Tests of Hesco gabions June 2011

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English summary

In June 2011 a number of tests of the protective properties of Hesco gabions relative to various weapon threats were accomplished. The experiments are part of a series of tests involving physical force protection. This report is primarily a documentation of the test results.

3.5 kg and 7.5 kg TNT charges corresponding to 120 mm and 155 mm grenades and also real 155 mm artillery ammunition were fired against Hesco MIL 3 units with different fill materials. The TNT charges destroyed the front side of the MIL 3 cells and threw out a large part of the fill materials, but the back side remained intact. Crushed rock and especially local soil were thrown considerably farther than sand and gravel. These types of fill material are therefore more dangerous to people. Tents behind the MIL 3 units were damaged by the 7.5 kg charges detonated against gabions directly in front of the tents. Detonation of 155 mm shells destroyed several MIL 3 cells and spread the fill material widely. The effect was much stronger than from the 7.5 kg TNT charges. Thus MIL 3 units are incapable as protection against 155 mm grenades.

400 kg TNT charges were detonated 20 m and 60 m in front of Hesco MIL 10 walls. The charges simulated car bombs (VBIEDs). The pressure behind the walls was measured to find the mitigating effect of the wall. Analysis of the pressure data will be presented in an upcoming report. With the charge 20 m from the wall the effect of the pressure wave to the tents behind the wall was devastating. An unprotected tent 70-80 m from the detonation got some damage.

The test series also included firings of 340 g shaped charges against gabions with different fill materials. The charges correspond to shaped charges used in RPG-7 weapons. The penetration depth was between 70 cm and 90 cm with a general trend of less penetration with larger stones in the fill material.

Sammendrag

Det ble i juni 2011 gjennomført en rekke forsøk for å teste Hesco-gabioners evne til å beskytte mot ulike våpentrusler. Forsøkene er en del av en serie tester knyttet til fysisk styrkebeskyttelse. Hensikten med denne rapporten er primært å dokumentere forsøksresultatene.

Ladninger på 3,5 kg og 7,5 kg TNT som tilsvarer ladningene i 120 mm og 155 mm granater, samt virkelig 155 mm artilleriammunisjon ble satt av mot Hesco MIL 3-enheter med forskjellige fyllmaterialer. TNT-ladningene ødela forsiden av gabionene og kastet ut en stor del av fyllmaterialet, men baksiden ble ikke skadet. Kult og spesielt stedlig masse ble kastet betraktelig lengre enn sand og pukk. Disse fyllmaterialene vil derfor lettere skade mennesker. Telt på baksiden av MIL 3-gabionene ble skadet av 7,5 kg TNT når detonasjonen av disse ladningene skjedde mot gabioner rett foran teltene. Sprengning av 155 mm granater ødela flere MIL 3-celler og spredte fyllmaterialet vidt ut. Virkningen var mye større enn fra ladningene på 7,5 kg TNT og viste at MIL 3 beskytter dårlig mot 155 mm granater.

TNT-ladninger på 400 kg ble detonert 20 m og 60 m foran Hesco MIL 10-vegger. Ladningene simulerte bilbomber. Trykket bak veggene ble målt for å finne veggens trykkdempende effekt. Analysen av måledataene vil bli presentert i en kommende rapport. Når ladningen ble detonert 20 m foran veggen, var trykkbølgen helt ødeleggende på teltene bak veggen. Ved en avstand på 70-80 m fra detonasjonen ble det noe skade på et ubeskyttet telt.

Forsøksserien omfattet også fyringer av 340 g bikubeladninger mot gabioner med ulike fyllmaterialer. Ladningene svarer til hulladninger som brukes i våpen av type RPG-7. Inntrengningsdybden var mellom 70 cm og 90 cm, og større steiner i fyllmaterialet ga generelt mindre inntrengning.

Contents

1 Introduction

In November 2010 a test series was carried out at Setermoen [1] to investigate the protective properties of field fortifications against relevant weapon threats. The fortifications were walls and shelters made of Hesco Concertainer units [2], which were filled with different soil materials.

A following second test series was carried out at Rena in June 2011 and is described in this report. Except omitting shelters as test objects, the tests at Rena were quite similar to the first tests at Setermoen. They were designed according to threat levels specified in STANAG 2280 [3], and uncased charges were detonated to simulate direct hits of certain weapon threats. In this second series the shaped charges were of a smaller calibre, and in addition some 155 mm artillery shells were detonated. A major distinction between the two test series was that the fill materials at Setermoen were frozen, which was not the case at Rena.

The Rena tests included tents. They were put up behind the Hesco walls to study how they were affected by the detonations.

The preparation and performance of the tests were made by the Norwegian Army Weapons School and the Norwegian Defence Logistics Organisation with support from the Military Academy and Norwegian Defence Research Establishment (FFI). FFI was responsible for the test registrations by pressure transducers and video cameras.

2 The tests

Figure 2.1 shows an overview of the test site. A squad tent and two NM 240 tents were placed between two walls of Hesco gabions. MIL 3 and MIL 10 designate Hesco units of different sizes. The bold numbers in the figure indicate the firing positions. First the 400 kg TNT charge behind the MIL 10 wall distant from the other objects test was detonated (test 2.1). Then 3.5 and 7.5 kg charges and 155 mm grenades were set off against MIL 3 units, at the opposite side of the tents (test 1.1-1.14). These tests were performed in the order the numbers specify, except that tests 2.2 and 2.3 were made between test 1.11 and 1.12.

In addition shaped charges were detonated against MIL 2 units. They are not included in the figure.

All the tests were captured by a HD video camera and a high-speed video camera.

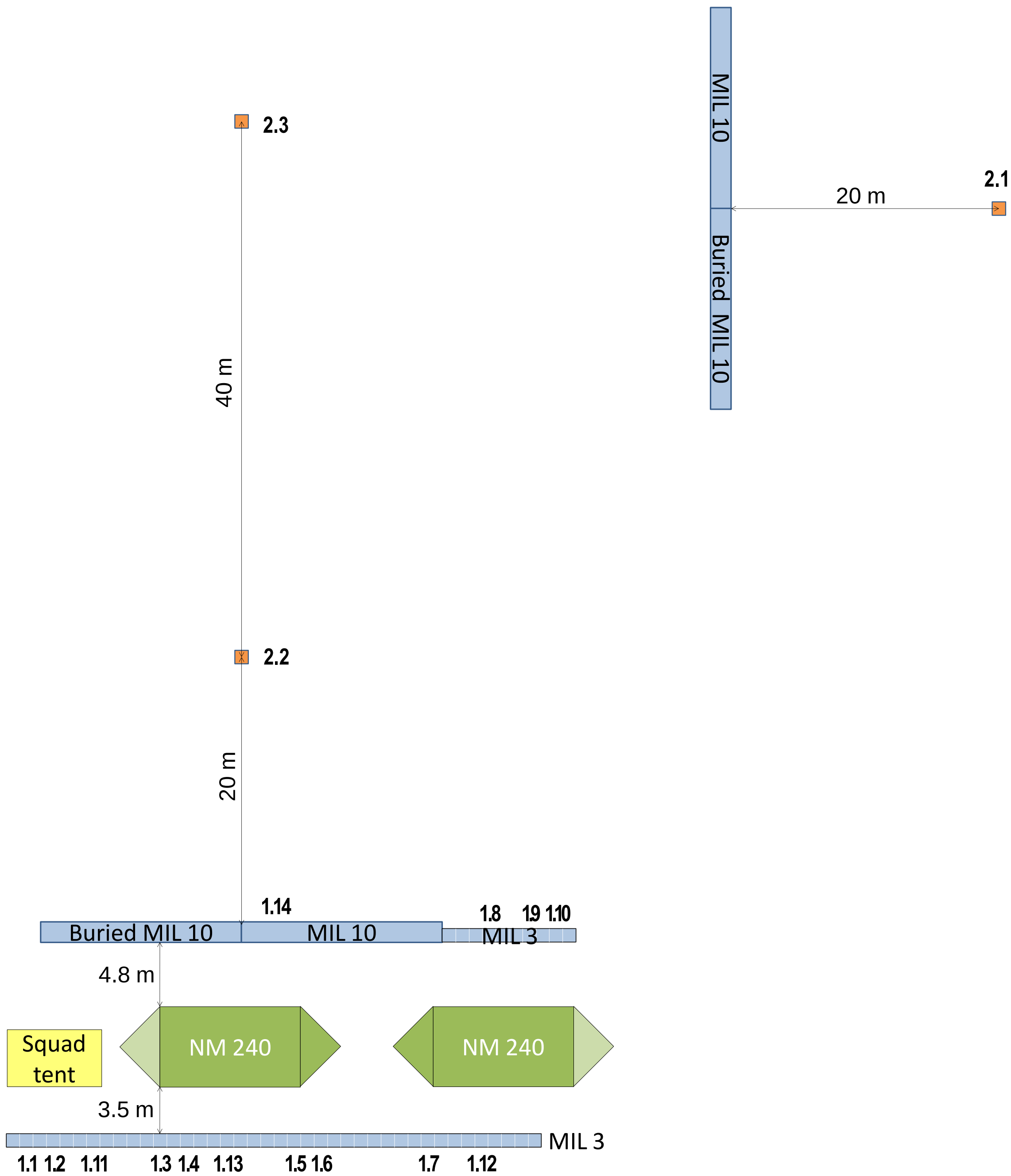

Figure 2.1 Firing positions of 3.5 kg/7.5 kg charges and 155 mm shells as numbered in table 2.1 (1.1-1.14) and of the 400 kg charges (2.1-2.3)

2.1 Tests with 3.5 kg and 7.5 kg TNT charges and 155 mm shells

2.1.1 Description

In the tests with 3.5 kg and 7.5 kg TNT charges and 155 mm shells (test 1) the charges were detonated in contact with the side of MIL 3 Hesco bastions. 3.5 kg and 7.5 kg TNT correspond to the explosives mass of 120 mm mortar ammunition and 155 artillery ammunition. The purpose was to find how different fill materials affect the debris thrown out and to compare the effects of

155 mm grenades and uncased 7.5 kg TNT charges. The result of the detonation to the tents nearby was also considered.

