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Environmental Simulations for EOD Shaped Charges

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Environmental Simulations for EOD Shaped Charges

This article describes the methodology and importance of environmental simulations and testing of shaped charges used for the disposal of explosive remnants of war and landmines. The author discusses a single sequence of tests conducted on a specific product as an example of the depth to which environmental factors should be investigated in order to address them before final production and manufacture.

by Reto Liechti [Saab Bofors Dynamics Switzerland, Ltd.]

Vibration caused by transportation, temperature changes and the natural aging process, as well as other environmental factors, can impact the safe operation of a product. Assessing environmental effects on a product can be time-consuming and expensive. However, in the case of explosive ordnance-disposal equipment, environmental simulations and testing are basic tools for the scientific investigation and production of safe new products.

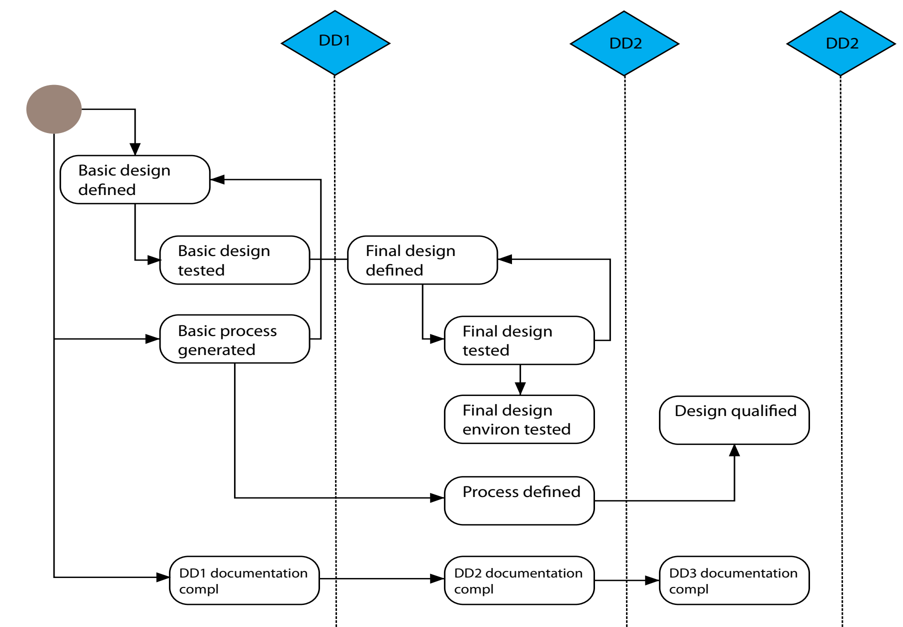

Figure 1. Diagram of development phases.
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The Need for Environmental Simulations

When handling explosives, safety and reliability are key factors for a successful mission. In demining operations with *in situ* disposal, shaped charges are often used, especially when inducing deflagration of submunitions (cluster bomblets). Thus, using shaped charges speeds up operations and minimizes hazardous risks to deminers.

Many shaped charges are available on the market. Any of these charges used in the field can cause harm if not used properly. The shaped charges referred to in this article are proven through a program of extensive environmental tests, not only in their development phase but also throughout the manufacturing stage. These environmental test programs include assessment, clearance checks (to ensure operators can handle them) and transport-vibration checks (to test for worst-case land, sea and air conditions). Environmental tests also consider extreme environmental aggression such as rapid and extensive changes in temperature, pressure, humidity and adverse immersion environments such as sand, dust storms and water. These tests guarantee the product can withstand different circumstances and provide full performance until the end of its anticipated life cycle.

Development Phase

Environmental simulations are often performed either before a product is in its early development phase or when a product is about to enter the market and go into service. Development phases are usually detailed programs with a number of activities and individual phases that some countries refer to as a series of Design Definitions. The content for each DD phase varies from one project to another but generally takes the form as illustrated in Figure 1.

Test Program

A test program can be performed with many individual and independent experiments that focus on individual test events. These tests do not represent real circumstances, and therefore a test program combines a variety of tests and possible scenarios either in parallel (each test performed independently) or in a sequence. Combinations are the most common and realistic approach. Figure 2 (right) shows six typical test sequences which are performed in parallel for the SM-EOD 33[1] explosive shaped charges. Each sequence can vary in the number of tests, and this example shows one or two tests in each sequence followed by an X-ray inspection and a static detonation at the end of each sequence.

