Heavyweight Torpedo warhead IM assessment

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ABSTRACT

Thanks to its stealth, range and fire power, the F21 heavyweight torpedo gives client navies an unrivalled tactical advantage over all threat. Exploiting a range of innovations and advances in torpedo technology, a single F21 can knock out any surface combatant or submarine. The high energy density primary battery offers both high maximum speed and extended range while the new-generation acoustic head guarantees improved search efficiency from very shallow to deep waters. Fully digitalized technologies result in improved signal processing and enhanced overall performance.

The F21 complies fully with the demanding safety requirements applicable to nuclear-powered submarines. Regarding to the warhead insensitivity, this high requirement level is reached because the ammunition embeds live improved IM components such as an RDX/Al/AP cast cure substance for the main charge and thermal igniter. Moreover, its specific internal rubber based Thermal Protection gives some additional surviving characteristics against thermal threat such as external fire.

IM assessment was performed according to a rigorous process. This paper will describe the design principles and focus on results obtained against full scale tests such as shaped charge test.

1. INTRODUCTION

The Insensitive Munition (IM) assessment is realized according to STANAG 4439 in order to determine ammunition responses for threats defined in AOP 39. In case of F21 torpedo development, the IM assessment has been performed according to a rigorous process to respond to STANAG 4439, but also to all threats in operational situations. NAVAL GROUP and EURENCO have worked as a team on this project and have developed an IM warhead for the F21 heavyweight torpedo, currently in mass production.

This paper describes the design principles and focus on results obtained against full scale tests and especially shaped charge jet impact.

2. THE F21 HEAVY TORPEDO

The F21 torpedo is ending its development and is now in qualification step. It is the only torpedo development program today in the world. It benefits from all new technologies and permits to offer a great tactical advantage. Some characteristics are given in the table below:

Characteristics	Value
Length	6 m
Weight	1500 kg
Diameter	533,4mm
Range	> 50 km
Speed	> 50 knots
Propulsion	Electric
Guidance	Automatic or pilotage by optical fiber

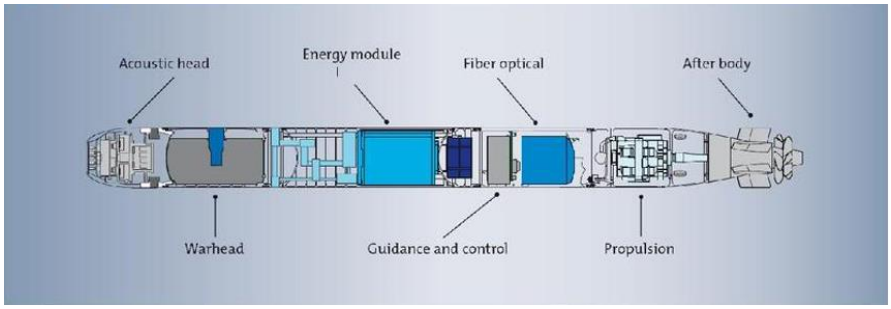
Thanks to its stealth, range and fire power, the F21 heavyweight torpedo gives client navies an unrivalled tactical advantage over all threats. The high energy density primary battery offers both high maximum speed and extended range while the new-generation acoustic head guarantees improved search efficiency from very shallow to deep waters. Fully digitalized technologies result in improved signal processing and enhanced overall performances .

The F21 torpedo has been developed with safety requirements applicable to nuclear-powered submarines. Besides great performances, all torpedo design drivers are thought on safety (warhead, primary battery…).

This paper focuses on the warhead section, which is qualified by French National Authority and already in service in one other client Navy, its design and security tests.

3. GENERAL DESCRIPTION OF THE WARHEAD

On the F21, the warhead is located in the front of the torpedo. The warhead section is mechanically and electrically connected with the Acoustic Head Section (AHS) in the front and with the Primary Battery in the rear.



