GENERAL DYNAMICS
Ordnance and Tactical Systems–Canada





#10595 - **Gun Tube Wear Reduction for 105 mm Artillery**

May 18th, 2010

Thomas Boncompain
Project engineer
450-581-3080 ext. 8507

PRESENTATION SUMMARY

- Initial Problem
- Gun Wear Mechanism
- Technical Approach
- Selected Wear Reducing Additive
- Selected Liner Design Configurations
- Barrel Measurement Assessment
- Test Results
- Way Ahead
- Conclusion

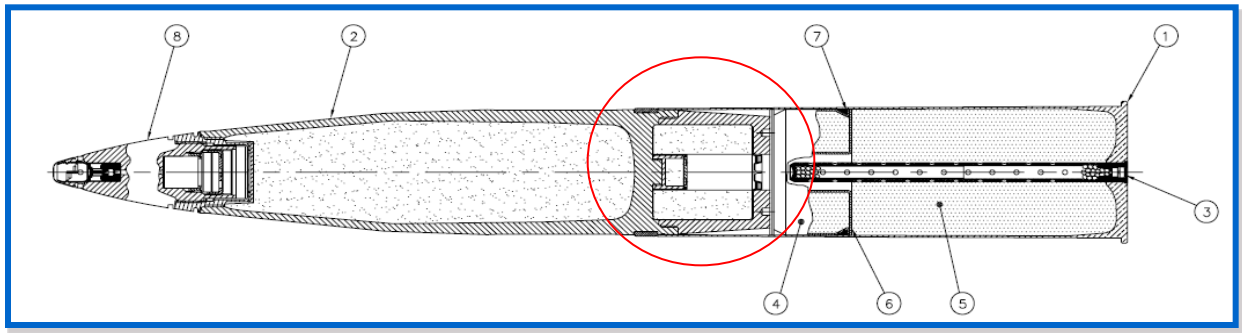
INITIAL PROBLEM

- **System Description**
  - Cartridge -105 mm C132 ER Artillery

	Muzzle velocity	Range	Propellant
Zone 1	579 m/s	14.4 km	Bulk Propellant
Zone 2	733 m/s	18.5 km	Bagged Propellant

