UN/SCETDG/21/INF.59

COMMITTEE OF EXPERTS ON THE TRANSPORT OF DANGEROUS GOODS AND ON THE GLOBALLY HARMONIZED SYSTEM OF CLASSIFICATION AND LABELLING OF CHEMICALS
Sub-Committee of Experts on the Transport of Dangerous Goods
(Twenty-first session, 1-10 July 2002)

Sensitivity Tests for HEF 100 Emulsion Carried out in 210 litre Drums and 311 mm Thick-walled Pipes May 2002

By: A J Rorke

Created: 02/06/24 02:13 PM

Bulk Mining Explosives (Pty) Ltd
P O Box 70040
Bryanston 2021

www.bme.co.za

Contents

Table of Figures

Summary and conclusions

A number of tests were carried out on gassed and ungassed emulsion to determine whether ungassed emulsion will sustain a detonation or not. Four tests were carried out in 210 litre drums using two different sized boosters. Another four tests were carried out using 311 mm thick walled pipes.

Measurements were made of the VOD of each test, the crater created by each test and the seismic air pressure wave. The results all showed that ungassed emulsion will not propagate a detonation. There is a zone of reaction around the booster in an ungassed emulsion, but this dies our rapidly over a short distance of about 300mm.

It is concluded, therefore, that ungassed HEF 100 emulsion is undetonable using a 150 g or 400 g pentolite booster.

It is concluded that ungassed HEF 100 will not detonate under any normal handling, transport and storage.

Introduction

A number of tests were carried out on the sensitivity of HEF 100 emulsion explosive during May 2002. The tests were carried out at Eikeboom and Optimum Collieries by R Webber and D Pieterse. They were assisted by A Visser and D Smith.

The tests involved the measurement of detonation sensitivity for ungassed HEF 100 emulsion explosive (at a density of 1.45 g/cm^3) and gasses emulsion explosive at a density of 1.05 g/cm^3). Tests were carried out in 210 litre drums and 1.5 m x .311 mm diameter pipes.

A number of measurements were made for each pipe that was tested:

1. Velocity of detonation
2. Volume of crater generated
3. Air blast amplitude

The pipe tests were carried out to compare the two test methods and ultimately develop a testing technique that is practical to carry out, but provides reliable results.

This document reports the testing technique and analyses the data obtained.

Reason for Testing

The tests are required to establish that HEF 100 in its ungassed state will not sustain a detonation. This information is necessary in terms being able to classify ungassed HEF 100 emulsion a non-explosive material.

The pipe tests were carried out to compare the results from the traditional 210 litre drum tests with a test method that is easier to apply and provide results that are more consistent.

Method

Two methods of testing were applied.

Drum Test Method

Six 210 litre drums were charged and fired in a safe area of the mine. The drums were charged as follows:

Table 1. Testing configuration for Drum Tests

	Test Sample	Booster Size (g)	Booster Position	Sample mass (kg)	Sample Density (g/cm3)
Drum 1	Water	150	Drum Bottom	209	1
Drum 2	Water	400	Drum Bottom	209	1
Drum 3	Ungassed HEF 100	150	Drum Bottom	304	1.45
Drum 4	Ungassed HEF 100	400	Drum Bottom	304	1.45
Drum 5	Gassed HEF 100	150	Drum Bottom	220	1.05
Drum 6	Gassed HEF 100	400	Drum Bottom	220	1.05

VODs were measured using a VODR-1 time domain recorder. This instrument is sensitive to low order detonation and low pressure waves and is best suited to this type of measurement. In each case, the sensor cable was attached to the primer by tape and was extended along the long axis of the sample in the centre of the sample. A tail length of sensor cable (about 3 to 4 m long) extended beyond the booster in each case to act as a trigger when the cable was severed by the detonation of the booster. The VODR-1 records VOD by measuring the rate of change of the length of cable from the booster in the direction of the instrument. For these tests, the instrument was set to record at a sample interval of 10 microseconds using RG58 coaxial cable as the sensor. A typical recorded trace of a detonation is shown in Figure 1.

