



## Report on test of ROFI face mask and body armour Armadillo according to CWA on testing PPE for the HMA.

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## **Abstract**

A new type of Personal Protective Equipment (PPE), the Body Armour “Armadillo“ and a Face Mask made by ROFI Industrier AS in Norway have been tested with guidance from a Comité Européen de Normalisation (CEN) developed CEN Workshop Agreement (CWA). Out of this CWA the test protocol for the blast testing of PPE was used. The test was undertaken with a pedestrian version 50th percentile male Hybrid III anthropomorphic dummy as wearer of the PPE during the test. It was dressed in the PPE and was placed in a kneeling position in front of an explosive charge equivalent of 240 g of TNT. The distance from the centre of the top surface of the simulated mine to the nose of the dummy was 550 mm and at 70° from the horizontal. The evaluation of the test results was focused on how different parts of the PPE worked together in the task of protecting the deminer, but also aimed at evaluating whether the different parts of PPE could withstand the effects caused by an Anti Personnel Mine blast. The results show that the PPE fulfils the requirements of the blast test stated in the new CEN CWA specifying protocols and demands on testing new PPE for the Humanitarian Mine Action (HMA) market.

## **Table of content**

<b>Background</b> .....	<b>4</b>
<b>Introduction</b> .....	<b>5</b>
Facemask .....	5
Body Armour Armadillo .....	6
<b>Test equipment</b> .....	<b>7</b>
<b>Preparation</b> .....	<b>7</b>
<b>Blast Test</b> .....	<b>7</b>
Evaluation.....	7
<b>Results</b> .....	<b>10</b>
The Body Armour .....	10
The Face Mask .....	10
<b>Discussion</b> .....	<b>12</b>

## ***Background***

A new type of PPE made by ROFI Industrier AS has been introduced to the Humanitarian Mine Action (HMA) market. It consists of a Body Armour in two parts called Armadillo and a Facemask. When new Personal protective equipments (PPE) are introduced to the HMA community, tests are expected to be carried out to demonstrate that the PPE can protect the deminer as required and intended. New standards has been developed to demonstrate that different parts of the PPE work together as a system for the protection of the deminer and also to show the integrity of PPE during a blast. A test protocol for testing PPE used in HMA (attached in the appendix) has recently been developed by the Comité Européen de Normalisation (CEN). The test protocol covers Ballistic, Blast and Ergonomic Suitability tests. Swedish Rescue Services Agency (SRSA) together with United Nations Mine Action Service (UNMAS) has called for a test, based on the new protocol, of ROFI's new type of PPE system. SRSA with assistance from Swedish EOD and Demining Centre (SWEDEC) tested the PPE using one part of the CEN test protocol covering a Blast Test.

## Introduction

The new CEN Workshop Agreement (CWA) on a test protocol for testing PPE used in HMA attempts to more realistically replicate mine effects than earlier standards. The test protocol is made up from three different sets of tests. According to the test protocol new PPE shall be tested as follows:

- Ballistic Test to evaluate the protection against secondary fragments;
- Blast Test to show how the different pieces of equipment function as a system;
- Ergonomic Suitability Test to assess the degree to which the PPE is fit for purpose.

These tests are intended to give guidance to key stakeholders involved in the design, procurement and utilisation of PPE in the HMA.

SRSA decided to do tests on the new ROFI Face Mask as a response to requests of their own and a request from UNMAS. SRSA also wanted to test the new body armour Armadillo from ROFI as a part of their procurement process of HMA PPE. Supported by SWEDEC, SRSA furthermore decided to only perform one part of the tests protocol stated in the new CWA. The Ballistic test was not performed due to lack of equipment and trained personnel. The Ergonomic Suitability Test was not performed since it was deemed to be useful only in a later stage of their procurement process.