A MIL 3 wall is made of 1 m x 1 m x 1 m cells, usually with five cells horizontally lined up. The cells are open at the top. In the test they were filled with sand (0-8 mm), medium gravel (8-22 mm), crushed rock (10-120 mm) or soil from the location (many small stones, but also stones up to 5-6 cm).

The three charge types were fired at each of four MIL 3 walls with different fill materials. The test shots are listed in table 2.1. The two tests with 7.5 kg TNT at gabions with gravel and crushed rock were repeated because the high speed video camera failed during the first attempts. An additional test was made with a 155 shell detonating against a MIL 10 wall (test 1.14).

Shot	Charge	Fill material
1.1	3.5 kg TNT	Sand
1.2	7.5 kg TNT	Sand
1.3	3.5 kg TNT	Gravel
1.4	7.5 kg TNT	Gravel
1.5	7.5 kg TNT	Crushed rock
1.6	3.5 kg TNT	Crushed rock
1.7	7.5 kg TNT	Local soil
1.8	7.5 kg TNT	Gravel
1.9	7.5 kg TNT	Crushed rock
1.10	3.5 kg TNT	Local soil
1.11	155 mm shell	Sand
1.12	155 mm shell	Local soil
1.13	155 mm shell	Gravel
1.14	155 mm shell	Local soil

Table 2.1 Test shots with 3.5 kg and 7.5 kg TNT and 155 mm shells

A high-speed video camera filmed the back side of the walls during the explosions, see figure 2.2. In addition ordinary video cameras were used.

Figure 2.2 High-speed video camera in test 1.1

Pictures of some of the walls and charges before the tests are shown in figures 2.3-2.7.

Figure 2.3 Setup of test 1.1 with 3.5 kg TNT at a MIL 3 wall with sand

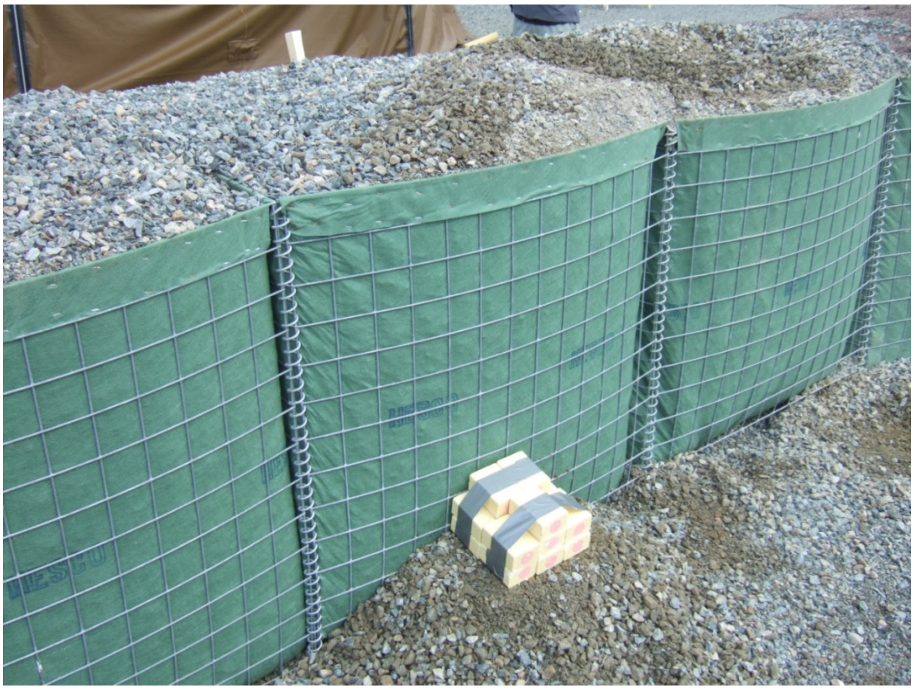

Figure 2.4   Setup of test 1.4 with 7.5 kg TNT at a MIL 3 wall with gravel

Figure 2.5   Setup of test 1.10 with 3.5 kg TNT at a MIL 3 wall with local soil

Figure 2.6 Setup of test 1.11 with a 155 shell at a MIL 3 wall with sand

Figure 2.7 Setup of test 1.14 with a 155 shell at a MIL 10 wall with local soil

2.1.2 Results

Figures 2.8-2.29 show pictures of the walls after the detonations.

Figure 2.8 Front side of MIL 3 wall with sand after detonation of 3.5 kg TNT (test 1.1)

Figure 2.9 Front side of MIL 3 wall with sand after detonation of 7.5 kg TNT (test 1.2)

Figure 2.10 MIL 3 wall with sand after detonation of 7.5 kg TNT (test 1.2)

Figure 2.11 Back side of MIL 3 wall with sand after detonation of 7.5 kg TNT (test 1.2)

The sand lifted out of the MIL 3 cell by the 3.5 kg charge did not go very far. The 7.5 kg charge threw away some more sand, but still a short distance.

Figure 2.12 Front side of MIL 3 wall with gravel after detonation of 3.5 kg TNT (test 1.3)

Figure 2.13 Back side of MIL 3 wall with gravel after detonation of 3.5 kg TNT (test 1.3)

Figure 2.14 Front side of MIL 3 wall with gravel after detonation of 7.5 kg TNT (test 1.4)

Figure 2.15 Back side of MIL 3 wall with gravel after detonation of 7.5 kg TNT (test 1.8)

The amount of soil thrown out from the MIL 3 cells with gravel was a bit larger than with sand. With the 3.5 kg charge most of it landed close to the wall, while it was somewhat more spread out with the 7.5 kg charge.

Figure 2.16 Front side of MIL 3 wall with crushed rock after detonation of 3.5 kg TNT (test 1.6)

Figure 2.17 Back side of MIL 3 wall with crushed rock after detonation of 3.5 kg TNT (test 1.6)

Figure 2.18 Front side of MIL 3 wall with crushed rock after detonation of 7.5 kg TNT (test 1.5)

Figure 2.19 Back side of MIL 3 wall with crushed rock after detonation of 7.5 kg TNT (test 1.9)

As the pictures show, the crushed rock was not thrown very far forward. In the backward direction, however, some stones were thrown 50 m – 80 m with the 7.5 kg charge.

Figure 2.20 Back side of MIL 3 wall with local soil after detonation of 3.5 kg TNT (test 1.10)

Figure 2.21 Front side of MIL 3 wall with local soil after detonation of 3.5 kg TNT (test 1.10)

Figure 2.22 Front side of MIL 3 wall with local soil after detonation of 7.5 kg TNT (test 1.7)

Figure 2.23 Back side of MIL 3 wall with local soil after detonation of 7.5 kg TNT (test 1.7)

The local soil was spread over a large area by the 7.5 kg charge. Some stones flew over a small hill about 75 m from the charge.

Figure 2.24 MIL 3 wall with sand after detonation of a 155 mm grenade (test 1.11)

Figure 2.25 Roof of NM 240 tent after detonation of a 155 mm grenade (test 1.11) at the opposite side of a MIL 3 wall with sand

Figure 2.26 MIL 3 wall with local soil after detonation of a 155 mm grenade (test 1.12)

Figure 2.27 MIL 3 wall with gravel after detonation of a 155 mm grenade (test 1.13)

Figure 2.28 Front side of MIL 10 wall with local soil after detonation of a 155 mm grenade (test 1.14)

Figure 2.29 Back side of MIL 10 wall with local soil after detonation of a 155 mm grenade (test 1.14)

When 155 mm artillery shells were detonated against MIL 3 walls, the Hesco units closest to the detonation were blown away, and the units next to them were destroyed. The sand was thrown onto the opposite MIL 10 wall, 15 m away. The effect was similar with gravel, and the stones from the local soil were spread far out.

When detonated against the MIL 10 wall the 155 mm grenade damaged the wall, but did not break it.

The velocity of some of the stones thrown out of the MIL 3 walls is determined from high-speed video recordings, see table 2.2. The camera's field of view did not cover the stones that landed more than a few meters from the walls.

Shot	Charge	Fill material	Velocity / m/s	Description
1.1	3.5 kg	Sand	2.4	
1.3	3.5 kg	Gravel	2.4 4.1	Front of stream At the end of the stream
1.6	3.5 kg	Crushed rock	1.8 4.8	Front of stream Large stone at the end
1.7	7.5 kg	Local soil	4.0 5.9 11	Front of stream Middle of stream At the end of the stream, stone landing 1 m from the wall
1.8	7.5 kg	Gravel	2.1 6.0 2.6	Front of stream At the end of the stream Single stones at the end
1.9	7.5 kg	Crushed rock	3.0 6.5	Front of stream Large stone at the end
1.10	3.5 kg	Local soil	4.1 2.7	Front of stream At the end of the stream
1.12	155 mm	Local soil	3.2 9.8	First part of the stream Large stone at the end
1.13	155 mm	Gravel	8.5 6.6 5.7 19	Front of stream Stream from the bottom of the wall Falling vertical stream of stones Stones at the end of the vertical stream

Table 2.2 Velocities of stones from MIL 3 walls after detonation of charges

The stream refers to the flood of stones streaming out from the top of the walls. The velocities are in general quite moderate. The largest velocities are found for the falling stones that have been thrown upwards by the explosion.