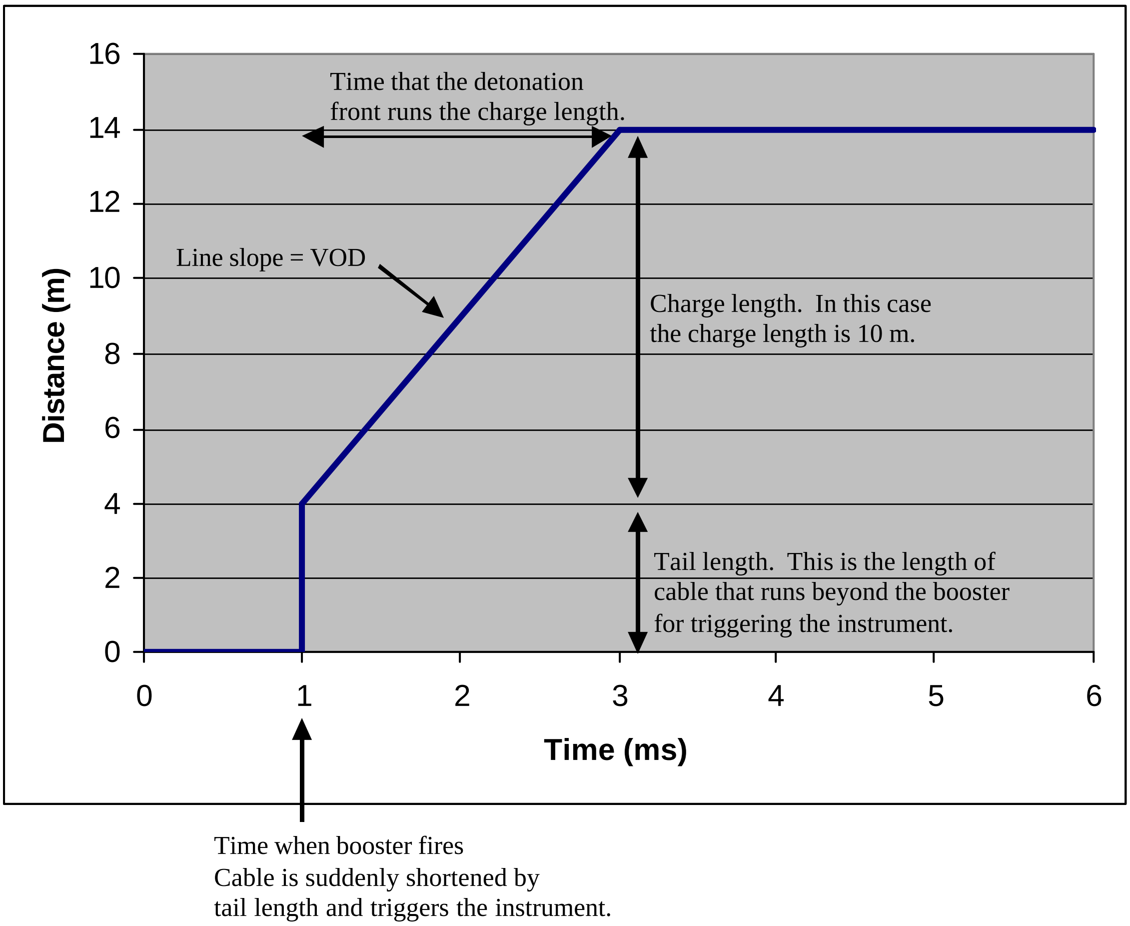

Figure 1. A simplified example of a VOD trace. The line slope indicates VOD. In a clean detonation, a relatively straight line can be expected. For increasing VOD, the line slope will increase with time. For a drop off in VOD, the line slope will decrease with time. This slope represents a detonation velocity of 5000 m/s and at this speed, a 10 m long charge will take 2 full milliseconds to detonate.

The RG58 sensor cable crushes effectively with a well-developed, high-pressure detonation front giving a clean noise-free VOD slope. However, as detonation pressure drops off, as would be the case for low order detonations, the trace becomes very noisy and stepped because the VOD cable is not as effectively crushed.

Two seismographs were positioned 300 m away on opposite sides of the firing point. These measurements provided an indication of the energy radiated through the air (air blast) for each test.

Crater depths were measured at the firing position for each sample fired. These are report in terms of the scaled crater volume. The crater volume was scaled according to the cubed root of the charge mass.

Equation 1

$$SV = \frac{V}{(Q)^{0.33}}$$

Where V = measured crater volume in cubic metres and Q = the charge mass fired in kg.

Pipe Test Method

The tests were repeated suing 311 mm PVC pipes with 12 mm wall thickness. The pipes were used because they have the advantage of a longer run-up measurement being longer than the drams and the provided a larger footprint on the ground thus providing a clearer indication of the cratering energy imparted.

Table 2. Testing configuration for Pipe Tests

	Test Sample	Booster Size (g)	Booster Position	Sample mass (kg)	Sample Density (g/cm3)
Pipe 1	Water	150	One end of column	91	1
Pipe 2	Water	400	One end of column	91	1
Pipe 3	Ungassed HEF 100	150	One end of column	132	1.45
Pipe 4	Ungassed HEF 100	400	One end of column	132	1.45
Pipe 5	Gassed HEF 100	150	One end of column	95	1.05
Pipe 6	Gassed HEF 100	400	One end of column	46	1.05

As with the drum tests, VOD measurements, air blast measurements and crater volume measurements were made for each test.

Data Analysis

The data are analysed in terms of VOD for both the drum and the pipe tests, followed by crater volume and then air pressure waves. Conclusions are provided at the end of each section.

VOD Analysis

The VOD curves are plotted from the data supplied in Appendices 1 and 2. These curves are combined onto single graphs for easier comparison.

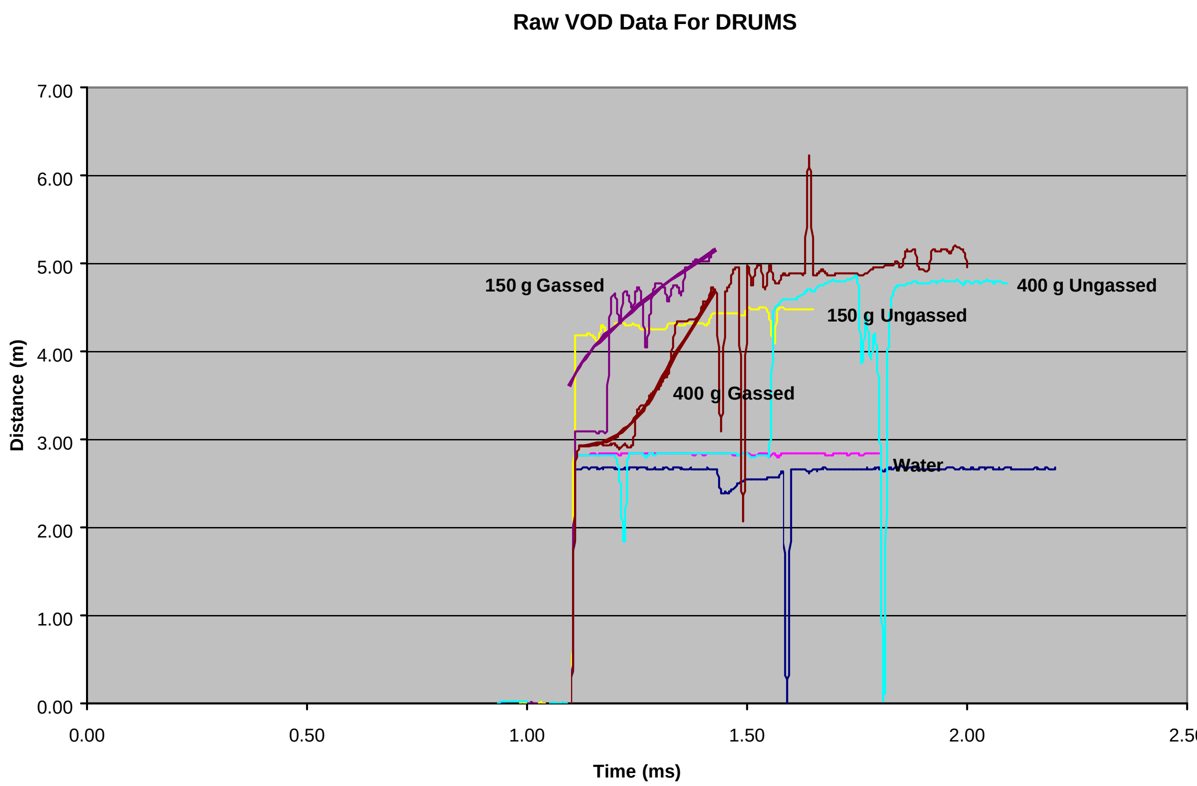

Figure 2. Combined traces from drum tests. Two well-defined slopes can be seen for the two gassed samples. These are highlighted by fitted curves.