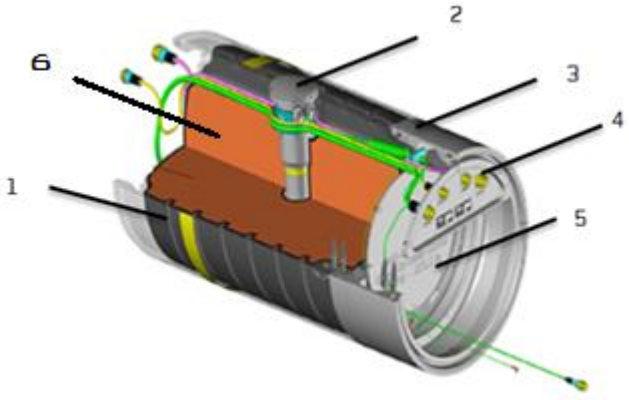
The F21 warhead is an anodized aluminium hull build in foundry. It contains three compartments:

- A chamber for the explosive loading,
- an impact fuze compartment
- a tunnel parallel to the axis for passing the electric cables between the acoustic head, in front of the torpedo, to the others torpedo sections. The crossing cables are located at the top of the hull. Its isolates cables and the explosive loading (Figure 1 : The F21 warhead).

This structure allows to resist to the pressure at the maximum depth.

The explosive loading is composed by :

- One cast-pbx main explosive charge B2211D (250 kg Net Explosive Weight),
- One thermal protection
- One fuze varnish



Mark	Designation
1	Aluminium hull
2	Impact Fuze
3	Cables
4	Connectors
5	Closing plate
6	Explosive loading

Figure 1 : The F21 warhead

Physical characteristics of the F21 warhead section are:

- Overall length : 1028 mm
- Diameter : 533,4 mm

4. MAIN EXPLOSIVE CHARGE CHARACTERISTCS

The explosive is designed by EURENCO, the Naval Group partner. It's an composite explosive B2211D composed by:

- ammonium perchlorate
- aluminium
- I-RDX® , insentive grade designed by EURENCO
- HTPB based inert binder

The F21 warhead contains 250kg of B2211D (350kg equivalent TNT). Some performance characteristics of B2211D are given below are (MSIAC's database source):

Density (kg/m^3)	1810
TNT equivalent (Peak pressure)	1,4
Detonation velocity (m/s)	5500

B2211D is an RDX/AP/Al HTPB-based cast-cure explosive, specifically designed for underwater applications and used in many warheads design since more than 30 years.

Results of some safety characteristics are given below (Source : MSIAC database):

B2211D	
Density	1810kg/m^3
Auto-ignition Temperature (STANAG 4491)	>200°C
Critical Diameter	76 mm
Friction sensitivity (AOP-7-STANAG 4489)	33J
Impact Sensitivity (AOP-7-STANAG 4487)	70N
Shock gap test (AOP-7-STANAG 4488)	80 cards
Capacity discharge (AOP-7-STANAG 4490)	No reaction

5. THERMAL PROTECTION

The thermal protection was developed in order to create thermal insulation between the aluminium hull and explosive. It delays temperature rising of the explosive in warhead section in case of external fire or any thermal attacks during life cycle.

The specific rubber material used has good thermal properties and thermal conductivity.

6. THERMAL FUZE VARNISH

The thermal fuze varnish was developed specially by EURENCO to prevent severe reactions under slow heating stimuli. Indeed, the live fuze compound auto-ignition temperature under slow heating conditions is far lower than B2211D's ignition temperature. So, burning initiation will start by fuze varnish in the rear part of the warhead and initiate the combustion of the main B2211D charge when external temperature reaches a certain threshold. The combustion start point prevents inner violent reaction of the main charge exposed to internal high temperature.

Moreover, burning gazes can escape with a weak closing plate between the warhead and the primary battery in the rear. So, two sections separate easily.

