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Technical Report ARMET-TR-09049

M228 FUZE IGNITER PRESSURE MEASUREMENT PART 1

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

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14. ABSTRACT

The M67 hand grenade is a traditional pull-pin grenade, widely used by the U.S. Army and Marine Corps. Pulling the pin in the grenade's fuze (the M213) releases the spoon and the hammer, which hits the primer at the top of the fuze body initiating the delay firing train (C70 det). This fuze train is simple and has functioned well and reliably in grenades for decades. Unfortunately, it also has major safety issues. Any unwanted stimulus that causes the primer to function, like fire, initiates the entire fuze train. The large quantities of primary explosive in the detonator can also be detonated by external stimulus with enough energy to function the entire grenade. This report describes the tests that were conducted to measure the pressure generated when the primer was ignited by removing the pin and allowing the striker to impact the primer. This was done with training round fuze, M228, which has same primer and delay element.

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M67 grenade   M228 and M213 fuze   Pressure

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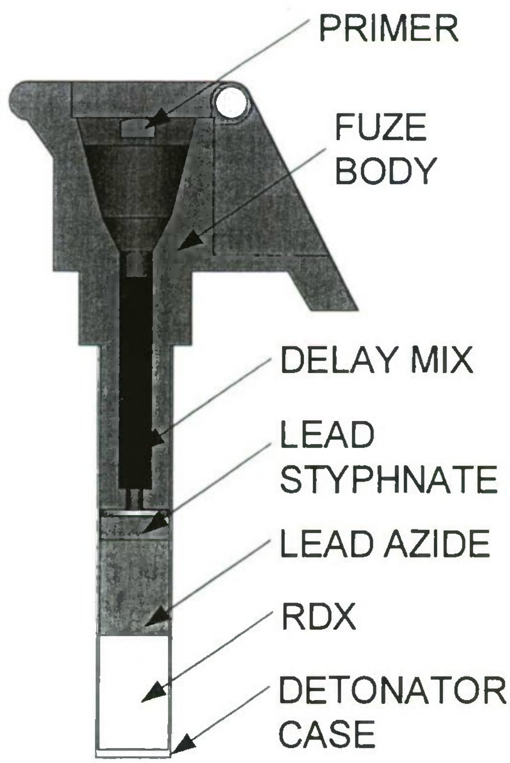
INTRODUCTION

The M67 fragmentation hand grenade is a traditional pull-pin grenade, widely used by the U.S. Army and Marine Corps. Pulling the pin in the grenade's fuze (the M213) releases the spoon and the hammer, which hits the primer at the top of the fuze body (fig. 1), initiating the firing train. The delay mix is ignited by the primer and burns several seconds before initiating the attached C70 detonator. This detonator is massive, containing approximately 10 times more lead styphnate, lead azide, and RDX than other detonators. This size is not simply a case of over engineering; the length is required to properly initiate the grenade's explosive fill for good fragmentation, while its diameter is dictated by the dimensions of the fuze body.

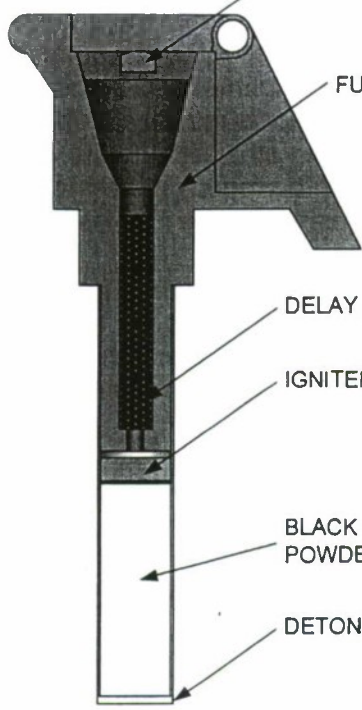
The M228 is also the grenade's fuze, which is used for training rounds. It has the same primer element at the top of the fuze body, initiating the firing train. The delay mix is ignited by the primer and burns several seconds before initiating the detonator, which only contains black powder compared to primary/secondary material, lead axide/RDX.

Pressure measurement tests were setup to determine the pressure generated when the primer was ignited when the pin was removed and the striker hit the primer. A total of 23 preliminary tests were made with two different fixtures before the most suitable fixture, test methodology, and generated pressure levels were determined. Sixty-four tests were then conducted after selecting the fixture and test method.



a) M213 fuze

Figure 1
M213 and M228 grenade fuze
(spoon and hammer not pictured)



b) M228 fuze

Figure 1
(continued)

TEST DESCRIPTION

The M228fuze igniter head and the two fixtures used to conduct pressure tests on the head are shown in figure 2. The head, which was modified by removing the delay tube, contains only the filled primer cup. It was screwed into the top of the fixture until it contacted a flat surface machined into the fixture. Teflon tape was wrapped around the head threads to seal against pressure leakage. Below the flat surface, the fixture was machined to accept a PCB model P119B12 pressure sensor. The first fixture had a recessed pressure sensor with a 5/16 in. gap between the igniter head and the sensor's active surface. This gap was filled by a steel pellet that was included to protect the sensor against heat from the burning igniter. The sensor is shown in figure 2 and the block diagram of the measurement system is shown in figure 3. Figures 4 through 8 show the assembled test unit, the test chamber, and instrumentation used to measure pressure. The test was conducted with the item in the small containment chamber (fig. 7). A string was tied to the safety pin. This string was drawn outside of one of the chamber ports so it could initiate in the closed chamber and it's safe. The string was pulled from outside, which pulled the pin to strike and hit the primer. Pulling the pin allowed the striker to hit the primer, igniting it, and generating pressure. The pressure was sensed by the pressure sensor, which sent a signal to a PCB model 402M186 inline amplifier and PCB model 482A22 signal conditioner. The signal was then sent to a LeCroy model 6050A digital storage oscilloscope where it was captured and stored. Waveforms from the 12 tests conducted with the first fixture are shown in figure 9. The waveforms were consistent, typically having an initial pulse of 220 to 390 mV peak (5326 to 9442 psi peak) and 20 μs duration, followed by a smaller step signal with an initial peak of 26 to 86 mV (629 to 2082 psi) that gradually diminished towards zero as the pressure leaked from the fixture cavity. The calibration factor for this PCB system was 24.21 psi/mV.

