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Blast Wave Characteristics and TNT Equivalent of Improvised Explosive Device at Small-scaled Distances

Maria Chiquito[#], Ricardo Castedo[#], Lina M. López[#,*], Anastasio P. Santos[#],
Juan M. Mancilla[@], and José I. Yenes[$]

[#]*Universidad Politécnica de Madrid, Madrid - CP 28003, Spain*
[@]*Compliance and Facilitation Directorate, World Customs Organization, Rue du Marché, Brussels - 30-B-1210, Belgium*
[$]*Infrastructures Command Ministry of Defense, Madrid - CP 28071, Spain*
[*]*E-mail: lina.lopez@upm.es*

ABSTRACT

A significant number of airblast test have been carried out with the purpose to characterise and analyse the properties of improvised explosive device (IED) with non-conventional explosives in terms of knowing the effects on people and/or structures. Small devices with 1.5 kg of explosive, initiated with a detonating cord have been studied. Seven different mixtures have been tested with two types of ammonium nitrate AN (technical and fertilizer) in different forms like prills or powder. In some cases, the ammonium nitrate has been mixed with fuel oil while in others, it has been mixed with aluminum. The TNT equivalent based on pressure, impulse, arrival time, positive phase duration and shock front velocity have been calculated and analysed for each mixture. Comparing the field test data obtained with respect to the representation of the UFC 3-340-02 values, it can be seen that the parameters measured are consistent. The IEDs with fertilizer ammonium nitrate do not detonate with the present charge conditions so the shockwave generated is only due to the detonating cord. When using the technical ammonium nitrate, ANFO can partially detonate and generate a potentially dangerous shockwave. Finally, the IED with AN and aluminum produces a TNT equivalent close to one when the technical AN is used.

Keywords: TNT equivalent; Air blast tests; Ammonium Nitrate; Blast waves

1. INTRODUCTION

The use of apparently harmless materials may involve hazards that in the hands of experts could lead to explosive devices with fatal consequences. Unfortunately, information on the subject, which was exclusive to a few people, now flows through the Internet and is available to everyone. This phenomenon generalises the use of improvised explosive devices (IED) with critical effects, such as Ansbach (Germany) and Brussels in 2016 or Manchester and St. Petersburg in 2017.

IEDs often contain 'homemade' explosives (HMEs), due to the relative ease of obtaining the components needed for their manufacture. The purchase of these products is totally legal and does not raise suspicions of the authority, so their study, analysis and knowledge is a great challenge for the scientific community[1-3]. Therefore, it is of great importance to investigate and increase knowledge about them. Knowing the power generated by the shock wave (pressure-time history) in a detonation of free air with HME, is an essential step to know the effects on people and/or structures[4]. The pressure-time curve presents two phase: the positive phase, where the pressure increases suddenly and then decays back to normal atmospheric pressure (compressive phase); and the negative one, where the pressure is under normal atmospheric value until its recovery (suction phase). From the positive phase, several parameters can be extracted such as the peak positive overpressure (P_{so}), incident impulse (i_{so}), the arrival time (t_a), and the positive phase duration (t_d). All parameters from the pressure-time history are usually expressed in terms of scaled distance. The scaled distance concept is based on the idea that two explosive charges with similar geometry but different size produce similar shock waves at the same scaled distance, defined as:

$$Z = \frac{R}{W^{1/3}} \tag{1}$$

where W is the mass of the explosive charge and R is the distance from the target.

The blast effects of a large number of civil and military explosives are commonly characterised by comparing them with the effects of a standard explosive like TNT (2, 4, 6-trinitrotoluene)[5-8]. However, there is a significant lack of information when dealing with homemade explosives especially at short scaled distances[5]. The TNT equivalent can be defined as a comparison between a mass of explosive other than TNT obtaining the same yield (same values of a property) as an equivalent weight of TNT[6], as:

$$E_{TNT} = \frac{W_{TNT}}{W_{EXP}} = \left(\frac{Z_{EXP}}{Z_{TNT}}\right)^3_{prop=const} \tag{2}$$