The 7.5 kg charges detonated near the NM 240 tents caused all the distance rods in the tents (see figure 2.30) as well as the top beams and the tie beams of the ridge frame to break. After test 1.5 the ridge tensioners had lost their attachments and the guy lines were broken. The beams of the framework of the adjacent NM 240 tent broke or were displaced during test 1.8. In test 1.9 the inner canvas roof of this tent fell down.

Figure 2.30 Distance rod of NM 240 tent after detonation of 7.5 kg TNT at the opposite side of a MIL 3 wall with crushed rock (test 1.4)

With the 7.5 kg charge against MIL 3 with sand (test 1.2) all the pegs attached to the bottom of the squad tent were destroyed because they were not flexible. The tent was lifted and displaced and a little deformed, but easy to fix. The 155 mm charge in test 2.11 ripped the canvas of the squad tent, and the end section fell flat.

2.2 Tests with 400 kg TNT

2.2.1 Description

In the tests with 400 kg TNT the charges were detonated 20 m and 60 m from a MIL 10 wall placed on the ground beside a MIL 10 wall buried 0.5 m below the ground, see figure 2.31. A MIL 10 wall is 1.52 m deep and 2.12 m high, and the width of each wall was 15 m (ten cells). The walls were filled with local soil. The charge, which simulated a car bomb (VBIED), consisted of 0.5 kg blocks in a wooden case, see figure 2.32.

Figure 2.31 400 kg TNT 20 m in front of a buried and an unburied MIL 10 wall (test 2.1)

Figure 2.32 400 kg TNT charge

Figure 2.33 Blast test device

Pressure measurements were made with pencil gauges, for details see appendix A.1. In addition a blast test device (BTD) as shown in figure 2.33 was used. This device is an aluminium cylinder with four pressure gauges at 90° intervals around the cylinder (appendix A.2), 1.22 m above the ground. The cylinder is 0.762 m long and has a diameter of 0.305 m, and it simulates the thorax of a standing man [4]. The measured pressures are input to the Axelsson model, which is used to estimate blast injury to the thorax [5].

At the first of the three shots the pressure transducers were at the positions shown in figure 2.34, see also figure 2.35. The distance from the charge to the wall was 20 m.

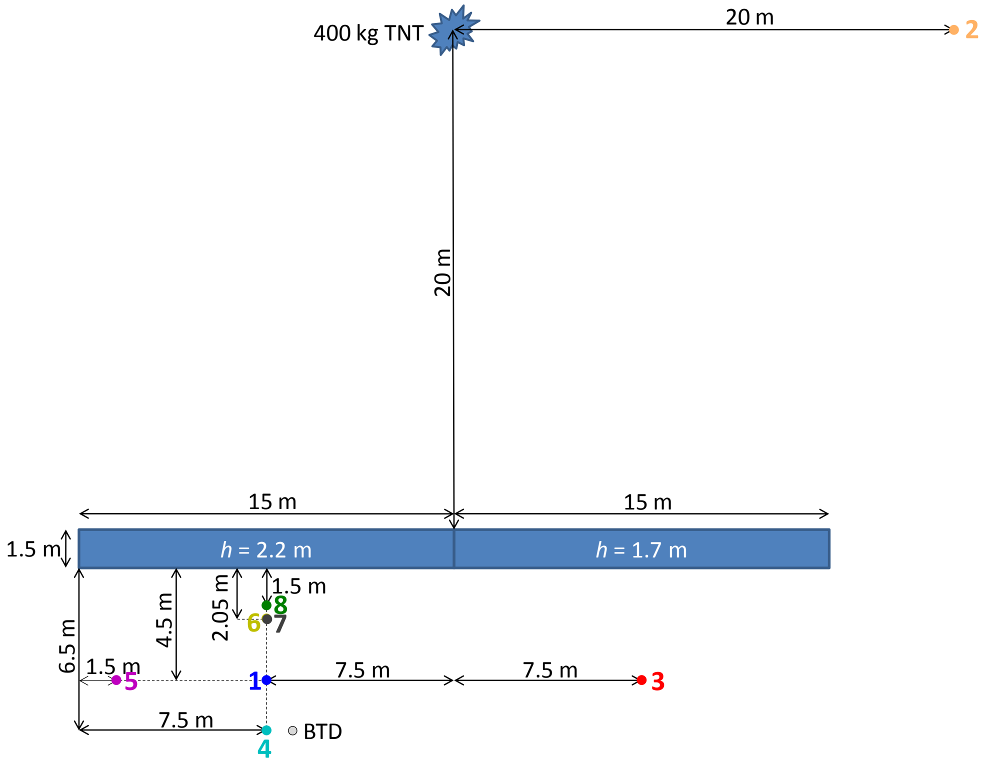

Figure 2.34 Setup of pressure transducers in test 2.1 with numbered pencil gauges and the blast test device (BTD)

Figure 2.35 Pressure transducers behind the wall in test 2.1

The pencil gauges behind the wall pointed perpendicularly towards the top edge of the wall, except gauge number 6 and 7, which were directed horizontally. Gauge 2 pointed towards the charge. The distance from the gauges to the ground was about 1.6 m (ref. table A.2), with the exception of the three mentioned above: The height above ground was 1.25 m for gauge 2, 0.25 m for gauge 6 and 0.99 m for gauge 7.

In test 2.2 and 2.3 400 kg charges were detonated in front of a MIL 10 wall with tents behind the wall as the photo in figure 2.36 shows.

Figure 2.36 Hesco MIL 10 wall (left) and tents before test 2.2 and 2.3

Figure 2.37 shows the position of the pressure sensors in test 2.2 with the charge 20 m from the wall. In test 2.3 the distances from the charge to the wall and from the charge to gauge 2 were both 60 m. In this test gauge number 1 was not used.

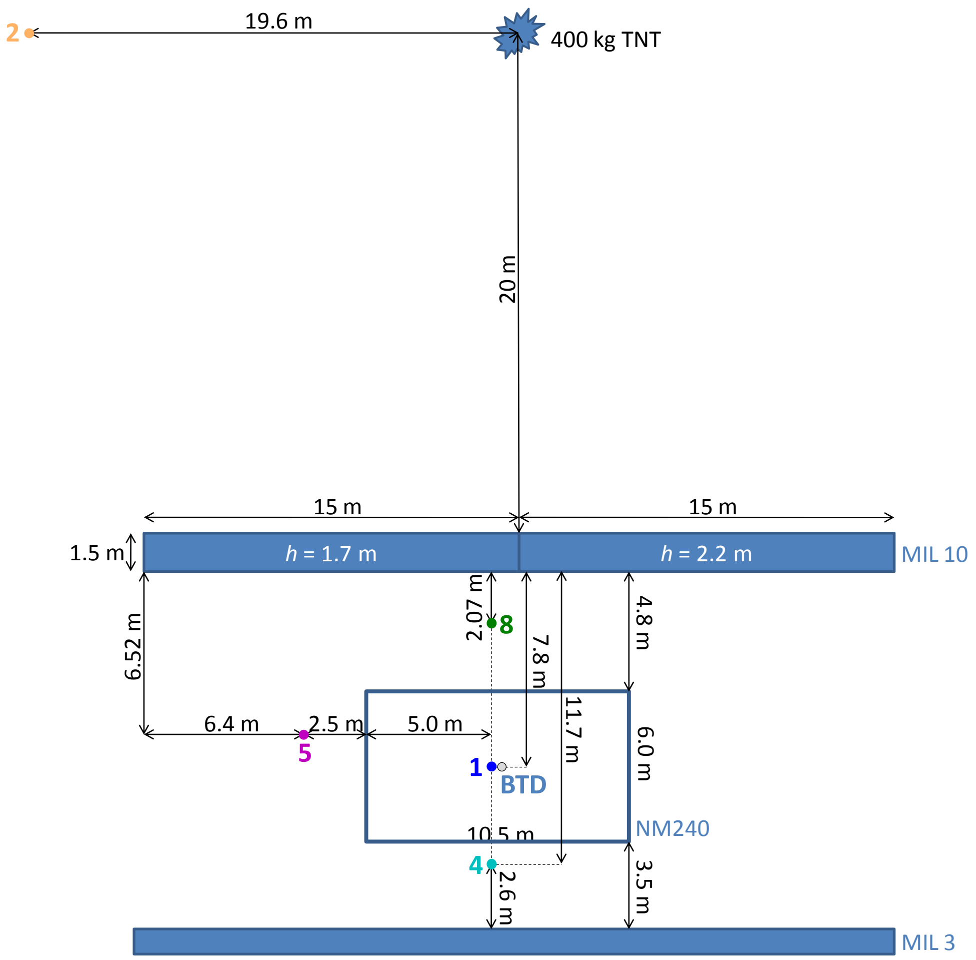

Figure 2.37 Setup of pressure transducers in test 2.2 with numbered pencil gauges and the blast test device

The gauges' height above ground was the same in test 2.2 and 2.3 as in test 2.1. Figure 2.39 shows pictures of the sensors behind the MIL 10 wall.

The blast test device was oriented with the direction of its sensors as shown in figure 2.38, where the drawing is oriented in the same direction as figure 2.34 and figure 2.37.

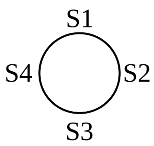

Figure 2.38 Position of sensors on the blast test device

Figure 2.39 Pressure transducers used in test 2.2

2.2.2 Results

The MIL 10 walls were undamaged after the detonation of the 400 kg charges.

2.2.2.1 Damage to tents

During test 2.1 distance rods of the NM 240 tent closest to the charge collapsed near the tension adjusters. All the guy ropes were broken. The top beams were broken off the ridge frame. Figure 2.40 shows some pictures of the damages. The harm to the NM 240 tent behind the MIL 10 wall was of a small extent. The squad tent did not get any damage.