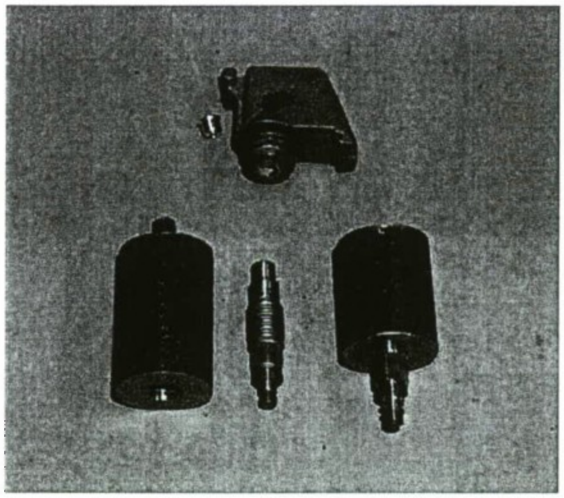


Figure 2
Fuze igniter head, fixtures, pressure sensor

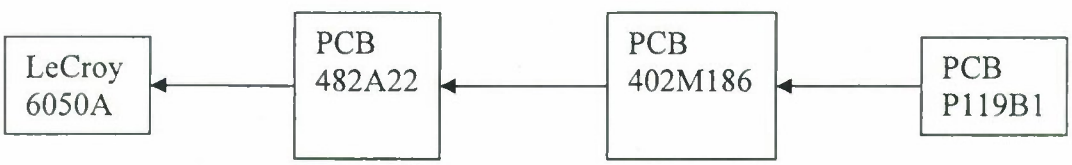


Figure 3
System block diagram

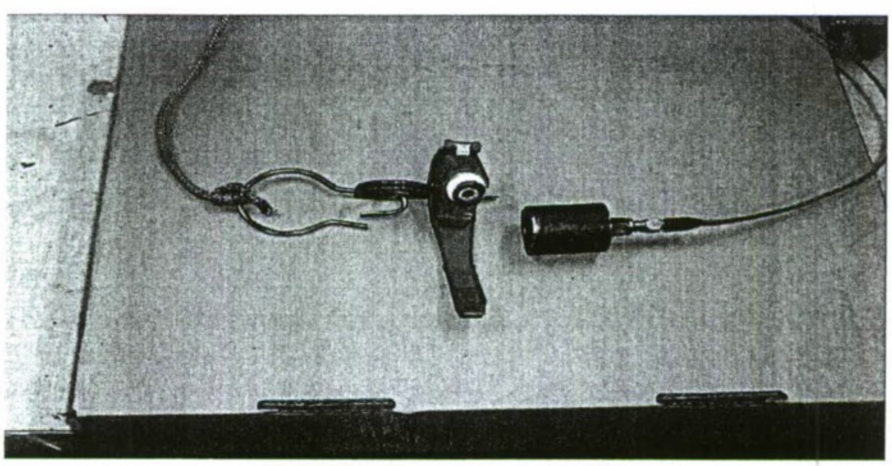


Figure 4
Preassembled components

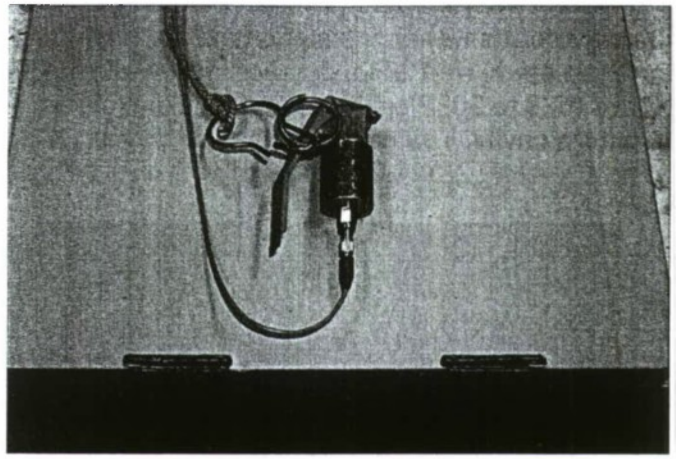


Figure 5
Assembled components

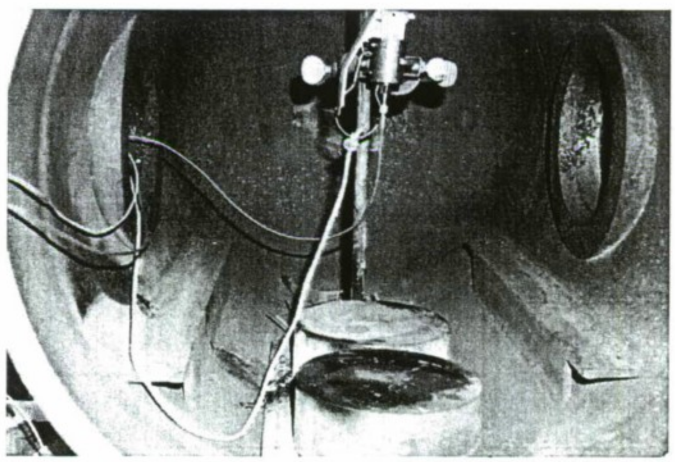


Figure 6
Test assembly in chamber

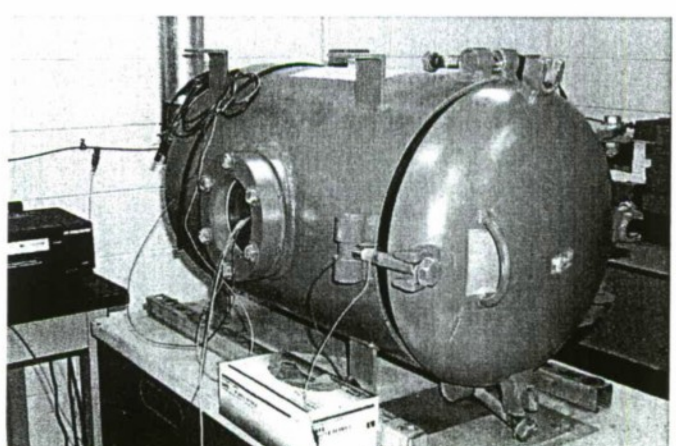


Figure 7
Test chamber

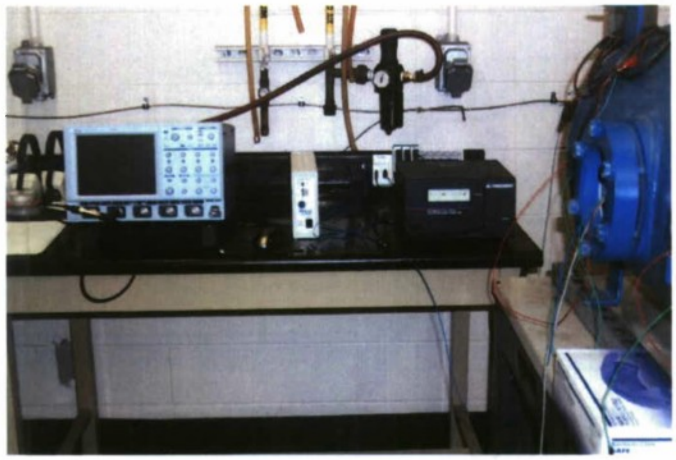


Figure 8
Test instrumentation

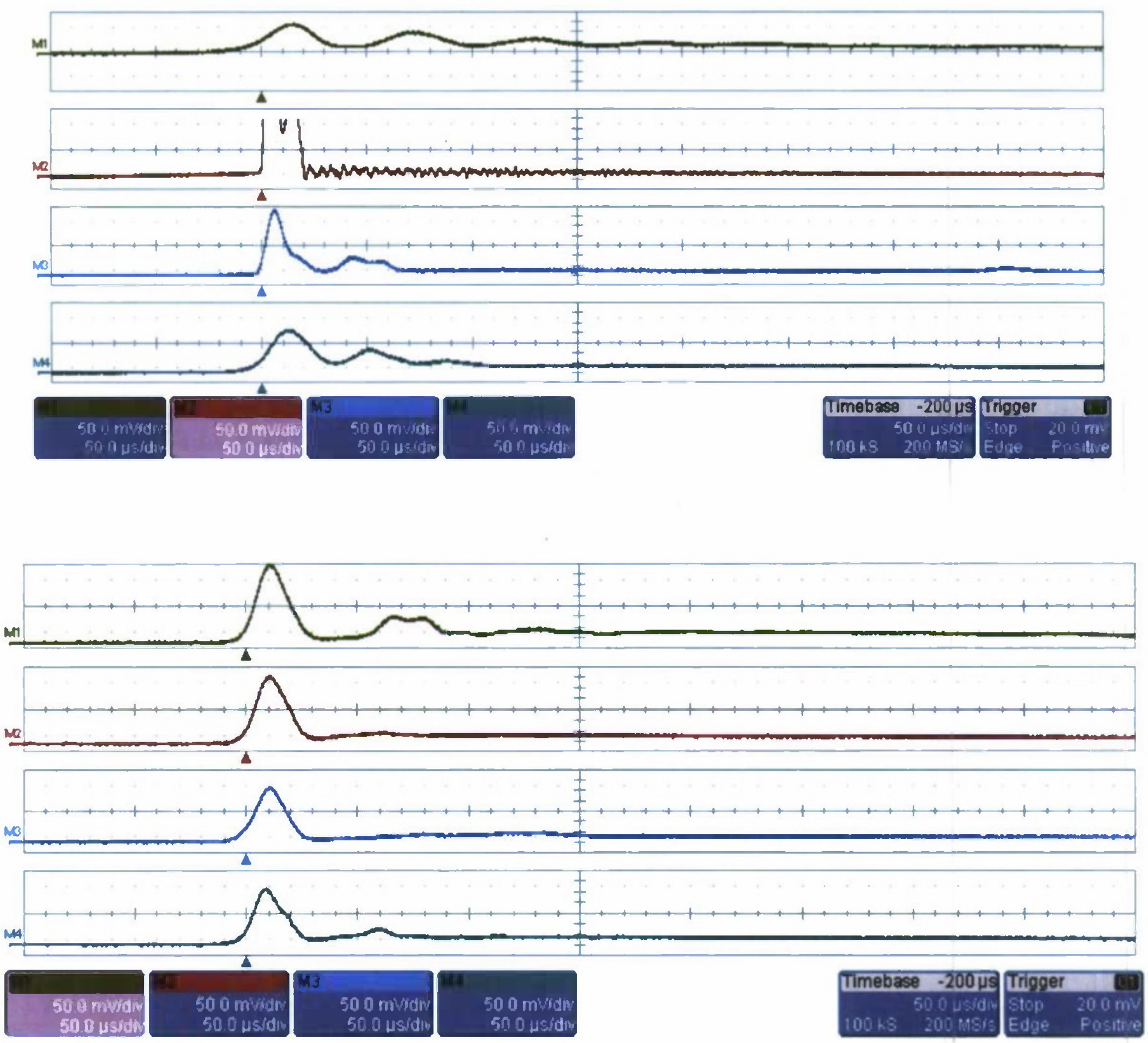


Figure 9
Pressure signals, recessed fixture

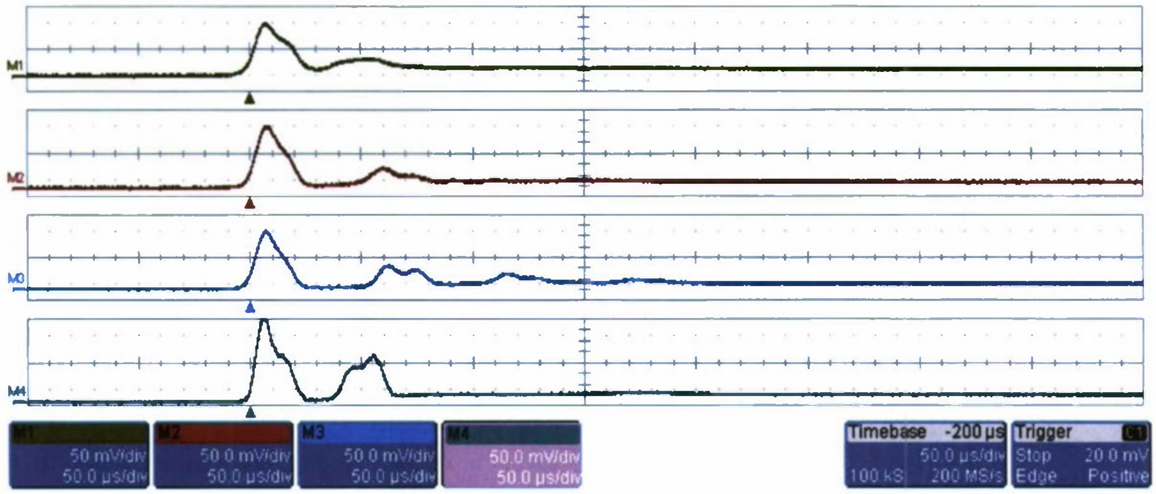


Figure 9
(continued)

RESULTS

Eleven tests were conducted with the second fixture which was designed to eliminate the large gap between the ignition head and sensor diaphragm. This fixture was machined so that the sensor diaphragm was almost flush with the flat surface in contact with the fuze head. The head diaphragm gap was approximately 0.010 in. Temperature protection was provided by vinyl tape for four tests and silicone grease for seven tests. The test methodology was the same for the second fixture as for the first fixture. Figure 10 shows the waveforms obtained for the tests conducted with vinyl tape placed across the sensor diaphragm. Those signals were not the same as the signals obtained with the first fixture. The second fixture signals did not have a pulse initially, but were step waveforms that were 54 to 76 mV peak (1307 to 1840 psi peak), which were similar to the step signals obtained with the first fixture that occurred after the first large pulse. PCB Engineers were asked if they could explain the presence of the first pulse in the first fixture tests. They were unable to come up with an explanation and no one involved with these tests could explain it either. However, the PCB engineers thought that the second fixture, with the flush diaphragm, should give the most accurate signals and they recommended using silicone grease or vinyl tape to protect the sensor. This was done for the next four tests where grease was placed in the airspace from the bottom of the truncated igniter head to the top of the channel where the delay composition normally goes (the delay composition was removed from the heads for all the tests to be conducted in this series). The waveforms obtained from these tests (fig. 11) are very similar to the three vinyl tape waveforms with peaks of 41 to 81 mV (993 to 1961 psi). The first signal (fig. 11) was obtained using the recessed fixture as a check on the sensor operation. The last three tests were made using twice the amount of grease to fill the head cavity. This was done to see if it would produce twice the signal peak, but results were inconclusive. However, the waveforms were similar with peaks of 39 to 111 mV (944 to 2687 psi). Table 1 summarizes the peak pressures obtained with fixture 1, which discounted the initial pulses, and fixture 2. These tests completed the exploratory phase of this project.

