

**PVTT**

*Enabling unthinkable*

# ***Underwater Performance Demonstrations and IM Responses of Two Insensitive Explosives***

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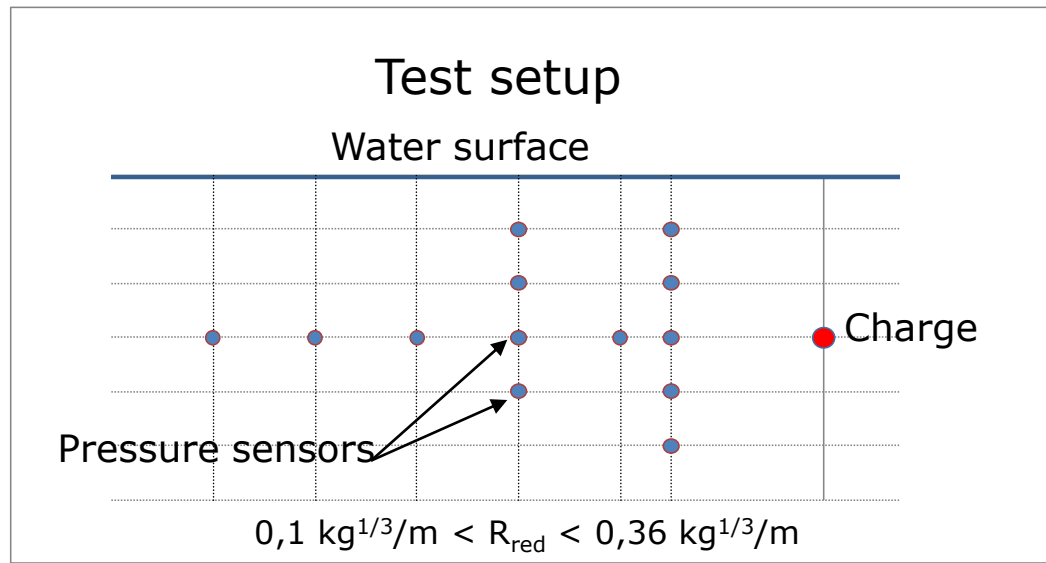
# Background

- FPX V40 explosive has shown extremely good detonation characteristics in DFC application having remarkably better performance than competing products
- Underwater performance parameters were measured since FPX V40 is also explosive fill in BOXER underwater mine disposal charge
- TNT and FOXIT were used as reference explosives since TNT is extensively tested in various applications and FOXIT is proved to be effective but extremely insensitive underwater explosive





# Underwater measurements



## Measured parameters

- Maximum pressures,  $P_{\text{max}}$
- Time, s

## Calculated parameters

- Time constants,  $\theta$
- Shock Impulses,  $I_{\text{shock}}$
- Shock energies,  $E_{\text{shock}}$





# Detonation parameters of the studied explosives

- Detonation velocities and pressures
  - TNT 6900 m/s ; 18 GPa
  - FPX V40 6600 m/s ; 17 GPa
  - FOXIT 5500 m/s ; 11 GPa
- Detonation energies according to modified Kistiakowsky-Wilson rule
  - TNT  $Q = 4250$  kJ/kg
  - FPX V40  $Q = 7280$  kJ/kg (H-6:  $Q = 7270$  kJ/kg)
  - FOXIT  $Q = 8030$  kJ/kg (HBX-3  $Q = 8930$  kJ/kg)
  - TNT / Al (60/40)  $Q = 8470$  kJ/kg
- Detonation power ( $Q \times V$ )
  - TNT  $Q \times V = 315$  kJl/kg<sup>2</sup>
  - FPX V40  $Q \times V = 435$  kJl/kg<sup>2</sup> (H-6:  $Q = 416$  kJl/kg<sup>2</sup>)
  - FOXIT  $Q \times V = 413$  kJl/kg<sup>2</sup> (HBX-3  $Q = 328$  kJl/kg<sup>2</sup>)
  - TNT / Al (60/40)  $Q \times V = 201$  kJl/kg<sup>2</sup>