In test 2.2 the tents were blown down, see figure 2.41. In the NM 240 tent closest to the charge the ridge frames broke and disassembled from the legs. In the NM 240 further away the doors went out of their frames, and one top beam was broken. Ropes were cut off, and rope holdings were broken both at the bottom and at the top. In both of the NM 240 tents the doors were disconnected from the doorsills.

Figure 2.40 NM 240 tent after detonation of 400 kg TNT in test 2.1 about 70 m away

Figure 2.41 Tents after detonation of 400 kg TNT in test 2.2

2.2.2.2 Pressure recordings

The pressure recorded by the pencil gauges in test 2.1 is shown in figure 2.42. Figure 2.43-2.45 shows the values over a shorter time span, together with impulse values.

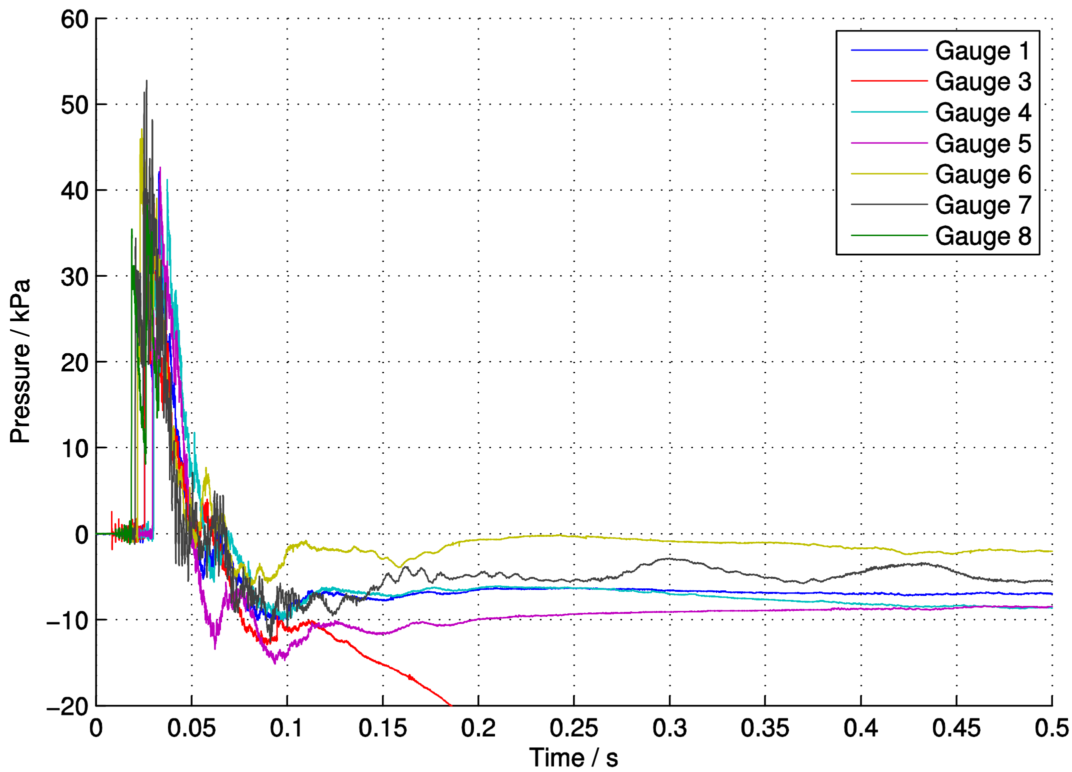

Figure 2.42 Recorded pressure values behind the MIL 10 wall in test 2.1

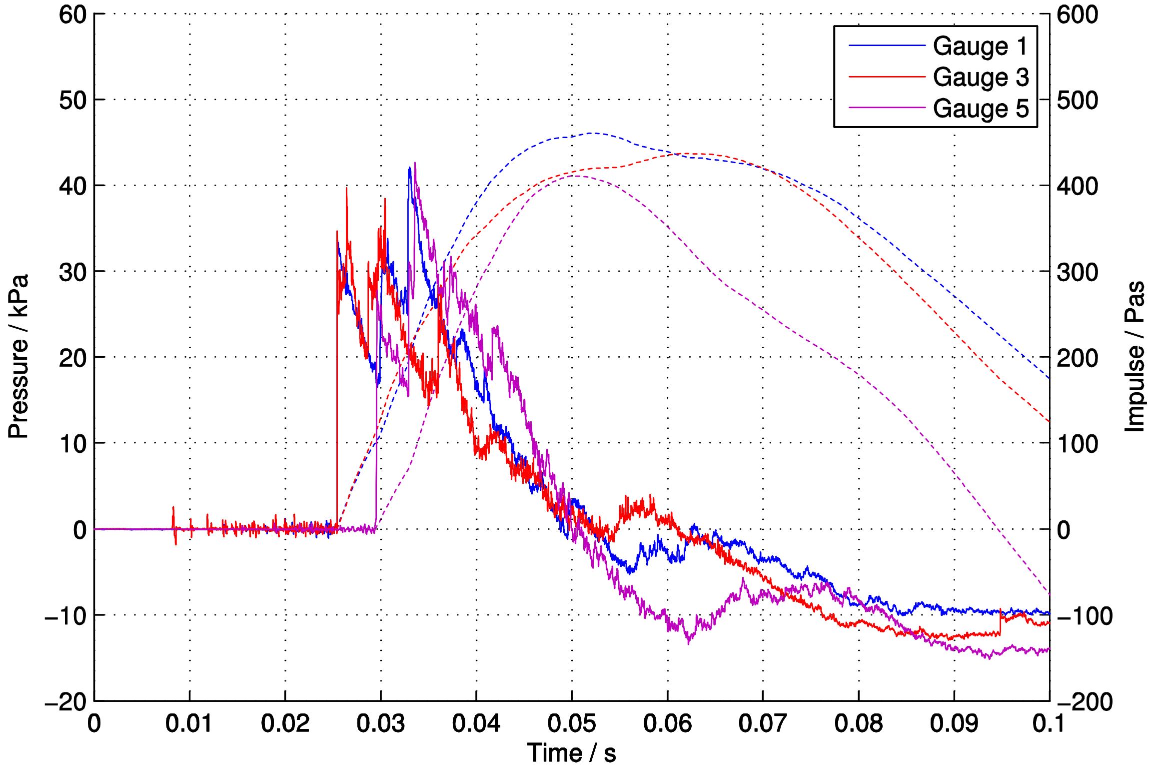

Figure 2.43 Pressure and impulse values (dashed lines) from the gauges 4.5 m behind the MIL 10 wall in test 2.1

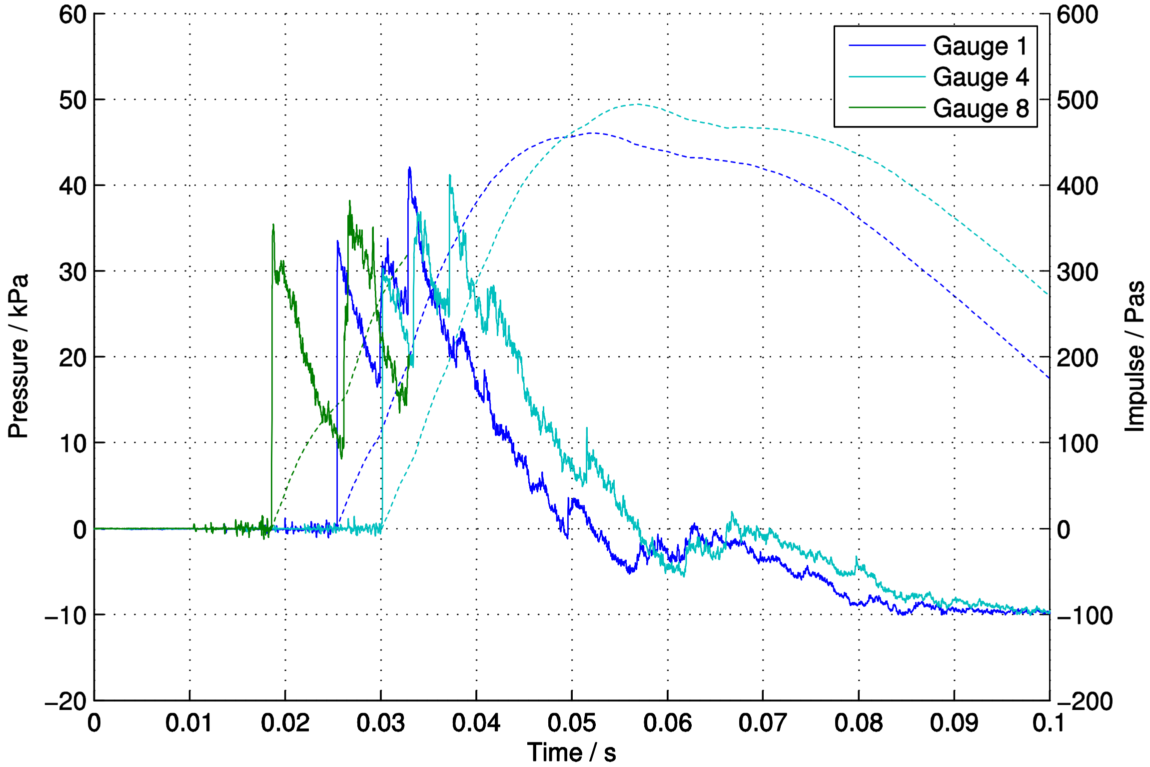

Figure 2.44 Pressure and impulse values (dashed lines) from the gauges at different distances behind the middle of the buried MIL 10 wall in test 2.1