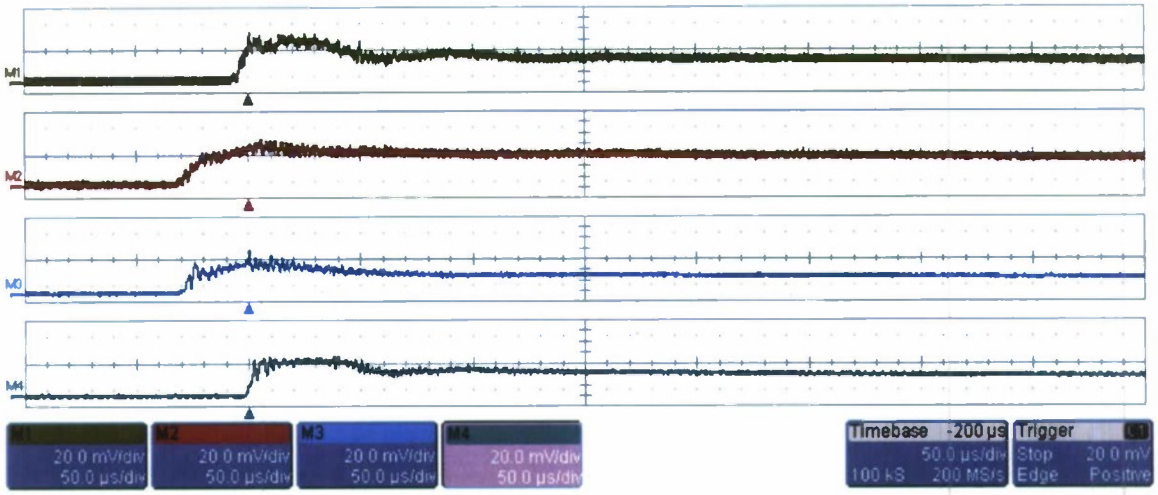


Figure 10
Pressure signals, flush fixture, vinyl tape

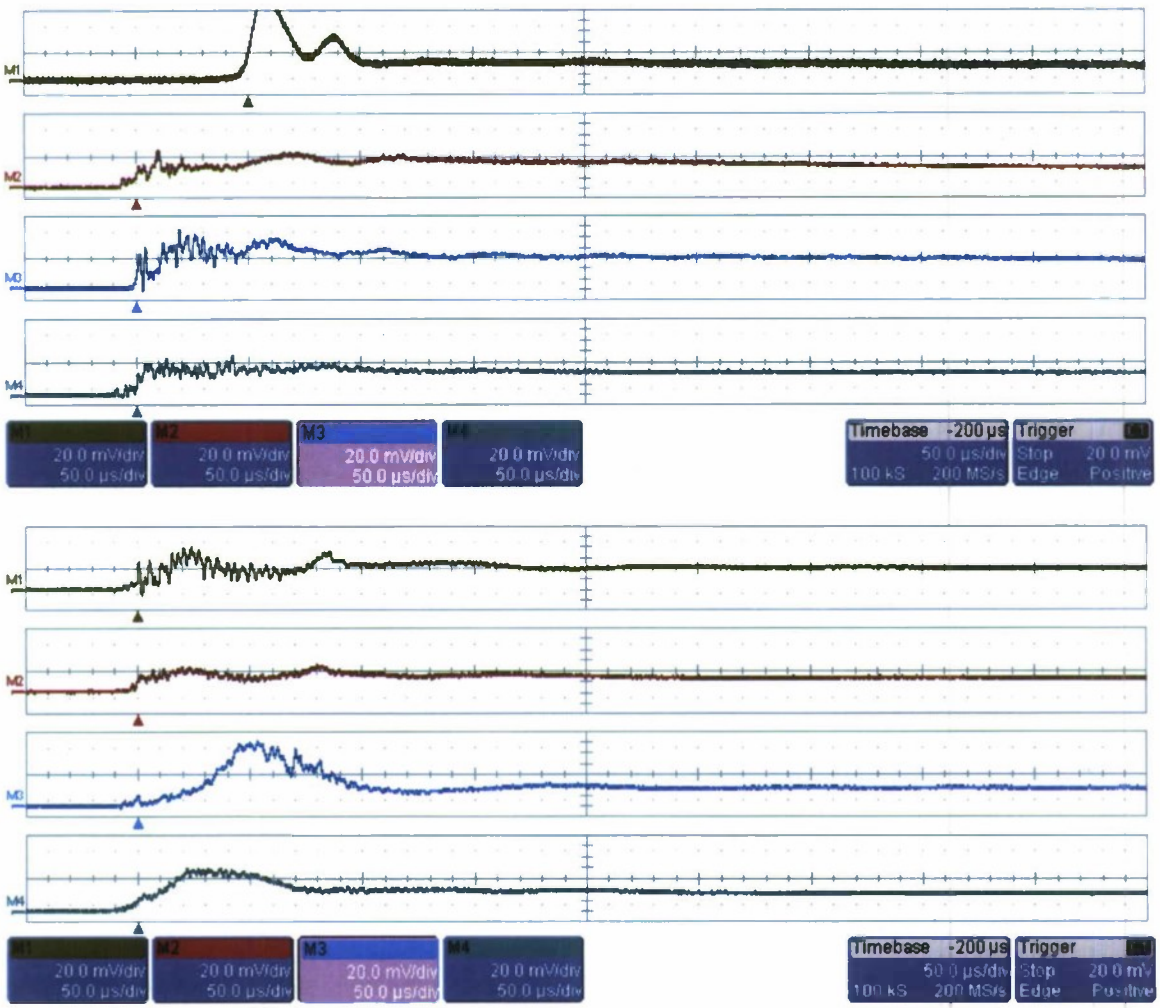


Figure 11
Pressure signals, flush fixture, grease

Table 1
Peak pressures, fixture 1 (discounted initial pulses) and fixture 2

Signal	Conditions	Peak pressure (psi)
Fig. 9, M1	Recessed fixture w/steel pellet	1210
M2	Recessed fixture w/steel pellet	629
M3	Recessed fixture w/steel pellet	2082
M4	Recessed fixture w/steel pellet	920
M1	Recessed fixture w/steel pellet	1501
M2	Recessed fixture w/steel pellet	1210
M3	Recessed fixture w/steel pellet	1017
M4	Recessed fixture w/steel pellet	968
M1	Recessed fixture w/steel pellet	1017
M2	Recessed fixture w/steel pellet	872
M3	Recessed fixture w/steel pellet	920
M4	Recessed fixture w/steel pellet	920
Fig. 10, M1	Flush fixture w/vinyl tape	1840
M2	Flush fixture w/vinyl tape	1767
M3	Flush Fixture w/vinyl tape	1307
M4	Flush fixture w/vinyl tape	1549
Fig. 11, M1	Recessed fixture w/steel pellet	944
M2	Flush fixture w/grease	993
M3	Flush fixture w/grease	1961
M4	Flush fixture w/grease	1210
M1	Flush fixture w/grease	1501
M2	Flush fixture w /2x grease	944
M3	Flush fixture w/2x grease	2687
M4	Flush fixture w/2x grease	1743

Sixty-four tests were then performed using the flush fixture with vinyl tape over the sensor surface. Figures12 through 28 show the pressure waveforms obtained from the 64 test items of this second group. Table 2 lists the peak pressures and rise times of the waveforms.