being *prop* the property analysed (P_{so}, i_{so}, t_a, t_d and u – Shock

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Front Velocity). Although there are several theoretical and experimental methodologies for calculating the TNT equivalent[5-8], the methodology followed here is based on shock wave data, usually known as airblast test. The TNT equivalent is usually obtained using the pressure (E_p) and impulse (E_i) data, while arrival time (E_{ta}) and positive phase duration (E_{td}) are less common[5-7,9-12]. In addition, the equivalent based on shock front velocity (E_u) is extremely rare; in fact, no reference has been found in open sources. However, the equivalent, obtained by different procedures or even the same, may be significantly different, depending on many factors such as the confinement of the explosive, the type of initiation, the explosive shape, the number of explosive items[3,7,13]. Ideally, the equivalent must be referred to a TNT charge with identical configuration (shape, initiation, etc.); but, in practice and to make the explosives or specific devices more comparable, the standard TNT data (UFC 3-340-02) are used as reference values.

To obtain a solution for the TNT equivalent, the field results must be compared with the UFC 3-340-02 values[4] and then solve the Eqn. (2). The UFC 3-340-02 values have been described numerically using a high-order polynomial fit – Eqn. (3) and Table 1, for each parameter[14]:

$$Prop = exp\left(\begin{array}{l} A + B \times \left(\ln(Z)\right) + C \times \left(\ln(Z)^2\right) + \\ D \times \left(\ln(Z)^3\right) + E \times \left(\ln(Z)^4\right) + F \times \left(\ln(Z)^5\right) \end{array} \right) \quad (3)$$

To improve the knowledge of the destructive capacity of IED with HMEs, a large number of tests have been carried out. In these tests, the pressure-time curves have been registered, conveniently processed and subsequently, the TNT equivalent based on different parameters has been obtained.

2. EXPERIMENTS

2.1 Test description and measuring devices

A total of 18 test were conducted in March and May of 2017. The HMEs used in this work consisted of ammonium nitrate (AN) mixed with fuel (ANFO) or aluminum (AMMONAL). Two type of commercial ammonium nitrate (AN) were employed in the trials: technical ammonium nitrate and ammonium nitrate fertilizer. The technical ammonium nitrate (TAN) used in the tests is classified as UN 1942[15]. This TAN produced for industrial purposes is basically pure ammonium nitrate with high porosity. The specifications provided by the manufacturer ensure that a minimum of 98.5 per cent is ammonium nitrate. By contrast, the fertilizer ammonium nitrate (FAN) used in the trials is classified as UN 2067. It is also a high quality ammonium nitrate (34.5 per cent of total nitrogen) composed by nitric (17.3 per cent) and ammonia (17.2 per cent). However, of the total weight, the ammonium nitrate ranges from a minimum of 80 per cent and a maximum of 97 per cent, being dolomite or limestone the other components. Both ammonium nitrates were commercialised in prills, and for some tests they were milled to have it in powder form.

The charge was approximately spherical in shape with 15 cm diameter and was hung from a rope at 46 cm above the ground in all tests. Figure 1 shows the test setup and charge position. Details of the tests can be seen in Table 2. For the ANFO mixture, the ammonium nitrate (in prills or powder) was mixed with the fuel oil (10 per cent by weight), and waited for testing until the fuel was fully absorbed into the mixture. For the ammonal mixture, aluminum powder was added to the ammonium nitrate at 10 per cent by weight. The aluminum used was already in powder form with a size of 230 microns with a purity of at least 98 per cent. The homogeneity of the mixtures was controlled visually by explosive ordinance disposal (EOD) personnel from the Spanish Army. All mixtures were made inside a plastic bag and introduced for testing in a powder-free latex gloves easily found in any store. In all cases, the explosive mass was initiated with ordinary detonator and 15 g/m PETN detonating cord. The total amount of PETN for each IED was 5.25 g, and using the TNT equivalent 1.34 given by[16], the explosive mass for the initiation system was 7.035 g TNT.