## Facemask

Picture 1



Front view of mask

Picture 2



Mask viewed from behind

Picture 3



Mask viewed from left side

The mask consists of a piece polycarbonate, fastening straps and a new composite material in three pieces, joined together in a characteristic profile. The new composite material pieces are joined together by four rivets with flatrounded heads (two on each side). The polycarbonate piece is screwed to the composite by four screws (two on each side) on to the outside of the mask. The screws are screwed into threaded rivets imbedded in the composite. Only the parts of the polycarbonate nearest the screw/rivet joint are in contact with the composite. The fastening straps are made out of elastic straps with Velcro tape stitched on to it. The straps are slipped through slots in the composite, at the back end near the wearers' ears and at the top near the wearers' forehead. Individual fitting of the mask can be made by adjusting the straps and Velcro. The manufacturer has provided the masks with two sets of cushions that can be placed on Velcro tape on the inside of the mask. This provides the mask with additional fitting possibilities.

## Body Armour Armadillo

Picture 4



Picture 5



Picture 6



Picture 7



Picture 4: The upper part of the Body Armour

Picture 5: The lower part of the Body Armour

Picture 6: Both parts worn at the same time

Picture 7: Both parts worn together with the face mask.

The Body Armour Armadillo consists of two separate parts. The upper that is carried on the shoulders and the lower carried on the hips. With overlapping areas, the upper and lower parts are connected to each other at the sides by two plastic buckles. The upper part is supposed to protect the upper half of the torso, shoulders and neck. It is provided with fixed elastic straps over the back making it stay in place. The lower part is supposed to protect the lower half of the torso, groin and crutch. A flap is fastened between the legs using two straps that are connected on the back to the hip belt with plastic buckles. The hip belt is fastened a larger plastic buckle. Individual fitting can be made by tightening the straps and belt.

The purpose of this blast test is on one hand to demonstrate that different parts of the selected PPE work together as a system for the protection of the deminer and on the other hand show the integrity of PPE during a blast.

## **Test equipment**

The test was undertaken with a pedestrian version 50th percentile male Hybrid III anthropomorphic dummy as wearer of the PPE during the test, as stipulated in the test protocol. Areas supposedly protected by the PPE were covered by a witness sheet. The witness sheet also covered an additional area 100 mm outside the protected area. The whole witness sheet was covered by the cling film. Materials used in the tests such as sand, cling film, and simulated blast mines, was chosen to meet the criteria of the CEN protocol. The sand was dry with a distribution of particle size according to the table (0-1,5) mm and placed in a steel cylinder with a 660 mm diameter. The witness sheet was made out of cotton sheet and the cling film of the *Gladpack* type. A simulated mine was made out of a charge with 145 g m/46 explosive (Pentyl). Pentyl is equivalent to 240 g of TNT according to the EOD IS database (conversion factor 1.66). In the tests an electric detonator was used and inserted from below to the centre of the charge. A smaller deviation from the protocol was made in the case of the plastic container for the charge. It had a thickness of  $(1.3 \pm 0.3)$  mm instead of the stipulated  $(2 \pm 0,5)$  mm i.e. a somewhat thinner container.

## **Preparation**

The simulated mine was buried in the sand with 2 cm overburden. The PPE was fitted to the dummy according to manufacturer's instructions. On the inside, the mask was fitted with the small pads provided by the manufacturer. When the dummy was positioned for the test, angular gauges and measuring tapes were used to achieve the correct position as stipulated in the test protocol. The dummy was set into a kneeling position by using a fixture system that was able to hold it in position. The distance from the centre of the top surface of the simulated mine to the nose of the dummy was  $550 \pm 10$  mm and at  $70 \pm 2^\circ$  from the horizontal.

## **Blast Test**

The test protocol stipulates that the test shall be carried out twice. If either of the tests is a failure, the test shall be repeated once. The PPE system was tested two times and both tests were considered a success. A separate witness sheet, cling film and PPE were used in each blast.

## **Evaluation**

After each test the result was observed in three different steps.

### **First step:**

*Examination of blast effects without touching any part of the dummy.*

After the blast an inspection of the blast site was carried out to see if any part of the PPE was missing and if so, where it might have landed. Broken and or missing parts were noted and collected. The ability of each part of the PPE to stay in the original place was noted. Visual examination of the cling film and witness sheet was made on places visible without moving the dummy.

### **Second step:**

*Examination of blast effects after removing the PPE.*

In this step the Dummy was placed on its back next to the blast site and removed of all PPE. The PPE, cling film and witness sheet was examined for penetrations made by fragments. The cling film over the eyes was examined for damage like melting or burns.