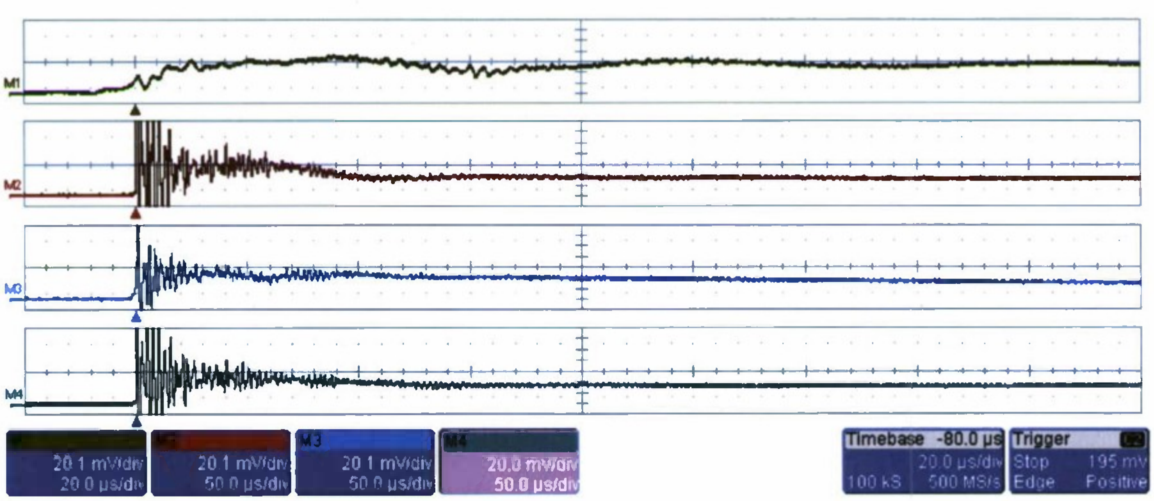


Figure 12
Pressure signals, test 1-4

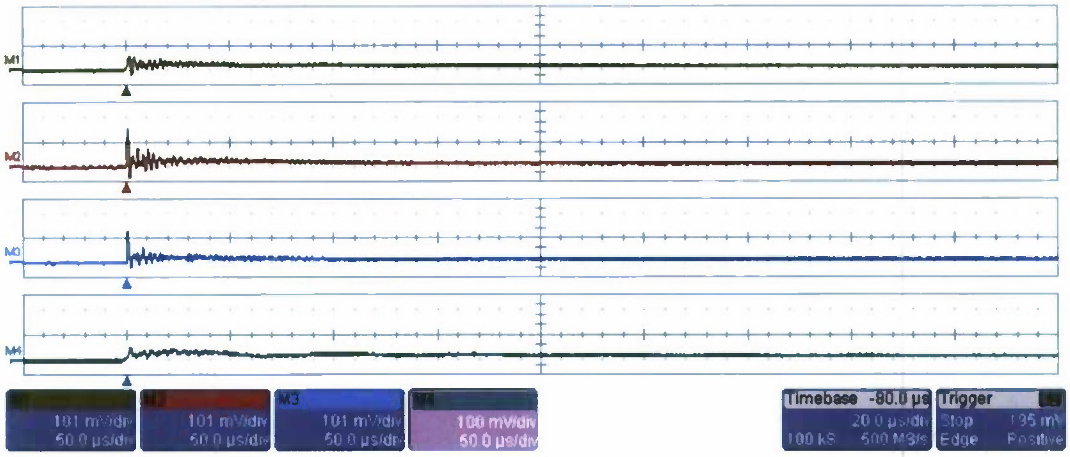


Figure 13
Pressure signals, test 5-8

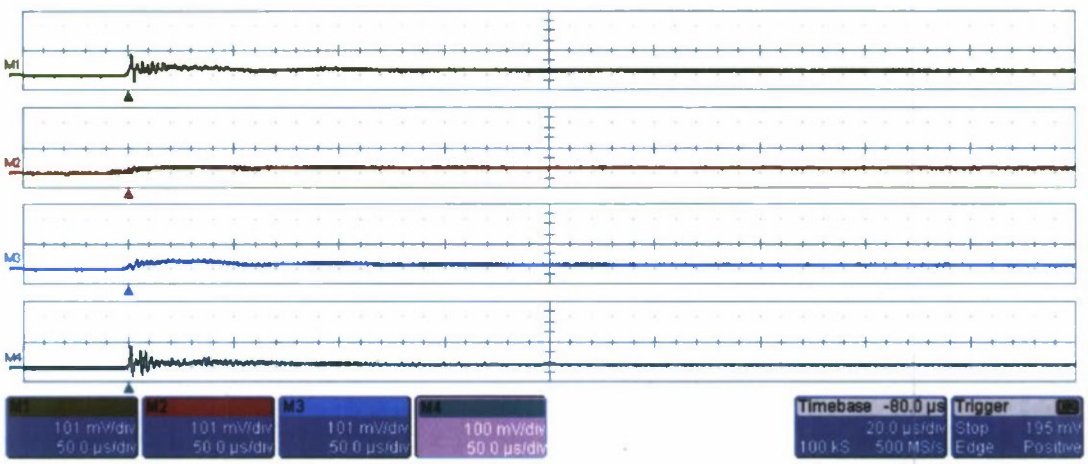


Figure 14
Pressure signals, test 9-12

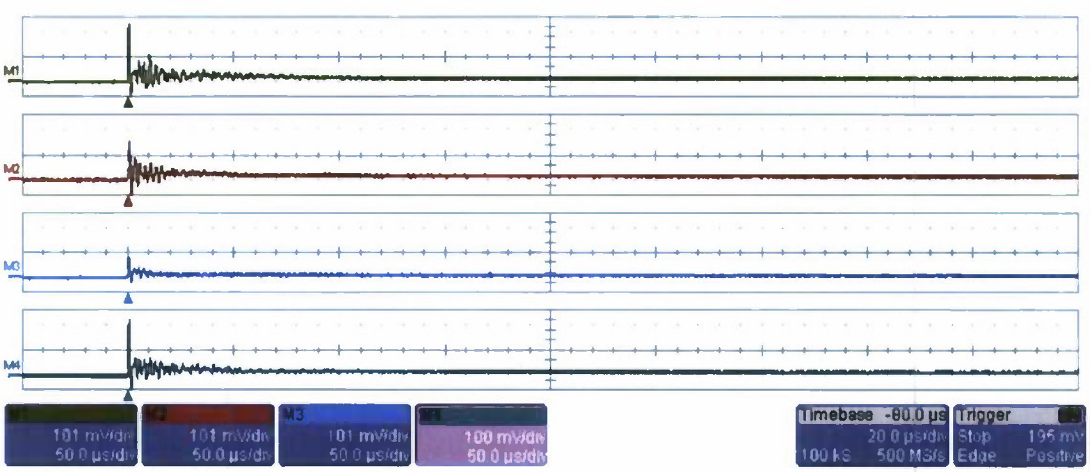


Figure 15
Pressure signals, test 13-16

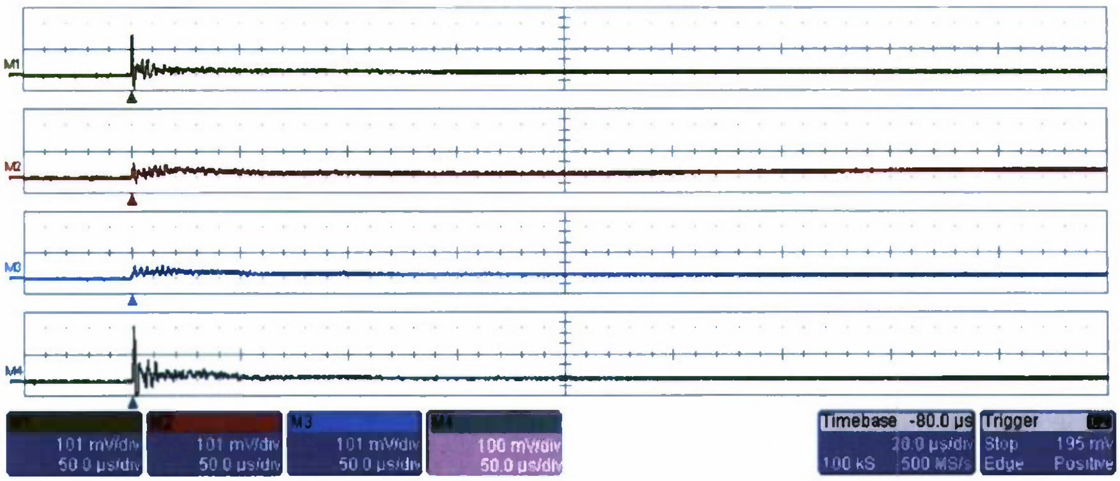


Figure 16
Pressure signals, test 17-20

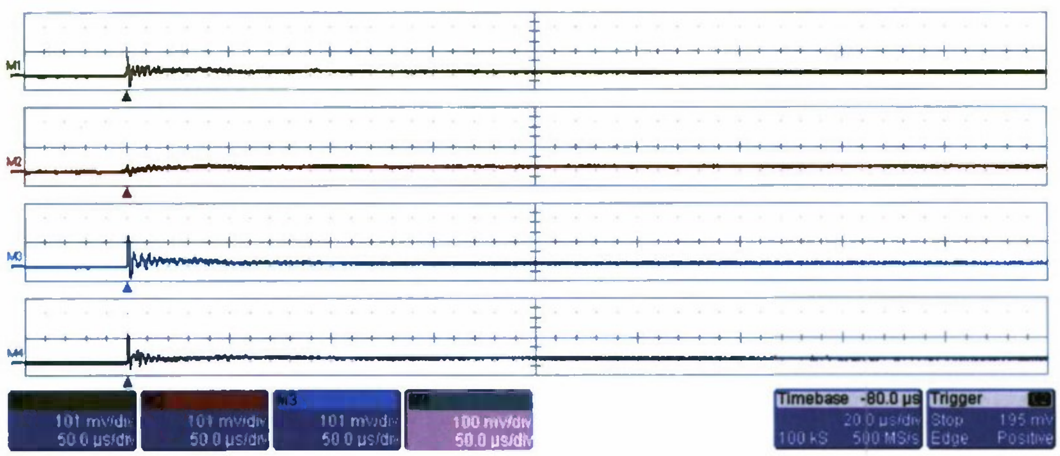


Figure 17
Pressure signals, test 21-24

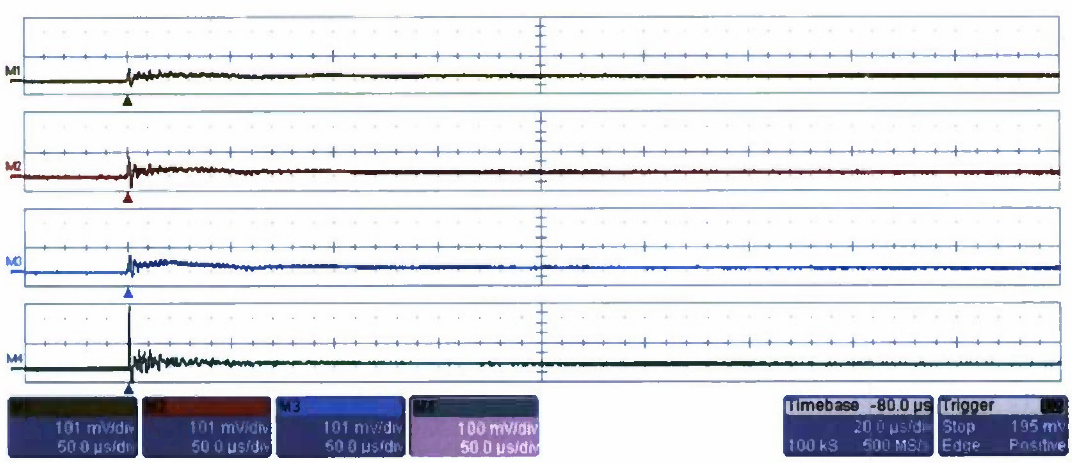


Figure 18
Pressure signals, test 25-28

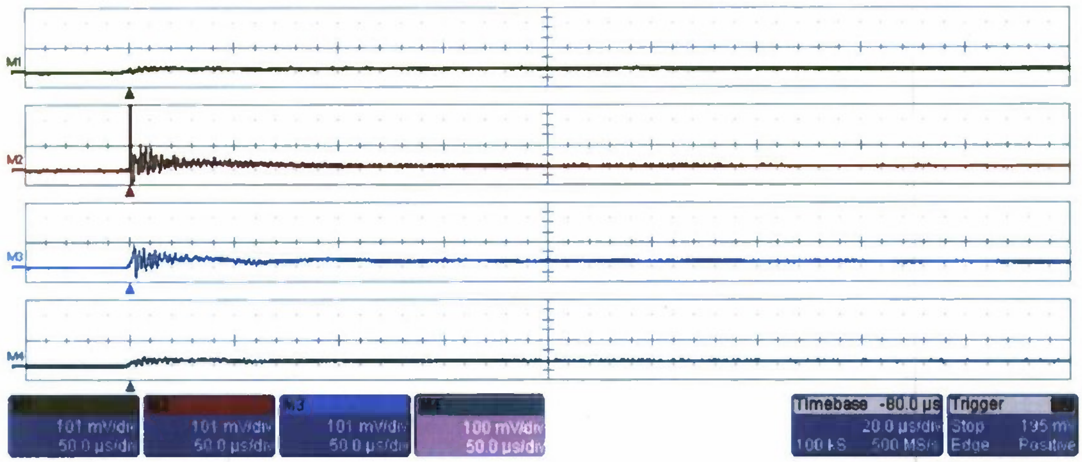


Figure 19
Pressure signals, test 29-32

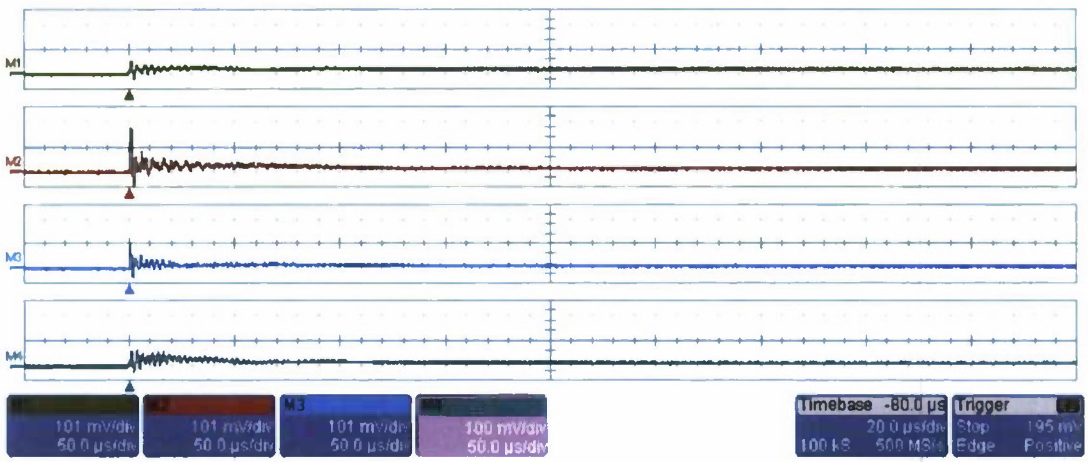


Figure 20
Pressure signals, test 33-36

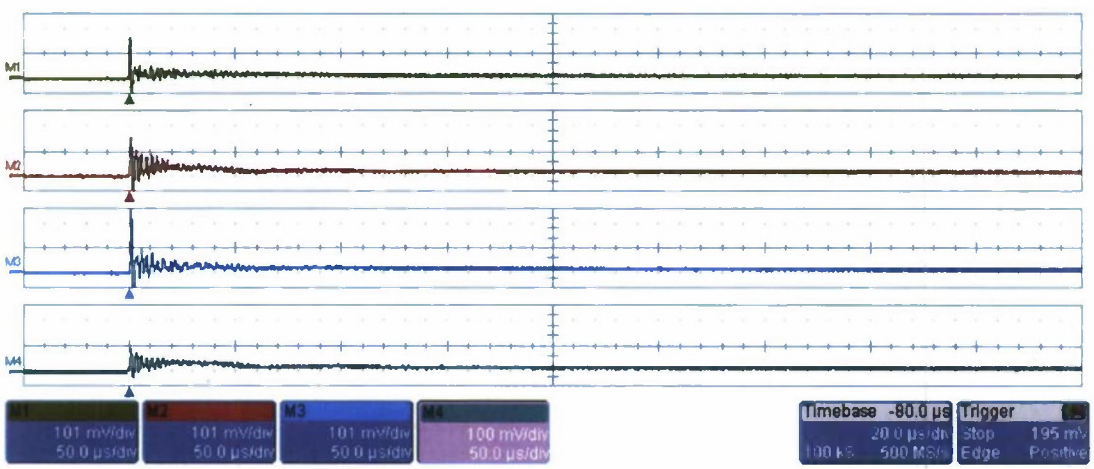


Figure 21
Pressure signals, test 37-40

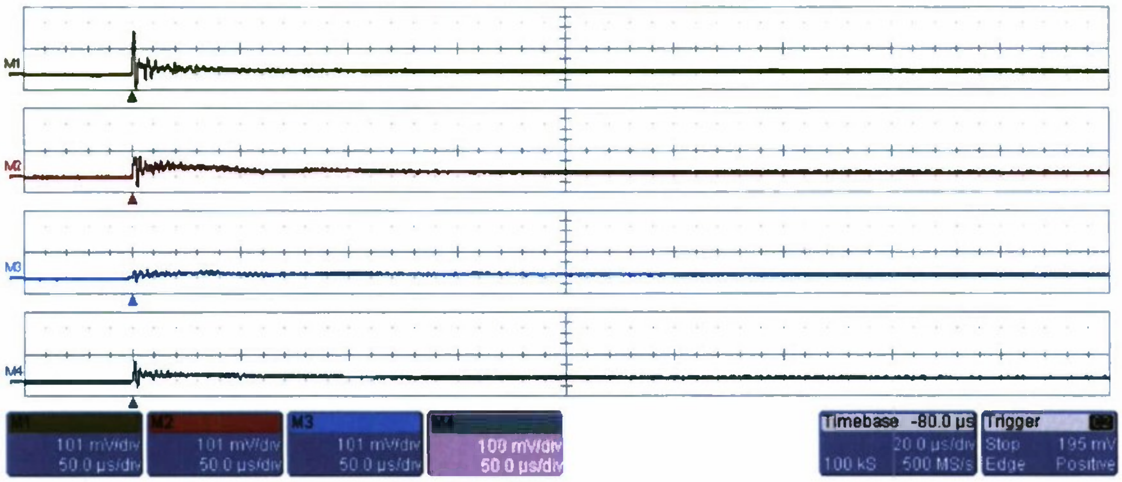


Figure 22
Pressure signals, test 41-44

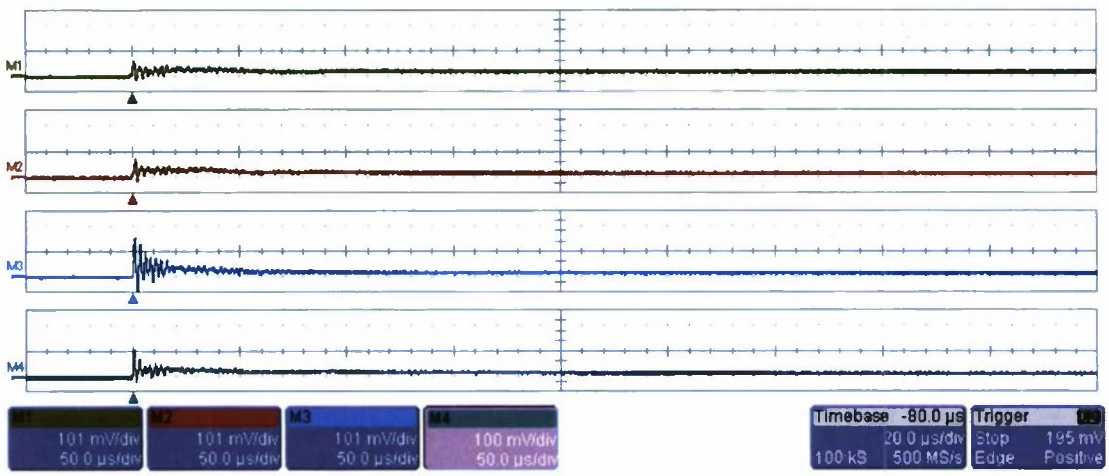


Figure 23
Pressure signals, test 45-48

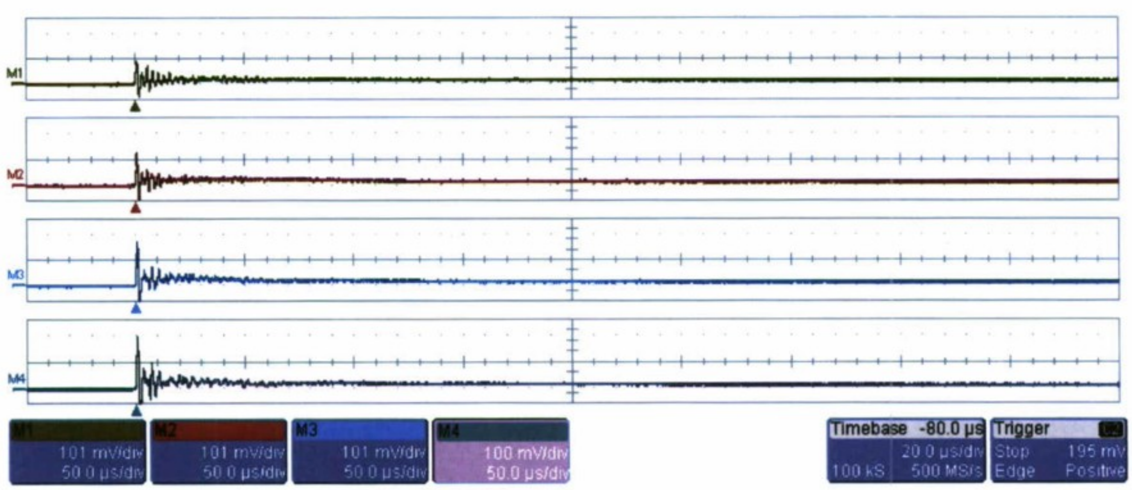


Figure 24
Pressure signals, test 49-52