INITIAL PROBLEM

Cartridge description



Propellant Bag

Bulk Propellant retained by a Combustible Separator

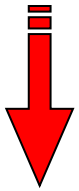
Propellant Bag

INITIAL PROBLEM

Problem Description

High Wear Rate: 1 µm /shot

Reduced Gun Performance



Frequent Barrel Replacement

Increased Lifecycle Costs

GUN WEAR MECHANISMS

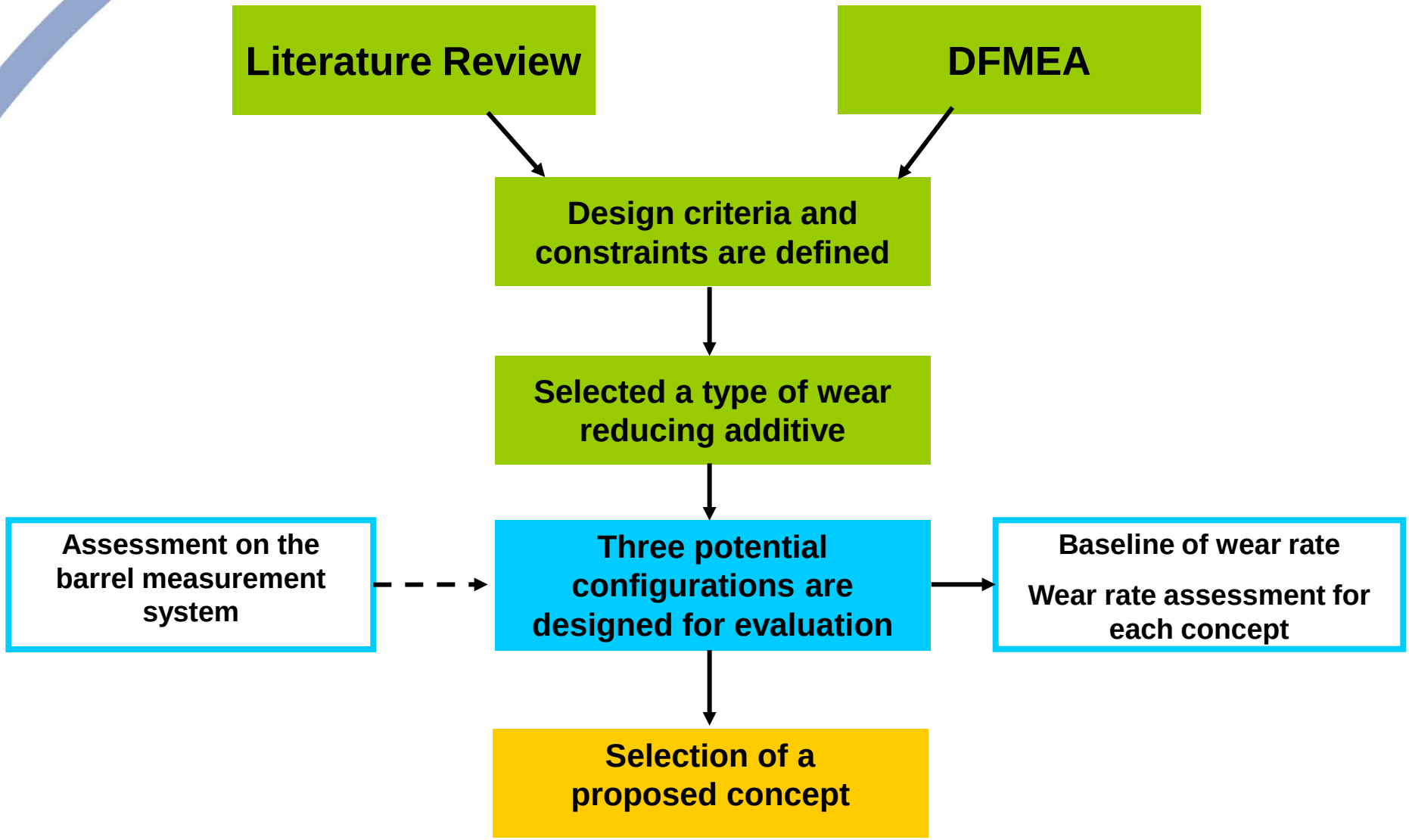
Wear

Thermal
- Gas Temperature
- Heat Transfer
- Firing Rate

Mechanical
- Gas Pressure
- Driving Band Engraving and Projectile Sliding Resistance

Chemical
- Products of Combustion

TECHNICAL APPROACH



TECHNICAL APPROACH

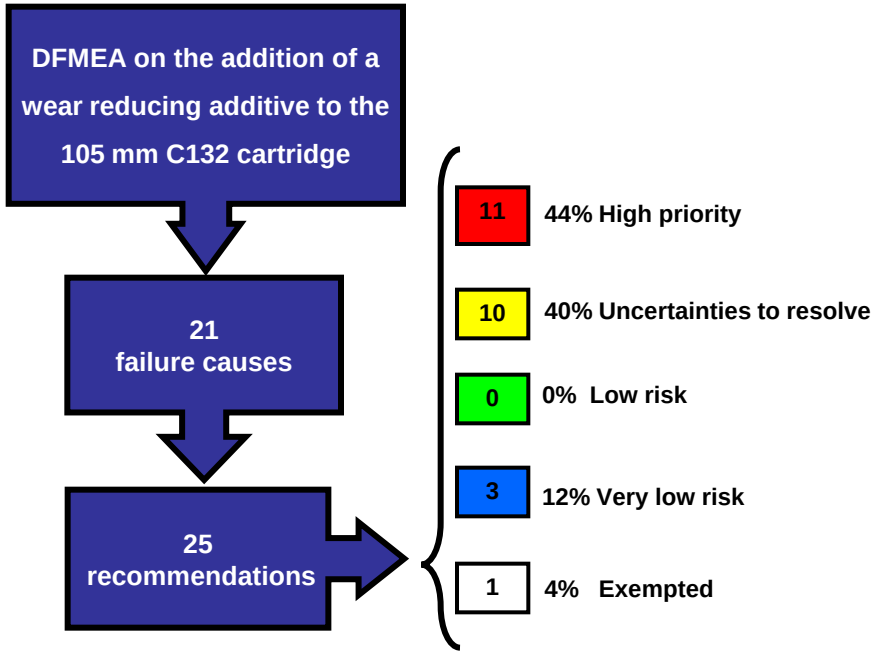
LITERATURE REVIEW

- Better understanding of barrel erosion mechanism (thermal, mechanical, chemical)
- Review of the various wear reduction additive and performance
- Wear reducing liner manufacturer is contacted: Akers Krutbruk (Swedish additive: TiO_2 /wax)
- Design criteria and constraints are established