Sequence

In order to discuss a sequence for environmental testing, one sequence of the tests will be more closely examined now. Each test is dependent on its predecessor. With this dependence, potential failures can be summed; this summation results in better estimates than the product's mechanical limit of the product (see Figure 3 page 72).

Images 1 and 2. Rain plant setup.
All photos © Saab Bofors Dynamics Switzerland Ltd.

Standards and Specifications

All tests should be according to certain test-method type standards such as:

- MIL STD 810[2]: Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
- MIL STD 331[3]: Department of Defense Test Method Standard for Fuze and Fuze Components, Environmental and Performance Tests
- STANAG 4370[4]: Environmental Testing (AECTP 300[5] & 400)[6]
- IEC 60068-2-Series[7]: Environmental Testing

Vibration Test

High-cycle fatigue materials performance[8] is commonly characterized by an S-N curve (S = stress, N = cycles to failure), also known as a Wöhler-curve. A vibration test simulates the effect with vibrations often experienced during transportation and operation. The test attempts to cover all occurrences the product will encounter during its product life cycle. In the case of explosive charges, the more intense the vibration environment, the faster the aging process occurs and the higher the possibility of discovering cracks and gaps in between the explosive filling and the mechanical body.

X-ray inspection will prove if the vibration tests had any influence see Figure 3). In this illustrative example, the procedure is undertaken according to MIL STD 810E, method 514.4, category one (basic transportation) with the following characteristics:

Vibration test specifications.

Configuration	Products in original packaging
Vibrator V 964	Horizontal, transversal and vertical axis vibrations
Frequency	10 - 500 Hz/1.04 g
Testing time	1 h per axis (3 axis)
MIL STD	MIL STD 810E, Meth. 514.4, Fig. 514.4 -1
Number of test pieces	n = 30 – batch no. 2050 – 2079
Packing	Wooden box no. 047 with polystyrene-foam
Temperature	Room temperature

Rain Test

The rain test simulates a strong rainfall on the field. In this illustrative example, a method of a 360-degree rain toward the product with specific intensity for a certain time was chosen. The details are as follows:

Rainfall test specifications.

Test order-No.	4182 09682 and 4185 09690
Used facility	Rain plant No. 80
Frequency	10 - 500 Hz/1.04 g
Type of test	Rain test unpacked
MIL STD	According to 810D, meth. 506.2
Rain quantity	100 mm/h, wind velocity 18 m/s
Duration	30 min.
Rotary table	Turning

The rain test determines the effectiveness of seals and cases in preventing water penetration. The test also shows the product capability to satisfy performance during and after exposure to water.

X-ray Inspection

An X-ray inspection is performed after each individual environmental test in a sequence. It is a real-time nondestructive subsurface inspection and shows the product's internal characteristics. The inspection is a dynamic 360-degree live image where the object is rotated in front of the X-ray source. During a visual inspection by trained operators, the X-ray will indicate any hairline cracks or air gaps.

The advantage of the X-ray inspection is that no harm will reach the product, but it will provide full information about the object's density, which is directly linked to quality and performance. Any cracks or gaps detected would expectedly have a negative impact on product performance and accuracy.

Performance Test

In addition to all previous tests, a final performance test simulates a mine or unexploded ordnance-disposal operation where, for instance, a mine body or artillery shell requires penetration before deflagration or detonation. The setup for such a performance test with a defined target can utilize multiple rolled homogenous armor plates as shown in the Images 4 and 5.[9] The penetration will show any performance problems such as variation, dispersion or inadequate penetration of the jet's tip that may not be detectable in any of the previous tests. The requirements for the performance penetration test are that it must be reproducible and permit comparisons to identify penetration performance, which is the most important testimony of a high-quality product. In the field, high accuracy and reproducibility will permit fast intervention and safe and successful operations.