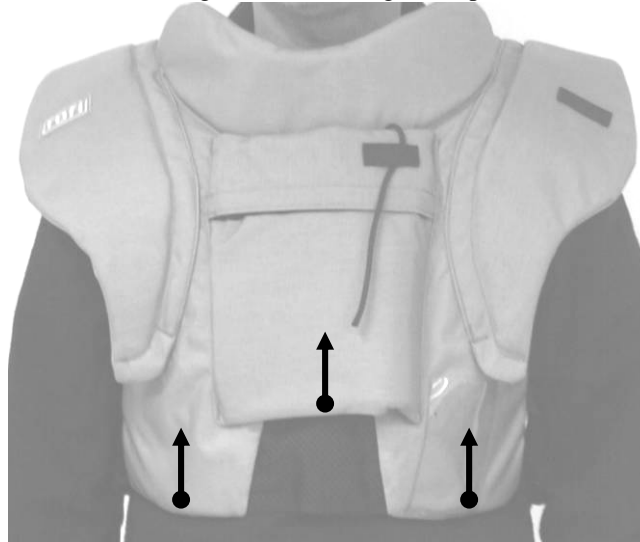
**Third step:***Examination of the removed PPE.*

After each blast the PPE, cling film and witness sheet was collected and placed in a plastic bag to be transported to the premises of SWEDEC. There it was possible to analyse the material in an indoor environment.

In the third step, the witness sheet, cling film, and PPE were examined by holding them against a source of light and thereby be able to see any penetrations from fragments. The PPE was examined visually looking for any traces of penetration. The overlapping areas of the PPE system was measured and noted. For the overlapping between the upper and lower part of the Body Armour Armadillo, the area on the upper part, not hit by fragments, was measured. The points of measuring consisted on one hand of centre measurement (from the PPE's lower edge to the first noted fragment hit in a 10 mm wide area), and on the other hand a measurement on each side with the same method as with the centre measurement. At the sides the measurement was made at the centre of the side pieces (picture 8)

Picture 8:

Points of measuring when examining overlap.

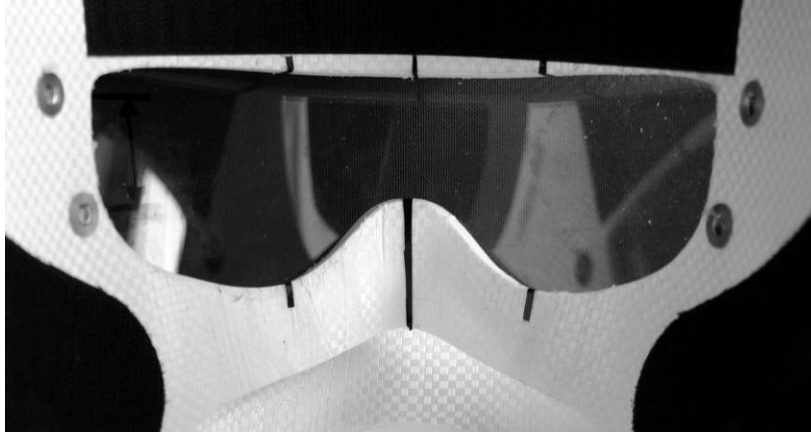


When examining the overlap of the Facemask towards the upper part of the PPE, the area of the mask that was not hit by fragments was measured. The points of measuring consisted of a centre measurement (from the mask's lower edge to the first noted fragment hit in a 10 mm wide area), and a measurement on each side with the same method as with the centre measurement. The measurements at the sides were made with a displacement of 50 mm from the centre on each side.