Table 1. Simplified Kingery airblast coefficients[14]

	Range, Z (m/kg$^{1/3}$)	A	B	C	D	E	F
P_{so_UFC} (kPa)	0.2 – 2.9	7.2106	-2.1069	-0.3229	0.1117	0.0685	0
	2.9 – 23.8	7.5938	-3.0523	0.40977	0.0261	-0.01267	0
	23.8 – 198.5	6.0536	-1.4066	0	0	0	0
i_{so_UFC} (kPa-ms/ kg$^{1/3}$)	0.2 – 0.96	5.522	1.117	0.6	-0.292	-0.087	0
	0.96 – 2.38	5.465	-0.308	-1.464	1.362	-0.432	0
	2.38 – 33.7	5.2749	-0.4677	-0.2499	0.0588	-0.00554	0
	33.7 – 158.7	5.9825	-1.062	0	0	0	0
t_{a_UFC} (ms/kg$^{1/3}$)	0.06 – 1.5	-0.7604	1.8058	0.1257	-0.0437	-0.0310	-0.00669
	1.5 – 40	-0.7137	1.5732	0.5561	-0.4213	0.1054	-0.00929
t_{d_UFC} (ms/kg$^{1/3}$)	0.2 – 1.02	0.5426	3.2299	-1.5931	-5.9667	-4.0815	-0.9149
	1.02 – 2.8	0.5440	2.7082	-9.7354	14.3425	-9.7791	2.8535
	2.8 – 40	-2.4608	7.1639	-5.6215	2.2711	-0.44994	0.03486
u_{UFC} (km/s)	0.06 – 1.50	0.1794	-0.956	-0.0866	0.109	0.0699	0.01218
	1.50 – 40	0.2597	-1.326	0.3767	0.0396	0.0351	0.00432

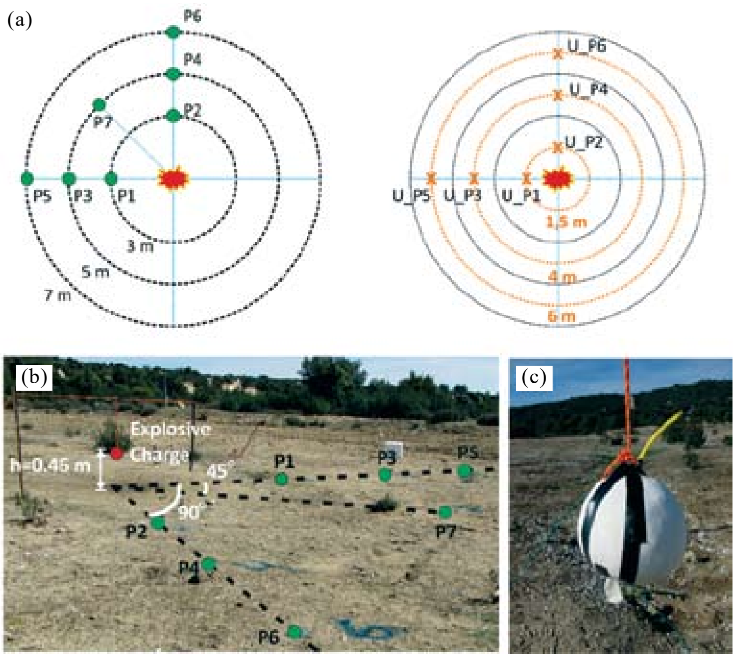


Figure 1. (a) Detail of the blast pressure transducer and target location, the right figure correspond with the points chosen for measuring shock front velocity, (b) Photograph of the test arrangement, and (b) Explosive charge.

Table 2. Details of the charges. The acronym is formed by the name of explosive, followed by a T or F (for Technical or Fertilizer ammonium nitrate) and M for milled AN

Acronym	Nº of tests	AN Type	Mass (kg)	AN (%)	FO (%)	Al (%)
ANFO-TM	3	Technical, milled	1.500	90	10	
ANFO-FM	3	Fertilizer, milled	1.500	90	10	
ANFO-T	3	Technical, prills	1.495	90	10	
ANFO-F	3	Fertilizer, prills	1.496	90	10	
AMMONAL-TM	3	Technical, milled	1.500	90		10
AMMONAL-F	3	Fertilizer,prills	1.501	90		10

Seven high frequency ICP® pressure sensors (Model PBC 102 B) located at 3, 5 and 7 m from the charge (see Fig. 1) were used in all trials. Data acquisition system was a Mrel (Model Datatrap II) that is a rugged and portable system with 8 channels and a sample rate of 10 MHz. Pressure gauges were located at surface level with the sensor surface parallel to the advanced direction of the shockwave so the pressure registered is the incident. The trigger of the system was introduced in the detonator so the time zero corresponds with the initiation of the charge.

