AN EVALUATION OF THE CONFINEMENT PROVIDED BY PVC AND CARDBOARD PIPES IN UNCONFINED DETONATION VELOCITY MEASUREMENTS

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A research project report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

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DECLARATION

I declare that this project report is my own, unaided work, except as specified in the Acknowledgements. It is being submitted for the Degree of Master of Science in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University. The information used in this project report has been obtained while employed by African Explosives Limited (AEL).

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Signed this _______ day of _____________ , 2005

ABSTRACT

African Explosives Limited (AEL) is involved with the Hybrid Stress Blast Model (HSBM) project in the characterisation of its bulk explosives and part of this involves the collection of unconfined detonation velocities (VoD). Historical methods of unconfined VoD measurement and earlier measurements taken for the HSBM project did not attribute significance to the strength of the light containment media used, which was either cardboard or PVC, in various wall thicknesses. The main focus of this exercise was to investigate this significance and to make recommendations to the HSBM on the choice of pipes for future tests. ANFO was used in order to avoid complexities of manufacturing and density variation, which arise with emulsion explosives.

Plastic sleeves were used as a control in defining a medium of negligible confinement in order to compare the results in PVC and cardboard pipes. The cardboard pipes selected had wall thicknesses of 2mm and 4mm, while the PVC pipes had pressure ratings of 4 Bar and 9 Bar with wall thicknesses from 1.5mm to 8.5mm. The inner diameters ranged between 45mm and 253mm.

The following findings have been made in this report.

- Plastic sleeves were not effective in comparing the effects of confinement, but the results suggest that thin walled cardboard pipes are probably very close to unconfined, even near the critical diameter.
- PVC pipes affect VoD more than cardboard pipes and the confinement provided by both types of pipes increases with their wall thickness.
- Critical diameter increases with weaker confinement and vice versa.
- VoDs in the different types of confinement converge as diameter increases.
- Future unconfined VoD tests should take cognisance of the findings of this project. A similar confinement investigation would be beneficial to determine whether similar trends prevail with Emulsion and Emulsion-ANFO blend explosives. However if such an evaluation is not conducted, the minimum requirements of further tests should be to apply the confinement and diameter relationships as determined for ANFO during this investigation.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

African Explosives LTD (AEL), as one of the sponsors of the Hybrid Stress Blast Model (HSBM) Project, is involved in identifying a methodology for the characterisation of its bulk explosives. The HSBM project is concerned with the release of explosive energy in blastholes, the transfer of this energy to the rock surrounding the holes, and the physical results of this energy transfer in terms of the requirements of mining operations. Part of the characterisation of these explosives involves the measurement of unconfined detonation velocities (VoD) at various diameters for each density of interest. A basic assumption made in previous research was that the confinement provided by cardboard and PVC pipes of different wall thicknesses is negligible. The main objective of this exercise was to quantify the effects of these light confinement media, if any, on the explosive performance, in terms of VoD.

It was decided to begin with Ammonium Nitrate Fuel Oil (ANFO) explosives as it would provide better assurance of a constant density, due to the complex nature of controlling densities in small batches during the manufacture of emulsion and blend products. A Mobile Manufacturing Unit (MMU) is required for the manufacture of emulsion and blend explosives and is further complicated by the need for a suitable mine testing site, whereas the use of packaged ANFO enabled testing to begin at AEL's "Far Range" test site. Only once a comprehensive study to understand the effect of the confinement medium using ANFO is completed, will tests be done with the emulsion and blend products at various densities. Hopefully the indications from the ANFO testing will be shown to be transferable to other explosives without extensive further trials.

The project was conducted in two stages. The first set of measurements was taken at AEL's "Far Range" test site at Modderfontein between the 21st and the 25th of June 2004 in pipe diameters between 45mm and 95mm. The second set of measurements was conducted at New Vaal Colliery between the 4th and 6th of July 2005, in pipe diameters up to 253mm.

With the unconfined VoD measurements for the HSBM being conducted by various sponsors from all over the world, it was important to ensure consistency in the experimental set-up and data collection procedure, and the author was to this effect assisted by Sedat Essen from the Julius Kruttschnitt Mineral Resource Centre (JKMRC). The standardisation of this process would further facilitate back-analysis of previously recorded data.

This report presents a detailed account of the project, with the primary objective of making recommendations to the HSBM project on the selection of light confinement media for future unconfined detonation velocity measurements.

2 LITERATURE REVIEW

This section of the literature review presents two examples of where unconfined VoD measurements have been conducted without attributing significance to the strength of the light confinement media.

The first reference given is from Onederra and Essen, 2003, in their report for the HSBM titled "Unconfined Velocity of Detonation Measurements of Dyno-Nobel Products at the BHPB IO Test Range, Newman, Western Australia".

The authors described the PVC pipes used in the tests as "thin walled" and thus considered the confinement provided as negligible. The following table was presented on the pipe specifications.

Table 1: PVC specifications

PVC pipe specifications		
Mean OD (mm)	Mean wall thickness (mm)	Type
251	5	SWP – Vindex
160	3	SWP – Vindex
110	3.5	DWP – Vindex
90	1.5	SWP – Vindex
69	3	DWP – Vindex

Note that a wall thickness of 3mm was considered equally negligible in both 69mm and 160mm pipe diameters, and also that the wall thickness at 90mm is less than at 69mm.

The second reference is from Tunaley, D. “An emulsion explosive system for blasting in reactive volcanic conditions” Fragblast 1999, Johannesburg, South African Institute of Mining and Metallurgy, 1999. (Page 316, Fragblast 6).

The unconfined detonation velocity of a high temperature primer was tabulated, together with its other technical properties, as “5350m/s – 5850m/s”. Although a footnote comment stated that the tests were measured in 51mm diameter cardboard tubing, the wall thickness of the pipe was not recorded and thus implied to be negligible.

2.1 Detonation theory

The ability to correctly predict realistic explosive performance in the field depends on a fundamental understanding of detonation theory. The science of detonation physics is well developed and it is not the purpose of this report to repeat the detailed physical derivations, but the author believes that an introduction to the theory is relevant to the subject being investigated.

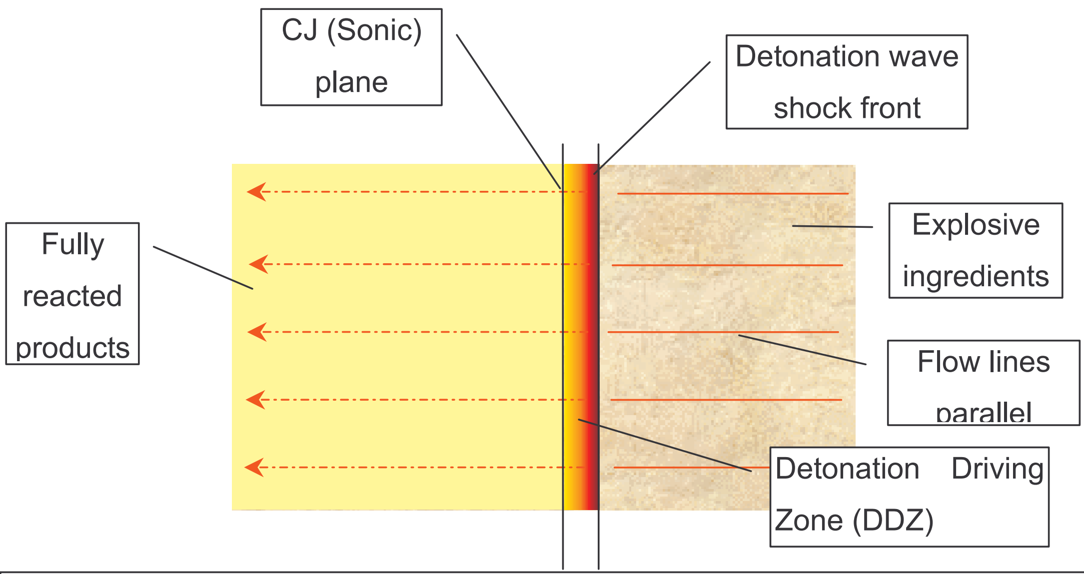
A detonation is a process in which a shock induced supersonic combustion wave propagates through a reactive mixture or exothermic compound. The shock wave heats the material by compressing it, thereby causing a rapid chemical reaction which generates the energy to support the shock.

Explosive performance has generally been determined from an ideal detonation calculation simply in terms of the total energy released by the explosive composition, without reference to the rate at which the energy is released and without consideration to the effects of confinement. In reality explosives behave non-ideally, where the explosive performance depends on the chemical composition of the explosive, the physical form (diameter) and confinement it is subjected to, the method of initiation and the extent of the partitioning of energy available for doing useful work on the rock. (Sheahan and Minchinton, 1988).

AEL has developed two new detonation codes, which fall under the code-name “Vixen”, representing Varied Ideality Explosives Energetics. The ideal detonation code is called Vixen_i and the non-ideal detonation code is called Vixen_n.

Differences in Ideal and Non-Ideal Detonation theory

The ideal detonation theory has been used since the turn of the 19th century to make estimates of theoretically available explosive energy. Figure 1 shows the simplicity of the ideal detonation theory, which is one-dimensional and does not take the surroundings or the reaction rate of the explosive into consideration. The reaction is complete at the CJ (Sonic) plane and there are no side losses of energy from the DDZ (detonation driving zone). All the chemical energy released feeds forward to the shock front, sustaining its amplitude and ensuring that the reaction continues to take place.

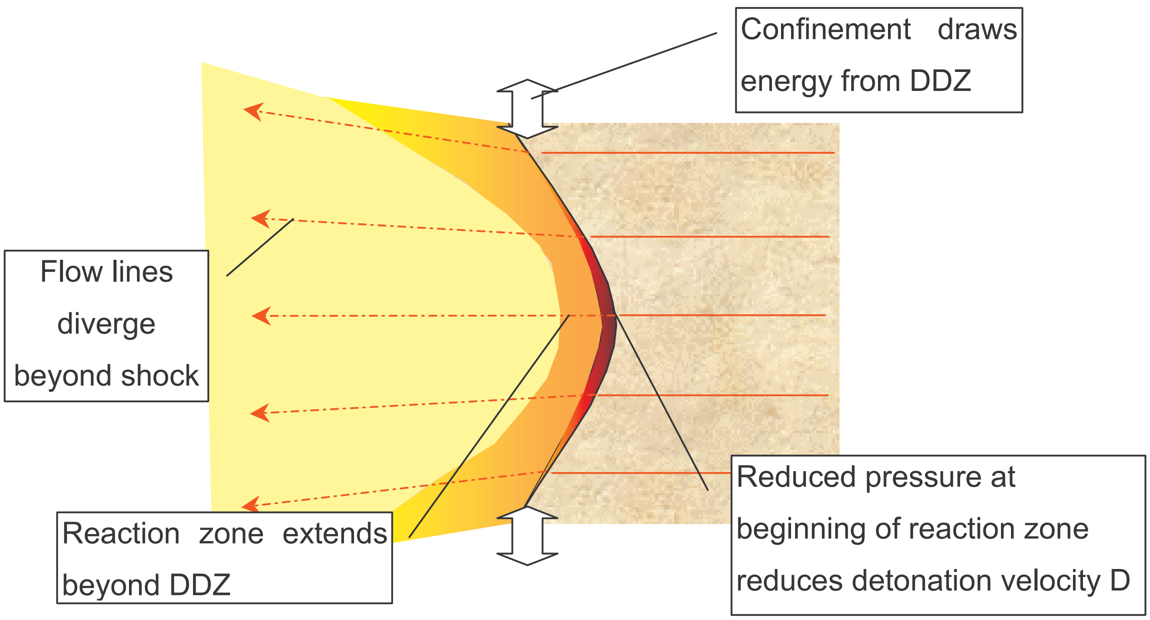


One dimensional, perpendicular shock wave is assumed stationary with explosive moving into it at detonation velocity D. Total reaction within the DDZ, no lateral expansion of products. (Cunningham C.V.B, 2005)

Figure 1: Ideal detonation

“Since the 1950’s attempts have been made to move to non-ideal detonation theory, in which reactivity, time and dimension are taken into account. The objective of moving to non-ideal detonation has been to understand, predict and therefore control both the sensitivity of explosives in various conditions and the way in which they affect and are in turn affected by their confining media.

Figure 2 shows that when the reaction rate and diameter of the explosive are finite, some of the energy in the DDZ leaks sideways, reducing the pressure behind the shock front, which drops both the VoD and the reaction rate. This means that reaction is not complete at the sonic plane, further depriving the DDZ of energy. Where pressure loss is greatest along the side of the detonation column, the shock front weakens and lags behind the axis of the charge where it is thickest. The extent of lateral loss and curvature of the shock front is determined by the rate of reaction, the resistance of the confinement, and the diameter of the charge. Clearly, the detonation velocity is a direct indication of the extent of reaction in the DDZ, and if this amounted to 100%, then the shock front would have no curvature and the measured VoD would be the Ideal value." (Cunningham C.V.B, 2005 – "Defining non-ideal performance")



Two dimensional, shock wave is assumed stationary with explosive moving into it with detonation velocity D. Note divergent flow of products, reaction complete beyond the DDZ, curvature of shock front, all dependent on explosive, charge diameter and strength of confinement. (Cunningham C.V.B, 2005)

Figure 2: Non-Ideal detonation

2.2 Effect of confinement on detonation modelling

"Near the critical diameter, explosive performance is strongly affected by diameter, confinement, density and composition. The critical diameter is also strongly related to the strength of confinement." (Cunningham, C.V.B, "Detonation Velocity: It's significance for Blast Modelling") Unconfined detonation velocities are used to calibrate non-ideal detonation codes such as Vixen_n. It is critical that these measurements are truly unconfined as the model calibrates the explosive performance from a consistently defined state. If the pipes provide any significant confinement resulting in higher VoDs and lower critical diameters, the model would be biased in overestimating the VoD in the confined state, as illustrated by the line diagram in figure 3.

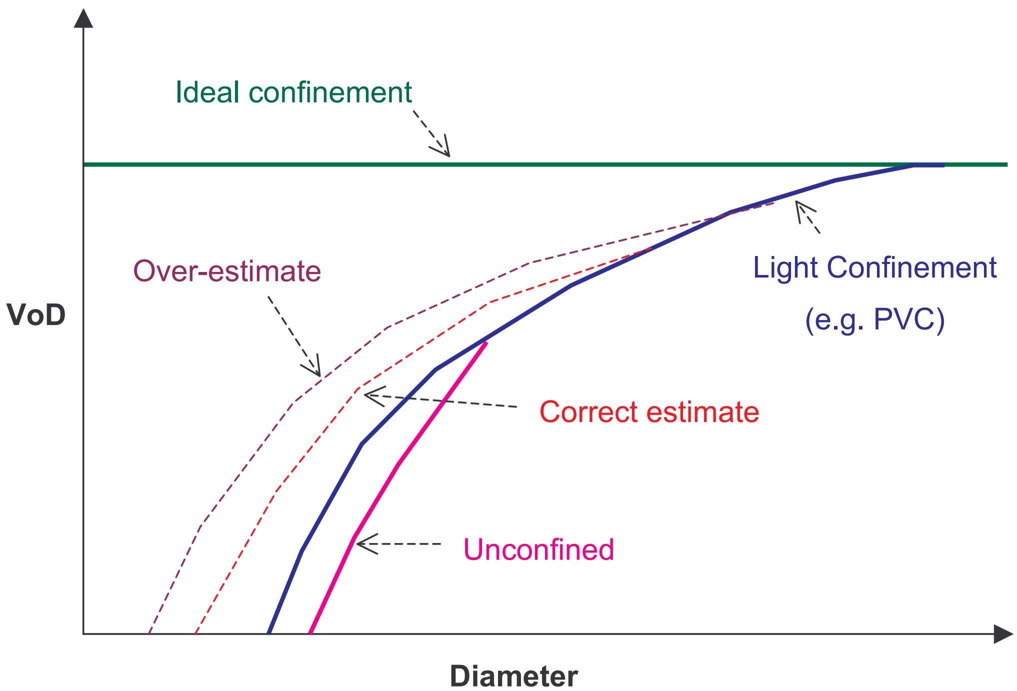


Figure 3: Bias in estimation of VoD

"Ideal confinement is totally rigid and non-conducting, so that detonation within the confinement will neither alter its volume or temperature; it will thus absorb no energy from detonation." (Cunningham, C.V.B, "Borehole pressure: What it really means and how we should use it")

Figure 4 is a VoD vs. inverse diameter plot describing the evolution of three data sets that have been measured for ANFO. The blue line and the red line are the fitted curves from the data sets measured by AEL in 2002 and Dyno-Nobel in 2003 respectively. Both of these tests did not attribute any significance to the confinement provided by the pipes. (The green line is the data from this project and shows the earlier bias in explosive performance as a result of confinement, especially close to the critical diameter.)   Note that although the unconfined measurements have not been taken in diameters greater than 250mm, the graphs all trend towards ideal VoD at infinite diameter. (The ideal VoD is calculated by an ideal detonation code and would be the VoD of the explosive at infinite diameter and confinement.)

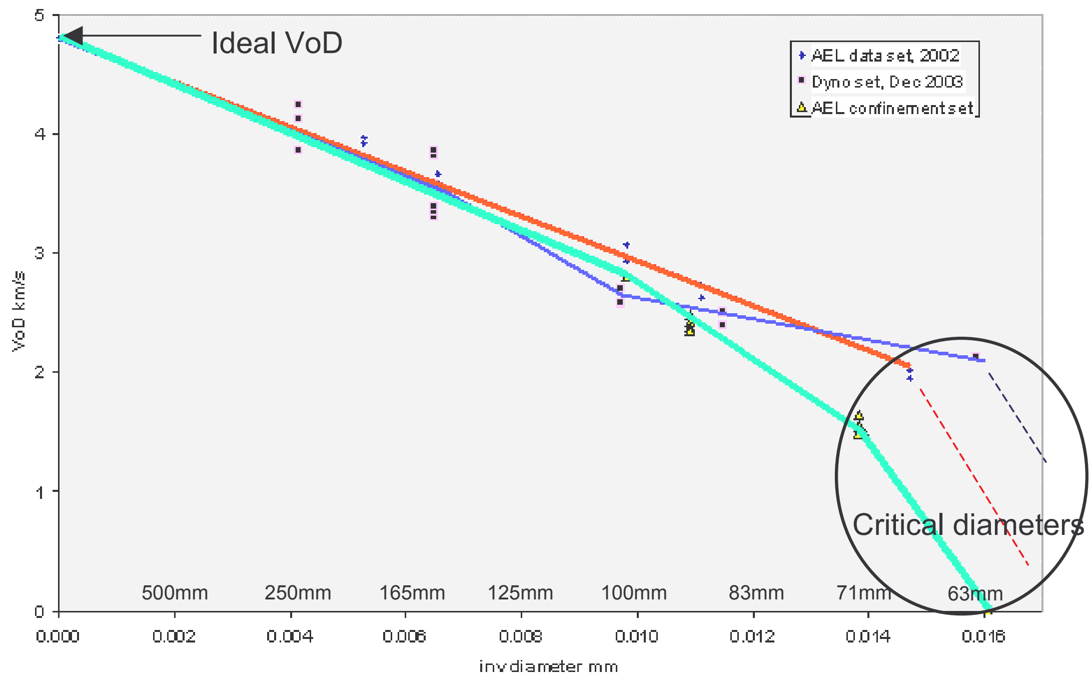


Figure 4: Evolution of ANFO data

2.3 Similar work

The author could not find any significant literature of a detailed investigation on the subject matter of this report. A few papers and reports seem to have touched on the topic but only with limited detail. A review of two such reports has been conducted which has reinforced the need for this investigation.

Comparison of the VoD of ANFEX in plastic sleeves and in PVC pipes

The first report reviewed involved an exercise conducted by the then AECI's research department to compare the VoD of ANFEX in plastic sleeves and in PVC pipes (Wallace. B.W, 1987). The objective of this exercise was to conduct tests to determine whether PVC pipes provided any confinement for ANFEX.

This was achieved by comparing the VoD in plastic sleeves to that in PVC pipes. It was assumed that plastic sleeves provide negligible confinement to the explosives. The VoD results are tabulated below.

Table 2: VoD Results

Container	Diameter (mm)	VoD (km/s)
Plastic sleeve	75	2.15 ± 0.08
PVC pipes	68 (i.d)	2.84± 0.01

Six out of ten of the plastic sleeved ANFEX cartridges misfired, suggesting that 75mm was close to the unconfined critical diameter of ANFEX. No misfires occurred in the 68mm PVC. Work previous to this exercise had shown that the critical diameter of ANFEX in PVC pipes was approximately 55mm.

These results gave two indications that PVC provides some confinement for the ANFEX, firstly from the higher VoD in PVC than in plastic sleeves and secondly from the lower critical diameter in the PVC than in the plastic sleeves. The conclusion of the report was that the findings were surprising because there had been general agreement until then that the confining effect of PVC was negligible.

It is interesting in comparing the VoD results of "ANFEX" presented in Table 2 with the results obtained from this project, in that the VoDs are much higher in the former at similar diameters. This much variation is not likely if the "ANFEX" in both investigations had the same chemical composition, physical form, density and confinement, of which no details are given in the test note. Note that no mention is made of the wall thickness of the PVC pipes used either. The author has also considered the fact that the VoD monitoring technology has improved over the ages, which might have had some impact on the accuracy of earlier results. All of this further illustrates the importance of proper and thorough documentation.

Detonation velocity measurements on ANFO

The second report reviewed was titled "Detonation velocity measurements on ANFO" (Sheahan, R.M., 1988). The aims of this project were to:

1. Obtain unconfined VoD data for normal porous prill ANFO's which are likely to represent the extremes of the sensitivity / critical diameter range.

2. Analyse the results using CPeX (Commercial Performance of Explosives), and to experimentally check CPeX predictions for the effect of confinement on velocity. (CPeX is a non-ideal detonation code that requires experimental unconfined VoD data as a function of charge diameter in order to make estimates of an explosive's performance - velocity and energy release rates - in any confinement.)

Although it was not one of Sheahan's objectives to evaluate the effect of light confinement media on VoD, some data was recorded in PVC and cardboard pipes, which was useful for analysis. Several tests were conducted, but only those that were relevant to the topic of light confinement media have been analyzed for this review. These include unconfined VoD measurements that were measured for a "sensitive" and a "slightly less sensitive" ANFO (density 0.83) in diameters between 50mm and 200mm. A 130g primer was used in pipe diameters less than 64mm and a 400g primer was used in diameters greater than 64mm.

VoDs of a "sensitive" ANFO measured in cardboard pipes are shown in Table 3.

<u>Table 3: VoD Results (sensitive ANFO – cardboard)</u>

Cardboard ID (mm) / OD (mm)	VoD (km/s)
44.2 / 45.6	1.10, 200mm – 400mm from primer, then fail
51.4 / 53.0	1.49
64.2 / 65.8	2.15
76.8 / 83.6	2.56
86.6 / 88.8	2.77
98.2 / 104.6	3.04
125.8 / 132.2	3.42
150 / 158	3.58
178 / 187	3.92
202 / 210	4.12

VoDs of the "slightly less sensitive" ANFO are shown in Table 4.

Table 4: VoD Results (less sensitive ANFO – cardboard)

Cardboard ID (mm) / OD (mm)	VoD (km/s)
51.4 / 53.0	1.09 – fail, 500mm butt left
64.2 / 65.8	1.74
98.2 / 104.6	2.88

VoDs measured in PVC pipes with the "slightly less sensitive" ANFO are shown in Table 5.

Table 5: VoD Results (less sensitive ANFO – PVC)

PVC ID (mm) / OD (mm)	Volume ratio	VoD (m/s)
42.8 / 48.4	0.28	1.41, 1.35, 1.32, 1.25, 1.11, 1.14, fail
45.0 / 48.6	0.17	1.28, 0.96, fail
50.6 / 56.2	0.23	1.68
53.0 / 60.6	0.31	1.99
63.0 / 69.0	0.20	2.38
75.0 / 89.0	0.41	2.96
76.0 / 82.8	0.19	2.70
81.4 / 89.0	0.20	2.89
86.6 / 90.6	0.10	2.77
96.0 / 114.4	0.42	3.56
101.0 / 114.4	0.28	3.31
103.4 / 110.6	0.14	3.26
104.4 / 114.6	0.20	3.17
134.0 / 140.4	0.10	3.44
142.6 / 160.0	0.26	3.62
151.2 / 160.4	0.13	3.43
152.0 / 159.8	0.11	3.55

Analysis of results

The report did not differentiate between the different wall thicknesses of the PVC pipes, so the author has used the volume ratio of the pipes to "categorising" them as follows:

Table 6: PVC "classification"

PVC Category	Volume ratio
PVC Category 1	0.10 – 0.14
PVC Category 2	0.15 – 0.25
PVC Category 3	0.26 – 0.41

(The volume ratio is a ratio of volume of the outer diameter to that of the inner diameter. The categories are roughly based on two of the classes of pipes used in the confinement project conducted by the author).

Before an analysis of the role of confinement can be made, it is firstly noted that the results in the PVC pipes are fragmented (i.e. the whole range of diameters are not represented within the sub-categories) and secondly that ANFO's of different sensitivity have been used in the tests. However, the results shown graphically in figure 5 seem to indicate that the cardboard pipes seem to provide less confinement than the PVC pipes in the smaller diameters. The VoDs also seem to converge in the cardboard and the PVC pipes with a lower volume ratio (thinner wall thickness) at a diameter of around 100mm. These VoDs then converge with those in the thicker walled PVC pipes at around 150mm. As could be expected the "slightly less sensitive" ANFO has lower VoDs than the more sensitive ANFO, in the same confinement and diameters.

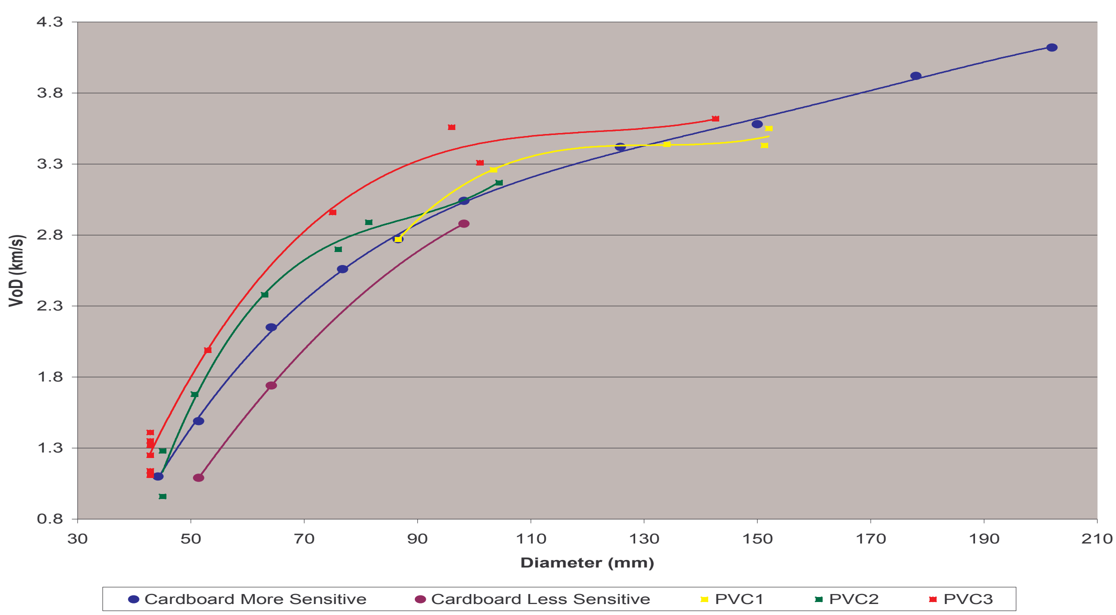


Figure 5: Results from Sheahan tests, 1988

3 UNCONFINED VoD TESTING AND DATA COLLECTION PROCEDURE

Explosives manufactured by Dyno-Nobel were tested at Mt. Newman, Western Australia (Onederra and Essen, November 2003) in their characterisation for the HSBM project. The authors recommended that the testing procedures followed during this exercise be standardised for the HSBM project and as such the methodology adopted for this project has also followed similar procedures.

The tests were conducted in cardboard and PVC pipes of various thicknesses, using the continuous resistance wire technique adopted by the HSBM Project, with the use of the Microtrap system, as described in the following chapters.

3.1 Data acquisition System

The unconfined VoD data were measured using specially manufactured high resistance VoD Proberods and the Microtrap, as shown in Figure 6. The system uses a continuous resistance monitoring technique for monitoring the VoD. A probe of known unit resistance is inserted axially into one end of the explosive column, with the primer inserted at the other end. As the detonation front of the explosive consumes the probe, the resistance of the circuit decreases in proportion to the length of the probe. The Microtrap records the resulting decrease in voltage across the probe versus time.

Figure 6: MREL Microtrap & VoD proberod

The features of the Microtrap are described in detail in the MREL Microtrap operations manual, but the following list is a summary of the main features:

- A VoD channel capable of recording up to 2 MHz (2 million data points per second), which provides a time resolution of one data point for every 0.5 microseconds. Thus for an explosive with a VoD of around 4000m/s, the Microtrap would record a data point every 2mm along the explosive column.
- An upgraded digital memory of 8 million data points, which allows the Microtrap to record for up to 4.0 seconds when recording at 2 MHz.
- The capability to store up to 16 events in its permanent (non-volatile) memory before having to download the data to a computer. Note that the recording time allocated per blast is inversely proportionate to the number of blasts programmed for recording. Thus if the Microtrap is programmed to record 16 blasts at 2 MHz it allocates 250 milliseconds per blast.

The VoD proberod is a rigid probe consisting of a high resistance insulated wire placed inside a small diameter copper tube, which acts as the return lead of the circuit. These proberods are specifically designed to measure VoDs of short sample tubes of explosives, under confined and unconfined conditions. They have a nominal length of 0.9m and are manufactured with a specific unit resistance of either 322.5ohms/m or 347.8ohms/m.

3.2 Instrumentation setup and data collection

The proberods used in this exercise have a unit resistance of 322.5ohms/m. A lead of approximately 100m of RG59 coaxial cable was used to connect the proberod to the Microtrap. The setup is illustrated in Figure 7.

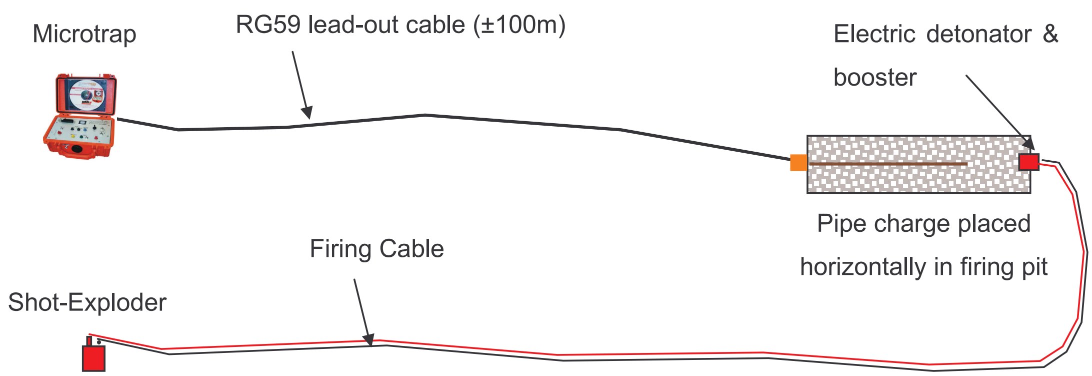


Figure 7: Instrumentation setup

A proberod is inserted axially into one end of the pipe with an electric detonator and a pentolite booster at the opposite end, as shown in figure 8. The length of each proberod is 0.9m and the pipes are 1.5m long, in order to minimise the influence of the primer on the steady state VoD of the explosive.

Figure 8: Instrumentation and firing setup

150-gram pentolite boosters were used in pipe diameters less than 95mm while 400-gram boosters were used in diameters greater than 95mm. These priming requirements were determined according to AEL's technical data sheet, which suggests figure 9 as a guideline for the optimum size of booster with increase in hole diameter.

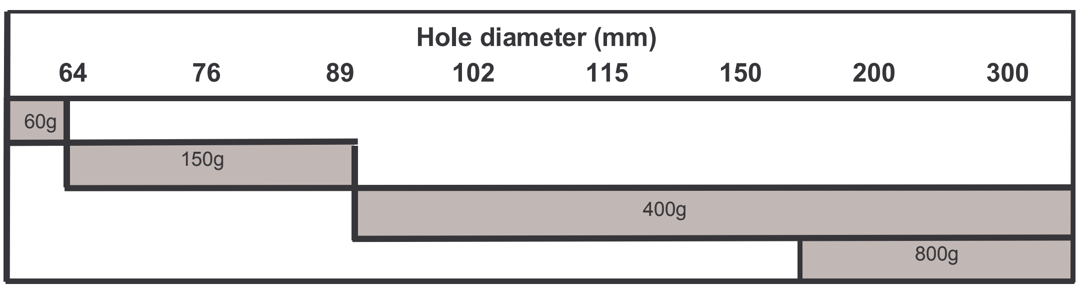


Figure 9: AEL's guideline for booster requirements

The pipes are placed horizontally in the firing pit and the location for subsequent shots was offset to prevent the formation of large craters. The internal triggering mechanism of the Microtrap was used in all the tests.

The data for each test were recorded in the same manner used for the previous tests done for the HSBM Project by Onederra and Essen, 2003. The unconfined VoD data collection sheets are included in Appendix 1.

4 TESTING AT AEL's "FAR RANGE"

The first tests were conducted at AEL's "Far Range" testing site at Modderfontein. Tests are limited to a maximum charge mass of 9kg per delay at the range due to noise considerations for nearby residential areas. This meant that the exercise was limited to pipes less than 100mm in diameter. Sedat Essen, from the JKMRC, assisted the author in the experimental setup and data collection. Two different MicroTrap instruments, one from AEL Blast Consult and the other from the JKMRC were available for this project. The AEL instrument was used in all of the tests and the JKMRC instrument was a standby unit. It was decided to do comparative tests using both instruments in four pipe tests, using two separate monitoring circuits. This was limited to only a few tests due to the possibility of interference between the two circuits. The two circuits were kept at least two metres apart to try and minimise potential interference, except in the immediate vicinity of the test pipes where the circuits converge as both probes are inserted into one pipe. The results of these comparative tests are presented and analysed in chapter 4.3.

4.1 Sample Preparation

The different types of containment media selected for this project are shown in figure 10. PVC and cardboard pipes were selected with the aim of comparing the effect of the strength of the confinement medium on the VoD of the explosive. The cardboard pipes were specially ordered and manufactured to the required specifications of wall thickness, diameter and length. The nominal wall thicknesses selected were 2mm and 4mm. It was not possible to keep the wall thickness constant in the required range of diameters with the PVC pipes, so it was decided to purchase them in two different pressure ratings of 4 bar and 9 bar respectively, namely Class 4 PVC and Class 9 PVC. The wall thickness in the two classes of PVC pipes increases with an increase in diameter and their specifications are summarised in Table 7.

Table 7: PVC Class 4 and Class 9 specifications

Type	OD (mm)	Wall thickness (mm)	ID (mm)	Volume ratio
Class 4: SABS 966 Part 1 PVC-U DUROFLO	50	1.5	47.0	0.13
	63	1.5	60.0	0.10
	75	1.5	72.0	0.09
	90	1.8	86.4	0.09
Class 9: SABS 966 –1 Petzetakis Supratuff	50	2.2	45.6	0.20
	63	2.7	57.6	0.20
	75	3.2	68.6	0.20
	90	3.9	82.2	0.20

Plastic sleeves with negligible wall thickness (50 to 100 microns) were used to define a confinement as close as practically possible to zero. These sleeves were not readily available off the shelf and as indicated in figure 10, were graciously provided by a polony (type of processed meat) packaging company. The nominal pipe length selected was 1.5m. While the cardboard pipes could be supplied in the required length, the PVC pipes are supplied off the shelf in 6m lengths and had to be cut into four sections. (A hacksaw was sufficient to cut the thinner walled pipes while an angle grinder became necessary in the thicker walled pipes).

Figure 10: Plastic sleeves, PVC pipes and cardboard pipes

The type of ANFO used is called ANFEX and is packaged in 25kg bags. The process of preparing the charges is shown in figure 11. The pipes and sleeves were sealed at one end using duct-tape and twine respectively and pour loaded with the ANFEX. As the pipes were being filled and moved around the test site, a small amount of settling occurred and the pipes were topped up accordingly. The pipes were then sealed with duct-tape and the sleeves tied-up. Each sample was weighed to calculate the loaded density and the cup density was also calculated by measuring the weight of the explosive filled into a plastic cup of known volume (1.230 Litres).

Figure 11: Test site – preparation of test pipes

4.2 Results

A total of 70 unconfined VoD tests were conducted using ANFEX manufactured by AEL. Tests at each diameter and confinement were repeated four or five times to obtain representative results. An example of a typical VoD trace is shown below in figure 12, where the raw data, filtered data and analysis regions for each trace have been superimposed on one graph. (The remaining traces can be referred to in Appendix 3.) The black line represent the raw data, while the blue line shows the filtered data after the "noise" has been manually cleaned-up, and the red line indicates the region from which the VoD was determined, using a simple linear regression analysis.

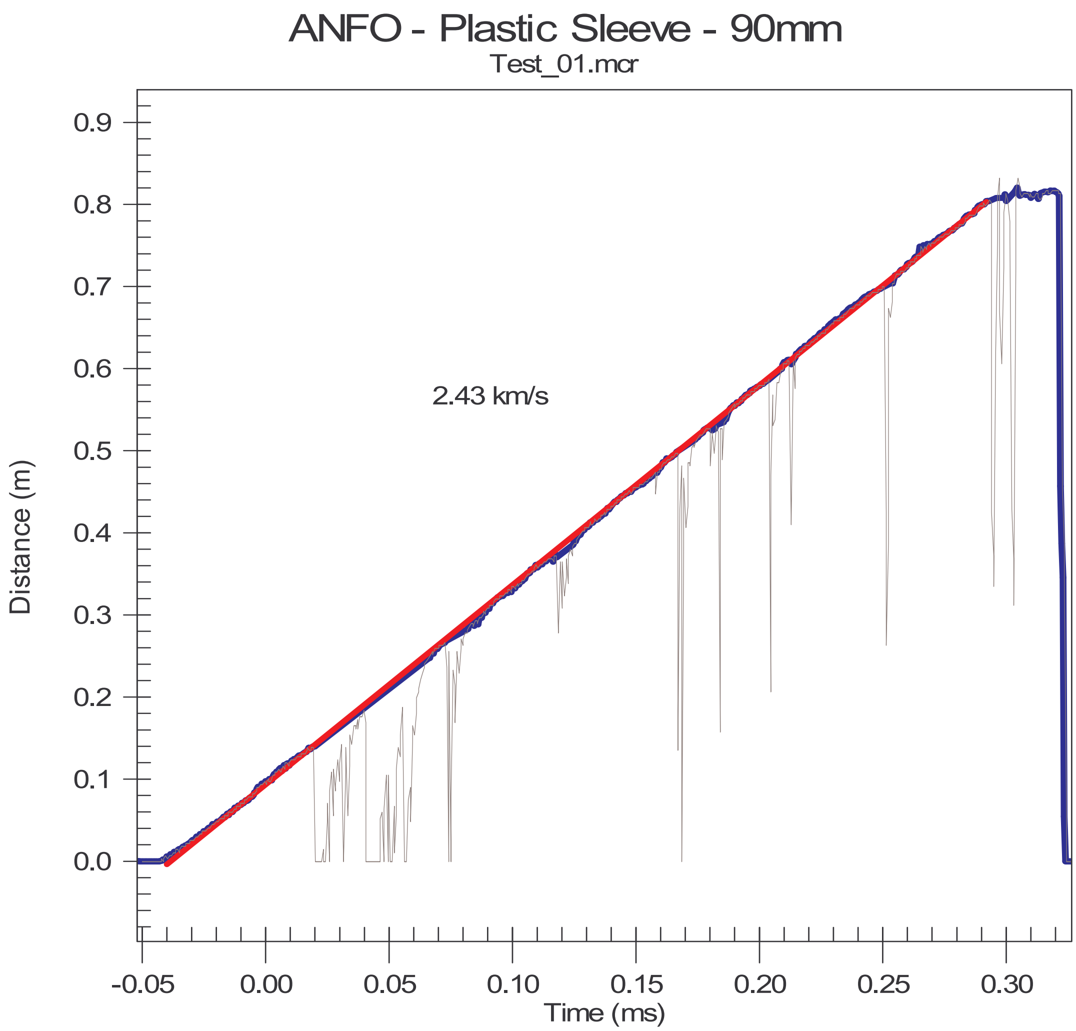


Figure 12: Typical VoD trace

Figure 13 shows a pipe in which partial detonation occurred as a result of being below the critical diameter. When this occurred, approximately 0.8m to 1.2m of the initial 1.5m remained after detonation and it is interesting to note the pulverisation and compaction of the ANFO prills at the detonation front, which occurs as a result of the detonation pressure.

Figure 13: Undetonated explosives below critical diameter

Tables 8, 9, 10, 11 and 12 show the results in plastic sleeves, 2mm cardboard, 4mm cardboard, Class 4 PVC and Class 9 PVC respectively. The corresponding unconfined VoD versus diameter plots are shown in Figures 13, 14, 15, 16 and 17.

Dual VoDs were recorded in some traces. Both results are indicated on the respective traces in Appendix 3, but only the higher of the dual VoDs have been used in the analysis for the following reasons:

- The results from the other samples at the same confinement and diameter are generally closer to the higher VoD.
- The lower VoD was recorded at the start of the traces in all of the instances. It is therefore being assumed that the detonation was still in a run-up stage and had not yet reached steady state.

Table 8: Plastic sleeves

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
Plastic sleeve	68.5	0.83 –0.84	No detonation in four tests		
Plastic sleeve	90.0	-	2.43		Test_01
Plastic sleeve	90.0	-	2.49		Test_02
Plastic sleeve	90.0	-	2.38		Test_03
Plastic sleeve	95.5	0.87	2.57	0.32	Wednesday_01
Plastic sleeve	95.5	0.82	2.65	0.85	Wednesday_02
Plastic sleeve	95.5	0.80	2.54	0.50	Wednesday_03
Plastic sleeve	95.5	0.83	2.66	0.46	Wednesday_04

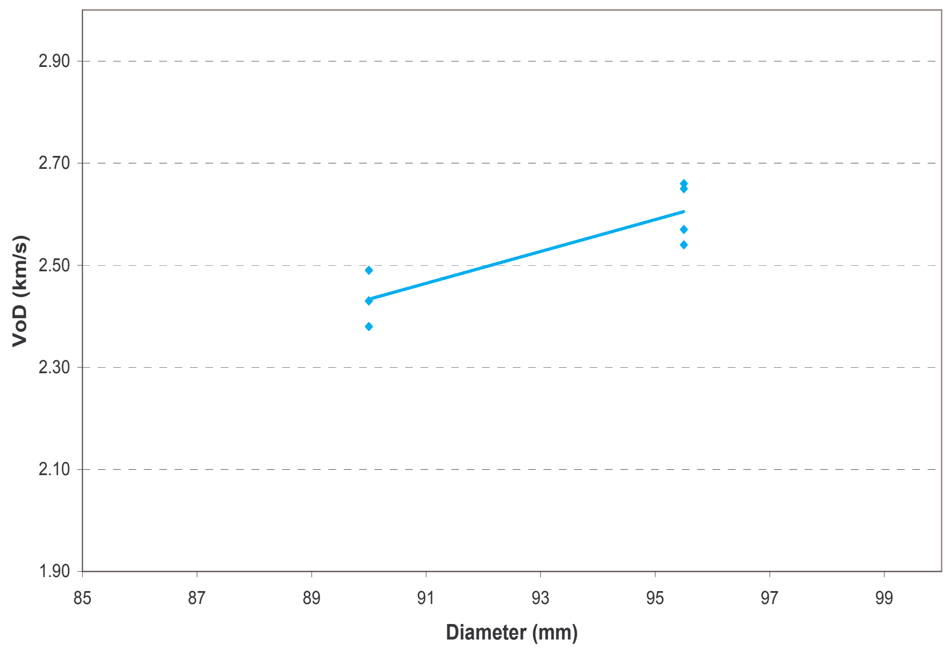


Figure 13: VoD vs. Diameter plot - Plastic Sleeves

Table 9: 2mm Cardboard

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
2mm Cardboard	61.9	0.77 – 0.78	No detonation in five tests		
2mm Cardboard	71.9	0.78	No result		Tuesday_02
2mm Cardboard	71.9	0.77	1.28	0.48	Tuesday_05
2mm Cardboard	71.9	0.76	1.32	0.41	Tuesday_07
2mm Cardboard	71.9	0.77	1.42	0.08	Tuesday_09
2mm Cardboard	71.9	0.77	1.29	0.55	Tuesday_11
2mm Cardboard	71.9	0.77	1.35	0.17	Friday_06
2mm Cardboard	91.8	0.78	2.36	0.82	Jkc_02
2mm Cardboard	91.8	0.79	2.55	0.82	Tuesday_03
2mm Cardboard	91.8	0.78	2.43	0.82	Tuesday_06
2mm Cardboard	91.8	0.78	2.49	0.48	Tuesday_08
2mm Cardboard	91.8	0.76	2.37	0.46	Tuesday_10
2mm Cardboard	91.8	0.76	2.50	0.82	Tuesday_12

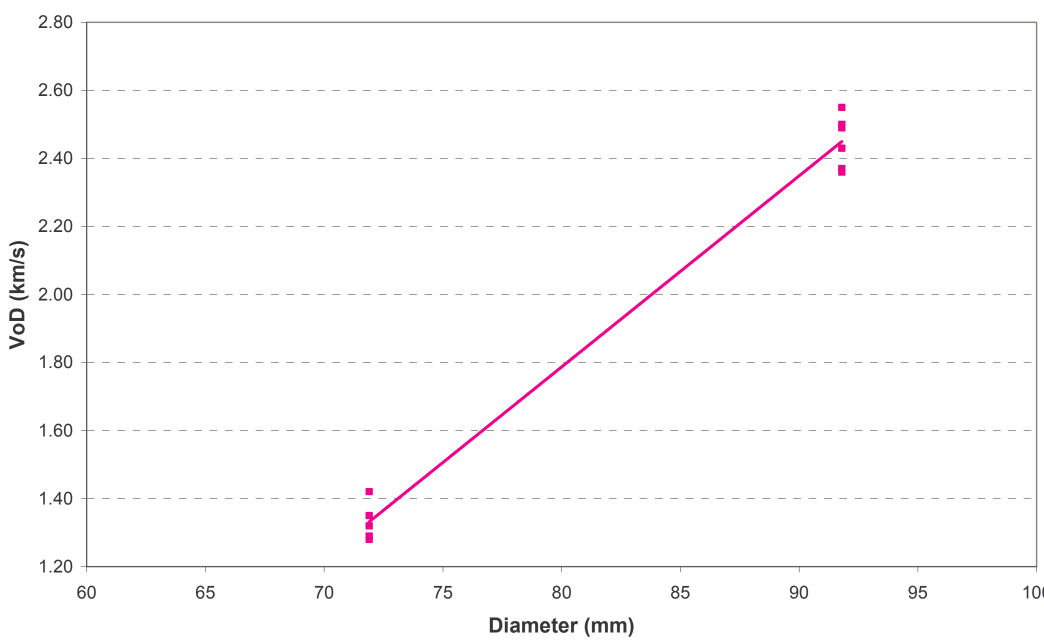


Figure 14: VoD vs. Diameter plot – 2mm Cardboard

Table 10: 4mm Cardboard

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
4mm Cardboard	62.3	0.77 – 0.78	No detonation in four tests		
4mm Cardboard	72.3	0.77	1.65	0.82	Wednesday_08
4mm Cardboard	72.3	0.78	1.59	0.82	Wednesday_09
4mm Cardboard	72.3	0.77	1.49	0.21	Wednesday_10
4mm Cardboard	72.3	0.77	1.56	0.82	Wednesday_11
4mm Cardboard	72.3	0.77	1.48	0.82	Friday_05
4mm Cardboard	91.7	0.78	2.42	0.85	Friday_07
			2.50	0.84	Jkc_01
4mm Cardboard	91.7	0.77	2.48	0.85	Wednesday_12
4mm Cardboard	91.7	0.76	2.39	0.78	Wednesday_13
			2.38	0.62	Jk_01
4mm Cardboard	91.7	0.76	2.35	0.75	Wednesday_14
4mm Cardboard	91.7	0.76	2.30	0.24	Wednesday_15

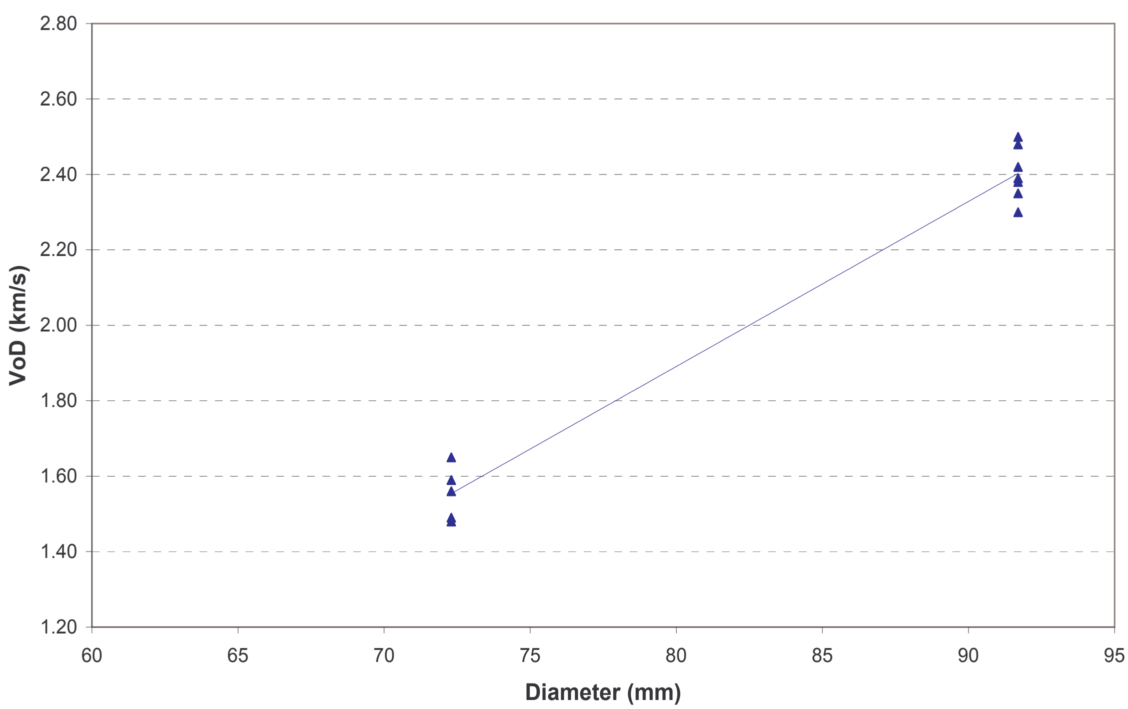


Figure 15: VoD vs. Diameter plot – 4mm Cardboard

Table 11: 4 Bar PVC

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
4 Bar – PVC	59.9	0.77	No detonation in four tests		
4 Bar – PVC	71.3	0.78	1.88	0.78	Thursday_03
4 Bar – PVC	71.3	0.79	1.91	0.80	Thursday_04
4 Bar – PVC	71.3	0.78	1.90	0.80	Thursday_05
4 Bar – PVC	71.3	0.78	1.89	0.80	Thursday_06
4 Bar – PVC	85.8	0.78	2.62	0.84	Thursday_11
			2.62	0.84	Jkb_01
4 Bar – PVC	85.8	0.76	No result		Thursday_12
			2.61	0.84	Jkb_02
4 Bar – PVC	85.8	0.76	2.65	0.66	Thursday_13
4 Bar – PVC	85.8	0.76	2.64	0.82	Thursday_14

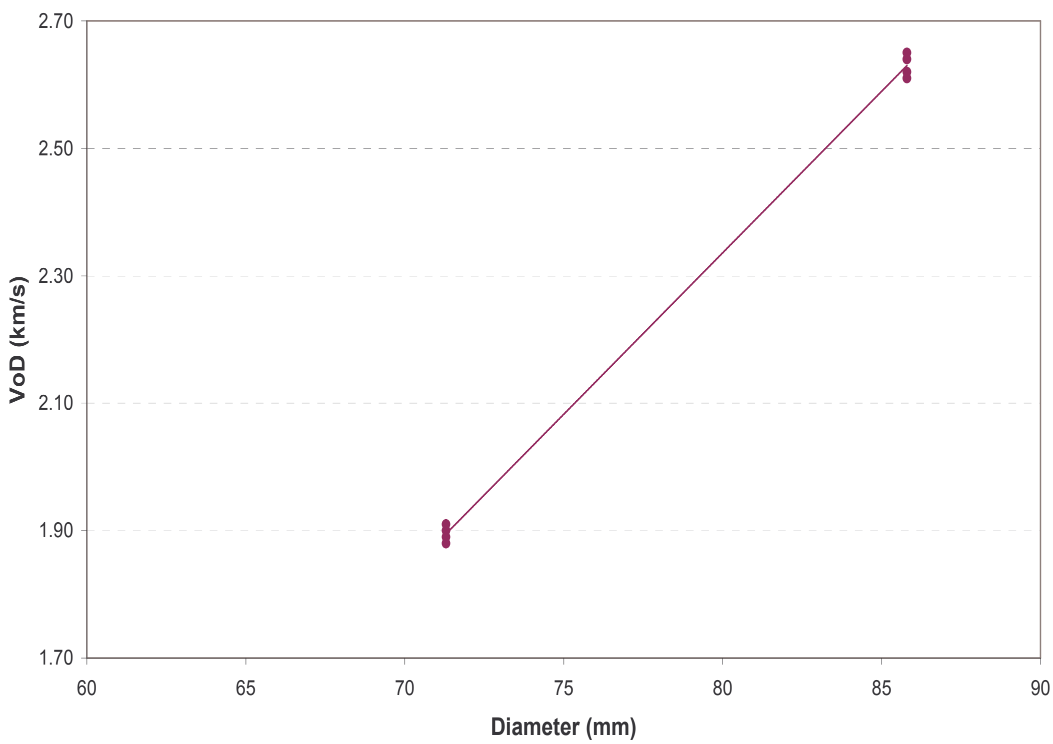


Figure 16: VoD vs. Diameter plot – 4Bar PVC

Table 12: 9 Bar PVC

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
9 Bar – PVC	45.2	0.73	No detonation in four tests		
9 Bar – PVC	57.2	0.75	1.66	0.62	Monday_01
9 Bar – PVC	57.2	0.78	1.71	0.40	Monday_02
9 Bar – PVC	57.2	0.76	No result		Monday_03
9 Bar – PVC	57.2	0.77	1.59	0.83	Tuesday_01
9 Bar – PVC	69.4	0.77	2.20	0.74	Thursday_07
9 Bar – PVC	69.4	0.77	2.17	0.83	Thursday_08
9 Bar – PVC	69.4	0.76	2.18	0.84	Thursday_09
9 Bar – PVC	69.4	0.76	2.20	0.83	Thursday_10
9 Bar – PVC	82.0	0.79	2.92	0.60	Friday_01
9 Bar – PVC	82.0	0.79	2.78	0.65	Friday_02
9 Bar – PVC	82.0	0.77	2.81	0.66	Friday_03
9 Bar – PVC	82.0	0.77	2.71	0.84	Friday_04

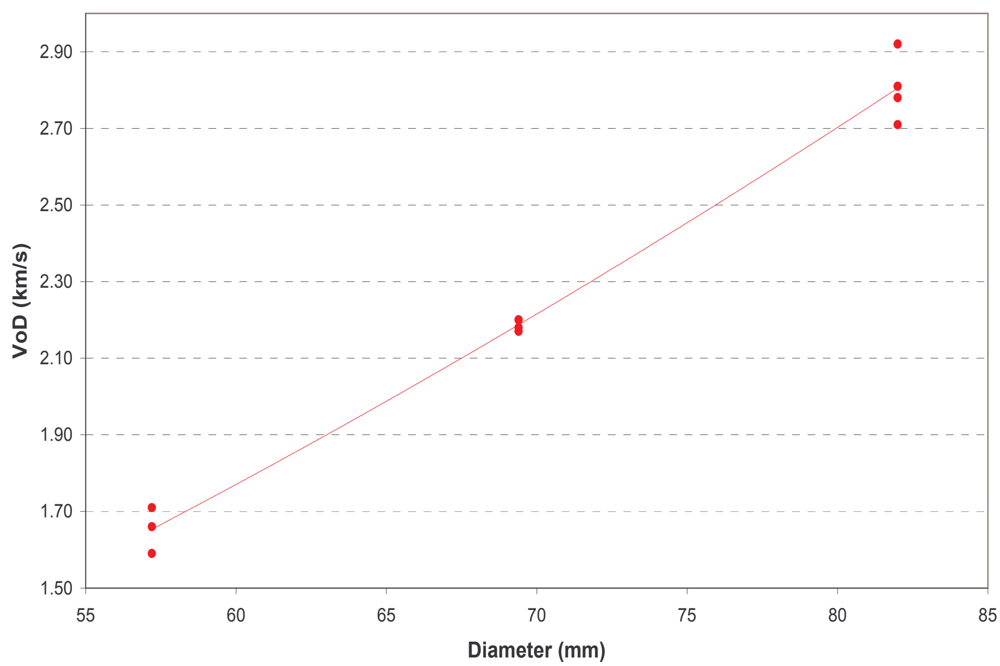


Figure 17: VoD vs. Diameter plot – 9Bar PVC

Table 13 shows a summary of the data using means and standard deviations for the VoD at each diameter and type of confinement.