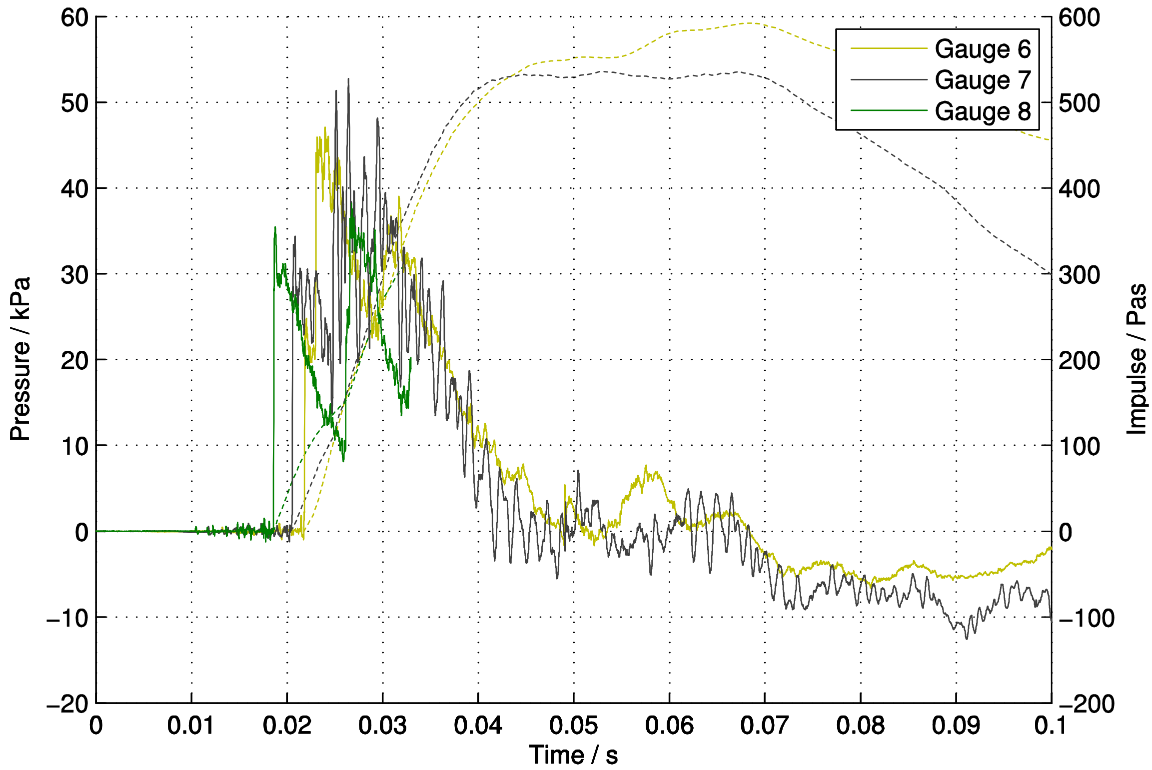

Figure 2.45 Pressure and impulse values (dashed lines) from the gauges at different heights, closest to the buried MIL 10 wall in test 2.1

The impulse values from gauge 8 are not shown because it produced signals only up to 0.033 s.

The maximum values of the pressure and the impulse and the duration of the first positive pressure phase are shown in table 2.3.

Gauge number	Maximum pressure / kPa	Impulse / Pas	Duration / ms
1	42	460	23
2*			
3	40	420	24
4	41	490	26
5	43	410	21
6	47	550	27
7	53	530	21
8	38		

*Sensor number 2 did not give any usable results.

Table 2.3 Properties of the pressure signals measured by the pencil gauges behind the MIL 10 wall in test 2.1

In the curves there are several peaks in the first positive phase of the pressure wave. They must be due to reflections on the ground.

The distance from the charge to gauge 1 and gauge 3 was the same, but the wall in front of gauge 3 was 0.5 m lower than the wall in front of gauge 1. Still the pressure at gauge 3 was not higher than at gauge 1, and the pressure wave arrived at the two gauges at the same time.

The differences between the pressure values at various distances from the wall are quite small (figure 2.44). Near the wall the maximum pressure is higher at gauge 7, 0.99 m above ground than at gauge 6, 0.25 m above ground (figure 2.45). At gauge 6 closer to the wall the reflection on the ground does not enhance the pressure as much as farther out.

Pressure values registered by the blast test device are shown in figure 2.46.

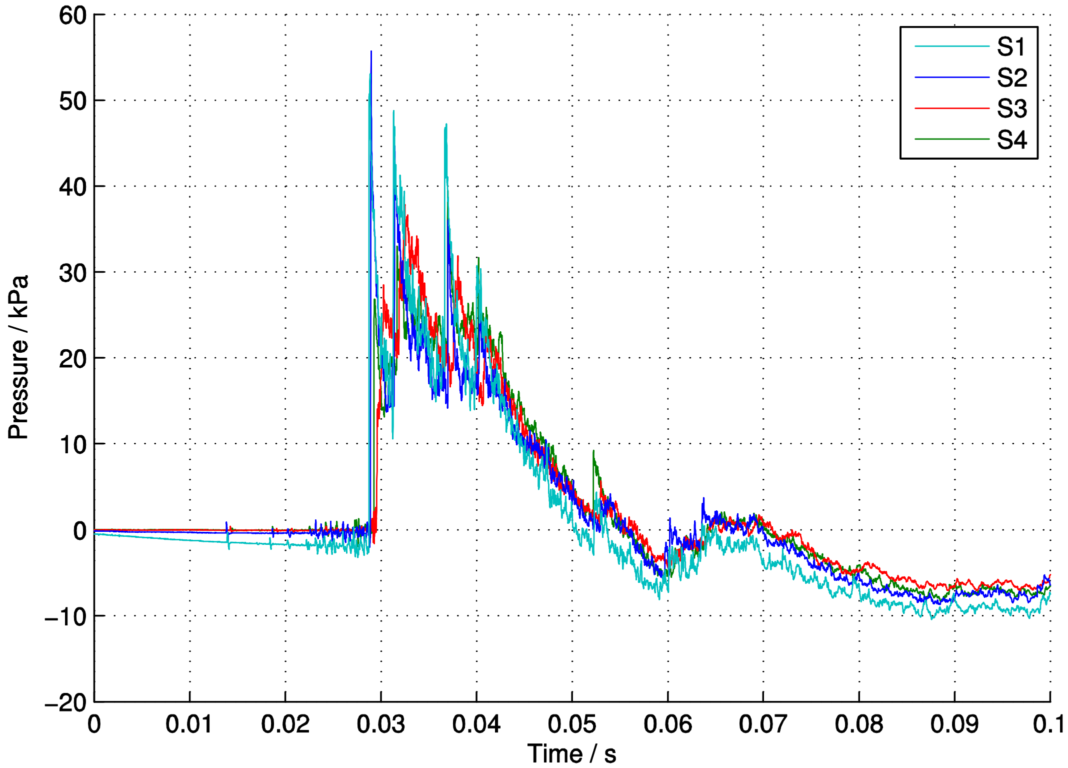

Figure 2.46 Pressures on the BTD in test 2.1

The maximum values of the pressure and the impulse and duration of the first positive phase are given in table 2.4.

Gauge	Maximum pressure / kPa	Impulse / Pas	Duration / ms
S1	53	400	21
S2	56	360	24
S3	38	400	26
S4	39	410	26

Table 2.4 Properties of the measured pressure signals at the BTD in test 2.1

Although gauge S1 was more directed towards the charge than gauge S2 (figure 2.38), the latter measured the highest pressure. The pressure waves behind the wall are however complex and also affected by the blast test device itself.

The pressure measured on the blast test device is quite similar to the pressure at gauge 4 (figure 2.44), which was close to the blast test device.

The pressure signals from test 2.2 are shown in figure 2.47.

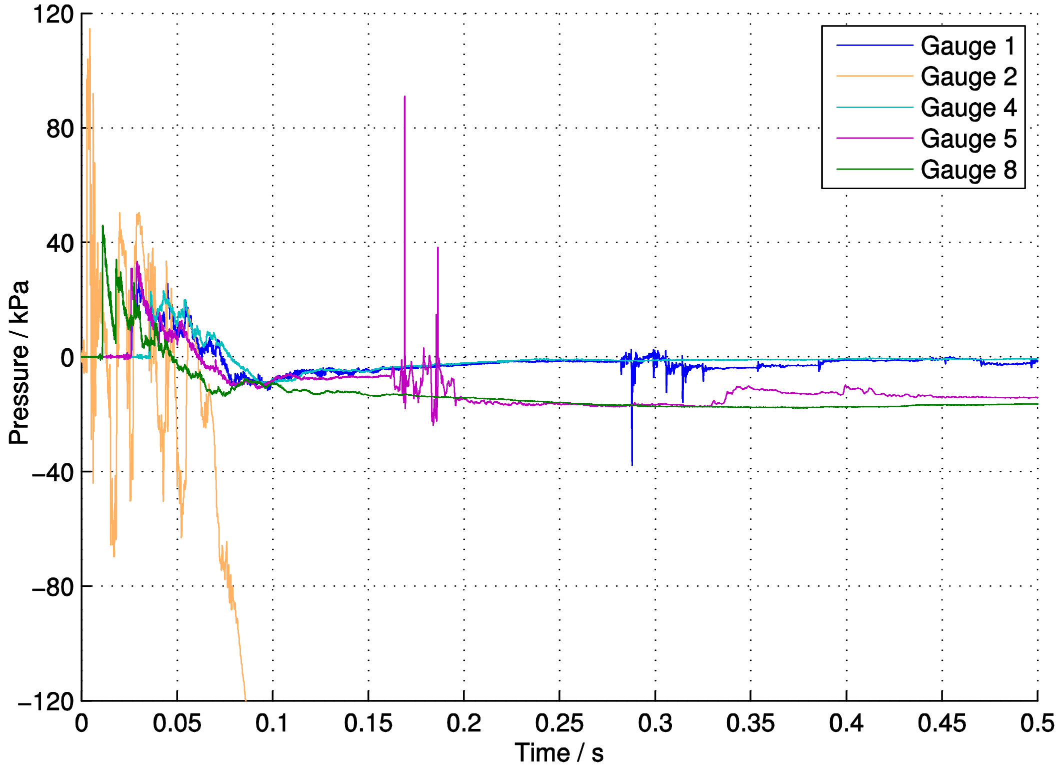

Figure 2.47 Recorded pressure values in test 2.2

Gauge 2 recorded the free field pressure 19.6 m from the charge. According to the Kingery-Bulmash relations [6] the measured maximum pressure of 115 kPa corresponds to a charge weight of 280 kg on the ground or 440 kg in free air. In both cases the corresponding duration is

18 ms. Therefore the measured pressure-time history with a duration of 2 ms and the resultant impulse seem unreliable.