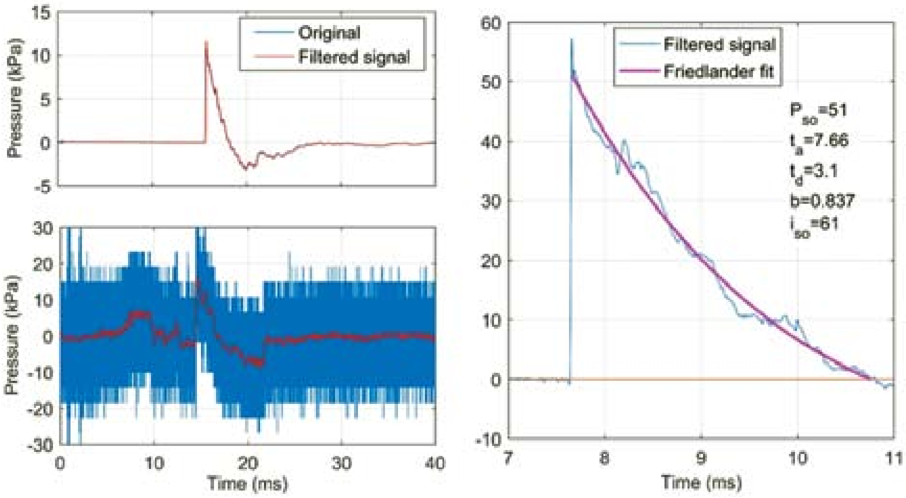
2.2 Blast Wave Treatment

The registration of the different pressure-time signals can present in some cases a high percentage of noise which mask the signal itself. When this happens, the signal filtering is necessary to obtain the shockwave parameters. The filter applied is of the type of Butterworth fourth order low pass filter, and if the signal presents an offset, it is corrected too. As an example, in Fig. 2(a) (top image), it can be seen a signal with a perfectly recognised free air detonation shape that did not need any filtering. However, in the other signal (Fig. 2(a) – bottom image) a filtered out was required to be able to extract the true pressure-time signal.

After getting the filtered signal, it is necessary to extract the key parameters of the positive phase to finally calculate the TNT equivalent. To do this, a code in MATLAB® was developed based on a least squares fit. This fitting has been done using the modified Friedlander Equation[17]:

$$P(t)=P_{so}\left(1-\frac{t}{t_d}\right)e^{-bt/t_d} \tag{4}$$

where b is known as the waveform parameter and controls the decay of the pressure-time curve (Fig. 2(b)). Note that P_{so} is a peak overpressure for incident wave above ambient conditions, P_0. Having those two parameters (P_{so} and b), the positive impulse can be also obtained by determining the integral of Eqn. (4):



(a) (b)

Figure 2. Pressure-time history. (a) top graph, P6 sensor in test 2 of AMMONAL-F without filtered necessity; bottom graph, P6 sensor in test 1 of ANFO-TM where filtering is required. (b) Example of the least squares fit to the Friedlander equation for sensor P3 in test number 2 of AMMONAL-TM.

$$i_{so} = \int_0^{t_d} P(t)\,dt = \frac{P_{so}\, t_d}{b^2}\left(b-1+e^{-b}\right) \tag{5}$$

The arrival time, defined as the time interval between the initiation of the detonator and the arrival of the blast wave at the measurement location, is determined as the point where the Friedlander equation reaches the maximum pressure (P_{so}).

2.3 TNT Equivalency

The concept of TNT equivalent offers the advantage of providing in a value, an identification of a given blast wave in terms of a standard explosive, whose blast effects have been widely documented. For P_{so}, i_{so}, t_a, t_d and u the equivalency was obtained with Eqn. (2) by equalising the value acquired in the tests through the equation of Friedlander with the values extracted from the UFC 3-340-02 (Eqn. (3) and Table 1) at the same scaled distance – Eqn. (1).