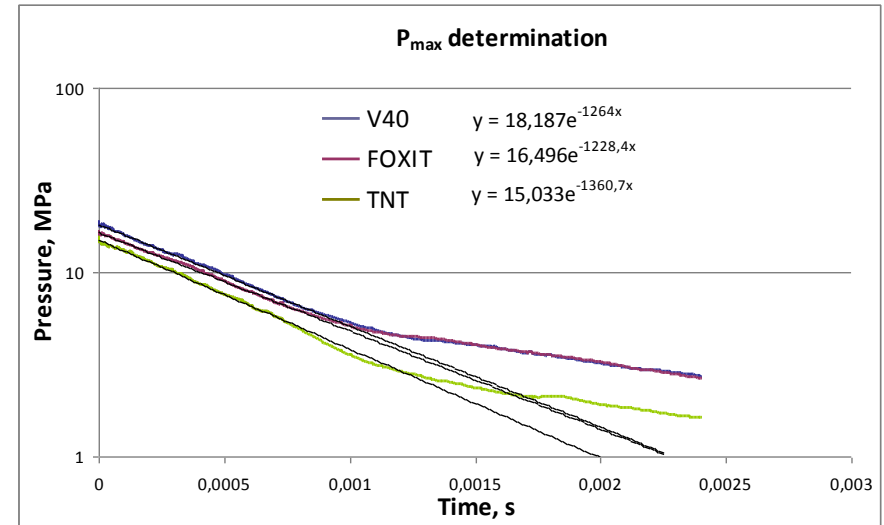
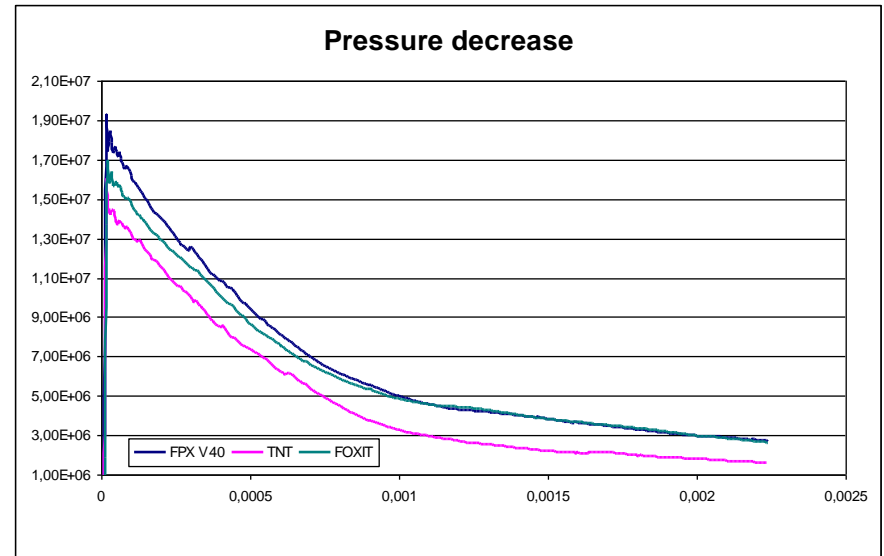


# Maximum pressures

- Pressure decrease

$$P = P_{\max} e^{-t/\theta}$$

- Time constant,  $\theta$  is the slope of the initial linear part in the logarithmic graph
- $P_{\max}$  is calculated from the equation of this initial linear part of the exponential curve