TECHNICAL APPROACH

DFMEA

- DFMEA: Analysis method used in engineering to document and explore ways that a product design might fail in real-world use



- Recommendations resulted in the following:
  - Test to be performed (vibration, compatibility, BBU…)
  - Design criteria's and constraints (positioning, quantity…)

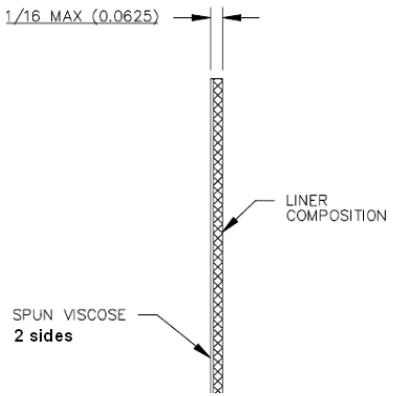
TECHNICAL APPROACH

- **Most important Design Criteria's and Constraints**
  - No wear reducing additive should be positioned in front of the BBU
  - Wear reducing additive should weight no more than 4% of Full Charge
  - Positioning is more important than quantity
  - Additive should be placed further ahead of the charge as possible
  - The combustible separator of the bulk propellant shall not be removed

- DFMEA
- Akers Krutbruk
- Literature review

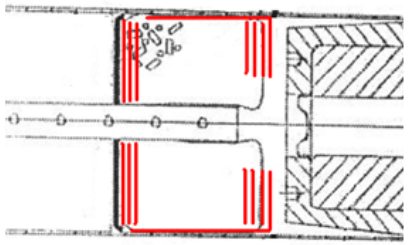
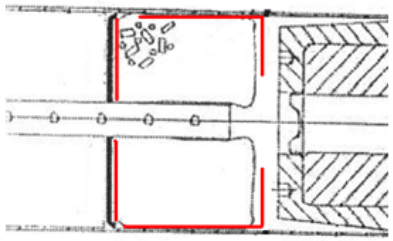
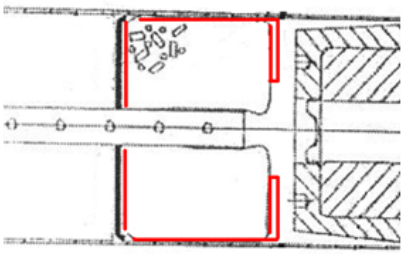
SELECTED WEAR REDUCING ADDITIVE

- Wear reducing candidates: Talc/wax; TiO_2/wax; Polyurethane foam
- TiO_2/wax is the best wear reducing candidate for the 105 mm HE C132 based on available information and historical results on similar applications.
- Two suppliers are identified for this product:
  - GD-OTS Canada
  - Akers Krutbruk

Additive (TiO_2/wax)	Akers Krutbruk	GD-OTS Canada
Drawing		
Chemical composition	Titanium dioxide 45-55 % Microwax 45-55 % Stearylic alcohol 0,5-1,5 % Rayon fabric Polyester foil	Titanium dioxide 55.2 % Paraffin wax 45.3% Stearylic alcohol 10% of mix max. Cloth spun viscose Gauze reinforcement
Melting point	Melting point 85 - 95 (°C)	Melting point 56 - 59 (°C)

SELECTED CONFIGURATIONS FOR EVALUATION

- 3 configurations are proposed for test evaluation
- Liner positioning will be above the combustible separator
- Addition of a wear reducing liner around the removable charge
- The liner will not be glued to the cartridge case