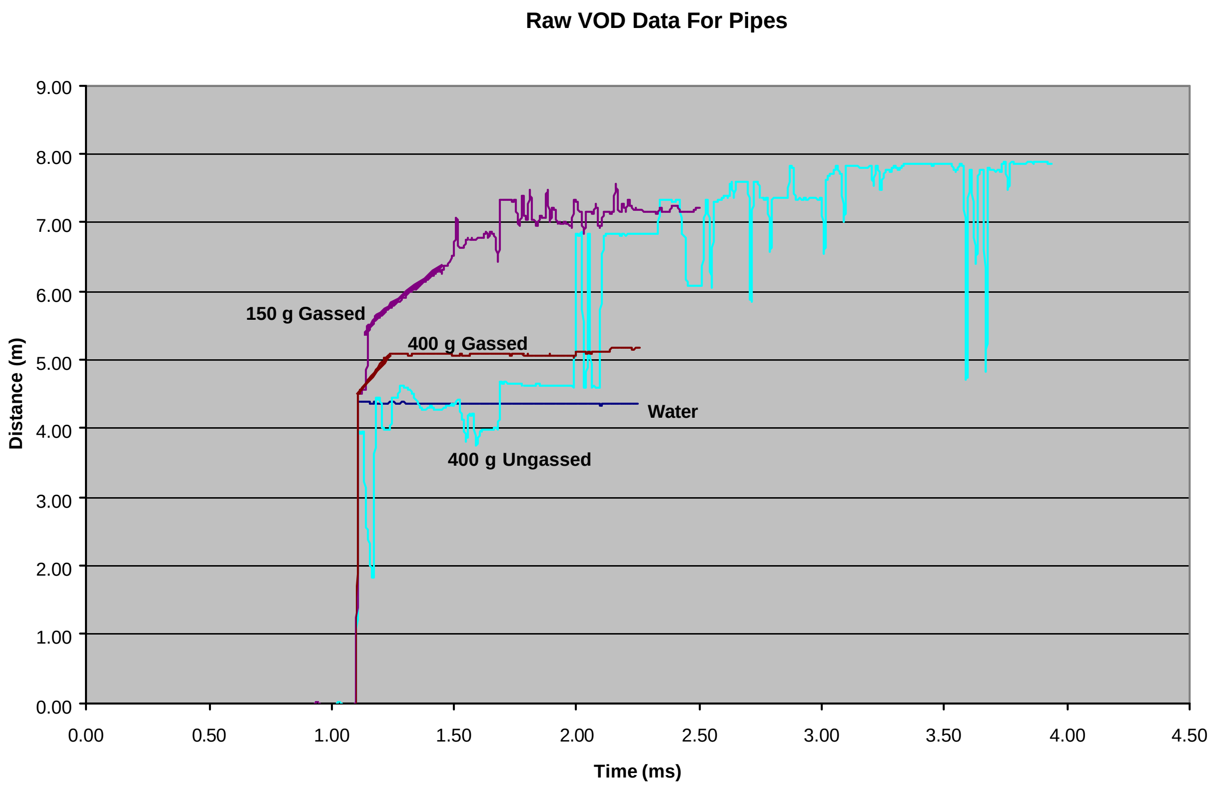

Figure 3. Combined traces from drum tests. Two well-defined slopes can be seen for the two gassed samples. These are highlighted by fitted curves. See text regarding the 150g ungassed sample that is missing from the data above.

For the pipe tests, a cable problem resulted in loss of data from the one water test and the 150 g ungassed sample. Other observations (seismic and crater measurements) help to fill this gap.

From both sets of tests, the following observations and conclusions are drawn:

1. The reaction time or VOD should not be longer than about 1ms. Remember that a 10 m long column at normal detonation velocity will take 2 ms. These tests are all about 1m long.
2. Water shows no reaction and there is a sharp step at the booster initiation time, but no following slope.

Drum Test

1. The ungassed emulsion with a 150 g booster reacted for a length of 330 mm and then died out. This reaction took place over a period of 1.5 ms and the VOD was therefore barely 220 m/s.
2. The ungassed emulsion with a 400 g booster showed no slope. After a period of 0.5 ms, there is a large step. This is difficult to interpret as the step may have been caused by a cut from a metal shard. Clearly, though, any reaction that occurred had a low detonation pressure that could not be detected by the VOD sensor cable.
3. The gassed emulsion for the 150 g and the 400 g boosters showed a very different character, with both detonating for their full length at an average VOD of 4000 m/s.

The Drum tests information show that an ungassed emulsion will not sustain a detonation and any reaction, from a very high pressure – high temperature source like a booster, will only react in its immediate vicinity.

Pipe Test

1. The test for water is the same as for the drum test.
2. The test for the ungassed emulsion with a 400 g booster is almost identical to the similar drum test, with a cut in the cable occurring 1 ms after the booster fired. The reaction, therefore, did not generate sufficient detonation pressure to be detected by the sensor cable.
3. Both of the gassed tests show a clean reaction trace with the 400 g booster resulting in a slightly higher VOD (4400 m/s) than the 150 g booster (2900 m/s). Both reactions occurred for the full test length[1].

The pipe tests show similar results compared to the drum tests and indicate that ungassed HEF 100 emulsion will not sustain a detonation.

The pipe tests have the advantage that longer test lengths can be used compared to the drum tests and a clearer indication can be obtained

Crater Volumes

Crater volumes were measured for each test by measuring the surface area and the depth. The data are detailed in Table 3. A scaled crater volume has also been calculated (See Equation1). The scaled volume is a more appropriate comparative measure because of the different densities of the three sample types.

[1] There was some difficulty in containing all the explosive in the large diameter pipes and there was some leakage from the pipe test for the gassed explosive with the 400 g booster. The result was a shorter column length for this test.

The tests were carried out on back-filled material that should have provided a relatively homogenous medium. The influence of variations in the test bed is not known and has been ignored.

Table 3. Crater volume for each test and the scaled volumes.