Figure 2.48 shows the pressure of the first 100 ms from the other gauges together with the impulse.

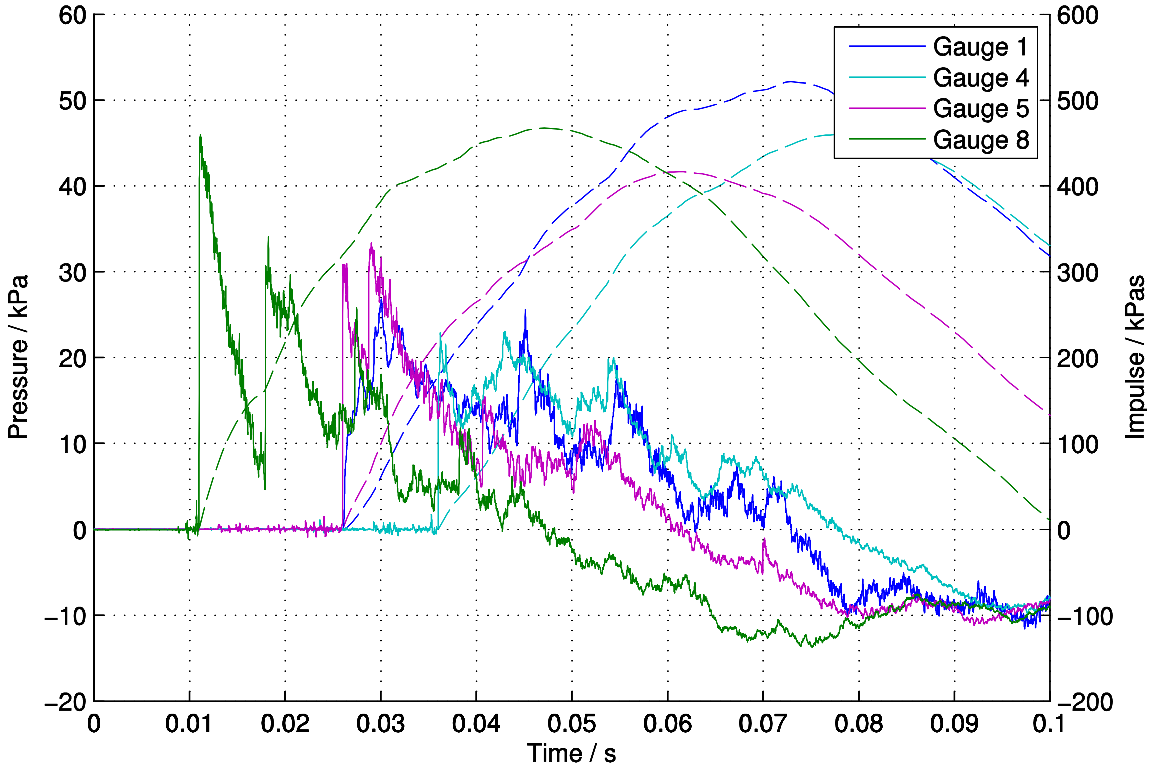

Figure 2.48 Pressure and impulse values (dashed lines)behind the MIL 10 wall in test 2.2

The maximum pressures and the duration and impulse of the first positive phase of the pressure wave are given in table 2.5.

Gauge number	Maximum pressure / kPa	Impulse / Pas	Duration / ms
1	27	490	37
2	115		
4	23	460	42
5	33†	420	34
8	46	460	32

†The sharp peak at 0.17 s reaches 91 kPa.

Table 2.5 Properties of the pressure signals measured by the pencil gauges in test 2.2

A comparison of the pressure at gauge 1 inside the tent with the pressure outside at gauge 5 may indicate how the tent affects the pressure wave. The distances from the gauges to the wall were different, but the distances to the charge were similar. The pressure at gauge 1 is somewhat lower than at gauge 5, but the difference between the impulses is smaller.

The blast test device measured pressures as shown in figure 2.49 and table 2.6.

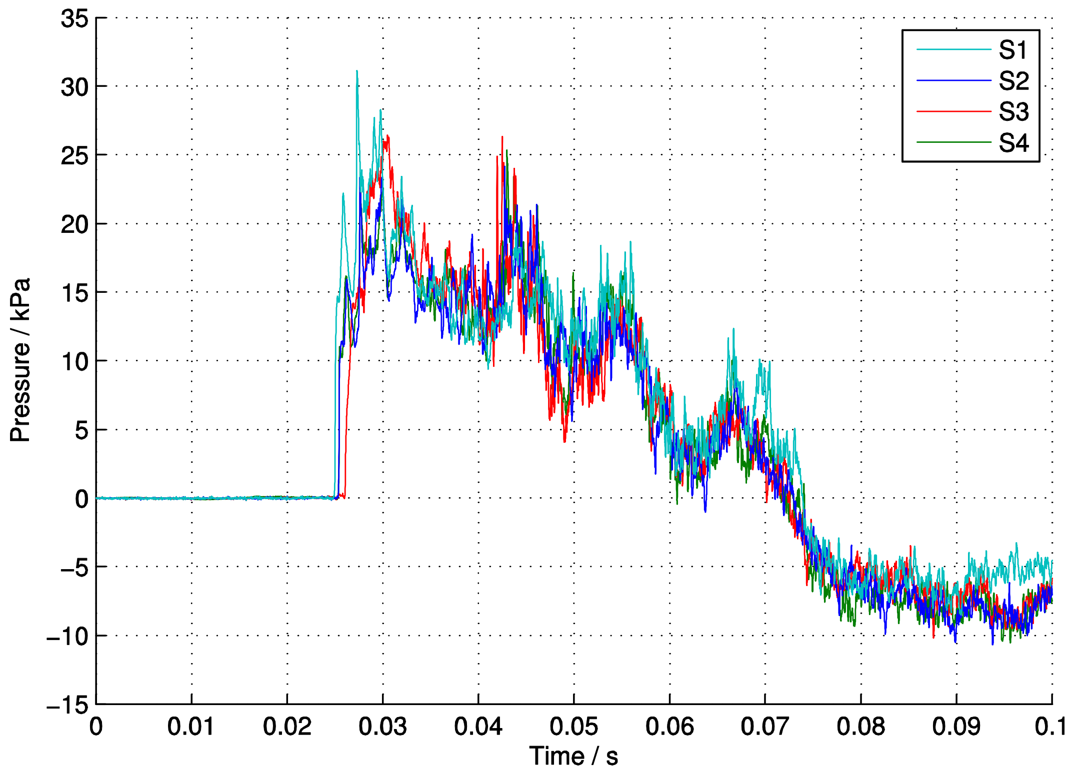

Figure 2.49 Pressure on the BTD in test 2.2

Gauge	Maximum pressure / kPa	Impulse / Pas	Duration / ms
S1	31	590	49
S2	24	480	38
S3	26	520	44
S4	25	480	35

Table 2.6 Properties of the measured pressure signals at the BTD in test 2.2

The durations of the first positive phase are considerably larger in test 2.2 than in test 2.1 (table 2.4), and the maximum pressures are smaller. Similar relations can be found in the measurements outside the tent. A comparison of the pressure values from the BTD and from gauge 1, where the incident pressure close to the BTD was registered, shows a reasonable agreement.
The pressure recordings from test 2.3 are shown in figure 2.50 and with the impulse included in figure 2.51.