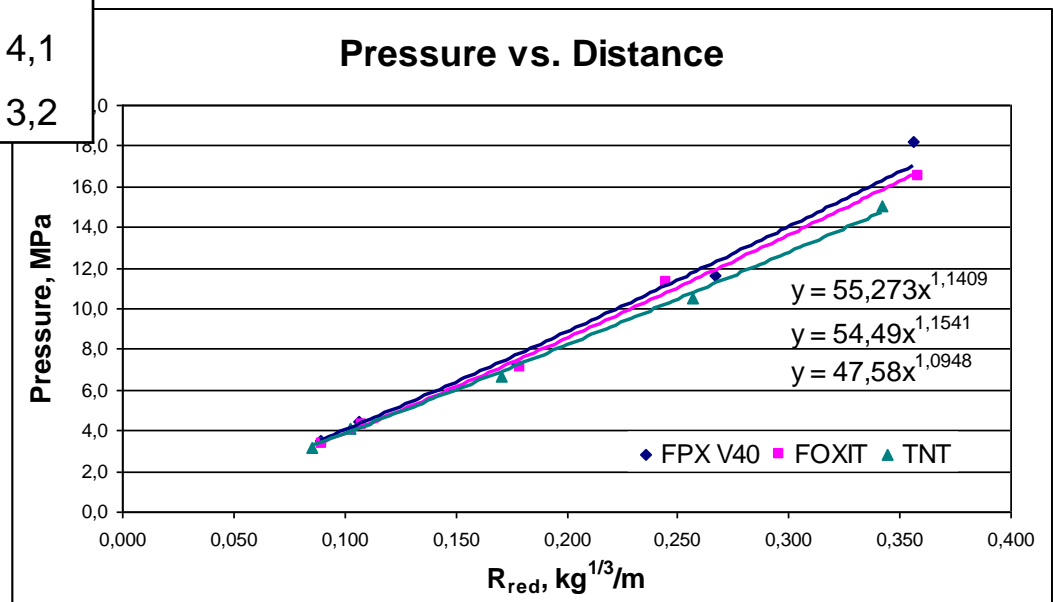


# Maximum pressures

V40		FOXIT		TNT	
$R_{red}$	$P_{max}$	$R_{red}$	$P_{max}$	$R_{red}$	$P_{max}$
0,356	18,2	0,359	16,5	0,342	15,0
0,267	11,6	0,245	11,3	0,256	10,5
0,178	7,3	0,179	7,1	0,171	6,7
0,133		0,135		0,128	
0,107	4,5	0,108	4,3	0,103	4,1
0,089	3,5	0,090	3,3	0,085	3,2

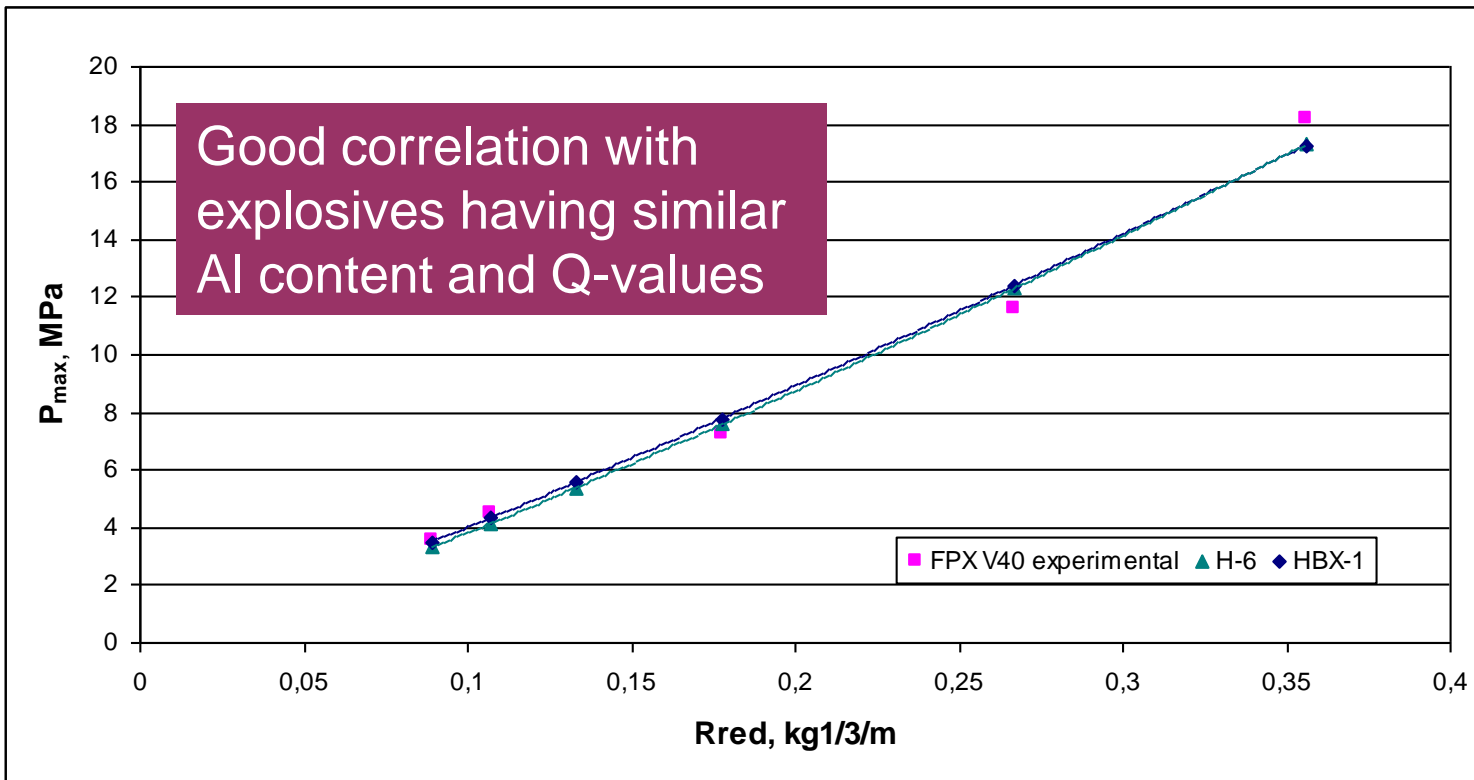
- Despite lower  $P_{CJ}$  values, FPX V40 and FOXIT showed higher maximum pressures than TNT
- Results are consistent with literature values