7. IM Assessment

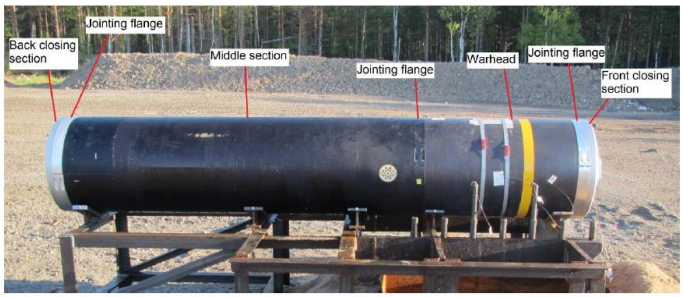
The F21 IM assessment was performed according to a rigorous process which combined analysis of experience feedback, simulations and tests.

Naval Group BU underwater weapons analyses F21 IM assessment according to STANAG 4439. Two tests are detailed in following paragraphs: fast cook-off and shaped charge jet impact.

Fast Cook-Off Test

- Demonstration : full-scale trial,
- Scope : to asses the warhead reaction under a kerosene fire,
- Applicable standard : STANAG 4240,
- Configuration : warhead with primary battery.

Warhead with primary battery



Fuel fire

Burning of main charge B2211D

End of burning

Figure 2 : Evolution in time of burning warhead

- Long burning time due to the total quantity of live material. Test performed with primary battery, no impact of the battery to the final reaction.
- No projection observed.
- Complete live material has burnt after the test
- **Conclusion : Type V (BURN)**

Shaped charge Jet Impact

Shape charge jet impact test is generally not performed because of most-likely expected Type II (partial detonation) or type III (explosion) reaction. Numeric simulations were predicting a possible type III or type IV reaction. The full-scale trial was performed to confirm or not this prediction.

- Demonstration : full-scale trial
- Scope : to asses the warhead reaction under a shaped charge jet impact
- Appicable standard : STANAG 4526
- Type of shaped charge used : RPG-7 (PG7M), see figure 3.
  - Caliber : 70mm
  - Steel armour penetration : 300mm
  - Main charge explosive : A IX-1 (96% RDX, 4% wax)
  - Net Explosive Weight : 320g
- Instrumentation :
  - steel witness plate,
  - pressure gauges,
  - high-speed camera.

Figure 3 : RPG-7 Shaped charge used for the trial

The nose cap of the RPG7 warhead was placed in direct contact with the test item and on a stand-alone of styrofoam, threaded rods and plywood. This was in the best way possible simulate a realistic scenario. The torpedo warhead was placed on steel witness plate.

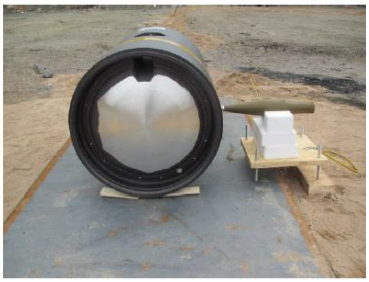


Figure 4 : Trial configuration : test specimen and RPG-7 shaped charge

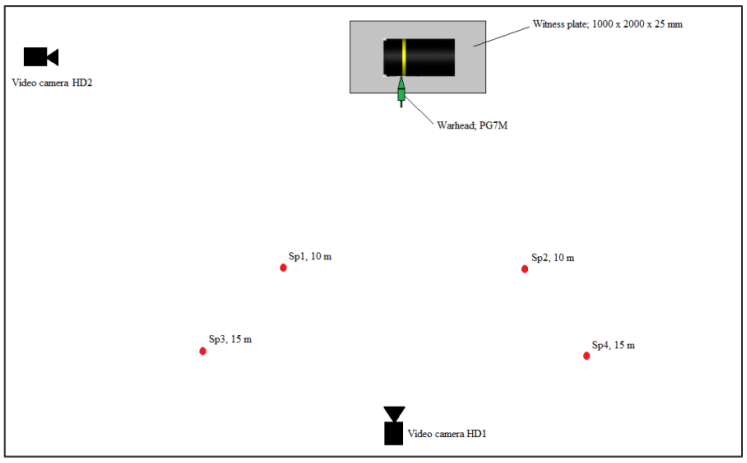


Figure 5 : Shaped charge Jet impact test layout

When the shaped charge jet hits the test item, parts and fragments from the test item are scattered around the test area (Figure6 : First seconds after shape charge ignition). The high explosive in the torpedo warhead is ignited and the test item burns with a white intensive flame for approximately 5 minutes (Figure 7 : Warhead burning).