For the TNT equivalent based on the u, the midpoints between two sensors or one sensor and the center of the charge were chosen as measuring points, then calculating the average velocity in this section (Fig. 1). Note that the P7 was not considered for having a different segment of distance from the charge as reference and therefore is not comparable with the u obtained with P3 and P4. The average velocity (u) was defined as the change of the position during a considered lapse of time. So that, having t_a and the distances between sensors (R_s), the u was calculated as follow:

$$u = \frac{R_{s_{n+1}} - R_{s_n}}{t_{a\_s_{n+1}} - t_{a\_n}} \tag{6}$$

3. RESULTS AND DISCUSSION

Once all data have been processed for each sensor in each test, these data are classified according to their scaled distances. There are the same scaled distances for all parameters (2.6, 4.4 and 6.1 m/kg$^{1/3}$) except for the shockwave velocity, which have scaled distances located at the midpoints between sensors (1.4, 3.5 and 5.2 m/kg$^{1/3}$) (see Fig. 1 for details). For each explosive, there are three potentially available tests and two or three records per distance, giving a total number of signals ranging from six to nine per explosive. Some authors suggest[18-19] that the variability between trials of the same explosive are negligible, while others disagreed[20-21]. To avoid data loss, the mean and standard deviation of all TNT equivalents have been calculated.

Table 3 shows a summary of the blast wave parameters obtained from the analysis of pressure signals. Three signals are plotted in Fig. 3 for the case with higher peak pressures (AMMONAL-TM) and the test with lower pressures (ANFO-F). All signals show a relatively sharp peak with a short rise time that range from 60 ms to 120 ms for the AMMONAL-TM and the ANFO-F, respectively. Furthermore, as can be seen in Table 3, all the shockwave velocities registered are bigger than the speed of sound in the air. Both parameters, rise time and shock wave velocity, confirm the fact that a shockwave has been generated.

The low pressure values obtained in all the IED with fertilizer AN (ANFO-FM, ANFO-F) indicate that there was no detonation of the explosive charge. 8 kPa at 3 m are exclusively due to the detonation of the initiation system with 7 g eq TNT (PETN in the detonating cord). In Fig. 4, there is a comparison

Table 3. Blastwave parameters results: (*Z*) scaled distance, (*P*$_{so}$) side-on pressure, (*I*$_{so}$) side-on impulse, (*t*$_a$) arrival time, (*t*$_d$) positive phase duration, (*Zu*) scaled distance for shockwave velocity, (*u*) shockwave velocity

Test	Signal number	*Z* (m/kg$^{1/3}$)	*Pso* (kPa)	*Iso* (kPa.ms)	*ta* (ms)	*td* (ms)	*Zu* (m/kg$^{1/3}$)	*u* (m/s)
ANFO-TM	5	2.6	44.14	25.21	5.98	1.55	1.4	525
	8	4.4	18.72	16.81	11.31	2.07	3.5	368
	4	6.1	10.26	9.31	16.30	2.08	5.2	373
ANFO-FM	6	2.6	7.48	2.91	7.71	0.94	1.4	393
	9	4.4	3.63	1.79	13.43	1.13	3.5	352
	3	6.1	2.96	1.39	18.08	1.19	5.2	373
ANFO-T	6	2.6	30.61	13.88	6.75	1.47	1.4	452
	9	4.4	13.54	9.91	12.16	1.72	3.5	359
	6	6.1	9.82	8.29	17.16	2.12	5.2	395
ANFO-F	6	2.6	6.09	2.36	7.65	0.89	1.4	397
	9	4.4	3.08	1.43	13.36	1.20	3.5	352
	3	6.1	2.60	1.30	18.11	1.20	5.2	373
AMMONAL-TM	6	2.6	134.60	94.05	3.30	1.88	1.4	919
	9	4.4	49.70	60.77	7.77	3.08	3.5	445
	2	6.1	30.12	43.46	11.90	3.65	5.2	420
AMMONAL-F	3	2.6	50.66	20.55	5.49	1.31	1.4	553
	6	4.4	18.53	18.47	10.90	2.44	3.5	359
	6	6.1	11.58	13.51	15.99	2.81	5.2	373