	Crater Volume	Scaled Crater Volume
w150 Drum	0.000	0.000
w400 Drum	0.000	0.000
U150 Drum	0.016	0.002
U400 Drum	0.482	0.073
G150 Drum	0.389	0.066
G400 Drum	0.768	0.129
W150 Pipe	0.000	0.000
W400 Pipe	0.000	0.000
U150 Pipe	0.075	0.015
U400 Pipe	0.720	0.144
G150 Pipe	3.154	0.702
G400 Pipe	2.016	0.570

The information in Table 3 is plotted in Figure 4. The data from the drum tests do not show any clear trend. This is likely to be because the booster was located at the base of the drum where the initial reaction, even though not sustained throughout the drum, will have created a crater in the soil.

The pipe tests, however, provide a much clearer difference, with scaled crater volumes that are six times larger for the gassed explosive than the ungassed explosive. Because the pipes were lying on their sides, the sustained detonation in the gassed samples was reflected very clearly in the ground compared to the unsustained detonation of the ungassed samples.

The data therefore indicate that ungassed HEF 100 explosive will not sustain a detonation after being impacted by a high pressure – high temperature shock wave.

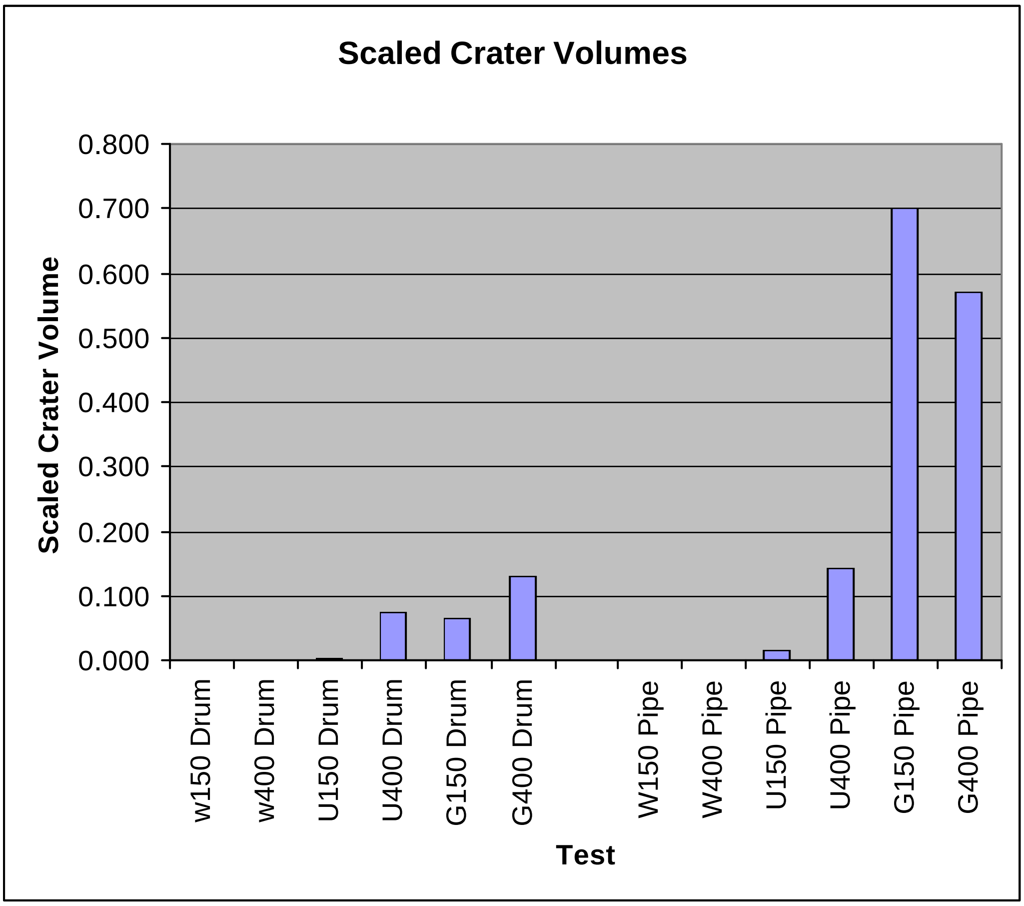

Figure 4. Scaled crater volumes for each test.

Air Blast

Air pressure waves, or air blast was measured at two sites for the drum tests and one position for the pipe tests. The seismographs were located 300 m from the test position. The information is summarized in Table 4 and the seismic traces are provided in Appendix 3.

The information in Table 1 shows the following interesting trends:

1. The peak amplitudes for the gassed HEF 100 samples were two to four times greater than the peak amplitude for the ungassed samples.
2. The dominant frequencies of the ungassed HEF 100 samples were consistently higher than the dominant frequencies for the gassed samples[2].

The lower frequencies and higher amplitudes from the gassed HEF 100 samples indicate much higher energy levels. The lower energies radiated by the ungassed HEF 100 samples indicate a less efficient detonation.

The higher frequencies of the ungassed samples suggest a shorter detonation length and therefore unsustained detonation.

[2] Dominant frequencies were obtained by FFT analysis of each air blast trace.

Table 4. Measured air pressure waves using the acoustic channel from Nomis blasting seismographs.

	Seismograph 1		**Seismograph 2**	
	Peak (Pa)	Freq (Hz)	Peak (Pa)	Freq (Hz)
w150 Drum				
w400 Drum				
U150 Drum	116	11.63	120	16.88
U400 Drum				
G150 Drum	448	8.75	500	10.25
G400 Drum	468	7.31	500	9.00

	Seismograph 1	
	Peak (Pa)	Freq (Hz)
W150 Pipe		
W400 Pipe		
U150 Pipe	152	20.63
U400 Pipe	212	20.75
G150 Pipe	452	6.63
G400 Pipe	452	6.63

The air blast measurements support the conclusion that HEF 100 is non detonable in its ungassed state.

Appendix 1 – Raw VOD Data for Drum Tests

Each set of columns represents the sample time and corresponding reduction in cable length in metres. W150 means water with a 150 g booster. U stands for ungassed and G stands for gassed.

