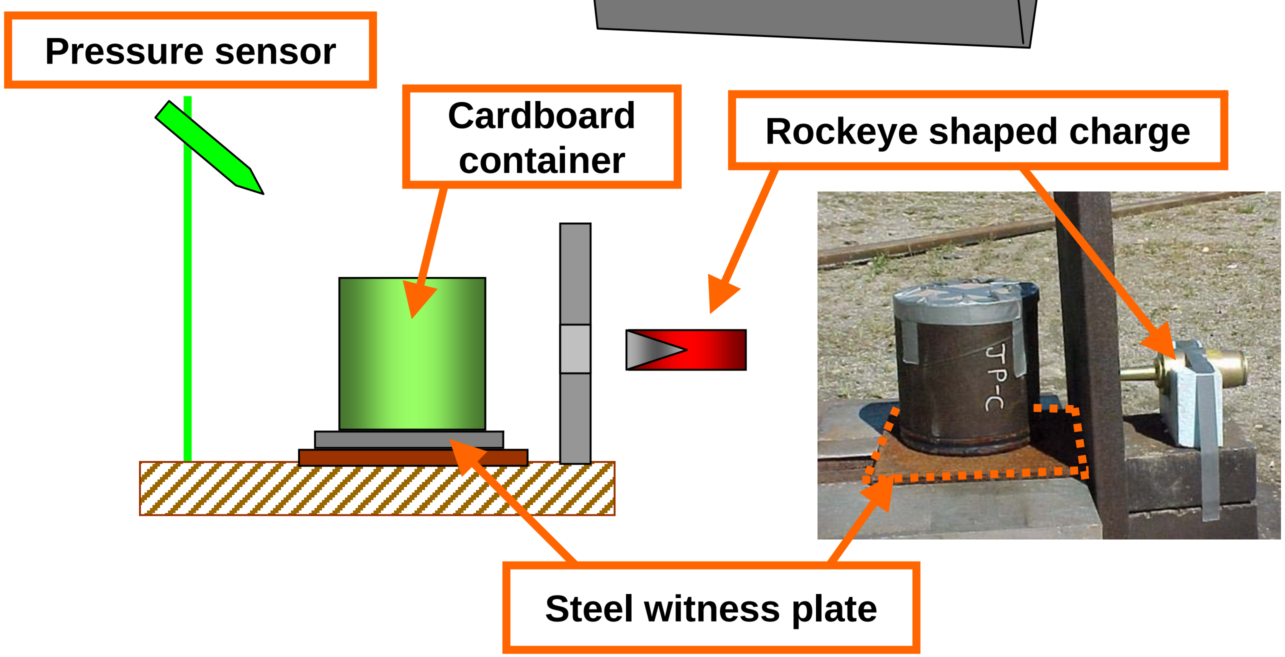
LOVA (JP-C)
> Burning

6-3 Fast Cook Off/Shaped Charge Jet Sensitivity Tests