Table 13: Mean VoD and Standard deviation

Confinement Type	ID (mm)	Mean VoD (km/s)	Std. Deviation (km/s)
Plastic sleeve	68.5	-	-
	90.0	2.43	0.06
	95.5	2.61	0.06
2mm Cardboard	61.9	-	-
	71.9	1.33	0.06
	91.8	2.45	0.08
4mm Cardboard	62.3	-	-
	72.3	1.55	0.07
	91.7	2.40	0.07
4 Bar – PVC	59.9	-	-
	71.3	1.90	0.01
	85.8	2.63	0.02
9 Bar – PVC	45.2	-	-
	57.2	1.65	0.06
	69.4	2.19	0.02
	82.0	2.81	0.09

4.3 Analysis of Results

The comparison of the results from the two Microtrap instruments from AEL and the JKMRC confirmed the precision of both instruments, as shown in Table 14. The "No result" obtained in one of the comparative tests indicates that the possibility of interference cannot be excluded when two instruments are used simultaneously in one test.

Table 14: MicroTrap - comparative test results

Confinement Type	ID (mm)	VoD (km/s)	Microtrap file name
4mm Cardboard	91.7	2.42	Friday_07.mcr
		2.50	Jkc_01.mcr
4mm Cardboard	91.7	2.39	Wednesday13.mcr
		2.38	Jk_01.mcr
4 Bar – PVC	85.8	2.62	Thursday_11.mcr
		2.62	Jkb_01.mcr
4 Bar – PVC	85.8	No result	Thursday_12.mcr
		2.61	Jkb_02.mcr

Plastic sleeves

Plastic sleeves were not effective in comparing the effects of confinement with PVC and cardboard because of consistently higher explosive densities in the plastic sleeves, which is attributed to the different settling mechanism of the ANFO prills in the flexible sleeves compared to rigid pipes. (The explosive density in most of the PVC and cardboard pipes ranged from 0.76 - 0.79g/cc, while the density in the plastic sleeves ranged from 0.80 to 0.87g/cc.) The effect of the higher density in the plastic sleeves is illustrated in Figure 18, which shows a higher VoD compared to cardboard pipes of 2mm wall thickness. This also suggests that the results in the 2mm cardboard pipes are probably very close to unconfined.

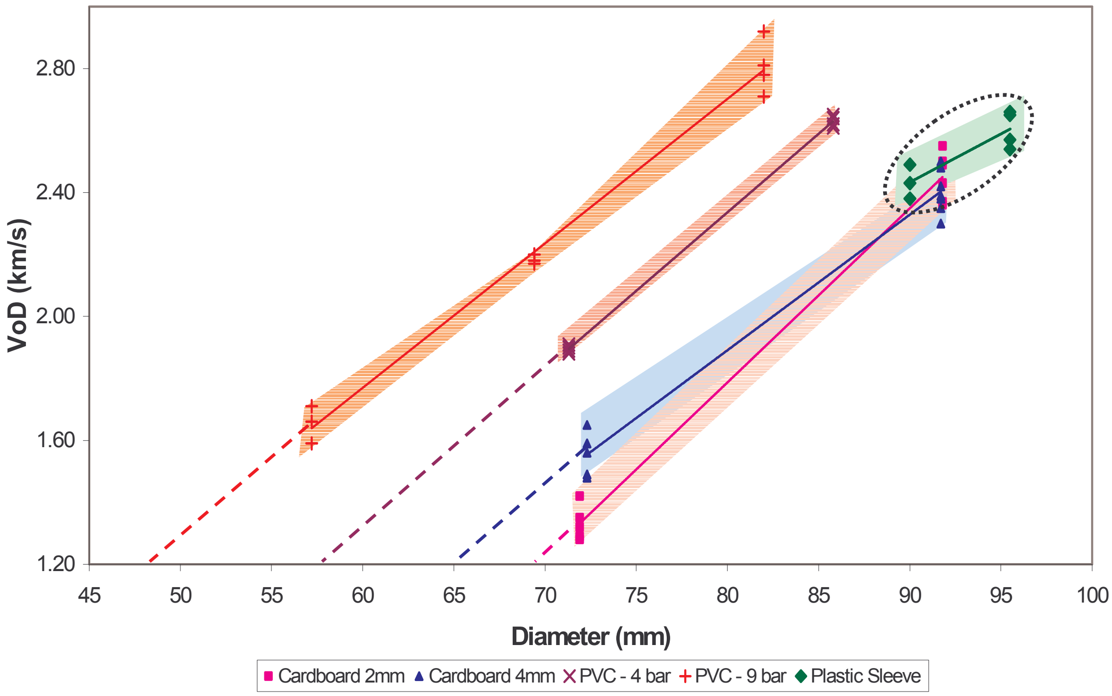


Figure 18: VoD vs. Diameter plot

In addition to the loading density, the use of plastic sleeves in routine testing is impractical for the following reasons:

- They are not readily available off-the-shelf and the range of diameters is limited.
- They are very cumbersome to prepare and difficult to take measurements from.
- They tend to assume a more oval than circular shape in cross section when laid on the ground, due to their flexibility.

Critical diameter vs. Confinement

Referring to figure 18, the dashed lines at the smaller diameters are estimates of where the critical diameter is extrapolated to be in each of the types of containment. It was not possible to determine the exact critical diameter with each type of confinement due to the limited range of pipe diameters available from the manufacturers. The range in which the critical diameter lies for each confinement is indicated in Table 15, which is simply the diameters between which detonation did not occur reliably and those where it did. The extrapolation of the critical diameter as shown in figure 18 is also indicated in Table 15, and shows a reduction in the critical diameter with the increased confinement.

Table 15: Critical diameters

Confinement Type	Critical diameter range (mm)	Extrapolated critical diameter (mm)
2mm Cardboard	61.9 – 71.9	70
4mm Cardboard	62.3 – 72.3	65
4 Bar PVC	59.9 – 71.3	58
9 Bar PVC	45.2 – 57.2	48

Figure 19 shows the recorded data together with some historical data on ANFO measured in a larger range of diameters.

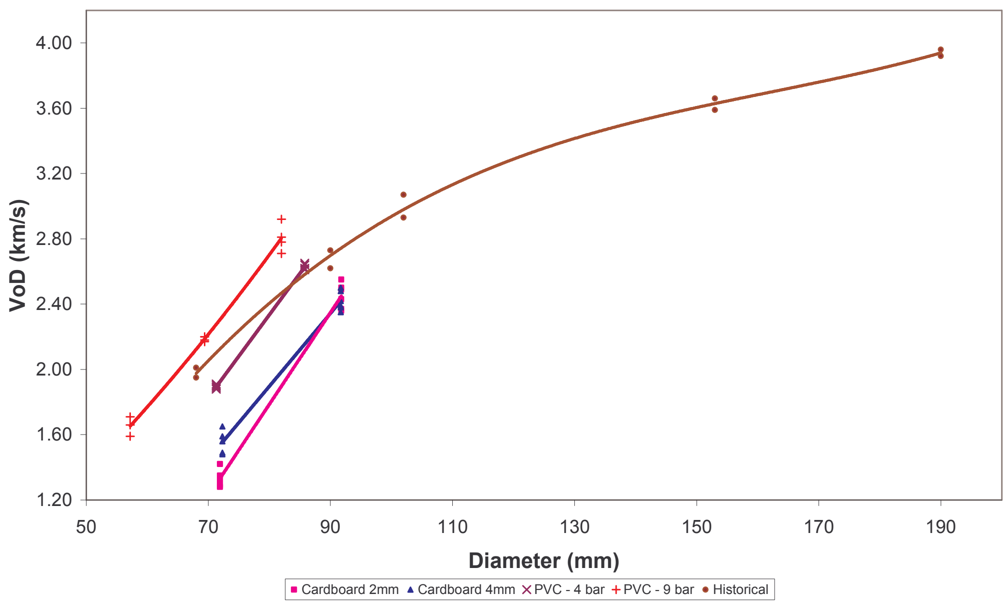


Figure 19: Current and historical data

VoD and Confinement

The results show that PVC pipes provide stronger confinement than cardboard pipes of similar wall thickness. The confinement also increases with wall thickness in both cardboard and PVC. As expected, these statements do not stand in isolation as similar VoDs at the same diameters are observed in some of the pipes, irrespective of the type of confinement. Table 16 shows the convergence points in the data. (The convergence of VoDs in two different types of pipes implies that the confinement of the stronger pipe is equivalent to that of the weaker pipe at diameters larger than at the point of convergence.)

Table 16: Convergence points

Convergence between:	Avg. VoD (km/s)	Diameter (mm)
2mm & 4mm Cardboard	2.3	90
4 Bar PVC & Historical data	2.5	85

Figure 20 shows a clear divergence at around 72mm diameter and convergence at 90mm in 2mm and 4mm thick cardboard pipes. However due to the absence of information in between these two diameters, the dashed line indicates how the actual point of convergence could be somewhere between the two measured diameters. The implication is that in order to ensure that measurements are as close to unconfined as possible with ANFO, the conservative approach is to use 4mm thick cardboard pipes only in diameters larger than 90mm. (The same principle applies to the convergence points that have been recorded in the larger diameters.)

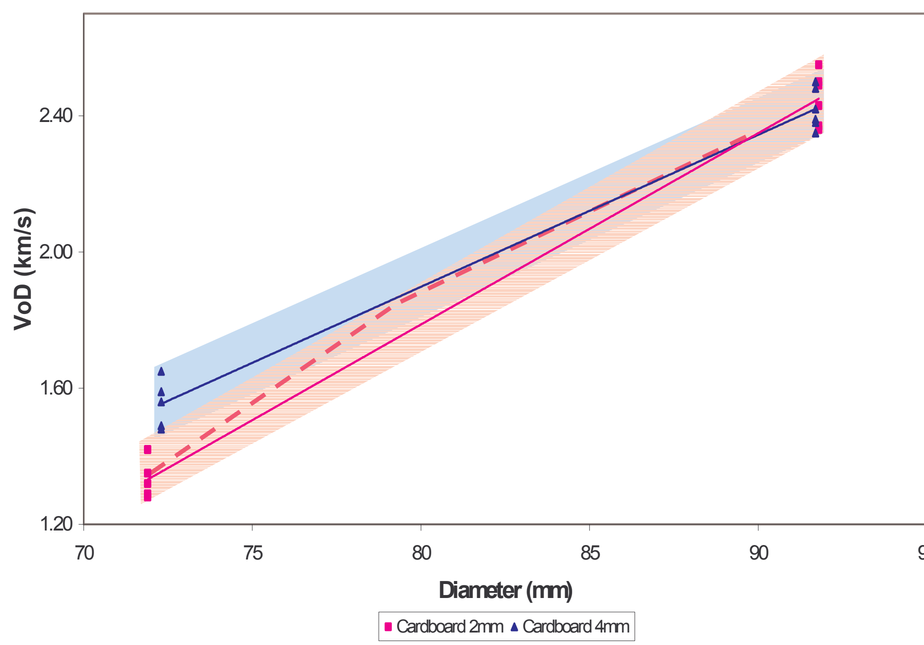


Figure 20: Convergence in 2mm and 4mm cardboard

The second phase of this project involved measurements at larger diameters. Figure 21 shows how the author indicated that the VoDs might behave at the larger diameters prior to the tests actually being conducted, with emphasis on the anticipated convergence points. It is interesting to note how the actual results eventually unfolded once the tests were conducted.

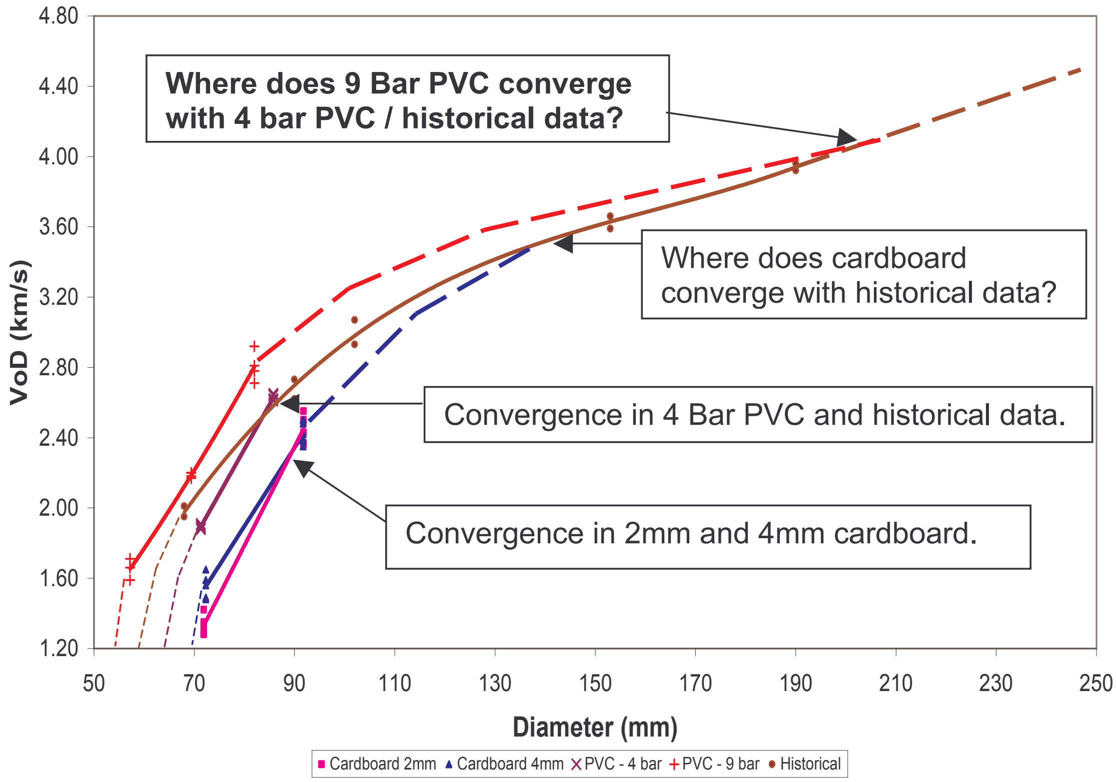


Figure 21: Anticipated convergence in larger diameters

5 TESTING AT NEW VAAL COLLIERY

The second phase of this project was conducted at New Vaal Colliery. The tests were continued in pipe diameters up to 252mm, at which point the noise levels started becoming of concern and the remaining tests were abandoned. Nevertheless, sufficient data had already been collected for the scope of this project.

5.1 Sample preparation

The results from the first series of tests in smaller diameters showed that it was not necessary to continue testing with plastic sleeves. The convergence in 2mm and 4mm thick cardboard pipes at 90mm furthermore suggested that the confinement of the 2mm thick pipe becomes negligible at larger diameters. Thus the remaining tests were conducted using only the 4mm thick cardboard, Class 4 PVC and Class 9 PVC. The specifications of the two classes of PVC pipes are summarised in Table 17.

Table 17: PVC Class 4 specification

Type	OD (mm)	Wall thickness (mm)	ID (mm)	Volume Ratio
Class 4: SABS 966 Part 1 PVC-U DUROFLO	160	3.5	153.0	0.09
	200	4.7	190.6	0.10
	250	5.0	240.0	0.09
Class 9: SABS 966 –1 Petzetakis Supratuff	160	6.0	148	0.17
	200	7.0	186	0.16
	250	8.5	233	0.15

A total of 36 pipes was prepared and fired over a period of three days. The preparation of these larger diameter pipes followed the same procedures as with the smaller diameter pipes, except that the ANFO was supplied out of a MMU (mobile manufacturing unit) due to the large quantities required. The main difference between “ANFEX” and the bulk ANFO is that the fuel oil (diesel) is mixed with the Ammonium Nitrate prills on the truck during the charging process (as opposed to in the factory). If the correct ratio is not achieved it would result in an oxygen imbalance in the explosive. Another difference between the two sources of explosives is that bulk ANFO prills could potentially be subjected to more handling, moisture and temperature fluctuations, which makes them more susceptible to changes in their physical structure, generation of fines and caking. In order to validate the bulk ANFO for these tests to be comparable to those in the smaller diameter pipes, it was therefore necessary to measure the densities and the percentage fuel oil and confirm that it complied with the required specification. The procedure to measure the percentage oil in ANFO is described in Appendix 4, together with the results obtained which confirmed the required quality.

The following pictures show some of the activities captured at the test site.

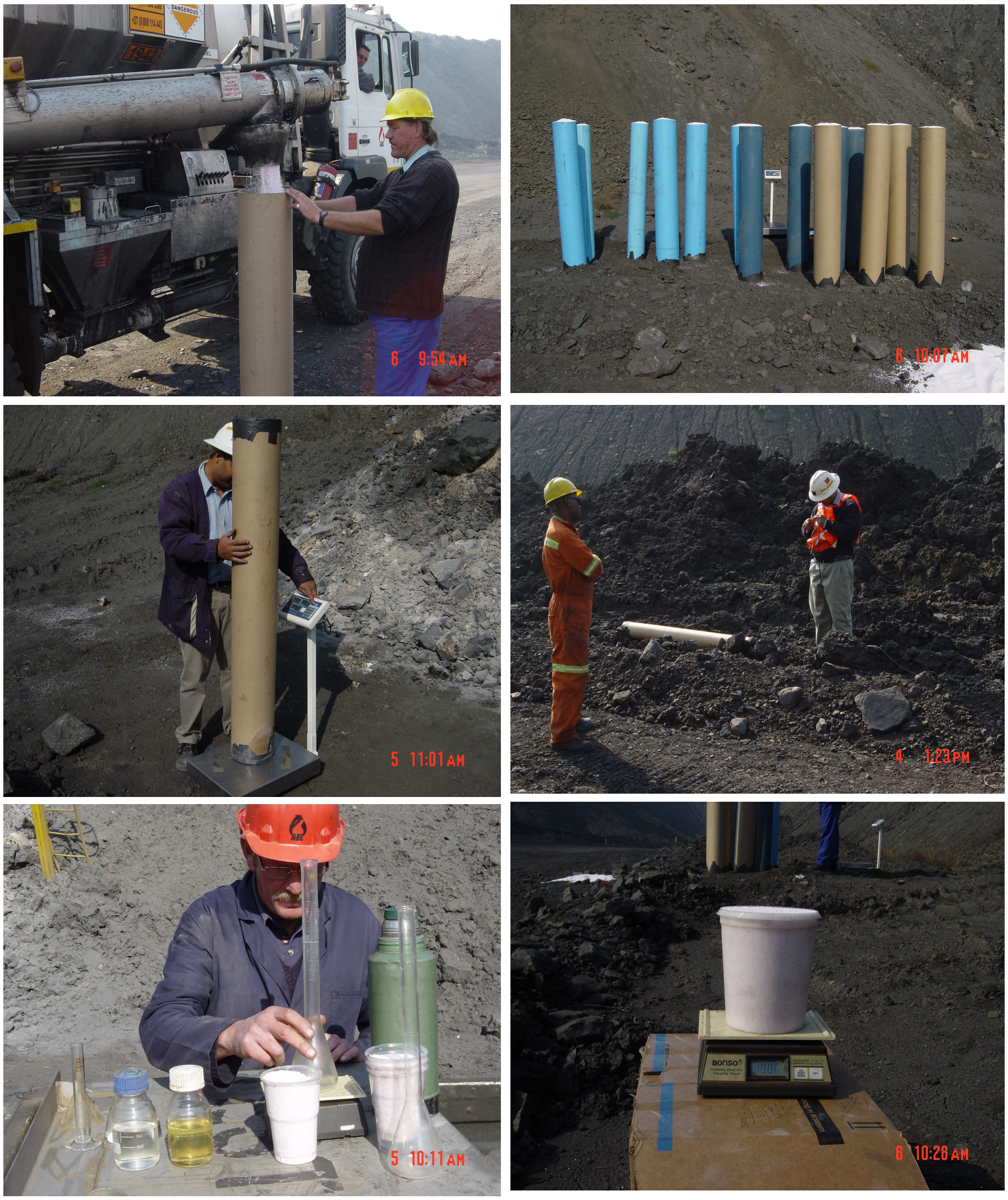


Figure 22: Pictures from the New Vaal test site

5.2 Results

Tables 18, 19 and 20 show the results in 4mm cardboard, Class 4 and Class 9 PVC respectively. The corresponding unconfined VoD versus diameter plots are shown in Figures 23, 24 and 25. (The graphs include the data from the first series of tests. A VoD versus inverse diameter plot is included in appendix 2)

Table 18: 4mm Cardboard

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
4mm Cardboard	151.5	0.78	3.33	0.38	Mon_01
4mm Cardboard	151.5	0.78	3.35	0.84	Mon_02
4mm Cardboard	151.5	0.77	3.45	0.90	Mon_03
4mm Cardboard	151.5	0.80	3.43	0.90	Mon_04
4mm Cardboard	202.0	0.80	3.88	0.68	Tue_01
4mm Cardboard	202.0	0.78	3.60	0.80	Tue_02
4mm Cardboard	202.0	0.78	3.75	0.80	Tue_03
4mm Cardboard	202.0	0.77	3.68	0.84	Tue_04
4mm Cardboard	253.0	0.79	4.18	0.82	Wed_11
4mm Cardboard	253.0	0.79	4.14	0.84	Wed_12
4mm Cardboard	253.0	0.79	2 x pipes not fired due to noise restrictions		

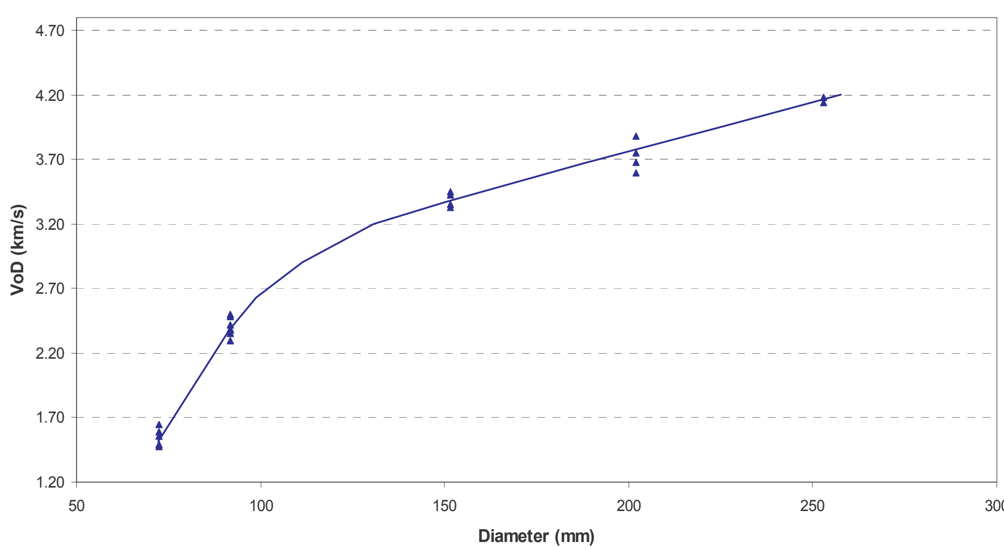


Figure 23: VoD vs. Diameter plot – 4mm Cardboard

Table 19: 4 Bar PVC

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
4 Bar – PVC	153.0	0.78	-	-	Mon_05
4 Bar – PVC	153.0	0.79	3.78	0.76	Mon_06
4 Bar – PVC	153.0	0.78	3.79	0.30	Tue_05.
4 Bar – PVC	153.0	0.79	3.92	0.70	Tue_06
4 Bar – PVC	190.6	0.78	3.76	0.75	Tue_11
4 Bar – PVC	190.6	0.77	3.74	0.82	Tue_12
4 Bar – PVC	190.6	0.78	3.70	0.70	Tue_13
4 Bar – PVC	190.6	0.78	3.88	0.90	Tue_14
4 Bar – PVC	240.0	0.79	3.79	0.76	Wed_07
4 Bar – PVC	240.0	0.79	3.90	0.45	Wed_08
4 Bar – PVC	240.0	0.78	3.93	0.68	Wed_09
4 Bar – PVC	240.0	0.78	3.93	0.84	Wed_10

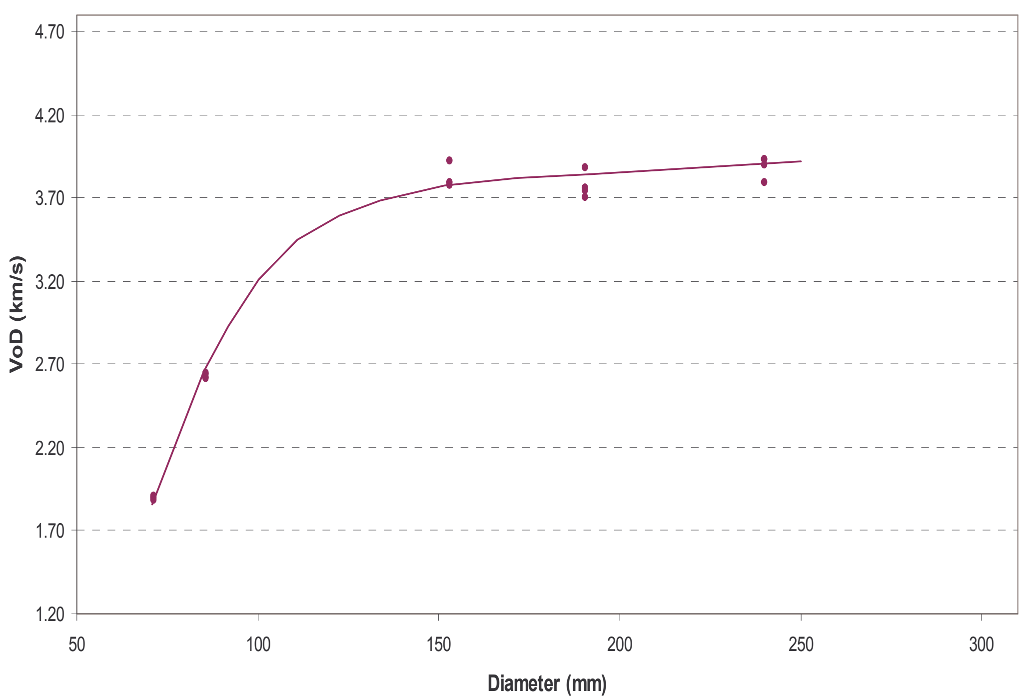


Figure 24: VoD vs. Diameter plot – 4Bar PVC

Table 20: 9 Bar PVC

Confinement Type	ID (mm)	Density (g/cc)	VoD (km/s)	Trace Length (m)	Microtrap File Name (.mcr)
9 Bar – PVC	148.0	0.79	3.68	0.84	Tue_07.mcr
9 Bar – PVC	148.0	0.78	3.66	0.76	Tue_08.mcr
9 Bar – PVC	148.0	0.78	3.74	0.60	Tue_09.mcr
9 Bar – PVC	148.0	0.79	3.68	0.72	Tue_10.mcr
9 Bar – PVC	186.0	0.78	3.65	0.76	Tue_15.mcr
9 Bar – PVC	186.0	0.77	3.91	0.54	Tue_16.mcr
9 Bar – PVC	186.0	0.78	3.73	0.82	Wed_01.mcr
9 Bar – PVC	186.0	0.78	3.75	0.84	Wed_02.mcr
9 Bar – PVC	233.0	0.78	3.95	0.82	Wed_03.mcr
9 Bar – PVC	233.0	0.78	4.03	0.72	Wed_04.mcr
9 Bar – PVC	233.0	0.79	3.74	0.76	Wed_05.mcr
9 Bar – PVC	233.0	0.78	3.95	0.82	Wed_06.mcr

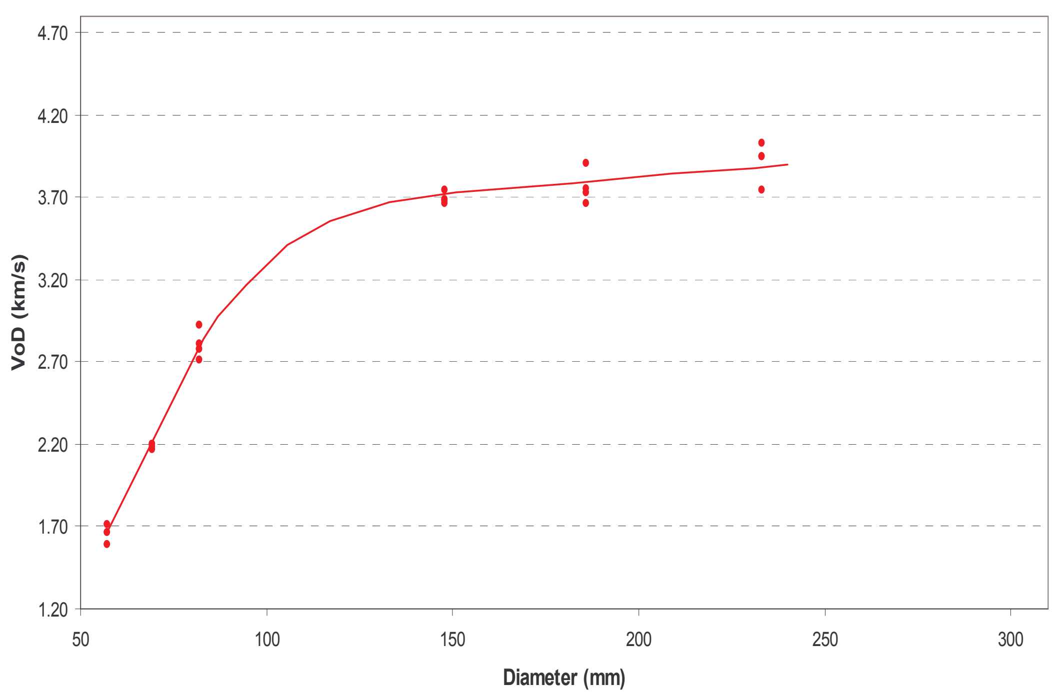


Figure 25: VoD vs. Diameter plot – 9 Bar PVC

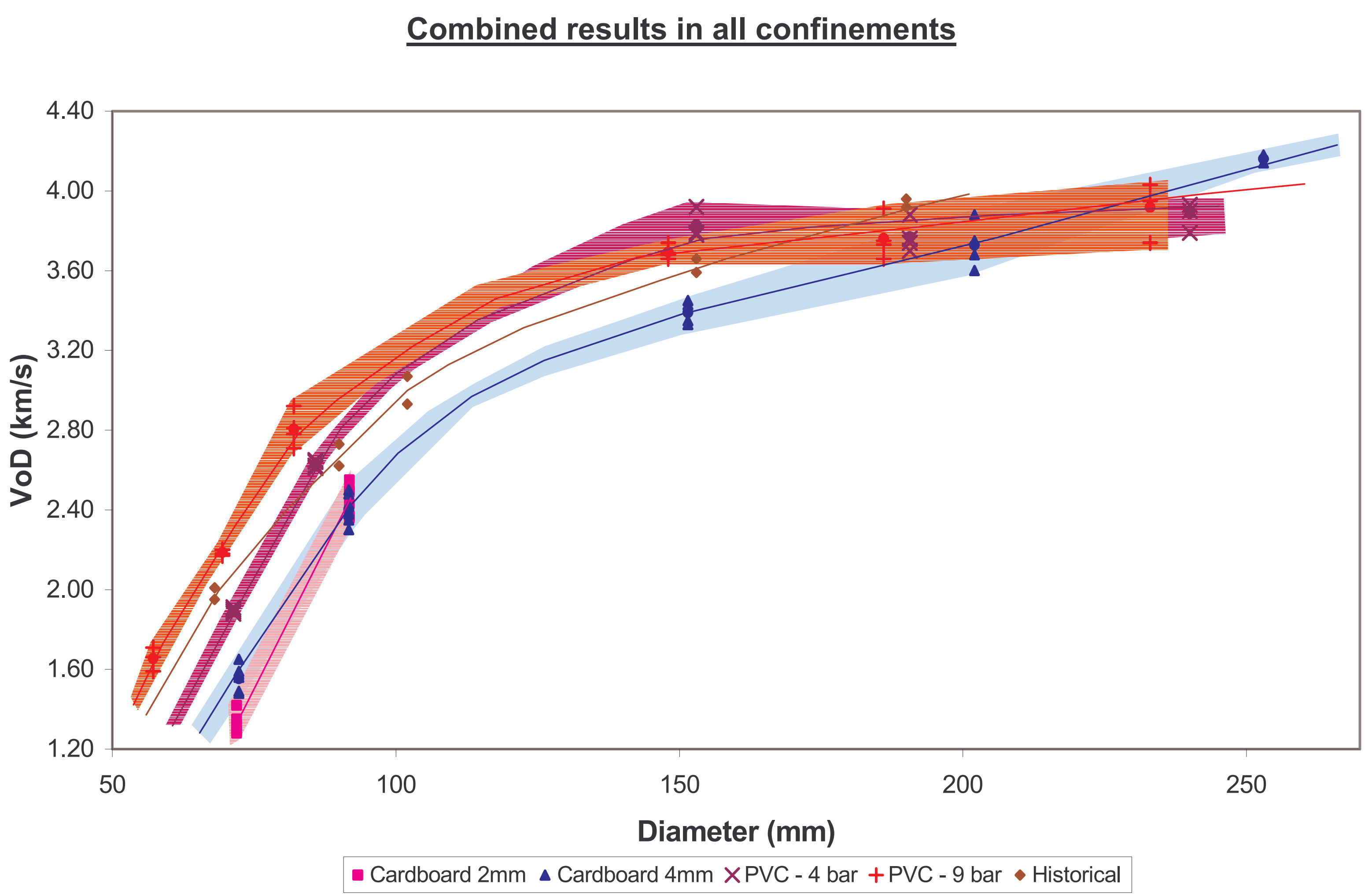


Figure 26: Combined results in all confinement

5.3 Analysis of Results

Figure 26 shows that the VoDs in the two classes of PVC pipes converge at a diameter somewhere between 100mm and 150mm, at around 3.6 km/s. They in turn converge with the VoDs from the 4mm cardboard at a diameter between around 200mm and 225mm, where the VoD is around 3.9 km/s. The VoD in the PVC pipes increases quite rapidly up to a diameter of around 150mm and then seems to level off or only increases gradually with the further increases in diameter. The rate of increase in VoD at smaller diameters is comparatively less in the 4mm cardboard, but it does not seem to level off as in the PVC pipes. The convergence in the PVC and cardboard pipes at around 200mm to 225mm also suggests that this is an inflexion point in the PVC confinement, representing the end of the “levelling off” period. Further tests are also required in larger diameters, to confirm that the VoD continues tending towards the ideal VoD as indicated by the dashed green line in the “inverse diameter vs. VoD” graph (Appendix 2).

6 CONCLUSIONS

One of the primary objectives of this project was to evaluate the confinement provided by cardboard and PVC pipes in unconfined VoD measurements and hence provide guidelines for the specification of pipes to use in future tests.

This exercise was not successful in using plastic sleeves as a control point in defining unconfined conditions in comparison with PVC and cardboard pipes due to differences in the loading density. The measurements also suggest that the confinement in thin walled cardboard pipes is probably as close to unconfined as practically possible and necessary.

The effect of the different types of light confinement media on VoD was pronounced at diameters close to the critical diameter. The PVC pipes provided stronger confinement and had lower critical diameters than the cardboard pipes. The confinement also increased in both the cardboard and PVC pipes with increase in wall thickness. There are several convergence points in the

VoD with increasing diameter in the different types of confinement. It worthwhile stressing that the confinement provided by the PVC pipes, particularly the Class 9 PVC pipes only became negligible in diameters larger than 200mm.

Future unconfined VoD tests, including those for different types of explosives such as Emulsions and various Emulsion-ANFO blends, should take cognisance of the findings of these tests in ANFO. Further confinement evaluation tests would also be worthwhile to determine whether similar trends prevail and to enable comparisons. However, if such an evaluation is not conducted before testing resumes, the conservative approach is to apply the relationships between the type of pipe used and diameters at which their effect on the performance of ANFO became negligible.

7 REFERENCES

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3. Sheahan, R.M. and Minchinton, A., 1988, “Non-Ideal explosive performance prediction using the CPEX model”, Explosives in Mining Workshop, EXPLO 88.
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APPENDIX 1

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Sedat Esen*
LOCATION:	*AEL Far range*
DATE:	*21.06.2004*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DAT	*06.06.2005*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.770	PVC CL9	50	2.4	1.497	1.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
2	ANFO	0.770	PVC CL9	50	2.4	1.495	1.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
3	ANFO	0.770	PVC CL9	50	2.4	1.499	1.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
4	ANFO	0.770	PVC CL9	50	2.4	1.497	1.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
5	ANFO	0.770	PVC CL4	50	2.1	1.501	1.82	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
6	ANFO	0.770	PVC CL4	50	2.1	1.500	1.82	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
7	ANFO	0.770	PVC CL4	50	2.1	1.500	1.82	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
8	ANFO	0.770	PVC CL4	50	2.1	1.501	1.82	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
9	ANFO	0.770	Cardboard	51.7	2.2	1.501	1.96	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
10	ANFO	0.770	Cardboard	51.7	2.2	1.497	1.86	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
11	ANFO	0.770	PVC CL9	63.4	3.1	1.500	2.91	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Monday_01.mcr
12	ANFO	0.770	PVC CL9	63.4	3.1	1.497	3.01	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Monday_02.mcr
13	ANFO	0.770	PVC CL9	63.4	3.1	1.497	2.91	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Monday_03.mcr
14															

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Sedat Esen*
LOCATION:	*AEL Far range*
DATE:	*21.06.2004*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DAT	*06.06.2005*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.770	PVC CL9	63.4	3.1	1.497	2.98	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday01.mcr
2	ANFO	0.770	Cardboard	65.7	1.9	1.500	3.49	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
3	ANFO	0.770	Cardboard	75.7	1.9	1.500	4.73	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday02.mcr
4	ANFO	0.770	Cardboard	96	2.1	1.500	7.88	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday03.mcr
5	ANFO	0.770	Cardboard	65.7	1.9	1.500	3.53	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday04.mcr/no detonation
6	ANFO	0.770	Cardboard	75.7	1.9	1.500	4.66	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday05.mcr
7	ANFO	0.770	Cardboard	96	2.1	1.500	7.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday06.mcr
8	ANFO	0.770	Cardboard	65.7	1.9	1.500	3.50	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
9	ANFO	0.770	Cardboard	75.7	1.9	1.500	4.61	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday07.mcr
10	ANFO	0.770	Cardboard	96	2.1	1.500	7.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday08.mcr
11	ANFO	0.770	Cardboard	65.7	1.9	1.500	3.50	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
12	ANFO	0.770	Cardboard	75.7	1.9	1.500	4.71	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday09.mcr
13	ANFO	0.770	Cardboard	96	2.1	1.500	7.55	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday10.mcr
14	ANFO	0.770	Cardboard	65.7	1.9	1.500	3.50	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
15	ANFO	0.770	Cardboard	75.7	1.9	1.500	4.72	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday11.mcr
16	ANFO	0.770	Cardboard	96	2.1	1.500	7.55	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	tuesday12.mcr

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Sedat Esen*
LOCATION:	*AEL Far range*
DATE:	*23.06.2004*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DATE:	*06.06.2005*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.770	Pl. Sleeve	95.5	0.0	1.335	8.30	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday01.mcr
2	ANFO	0.770	Pl. Sleeve	95.5	0.0	1.380	8.10	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday02.mcr
3	ANFO	0.770	Pl. Sleeve	95.5	0.0	1.380	7.90	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday03.mcr
4	ANFO	0.770	Pl. Sleeve	95.5	0.0	1.370	8.10	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday04.mcr
5	ANFO	0.770	Cardboard	70.3	4.0	1.500	3.56	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation/wednesday05.mcr
6	ANFO	0.770	Cardboard	70.3	4.0	1.500	3.52	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation/wednesday06.mcr
7	ANFO	0.770	Cardboard	70.3	4.0	1.500	3.54	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation/wednesday07.mcr
8	ANFO	0.770	Cardboard	70.3	4.0	1.500	3.57	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
9	ANFO	0.770	Cardboard	80.3	4.0	1.500	4.77	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday08.mcr
10	ANFO	0.770	Cardboard	80.3	4.0	1.500	4.77	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday9.mcr
11	ANFO	0.770	Cardboard	80.3	4.0	1.500	4.75	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday10.mcr
12	ANFO	0.770	Cardboard	80.3	4.0	1.500	4.77	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday11.mcr
13	ANFO	0.770	Cardboard	99.7	4.0	1.500	7.62	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday12.mcr
14	ANFO	0.770	Cardboard	99.7	4.0	1.500	7.52	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday13.mcr/jk01.mcr
15	ANFO	0.770	Cardboard	99.7	4.0	1.500	7.52	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday14.mcr
16	ANFO	0.770	Cardboard	99.7	4.0	1.500	7.52	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	wednesday15.mcr

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Sedat Esen*
LOCATION:	*AEL Far range*
DATE:	*24.06.2004*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DAT	*06.06.2005*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.770	PVC CL4	63.3	1.7	1.504	3.28	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation/thursday01.mcr
2	ANFO	0.770	PVC CL4	63.3	1.7	1.502	3.26	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
3	ANFO	0.770	PVC CL4	63.3	1.7	1.502	3.26	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation
4	ANFO	0.770	PVC CL4	63.3	1.7	1.501	3.26	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	no detonation/thursday02.mcr
5	ANFO	0.770	PVC CL4	74.9	1.8	1.500	4.67	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday03.mcr
6	ANFO	0.770	PVC CL4	74.9	1.8	1.501	4.71	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday04.mcr
7	ANFO	0.770	PVC CL4	74.9	1.8	1.500	4.67	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday05.mcr
8	ANFO	0.770	PVC CL4	74.9	1.8	1.497	4.65	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday06.mcr
9	ANFO	0.770	PVC CL9	75.2	2.9	1.500	4.38	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday07.mcr
10	ANFO	0.770	PVC CL9	75.2	2.9	1.498	4.36	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday08.mcr
11	ANFO	0.770	PVC CL9	75.2	2.9	1.497	4.33	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday09.mcr
12	ANFO	0.770	PVC CL9	75.2	2.9	1.496	4.33	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday10.mcr
13	ANFO	0.770	PVC CL4	90	2.1	1.506	6.63	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday11.mcr/jkb01.mcr
14	ANFO	0.770	PVC CL4	90	2.1	1.510	6.68	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday12.mcr/jkb02.mcr
15	ANFO	0.770	PVC CL4	90	2.1	1.495	6.58	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday13.mcr
16	ANFO	0.770	PVC CL4	90	2.1	1.518	6.68	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	thursday14.mcr

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Sedat Esen*
LOCATION:	*AEL Far range*
DATE:	*25.06.2004*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DATE:	*06.06.2005*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.770	PVC CL9	90.2	4.1	1.490	6.200	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_01.mcr
2	ANFO	0.770	PVC CL9	90.2	4.1	1.510	6.300	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_02.mcr
3	ANFO	0.770	PVC CL9	90.2	4.1	1.495	6.100	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_03.mcr
4	ANFO	0.770	PVC CL9	90.2	4.1	1.515	6.200	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_04.mcr
5	ANFO	0.770	PVC CL4	79.8	4.0	1.505	4.752	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_05.mcr
6	ANFO	0.770	PVC CL4	75.3	1.9	1.505	4.714	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_06.mcr
7	ANFO	0.770	Cardboard	99.7	4.0	1.503	7.715	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	Friday_07.mcr/jkc01.mcr
8	ANFO	0.770	PVC CL4	96.2	2.1	1.503	7.734	Proberod	322.5	2.0	Poured	Pentolite150, 38 mm	Electrical	Internal	_/jkc02.mcr

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Thabo Makeki*
LOCATION:	*New Vaal Colliery*
DATE:	*04.07.2005*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DATE:	*13.06.2006*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.786	Cardboard	159.5	4.0	1.505	21.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Mon_01.mcr
2	ANFO	0.786	Cardboard	159.5	4.0	1.505	21.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Mon_02.mcr
3	ANFO	0.786	Cardboard	159.5	4.0	1.505	21.00	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Mon_03.mcr
4	ANFO	0.786	Cardboard	159.5	4.0	1.505	21.60	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Mon_04.mcr
5	ANFO	0.786	PVC CL4	160.0	3.5	1.515	21.70	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Mon_05.mcr
6	ANFO	0.786	PVC CL4	160.0	3.5	1.525	22.20	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Mon_06.mcr
7															

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

NAME:	*Tiju Thomas & Thabo Makeki*
LOCATION:	*New Vaal Colliery*
DATE:	*05.07.2005*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DATE:	*13.06.2006*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.786	Cardboard	210	4.0	1.508	38.70	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_01.mcr
2	ANFO	0.786	Cardboard	210	4.0	1.509	37.60	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_02.mcr
3	ANFO	0.786	Cardboard	210	4.0	1.509	37.60	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_03.mcr
4	ANFO	0.786	Cardboard	210	4.0	1.513	37.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_04.mcr
5	ANFO	0.786	PVC CL4	160	3.5	1.513	21.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_05.mcr
6	ANFO	0.786	PVC CL4	160	3.5	1.511	22.00	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_06.mcr
7	ANFO	0.786	PVC CL9	160	6.0	1.500	20.40	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_07.mcr
8	ANFO	0.786	PVC CL9	160	6.0	1.505	20.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_08.mcr
9	ANFO	0.786	PVC CL9	160	6.0	1.505	20.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_09.mcr
10	ANFO	0.786	PVC CL9	160	6.0	1.508	20.40	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_10.mcr
11	ANFO	0.786	PVC CL4	200	4.7	1.492	33.30	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_11.mcr
12	ANFO	0.786	PVC CL4	200	4.7	1.495	33.00	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_12.mcr
13	ANFO	0.786	PVC CL4	200	4.7	1.494	33.30	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_13.mcr
14	ANFO	0.786	PVC CL4	200	4.7	1.500	33.20	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_14.mcr
15	ANFO	0.786	PVC CL9	200	7.0	1.491	31.40	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_15.mcr
16	ANFO	0.786	PVC CL9	200	7.0	1.500	31.50	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_16.mcr

Pre and post test check list	
Visual check of cables	✓
Resistance checks at all connection points	✓
Check continuity of wirebreak cable	✓
Make area safe	✓
Check monitor functionality and activate	✓

UNCONFINED VOD DATA COLLECTION SHEET

HSBM - PROJECT

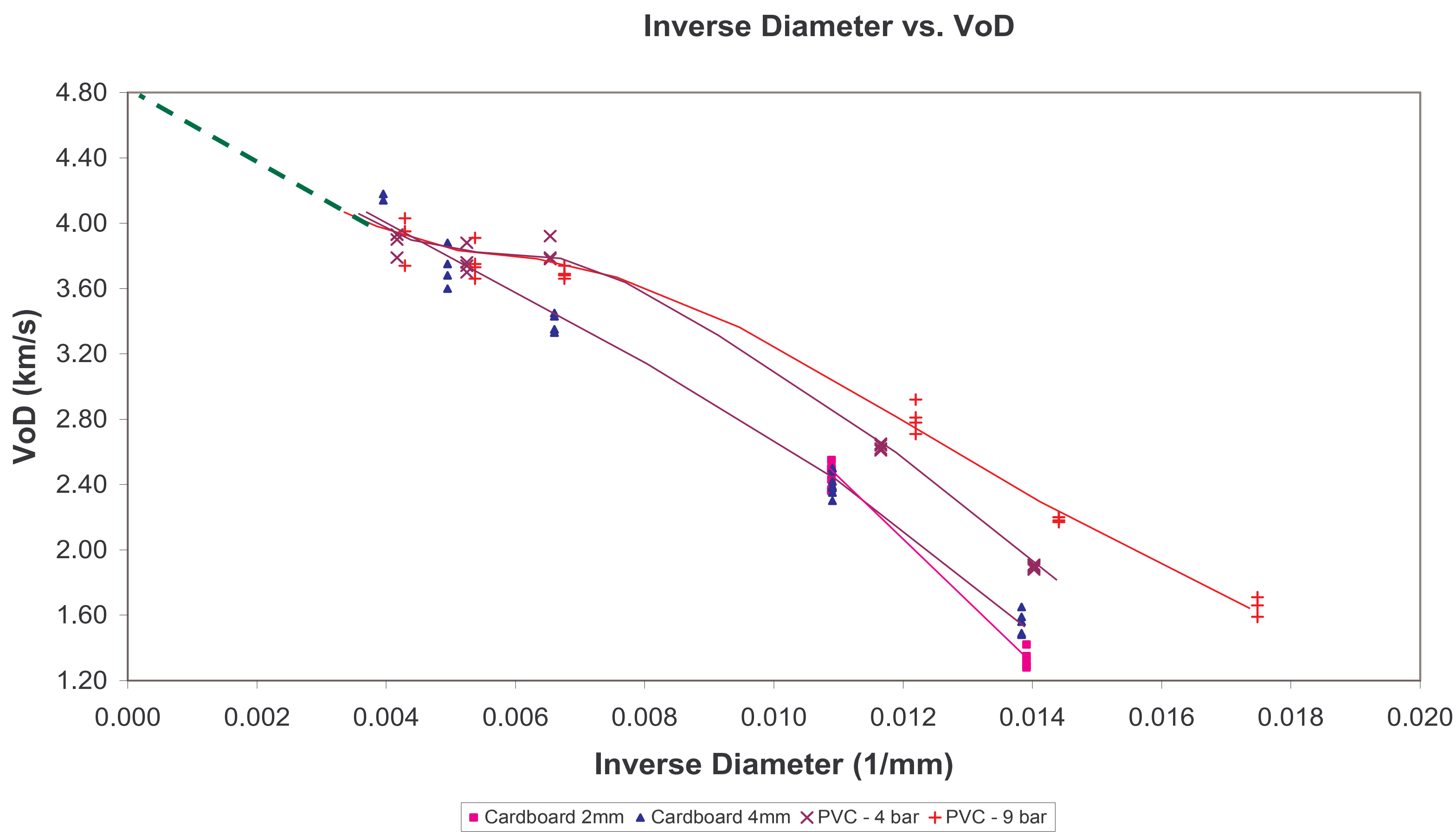
NAME:	*Tiju Thomas & Thabo Makeki*
LOCATION:	*New Vaal Colliery*
DATE:	*06.07.2005*
EQUIPMENT TYPE:	*Microtrap #6208*
CALIBRATION DUE DATE:	*13.06.2006*

TEST DATA

Test #	Explosive type	Cup density (g/cc)	Confinement type	OD (mm)	Thickness (mm)	Charge length (m)	Sample Weight (kg)	VOD probe type	Probe resistance (ohms/m)	Sampling rate (MHz)	Charging mode	Priming (Type/D/W)	Initiation (type)	Triggering Method	Notes Microtrap file name
1	ANFO	0.786	PVC CL9	200	7.0	1.495	31.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_01.mcr
2	ANFO	0.786	PVC CL9	200	7.0	1.495	31.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_02.mcr
3	ANFO	0.786	PVC CL9	250	8.5	1.480	49.50	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_03.mcr
4	ANFO	0.786	PVC CL9	250	8.5	1.490	49.70	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_04.mcr
5	ANFO	0.786	PVC CL9	250	8.5	1.482	49.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_05.mcr
6	ANFO	0.786	PVC CL9	250	8.5	1.490	49.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_06.mcr
7	ANFO	0.786	PVC CL4	250	5.0	1.490	53.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_07.mcr
8	ANFO	0.786	PVC CL4	250	5.0	1.490	53.20	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_08.mcr
9	ANFO	0.786	PVC CL4	250	5.0	1.460	51.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_09.mcr
10	ANFO	0.786	PVC CL4	250	5.0	1.492	52.90	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_10.mcr
11	ANFO	0.786	Cardboard	261	4.0	1.508	60.20	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_11.mcr
12	ANFO	0.786	Cardboard	261	4.0	1.510	60.10	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_12.mcr
13	ANFO	0.786	Cardboard	261	4.0	1.500	59.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_13.mcr
14	ANFO	0.786	Cardboard	261	4.0	1.498	59.80	Proberod	322.5	2.0	Poured	Pentolite400, 53 mm	Electrical	Internal	Tue_14.mcr
15															
16															