Time	W150	Time	W400	Time	U150	Time	U400	Time	G150	Time	G400
0.90	0.00	0.90	0.00	0.98	0.00	0.85	0.00	1.00	0.00	1.02	0.00
0.91	0.00	0.91	0.00	0.99	0.01	0.86	0.00	1.01	0.01	1.03	0.00
0.92	0.00	0.92	0.00	1.00	0.00	0.87	0.00	1.02	0.00	1.04	0.00
0.93	0.00	0.93	0.00	1.01	0.00	0.88	0.00	1.03	0.00	1.05	0.00
0.94	0.01	0.94	0.00	1.02	0.00	0.89	0.00	1.04	0.00	1.06	0.00
0.95	0.00	0.95	0.00	1.03	0.01	0.90	0.00	1.05	0.00	1.07	0.00
0.96	0.00	0.96	0.00	1.04	0.00	0.91	0.00	1.06	0.00	1.08	0.00
0.97	0.00	0.97	0.00	1.05	0.00	0.92	0.00	1.07	0.00	1.09	0.00
0.98	0.00	0.98	0.00	1.06	0.00	0.93	0.00	1.08	0.00	1.10	0.00
0.99	0.00	0.99	0.00	1.07	0.00	0.94	0.01	1.09	0.00	1.11	2.71
1.00	0.00	1.00	0.00	1.08	0.00	0.95	0.01	1.10	0.00	1.12	2.93
1.01	0.00	1.01	0.00	1.09	0.00	0.96	0.01	1.11	3.08	1.13	2.93
1.02	0.00	1.02	0.00	1.10	0.00	0.97	0.01	1.12	3.09	1.14	2.93
1.03	0.00	1.03	0.00	1.11	4.17	0.98	0.01	1.13	3.09	1.15	2.93
1.04	0.00	1.04	0.00	1.12	4.18	0.99	0.01	1.14	3.09	1.16	2.95
1.05	0.00	1.05	0.00	1.13	4.18	1.00	0.01	1.15	3.09	1.17	2.95
1.06	0.00	1.06	0.00	1.14	4.21	1.01	0.00	1.16	3.08	1.18	2.93
1.07	0.00	1.07	0.00	1.15	4.18	1.02	0.00	1.17	3.09	1.19	2.95
1.08	0.00	1.08	0.00	1.16	4.12	1.03	0.00	1.18	3.09	1.20	2.95
1.09	0.00	1.09	0.00	1.17	4.30	1.04	0.00	1.19	4.60	1.21	2.90
1.10	0.00	1.10	0.00	1.18	4.23	1.05	0.00	1.20	4.66	1.22	2.95
1.11	2.65	1.11	2.82	1.19	4.24	1.06	0.01	1.21	4.31	1.23	2.91
1.12	2.66	1.12	2.83	1.20	4.31	1.07	0.00	1.22	4.68	1.24	2.95
1.13	2.69	1.13	2.83	1.21	4.31	1.08	0.01	1.23	4.65	1.25	3.33
1.14	2.67	1.14	2.83	1.22	4.31	1.09	0.00	1.24	4.49	1.26	3.39
1.15	2.69	1.15	2.84	1.23	4.30	1.10	0.00	1.25	4.74	1.27	3.40
1.16	2.67	1.16	2.83	1.24	4.31	1.11	2.80	1.26	4.61	1.28	3.51
1.17	2.67	1.17	2.84	1.25	4.30	1.12	2.82	1.27	4.05	1.29	3.55
1.18	2.69	1.18	2.84	1.26	4.25	1.13	2.82	1.28	4.47	1.30	3.59
1.19	2.69	1.19	2.84	1.27	4.27	1.14	2.82	1.29	4.76	1.31	3.70
1.20	2.67	1.20	2.84	1.28	4.27	1.15	2.83	1.30	4.78	1.32	3.75
1.21	2.66	1.21	2.83	1.29	4.25	1.16	2.83	1.31	4.74	1.33	4.10
1.22	2.67	1.22	2.85	1.30	4.25	1.17	2.83	1.32	4.57	1.34	4.34
1.23	2.67	1.23	2.85	1.31	4.25	1.18	2.83	1.33	4.74	1.35	4.34
1.24	2.69	1.24	2.84	1.32	4.31	1.19	2.82	1.34	4.75	1.36	4.35
1.25	2.67	1.25	2.85	1.33	4.31	1.20	2.82	1.35	4.66	1.37	4.37
1.26	2.69	1.26	2.85	1.34	4.31	1.21	2.55	1.36	4.95	1.38	4.37
1.27	2.67	1.27	2.84	1.35	4.30	1.22	1.84	1.37	4.97	1.39	4.41
1.28	2.65	1.28	2.84	1.36	4.31	1.23	2.83	1.38	5.04	1.40	4.56
1.29	2.67	1.29	2.84	1.37	4.31	1.24	2.84	1.39	5.04	1.41	4.56
1.30	2.65	1.30	2.84	1.38	4.31	1.25	2.84	1.40	5.04	1.42	4.73
1.31	2.67	1.31	2.84	1.39	4.31	1.26	2.84	1.41	5.03	1.43	4.66
1.32	2.67	1.32	2.84	1.40	4.31	1.27	2.80	1.42	5.16	1.44	3.10
1.33	2.67	1.33	2.84	1.41	4.31	1.28	2.84			1.45	4.66
1.34	2.69	1.34	2.85	1.42	4.43	1.29	2.83			1.46	4.76
1.35	2.67	1.35	2.84	1.43	4.43	1.30	2.84			1.47	4.94
1.36	2.66	1.36	2.85	1.44	4.43	1.31	2.84			1.48	4.95
1.37	2.67	1.37	2.85	1.45	4.43	1.32	2.84			1.49	2.07
1.38	2.67	1.38	2.82	1.46	4.43	1.33	2.85			1.50	4.95