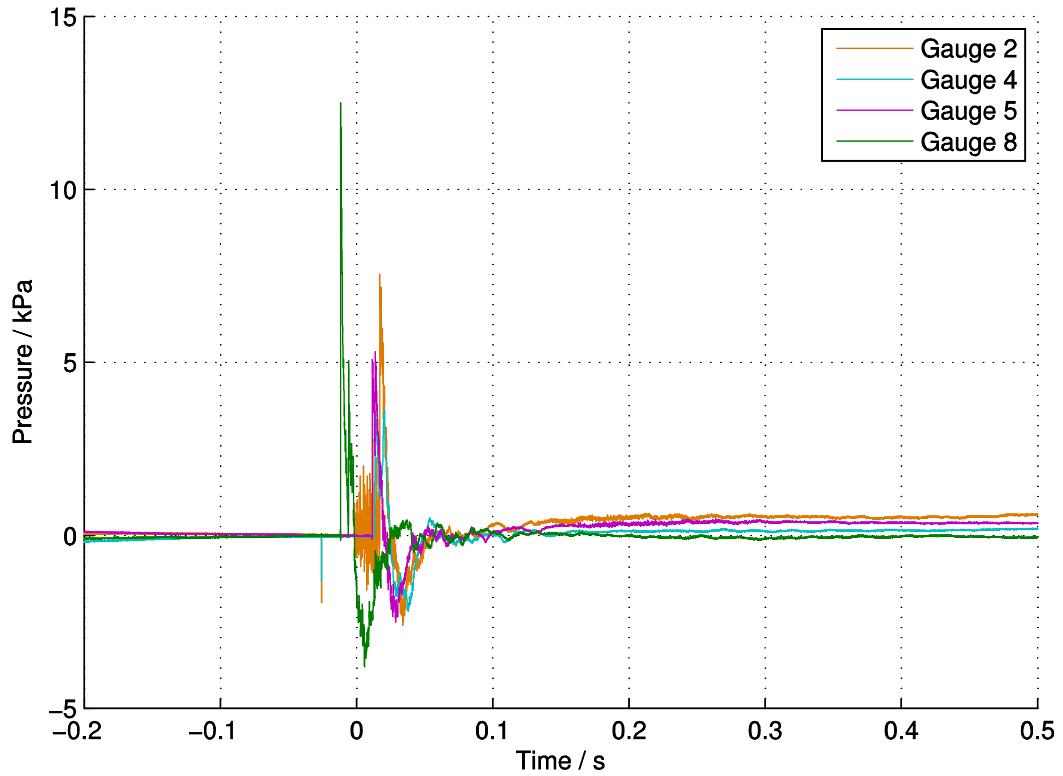

Figure 2.50 Recorded pressures in test 2.3

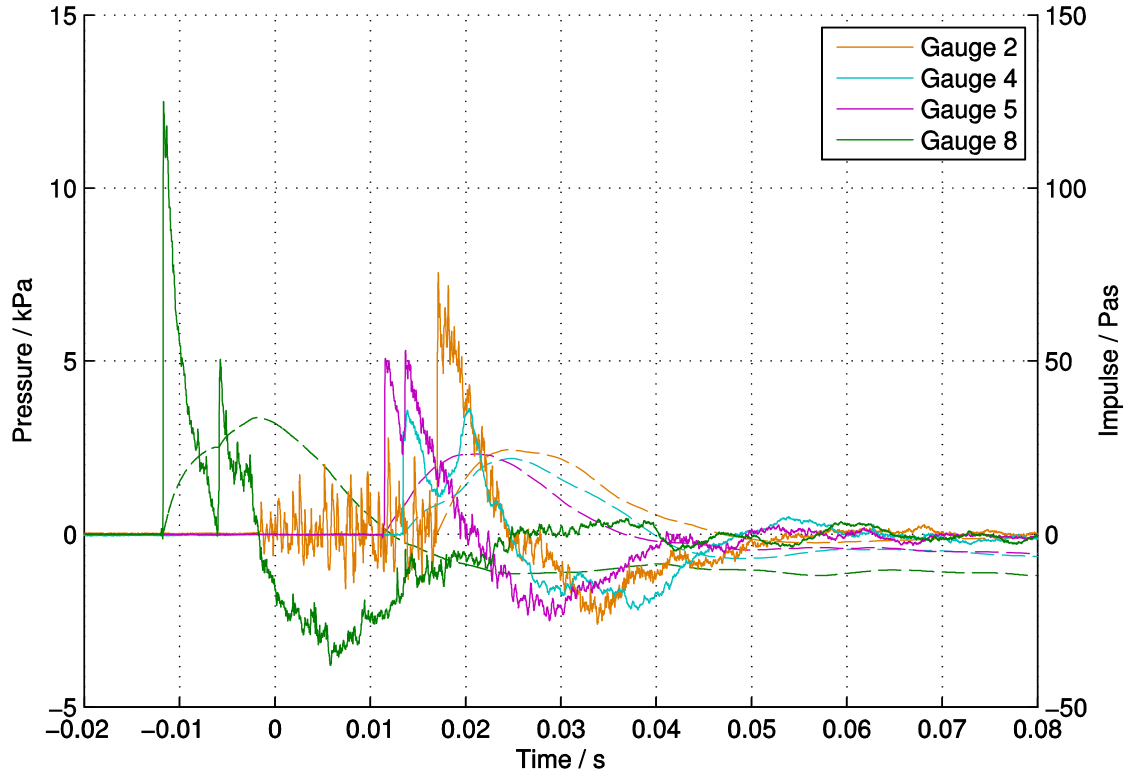

Figure 2.51 Pressure and impulse values (dashed lines) in test 2.3

Table 2.7 shows the maximum pressures, impulses and the duration of the first positive phase.

Gauge number	Maximum pressure / kPa	Impulse / Pas	Duration / ms
2	7.6	24	7
4	3.6	22	11
5	5.3	23	8
8	12.5	25‡	6

‡The maximum impulse of 34 Pas at -1.7 ms includes the second positive phase.

Table 2.7 Properties of the pressure signals measured by the pencil gauges in test 2.3

Figure 2.52 shows the maximum pressures measured in all the three tests. In this figure the symbol colours are given by the sideways distance, and the different shots have different symbol shapes. Figure 2.53 shows the corresponding diagram for the impulses.

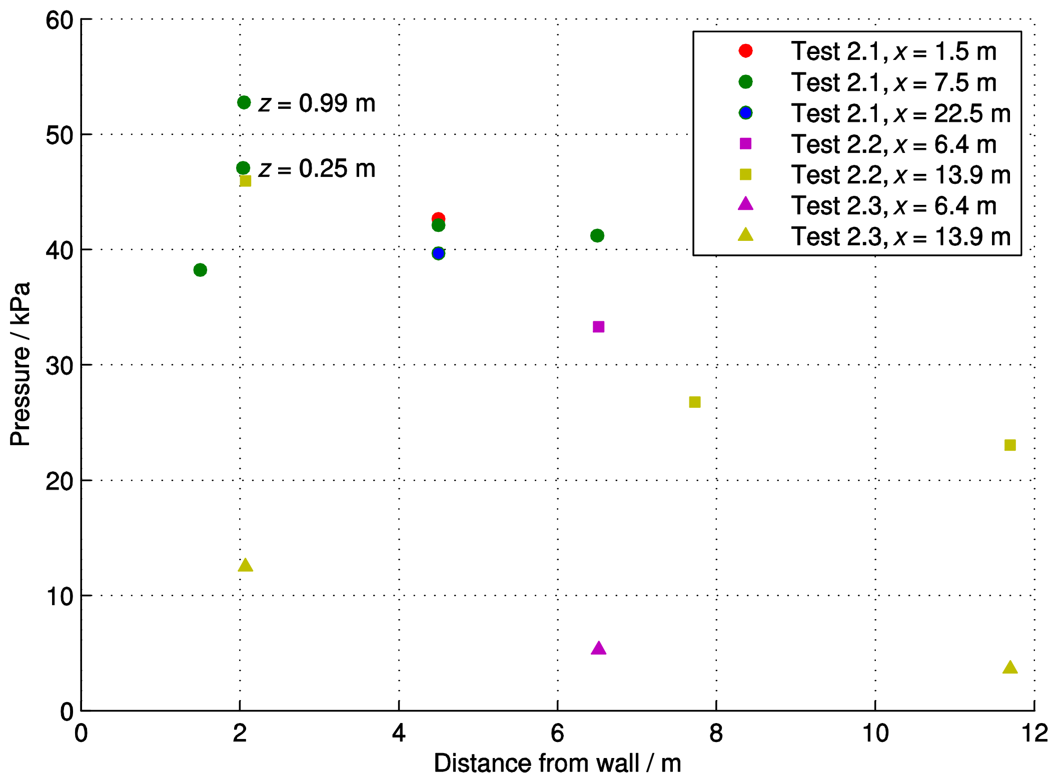

Figure 2.52 Maximum pressures behind the wall in the tests with 400 kg TNT where x is the sideways distance from the left edge of the wall and z is height above ground

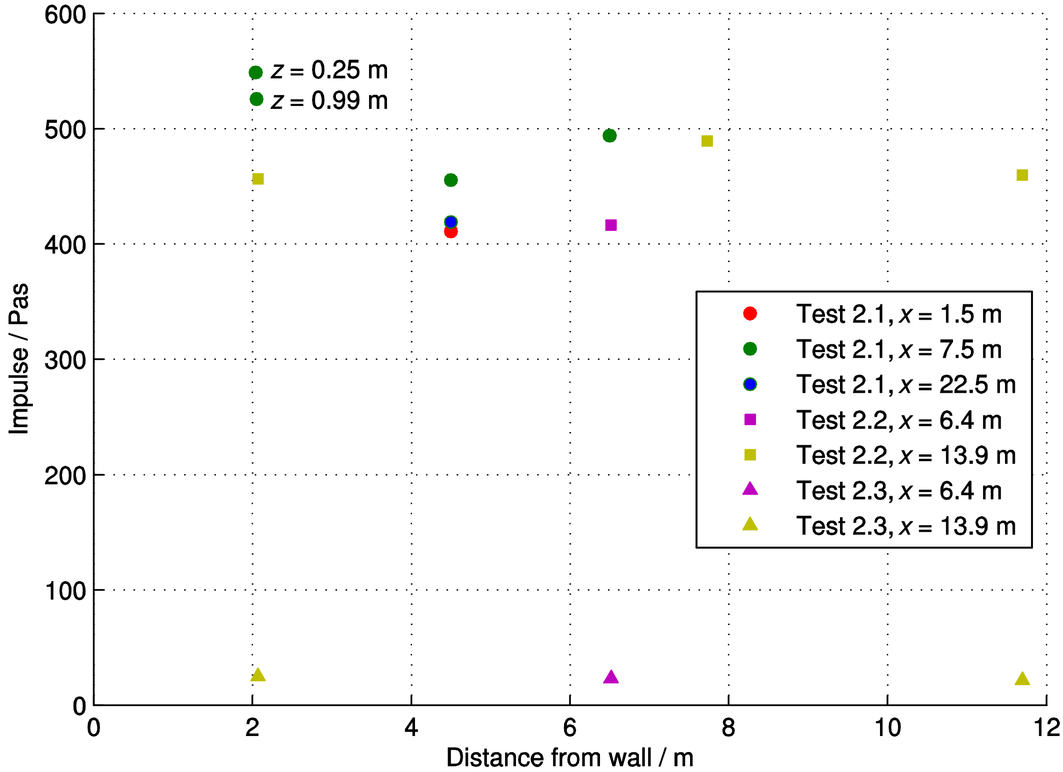

Figure 2.53 Maximum impulses behind the wall in the tests with 400 kg TNT where x is the sideways distance from the left edge of the wall and z is height above ground

The maximum pressure and the impulse 6.5 m from the wall were lower in test 2.2 (gauge 5) than in test 2.1 (gauge 4). This suggests that the magnitude of the incident blast wave was larger in test 2.1. It may be noticed that relative to values at other positions the impulse values inside and behind the tent in test 2.2 (x = 13.9 m, distance from wall 7.5 m and 11.7 m) are higher than the pressure values.