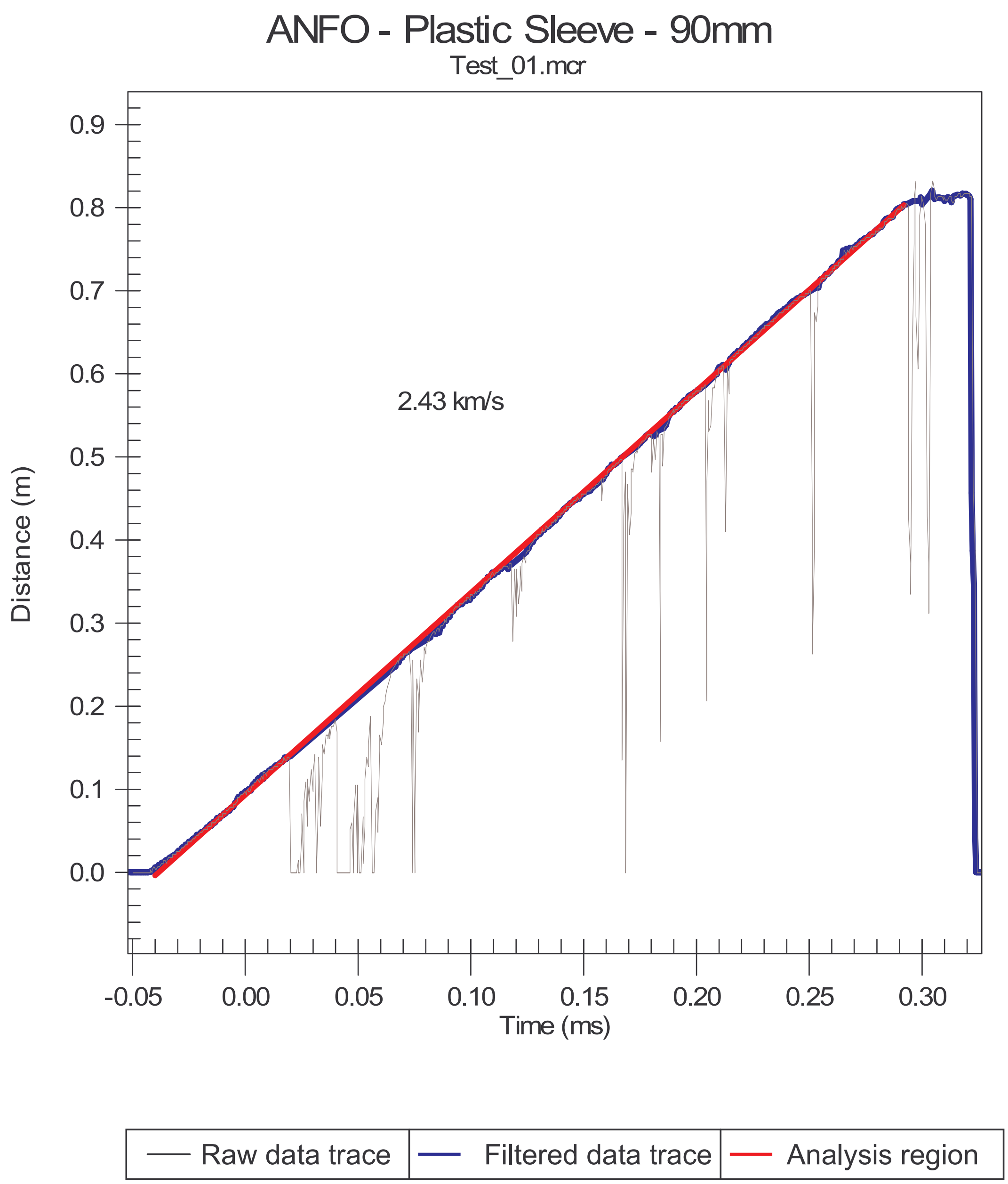
Pre and post test check list	
Visual check of cables	✓
Resistance checks at all connection points	✓
Check continuity of wirebreak cable	✓
Make area safe	✓
Check monitor functionality and activate	✓

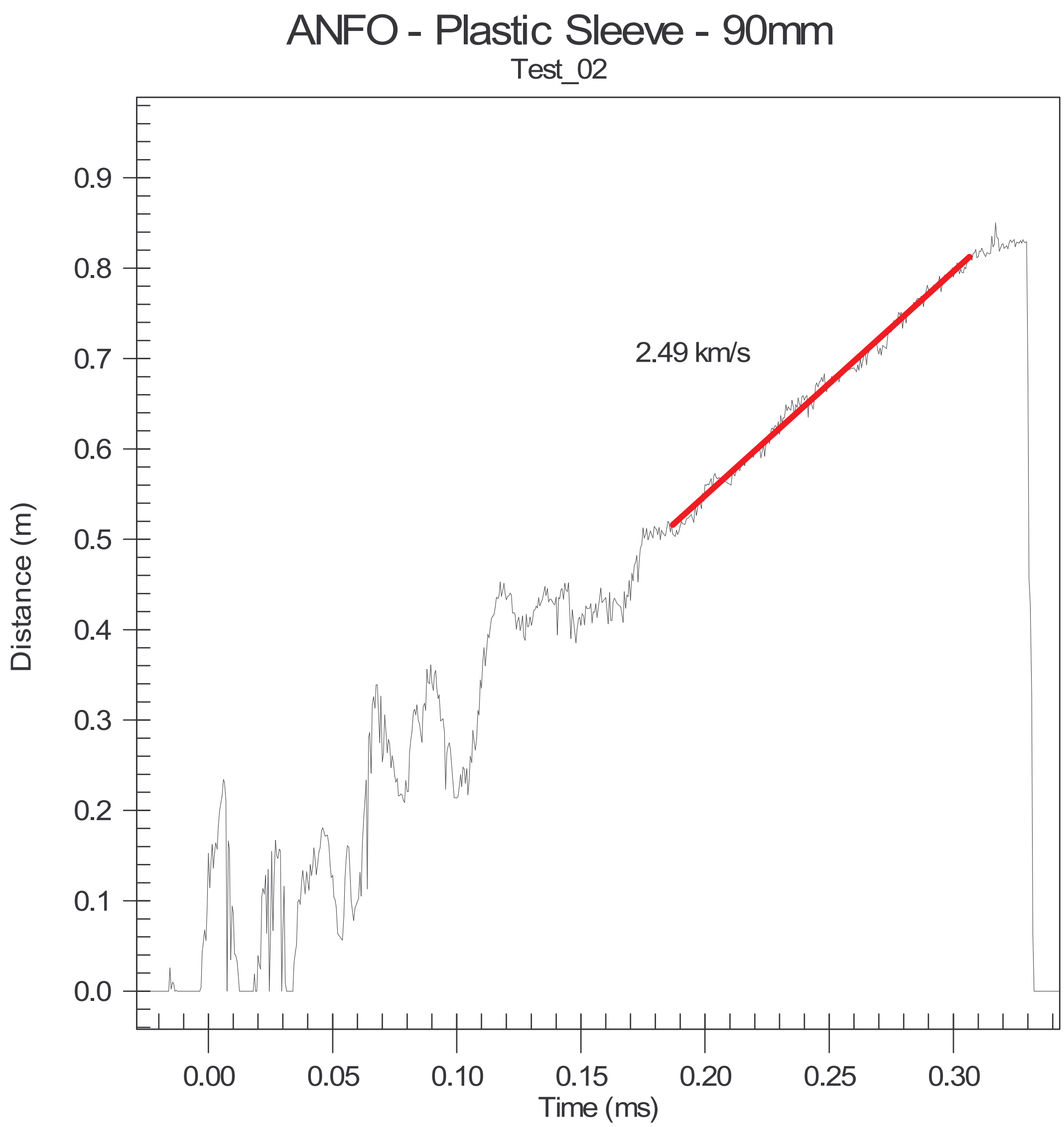
APPENDIX 2

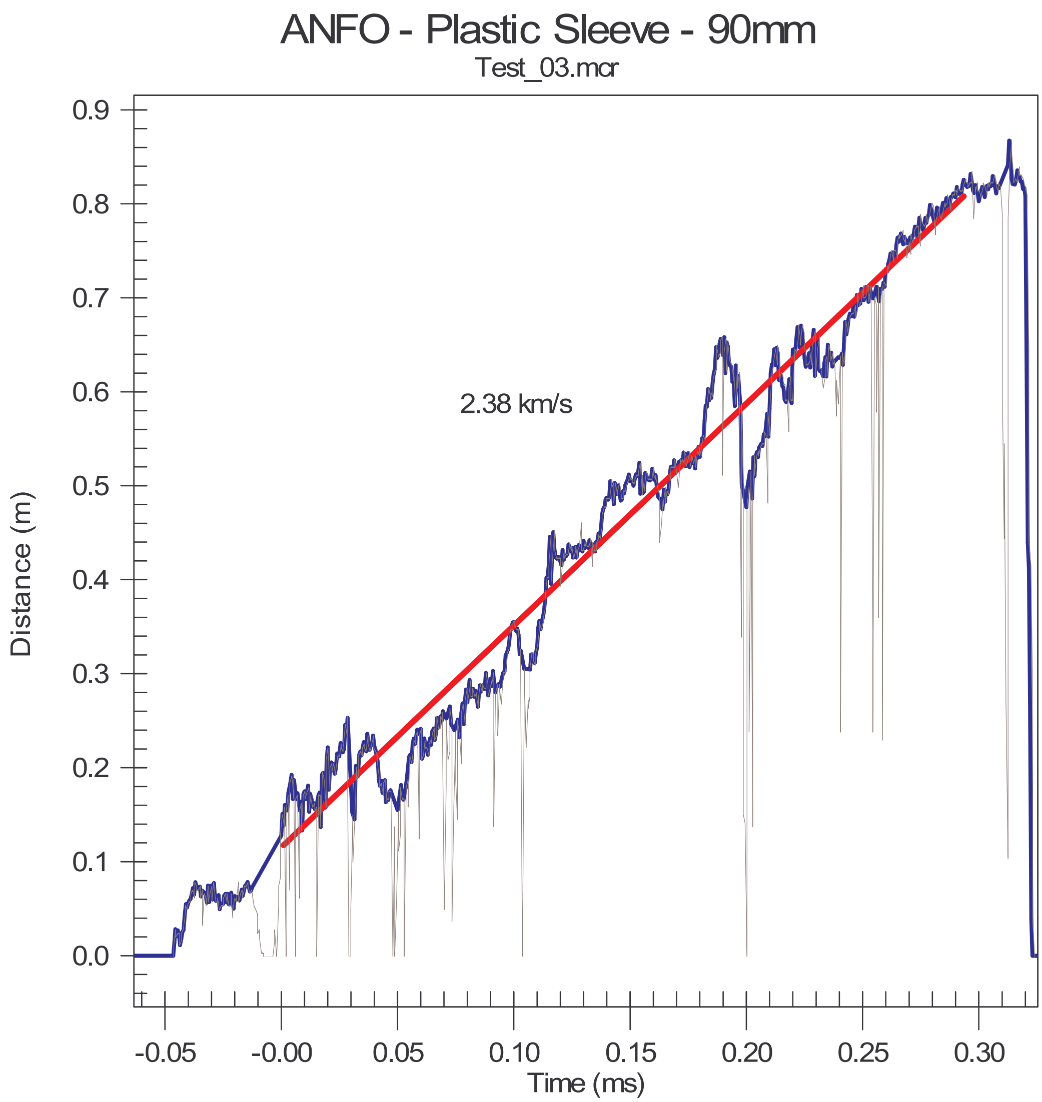


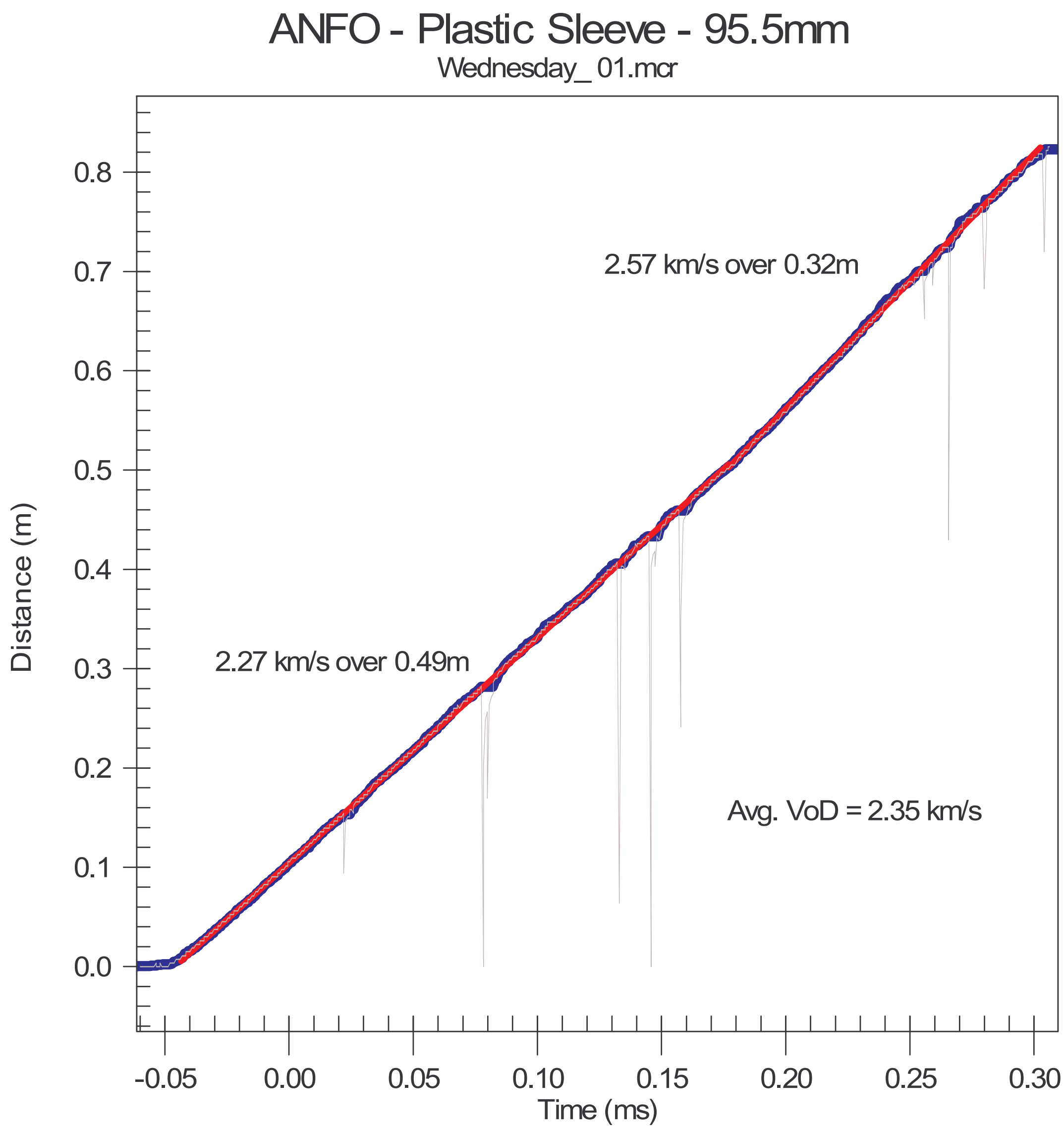
Inverse Diameter vs. VoD graph

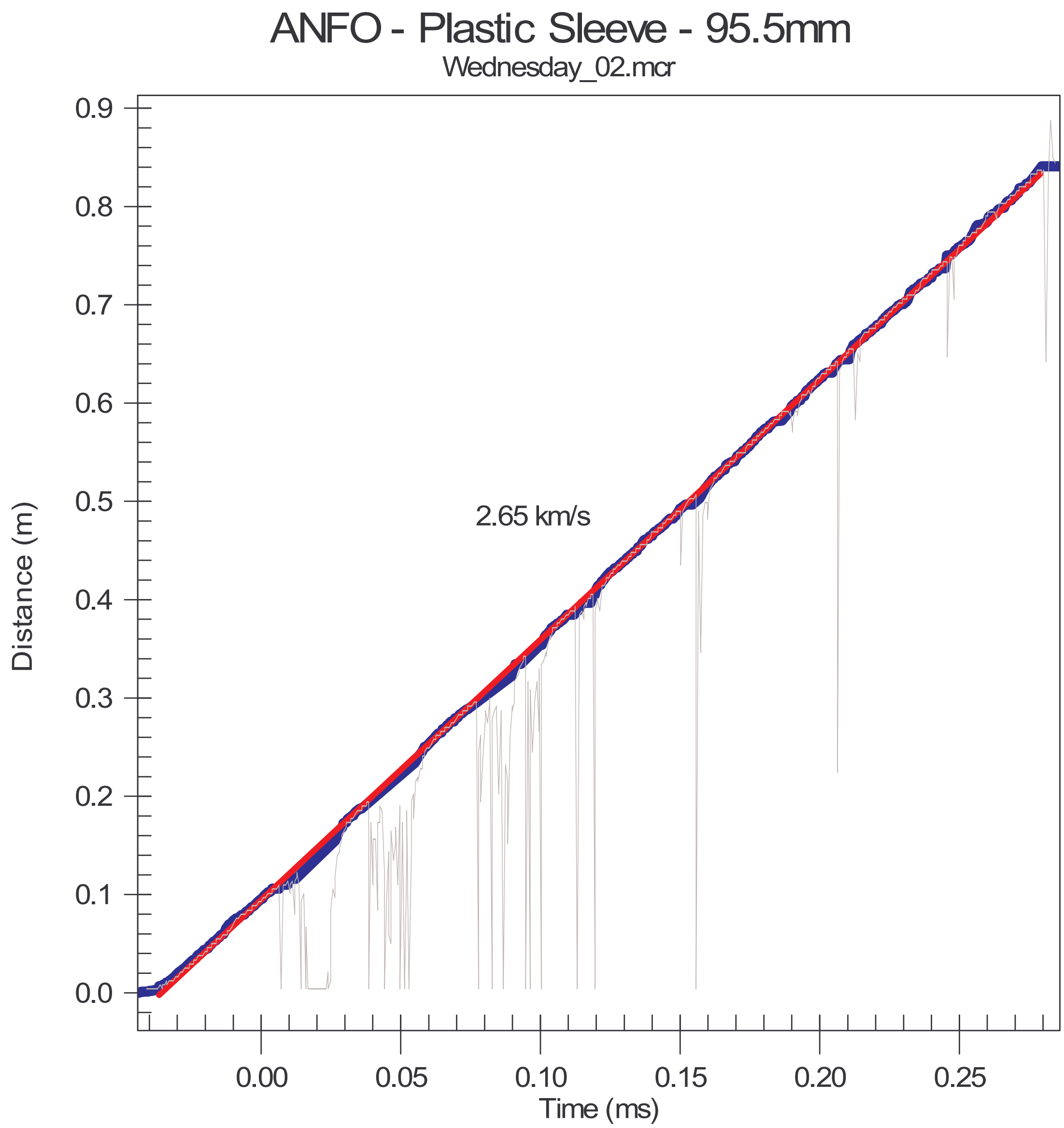
APPENDIX 3

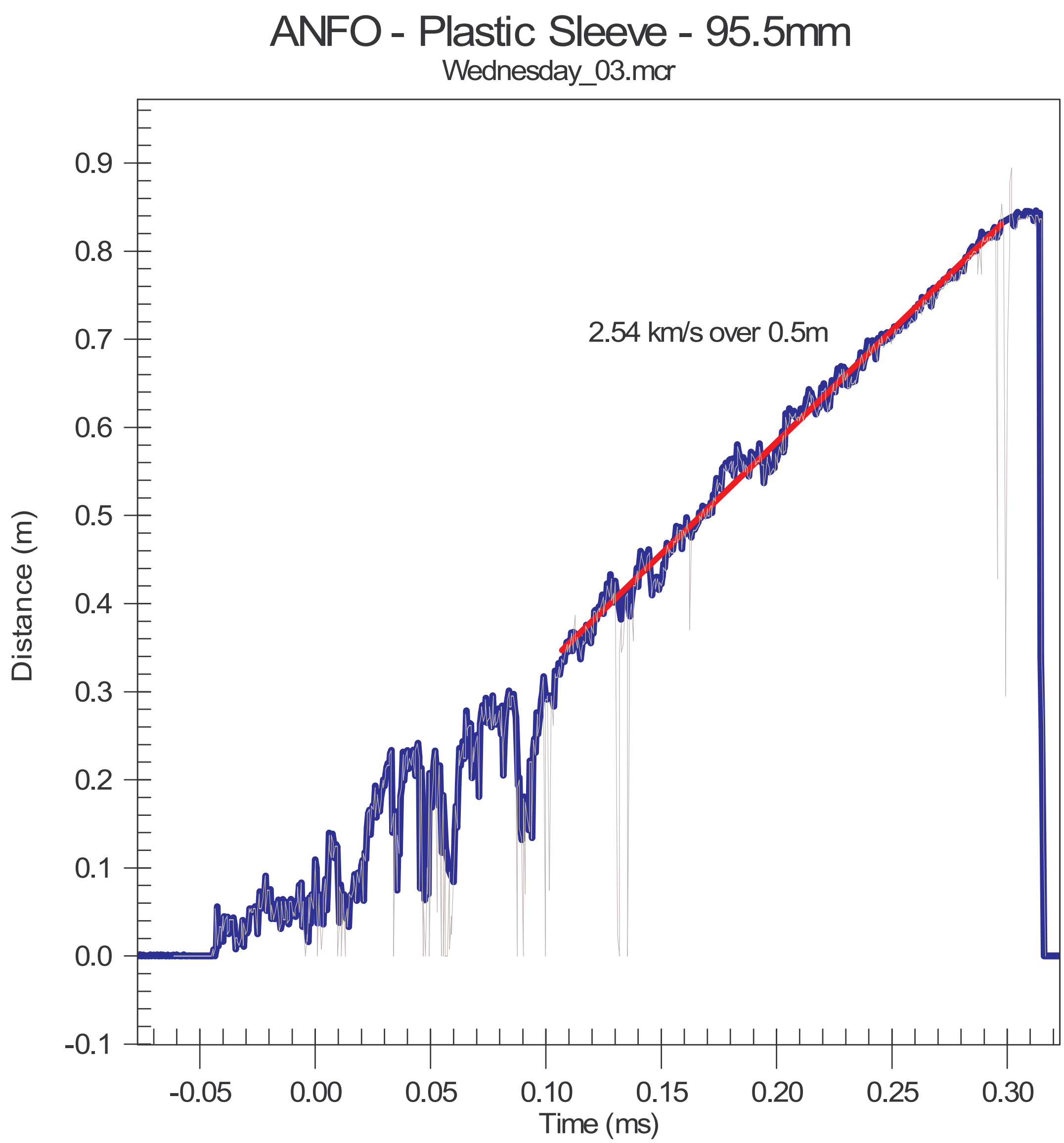

ANFO - Plastic Sleeve - 90mm
Test_01.mcr
2.43 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (ms)
Raw data trace
Filtered data trace
Analysis region

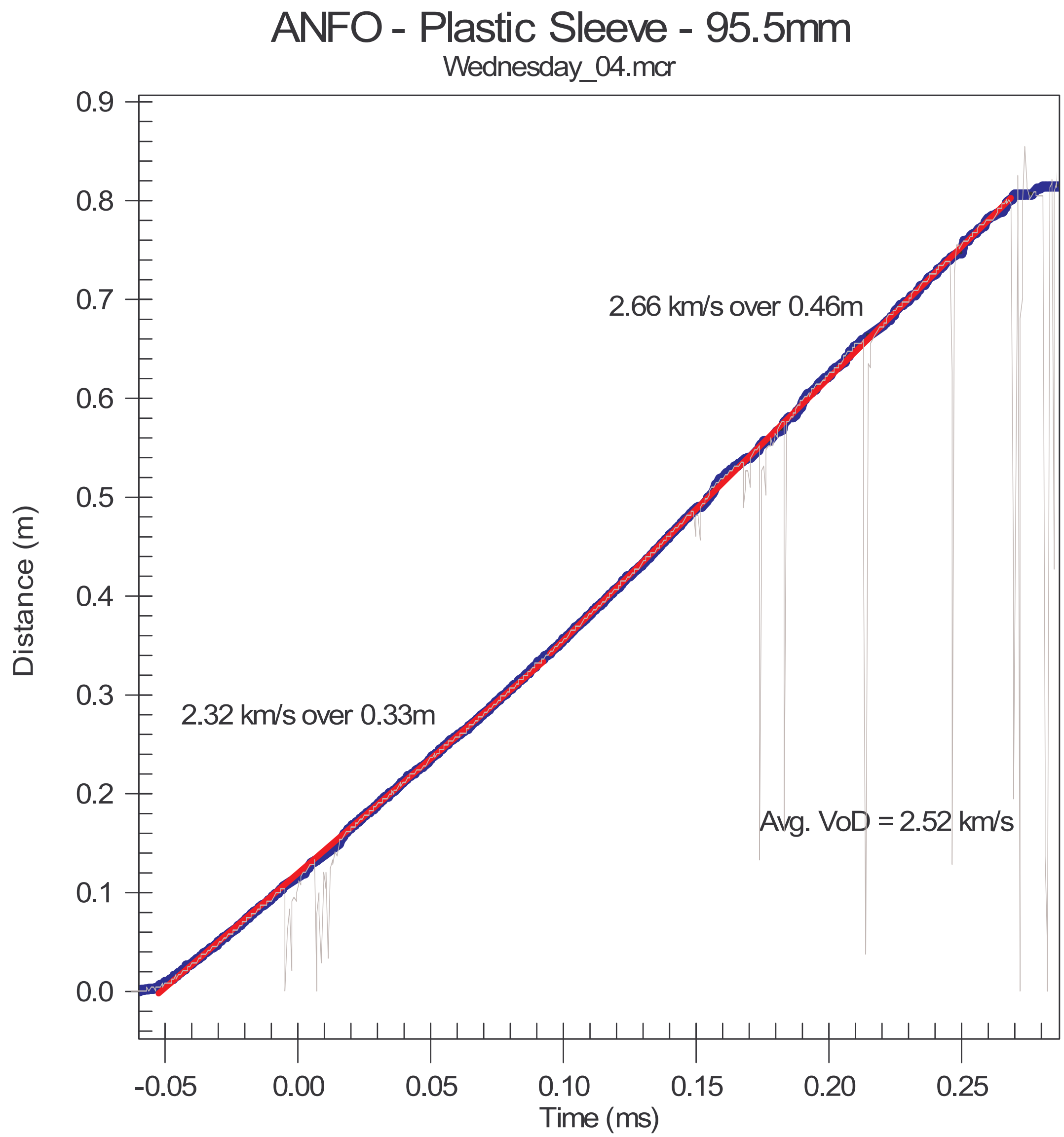

ANFO - Plastic Sleeve - 90mm
Test_02
2.49 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time (ms)
0.00
0.05
0.10
0.15
0.20
0.25
0.30

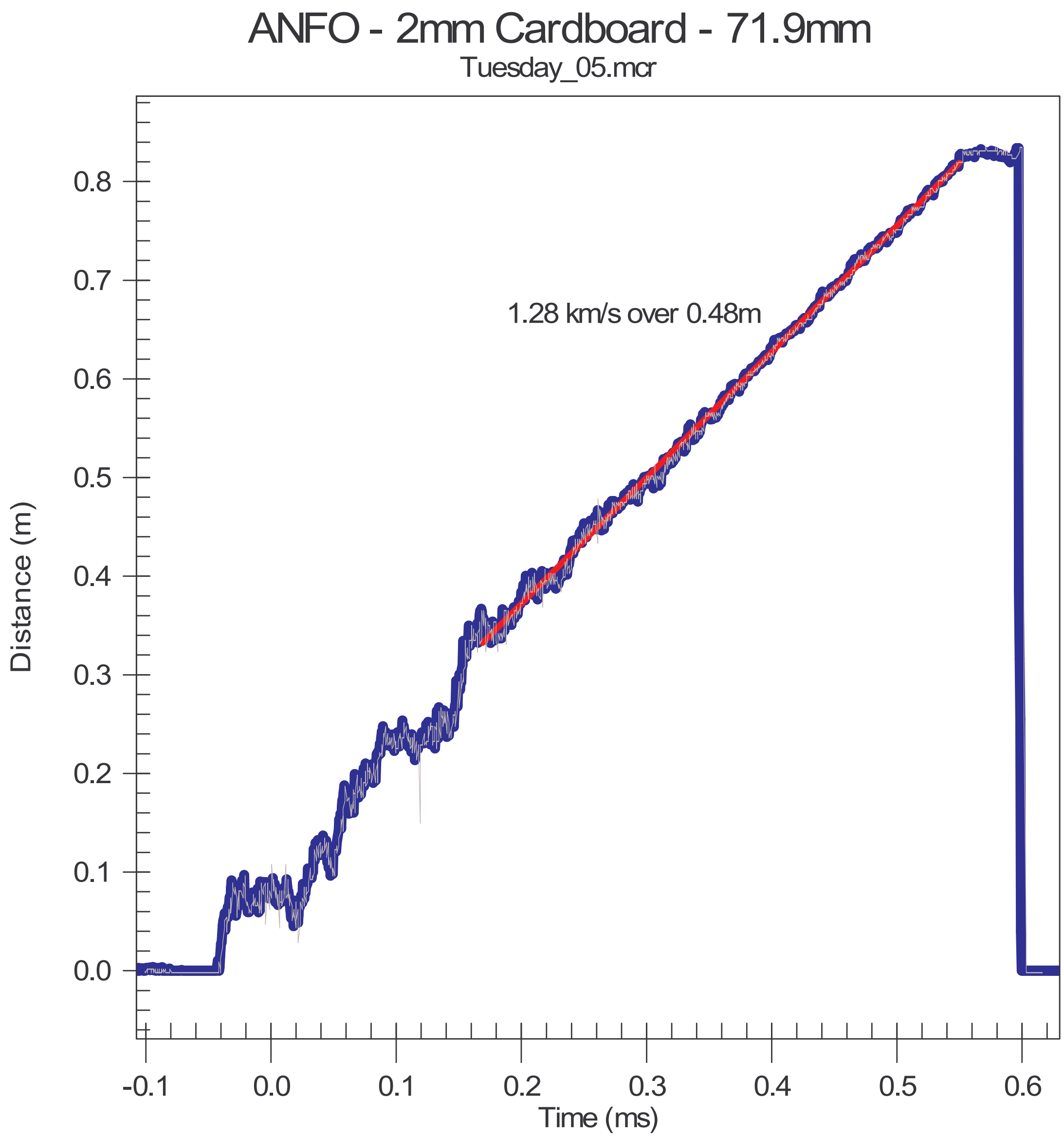

ANFO - Plastic Sleeve - 90mm
Test_03.mcr
2.38 km/s
Distance (m)
Time (ms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
-0.00
0.05
0.10
0.15
0.20
0.25
0.30


ANFO - Plastic Sleeve - 95.5mm
Wednesday_ 01.mcr
2.57 km/s over 0.32m
2.27 km/s over 0.49m
Avg. VoD = 2.35 km/s
Distance (m)
Time (ms)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

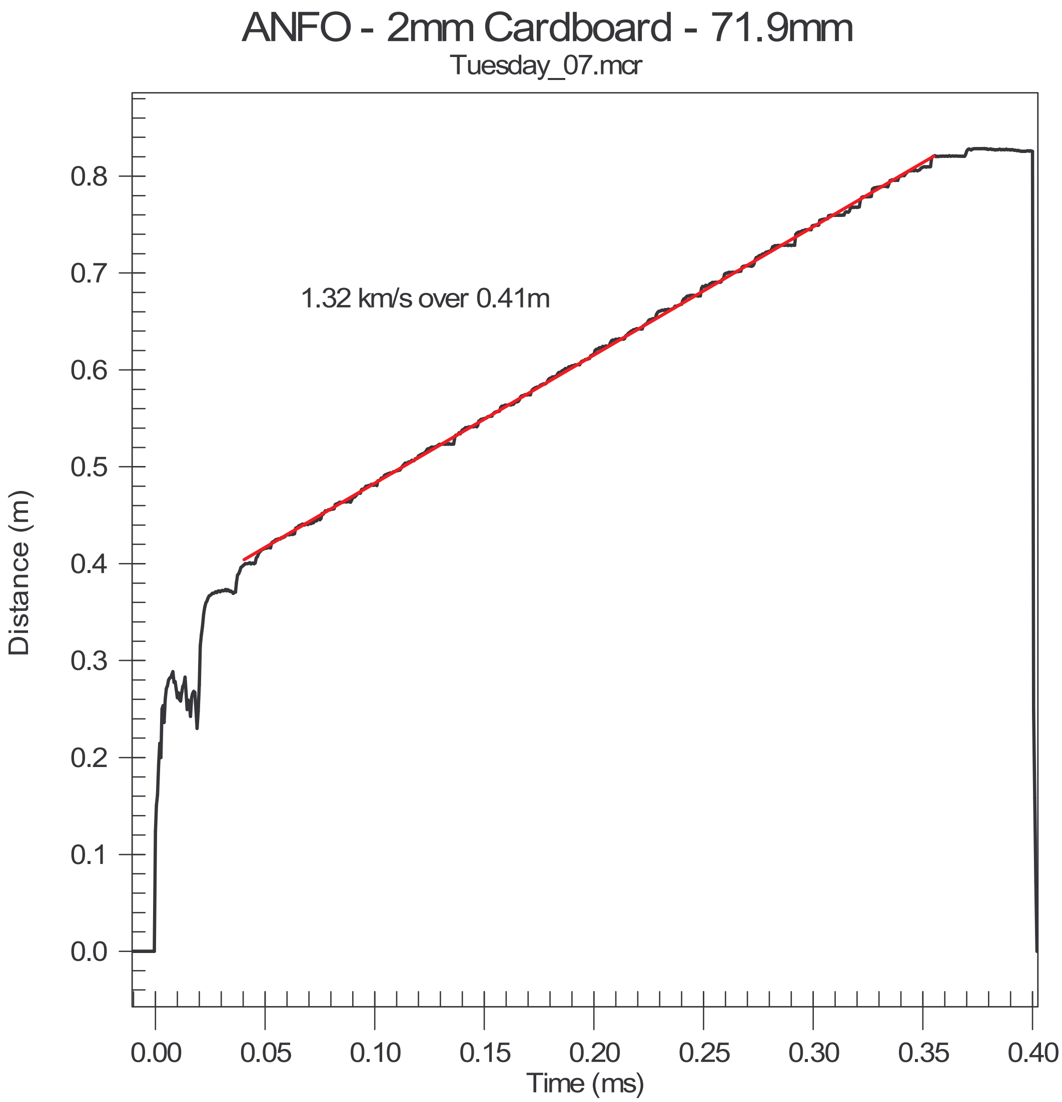

ANFO - Plastic Sleeve - 95.5mm
Wednesday_02.mcr
2.65 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time (ms)
0.00
0.05
0.10
0.15
0.20
0.25

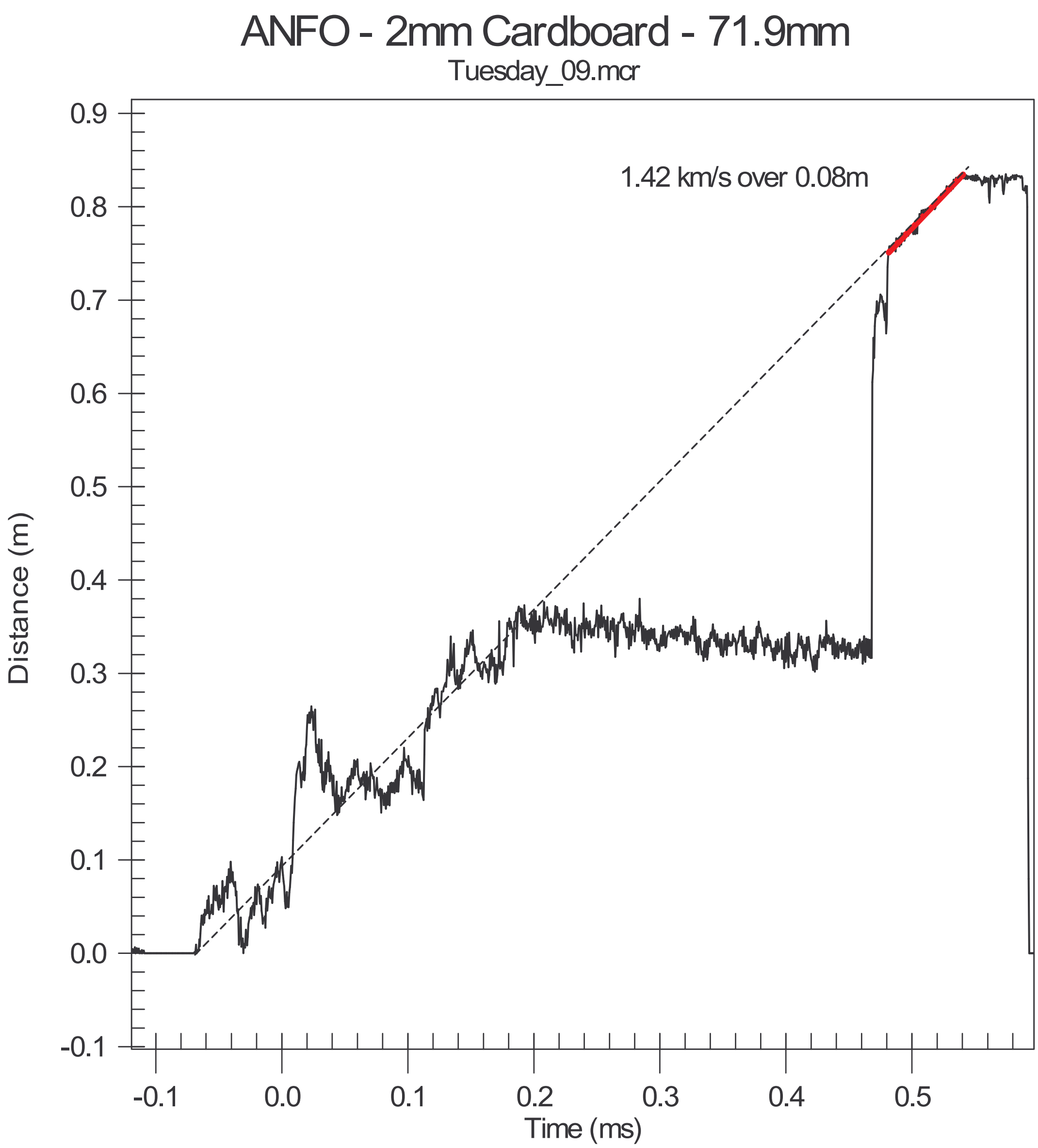

ANFO - Plastic Sleeve - 95.5mm
Wednesday_03.mcr
2.54 km/s over 0.5m
Distance (m)
Time (ms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

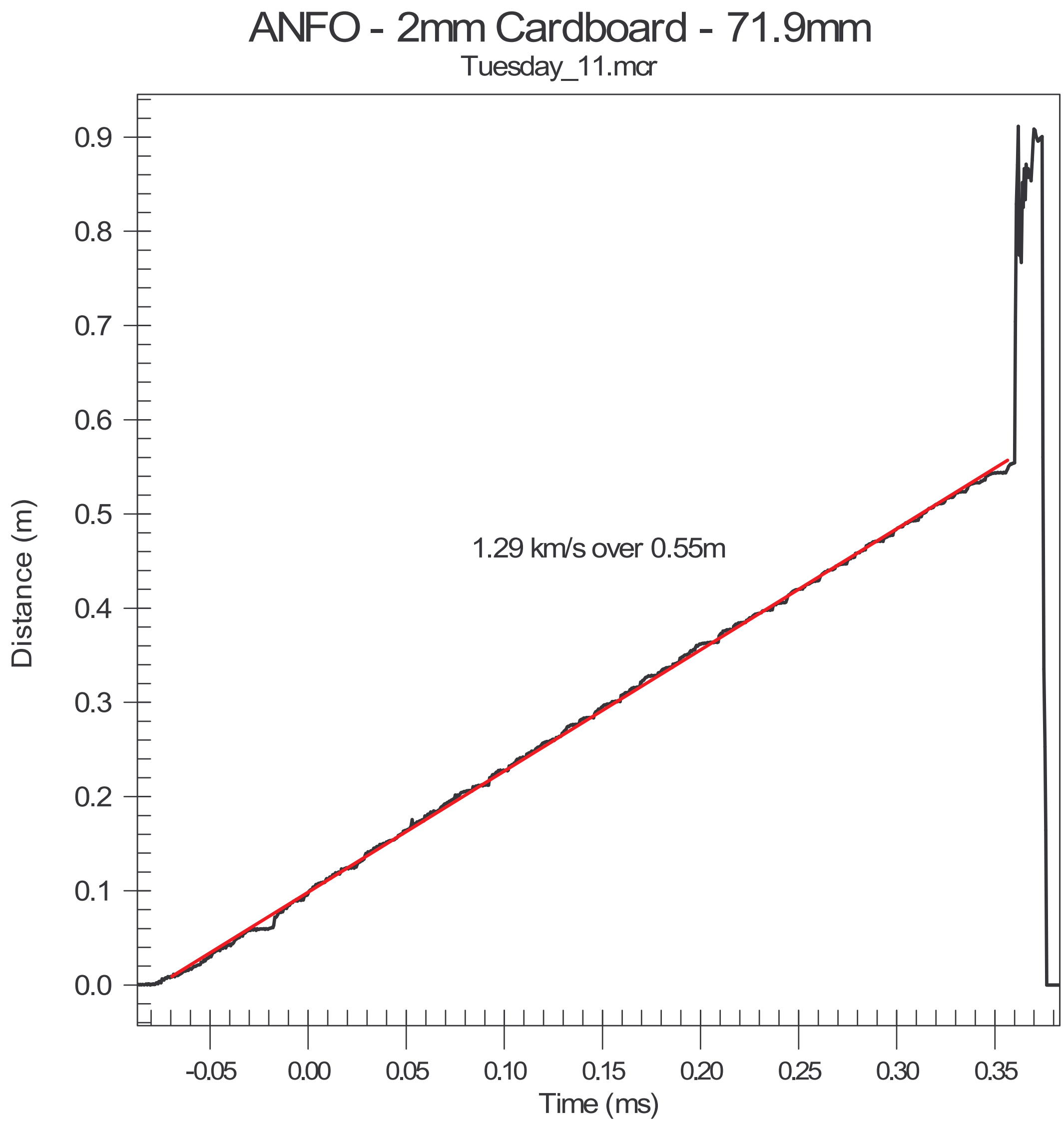

ANFO - Plastic Sleeve - 95.5mm
Wednesday_04.mcr
2.66 km/s over 0.46m
2.32 km/s over 0.33m
Avg. VoD = 2.52 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.05
0.00
0.05
0.10
0.15
0.20
0.25



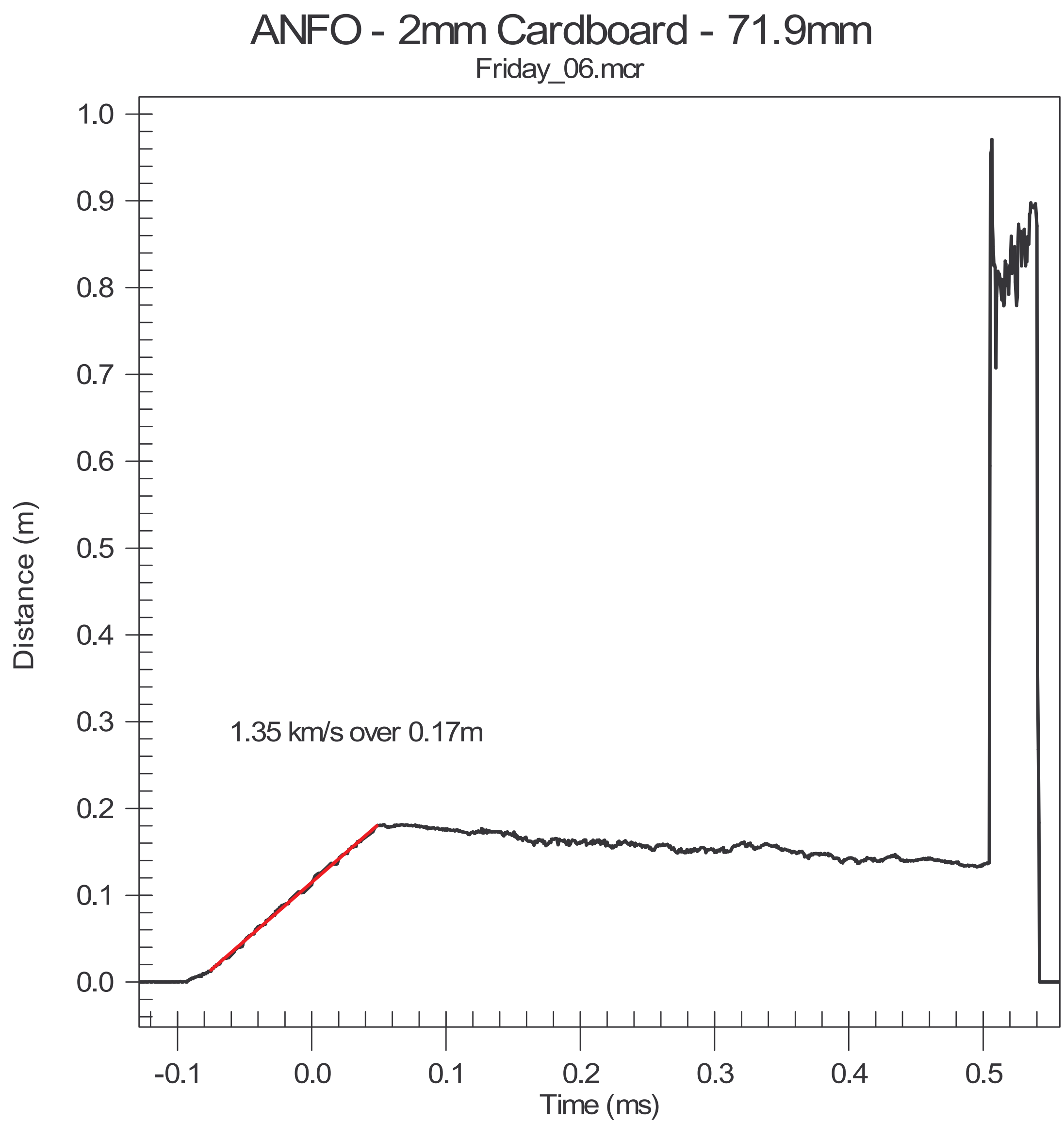
ANFO - 2mm Cardboard - 71.9mm
Tuesday_05.mcr
1.28 km/s over 0.48m
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6

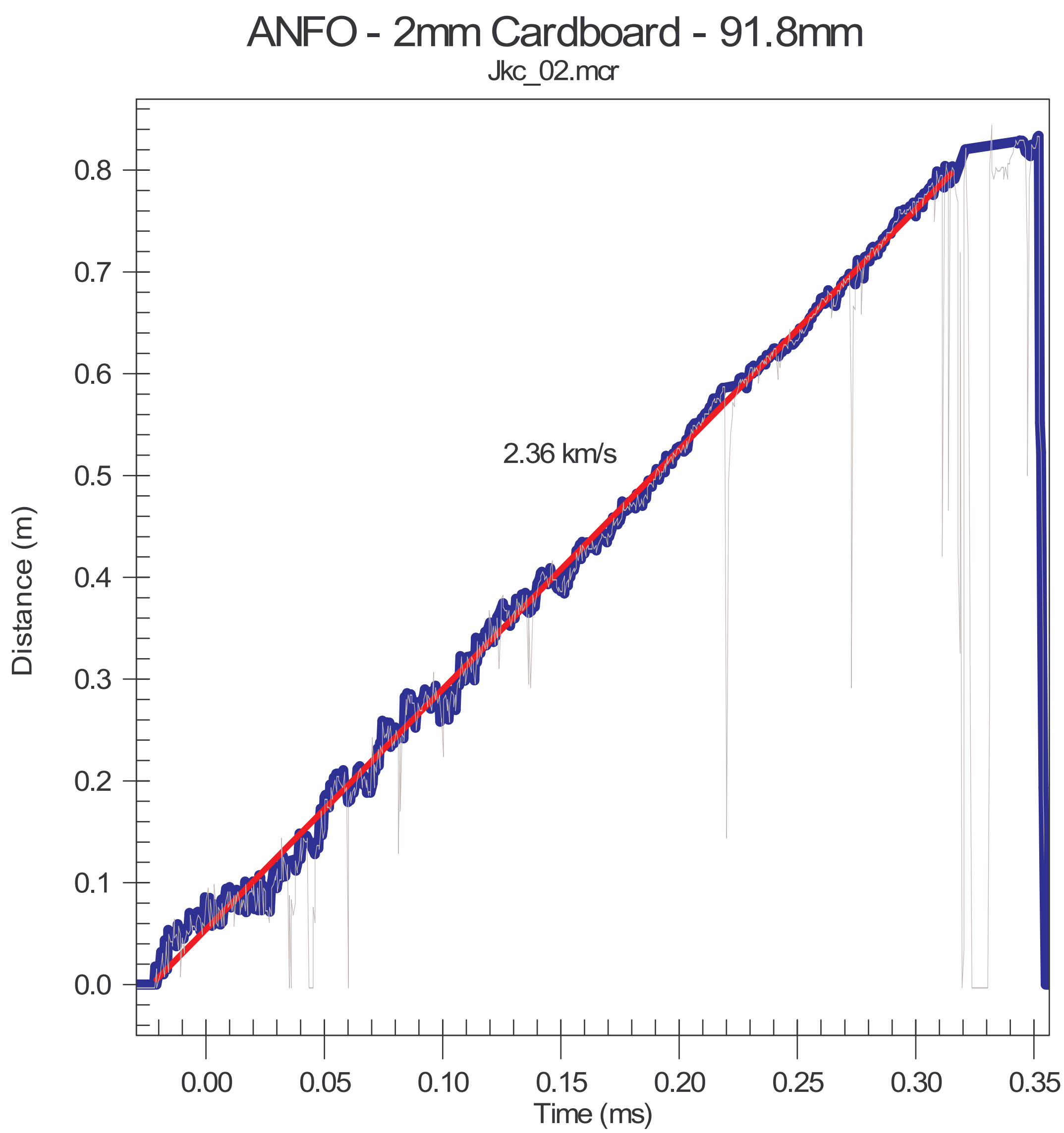

ANFO - 2mm Cardboard - 71.9mm
Tuesday_07.mcr
1.32 km/s over 0.41m
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Time (ms)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


ANFO - 2mm Cardboard - 71.9mm
Tuesday_09.mcr
1.42 km/s over 0.08m
Distance (m)
Time (ms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
-0.1
0.0
0.1
0.2
0.3
0.4
0.5

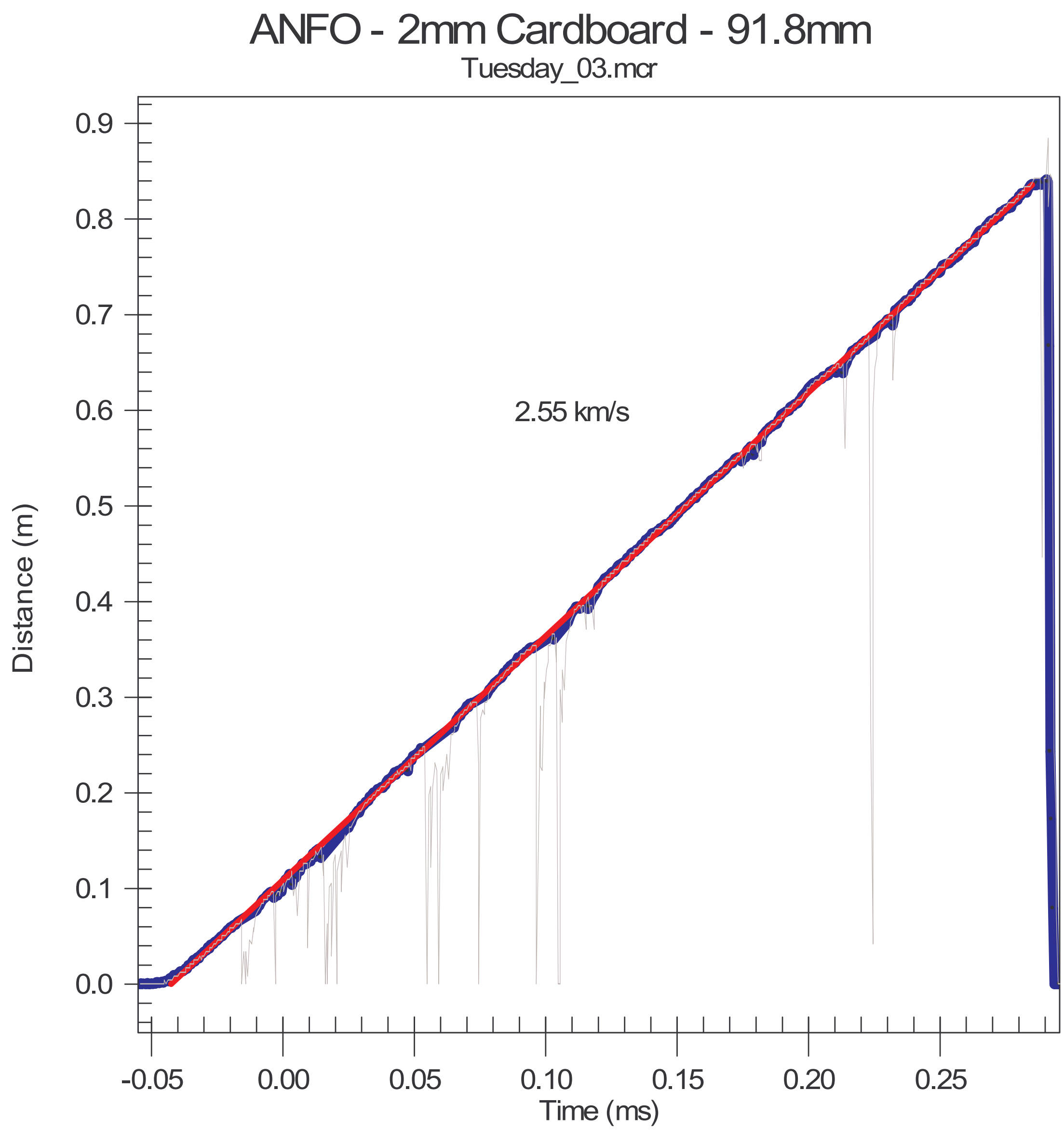


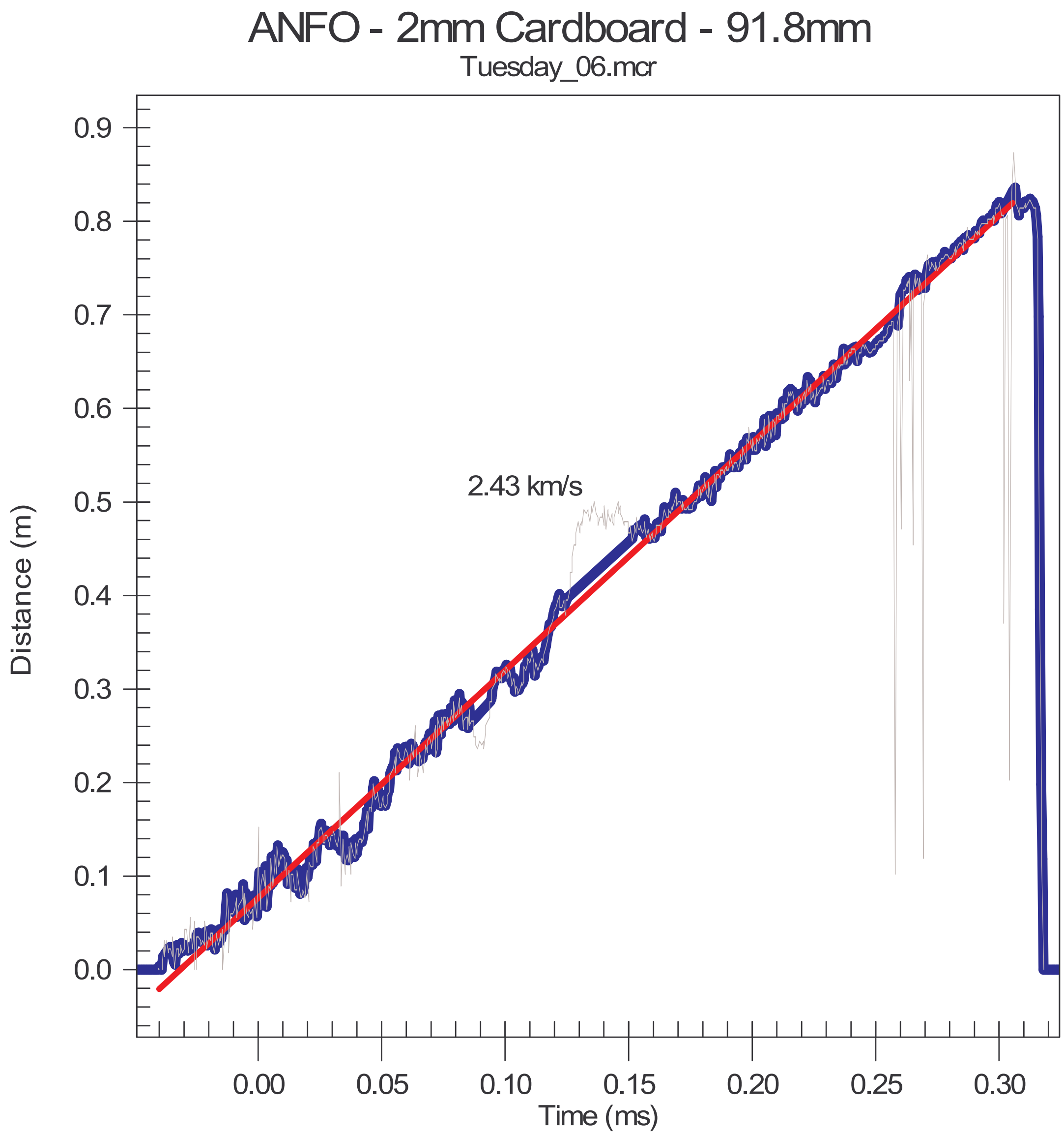
ANFO - 2mm Cardboard - 71.9mm
Tuesday_11.mcr
1.29 km/s over 0.55m
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