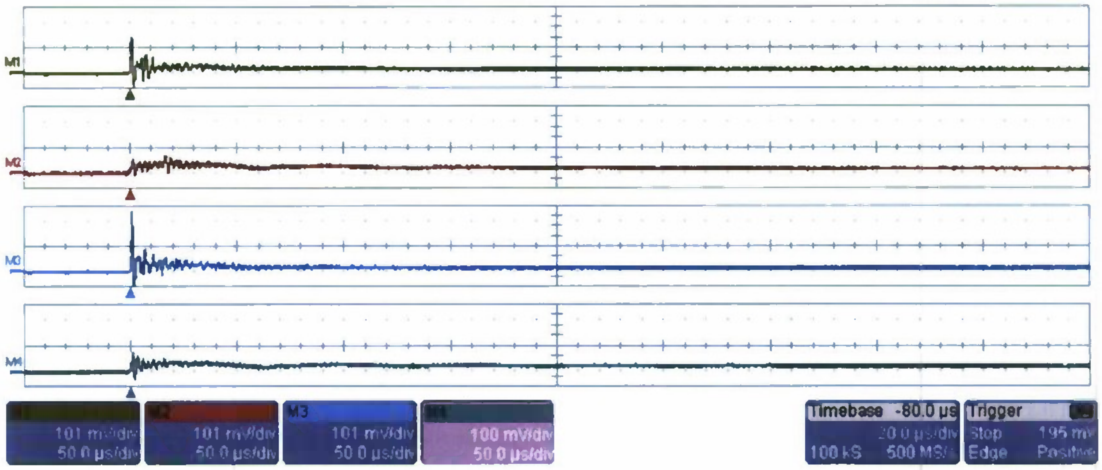


Figure 25
Pressure signals, test 53-56

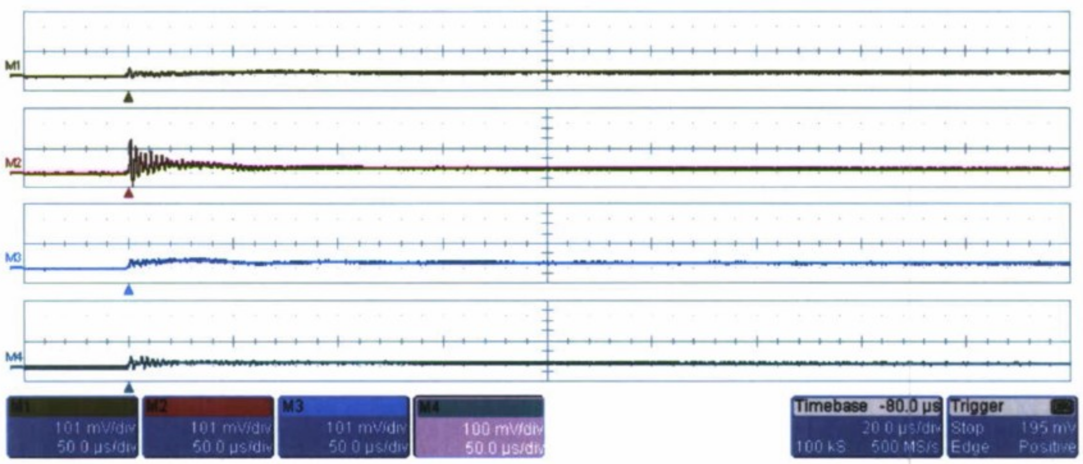


Figure 26
Pressure signals, test 57-60

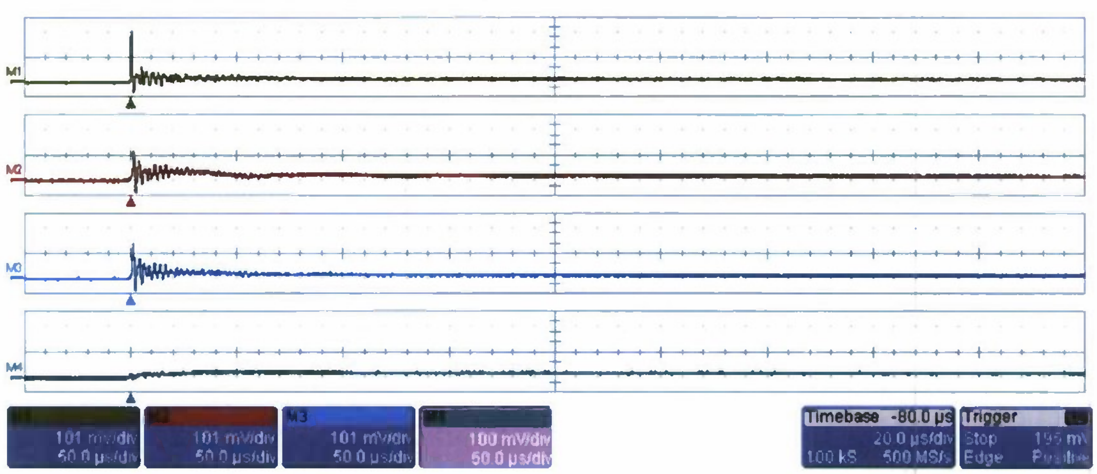


Figure 27
Pressure signals, test 61-64

Table 2
Peak pressures with rise time of the waveforms

Test number	Initial peak pressure (psi)	Initial peak rise time (µs)
1	1700	31
2	4100	0.6
3	4100	1.5
4	Off Scale	na
5	3500	1.0
6	3500	2.0
7	3500	2.0
8	7500	0.4
9	3200	2.8
10	1500	20
11	2200	5.0
12	5200	1.0
13	13800	0.38
14	9000	0.65
15	4600	0.54
16	1400	0.45
17	9200	0.36
18	3200	0.98
19	2700	1.5
20	12100	0.73
21	4600	0.94
22	1700	0.68
23	7500	0.78
24	6500	0.44
25	2900	1.2
26	4400	0.84
27	4200	1.2
28	15000	0.38
29	970	2.7
30	16500	0.3
31	5300	2.4
32	1500	3.3
33	2800	1.2
34	10300	0.95
35	6100	0.58
36	3600	1.7
37	9800	0.3
38	9000	0.7
39	15300	0.68
40	5200	0.82
41	9900	0.89
42	4200	0.94
43	1700	1.6
44	4400	0.91
45	3500	0.94
46	4000	1.4
47	9200	0.96
48	6300	0.48
49	5200	0.9

Table 2
(continued)

Test number	Initial peak pressure (psi)	Initial peak rise time (µs)
50	7500	0.78
51	10000	0.82