In addition to gentle slope of the pressure drop as a function of time, in aluminized compositions, max pressure seems to remain higher also as a function of distance.





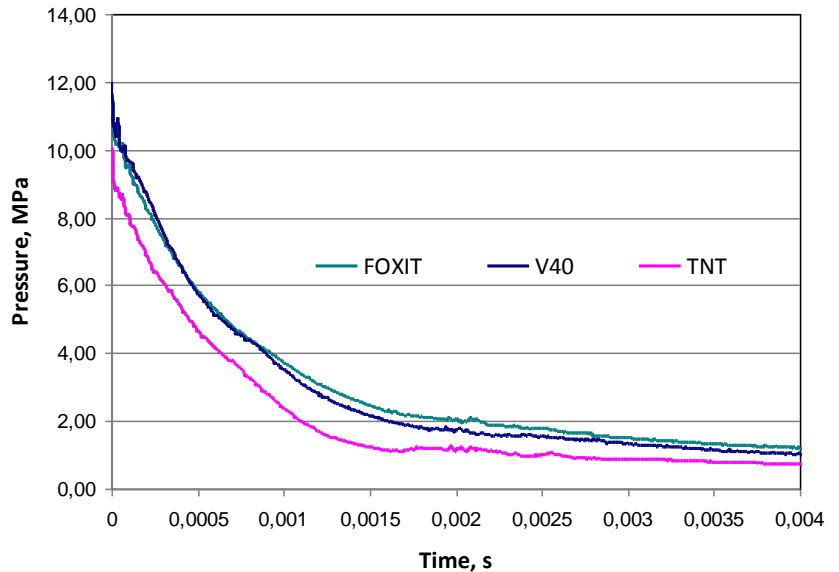
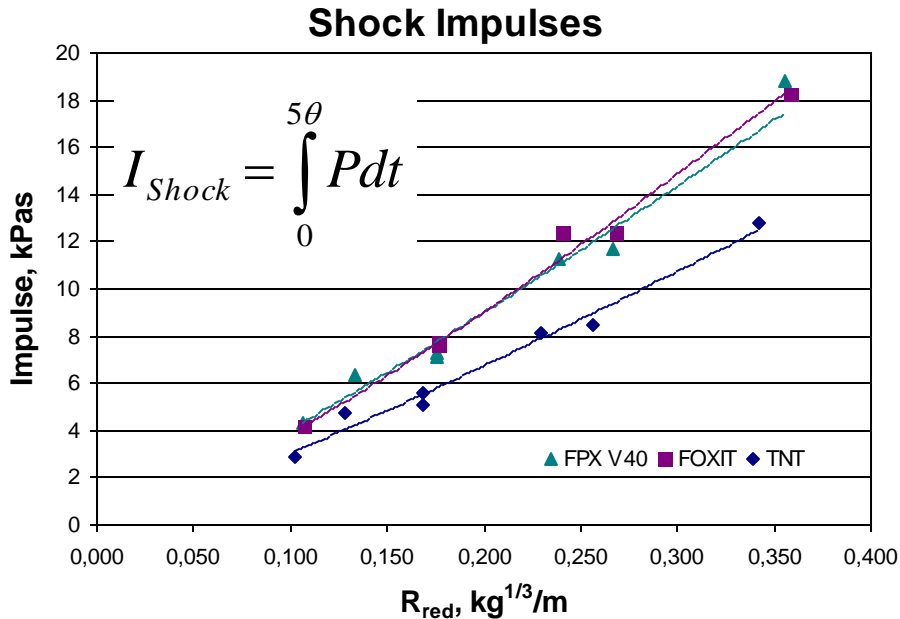
# Maximum pressures - Experimental vs. Literature