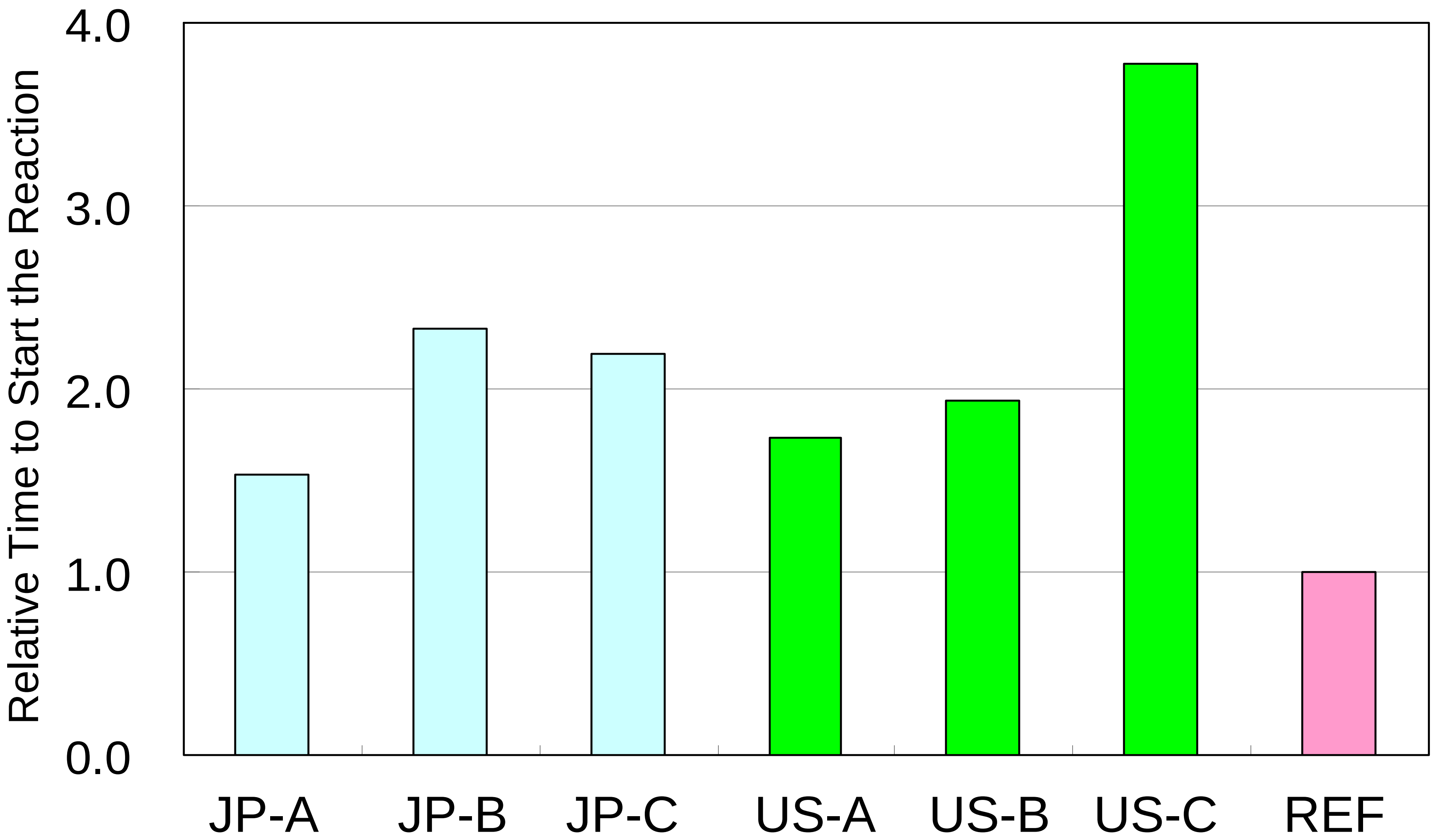
FCO



SCJ

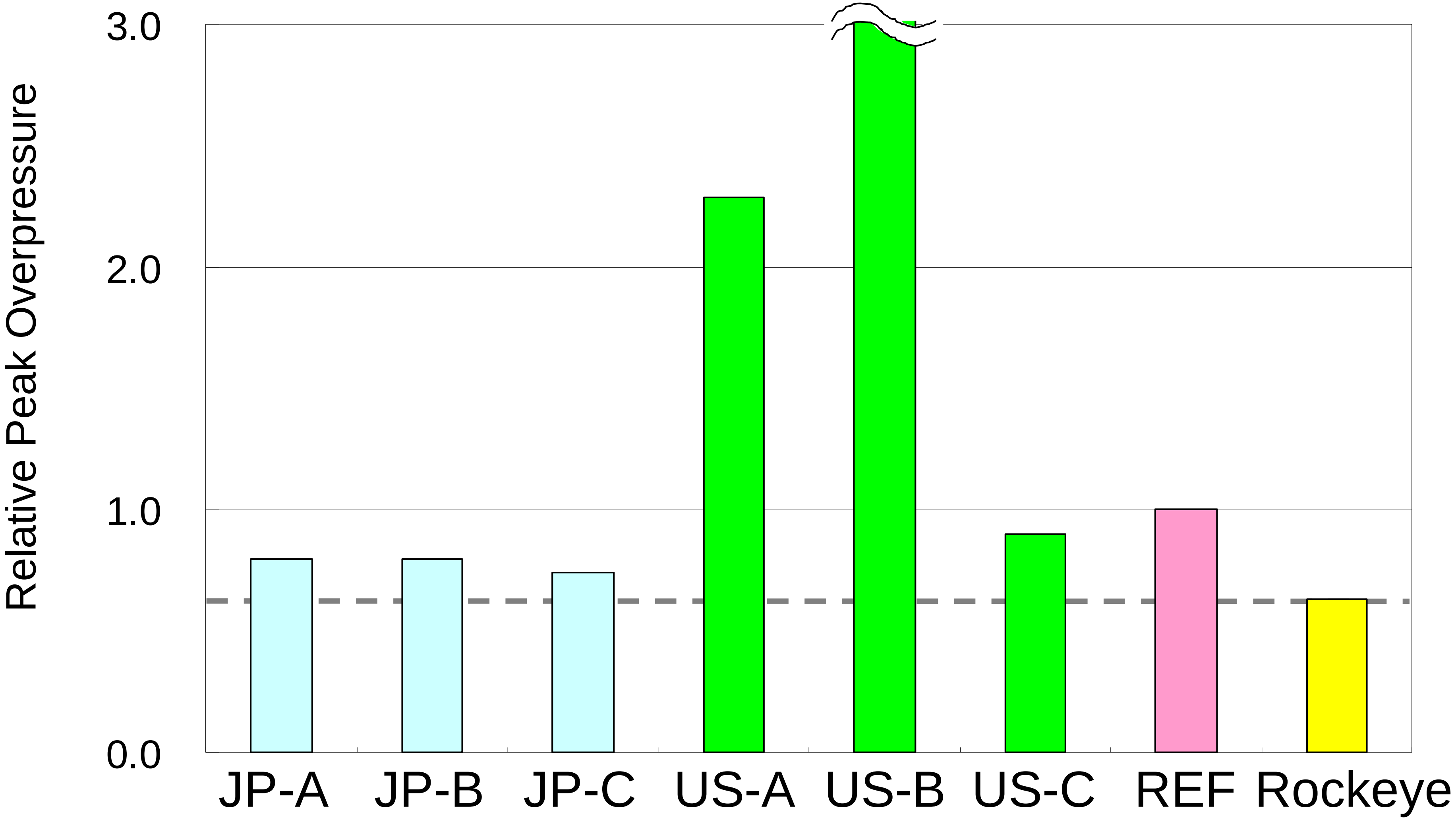


6-3 Fast Cook Off Test Results
Comparison of Time to Start the Reaction