Figure 6 : First seconds after jet has impacted the warhead

Figure 7 : warhead burning and after complete burn

Air blast pressure

The registered maximum air blast pressure values are shown in the following table. It is assumed that most part of this air blast pressure is caused by the PG7M warhead detonation itself.

Registered maximum air blast pressure values (kPa)			
Sp1, 10 m	**Sp2, 10 m**	**Sp3, 15 m**	**Sp4, 15 m**
10.1	10.7	6.0	6.4

Witness plate

No penetration holes or detontation evidence can be seen after the test, as shown in figure 9 below.

Figure 8 : witness plate after the test

Recovered fragments

Five pieces of unreacted high explosives were found, also some metallic pieces as well the front part of the warhead (Figure 10 : Front part of the warhead). This massive fragment can be observed on high speed camera, and is visible on Figure 7 (right) during the first seconds after shape charge initiation.

Figure 9 : front part of the warhead

Fragments distribution vs AOP-39 Energy / distance 20J criteria

The diagram below shows the recovered fragments : X-axis = mass of the fragment (g), Y-axis = Distance (m), compared to the 20J threshold criteria from AOP-39.

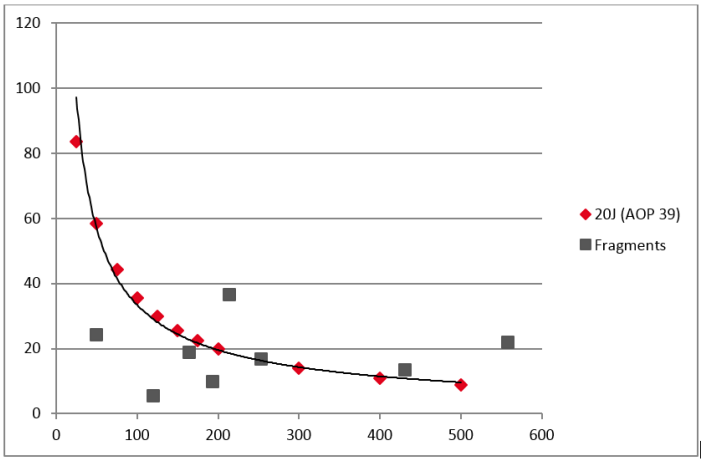


Figure 10 : Fragments distribution vs AOP-39 20J criteria

Test conclusion

According to AOP-39, the F21 warhead response is estimated as a Type IV reaction (Deflagration). Some fragments were thrown beyond 15m with an energy level greater than 20 J (Figure 10 : Fragments distribution based on the distance (m)/mass (g) AOP-39 relationship).

The maximum air blast pressure levels were relatively low and most likely caused by the PG7M warhead itself.

8. IM Signature

The IM signature was established using full-scale trials, analyses based on simulations or semi empirical tools as well as reading across experimental results obtained in equivalent configurations.

STANAG 4439 Requirements		FH	SH	BI	SR	FI-L	FI-H	SCJI
IM Signature	NR							
	V	●		❍		❍		
	IV		●					●
	III				❍		❍	
	II							
	I							

Full compliance with STANAG 4439

● : Assessment by Full-scale trial

❍ : Assessment by analysis and/or read-across with other configurations

9. CONCLUSION

The warhead of F21 heavy torpedo was designed to meet the highest standard of IM specifications. The level of reactions observed during full-scale trials such as Fast Cook-Off and RPG-7 Shaped charge jet test demonstrates that the warhead can withstand very severe stimuli which are considered as critical regarding the Navy platform.