# Shock impulses

- FPX V40 and FOXIT showed much higher  $I_{shock}$  values than TNT
- FOXIT has even higher  $I_{shock}$  than FPX V40



**FOXIT showed the highest  $I_{Shock}$  values**

- Lower  $P_{max}$
- + Low gradient of pressure drop
- + Pressure remains higher for longer time

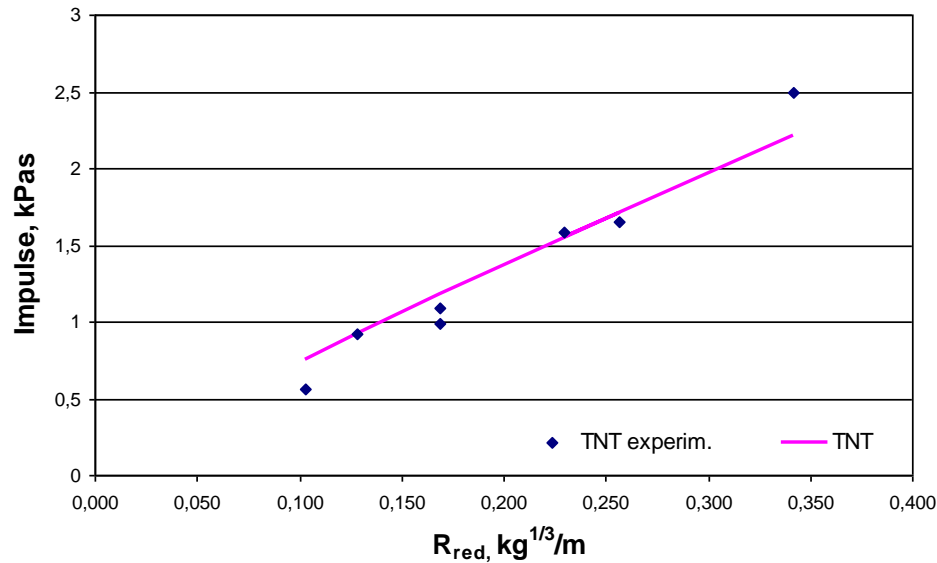
**Higher Al content and Q value**







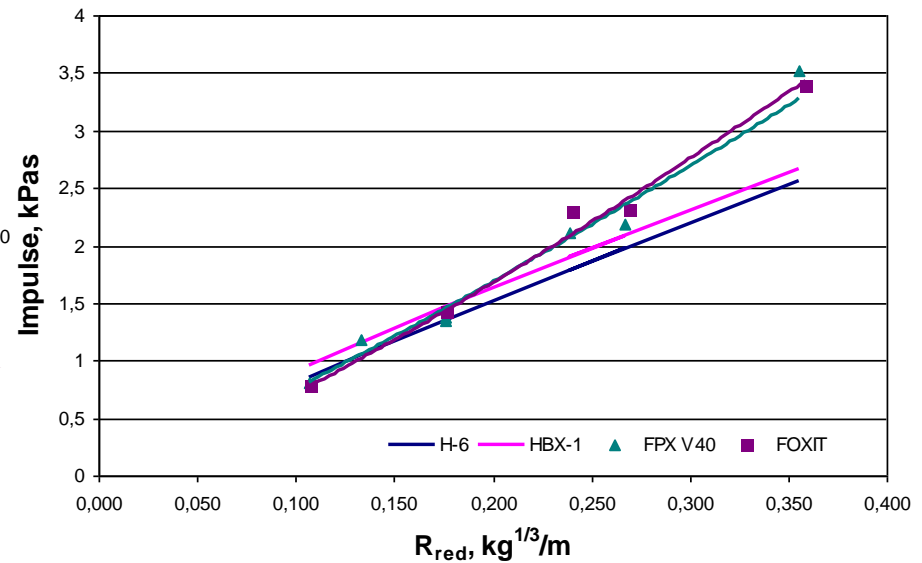
# Shock impulses – Experimental vs. Literature