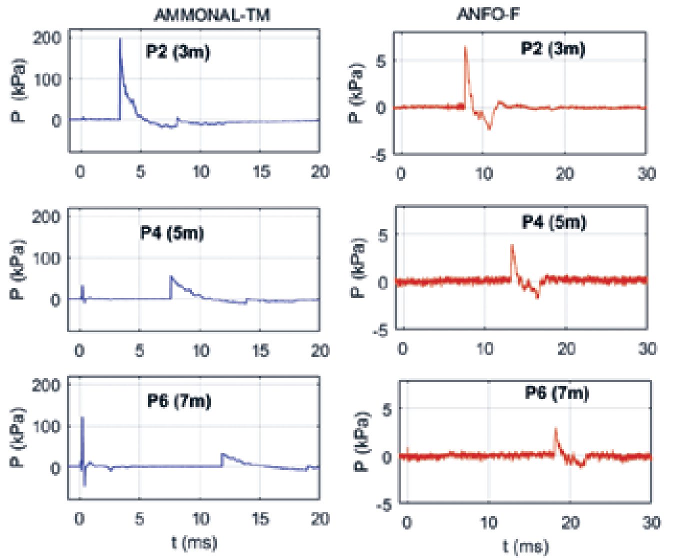


Figure 3. Pressures signals at three distances (3, 5 and 7 m) for test 1 of AMMONAL-TM (left) and for test 1 of ANFO-F2 (right).

between the value of three shockwave characteristics (P_{so}, t_a and u) given by UFC with the experimental values using only the equivalent TNT charge of PETN in the scaled distance.

As can be seen in Tables 4 and 5, globally a large number of useful signals have been obtained. For each scaled distance and for each available signal, all the equivalent TNT are calculated with the Eqn. (2) and finally a mean value (and its standard deviation) are obtained for each Z (see Tables 4 and 5).

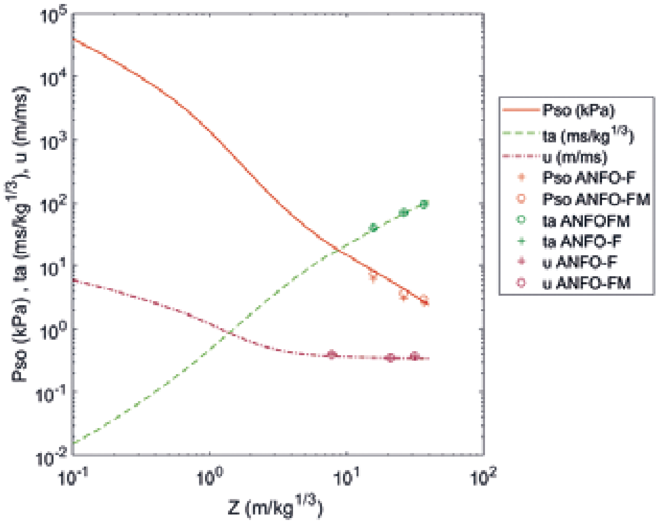


Figure 4. PETN initiation system charge for trials ANFO-F and ANFO-FM (7 g eq. TNT) compared with the shock wave parameters from UFC[4].

TNT equivalent values based on pressure (E_p) in general decrease with the scaled distance (Table 4 and Fig. 5). This general trend presents some anomalies: in the case of ANFO-T, where the equivalent at 2.6 m/kg$^{1/3}$ is higher than at 4.4 m/kg$^{1/3}$ but lower than at 6.1 m/kg$^{1/3}$ or in the case of AMMONAL-TM, where the highest value is presented at 6.1 m/kg$^{1/3}$ while for other scaled distances the value is almost the same. The deviation from the mean is high overall due to different reasons: in one test of the ANFO-T series the support to place

Table 4. TNT equivalent values of pressure (E_P), impulse (E_I), arrival time (E_{ta}) and positive phase duration (E_{td}) for each trial; being μ the mean and σ the standard deviation. The scaled distance Z is calculated based in the mass of explosive employed

Test	Z m/kg$^{1/3}$	Signal number	E_P		E_I		E_{ta}		E_{td}	
			μ	σ	μ	σ	μ	σ	μ	σ
ANFO-TM	2.6	5	0.169	0.132	0.099	0.095	0.091	0.116	0.028	0.017
	4.4	8	0.155	0.113	0.108	0.091	0.099	0.114	0.058	0.049
	6.1	4	0.106	0.096	0.063	0.035	0.117	0.120	0.029	0.005
ANFO-FM	2.6	6	0.004	0.002	0.003	0.001	0.002	0.000	0.003	0.001
	4.4	9	0.003	0.001	0.003	0.001	0.002	0.001	0.004	0.002
	6.1	3	0.005	0.002	0.003	0.001	0.006	0.002	0.003	0.000
ANFO-T	2.6	6	0.085	0.060	0.036	0.028	0.017	0.014	0.031	0.045
	4.4	9	0.072	0.037	0.044	0.025	0.023	0.017	0.024	0.020
	6.1	6	0.090	0.040	0.053	0.026	0.037	0.025	0.037	0.022
ANFO-F	2.6	6	0.002	0.000	0.002	0.000	0.002	0.001	0.002	0.001
	4.4	9	0.002	0.001	0.002	0.001	0.002	0.001	0.005	0.003
	6.1	3	0.004	0.001	0.003	0.000	0.006	0.001	0.003	0.000
AMMONAL-TM	2.6	6	0.855	0.055	0.695	0.077	0.953	0.060	0.062	0.026
	4.4	9	0.856	0.044	0.697	0.028	0.947	0.072	0.263	0.065
	6.1	2	0.882	0.025	0.641	0.015	1.201	0.048	0.352	0.012
AMMONAL-F	2.6	3	0.196	0.036	0.062	0.004	0.085	0.014	0.012	0.002
	4.4	6	0.136	0.034	0.110	0.021	0.084	0.025	0.099	0.054
	6.1	6	0.126	0.024	0.111	0.019	0.101	0.035	0.111	0.035