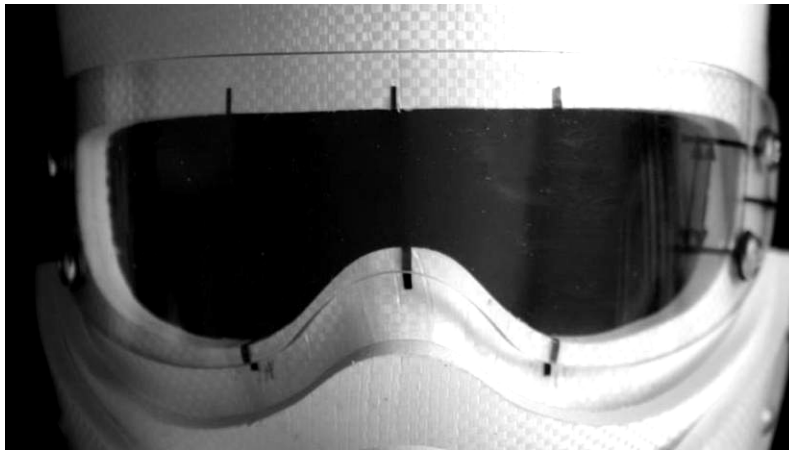
On the mask, the polycarbonate piece of the mask has an overlap against the composite. The area protected from fragment hits was measured in the centre, next to the eyes and at the outer edges (picture 9 and 10). Measurements were made from the edge of the opening to the first noted fragment hit in a 10 mm wide area (5 mm to each side of measuring point). Measuring points next to the eyes was determined before the tests using 10 randomly chosen persons (9 men and 1 woman). They put the mask on and their eye position relative to the mask was noted. The mean of these measurements was then used as measuring point when analysing the overlap between polycarbonate and the composite. On the lower edge the measuring points

was located 63 mm (calculated using calliper between the mark and the centre of each side's lower threaded rivet). On the upper edge the measuring point was 71 mm (calculated using calliper between the mark and the centre of each side's upper threaded rivet). Measuring points for the outer edges was determined to be in the middle between the two screws and along a line perpendicular to the outer edge (picture 11)

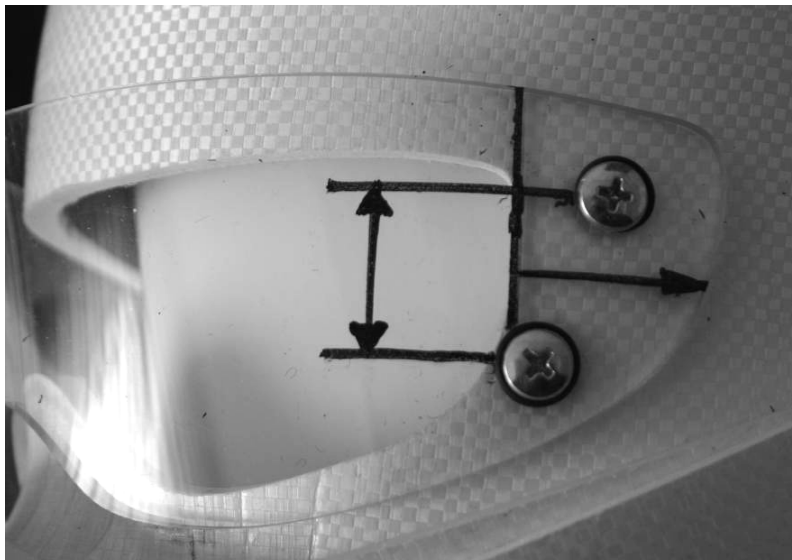
Picture 9: View of measuring points on the inside of the mask



Picture 10: View of measuring points on the outside of the mask



Picture 11: View of measuring points on the outer edge of the mask



## Results

The purpose of this blast test was on one hand to demonstrate that different parts of the selected PPE work together as a system for the protection of the deminer and on the other hand to show the integrity of PPE during a blast.

### The Body Armour

In the first part where the whole system was tested the results shows that the Armadillo Body Armour together with the face mask meet the criterion stated in the CEN test protocol concerning overlapping protection between different parts. The PPE system stayed on the dummy in a mine blast situation. No fragments could pass in-between the different parts of the PPE system. After the blasts the overlapping areas were a clearly visible are, since the fragments left clear marks. The overlap between the upper and the lower body armour parts are shown in table 1.

Table 1

<b>Overlap between upper and lower body armour</b>			
	<b>Centre</b>	<b>Right</b>	<b>Left</b>
<b>1st test</b>	157 mm	123 mm	130 mm
<b>2nd test</b>	128 mm	123 mm	141 mm

In the second part where the integrity of the PPE was tested, the results shows that the Armadillo body armours meet the criterion stated in the CEN test protocol. The Armadillo body armour stayed in place through the blast. No buckles connecting the upper and lower parts were torn apart or showed any damage. The front surface showed some damage from blast ejecta but nothing penetrated. The system also protected the witness sheet from fragment penetrations over the stated area of the dummy.