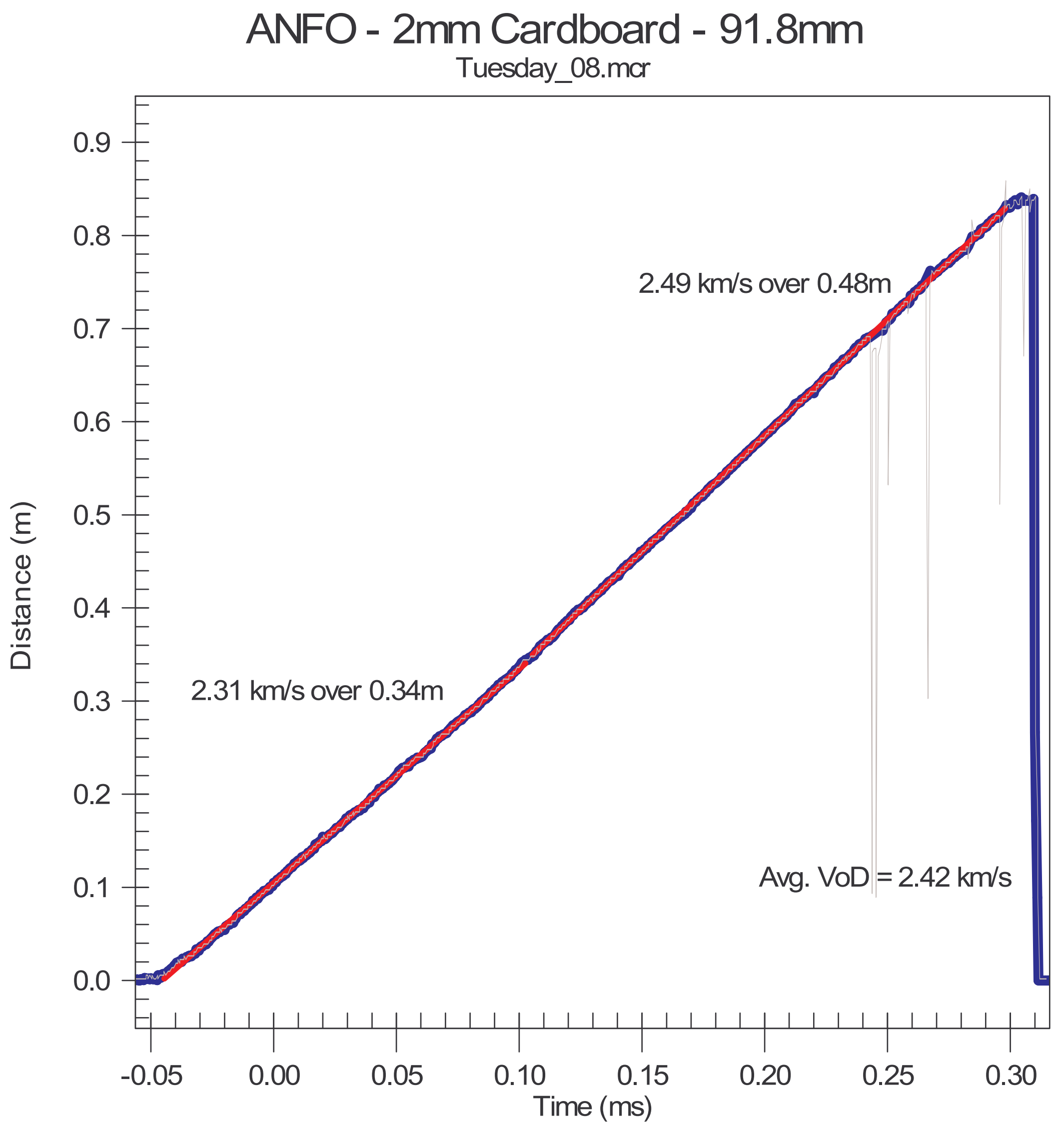

ANFO - 2mm Cardboard - 71.9mm
Friday_06.mcr
Distance (m)
Time (ms)
1.35 km/s over 0.17m
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0.0
0.1
0.2
0.3
0.4
0.5

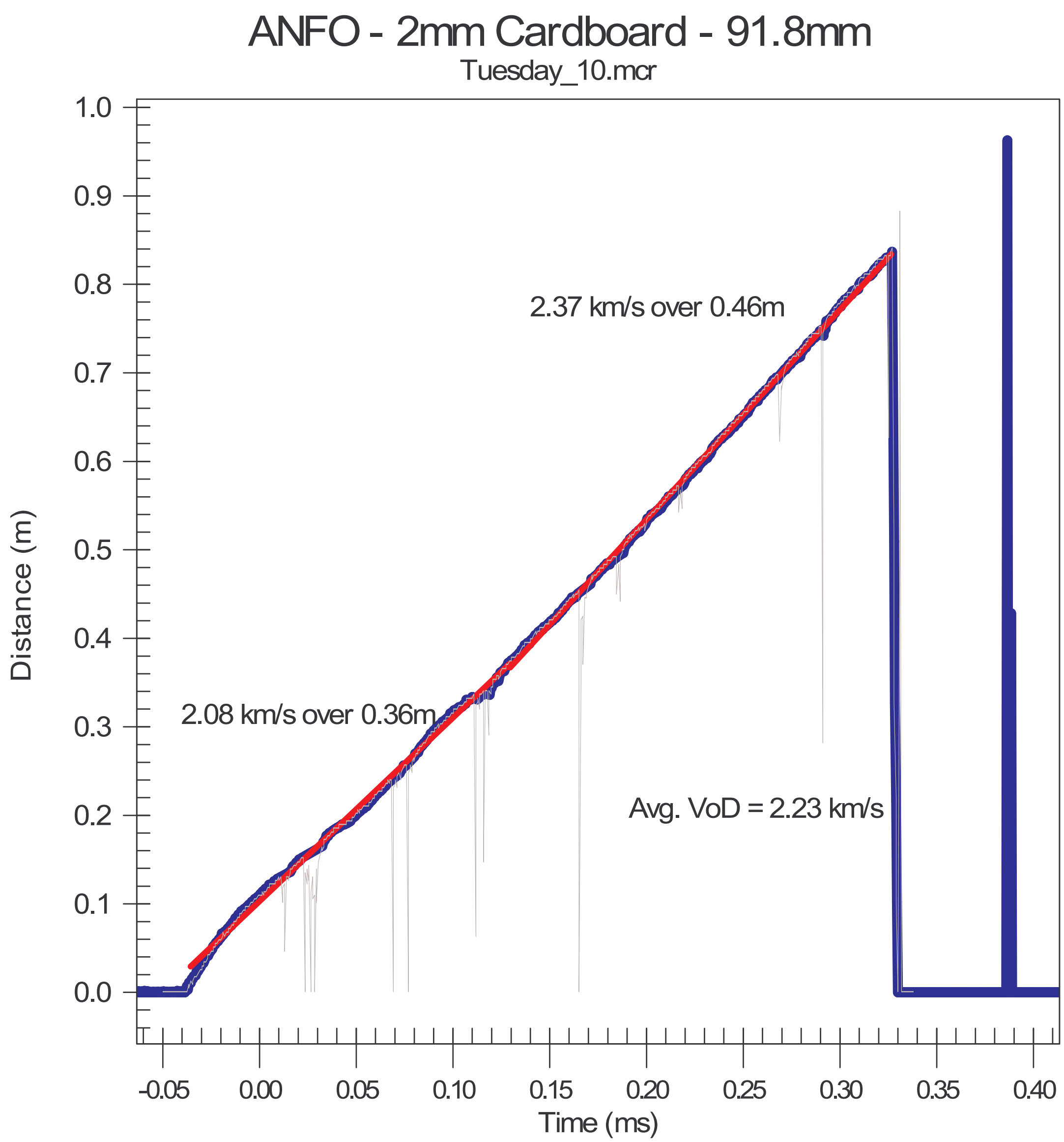


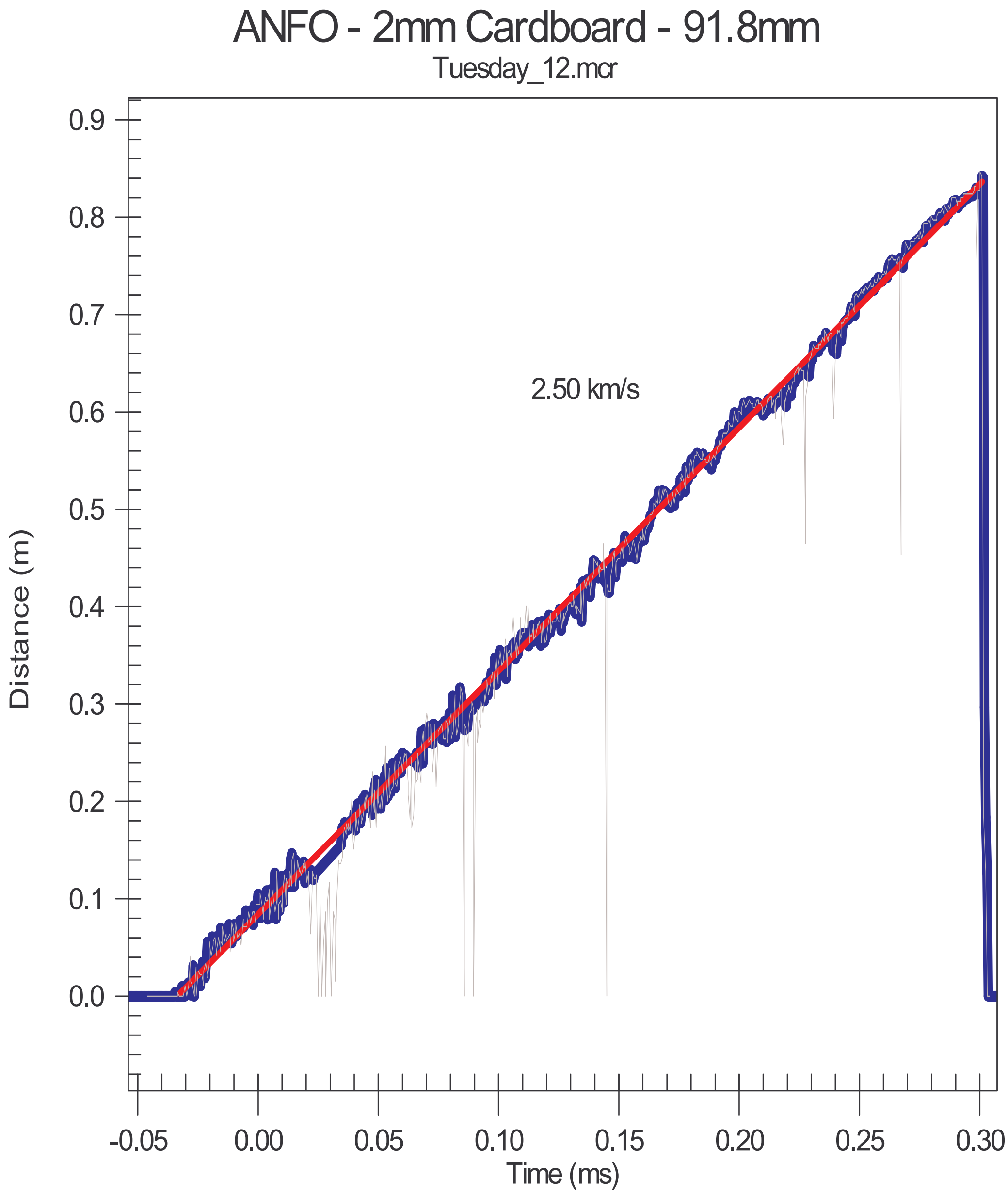
ANFO - 2mm Cardboard - 91.8mm
Jkc_02.mcr
2.36 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Time (ms)


ANFO - 2mm Cardboard - 91.8mm
Tuesday_03.mcr
2.55 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

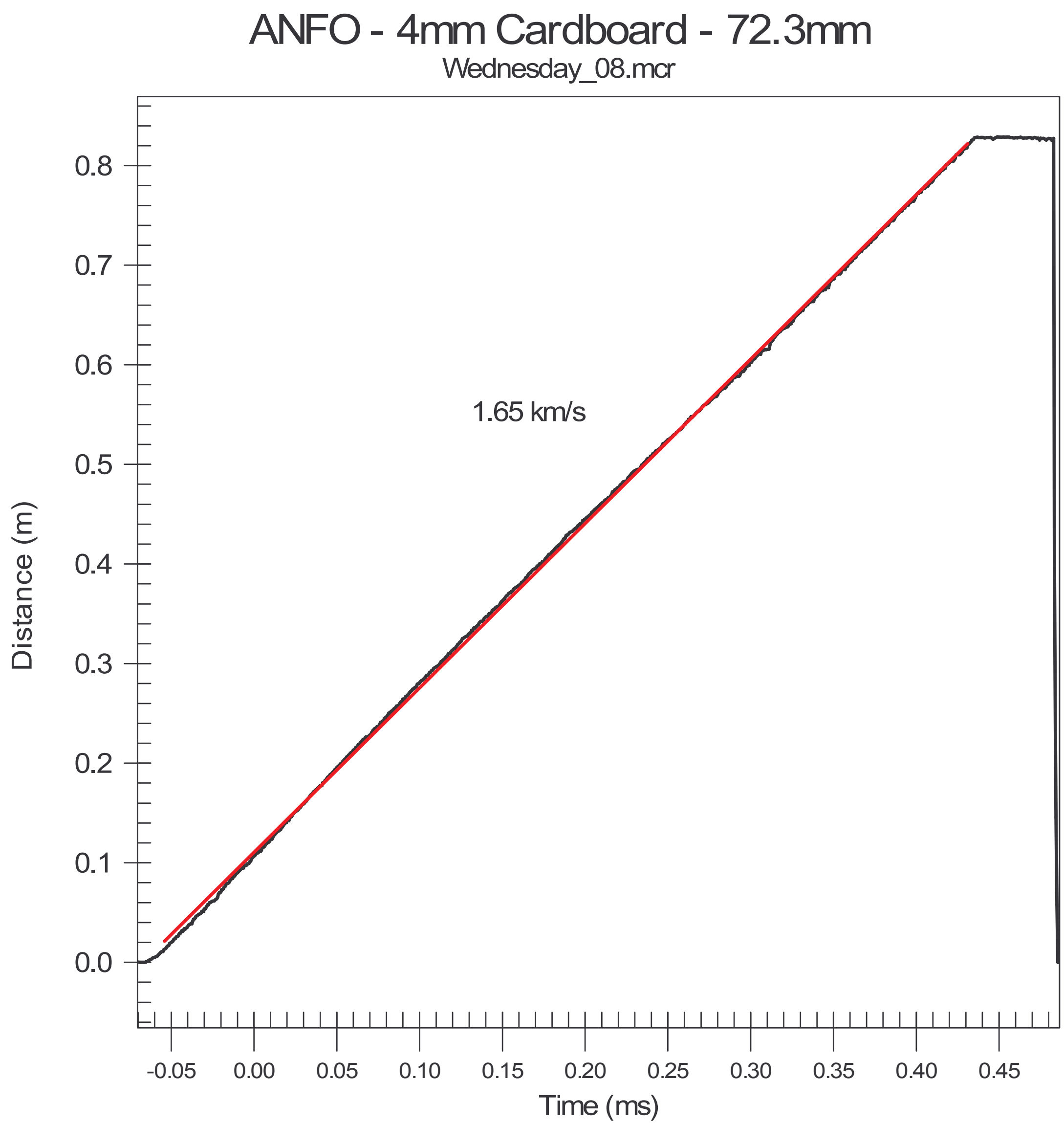

ANFO - 2mm Cardboard - 91.8mm
Tuesday_06.mcr
2.43 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (ms)

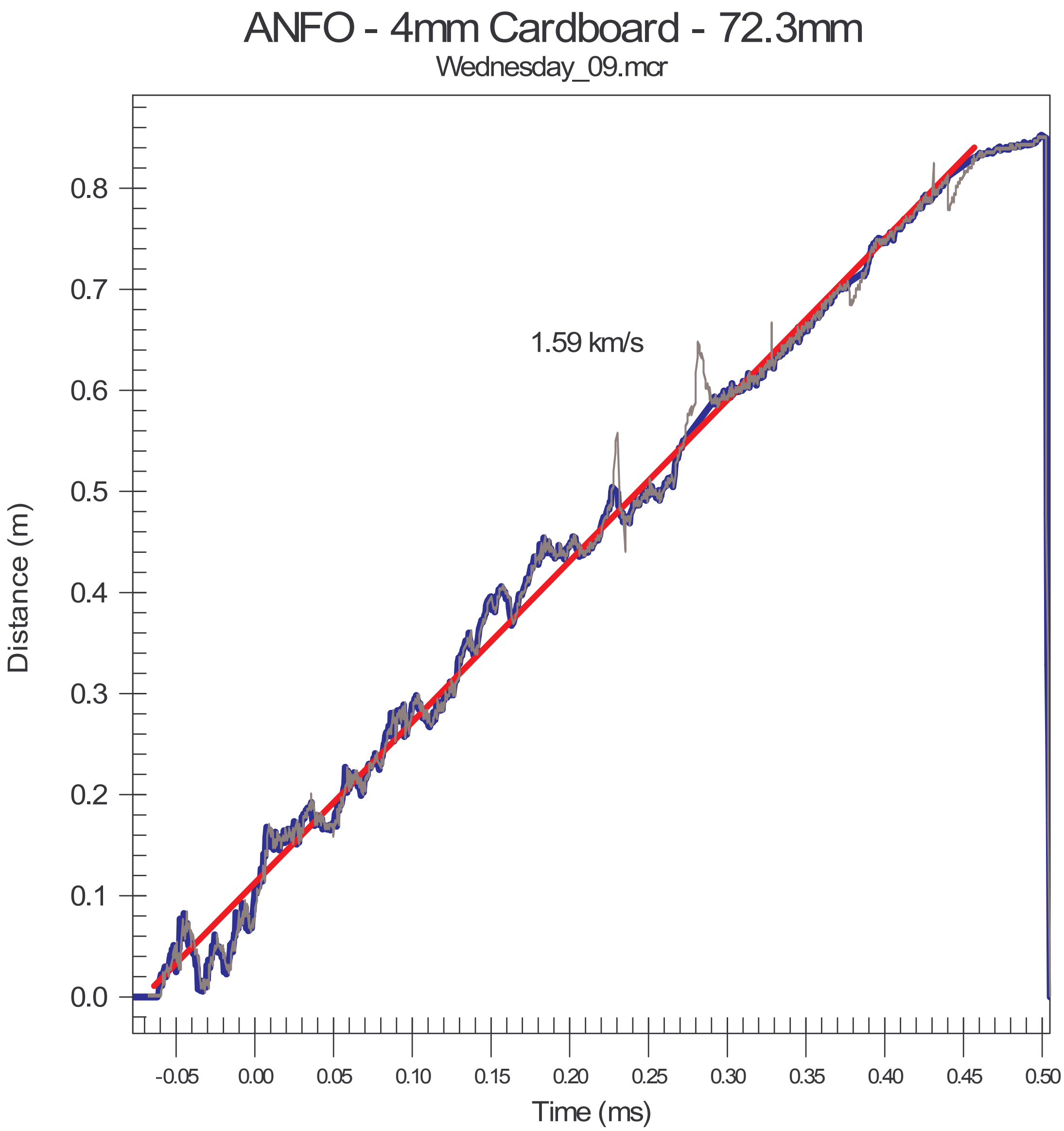

ANFO - 2mm Cardboard - 91.8mm
Tuesday_08.mcr
Distance (m)
Time (ms)
2.31 km/s over 0.34m
2.49 km/s over 0.48m
Avg. VoD = 2.42 km/s
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

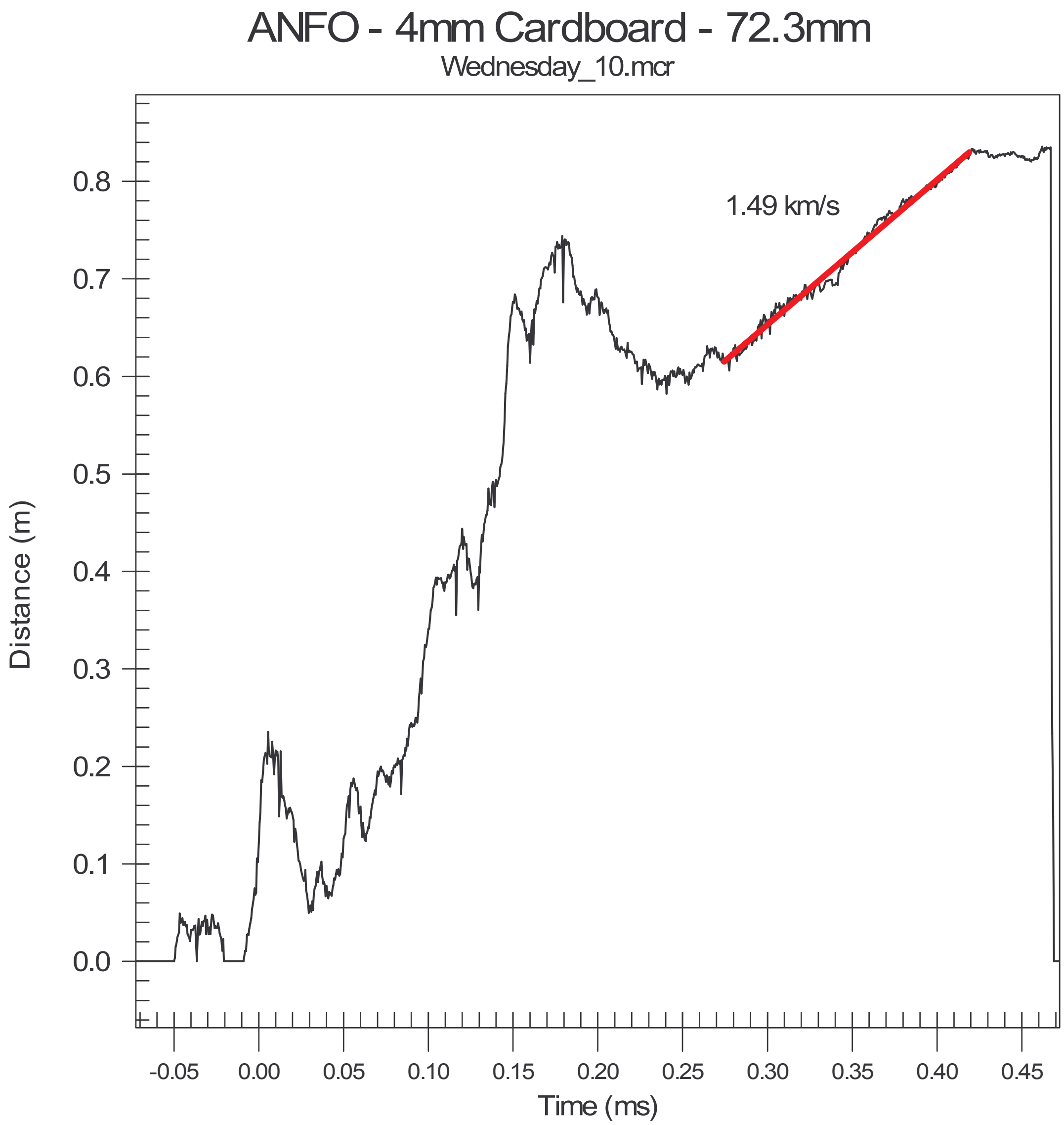

ANFO - 2mm Cardboard - 91.8mm
Tuesday_10.mcr
Distance (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
Time (ms)
2.37 km/s over 0.46m
2.08 km/s over 0.36m
Avg. VoD = 2.23 km/s

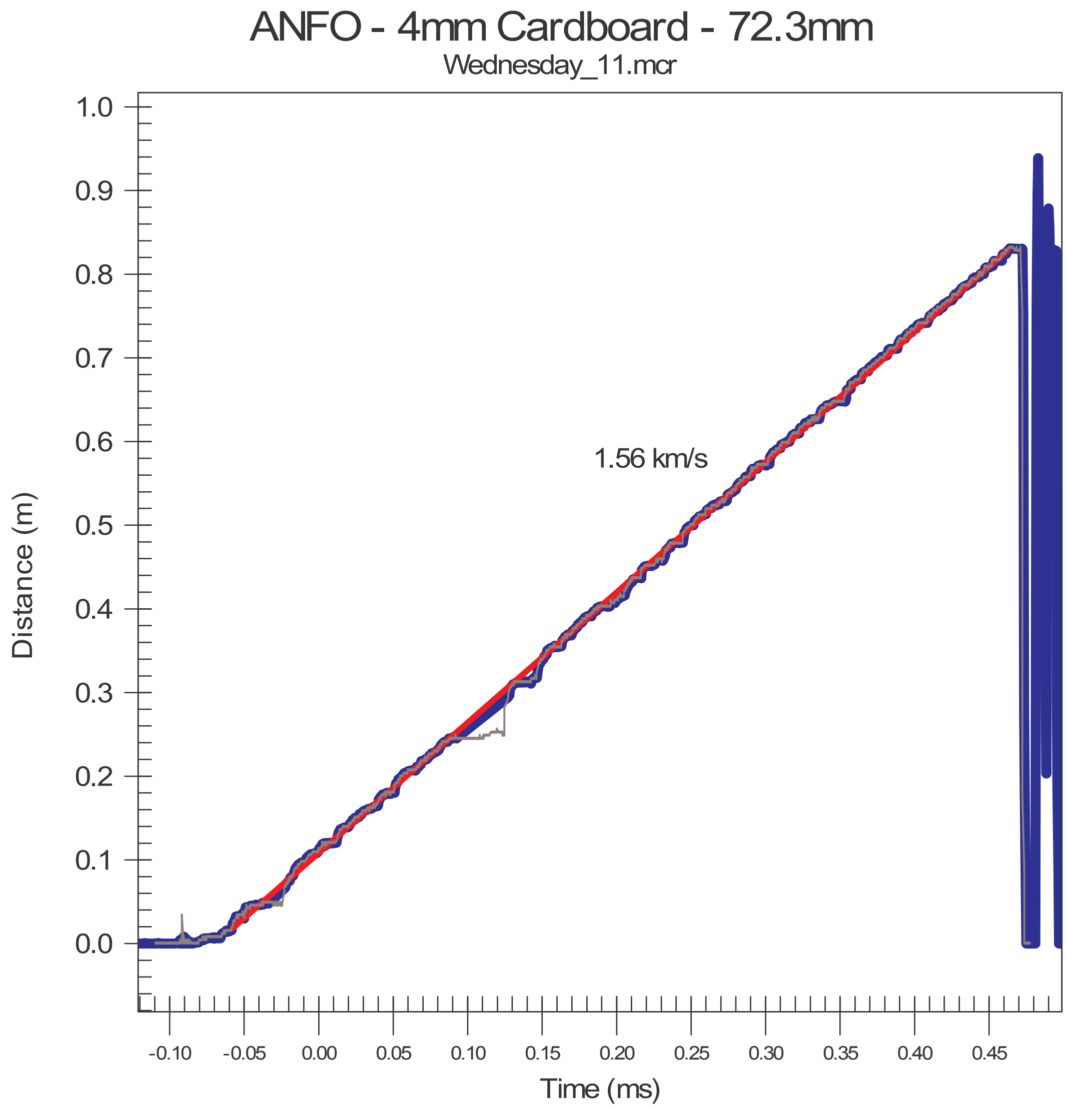


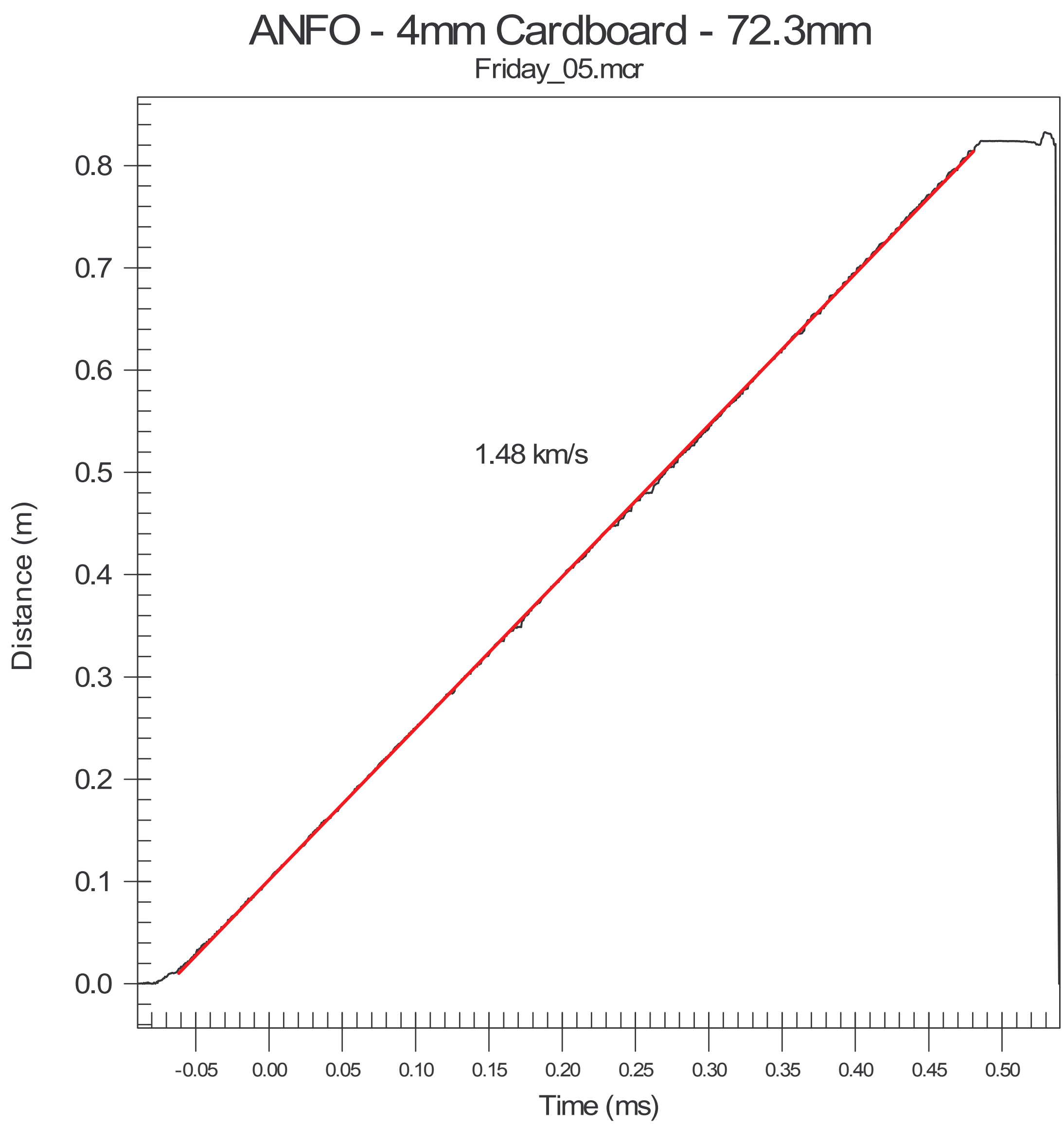
ANFO - 2mm Cardboard - 91.8mm
Tuesday_12.mcr
2.50 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (ms)

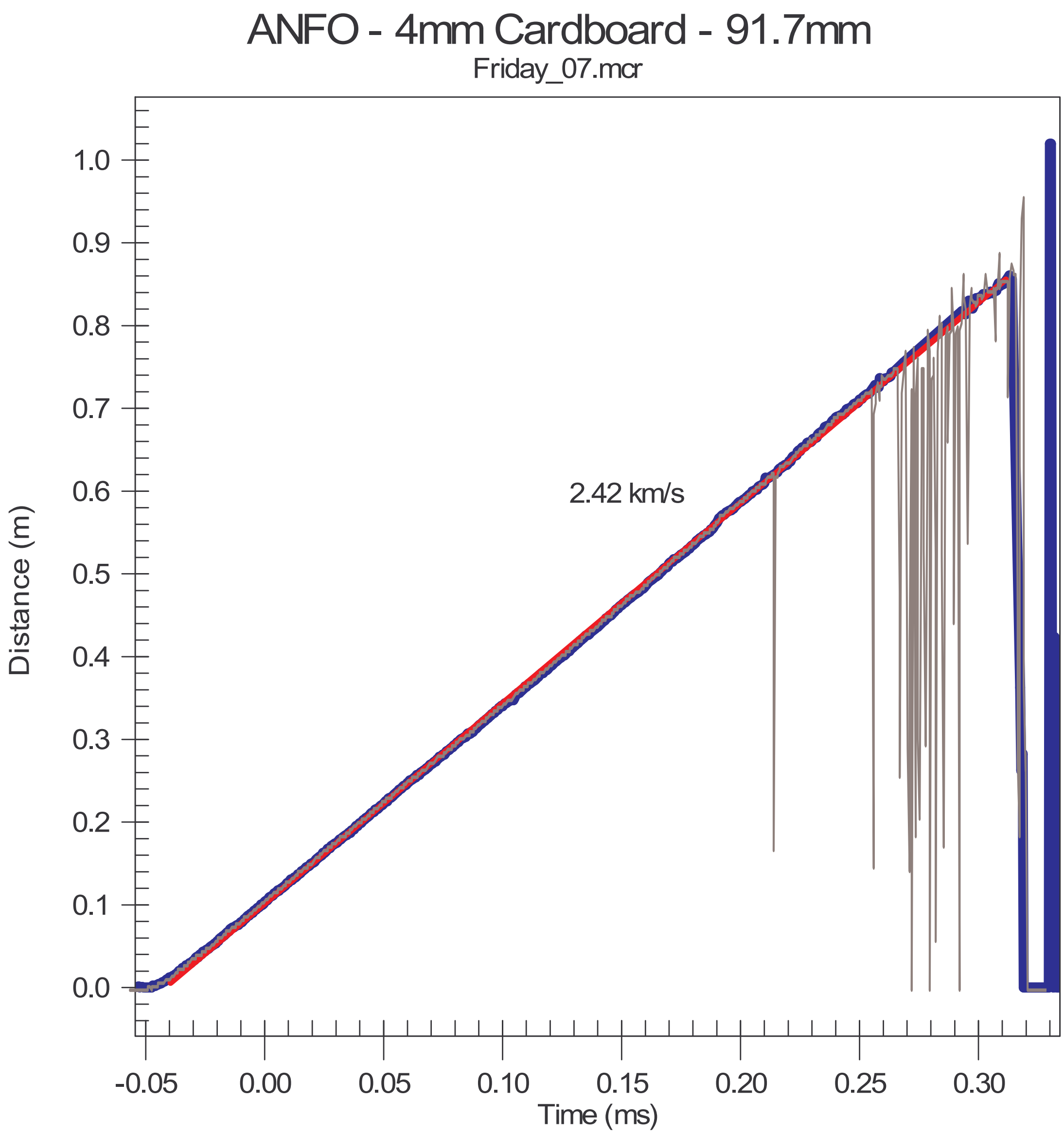

ANFO - 4mm Cardboard - 72.3mm
Wednesday_08.mcr
1.65 km/s
Distance (m)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Time (ms)

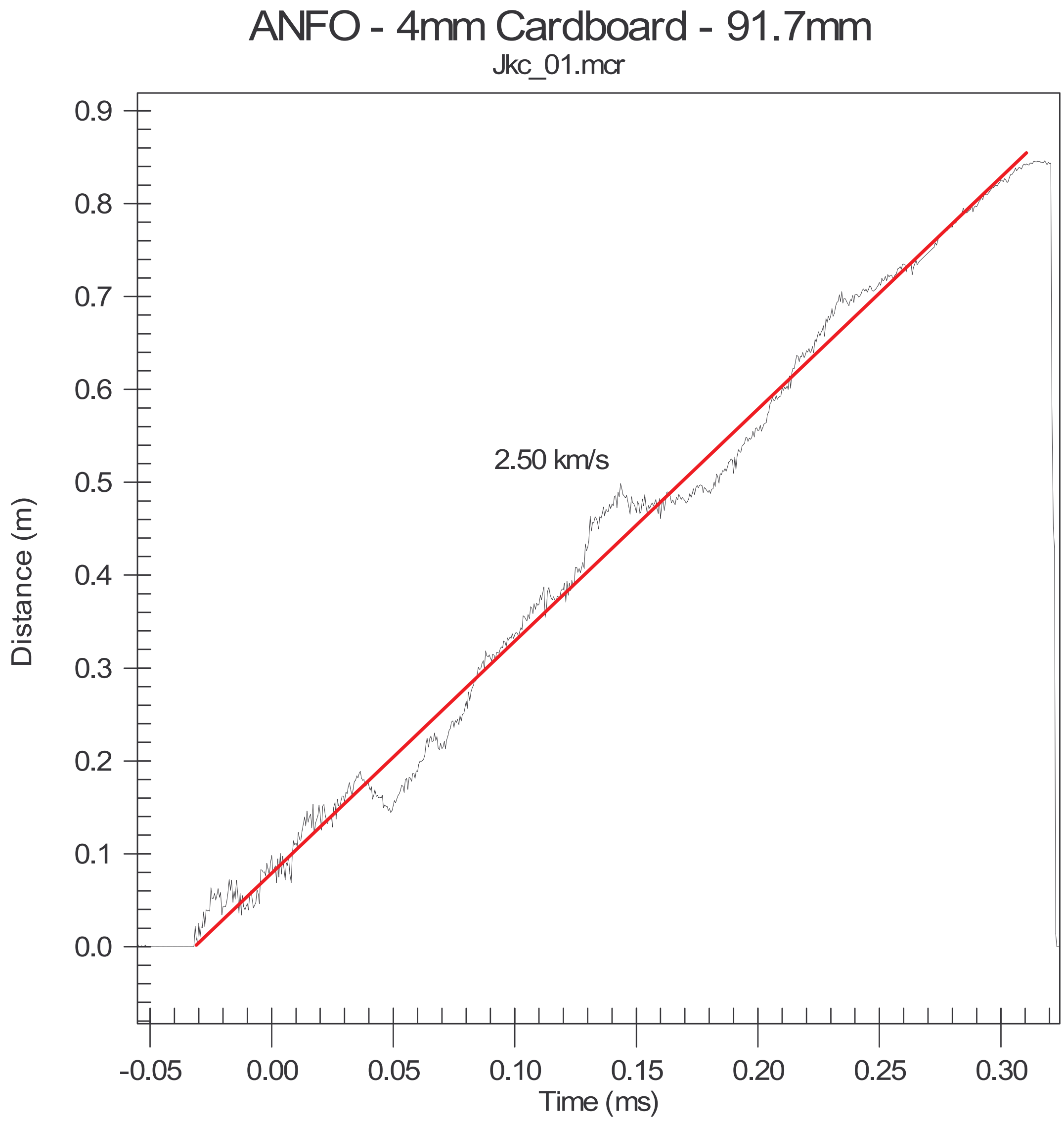

ANFO - 4mm Cardboard - 72.3mm
Wednesday_09.mcr
1.59 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Time (ms)


ANFO - 4mm Cardboard - 72.3mm
Wednesday_10.mcr
1.49 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Time (ms)

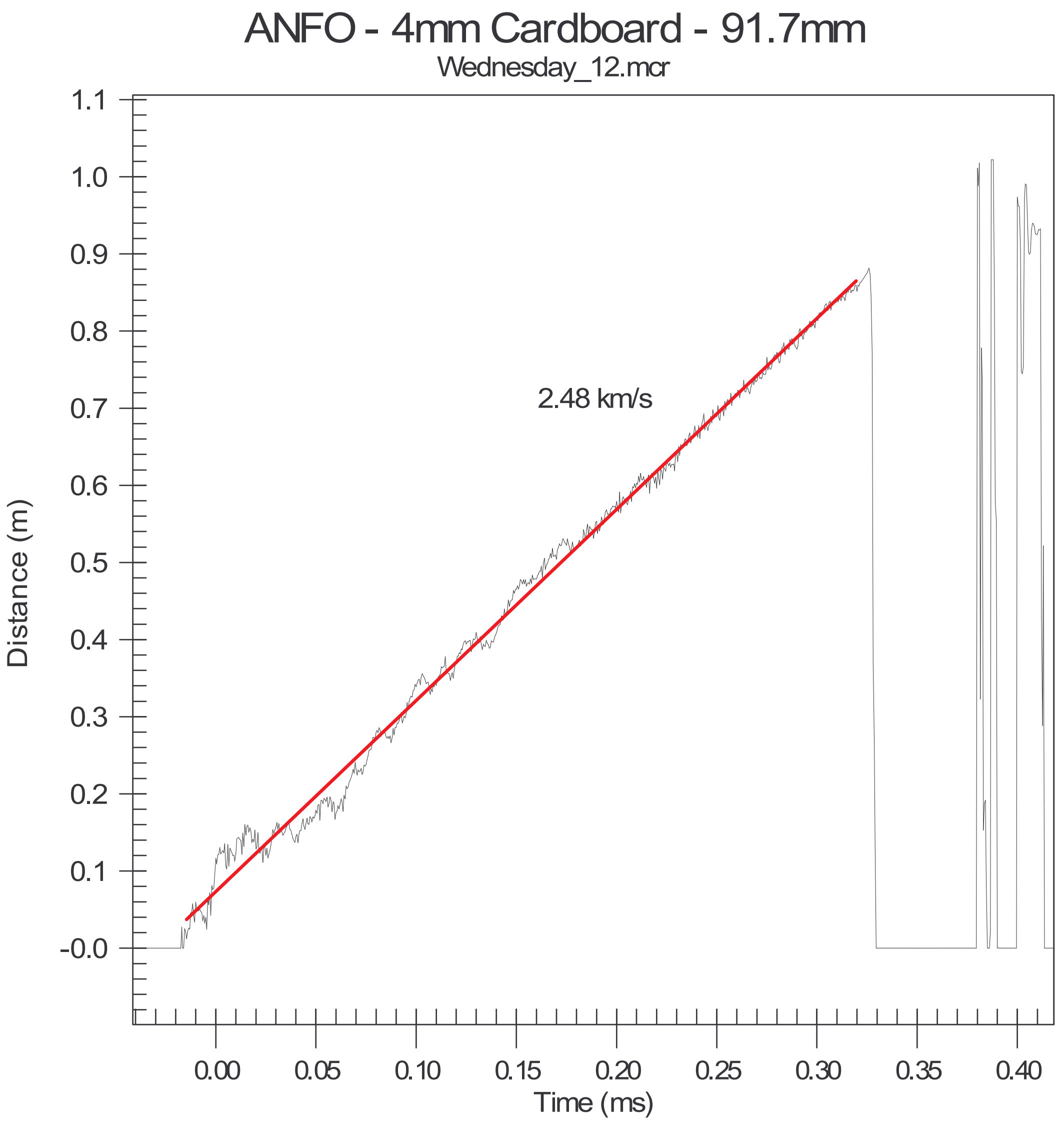

ANFO - 4mm Cardboard - 72.3mm
Wednesday_11.mcr
1.56 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45


ANFO - 4mm Cardboard - 72.3mm
Friday_05.mcr
1.48 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Time (ms)
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50

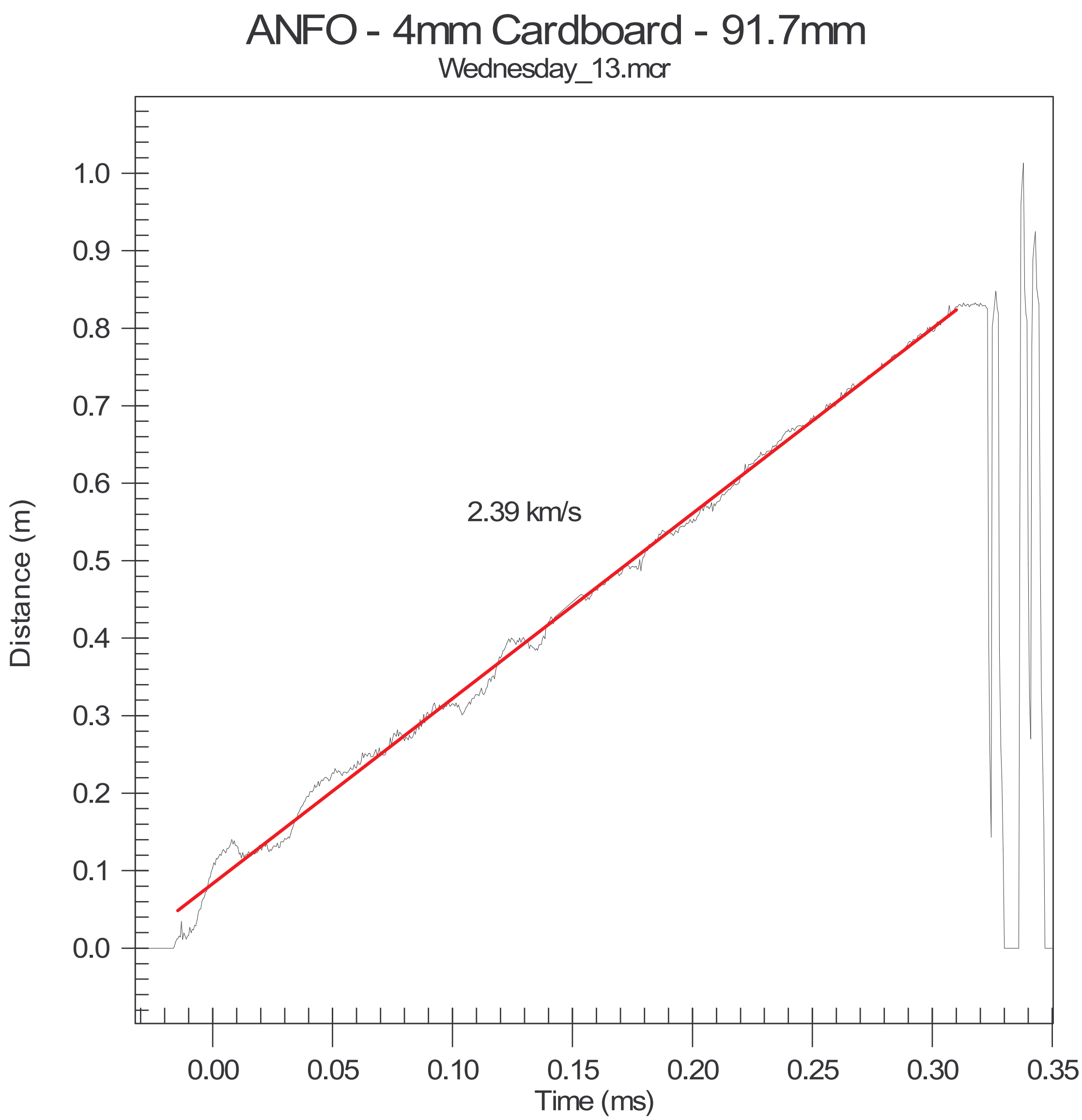

ANFO - 4mm Cardboard - 91.7mm
Friday_07.mcr
2.42 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

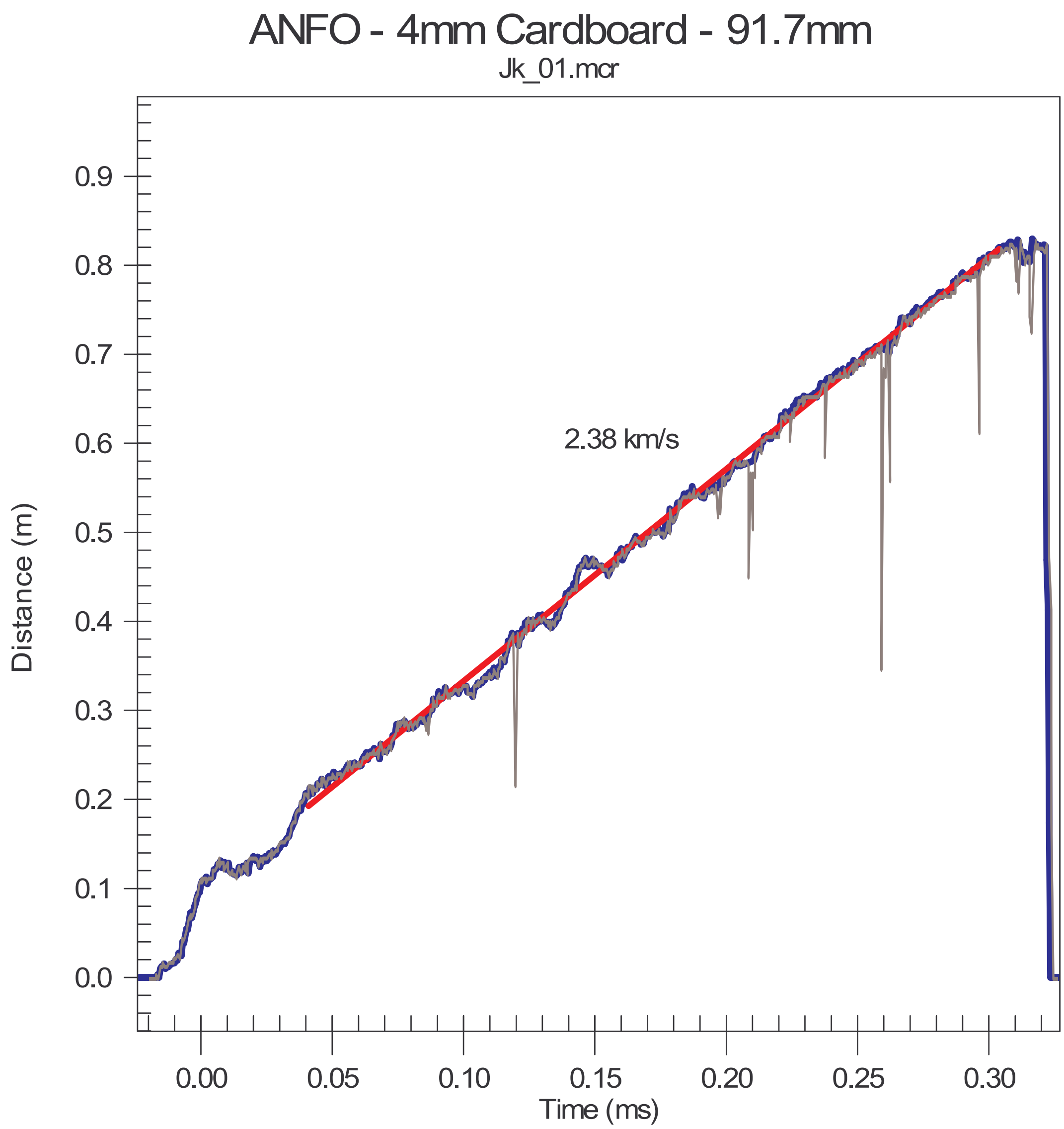


ANFO - 4mm Cardboard - 91.7mm
Jkc_01.mcr
2.50 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (ms)