1.39	2.67	1.39	2.85	1.47	4.43	1.34	2.84	1.51	4.76
1.40	2.67	1.40	2.82	1.48	4.43	1.35	2.84	1.52	4.95
1.41	2.67	1.41	2.85	1.49	4.41	1.36	2.84	1.53	4.97
1.42	2.66	1.42	2.84	1.50	4.49	1.37	2.84	1.54	4.71
1.43	2.66	1.43	2.85	1.51	4.49	1.38	2.84	1.55	4.98
1.44	2.40	1.44	2.84	1.52	4.48	1.39	2.84	1.56	4.82
1.45	2.40	1.45	2.84	1.53	4.50	1.40	2.84	1.57	4.78
1.46	2.40	1.46	2.84	1.54	4.50	1.41	2.84	1.58	4.88
1.47	2.46	1.47	2.83	1.55	4.40	1.42	2.84	1.59	4.87
1.48	2.51	1.48	2.83	1.56	4.09	1.43	2.84	1.60	4.90
1.49	2.53	1.49	2.84	1.57	4.49	1.44	2.84	1.61	4.90
1.50	2.54	1.50	2.84	1.58	4.50	1.45	2.84	1.62	4.88
1.51	2.54	1.51	2.83	1.59	4.48	1.46	2.84	1.63	4.90
1.52	2.55	1.52	2.83	1.60	4.48	1.47	2.84	1.64	6.23
1.53	2.55	1.53	2.84	1.61	4.48	1.48	2.83	1.65	4.88
1.54	2.55	1.54	2.84	1.62	4.49	1.49	2.84	1.66	4.88
1.55	2.57	1.55	2.80	1.63	4.48	1.50	2.84	1.67	4.93
1.56	2.57	1.56	2.84	1.64	4.48	1.51	2.79	1.68	4.88
1.57	2.57	1.57	2.80	1.65	4.48	1.52	2.82	1.69	4.86
1.58	2.63	1.58	2.85			1.53	2.83	1.70	4.88
1.59	0.00	1.59	2.84			1.54	2.83	1.71	4.90
1.60	2.66	1.60	2.85			1.55	2.82	1.72	4.88
1.61	2.66	1.61	2.85			1.56	4.46	1.73	4.88
1.62	2.66	1.62	2.85			1.57	4.54	1.74	4.88
1.63	2.66	1.63	2.84			1.58	4.59	1.75	4.88
1.64	2.63	1.64	2.84			1.59	4.59	1.76	4.86
1.65	2.66	1.65	2.84			1.60	4.59	1.77	4.90
1.66	2.65	1.66	2.84			1.61	4.60	1.78	4.93
1.67	2.67	1.67	2.84			1.62	4.63	1.79	4.95
1.68	2.67	1.68	2.83			1.63	4.67	1.80	4.95
1.69	2.67	1.69	2.83			1.64	4.71	1.81	4.97
1.70	2.67	1.70	2.84			1.65	4.68	1.82	4.98
1.71	2.67	1.71	2.84			1.66	4.74	1.83	4.98
1.72	2.67	1.72	2.84			1.67	4.76	1.84	5.03
1.73	2.67	1.73	2.83			1.68	4.78	1.85	4.95
1.74	2.67	1.74	2.84			1.69	4.81	1.86	5.14
1.75	2.67	1.75	2.84			1.70	4.81	1.87	5.14
1.76	2.67	1.76	2.82			1.71	4.81	1.88	5.16
1.77	2.67	1.77	2.84			1.72	4.81	1.89	4.94
1.78	2.66	1.78	2.84			1.73	4.82	1.90	4.93
1.79	2.67	1.79	2.84			1.74	4.84	1.91	4.92
1.80	2.67	1.80	2.84			1.75	4.86	1.92	5.17
1.81	2.64					1.76	3.89	1.93	5.14
1.82	2.67					1.77	4.41	1.94	5.16
1.83	2.67					1.78	3.91	1.95	5.17
1.84	2.69					1.79	4.21	1.96	5.12
1.85	2.70					1.80	3.34	1.97	5.20
1.86	2.67					1.81	0.02	1.98	5.18
1.87	2.69					1.82	4.10	1.99	5.16
1.88	2.69					1.83	4.66	2.00	4.97
1.89	2.67					1.84	4.75		
1.90	2.67					1.85	4.76		
1.91	2.67					1.86	4.76		
1.92	2.67					1.87	4.78		
1.93	2.67					1.88	4.81		
1.94	2.67					1.89	4.78		

1.95	2.67
1.96	2.69
1.97	2.67
1.98	2.67
1.99	2.67
2.00	2.65
2.01	2.67
2.02	2.65
2.03	2.69
2.04	2.67
2.05	2.69
2.06	2.67
2.07	2.67
2.08	2.66
2.09	2.69
2.10	2.67
2.11	2.67
2.12	2.67
2.13	2.67
2.14	2.67
2.15	2.67
2.16	2.67
2.17	2.65
2.18	2.69
2.19	2.65
2.20	2.67

1.90	4.78
1.91	4.78
1.92	4.81
1.93	4.79
1.94	4.81
1.95	4.81
1.96	4.81
1.97	4.81
1.98	4.81
1.99	4.76
2.00	4.81
2.01	4.78
2.02	4.81
2.03	4.78
2.04	4.81
2.05	4.81
2.06	4.79
2.07	4.81
2.08	4.79
2.09	4.79
2.10	4.78

Appendix 2 – Raw VOD Data for Pipe Tests

Each set of columns represents the sample time and corresponding reduction in cable length in metres. W400 means water with a 400 g booster. U stands for ungassed and G stands for gassed.