### The Face Mask

The face mask results, in the second part where the integrity was tested, showed that the mask meet the criterion stated in the CEN protocol. The face mask stayed in place through the blast even though the straps holding the mask were damaged and or torn apart and showed some damage. The threaded rivets holding the polycarbonate piece to the composite part could not withstand the strains of the blast. In the first blast they were ripped out of the composite material. The polycarbonate piece was torn completely of and landed within 20 cm in front of the dummy's left knee. In the second blast, three out of four rivets were torn out and the fourth was damaged. The polycarbonate piece stayed attached to the mask through the fourth rivet. Neither at the first or second step (at the blast site) nor at the third step (at premises of SWEDEC) has it been possible to find evidence of any fragment penetrated the cling film or the witness sheet behind the mask. The polycarbonate showed no damage on the inside. The front surface of the mask showed some damage from blast ejecta but nothing penetrated. The cling film over the eyes did not show any damage from heat. In the blast the mask was pushed up against the forehead of the dummy but there was still an overlapping area between

the mask and the upper body armour. After the blasts were the overlapping areas clearly visible as unaffected areas of the masks lower part. The overlap is shown in table 2.

Table 2

<b>Overlap between upper body armour and face mask</b>			
	<b>Centrum</b>	<b>Höger</b>	<b>Vänster</b>
<b>1st test</b>	84 mm	66 mm	85 mm
<b>2nd test</b>	53 mm	42 mm	48 mm

The polycarbonate has an overlap over the opening for the eyes in the composite. After both blasts, there was a clear mark indicating where the polycarbonate was pressed against the composite all around the opening. Inside the mark was no visible hit from fragments. Outside the same mark were hits from fragments found in various extents. The results from measuring the protective overlap are shown in table 3 and 4.

Table 3

<b>Overlap between polycarbonate and composite Part 1</b>				
	<b>Centre</b>		<b>Next to the right eye</b>	
	<b>Upper edge</b>	<b>Lower edge</b>	<b>Upper edge</b>	<b>Lower edge</b>
<b>1st test</b>	23 mm	28 mm	24 mm	6 mm
<b>2nd test</b>	11 mm	6 mm	10 mm	2 mm

Table 4

<b>Overlap between polycarbonate and composite Part 2</b>				
	<b>Next to the right eye</b>		<b>Outer edge</b>	
	<b>Upper edge</b>	<b>Lower edge</b>	<b>Right</b>	<b>Left</b>
<b>1st test</b>	28 mm	>4 mm <sup>/1</sup>	>31 mm <sup>/2</sup>	>31 mm <sup>/2</sup>
<b>2nd test</b>	20 mm	7 mm	>31 mm <sup>/2</sup>	>31 mm <sup>/2</sup>

<sup>/1</sup> At 4 mm was a distinctive mark showing where the polycarbonate was pressed into the composite. Beyond this was no fragment hits

<sup>/2</sup> No marks from fragment were found up to this distance or beyond the point consisting of the polycarbonate's most distant position before the blast.

## ***Discussion***

These tests of PPE have only considered the ability to meet the criteria concerning a blast test, stipulated in the CWA - protocol created by CEN to test PPE in HMA. The PPE performed in a way that no fragments from the blast passed through any part of the PPE and into the cling film or the witness sheet. It also performed in a way that no fragments passed in between the different components of the PPE so that cling film and/or witness sheet were penetrated. The blasts have not caused heat damage in the area of the dummies' eyes i.e. melting or burning of the cling film. The area of the deminers' body that, according to the CWA, needs to be protected (i.e. torso including shoulders, groins, crutch as well as neck and the forward facing half of the head) has been protected from fragment penetration in the cling film and witness sheet. The equipment has, in the case of Body Armour Armadillo, functioned without loosening or damaging buckles or straps. On the other hand, the Face Mask was damaged and lost its polycarbonate part in the first test. In the second test the polycarbonate part was only partially broken away. The test results, as shown from the cling film as well as from the witness sheet, both from the first and second test, indicates that the polycarbonate has protected the eyes from being hit by fragments before it was torn of. Because of this, the face mask is considered to meet the requirements stated in the CWA even though the equipment broke.