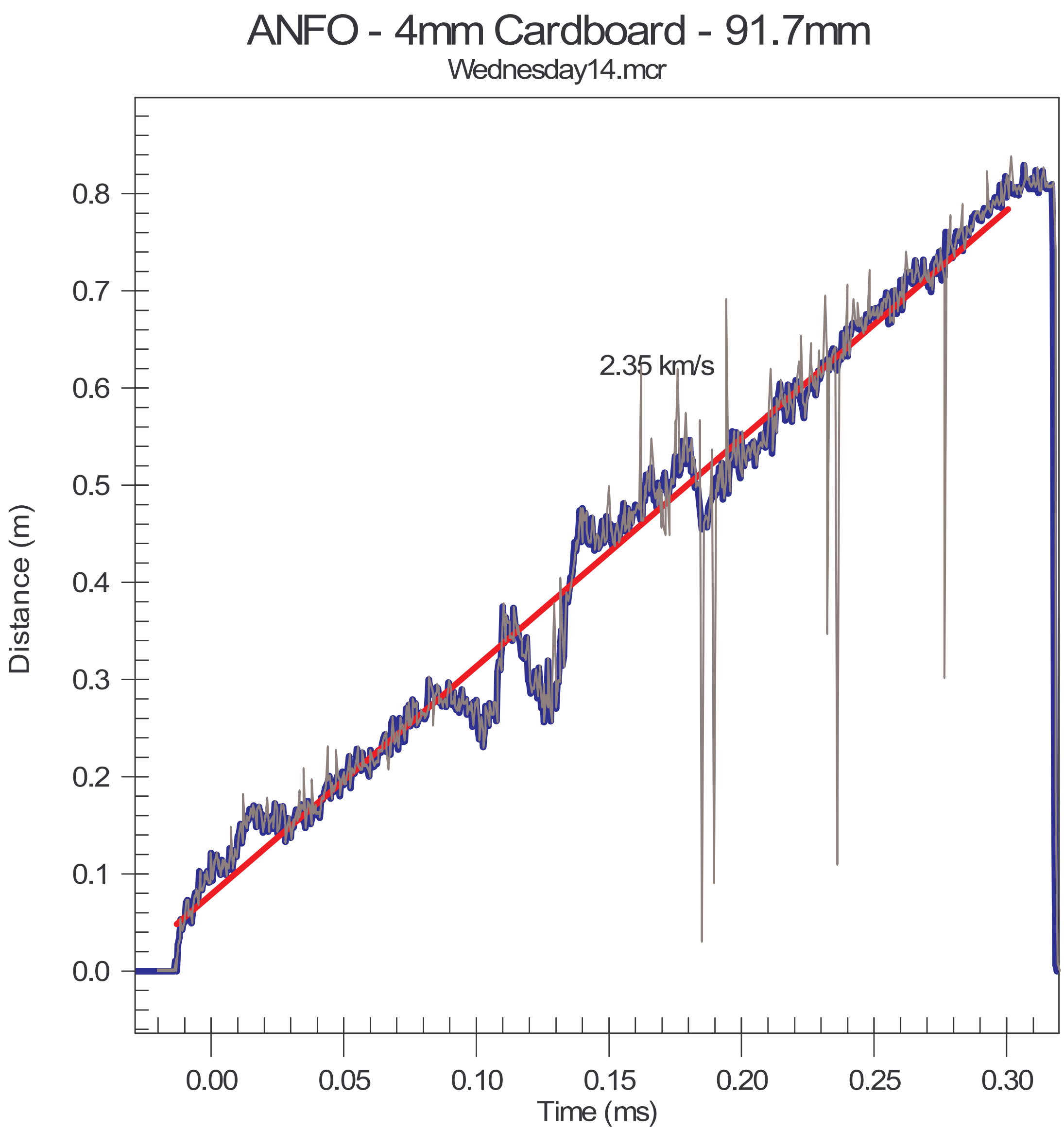


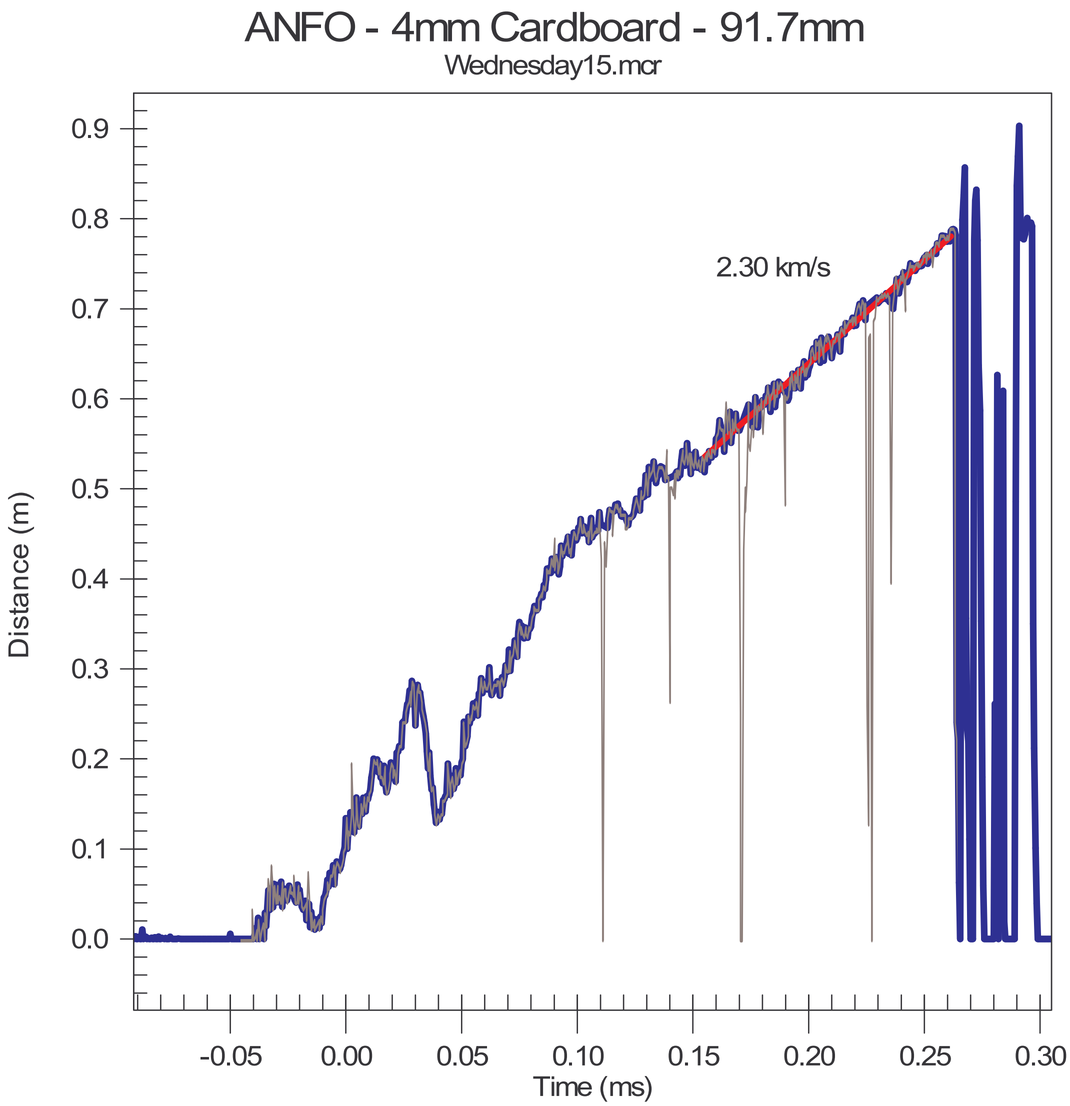
ANFO - 4mm Cardboard - 91.7mm
Wednesday_12.mcr
2.48 km/s
Distance (m)
Time (ms)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40


ANFO - 4mm Cardboard - 91.7mm
Wednesday_13.mcr
Distance (m)
Time (ms)
2.39 km/s
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

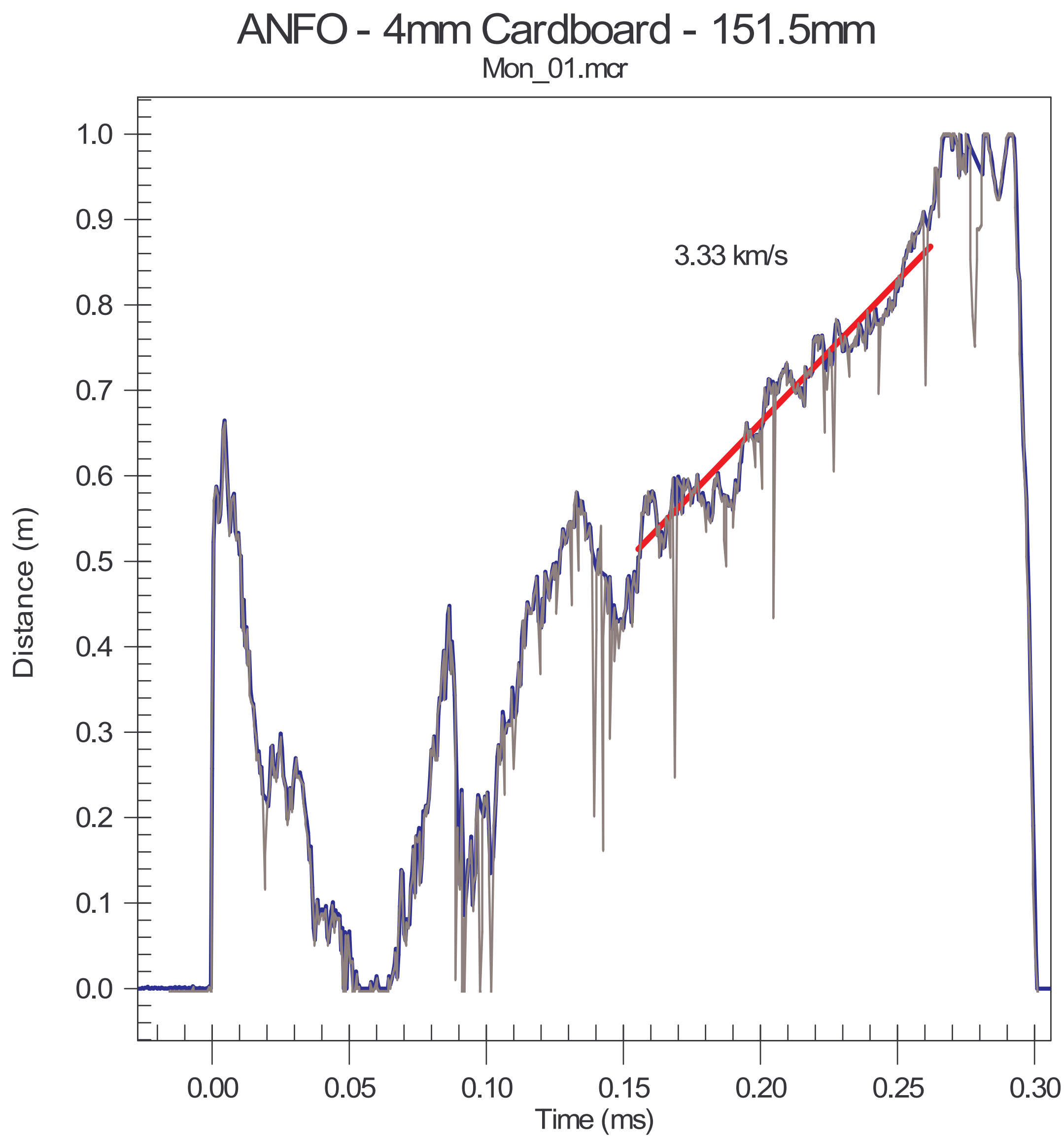


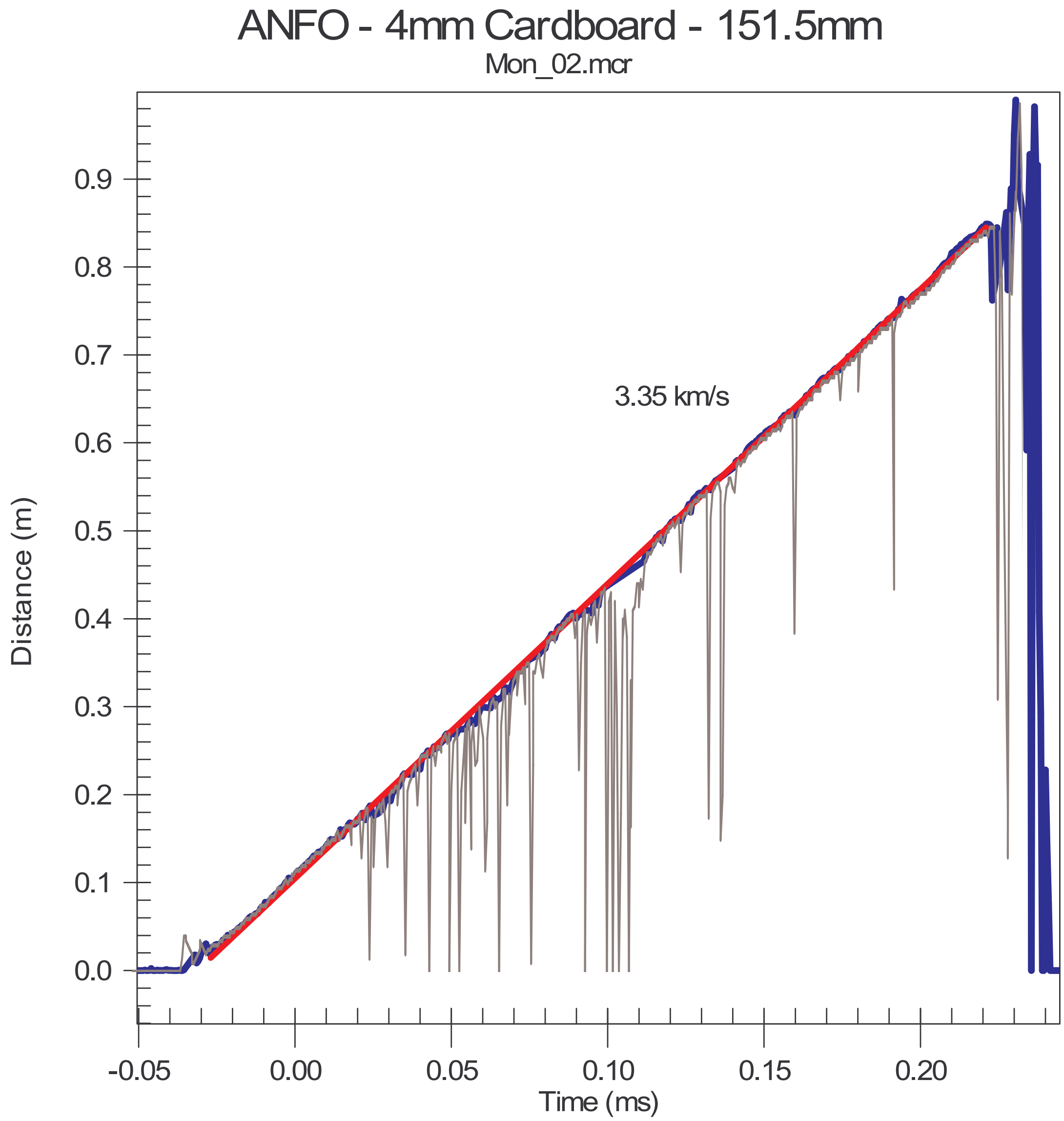
ANFO - 4mm Cardboard - 91.7mm
Jk_01.mcr
2.38 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time (ms)
0.00
0.05
0.10
0.15
0.20
0.25
0.30

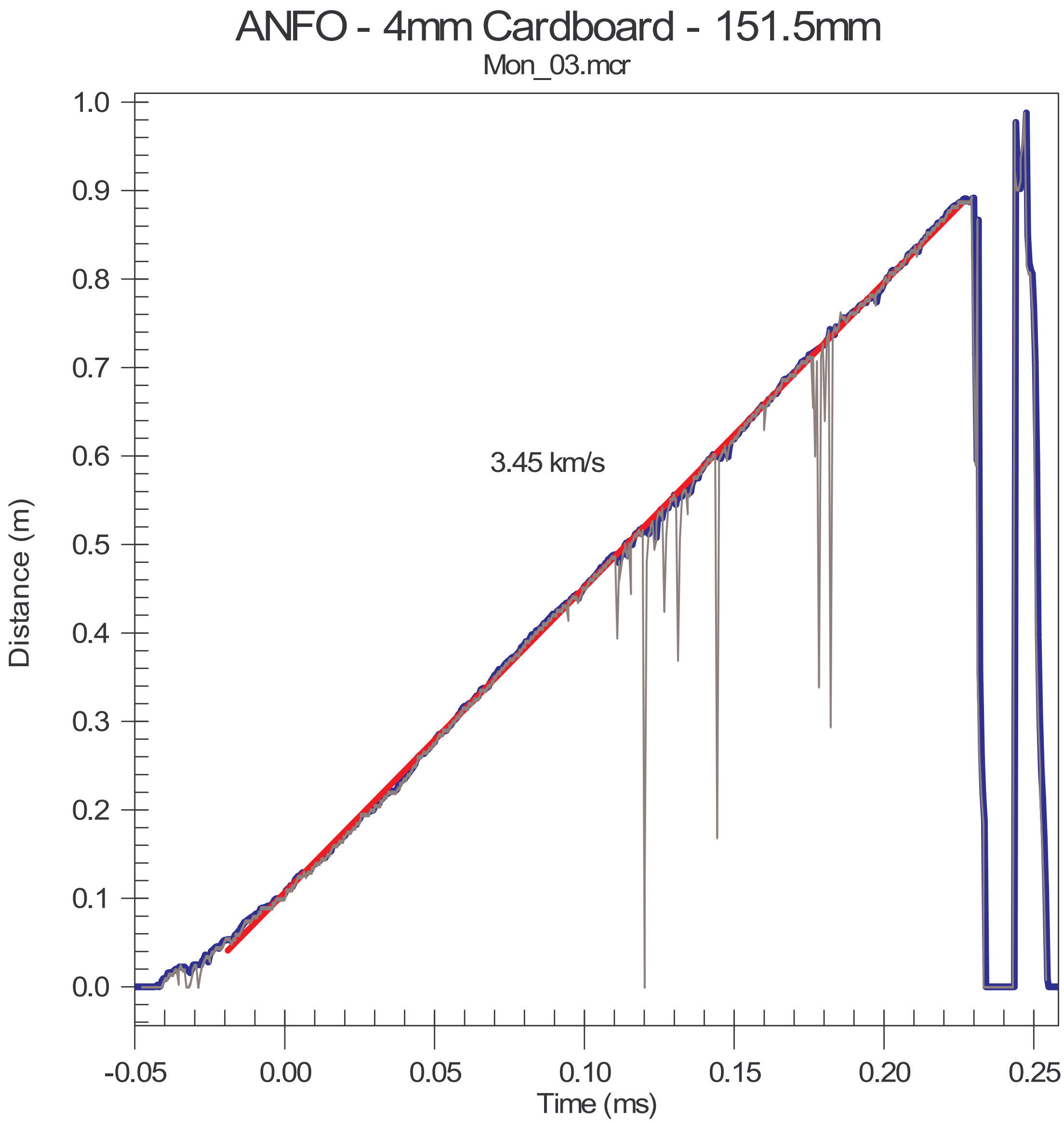

ANFO - 4mm Cardboard - 91.7mm
Wednesday14.mcr
2.35 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.00
0.05
0.10
0.15
0.20
0.25
0.30

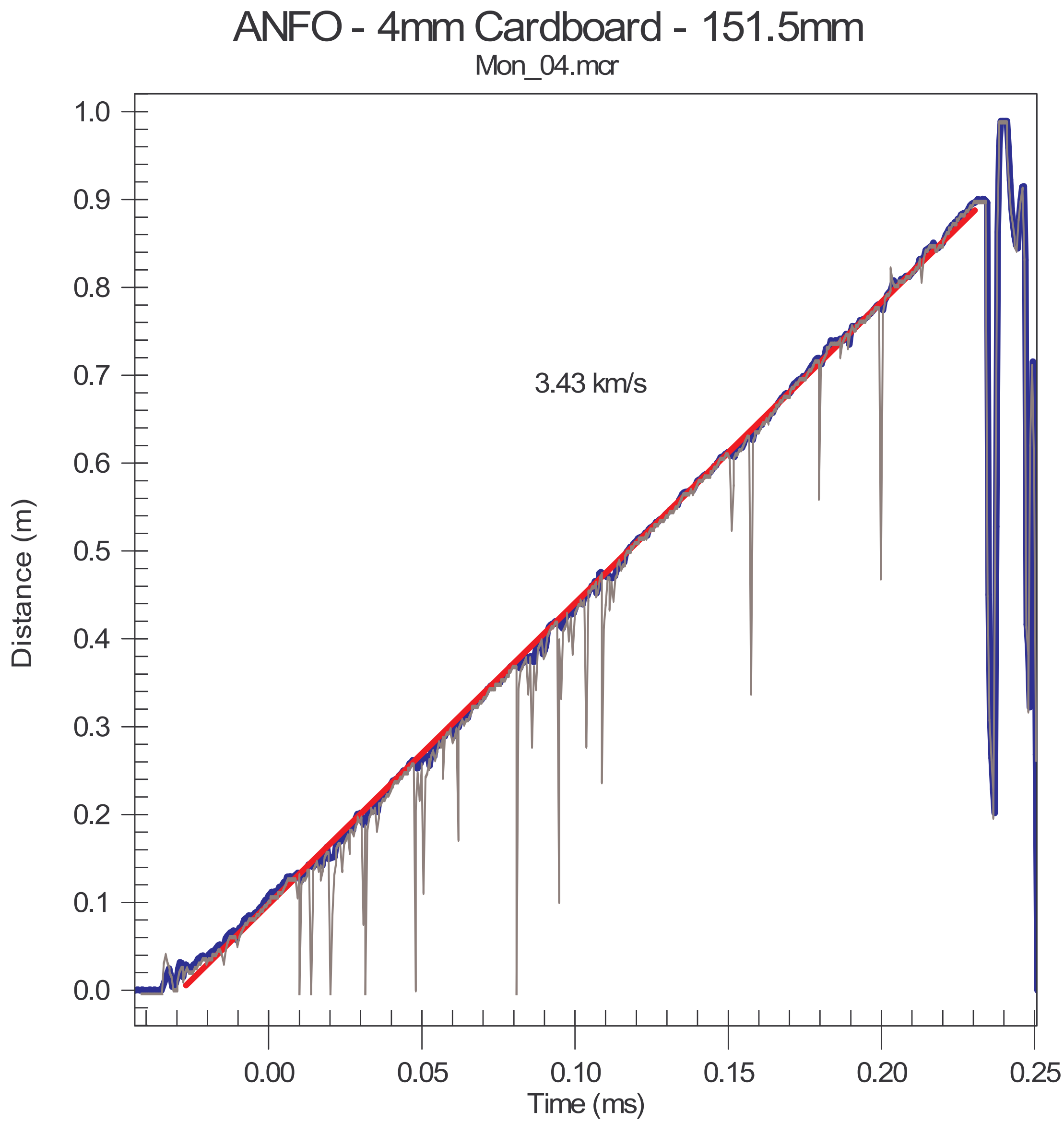


ANFO - 4mm Cardboard - 91.7mm
Wednesday15.mcr
2.30 km/s
Distance (m)
Time (ms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

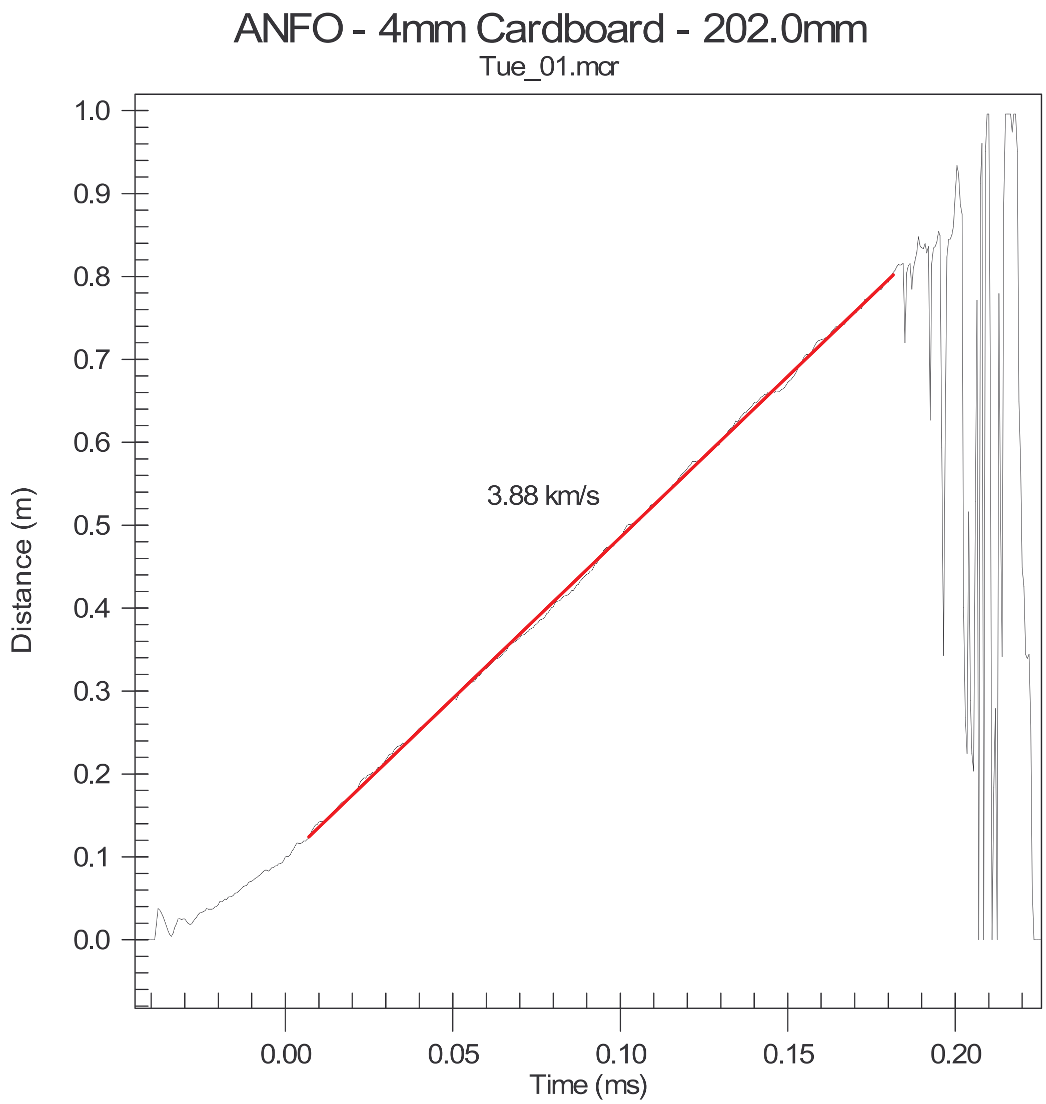

ANFO - 4mm Cardboard - 151.5mm
Mon_01.mcr
3.33 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30


ANFO - 4mm Cardboard - 151.5mm
Mon_02.mcr
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
3.35 km/s
-0.05
0.00
0.05
0.10
0.15
0.20
Time (ms)

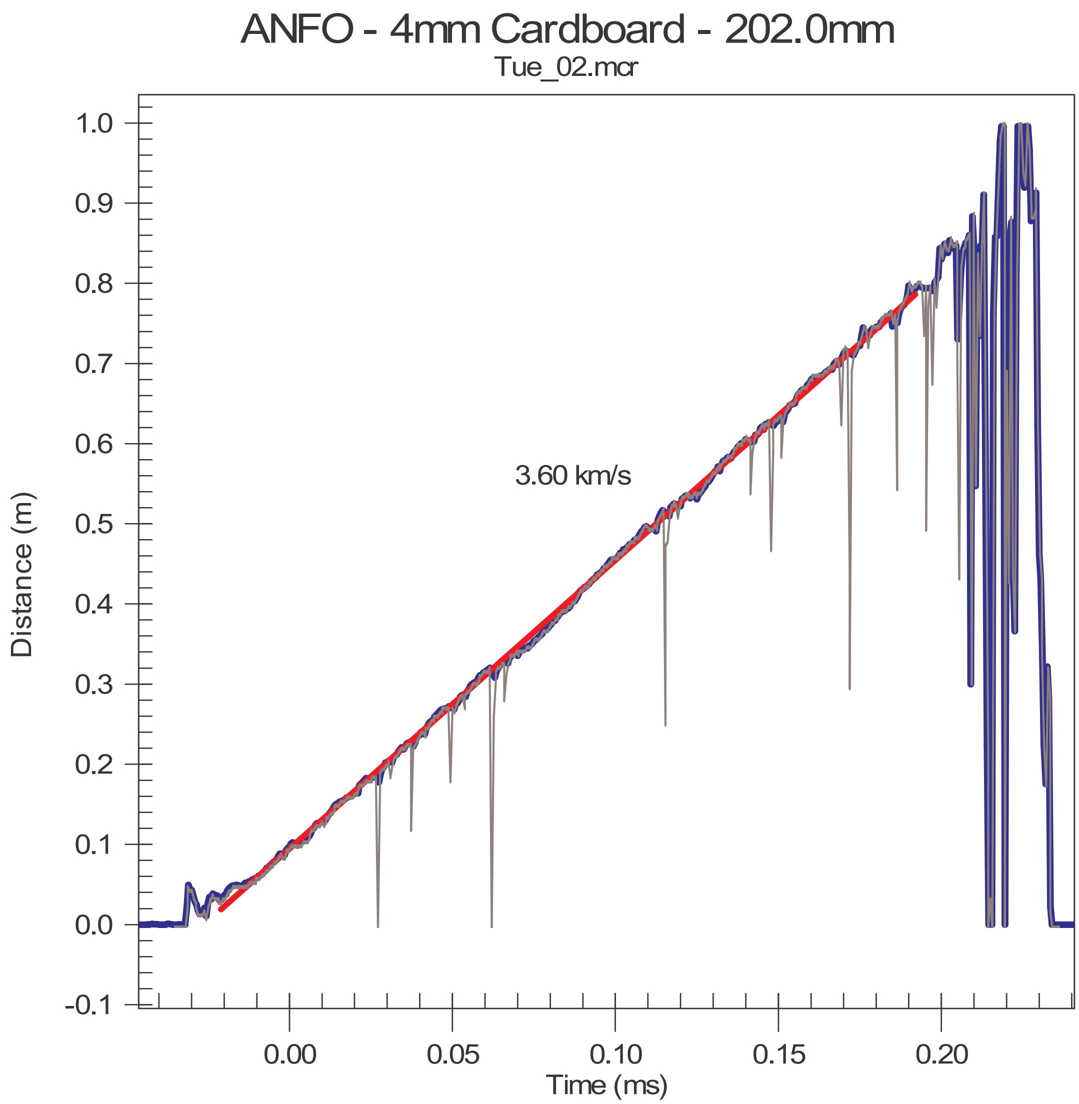

ANFO - 4mm Cardboard - 151.5mm
Mon_03.mcr
3.45 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25

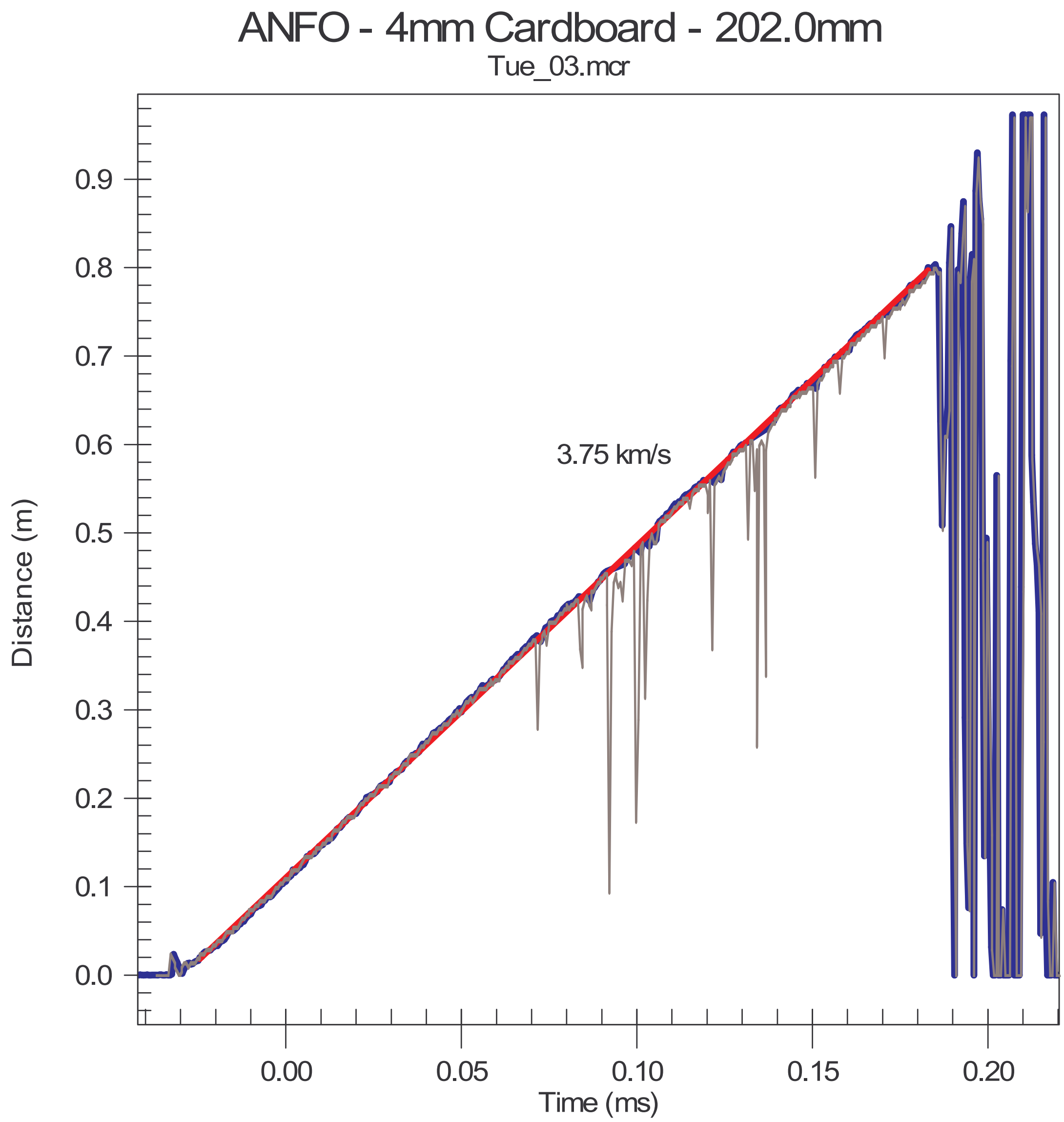


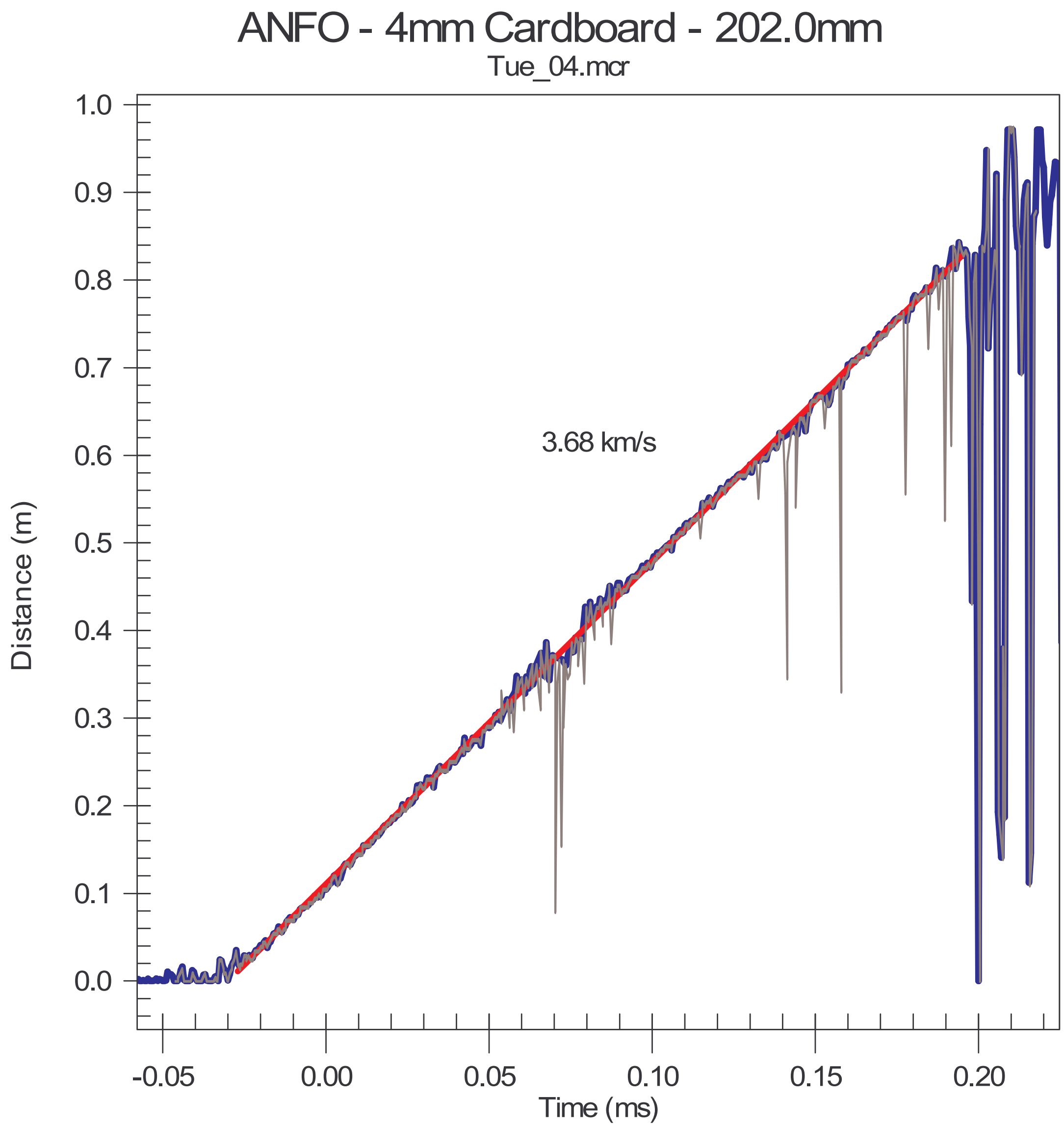
ANFO - 4mm Cardboard - 151.5mm
Mon_04.mcr
3.43 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25

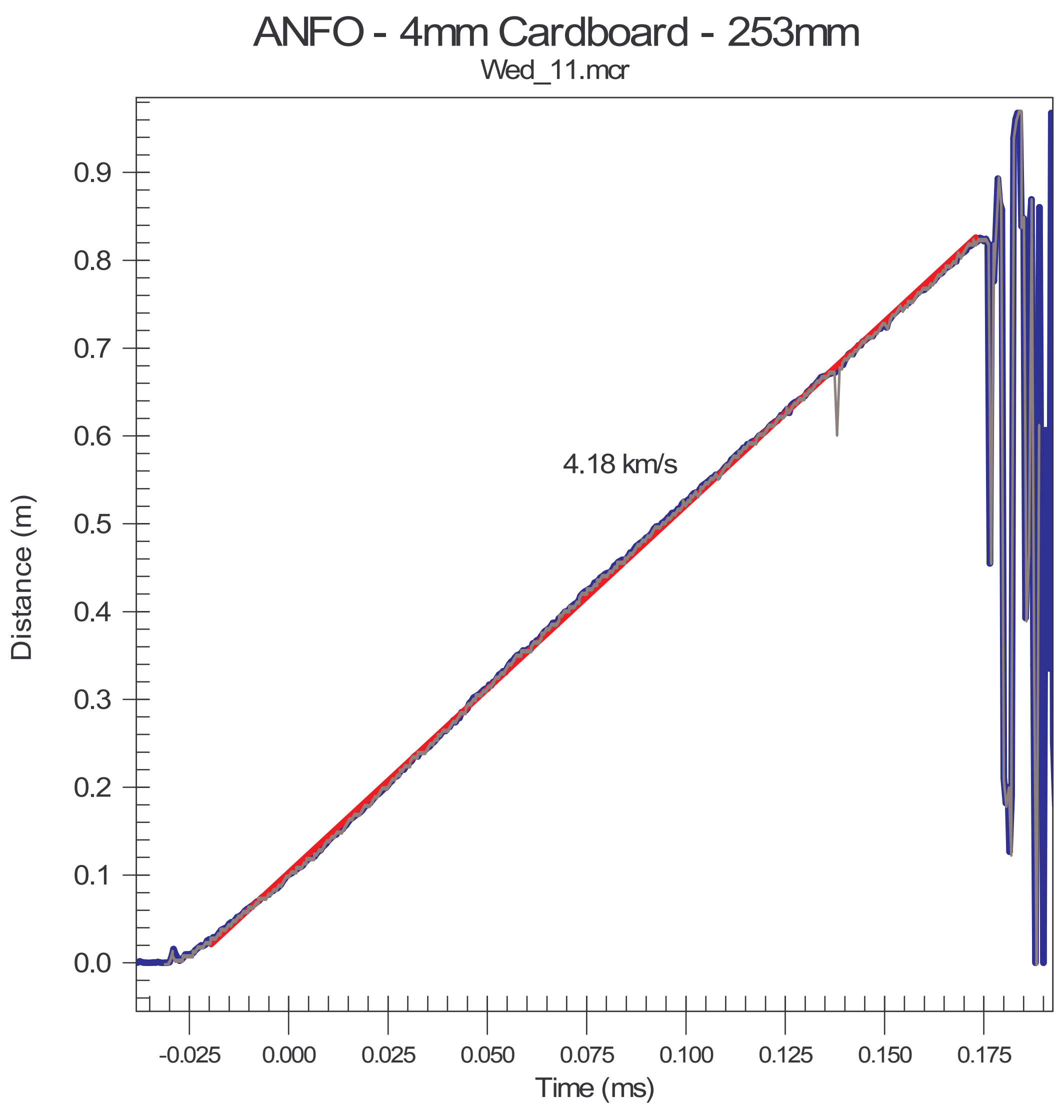


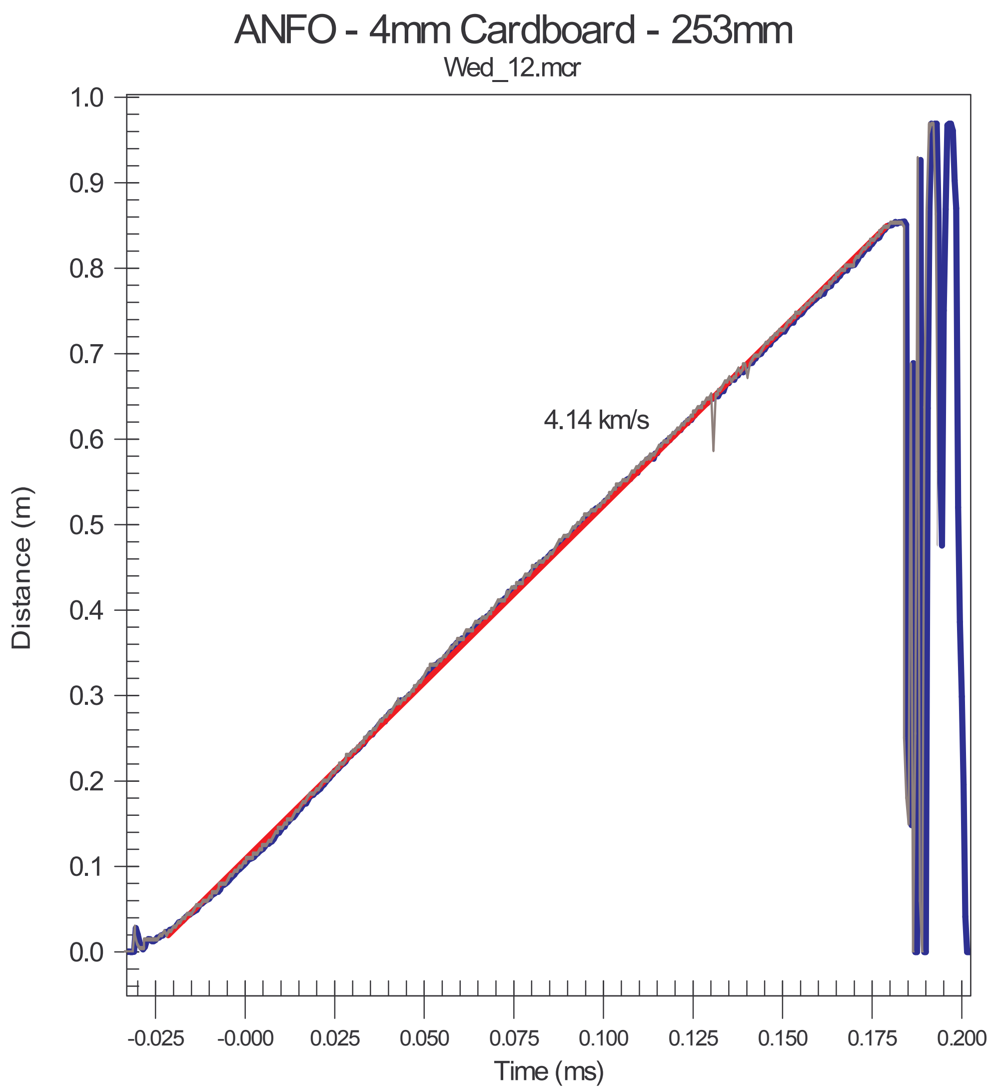
ANFO - 4mm Cardboard - 202.0mm
Tue_01.mcr
3.88 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20


ANFO - 4mm Cardboard - 202.0mm
Tue_02.mcr
3.60 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.1
0.00
0.05
0.10
0.15
0.20

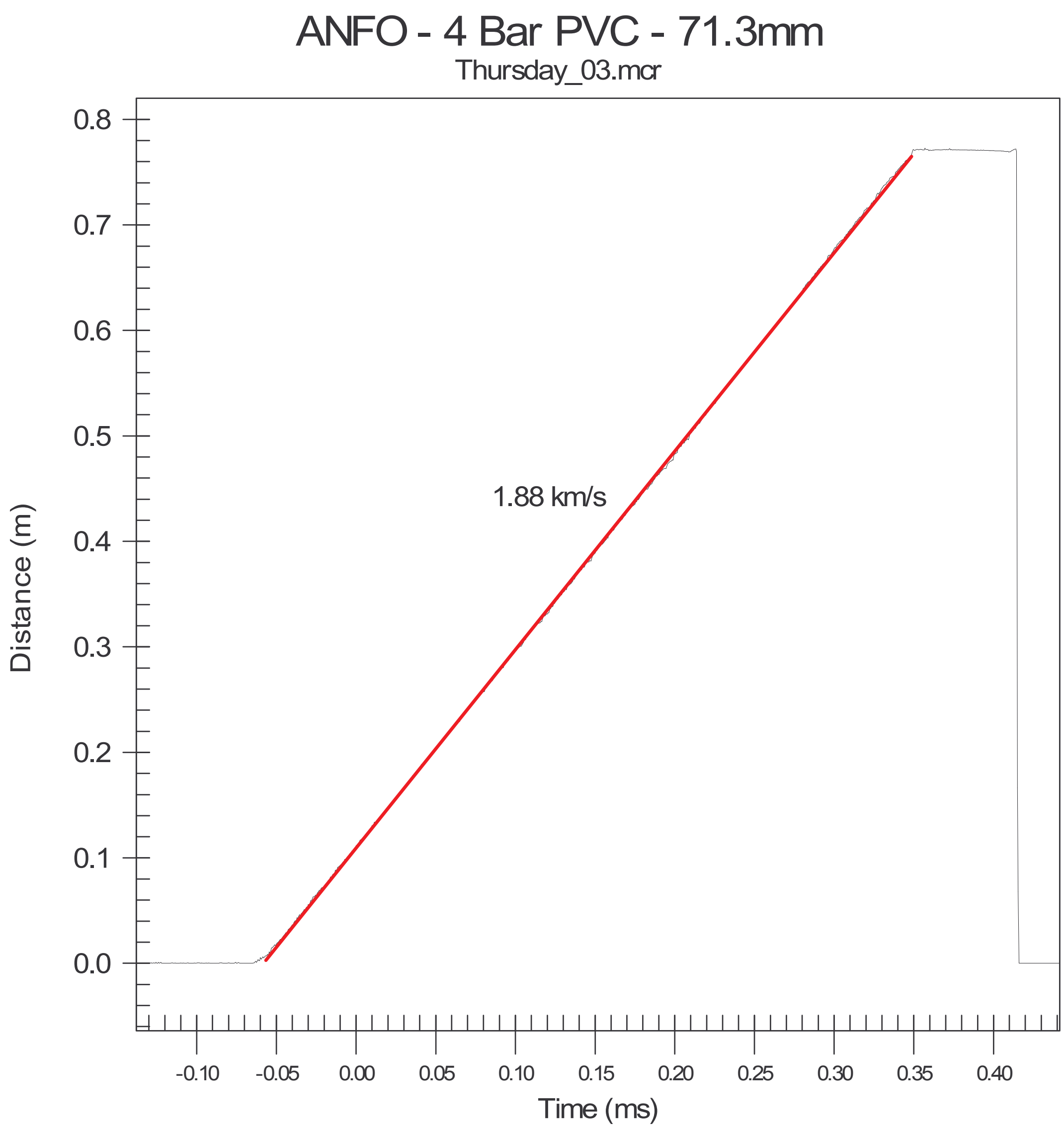

ANFO - 4mm Cardboard - 202.0mm
Tue_03.mcr
3.75 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.00
0.05
0.10
0.15
0.20
Time (ms)

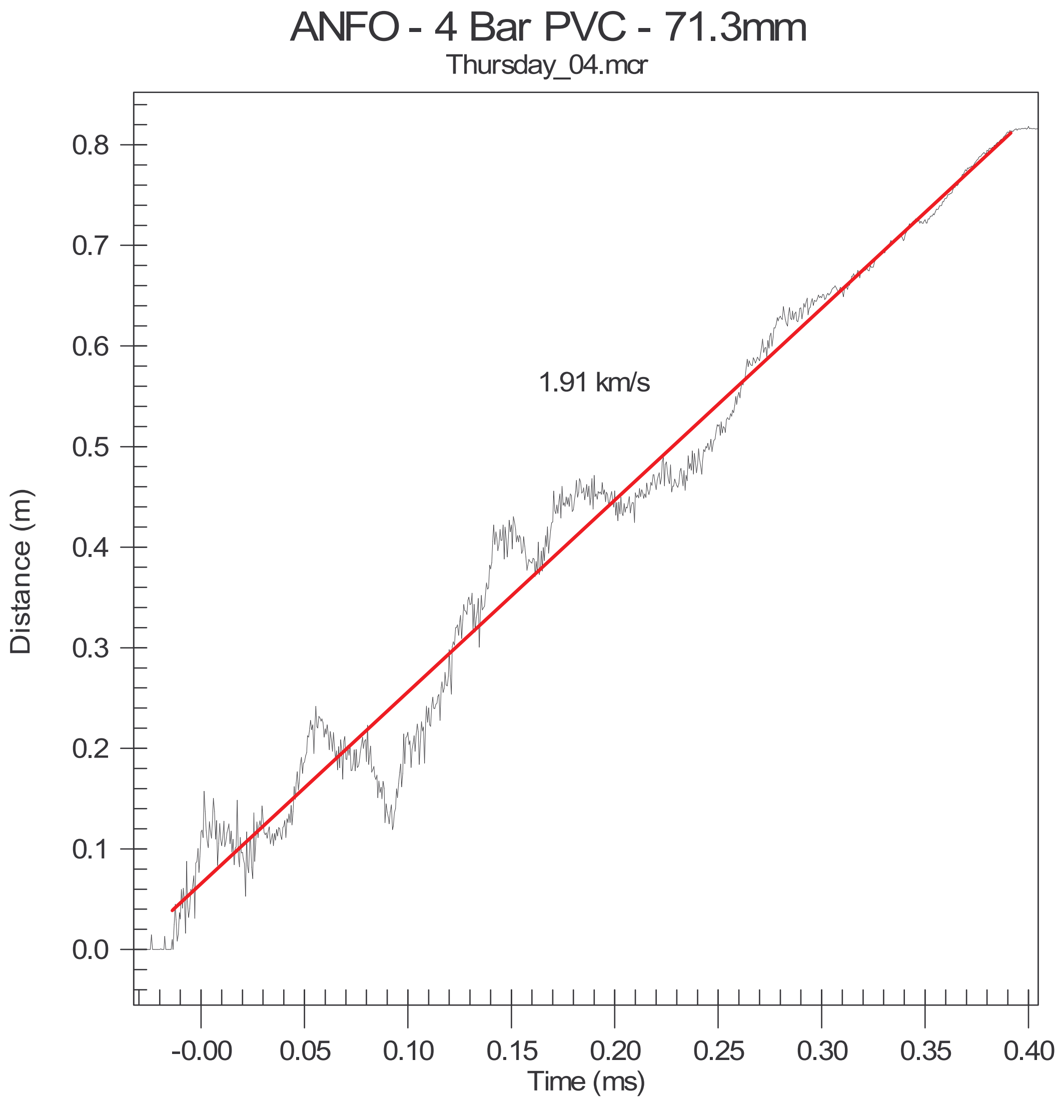

ANFO - 4mm Cardboard - 202.0mm
Tue_04.mcr
3.68 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20

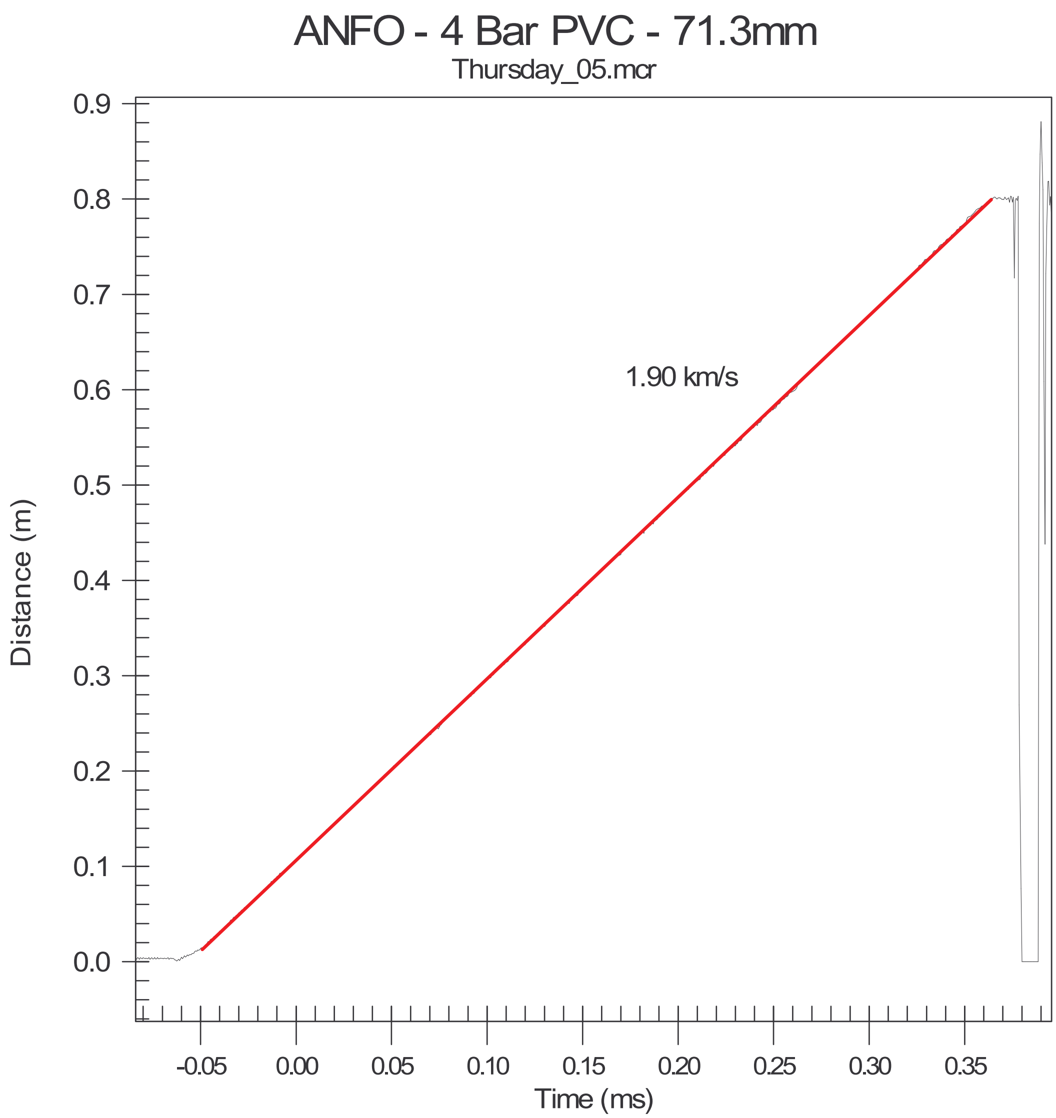

ANFO - 4mm Cardboard - 253mm
Wed_11.mcr
4.18 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.025
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175