Time	W400	Time	U400	Time	G150	Time	G400
1.00	0.00	1.00	0.00	0.90	0.00	1.10	0.00
1.01	0.00	1.01	0.00	0.91	0.00	1.11	4.48
1.02	0.00	1.02	0.00	0.92	0.00	1.12	4.56
1.03	0.00	1.03	0.01	0.93	0.00	1.13	4.61
1.04	0.00	1.04	0.00	0.94	0.01	1.14	4.66
1.05	0.00	1.05	0.00	0.95	0.00	1.15	4.70
1.06	0.00	1.06	0.00	0.96	0.00	1.16	4.75
1.07	0.00	1.07	0.00	0.97	0.00	1.17	4.79
1.08	0.00	1.08	0.00	0.98	0.00	1.18	4.84
1.09	0.00	1.09	0.00	0.99	0.00	1.19	4.89
1.10	0.00	1.10	0.00	1.00	0.00	1.20	4.93
1.11	4.38	1.11	3.93	1.01	0.00	1.21	4.98
1.12	4.38	1.12	3.93	1.02	0.00	1.22	5.03
1.13	4.38	1.13	3.94	1.03	0.00	1.23	5.05
1.14	4.38	1.14	2.67	1.04	0.00	1.24	5.07
1.15	4.38	1.15	2.44	1.05	0.00	1.25	5.07
1.16	4.37	1.16	2.00	1.06	0.00	1.26	5.09
1.17	4.37	1.17	1.84	1.07	0.00	1.27	5.09
1.18	4.38	1.18	4.43	1.08	0.00	1.28	5.07
1.19	4.36	1.19	4.43	1.09	0.00	1.29	5.09
1.20	4.37	1.20	4.43	1.10	0.01	1.30	5.07
1.21	4.36	1.21	4.00	1.11	4.49	1.31	5.07
1.22	4.37	1.22	3.99	1.12	4.50	1.32	5.06
1.23	4.37	1.23	3.98	1.13	4.57	1.33	5.09
1.24	4.38	1.24	3.98	1.14	4.56	1.34	5.07
1.25	4.38	1.25	4.44	1.15	5.38	1.35	5.09
1.26	4.37	1.26	4.44	1.16	5.48	1.36	5.10
1.27	4.37	1.27	4.44	1.17	5.53	1.37	5.09
1.28	4.37	1.28	4.60	1.18	5.57	1.38	5.09
1.29	4.38	1.29	4.61	1.19	5.61	1.39	5.09
1.30	4.37	1.30	4.60	1.20	5.63	1.40	5.09
1.31	4.37	1.31	4.59	1.21	5.67	1.41	5.09
1.32	4.37	1.32	4.55	1.22	5.70	1.42	5.07
1.33	4.37	1.33	4.52	1.23	5.74	1.43	5.07
1.34	4.37	1.34	4.44	1.24	5.75	1.44	5.07
1.35	4.36	1.35	4.40	1.25	5.79	1.45	5.07
1.36	4.37	1.36	4.31	1.26	5.81	1.46	5.07
1.37	4.37	1.37	4.28	1.27	5.85	1.47	5.07
1.38	4.36	1.38	4.28	1.28	5.85	1.48	5.07
1.39	4.37	1.39	4.29	1.29	5.89	1.49	5.07
1.40	4.36	1.40	4.31	1.30	5.91	1.50	5.06
1.41	4.37	1.41	4.31	1.31	5.95	1.51	5.05
1.42	4.37	1.42	4.28	1.32	5.98	1.52	5.06
1.43	4.37	1.43	4.28	1.33	6.01	1.53	5.07
1.44	4.37	1.44	4.27	1.34	6.04	1.54	5.06
1.45	4.37	1.45	4.28	1.35	6.04	1.55	5.06
1.46	4.37	1.46	4.30	1.36	6.07	1.56	5.06
1.47	4.37	1.47	4.33	1.37	6.11	1.57	5.09
1.48	4.37	1.48	4.34	1.38	6.14	1.58	5.09
1.49	4.37	1.49	4.35	1.39	6.15	1.59	5.09

1.50	4.37	1.50	4.35	1.40	6.19	1.60	5.09
1.51	4.37	1.51	4.40	1.41	6.21	1.61	5.07
1.52	4.36	1.52	4.42	1.42	6.24	1.62	5.09
1.53	4.37	1.53	4.19	1.43	6.29	1.63	5.07
1.54	4.37	1.54	4.06	1.44	6.30	1.64	5.07
1.55	4.37	1.55	3.81	1.45	6.26	1.65	5.07
1.56	4.37	1.56	4.19	1.46	6.37	1.66	5.07
1.57	4.36	1.57	4.19	1.47	6.36	1.67	5.07
1.58	4.37	1.58	4.19	1.48	6.43	1.68	5.07
1.59	4.37	1.59	3.77	1.49	6.49	1.69	5.07
1.60	4.37	1.60	3.87	1.50	6.55	1.70	5.07
1.61	4.37	1.61	3.97	1.51	7.07	1.71	5.07
1.62	4.37	1.62	3.98	1.52	6.63	1.72	5.10
1.63	4.37	1.63	3.99	1.53	6.63	1.73	5.06
1.64	4.36	1.64	3.99	1.54	6.65	1.74	5.09
1.65	4.36	1.65	3.99	1.55	6.75	1.75	5.07
1.66	4.36	1.66	3.99	1.56	6.76	1.76	5.07
1.67	4.37	1.67	4.00	1.57	6.76	1.77	5.07
1.68	4.36	1.68	4.00	1.58	6.75	1.78	5.07
1.69	4.36	1.69	4.67	1.59	6.75	1.79	5.06
1.70	4.36	1.70	4.66	1.60	6.78	1.80	5.07
1.71	4.36	1.71	4.67	1.61	6.77	1.81	5.06
1.72	4.36	1.72	4.66	1.62	6.77	1.82	5.06
1.73	4.36	1.73	4.66	1.63	6.87	1.83	5.06
1.74	4.36	1.74	4.66	1.64	6.78	1.84	5.06
1.75	4.36	1.75	4.65	1.65	6.86	1.85	5.06
1.76	4.36	1.76	4.65	1.66	6.83	1.86	5.06
1.77	4.36	1.77	4.65	1.67	6.75	1.87	5.06
1.78	4.37	1.78	4.63	1.68	6.44	1.88	5.06
1.79	4.36	1.79	4.63	1.69	7.33	1.89	5.07
1.80	4.37	1.80	4.63	1.70	7.32	1.90	5.06
1.81	4.37	1.81	4.62	1.71	7.32	1.91	5.06
1.82	4.36	1.82	4.63	1.72	7.32	1.92	5.06
1.83	4.36	1.83	4.62	1.73	7.32	1.93	5.06
1.84	4.36	1.84	4.65	1.74	7.31	1.94	5.06
1.85	4.36	1.85	4.63	1.75	7.32	1.95	5.05
1.86	4.36	1.86	4.63	1.76	7.00	1.96	5.06
1.87	4.36	1.87	4.62	1.77	6.96	1.97	5.05
1.88	4.36	1.88	4.63	1.78	7.39	1.98	5.05
1.89	4.36	1.89	4.62	1.79	7.06	1.99	5.05
1.90	4.36	1.90	4.62	1.80	7.06	2.00	5.12
1.91	4.35	1.91	4.62	1.81	7.46	2.01	5.11
1.92	4.36	1.92	4.62	1.82	7.05	2.02	5.12
1.93	4.36	1.93	4.62	1.83	7.02	2.03	5.11
1.94	4.37	1.94	4.61	1.84	6.94	2.04	5.10
1.95	4.36	1.95	4.62	1.85	7.08	2.05	5.11
1.96	4.36	1.96	4.61	1.86	7.07	2.06	5.10
1.97	4.37	1.97	4.61	1.87	7.07	2.07	5.11
1.98	4.36	1.98	4.61	1.88	7.47	2.08	5.12
1.99	4.36	1.99	4.61	1.89	7.01	2.09	5.12
2.00	4.36	2.00	6.83	1.90	7.20	2.10	5.12
2.01	4.36	2.01	6.81	1.91	7.19	2.11	5.11
2.02	4.36	2.02	6.84	1.92	7.00	2.12	5.11
2.03	4.36	2.03	4.61	1.93	7.00	2.13	5.11
2.04	4.36	2.04	4.61	1.94	6.97	2.14	5.17
2.05	4.36	2.05	6.83	1.95	7.00	2.15	5.17