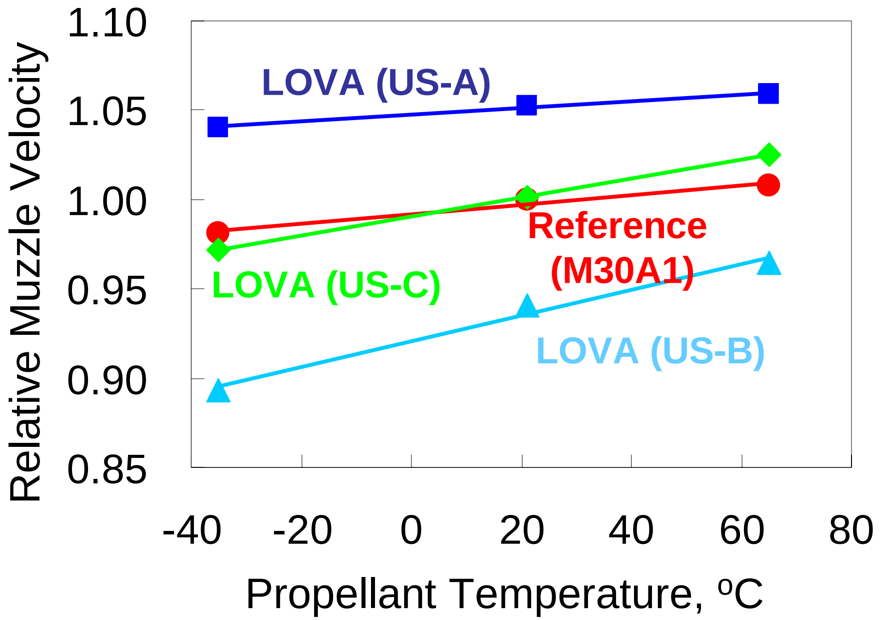
Time to Start the Reaction of REF is taken as unity.

6-3 Shaped Charge Jet Impact Test Results