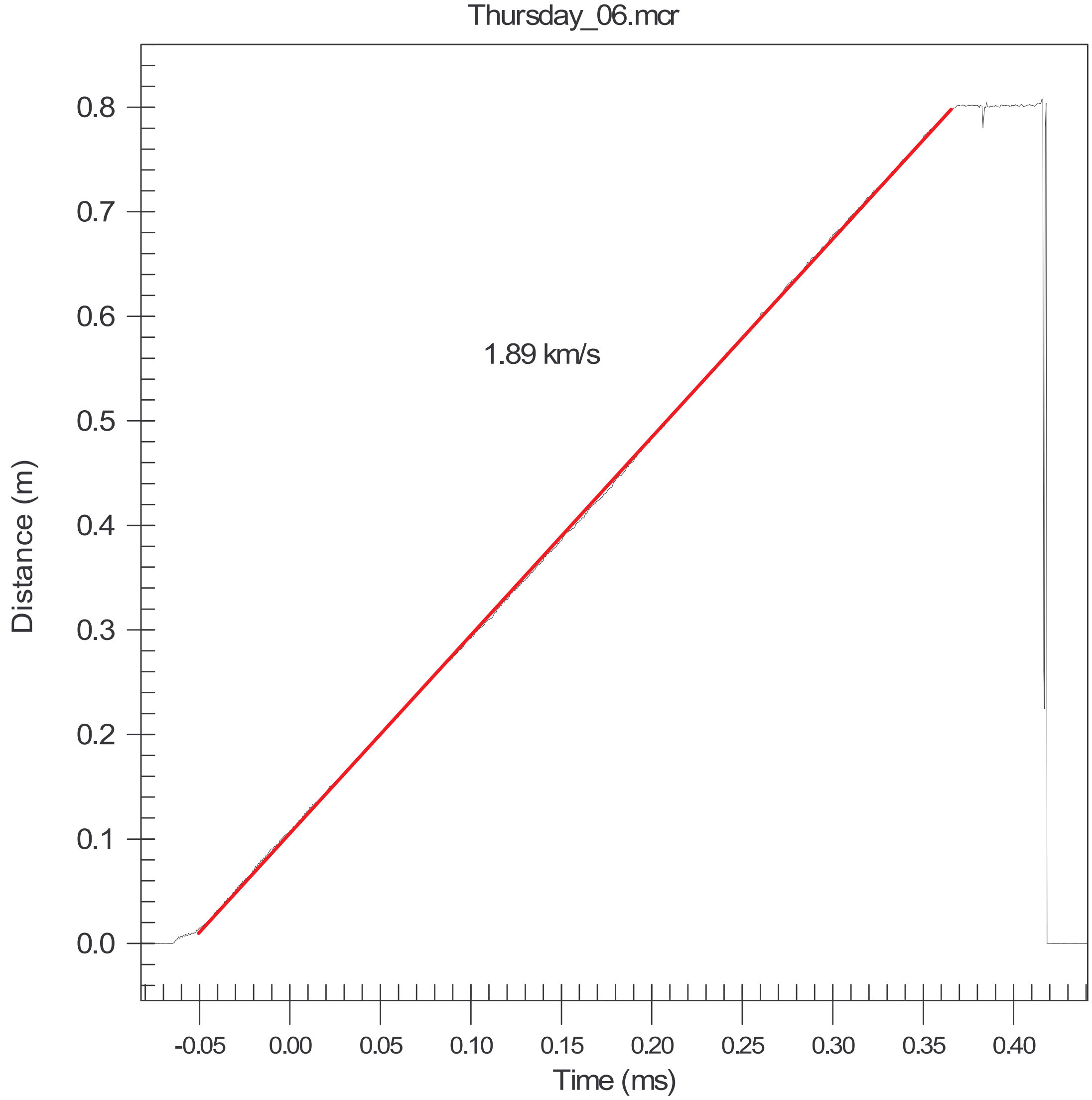
ANFO - 4mm Cardboard - 253mm
Wed_12.mcr
Distance (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
4.14 km/s
-0.025
-0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
Time (ms)

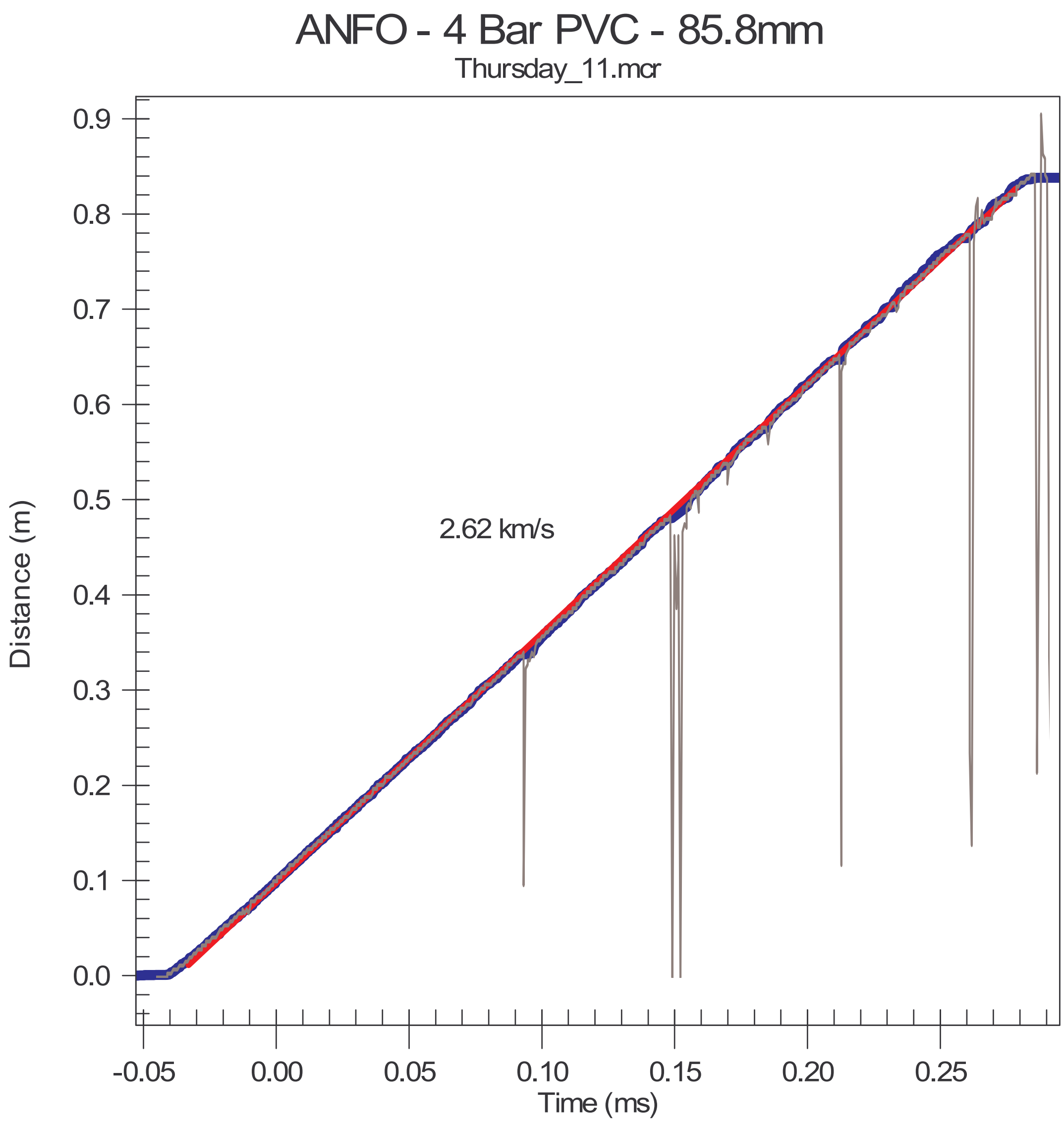

ANFO - 4 Bar PVC - 71.3mm
Thursday_03.mcr
1.88 km/s
Distance (m)
Time (ms)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

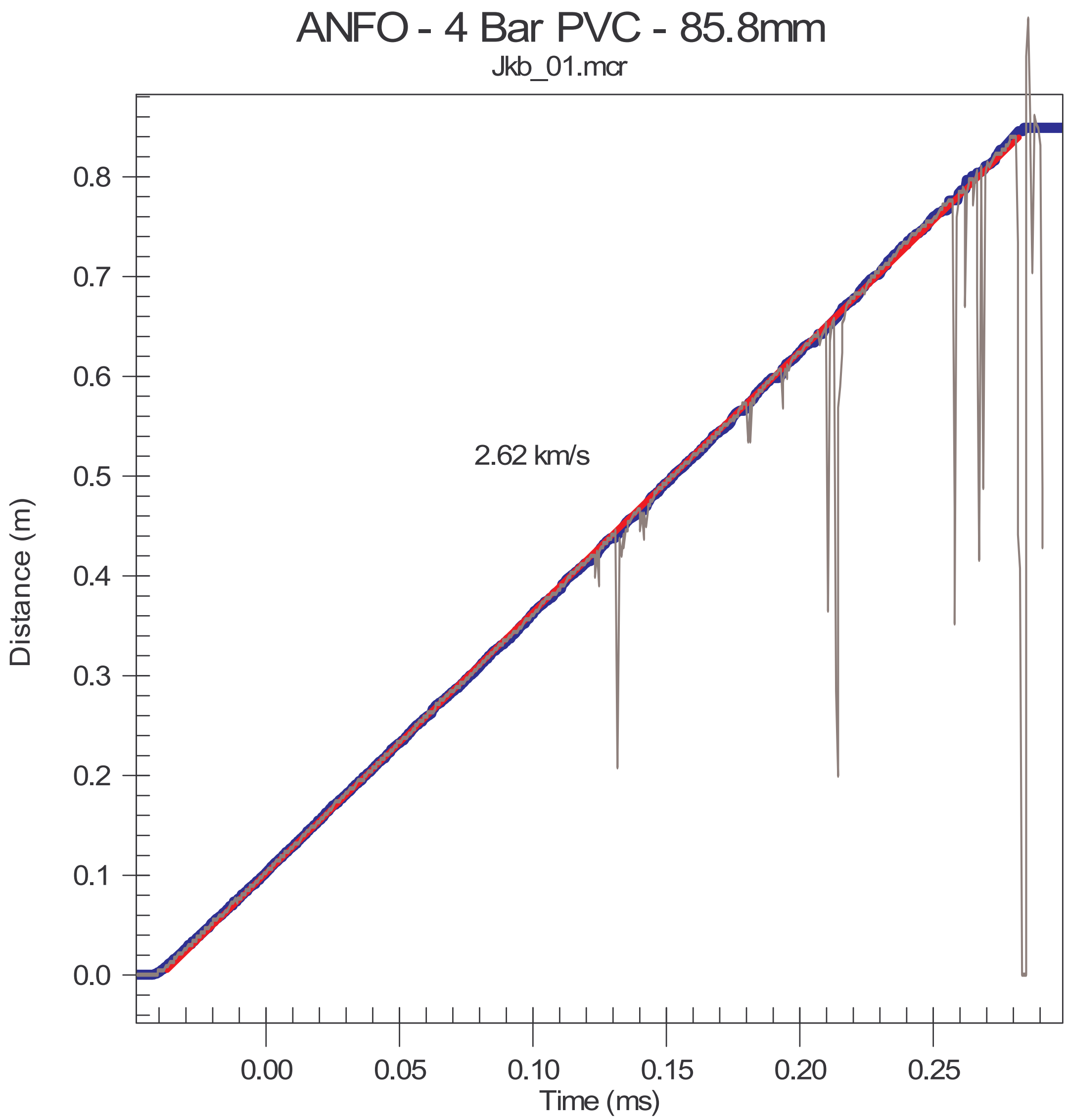

ANFO - 4 Bar PVC - 71.3mm
Thursday_04.mcr
1.91 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Time (ms)
-0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40

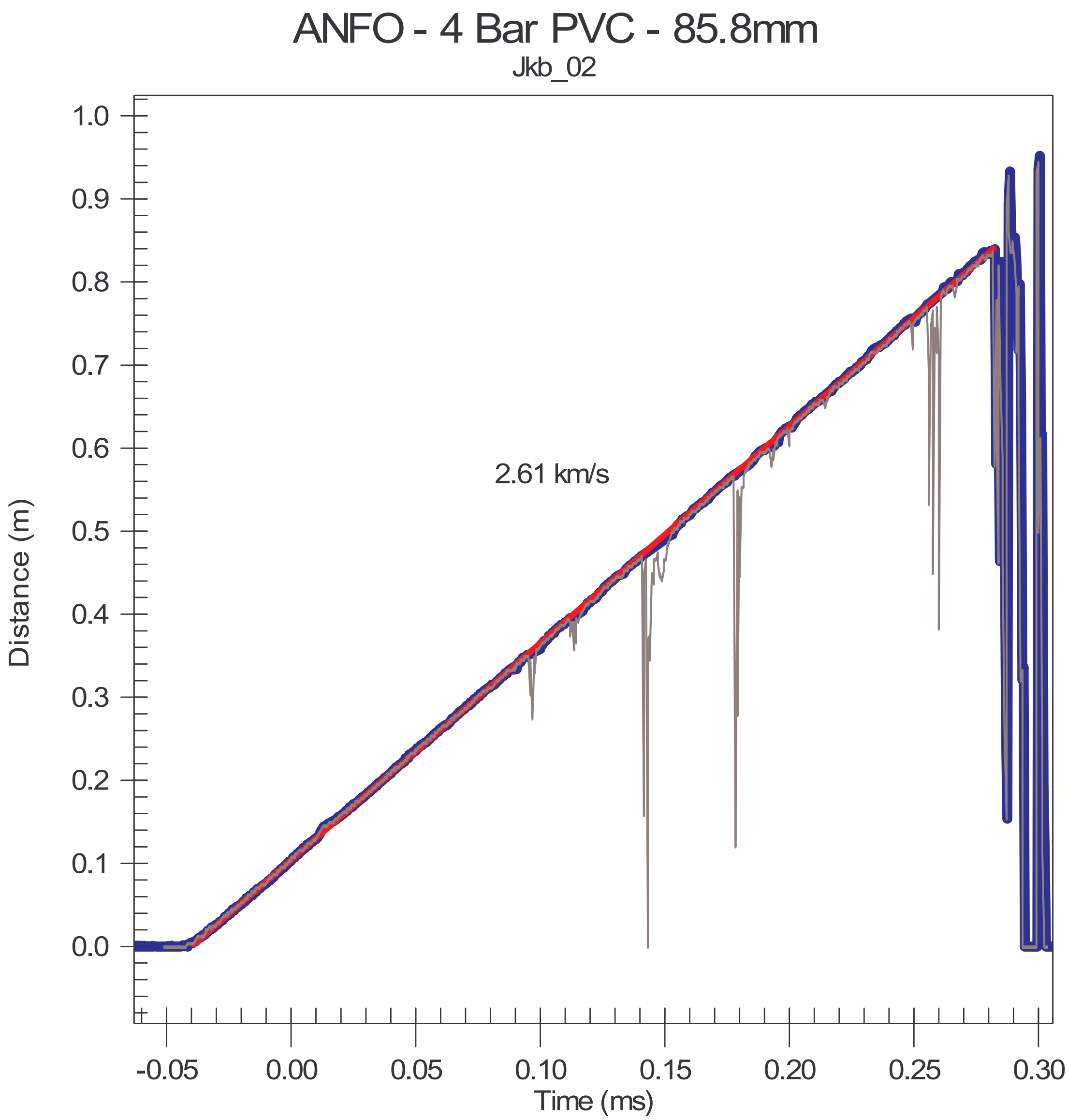

ANFO - 4 Bar PVC - 71.3mm
Thursday_05.mcr
1.90 km/s
Distance (m)
Time (ms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

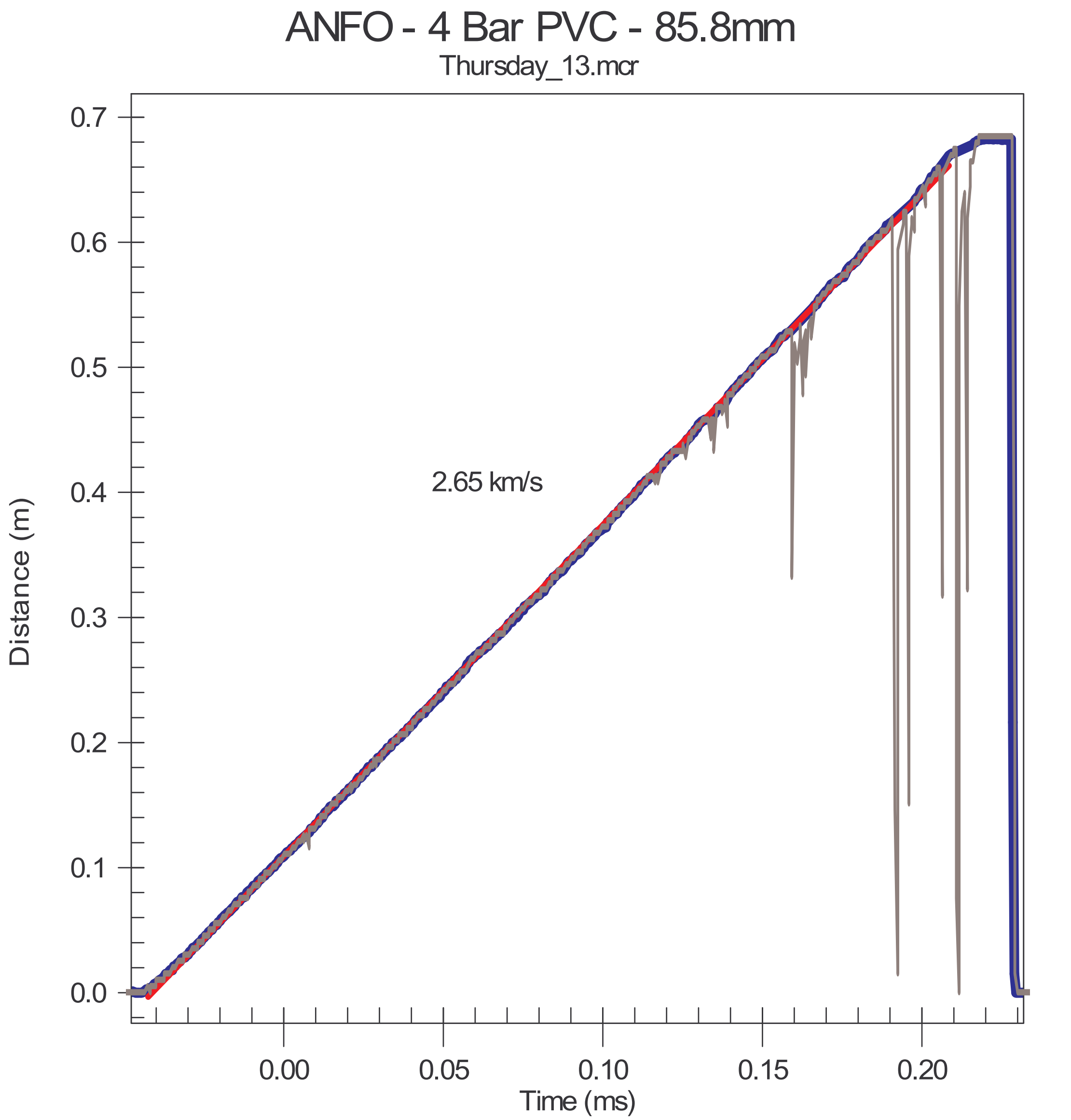
ANFO - 4 Bar PVC - 71.3mm

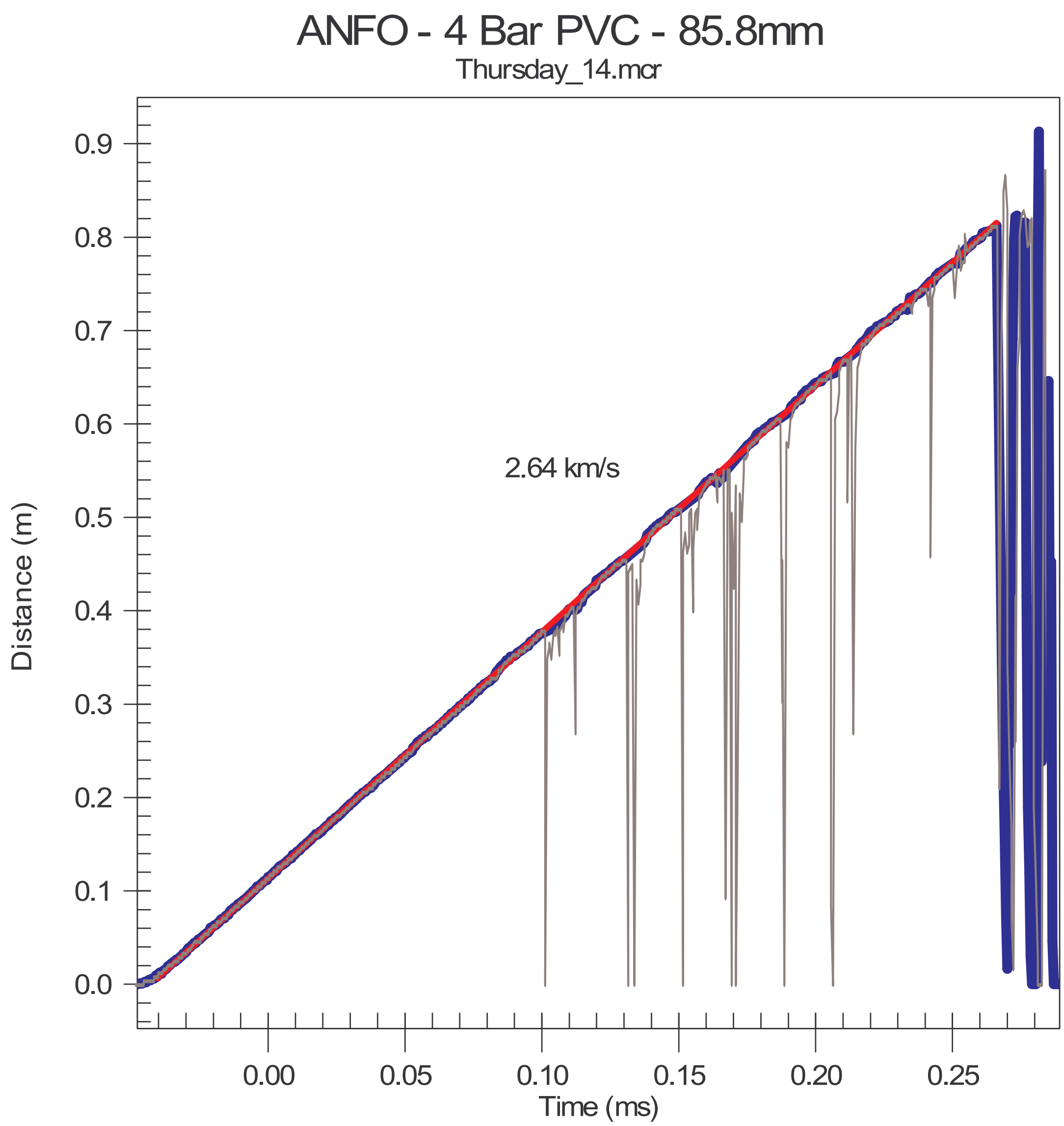



ANFO - 4 Bar PVC - 85.8mm
Thursday_11.mcr
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.62 km/s
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

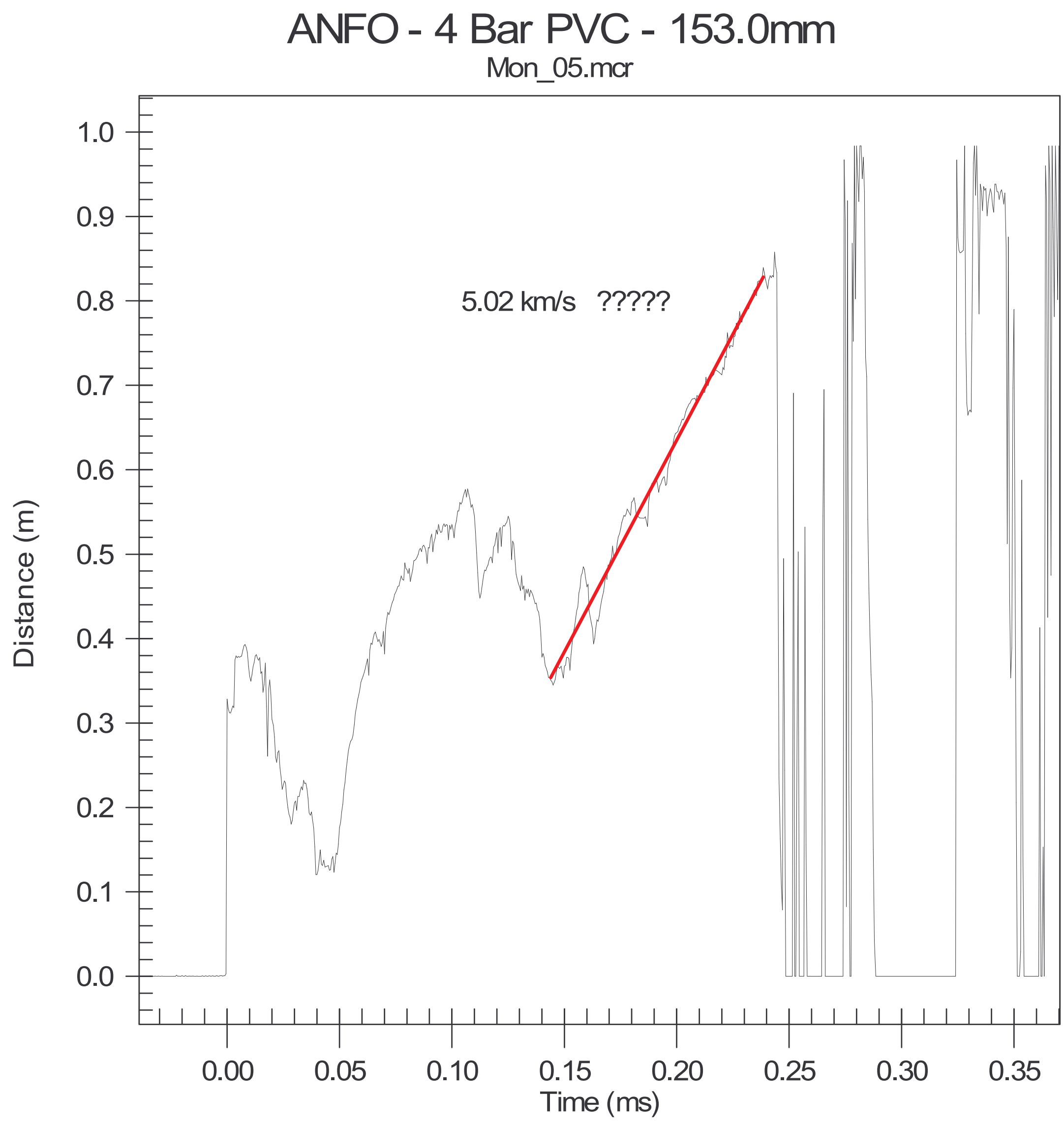

ANFO - 4 Bar PVC - 85.8mm
Jkb_01.mcr
2.62 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
Time (ms)
0.00
0.05
0.10
0.15
0.20
0.25

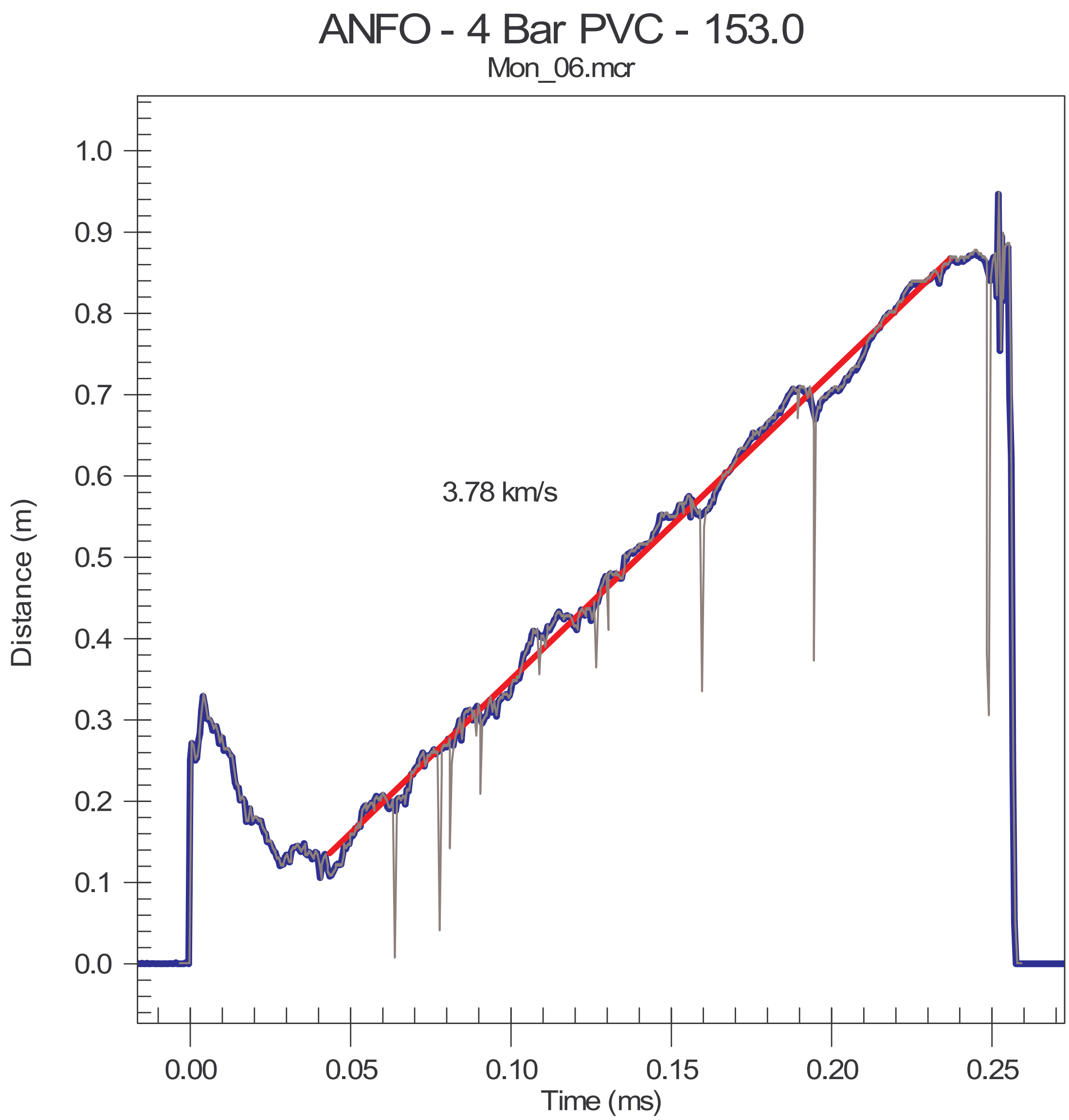

ANFO - 4 Bar PVC - 85.8mm
Jkb_02
2.61 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

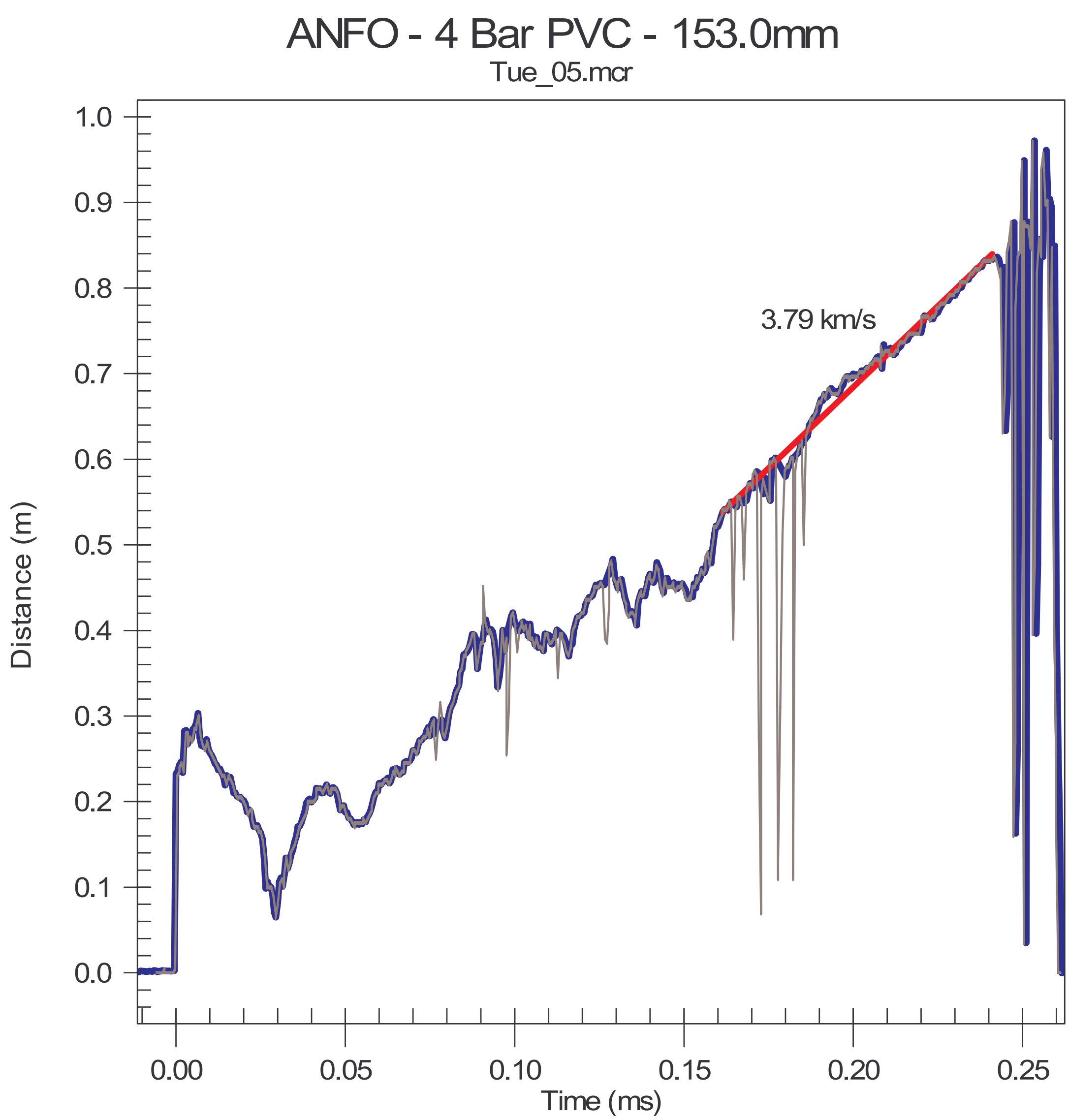

ANFO - 4 Bar PVC - 85.8mm
Thursday_13.mcr
2.65 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.00
0.05
0.10
0.15
0.20

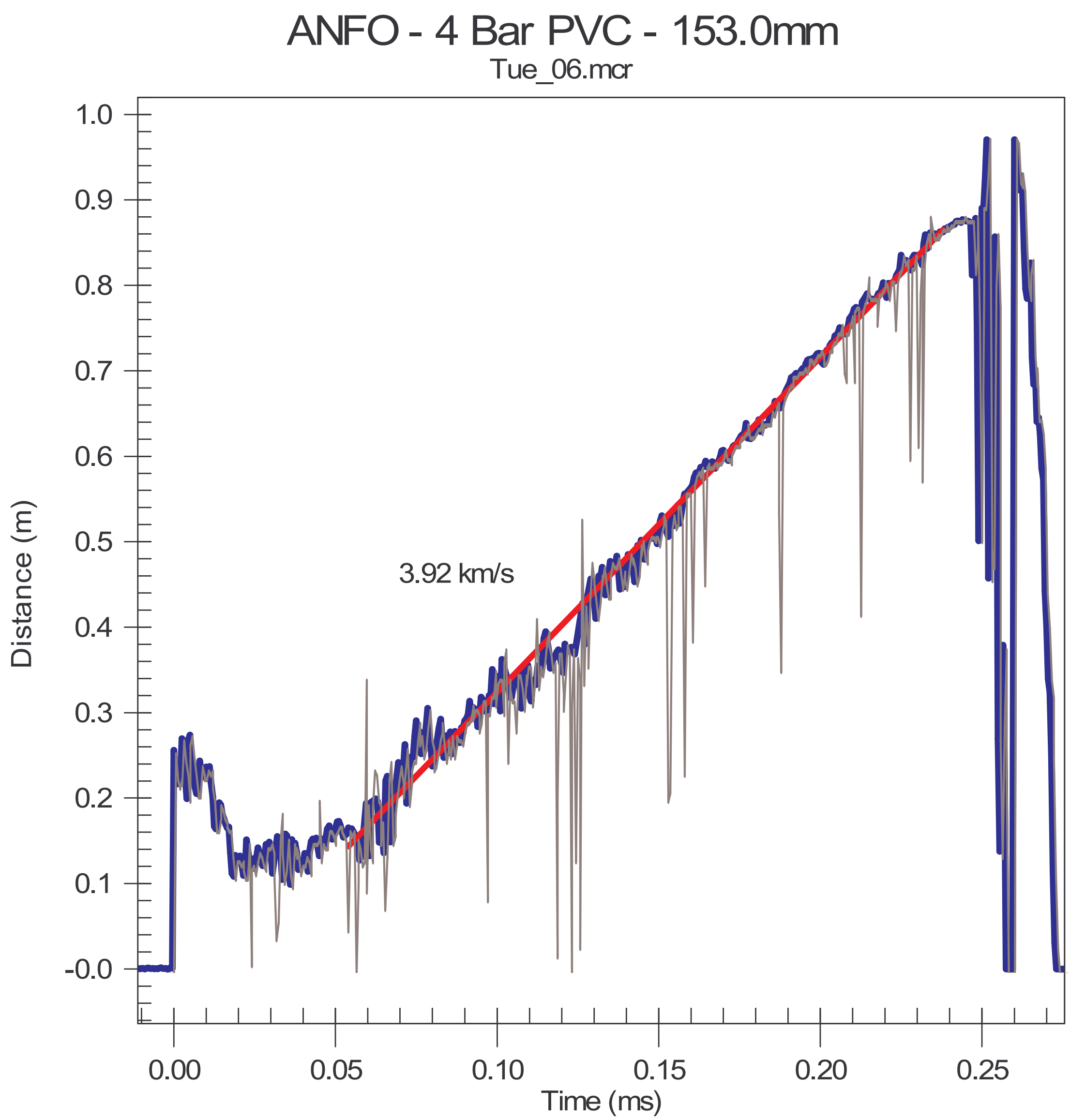


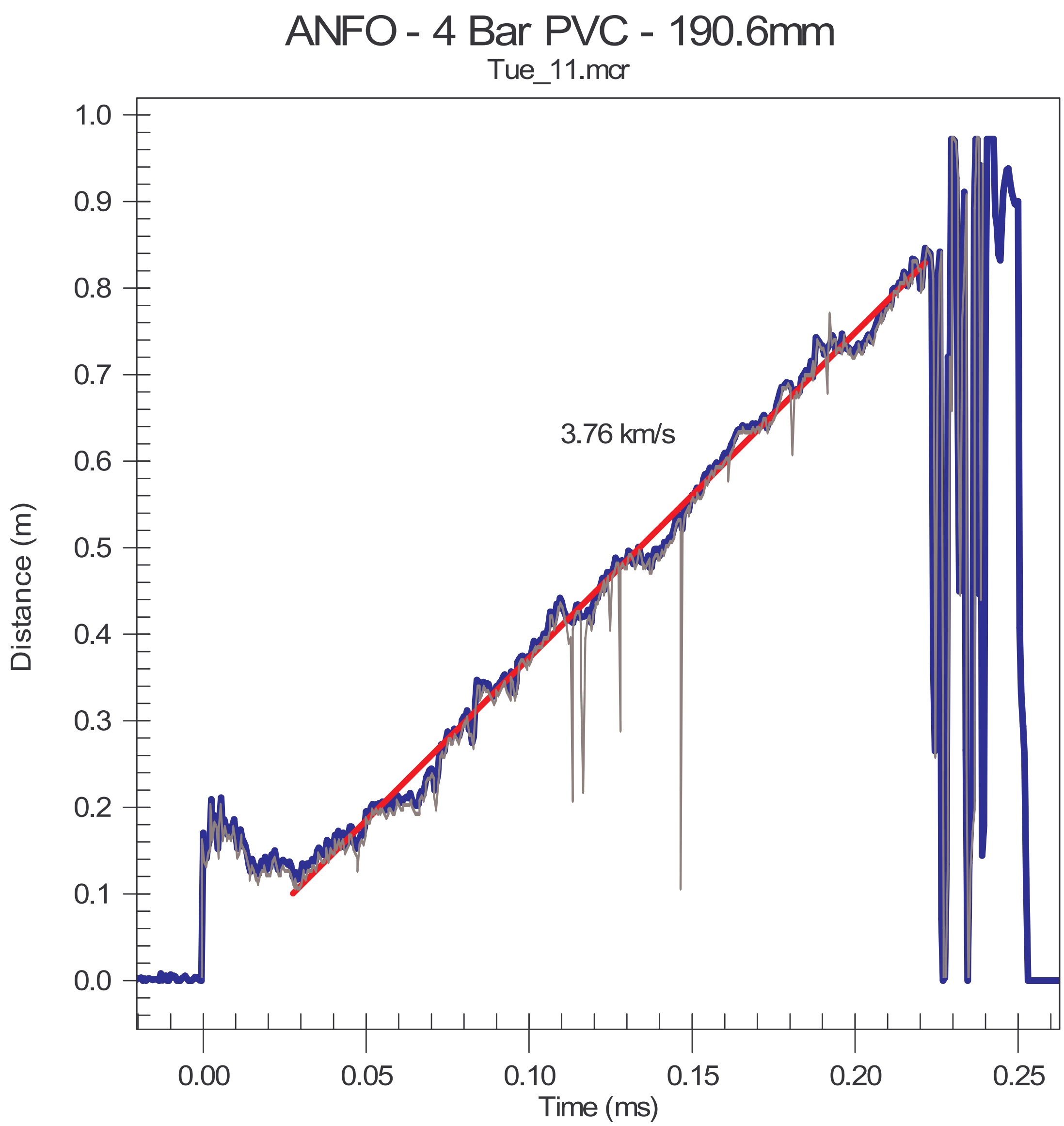
ANFO - 4 Bar PVC - 85.8mm
Thursday_14.mcr
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
2.64 km/s
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

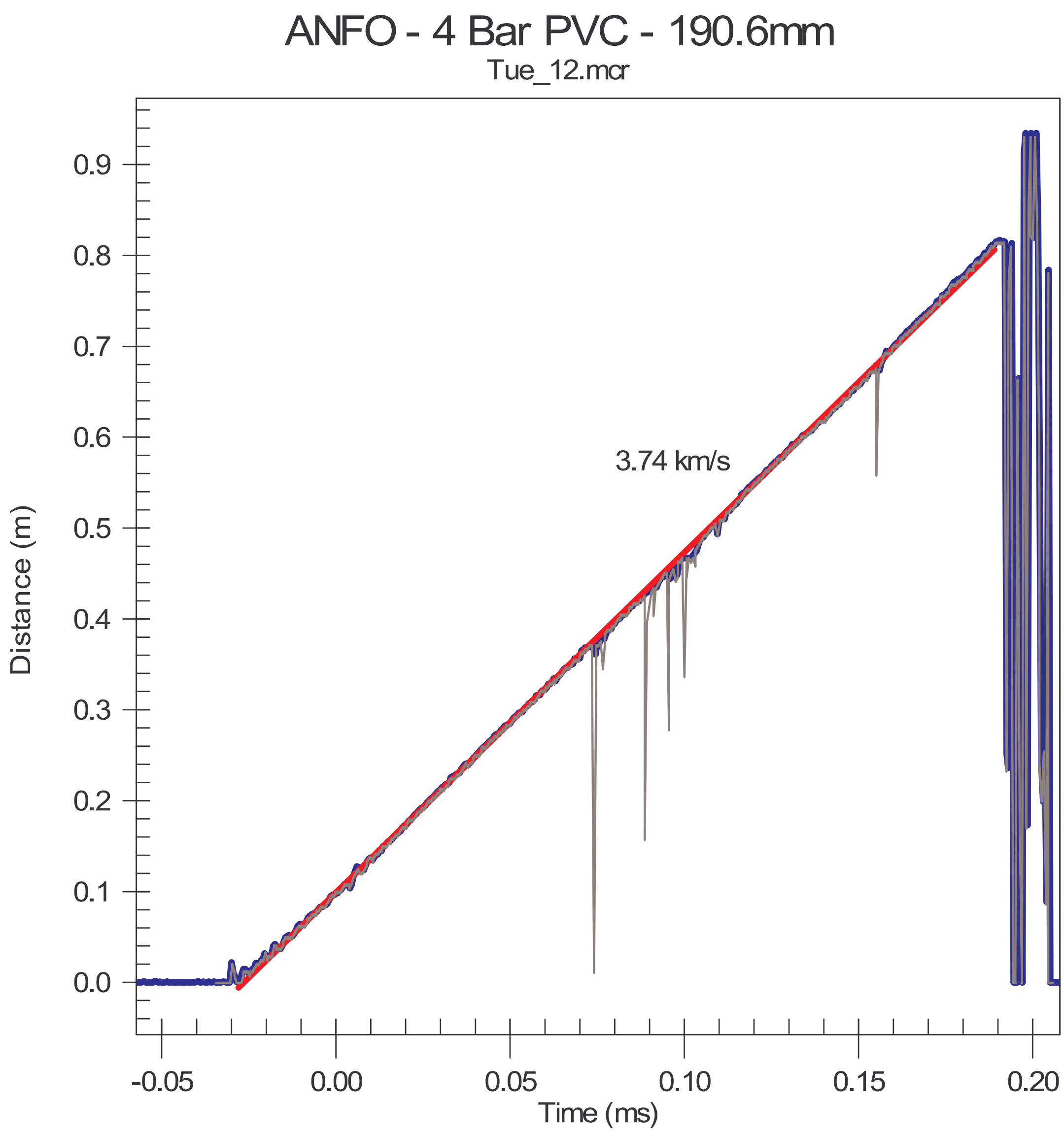

ANFO - 4 Bar PVC - 153.0mm
Mon_05.mcr
5.02 km/s ?????
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35

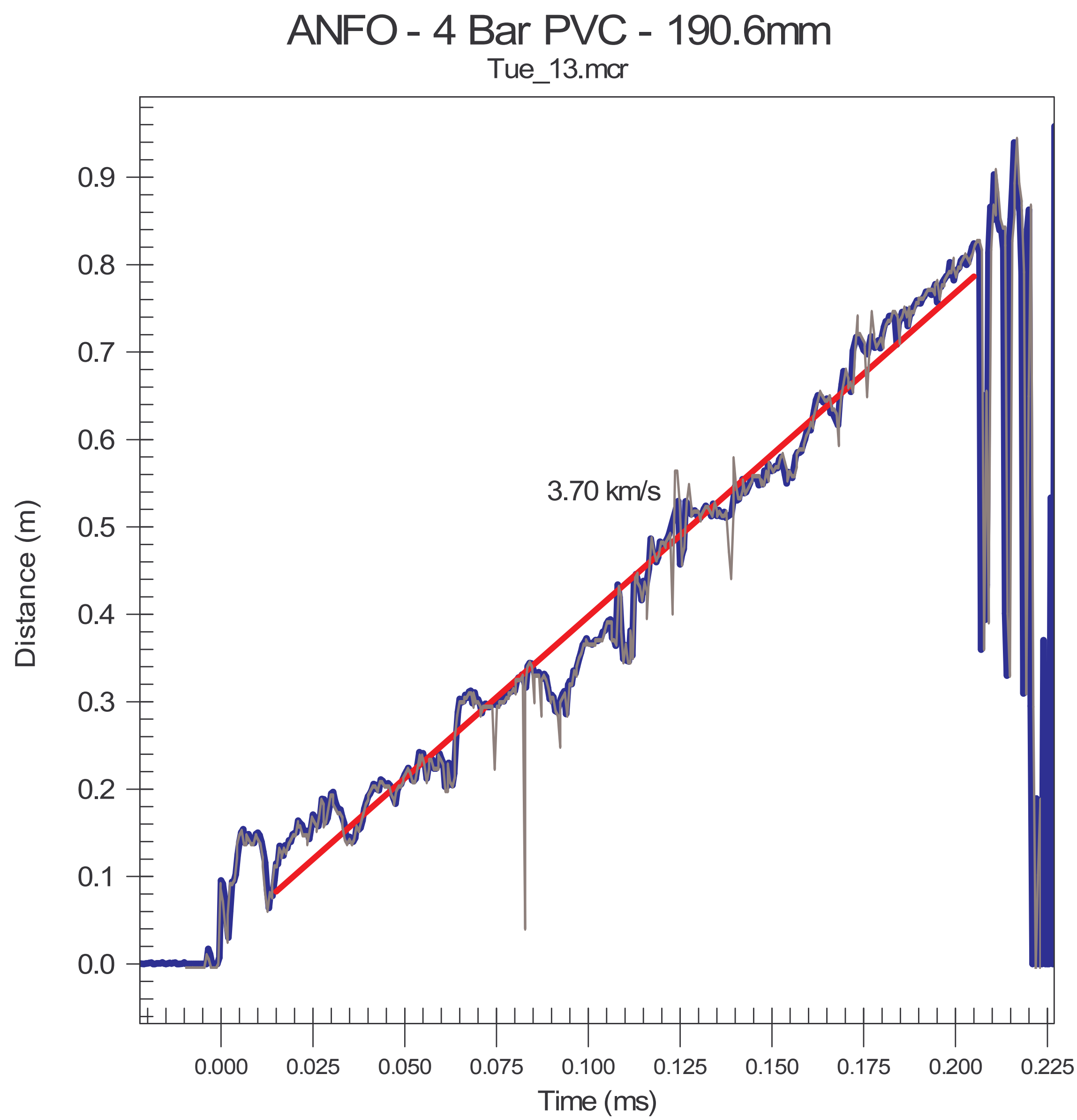

ANFO - 4 Bar PVC - 153.0
Mon_06.mcr
Distance (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3.78 km/s
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)


ANFO - 4 Bar PVC - 153.0mm
Tue_05.mcr
3.79 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25

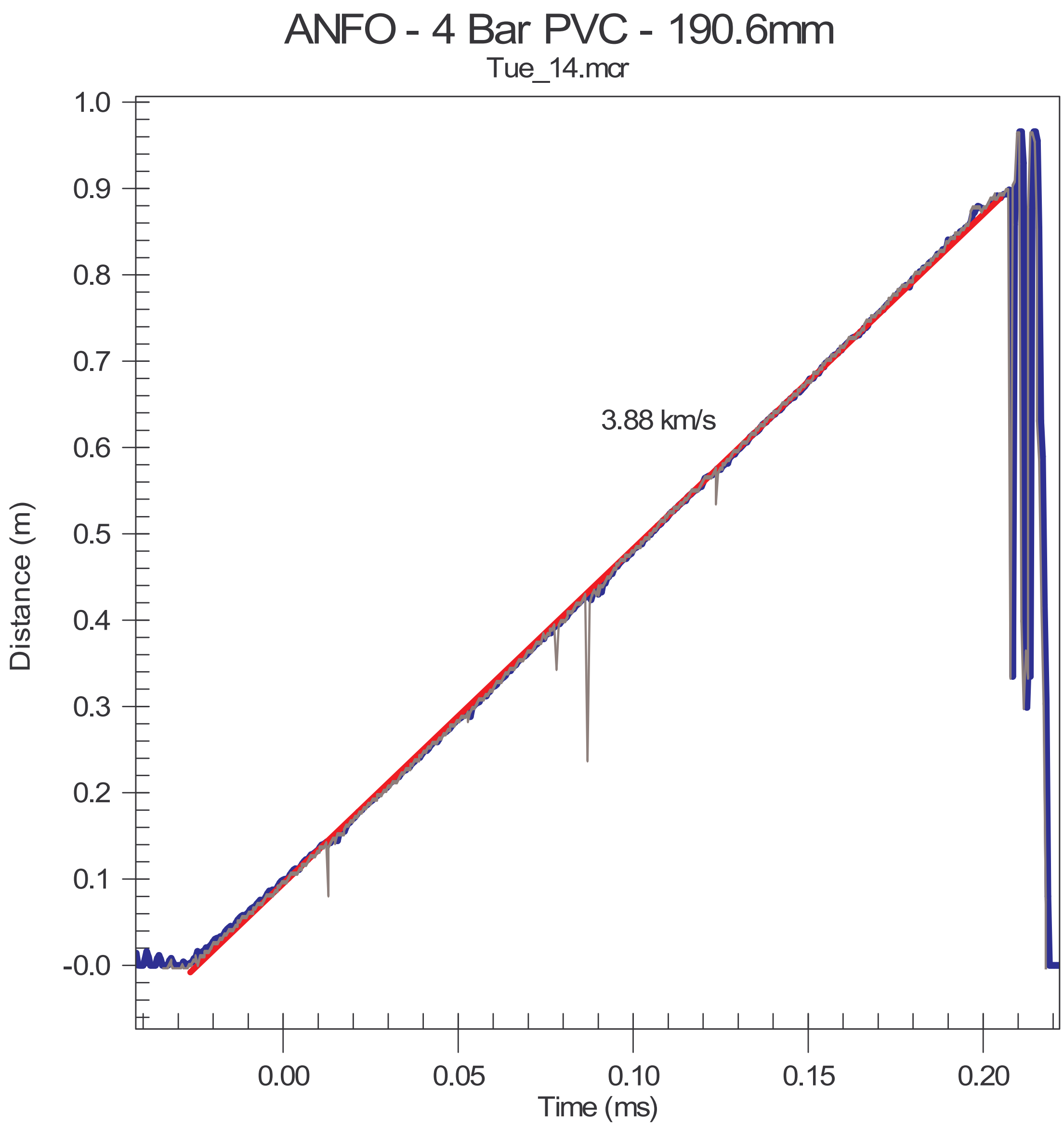

ANFO - 4 Bar PVC - 153.0mm
Tue_06.mcr
Distance (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
3.92 km/s
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