2.06	4.36	2.06	4.61	1.96	6.97	2.16	5.17
2.07	4.36	2.07	4.61	1.97	6.96	2.17	5.17
2.08	4.36	2.08	4.60	1.98	6.94	2.18	5.17
2.09	4.36	2.09	4.60	1.99	7.31	2.19	5.17
2.10	4.34	2.10	6.07	2.00	7.31	2.20	5.17
2.11	4.36	2.11	6.77	2.01	7.15	2.21	5.17
2.12	4.36	2.12	6.83	2.02	7.13	2.22	5.17
2.13	4.36	2.13	6.83	2.03	6.83	2.23	5.14
2.14	4.36	2.14	6.83	2.04	7.15	2.24	5.17
2.15	4.36	2.15	6.83	2.05	7.15	2.25	5.18
2.16	4.36	2.16	6.83	2.06	7.14	2.26	5.17
2.17	4.36	2.17	6.83	2.07	7.14		
2.18	4.36	2.18	6.81	2.08	7.26		
2.19	4.36	2.19	6.83	2.09	6.94		
2.20	4.36	2.20	6.81	2.10	6.96		
2.21	4.36	2.21	6.83	2.11	7.16		
2.22	4.36	2.22	6.83	2.12	7.14		
2.23	4.36	2.23	6.83	2.13	7.16		
2.24	4.35	2.24	6.83	2.14	7.13		
2.25	4.36	2.25	6.84	2.15	7.18		
		2.26	6.83	2.16	7.57		
		2.27	6.83	2.17	7.18		
		2.28	6.83	2.18	7.16		
		2.29	6.83	2.19	7.28		
		2.30	6.83	2.20	7.16		
		2.31	6.83	2.21	7.33		
		2.32	6.83	2.22	7.25		
		2.33	6.83	2.23	7.19		
		2.34	7.33	2.24	7.20		
		2.35	7.33	2.25	7.19		
		2.36	7.33	2.26	7.19		
		2.37	7.33	2.27	7.16		
		2.38	7.33	2.28	7.15		
		2.39	7.31	2.29	7.14		
		2.40	7.31	2.30	7.15		
		2.41	7.32	2.31	7.14		
		2.42	7.32	2.32	7.14		
		2.43	6.83	2.33	7.14		
		2.44	6.80	2.34	7.21		
		2.45	6.07	2.35	7.16		
		2.46	6.07	2.36	7.14		
		2.47	6.07	2.37	7.16		
		2.48	6.07	2.38	7.16		
		2.49	6.07	2.39	7.25		
		2.50	6.07	2.40	7.25		
		2.51	6.07	2.41	7.25		
		2.52	7.00	2.42	7.16		
		2.53	7.32	2.43	7.15		
		2.54	7.00	2.44	7.15		
		2.55	6.06	2.45	7.15		
		2.56	7.31	2.46	7.14		
		2.57	7.31	2.47	7.15		
		2.58	7.32	2.48	7.18		
		2.59	7.32	2.49	7.22		
		2.60	7.38	2.50	7.22		
		2.61	7.38				

2.62	7.38
2.63	7.58
2.64	7.37
2.65	7.58
2.66	7.58
2.67	7.59
2.68	7.58
2.69	7.58
2.70	7.58
2.71	5.86
2.72	7.58
2.73	7.58
2.74	7.59
2.75	7.36
2.76	7.36
2.77	7.32
2.78	7.37
2.79	6.58
2.80	7.37
2.81	7.36
2.82	7.36
2.83	7.36
2.84	7.36
2.85	7.36
2.86	7.36
2.87	7.81
2.88	7.81
2.89	7.36
2.90	7.32
2.91	7.36
2.92	7.32
2.93	7.36
2.94	7.33
2.95	7.36
2.96	7.36
2.97	7.36
2.98	7.34
2.99	7.34
3.00	7.34
3.01	6.55
3.02	7.65
3.03	7.69
3.04	7.70
3.05	7.75
3.06	7.82
3.07	7.75
3.08	7.66
3.09	7.01
3.10	7.83
3.11	7.83
3.12	7.83
3.13	7.83
3.14	7.82
3.15	7.81
3.16	7.81
3.17	7.81

3.18	7.81
3.19	7.81
3.20	7.81
3.21	7.55
3.22	7.81
3.23	7.79
3.24	7.46
3.25	7.68
3.26	7.75
3.27	7.76
3.28	7.74
3.29	7.81
3.30	7.81
3.31	7.77
3.32	7.78
3.33	7.84
3.34	7.85
3.35	7.85
3.36	7.84
3.37	7.84
3.38	7.84
3.39	7.84
3.40	7.85
3.41	7.84
3.42	7.84
3.43	7.85
3.44	7.85
3.45	7.83
3.46	7.85
3.47	7.87
3.48	7.85
3.49	7.84
3.50	7.85
3.51	7.85
3.52	7.85
3.53	7.85
3.54	7.76
3.55	7.76
3.56	7.82
3.57	7.84
3.58	7.76
3.59	4.72
3.60	7.64
3.61	7.77
3.62	6.96
3.63	6.42
3.64	7.74
3.65	7.77
3.66	7.75
3.67	4.82
3.68	7.78
3.69	7.77
3.70	7.76
3.71	7.75
3.72	7.76
3.73	7.75

3.74	7.87
3.75	7.87
3.76	7.49
3.77	7.87
3.78	7.87
3.79	7.87
3.80	7.85
3.81	7.87
3.82	7.87
3.83	7.85
3.84	7.88
3.85	7.88
3.86	7.87
3.87	7.88
3.88	7.88
3.89	7.88
3.90	7.88
3.91	7.88
3.92	7.87
3.93	7.87
3.94	7.87

Appendix 3 – Seismic Traces