52	11700	0.72
53	8200	0.89
54	3000	1.7
55	14400	0.63
56	4500	0.92
57	1900	1.3
58	8000	1.1
59	2100	1.6
60	2400	1.2
61	12100	0.4
62	7000	1.6
63	8500	1.4
64	1500	28

Most of the waveforms have an exponentially damped oscillation of about 500 KHz at the start of the signal. It is believed the oscillations were caused by the resonance of the pressure sensor that distorts the signal in that fashion. Future tests should be conducted with a 100 KHz low pass filter inserted at the output of the signal chain. As far as the 64 tests already conducted are concerned, an arbitrary function generator can be used to reproduce the original signals and pass them through the 100 KHz filter before capturing them with an oscilloscope. Figure 28 shows a pressure signal before and after filtering. The signal was obtained from a different type of explosive reaction using the 119B pressure sensor. An arbitrary function generator is currently on order for this group.

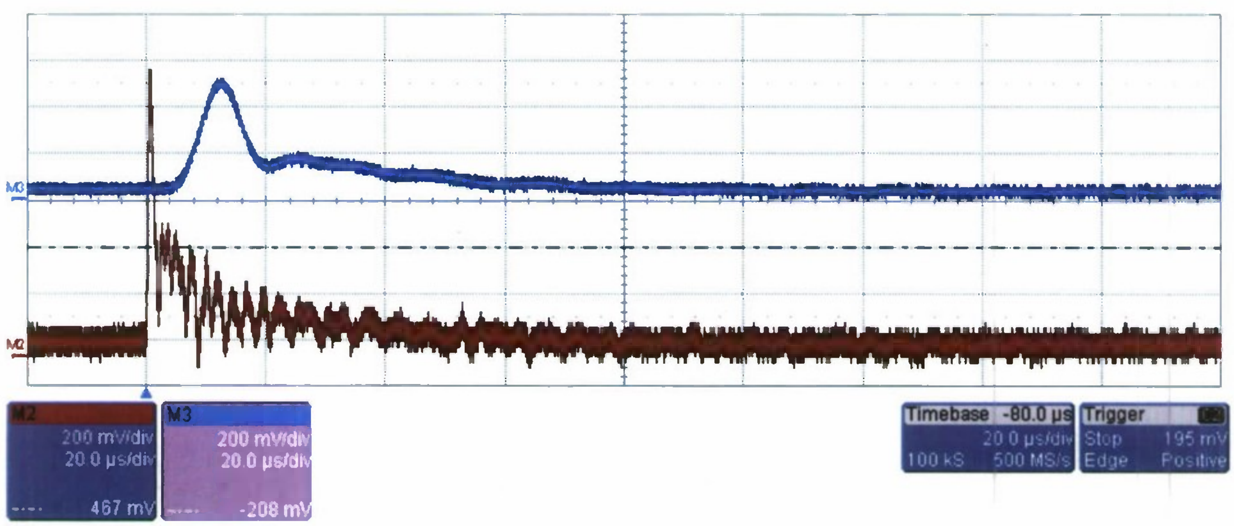


Figure 28
Milliwell pressure test, filtered and unfiltered signal

CONCLUSIONS

Preliminary Tests

There was a considerable variation in the test results from both fixtures. The fixture with the recessed pressure gauge and steel pellet produced a large initial pulse the cause of which could not be determined. The fixture with the flush pressure gauge was better suited to make the pressure measurements. Peak pressures generated by the primer composition in the flush fixture ranged from 944 psi to 2687 psi. Tests with the vinyl tape gave higher pressures with less variation. There was too much variation in the length of the truncated head.

Final Tests

Peak pressures ranged from 970 psi to 16,500 psi. Rise times were from 0.3 μs to 28 μs. There was considerable variation in pressures for the final tests also. The test method did not address the cause of this variation.

RECOMMENDATIONS

Use the flush fixture for future tests with vinyl tape over the sensor head. Machine the head to a uniform length. Add a 100 KHz low pass filter at the output of the signal chain to reduce effects of sensor resonance.

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