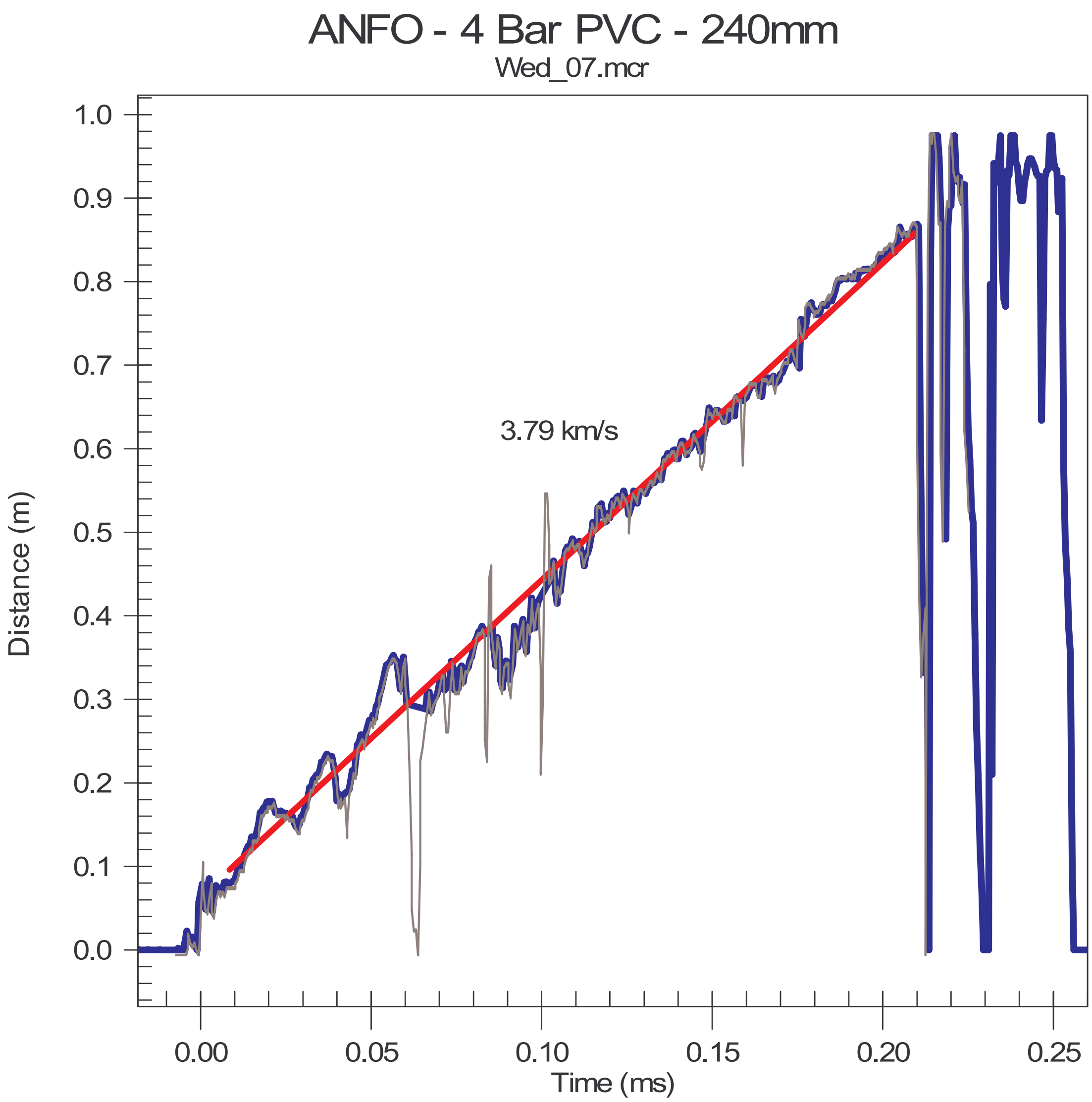

ANFO - 4 Bar PVC - 190.6mm
Tue_11.mcr
Distance (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3.76 km/s
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

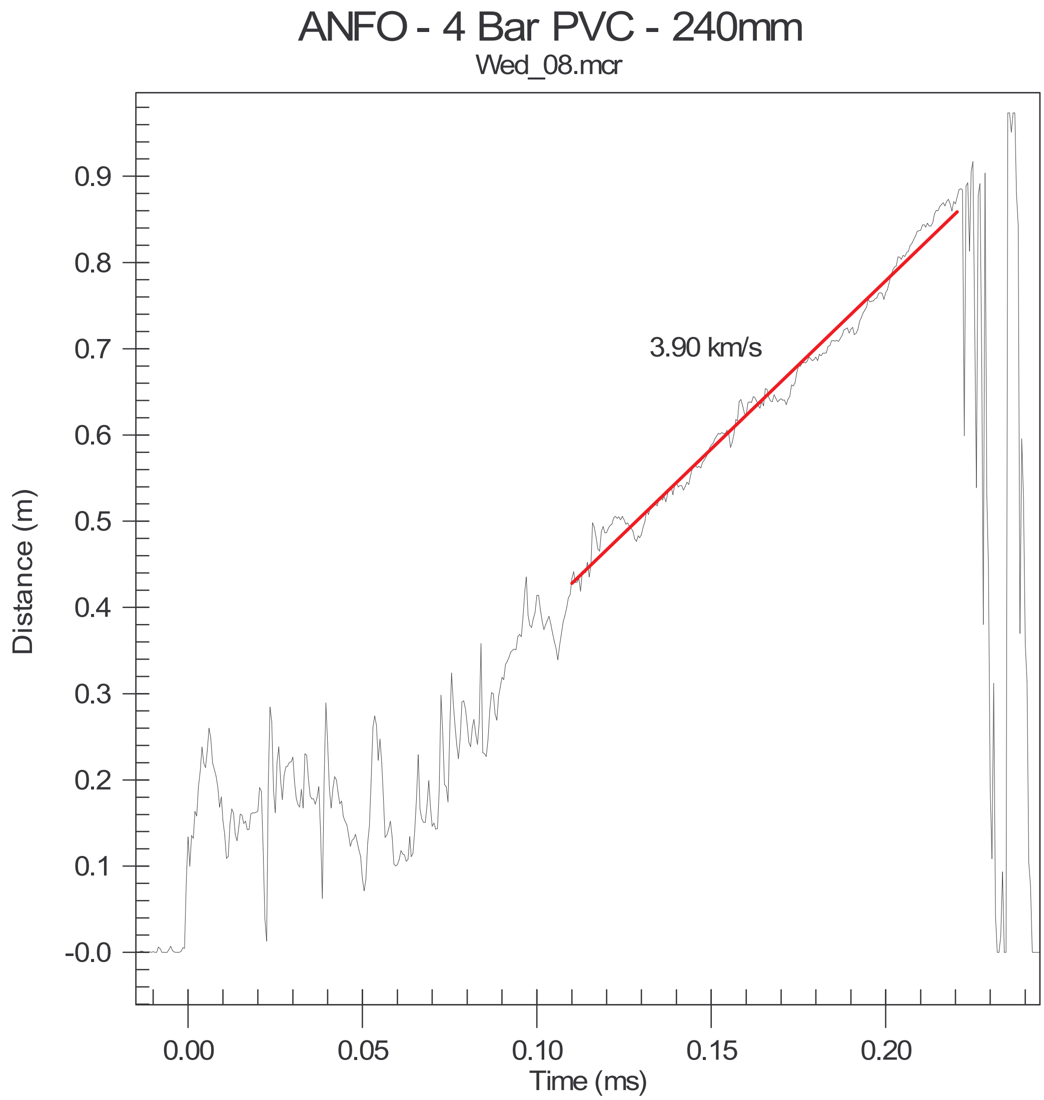

ANFO - 4 Bar PVC - 190.6mm
Tue_12.mcr
3.74 km/s
Distance (m)
Time (ms)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20



ANFO - 4 Bar PVC - 190.6mm
Tue_13.mcr
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3.70 km/s
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
0.225
Time (ms)

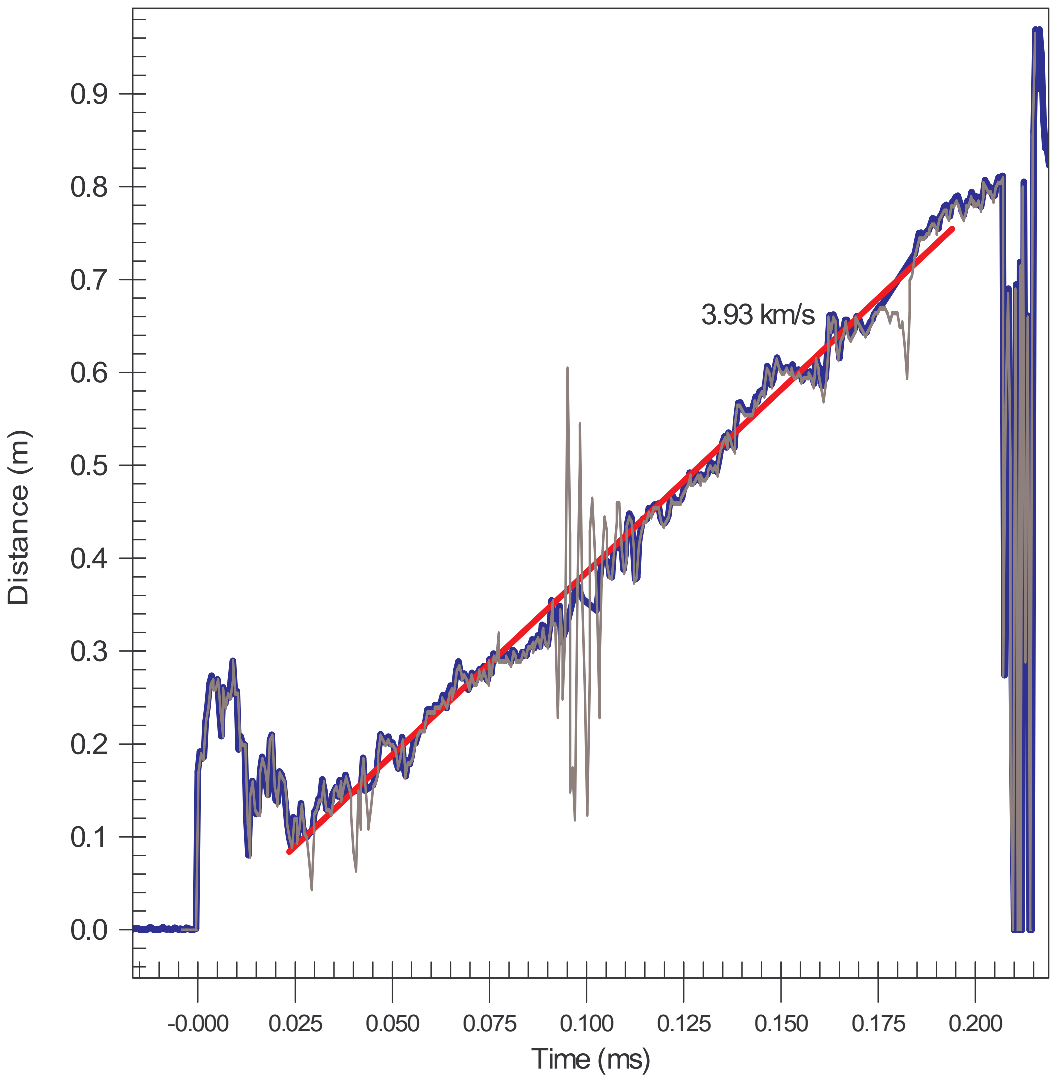

ANFO - 4 Bar PVC - 190.6mm
Tue_14.mcr
3.88 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
0.00
0.05
0.10
0.15
0.20

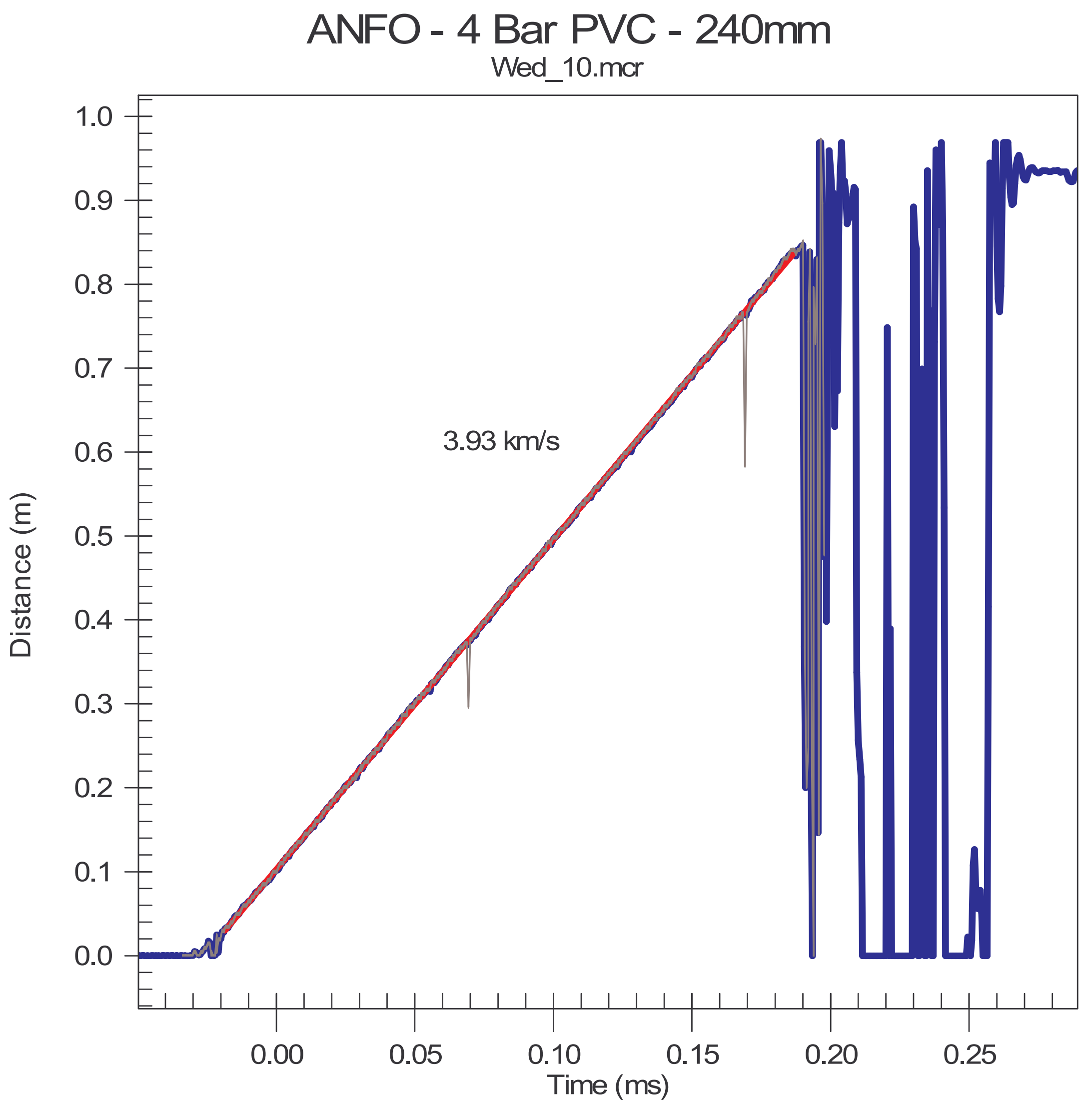

ANFO - 4 Bar PVC - 240mm
Wed_07.mcr
3.79 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25


ANFO - 4 Bar PVC - 240mm
Wed_08.mcr
3.90 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
0.00
0.05
0.10
0.15
0.20
Time (ms)

ANFO - 4 Bar PVC - 240mm

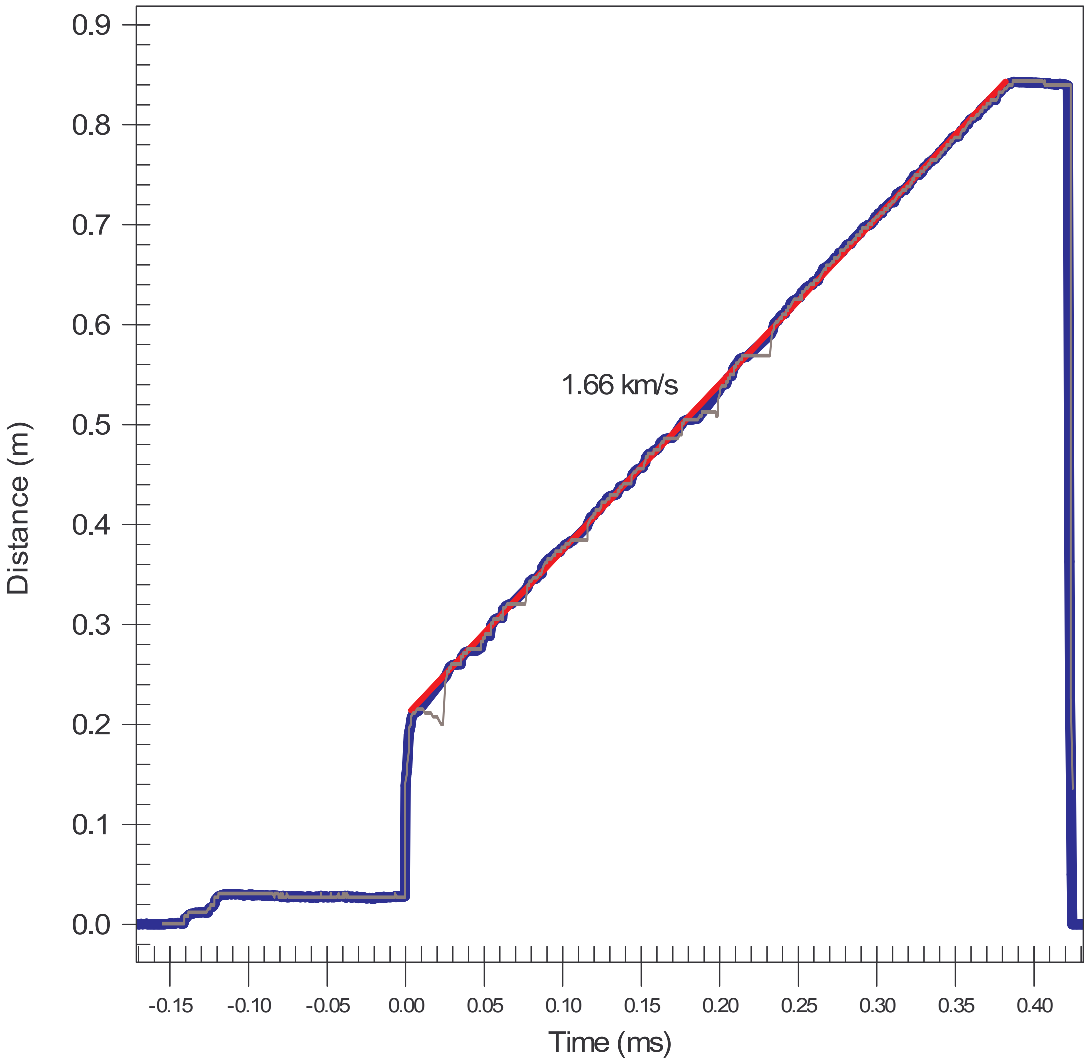
Wed_09.mcr

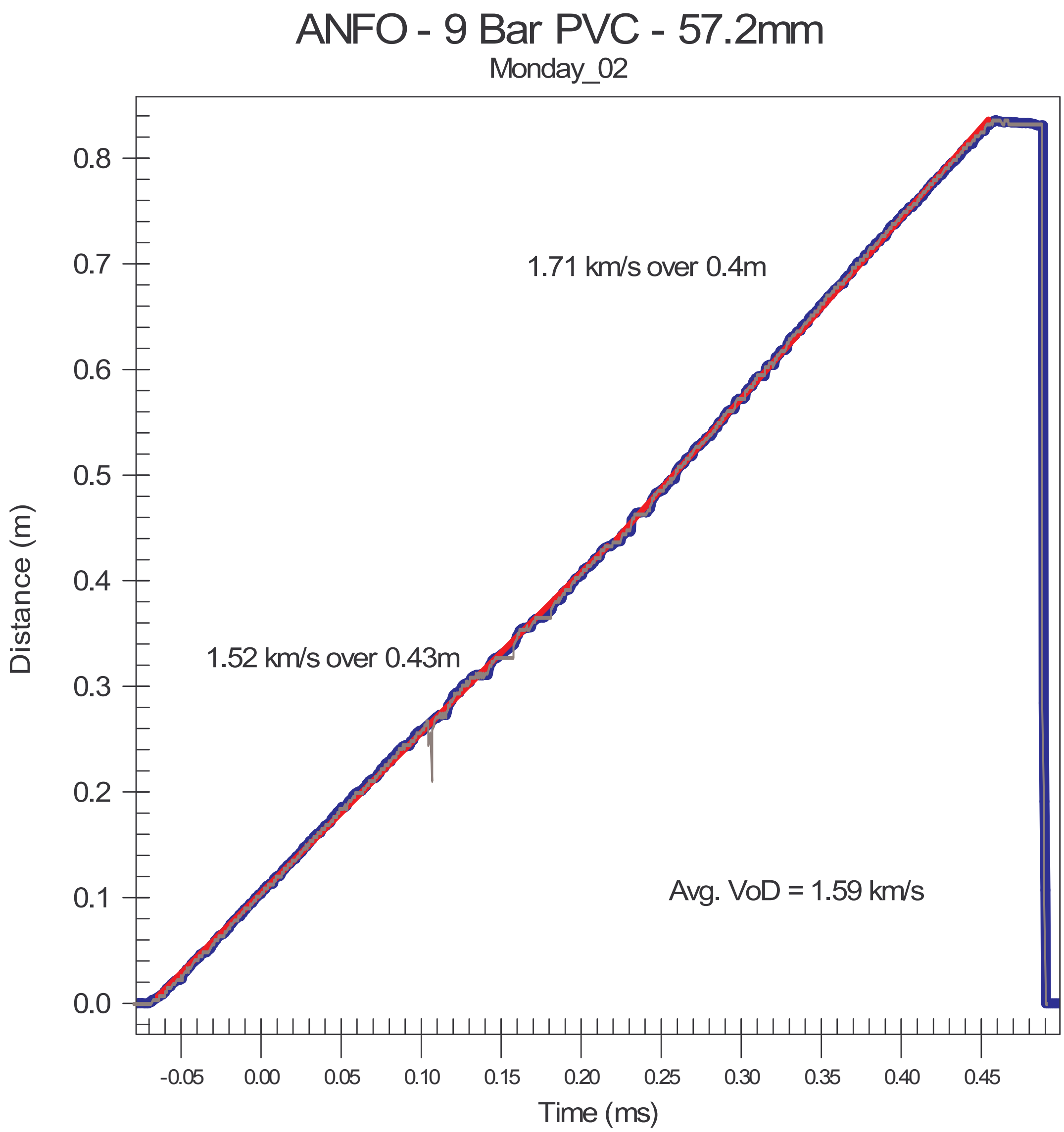



ANFO - 4 Bar PVC - 240mm
Wed_10.mcr
3.93 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25

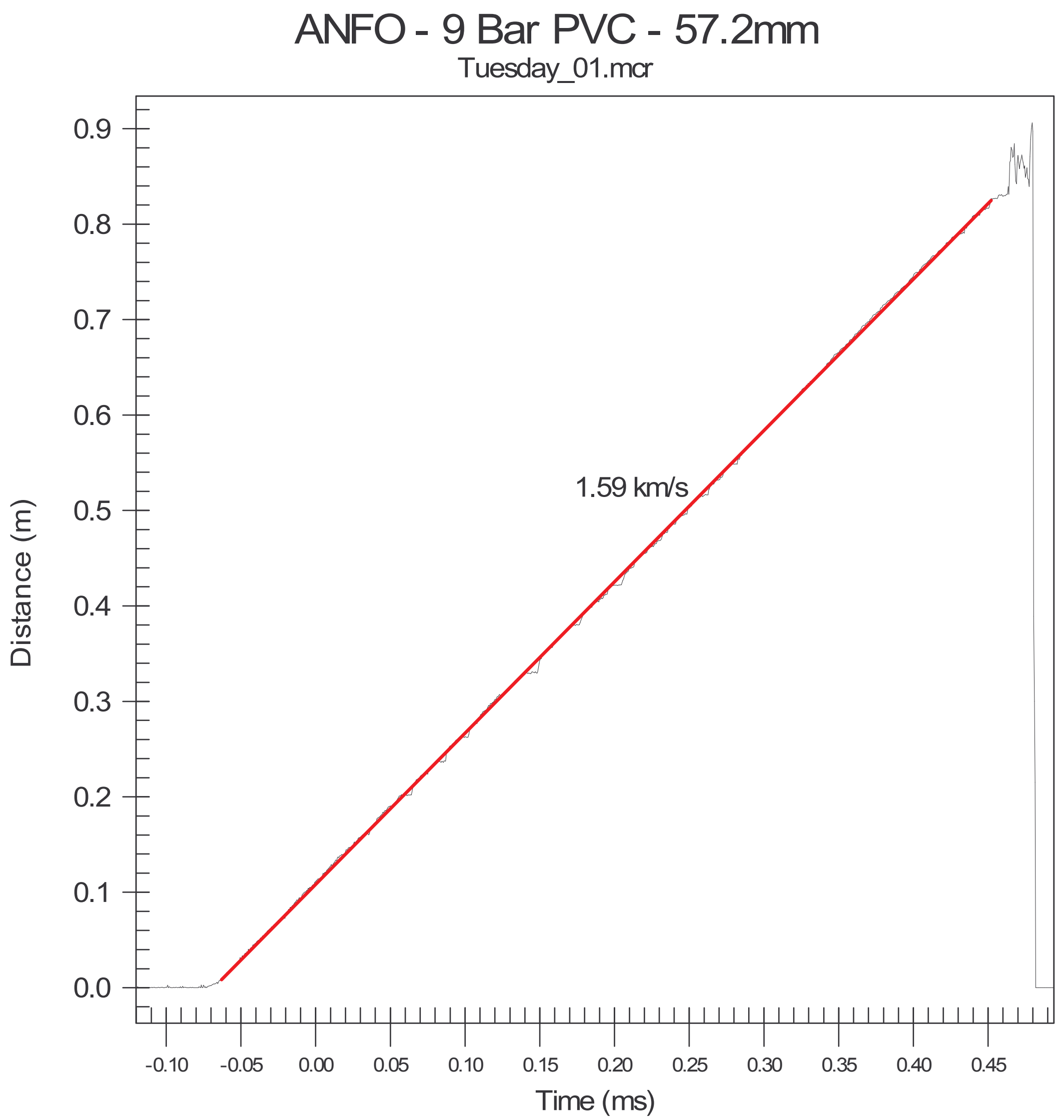
ANFO - 9 Bar PVC - 57.2mm

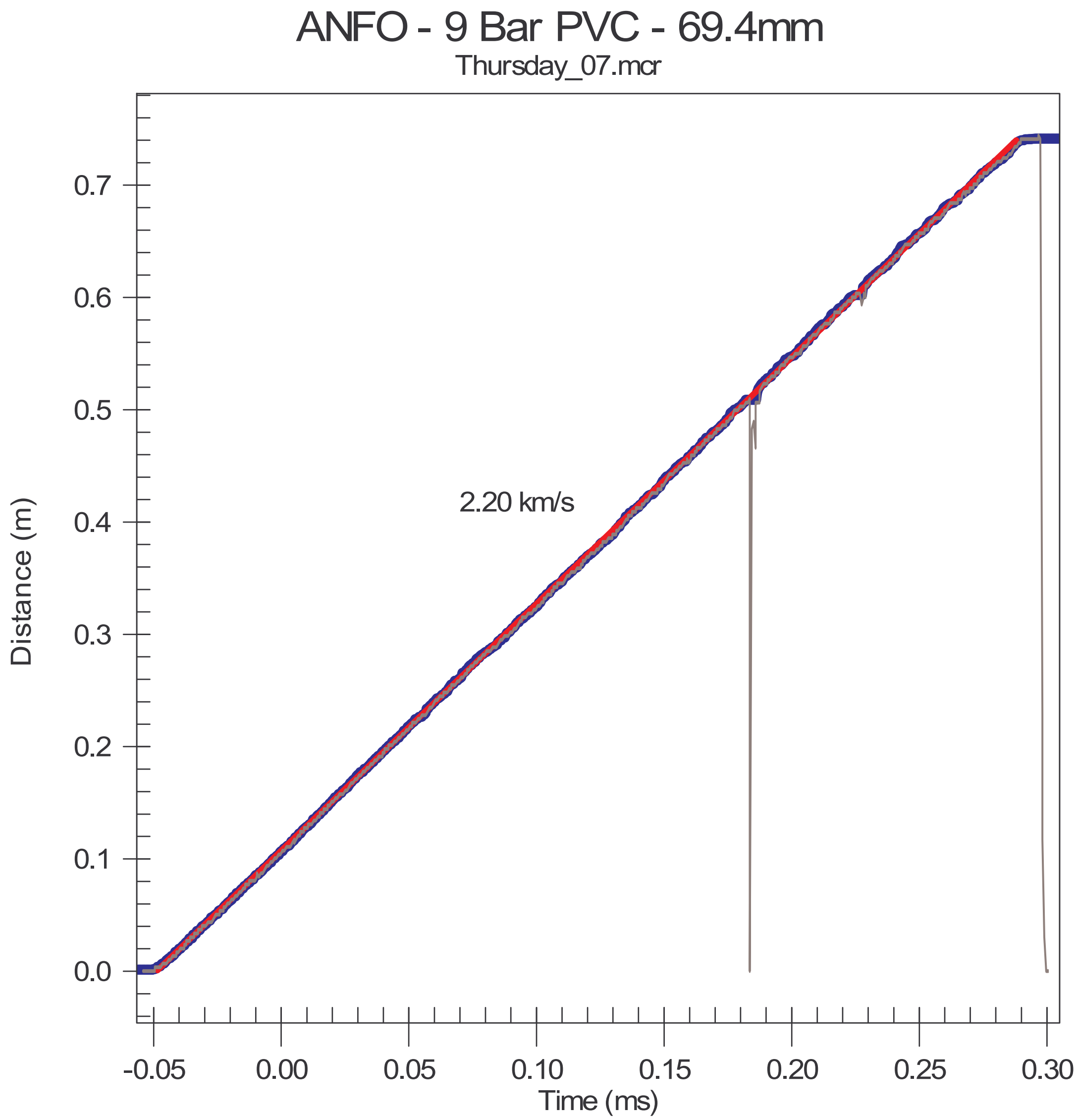
Monday_01.mcr



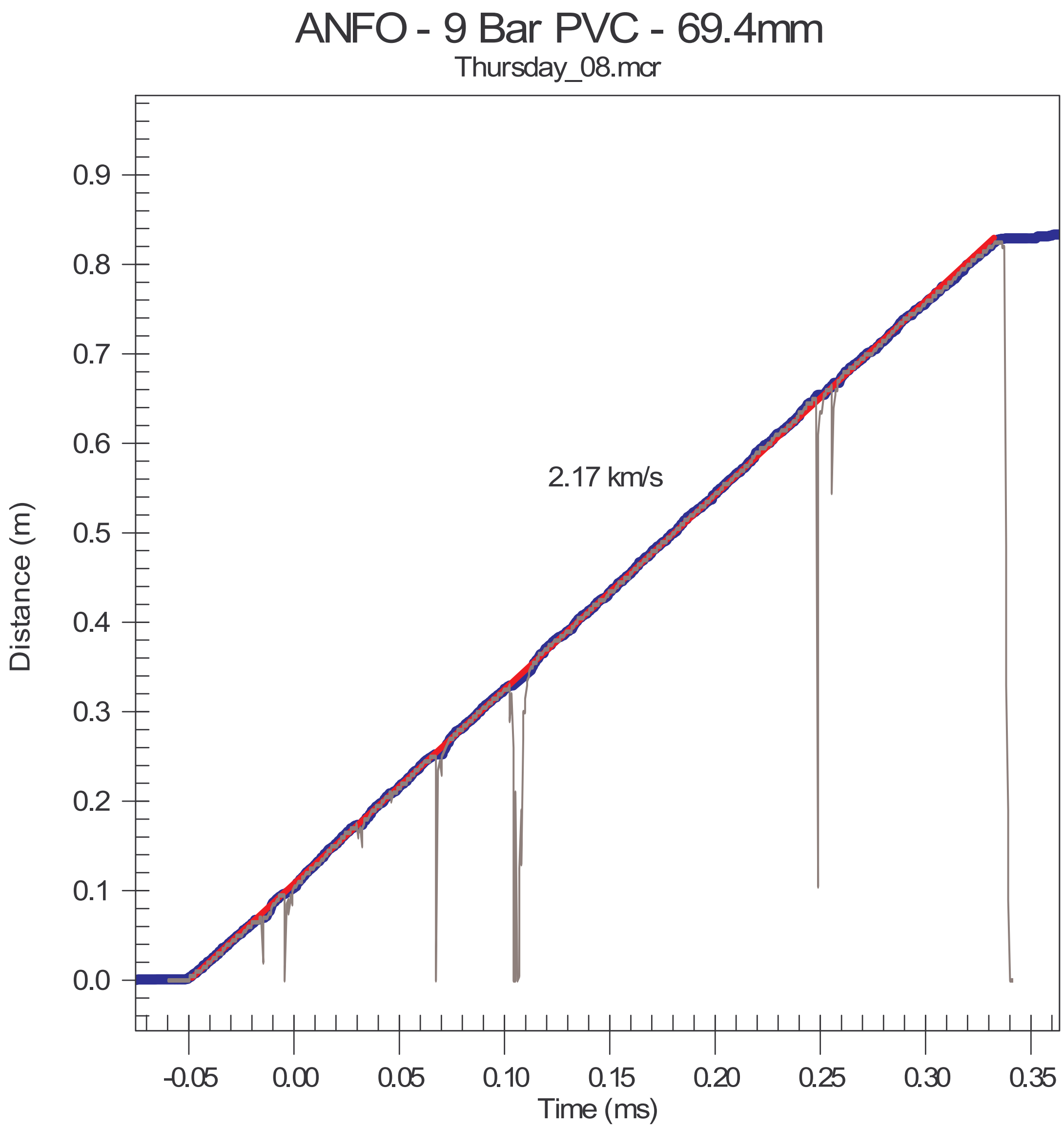


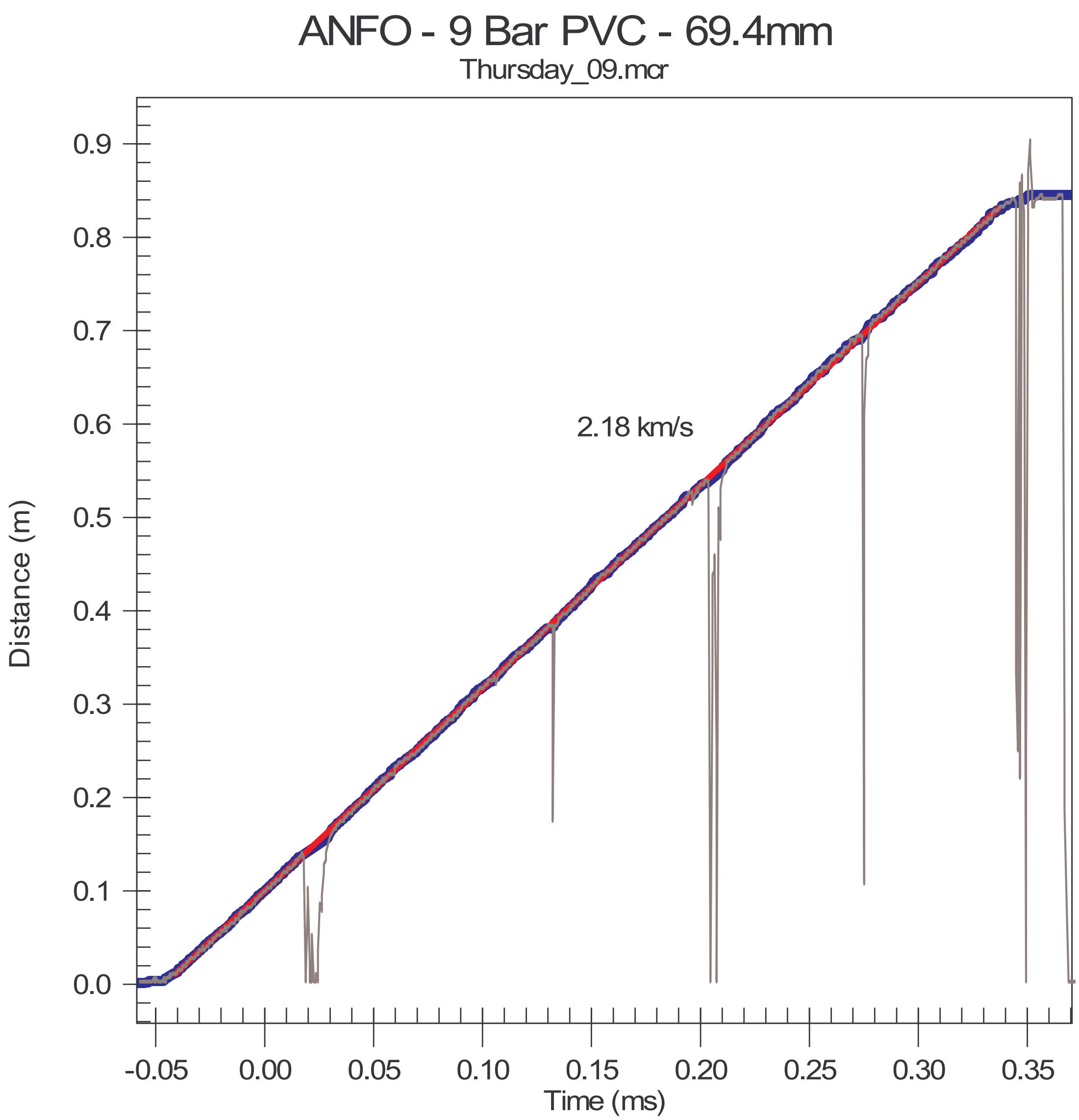
ANFO - 9 Bar PVC - 57.2mm
Monday_02
1.71 km/s over 0.4m
1.52 km/s over 0.43m
Avg. VoD = 1.59 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Time (ms)

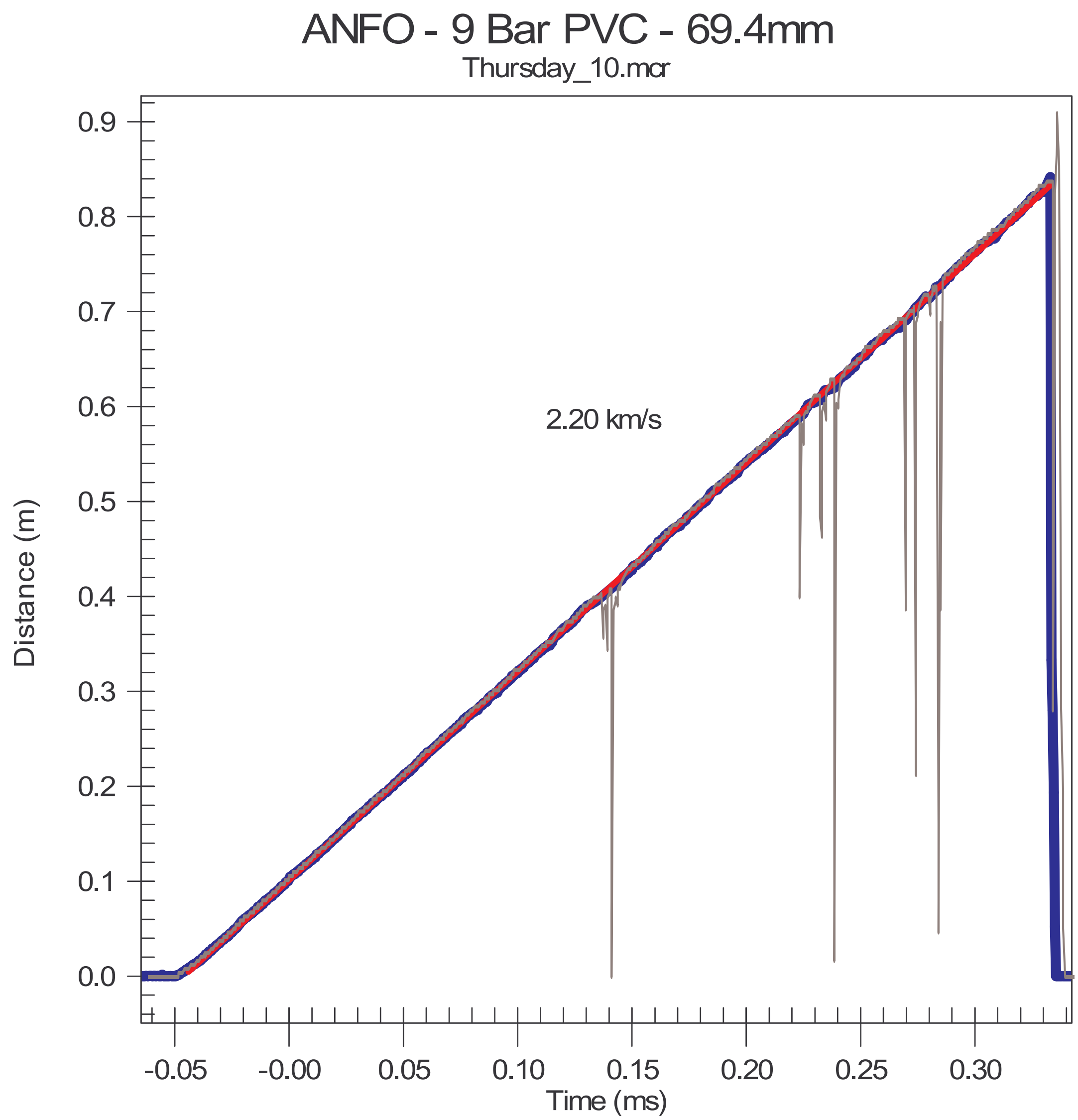

ANFO - 9 Bar PVC - 57.2mm
Tuesday_01.mcr
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Distance (m)
1.59 km/s
-0.10
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
Time (ms)



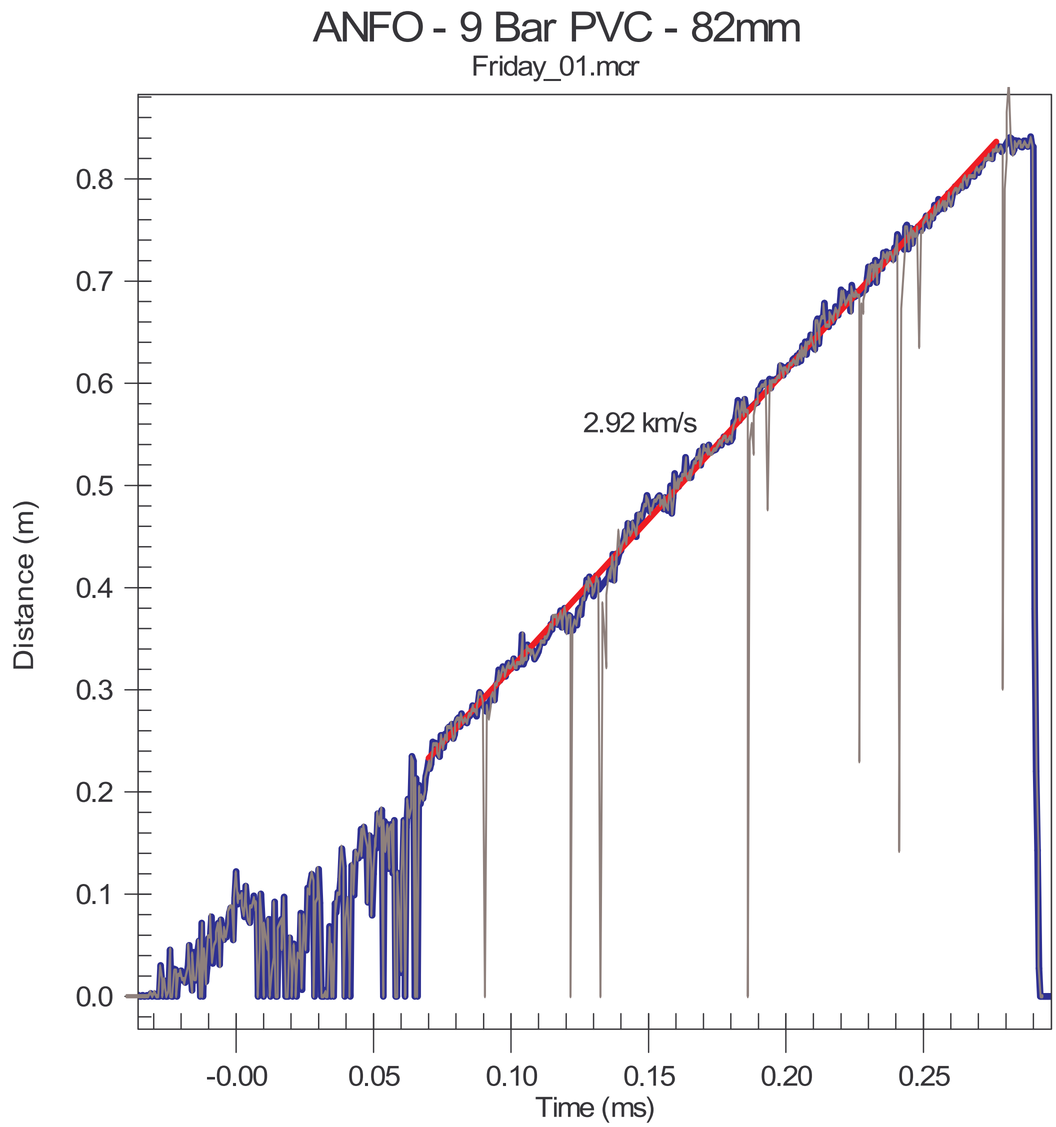
ANFO - 9 Bar PVC - 69.4mm
Thursday_07.mcr
2.20 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30

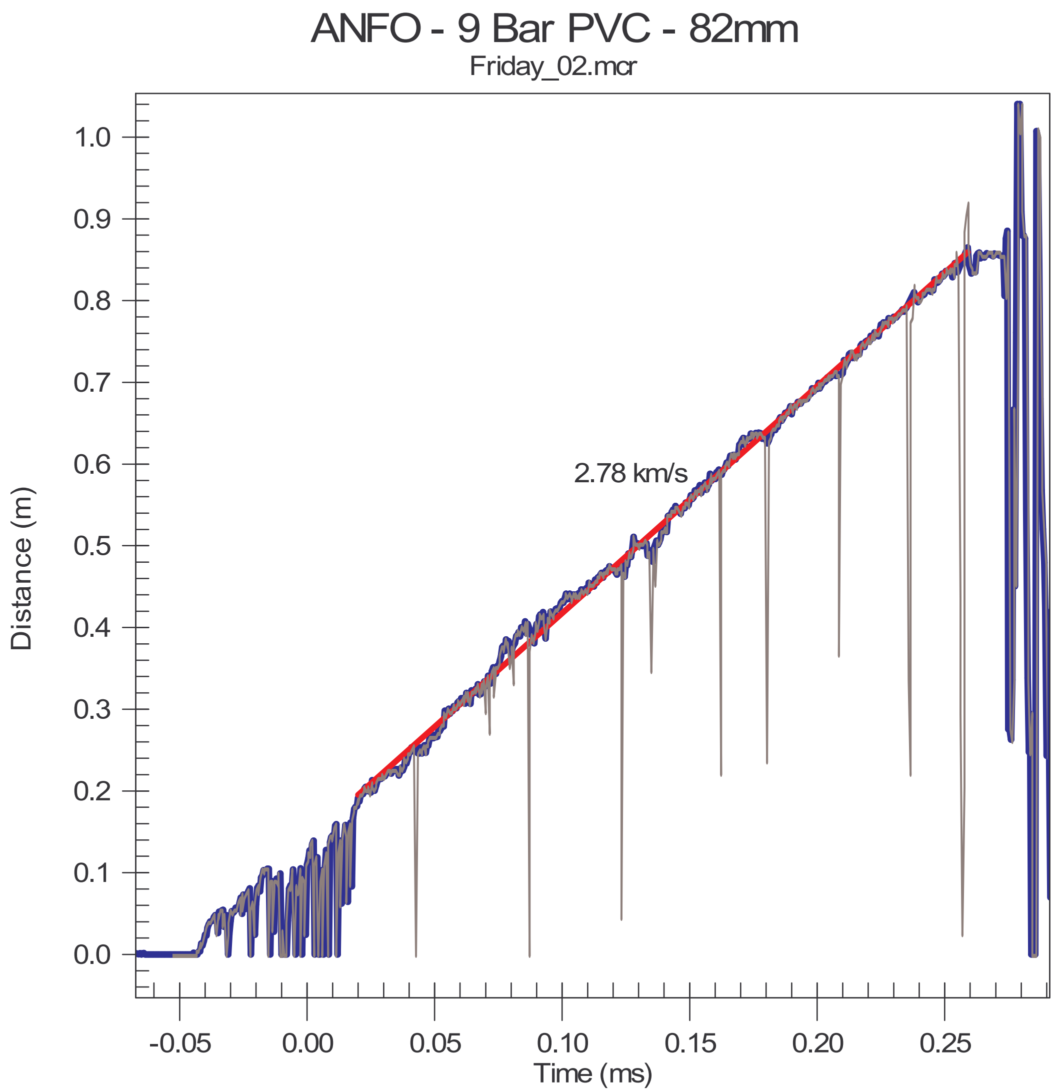

ANFO - 9 Bar PVC - 69.4mm
Thursday_08.mcr
2.17 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Time (ms)

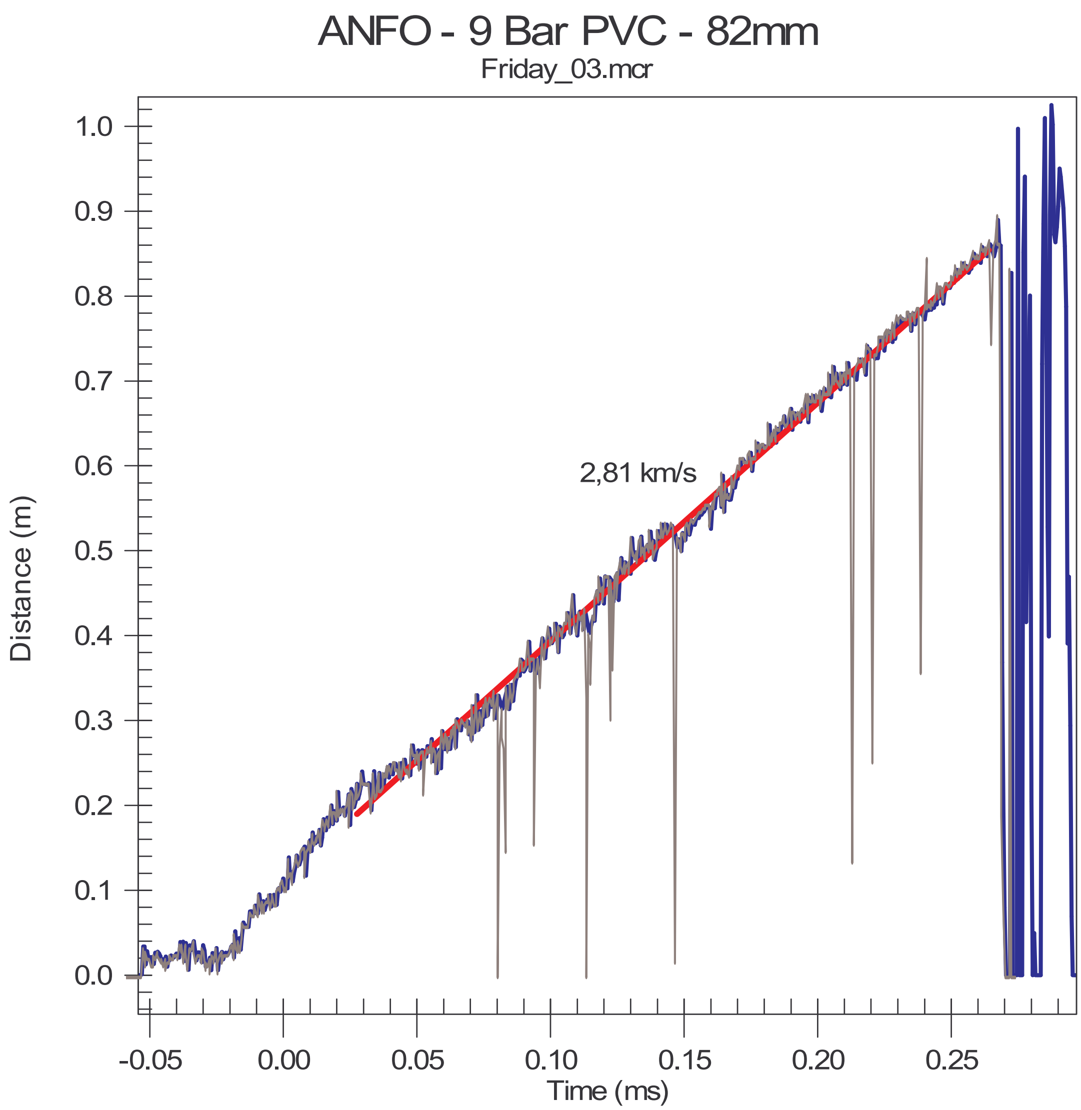

ANFO - 9 Bar PVC - 69.4mm
Thursday_09.mcr
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.18 km/s
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
Time (ms)