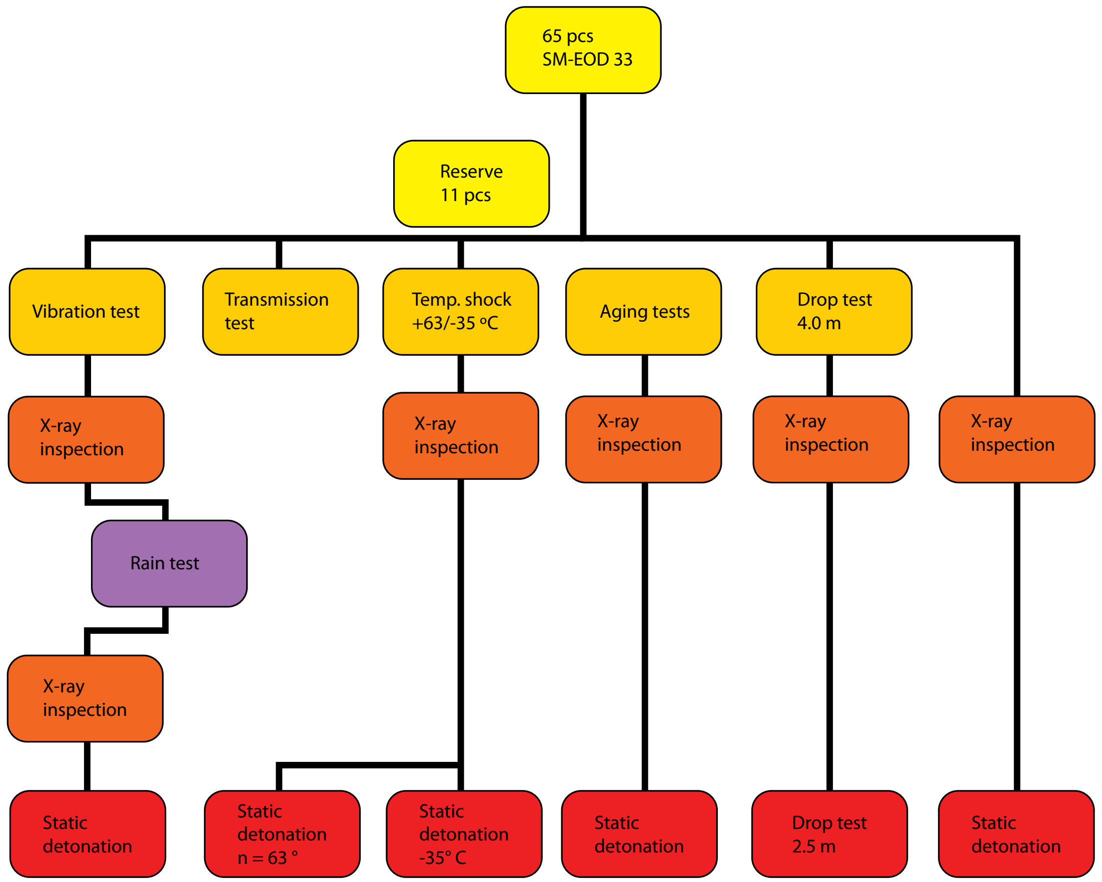


Figure 2. Example of a test program.

Performance test specifications.

Test order-No.	33, charge 18
Used facility	Bunker No. 3
Type of test	Rain test unpacked
Test temperature	+ 7° C (44° F)

Additional Tests

In addition to the tests described above, the SM-EOD 33 products are subject to:

- Sand and dust tests
- Heat and cooling tests
- Water dip tests
- Visual structural inspections
- Weight inspections
- Size and density inspection of explosives

Independence

Environmental simulation and testing can have a higher credibility if a neutral, independent company performs the testing and analysis. An external laboratory without any affiliations to the supplier is common. However, not all laboratories can undertake tests with explosives, which in the case of explosive products, limits the number of test suppliers available.

Conclusion

This article discusses a single sequence of tests conducted on a specific product as an example of the depth to which environmental factors should be investigated in order to address life-cycle problems before final production and manufacture.

Image 3. Dynamic X-ray inspection.

In the early development phase of most products, environmental simulations and testing can uncover potential future risks and reduce the eventual time to market. Simulations and testing can improve designs and ensure the product is safe and reliable throughout its full life cycle. These environmental assessments can be time-consuming and expensive, but assessment prior to product use in the field is more economical and ethical than marketing untested products that may result in considerable damages and loss of life.

See endnotes page 83

Images 4 and 5. Penetration performance witness.