TNT results correlate quite well with literature values

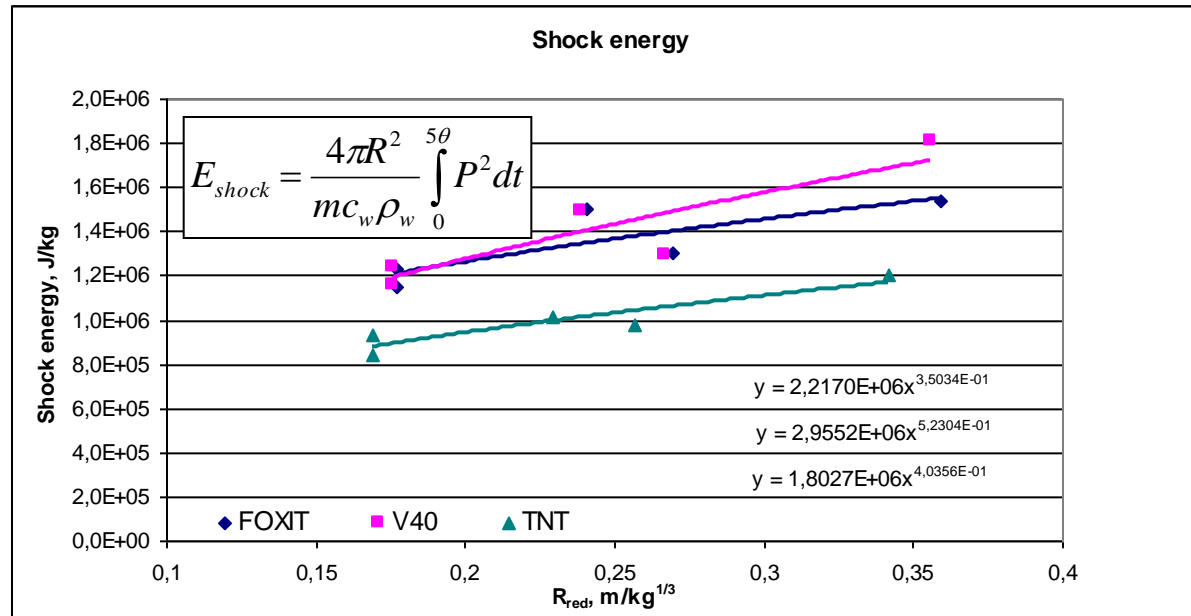
At shorter distances FPX V40 and FOXIT have higher  $I_{shock}$  values than H-6 or HBX-1

Because of higher oxygen content?





# Shock energy



- FPX V40 has the highest  $E_{shock}$  value, although  $I_{shock}$  was lower than for FOXIT
  - Shock energy difference increased with decreasing distance to charge in favor of FPX V40
- Despite higher detonation values ( $VoD$ ,  $P_{CJ}$ ), TNT showed lower  $E_{shock}$  values at all measured distances
  - The  $E_{shock}$  values were lower even if the shock compensation coefficient is taken into account





# IM responses - FPX V40

- Unfortunately the IM testing of BOXER has been delayed, and although the testing has begun, no results are available at this point.
- FPX V40 has been extensively tested in Forcix's DFC, where IM properties have been verified as follows

Test	Reaction level
Bullet Impact	V, No reaction
Fast Heating	V, Burning
Slow Heating	V, Burning
Sympathetic Reaction	V-VI, Burning / Deflagration
Fragment Impact	V, Burning
Shaped Charge Jet	I-II, Detonation / Partial Detonation





# Conclusions

- According to these results
  - FPX V40's underwater performance is superior to TNT, H-6 and HBX-1/3
  - High pressure stage of shock lasts longer increasing the shock impulse
  - Shock energy is higher than FOXIT's especially with short distances from the charge
- IM test results show that insensitiveness does not compromise high energy content or detonation performance





# *Thank You for Your Attention*

From the song

## The Blackest Ace

Fortuna balls  
Lips of eager women  
Lady Luck thanks the brave man  
Carves a notch on the headboard

Life is the color of the missing card

I played away my homestead – ridgepole and  
all

The blackest ace, the mirror of soul

If I didn't win with these, I lost

Now the blackest ace is the mirror of soul

~ **VIIKATE** (= Scythe)

Orig. lyrics Kaarle Viikate

Engl. translation Marko Niskapohja