Comparison of Blast Overpressure

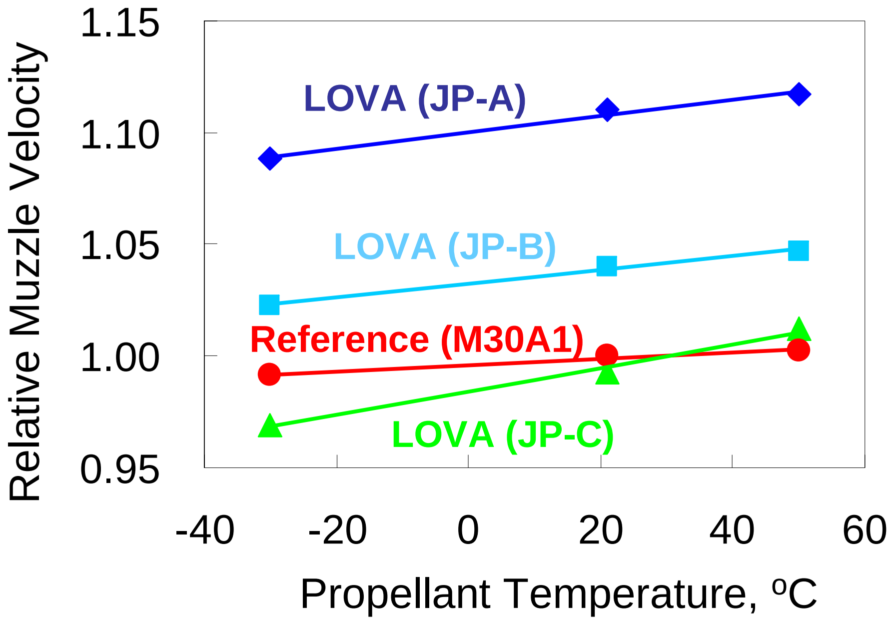


Peak Overpressure of REF is taken as unity.