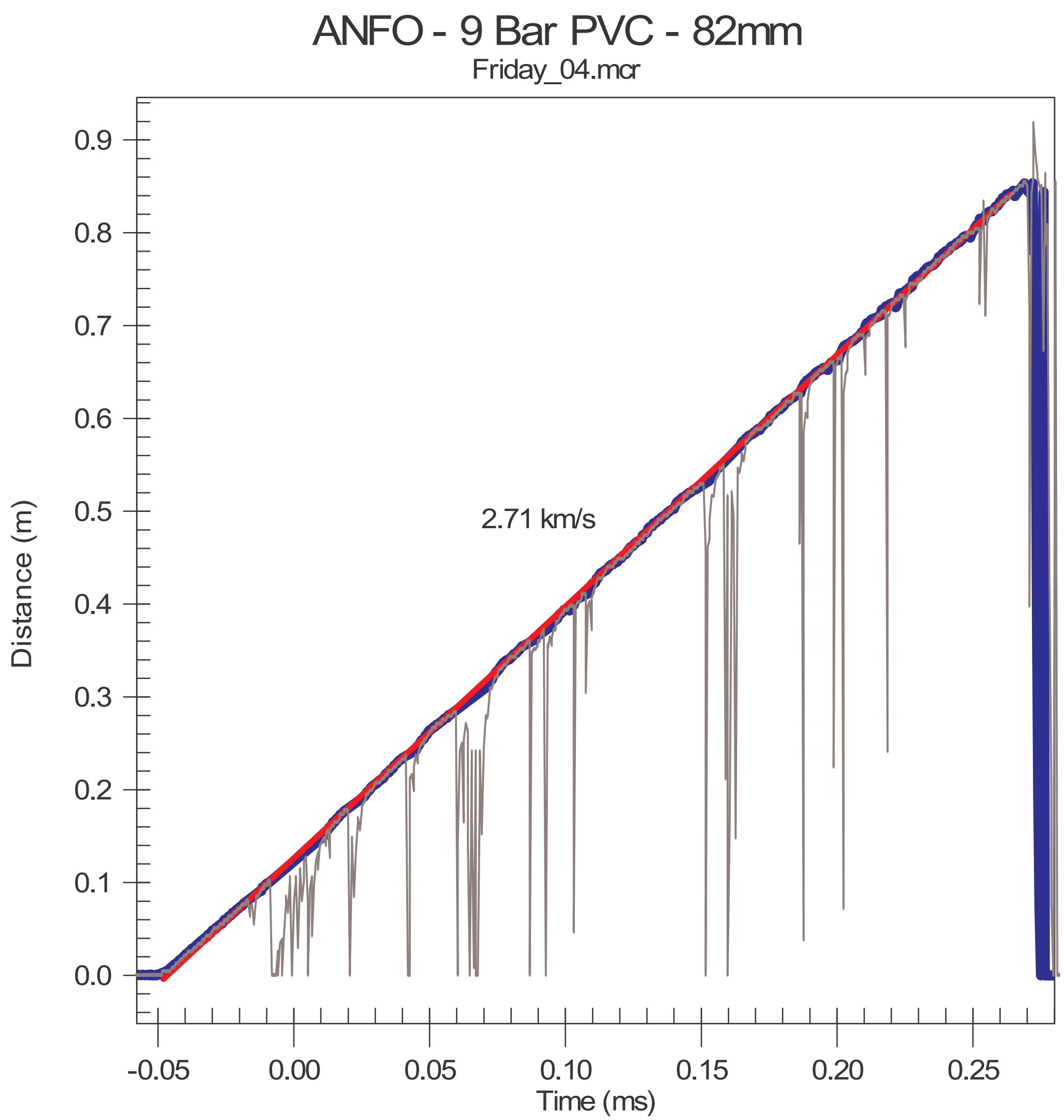


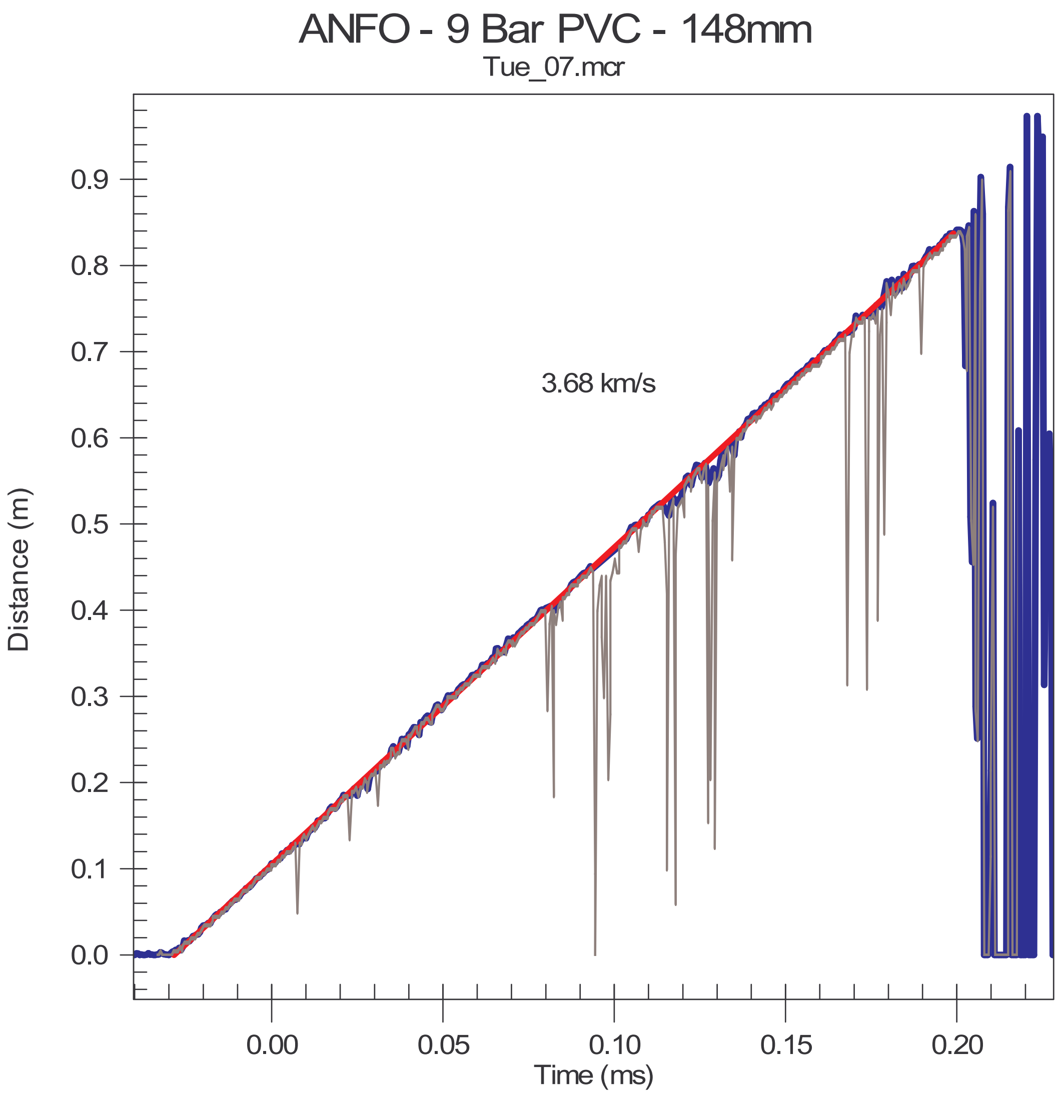
ANFO - 9 Bar PVC - 69.4mm
Thursday_10.mcr
2.20 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
-0.00
0.05
0.10
0.15
0.20
0.25
0.30
Time (ms)

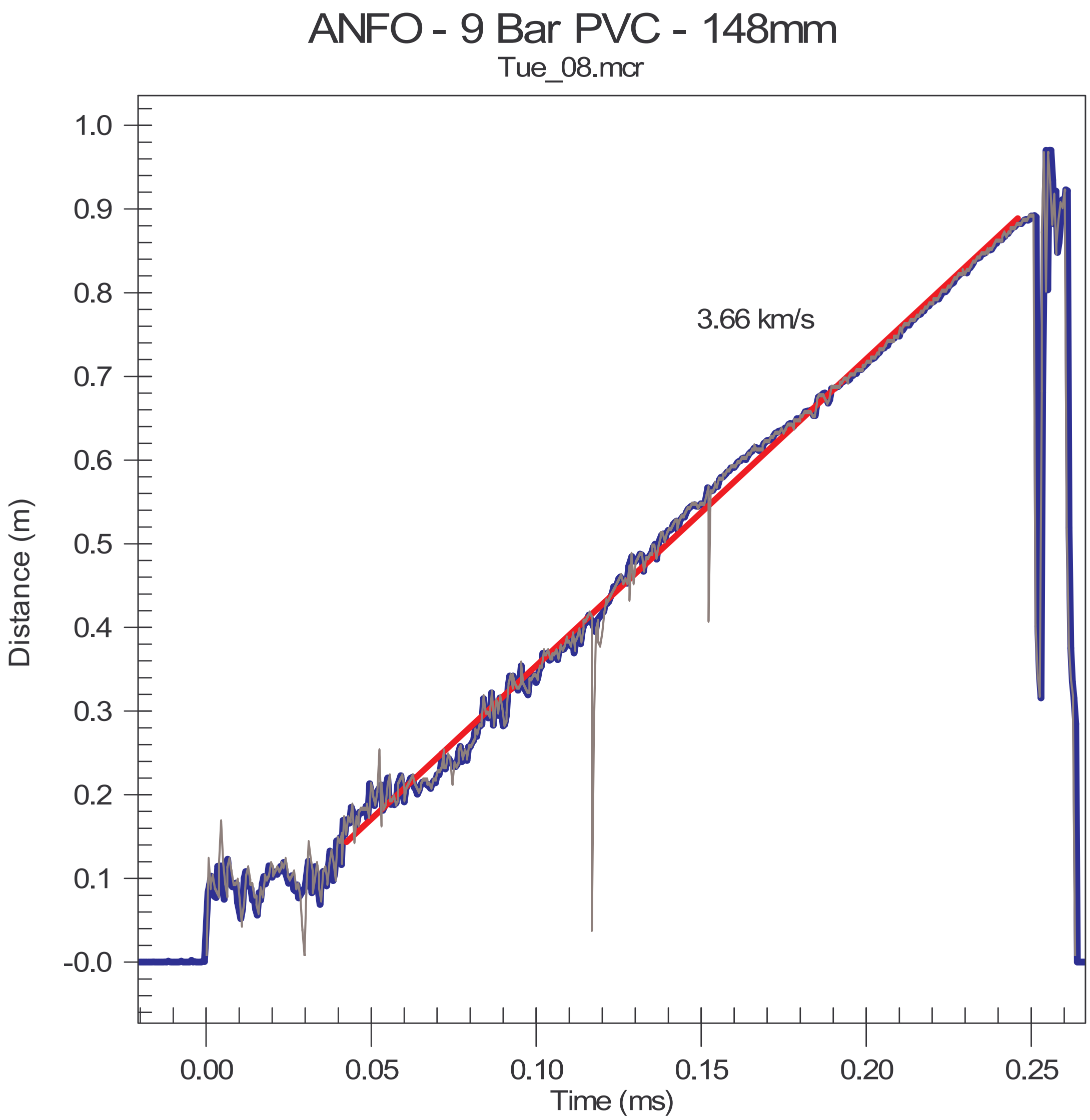

ANFO - 9 Bar PVC - 82mm
Friday_01.mcr
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
2.92 km/s
-0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

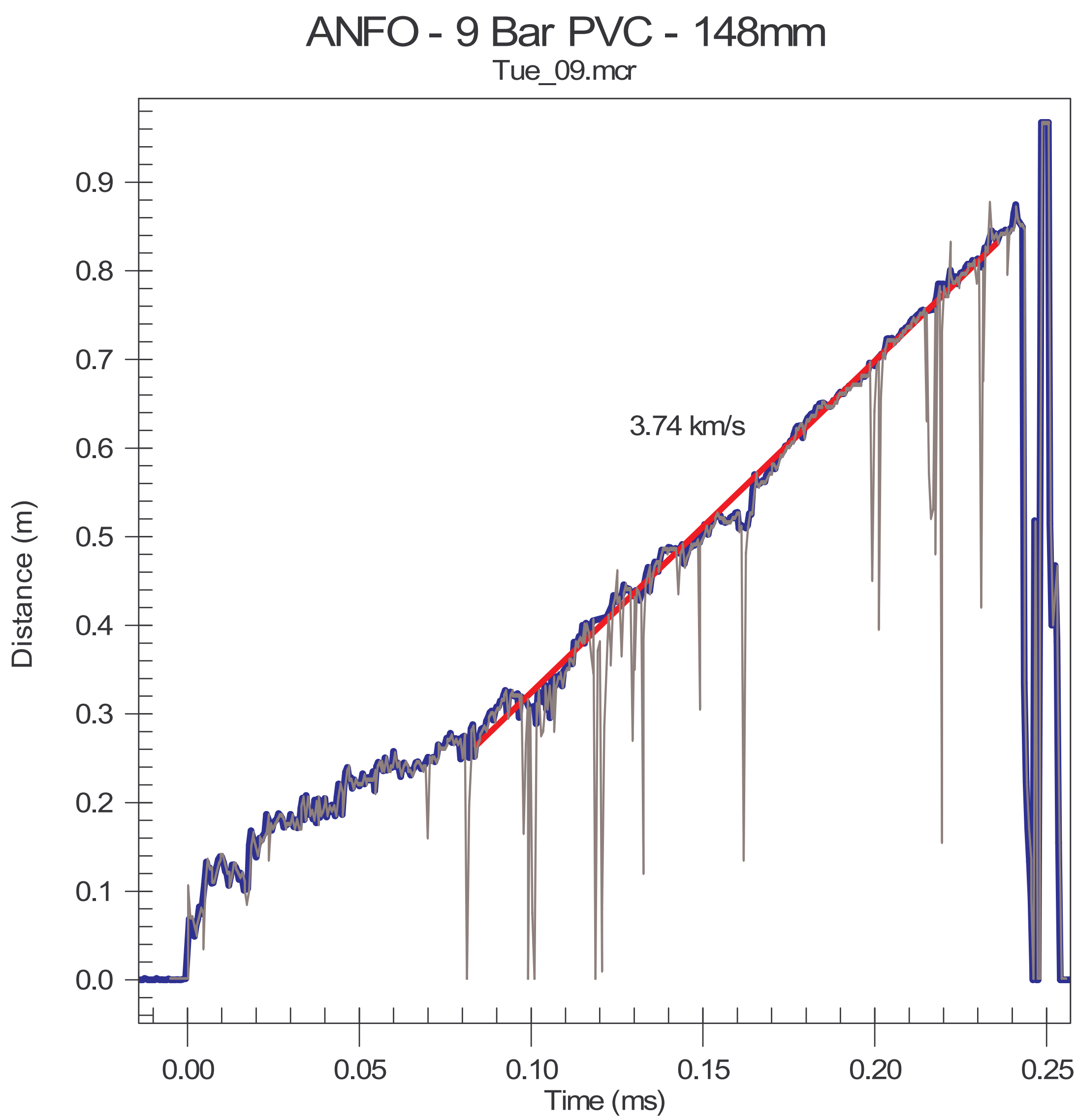

ANFO - 9 Bar PVC - 82mm
Friday_02.mcr
2.78 km/s
Distance (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)


ANFO - 9 Bar PVC - 82mm
Friday_03.mcr
2,81 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.05
0.00
0.05
0.10
0.15
0.20
0.25

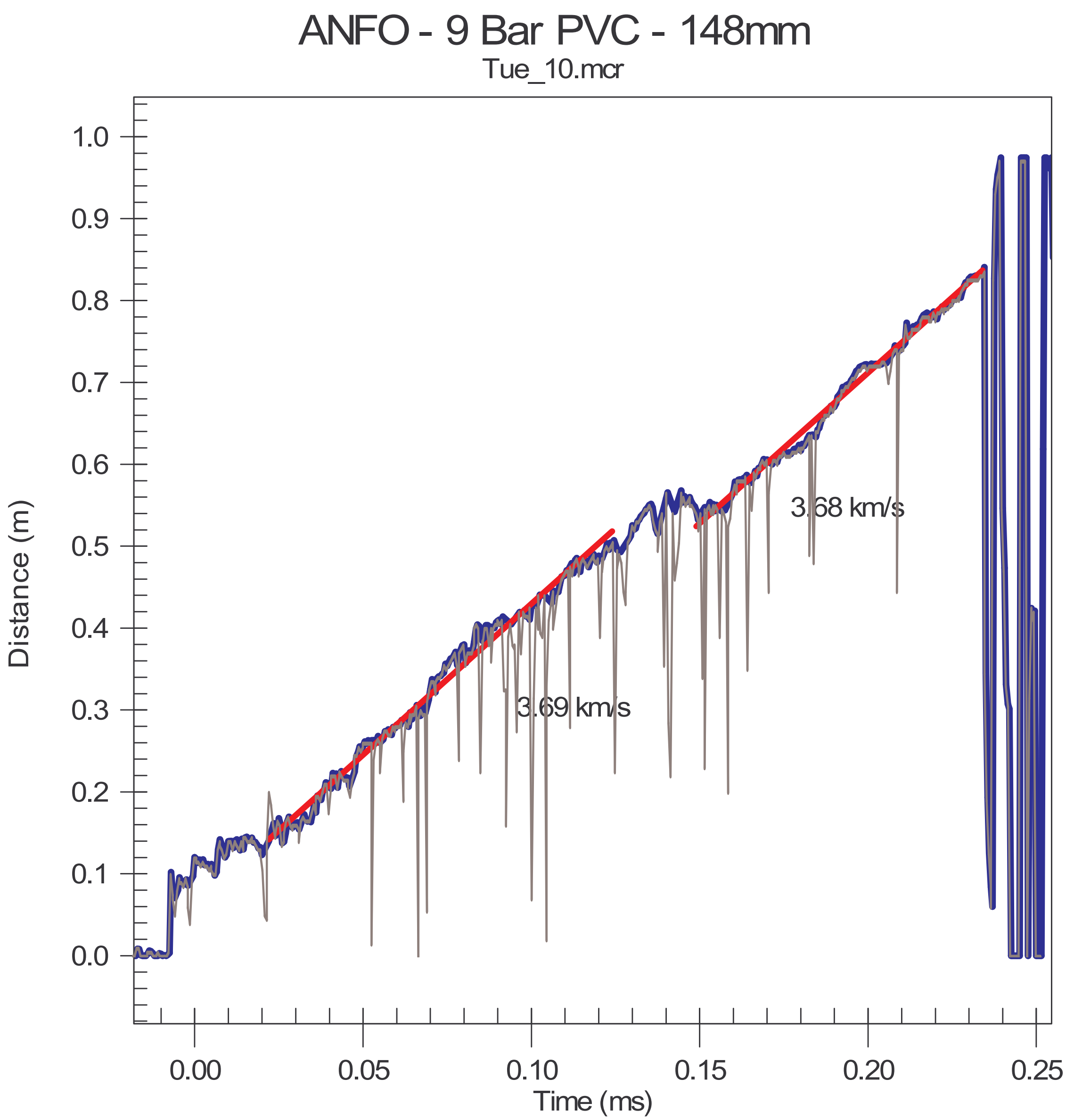

ANFO - 9 Bar PVC - 82mm
Friday_04.mcr
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.71 km/s
-0.05
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)


ANFO - 9 Bar PVC - 148mm
Tue_07.mcr
3.68 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.00
0.05
0.10
0.15
0.20

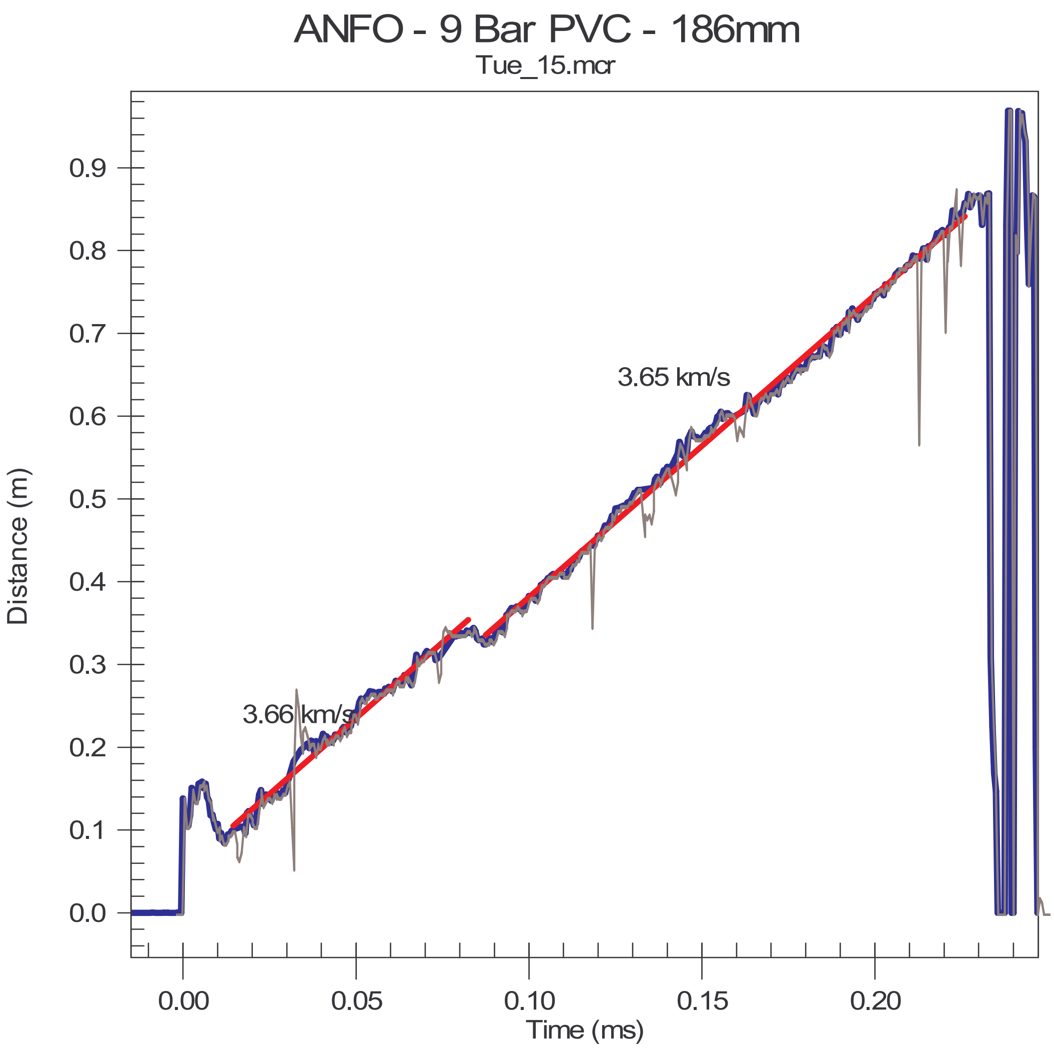

ANFO - 9 Bar PVC - 148mm
Tue_08.mcr
Distance (m)
Time (ms)
3.66 km/s
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.0
0.00
0.05
0.10
0.15
0.20
0.25

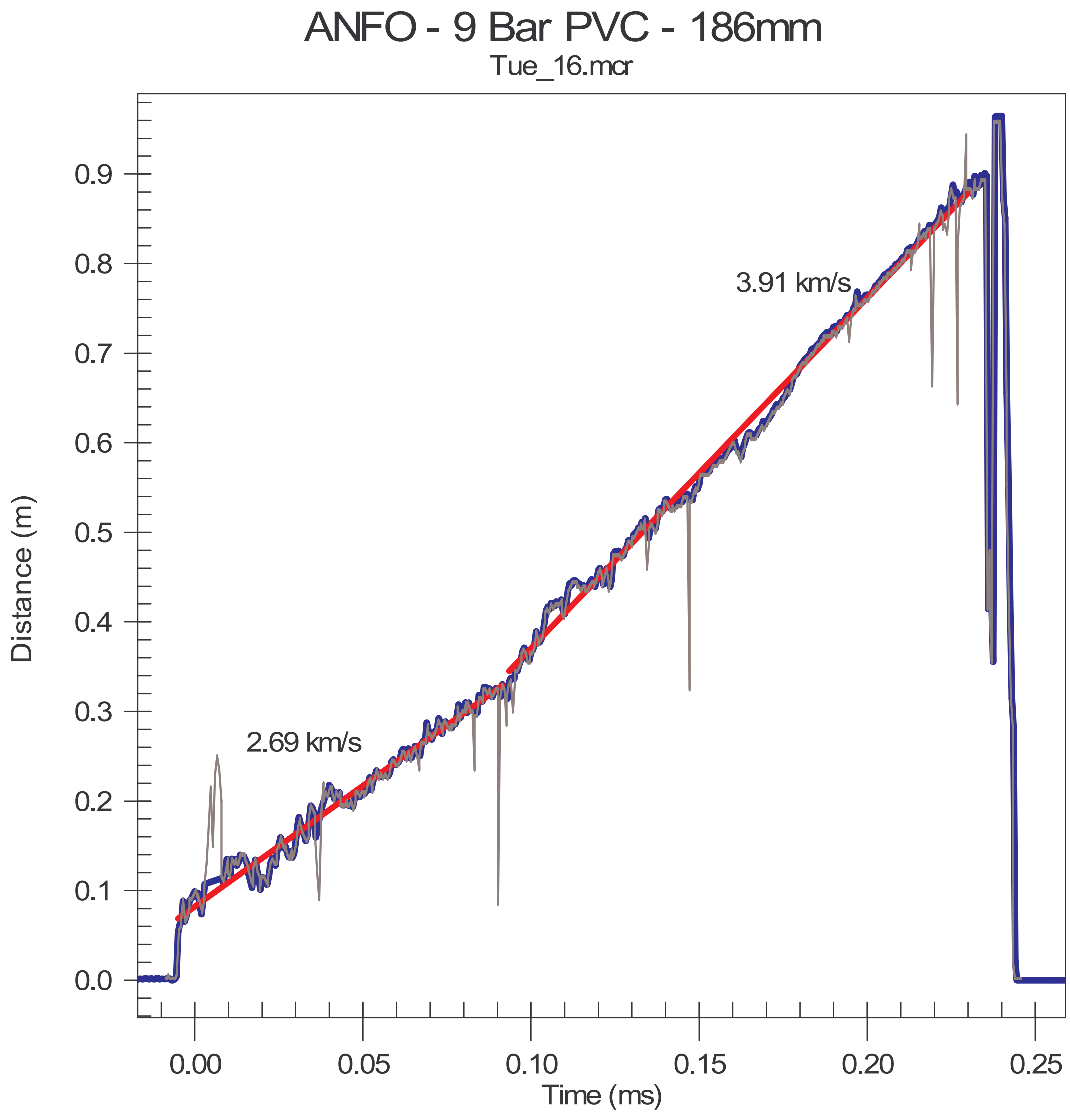


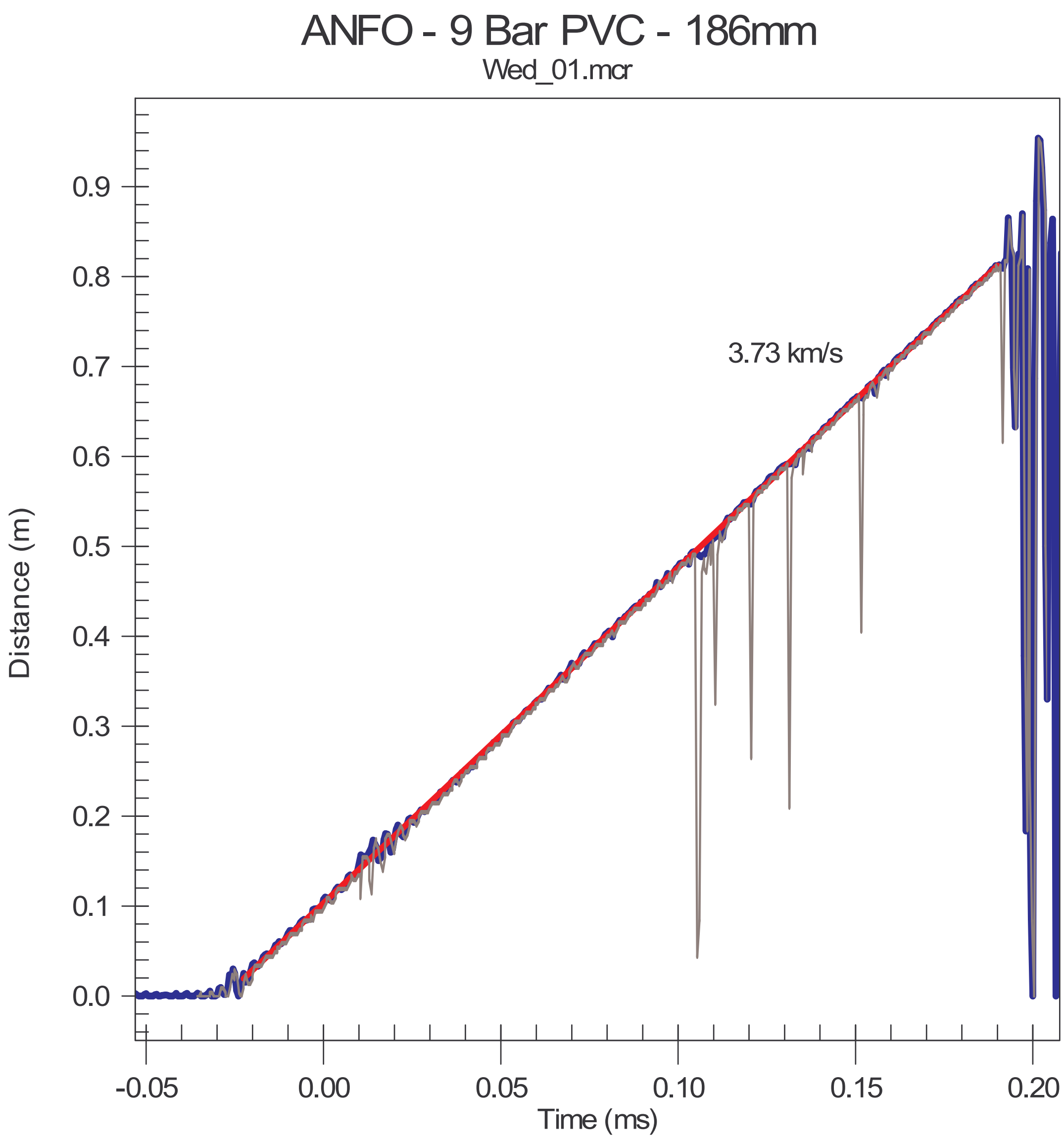
ANFO - 9 Bar PVC - 148mm
Tue_09.mcr
3.74 km/s
Distance (m)
Time (ms)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0.00
0.05
0.10
0.15
0.20
0.25

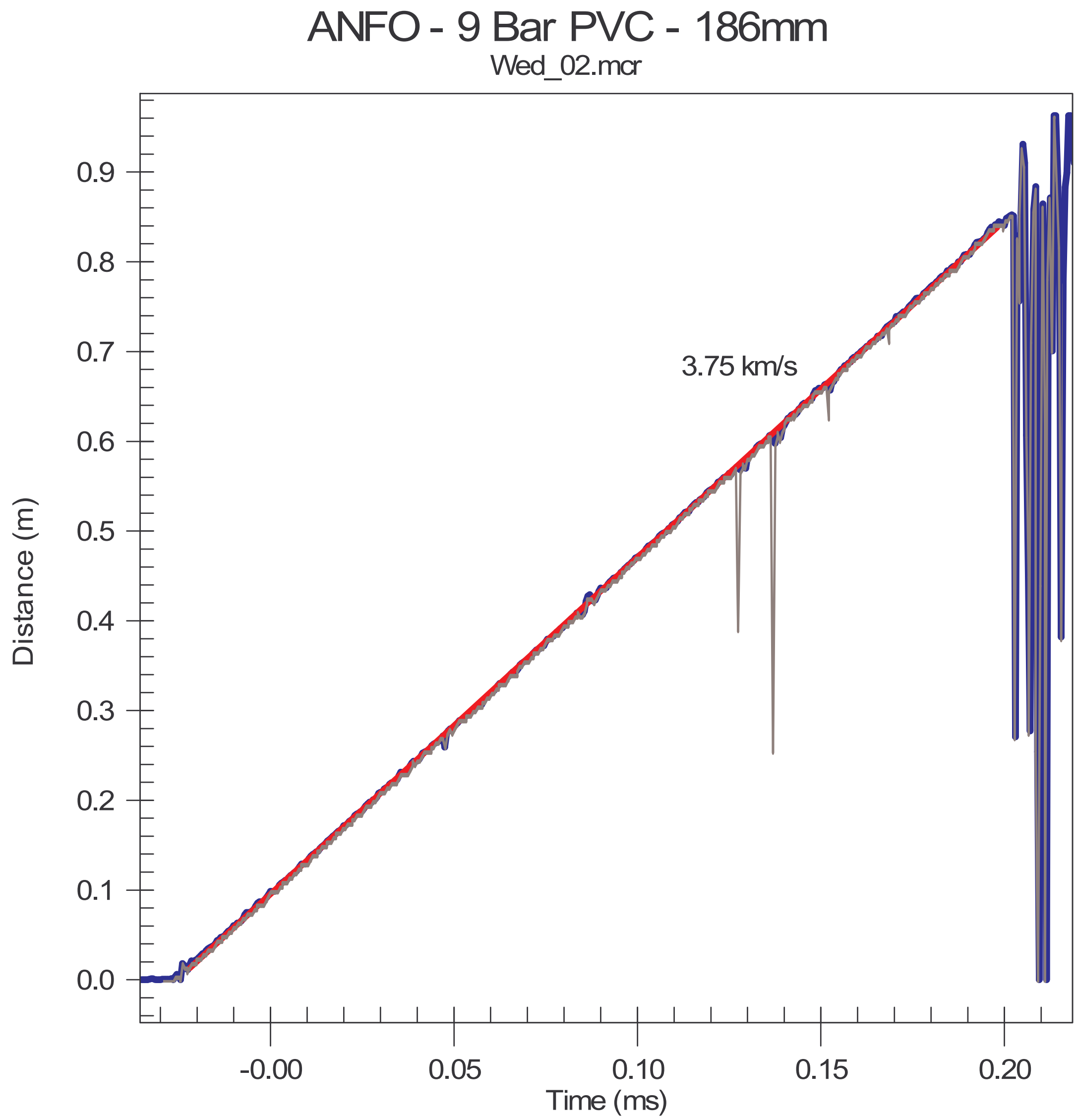


ANFO - 9 Bar PVC - 148mm
Tue_10.mcr
Distance (m)
Time (ms)
3.69 km/s
3.68 km/s
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20
0.25


ANFO - 9 Bar PVC - 186mm
Tue_15.mcr
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
3.66 km/s
3.65 km/s
0.00
0.05
0.10
0.15
0.20
Time (ms)


ANFO - 9 Bar PVC - 186mm
Tue_16.mcr
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2.69 km/s
3.91 km/s
0.00
0.05
0.10
0.15
0.20
0.25
Time (ms)

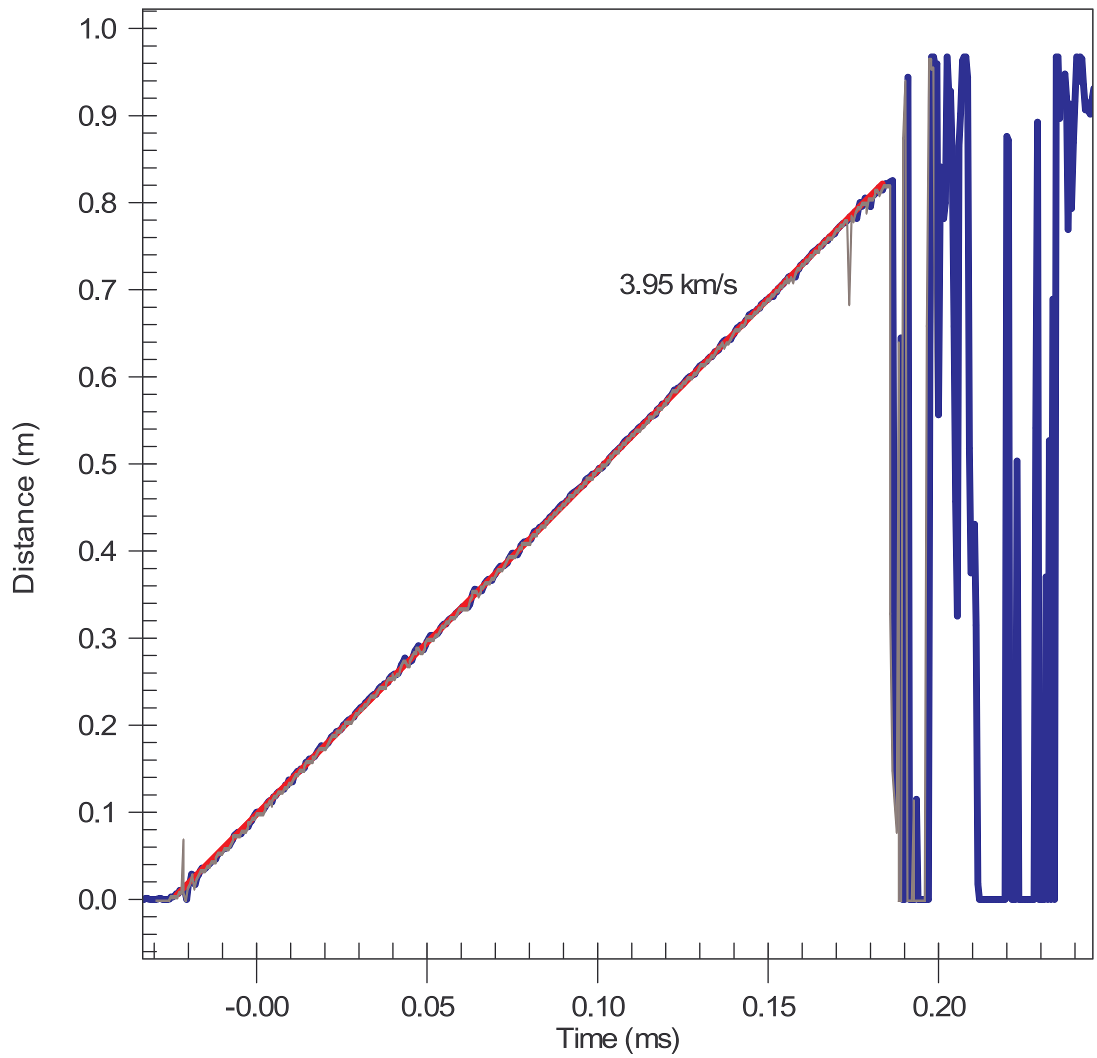

ANFO - 9 Bar PVC - 186mm
Wed_01.mcr
3.73 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Time (ms)
-0.05
0.00
0.05
0.10
0.15
0.20

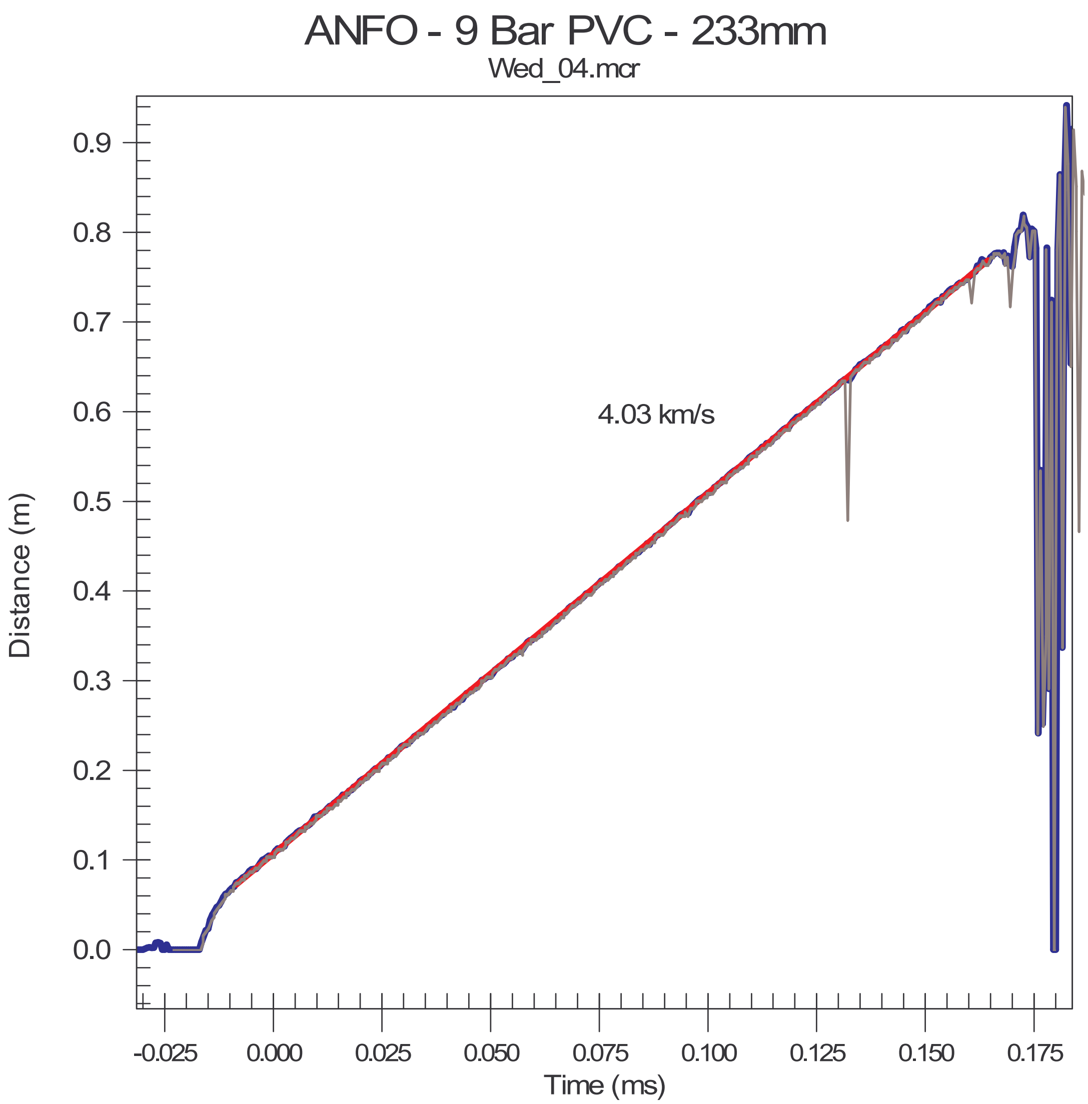


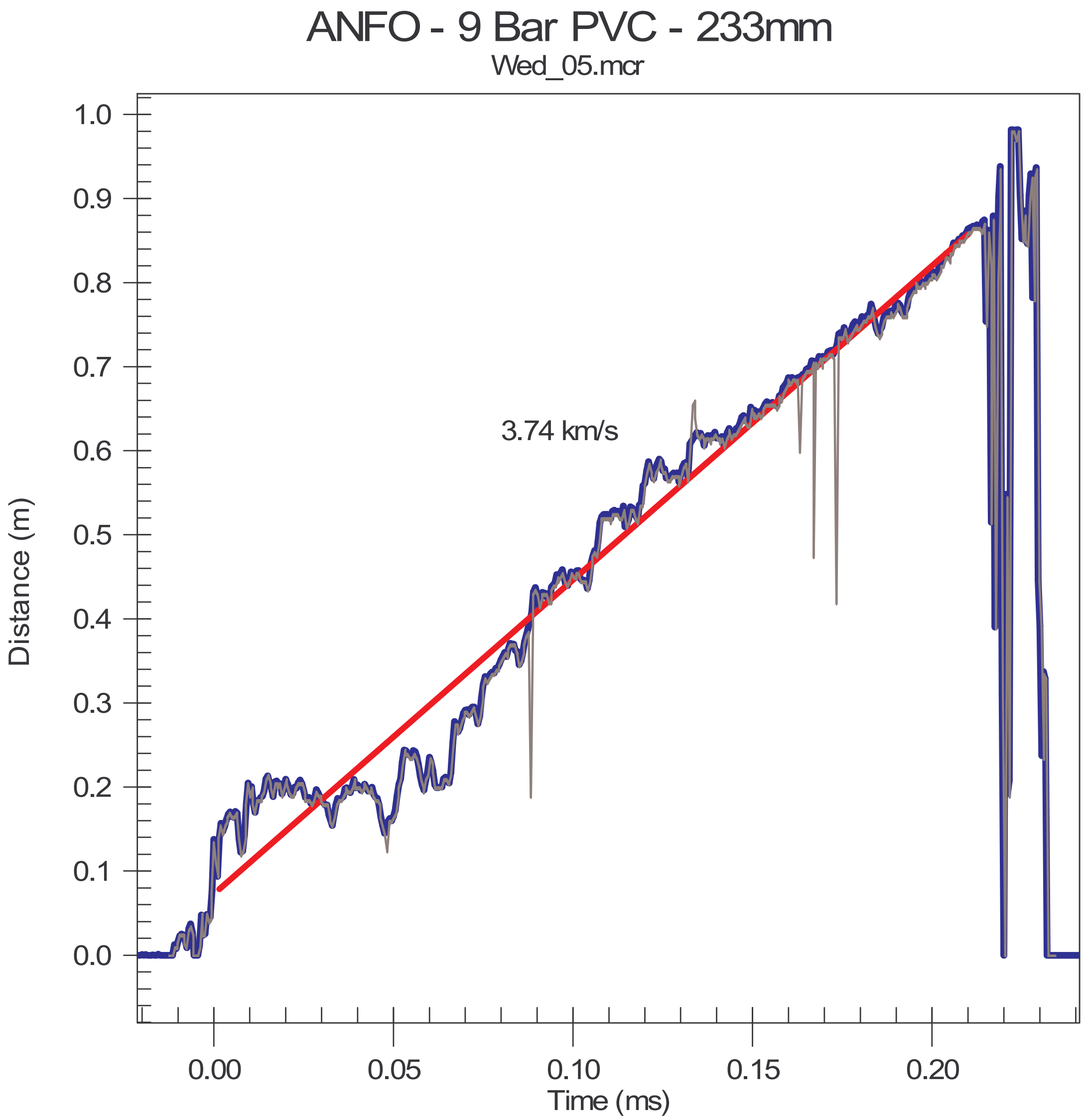
ANFO - 9 Bar PVC - 186mm
Wed_02.mcr
3.75 km/s
Distance (m)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
-0.00
0.05
0.10
0.15
0.20
Time (ms)

ANFO - 9 Bar PVC - 233mm

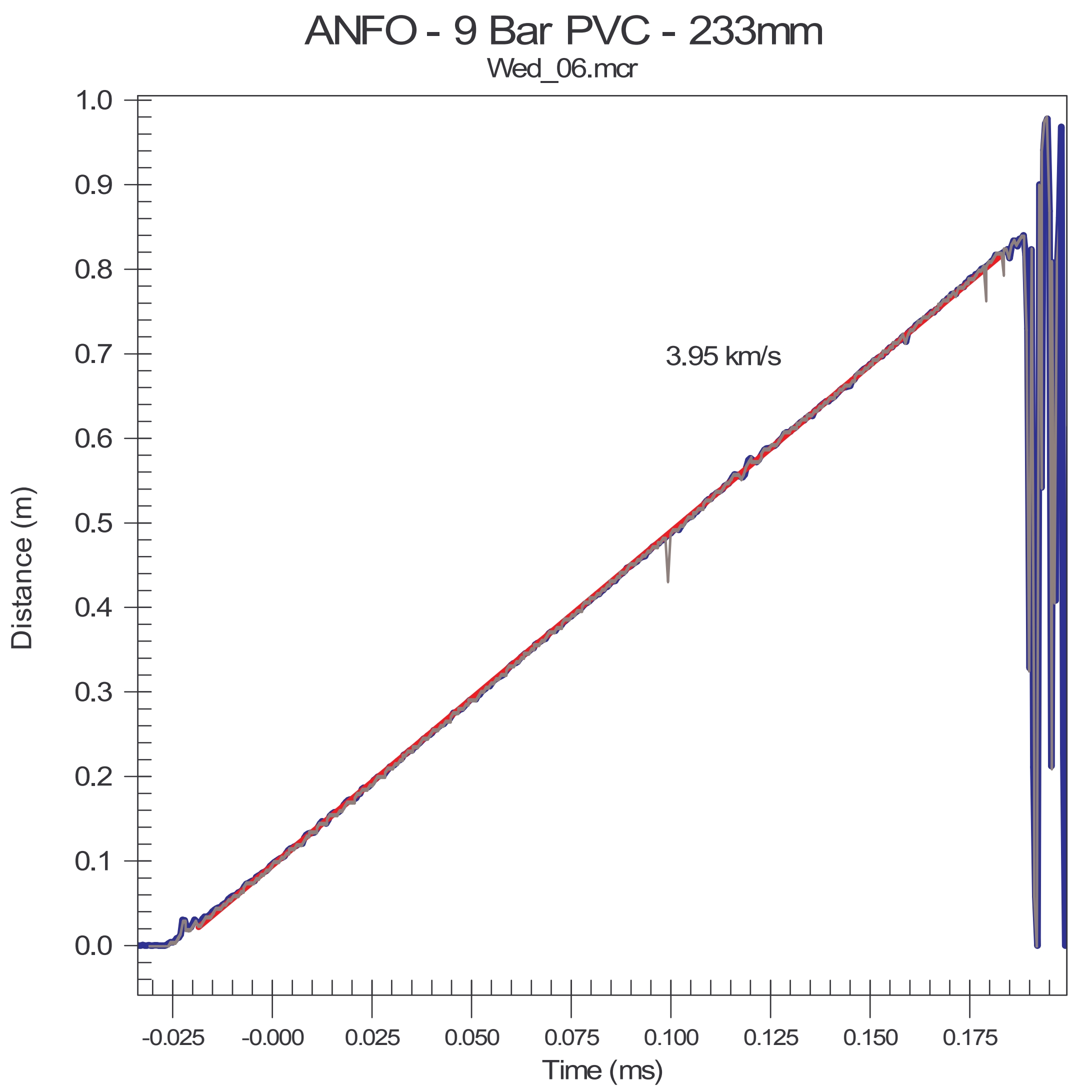
Wed_03.mcr




ANFO - 9 Bar PVC - 233mm
Wed_04.mcr
4.03 km/s
Distance (m)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.025
0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175
Time (ms)



ANFO - 9 Bar PVC - 233mm
Wed_05.mcr
3.74 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.05
0.10
0.15
0.20


ANFO - 9 Bar PVC - 233mm
Wed_06.mcr
3.95 km/s
Distance (m)
Time (ms)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.025
-0.000
0.025
0.050
0.075
0.100
0.125
0.150
0.175

APPENDIX 4

AEL Field Procedure for Measuring ANFO Oil Content (Document ref. TM/AN05)

Introduction

This method, when used out in the field, is able to give an indication of the oil content in ANFO to ±0.2%. It can be used for on-the-spot checks on the ANFO trucks while loading blastholes.

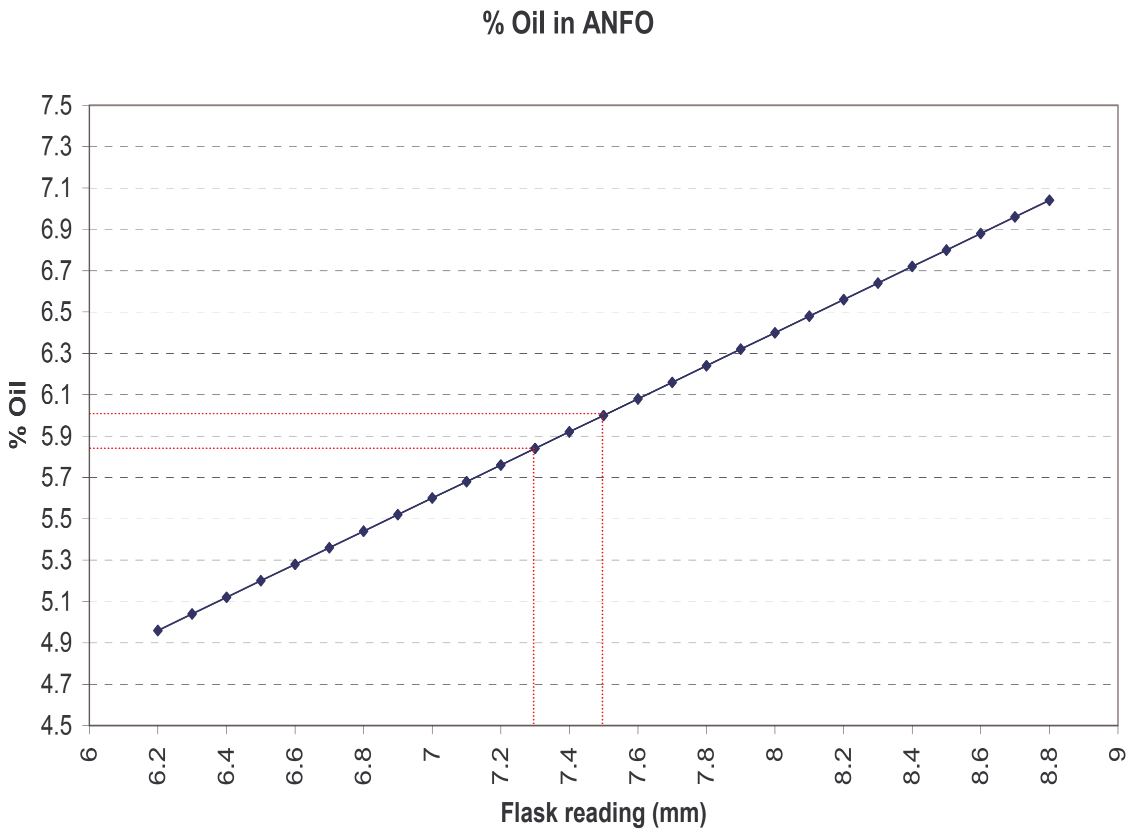
Apparatus

2 x 320ml assisted cassia flask	2 x stoppers for cassia flasks
2 x 1L thermos flask	2 x funnels
2 x 200ml shot bottles	2.5 L hydrochloric acid
1 x 25ml measuring cylinder	200ml separating fluid
1 x 5ml syringe	1 x conversion chart
1 x digital balance	

Method

- Weigh out 100g ANFO sample into cassia flask.
- Pour enough hot water into the flask to cover the ANFO.
- Place a stopper on the flask and shake (once or twice) to dissolve the ANFO.
- Add 20ml HCL to flask and shake (once). Discoloration of the surface occurs when separation occurs.
- Use the syringe to add 1 ml of separating fluid to the solution and shake gently (once or twice).
- Top up the flask with hot water to the 300ml mark.
- Replace the stopper and invert the flask (twice or thrice) to ensure complete mixing of the solution. (No residue should be left in the neck above the liquid.)
- Place the flask on a level surface and allow the solution to settle for one minute.

- After five minutes a distinct band of dark liquid will have formed in the upper neck of the flask.
- Wait another five minutes before reading off the number of graduations covered by the darker liquid
- Use the chart below to calculate the approximate percentage of oil in the ANFO.



Results

MMU-E15: 04 July 2005 - Reading of 7.3mm on the flask = 5.85% oil.

MMU-E06: 05 July 2005 - Reading of 7.5mm on the flask = 6.00% oil.

(The specification for the oil (fuel) content of an oxygen balanced ANFO is 6.0%. The variance that was considered acceptably for these tests is 6.0% ± 0.5%.)