2.3 Tests with shaped charges

2.3.1 Description

To investigate the penetration of shaped charges into different soil types, 340 g charges of RDX/TNT were set off against MIL 2 units. The charges are similar to warheads used in RPG-7 systems, which are shoulder-launched anti-tank weapons.

A MIL 2 unit consists of two cells attached together. The side lengths of the cubic cells are 0.61 m. Wallboards were placed at the middle and at the end of the cells as indicators of the penetration depth. As in test 1 the soil types were sand, gravel, crushed rock and local soil. Figure 2.54 shows the setup of the first shot against sand.

Figure 2.54 Setup of the test with a 340 g shaped charge against MIL 2 with sand

2.3.2 Results

The effect of the shaped charges to the MIL 2 units with different fill materials is shown in figures 2.55-2.58.

Figure 2.55 Front side of MIL 2 filled with sand after detonation of a 340 g shaped charge

Figure 2.56 Front side of MIL 2 filled with gravel after detonation of a 340 g shaped charge

Figure 2.57 Front side of MIL 2 filled with crushed rock after detonation of a 340 g shaped charge

Figure 2.58 Front side of MIL 2 filled with local soil after detonation of a 340 g shaped charge

After the firings the position of the liner slug (figure 2.59) was measured. Table 2.8 shows the values.

Soil type	Penetration / cm
Sand	90
Gravel	85
Crushed rock	72
Local soil	80

Table 2.8 Penetration depth of shaped charges in MIL 2 with different fill materials

Figure 2.59 Shaped charge slug

3 Conclusions

In tests where TNT charges simulating 120 mm mortar and 155 mm artillery rounds were detonated against Hesco MIL 3 units, considerable damage was made to the cells in contact with the charge, and the front side was mainly destroyed. The amount of fill material that was thrown out increased somewhat with the stone size. The throw distance was much larger with crushed rock and local soil then with sand and gravel, and the velocity of the stones was correspondingly higher. Therefore crushed rock and local soil cannot be recommended as fill material in gabions.

MIL 3 units with sand and gravel provide quite good protection against one 3.5 kg or 7.5 kg TNT charge detonated in contact with the unit.

155 mm shells fired against MIL 3 units blew away three cells and damaged more. Thus MIL 3 gabions give little protection against this threat. Besides, the conclusions drawn from the tests with uncased charges of 7.5 kg TNT are not applicable to cased warheads. The amount of debris was about the same for all the fill materials. Still, sand and gravel will cause less damage to persons and objects than the larger stones of crushed rock and local soil.

3.5 kg TNT charges caused no damage to the tents behind the MIL 3 walls. The damage to NM 240 tents near the detonation of 7.5 kg charges was however significant. The squad tent was deformed, but only the pegs were destroyed. The 400 kg charge detonated 20 m in front of a MIL 10 wall made extensive damage to the tents behind the wall. Thus a car bomb at this distance may cause damage to people being hit by beams or other hard objects. Some damage was also made to the NM 240 tent unprotected by the MIL 10 wall when a 400 kg TNT charge was detonated 70-80 m away.

Pressure values registered behind the MIL 10 walls when 400 kg TNT was detonated in front are presented in this report. These values and values from the previous test series are employed to verify simulations [6] and will be further analysed and compared with criteria for air blast damage.

The penetration of a 340 g shaped charge into a gabion decreases when the size of the stones in the fill material increases. The penetration depth in local soil with a mixture of stone sizes also depends on whether the charge liner hits a large stone or not. The fronts of the gabions were partly damaged by the charge simulating a RPG-7 warhead, but the gabions were still so intact that they seemed to offer good protection against additional shots.

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Appendix A Pressure sensors

The recorded pressure data were filtered by a fourth-order Bessel filter with a cut-off frequency of 22 kHz [7].

A.1 8-channel pencil pressure sensors

The pressure sensors for measuring incident pressure were pencil gauges of type PCB 137 A23. They were connected through 100 m coax-cables to two PCB 482C16 amplifiers. Data were sampled with a frequency of 204 800 Hz at a data acquisition card of type National Instruments PCI-4462 controlled by a Labview program.

The following sensors were connected to the data acquisition system:

Sensor number	Serial number	kPa/V	Dev name
1	8823	71.37	Dev2/ai0
2	8824	69.82	Dev2/ai1
3	8825	70.75	Dev2/ai2
4	8826	72.63	Dev2/ai3
5	8839	75.81	Dev5/ai0
6	8840	72.69	Dev5/ai1
7	8841	70.99	Dev5/ai2
8	8851	74.30	Dev5/ai3

Table A.1 Data for 8-channel pressure sensors

In test 2.1 the pressure sensors were at the positions shown in table A.2.

Sensor number	Height above ground / m	Distance from wall / m	Sideways distance from wall edge / m
1	1.67	4.50	7.50
2	1.25		
3	1.58	4.50	22.50
4	1.63	6.50	7.50
5	1.64	4.50	1.50
6	0.25	2.04	7.50
7	0.99	2.05	7.50
8	1.61	1.5	7.50

Table A.2 Position of 8-channel pressure sensors in test 2.1

Sensor number 2 was not behind the wall, but positioned 20 m to the side of the charge.

The positions of the pressure sensors in test 2.2 are listed in table A.3.

Sensor number	Height above ground / m	Distance from wall / m	Sideways distance from wall edge / m
1	1.67	7.8	13.9
2	1.25		
4	1.63	11.70	13.9
5	1.64	6.52	6.4
8	1.61	2.07	13.9

Table A.3 Position of 8-channel pressure sensors in test 2.2

Sensor 2 was positioned 19.6 m sideways from the charge.

In test 2.3 the charge was 60 m from the wall, and the distance from sensor 2 to the charge was also 60 m. Sensor 1 was removed. The rest of the setup was similar to test 2.2.

The recorded pressure values were shifted by the following values to get zero pressure at the time the shock wave arrived at the sensors:

Sensor number	Test 2.1	Test 2.2	Test 2.3
1		− 0.2 kPa	− 0.2 kPa
2		+ 1.8 kPa	+ 1.0 kPa
3	− 0.9 kPa		
4	+ 1 kPa	− 0.6 kPa	+ 0.2 kPa
5	+ 0.5 kPa	− 0.4 kPa	+ 0.7 kPa
6	− 0.24 kPa		
7	− 0.4 kPa		
8	− 0.65 kPa		

Table A.4 Adjustments of pressure values recorded by 8-channel pressure sensors

In test 2.3 there was a trend of increasing pressure values from sensor 8 from -0.14 s up to the time when the blast wave hit the gauge. The trend was removed by subtracting values from a polynomial fitted to the recorded values in the time interval from -0.14 to 0.5 s. With an extra adjustment of -0.11 kPa to get the desired zero level the values subtracted from the recorded values are given by the function,

$$p_{\mathrm{RED}} = \begin{matrix} -0.0262799 & t \le -0.14 \\ -4.3491807 \cdot t^2 + 3.3506828 \cdot t + 0.5280597 & t > -0.14 \end{matrix} \qquad \text{(A.1)}$$

where p_{RED} is given in kPa and t is time/s. Pressure values after 0.5 s are not considered.

A.2 BTD sensors

The blast test device (BTD) has four sensors of type PCB 102A05 which are connected to a PCB 482C64 amplifier. The data were sampled at 205 128 Hz with a compact DAQ device of type National Instruments 9188 with a 9223 module. The data acquisition was controlled by a Labview program. The properties of the sensors are specified in table A.5.

Serial number	Dev name	mV/kPa (up to 10 psi)
32617	ai0	7.178
32618	ai1	7.061
32616	ai2	7.417
32614	ai3	7.521

Table A.5 Data for pressure sensors at the blast test device

In this report the sensors are labelled S1-S4 in accordance with figure A.1. The labels thus represent different sensors in the two tests.

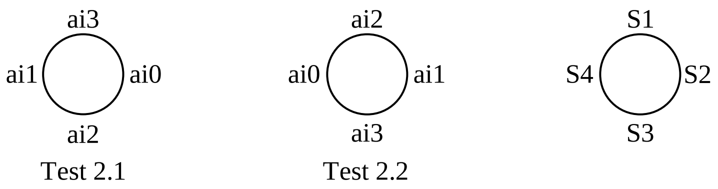

Figure A.1 Position of sensors at the BTD in test 2.1 and 2.2

Adjustments were also made to pressure values recorded by the BTD sensors:

Sensor	Test 2.1	Test 2.2
S1	+ 0.85 kPa	− 0.04 kPa
S2	+ 0.58 kPa	− 0.09 kPa
S3	+ 0.26 kPa	− 0.03 kPa
S4	+ 0.15 kPa	0

Table A.6 Adjustments of pressure values recorded by BTD sensors