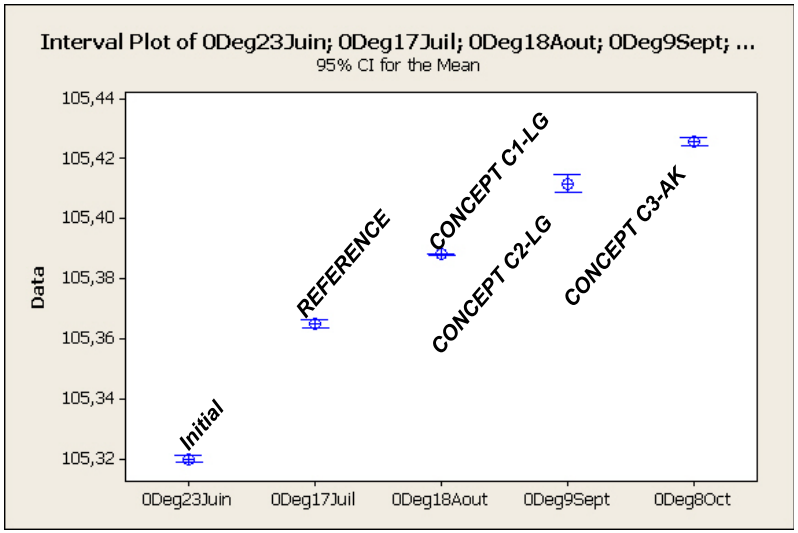
Configuration	C1 - LG	C2 - LG	C3 - AK
Layout			
Supplier	**GD-OTS Canada**	**GD-OTS Canada**	Akers Krutbruk
Additive weight	76 g	44 g	61 g
% Charge weight	3.7%	2 %	2.8 %
Full charge weight	2 052 g	2 152 g	2 152 g

Reduced Charge Weight

BARREL MEASUREMENT ASSESSMENT

- **Gauge R&R measures the amount of variability induced in measurements by the measurement system itself**
- **Gage R&R results**
  - Improvement of the repeatability of the Bore Gage
  - Increased number of measurement at critical location (2763 mm)
- **Required shots per evaluation**
  - Statistical analysis to determine the required number of rounds to fire per concept
- **Measurement location for sentence on wear rate reduction performance**
  - 2763 mm from the muzzle face

Distance from the muzzle face	Angles	Number of measurements per Land	Number of measurements per Groove
30 mm	0° et 90 °	3	3
100 mm	0° et 90 °	3	3
1400 mm	0° et 90 °	3	3
2550 mm	0° et 90 °	3	3
2610 mm	0° et 90 °	3	3
2763 mm	0°, 45°, 90°, 135°	10	3



TEST RESULTS

Areas of concern

- **BBU Performance:** Following 55 shots of the standard 105 mm C132 and 163 shots of the 105 mm C132, all the BBU initiated without any evidence of malfunction
- **Pressure:** There is a slight increase in pressure
- **Muzzle velocity:** No effect on muzzle velocity for equivalent full charge therefore the range is maintained

Configuration	Pressure at +21 °C in LGI (SD)	Propellant charge state	Muzzle velocity at +21 °C *Req. 715 ± 8 m/s*		Measured wear rate	
			Average	Standard deviation	Absolute	Reduction %
Reference (no liner)	297 MPa (3.8)	Full	713.4	1.5	0.977 µm / Shot	-
4 % with liner C1-LG	275 MPa (2.0)	Reduced	690.5	2.6	0.477 µm / Shot	50.00 %
2 % with liner C2-LG	300 MPa (4.8)	Full	713.5	1.8	0.588 µm / Shot	38.75 %
3 % with liner C3-AK	301 MPa (3.5)	Full	713.6	1.5	0.422 µm / Shot	55.00 %

TEST RESULTS

Liner Concept Advantage and Disadvantage Comparison

Configuration	C1- LG (4%) (- 50% wear)	C2 - LG (2%) (- 39% wear)	C3 – AK (3%) (- 55% wear)
Wear rate performance	++	+	+++
Firing table required	yes	no	no
Range	- 544 m	+ 0	+ 0
Pressure @ + 21°C	OK	OK	OK

TEST RESULTS

- **Preferred Wear Reduction Additive (3% charge weight)**
  - C3-AK : Liner Akers Krutbruk with no effect on range
    - (+) 18.5 km range maintained
    - (+) Wear reduction of 55 %
    - (+) Preferred liner for the modification of the cartridge on a production line
    - (+) Higher liquefaction temperature

WAY AHEAD

- Packaging and design optimization including end user input
- Preliminary vibration analysis
- Preliminary thermal cycling
- Confirmation of maximum pressures in @ +63 ºC
- Reconfirmation of wear in tube between 1/8 and ¼ life @ +21ºC
- Range validation following sequential environmental test

TECHNICAL CONCLUSION

Conclusion

- With a well positioned additive with the right quantity, It is possible to reduce wear
- Our proposed solution increases barrel life by 55%
- No effect on range
- Implementing a C132 wear reduction solution is technically feasible
- Activities for the way ahead have been established
- Minimal Qualification is anticipated

QUESTIONS