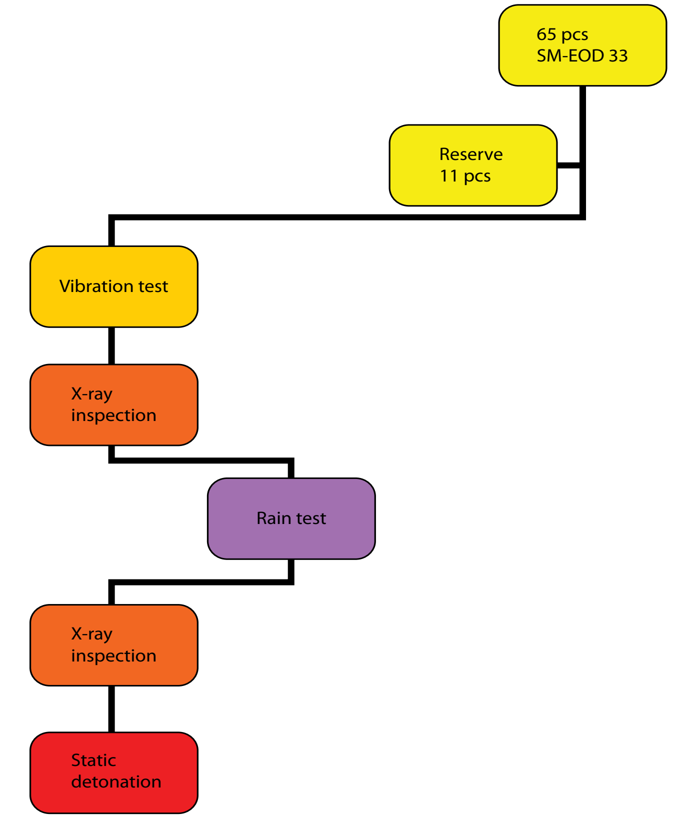


Figure 3. Single sequence of test program.

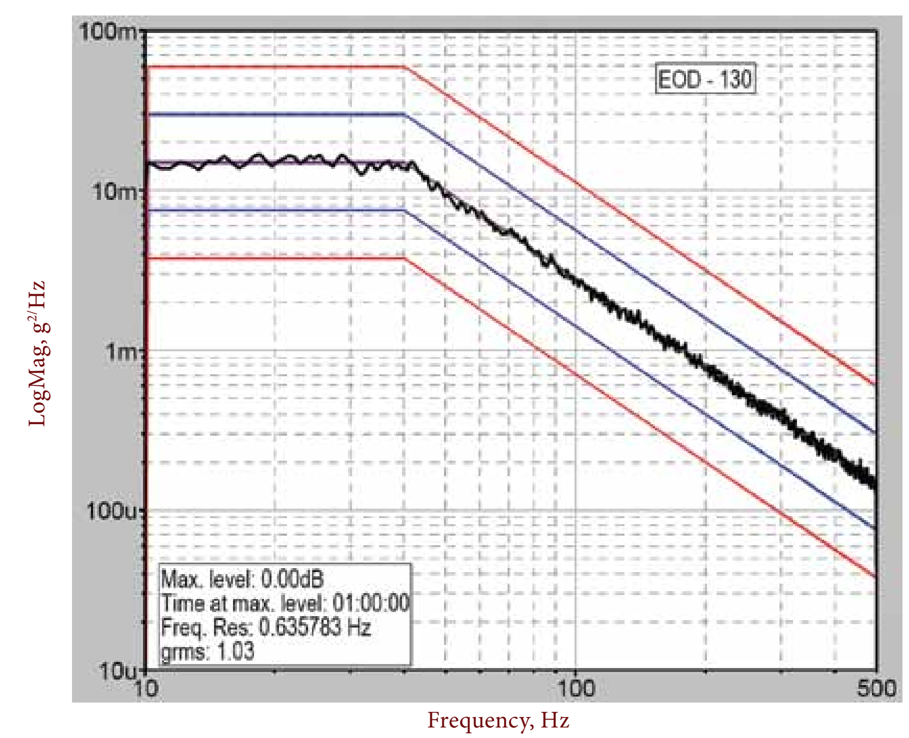
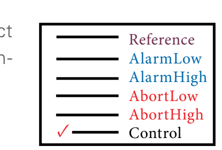


Figure 4. Protocol of vibration test. The test verifies whether the product will function and withstand the anticipated vibration exposures throughout its life cycle.



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