6-4 Ballistic Test Results



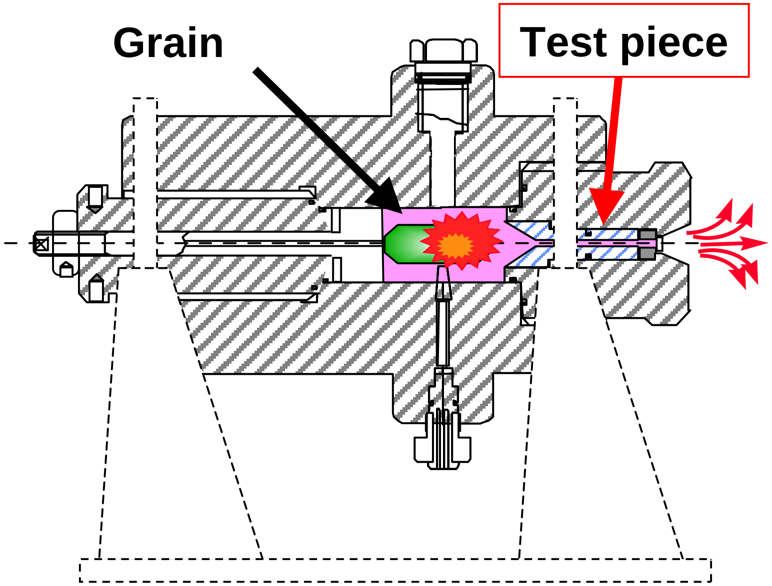
US- 30 mm Ballistic Test Data



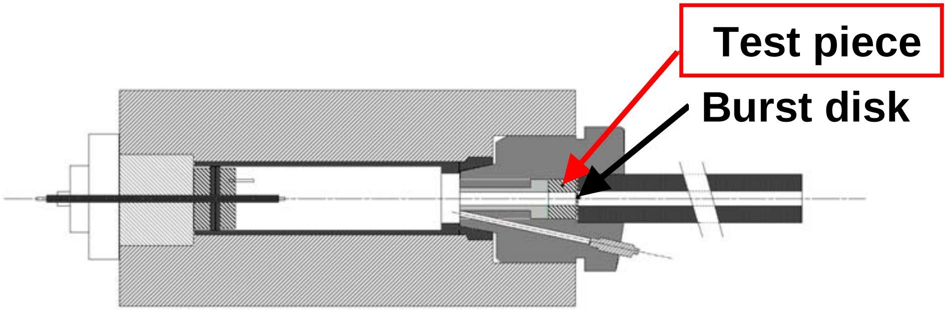
Japan- 40 mm Ballistic Test Data

Muzzle Velocity of REF (21 ºC) is taken as unity.

6-5 Erosion Bomb Tests



TRDI Erosion Bomb



ARDEC Erosion Bomb

Degree of gas erosion is evaluated by weighing the test piece before and after the firing.

6-6 Aging Characteristics Tests

Temp.	65 ^{o}C	55 ^{o}C	45 ^{o}C	Room
Duration in days	15, 60	60, 120	60, 120	1 year

Method	Results
NOx evolution rate analysis	pass
Microcalorimetric analysis	pass
Direct chemiluminescence analysis	pass
Remaining virgin Stabilizer analysis	pass

7 Overall Result Chart

Item	Criteria		JP-A	JP-B	JP-C	US-A	US-B	US-C
LOVA	1 rank safer	FCO	+	+	+	0	+	+
		SCJ	0	0	0	-	-	0
		FIT	+	++	++	+	0	++
		BIT	++	++	++	+	0	++
Energy	0-5% up	Impetus	3%	3%	~0%	~0%	~0%	~0%
		Velocity	+	+	0	+	-	0
Combustion	Similar characteristics	Pressure exponent	-	-	-	-	-	-
		Temp. sensitivity	0	0	-	0	0	-
Erosivity	20% less		~0%	~0%	+43%	-80%	-74%	+26%
Aging	better		+	+	+	+	+	+
System	Priority: Safety		a	aa	b	c	c	b

Note: + = better, 0=equal to, - = inferior than M30A1, a=promising, b=fair, c=needs improvement

8 Conclusion

Two of six CAN based formulations demonstrated measurable improvement in terms of the most of the performance goals.

Overall, CAN material is a good binder except for the low burning rate at low pressure.

The research project has produced propellant formulations, that once optimized, could potentially present viable candidates for transition to current and future weapon systems.

9 Future Plan

U.S. Side

Continue to develop CAN based propellant for other applications. Discussions to continue under artillery DEA and possibility of future cooperation to be explored.

Japan Side

Integrating LOVA propellant into the charge system in service and demonstrating LOVA propellant system for 155mm Howitzer.