Table 5. TNT equivalent values of shock front velocity (E_u) for each trial; being μ the mean and σ the standard deviation

Test	Z m/kg$^{1/3}$	Signal number	E_u	
			μ	σ
ANFO-TM	1.4	5	0.182	0.176
	3.5	5	0.122	0.155
	5.2	5	0.439	0.340
ANFO-FM	1.4	6	0.018	0.030
	3.5	6	0.022	0.023
	5.2	6	0.679	0.083
ANFO-T	1.4	6	0.067	0.034
	3.5	6	0.057	0.067
	5.2	6	0.568	0.716
ANFO-F	1.4	6	0.021	0.006
	3.5	6	0.040	0.003
	5.2	3	0.390	0.018
AMMONAL-TM	1.4	6	1.141	0.060
	3.5	6	1.006	0.287
	5.2	2	1.953	0.130
AMMONAL-F	1.4	3	0.197	0.022
	3.5	3	0.036	0.016
	5.2	6	0.425	0.253

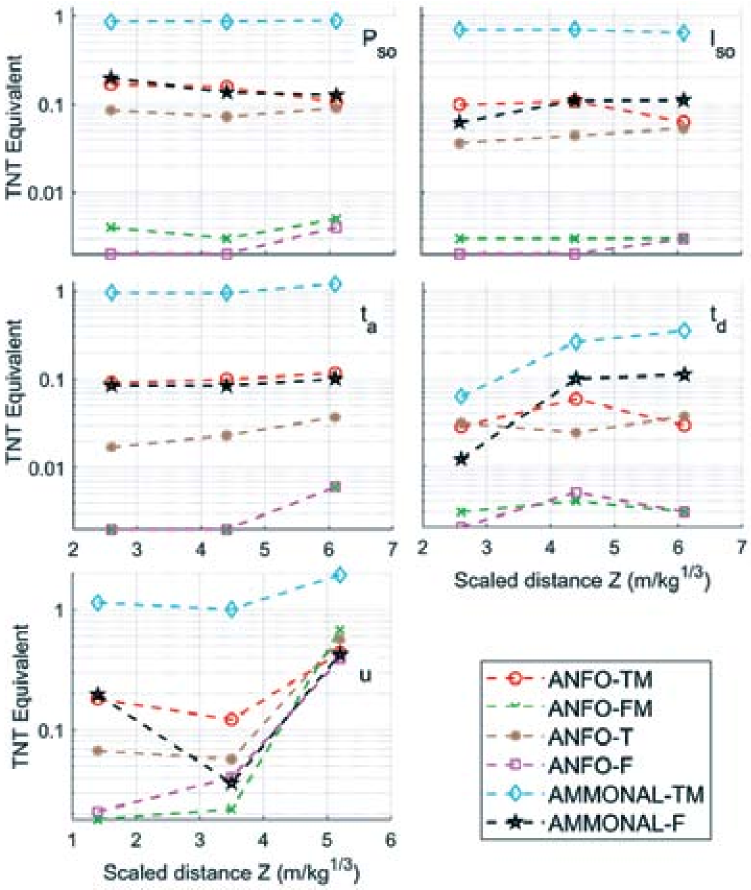


Figure 5. TNT equivalent versus scaled distance.

the explosive was an expanded polystyrene cubic base. This kind of support should not affect the measures[22]; however, the pressure values obtained here are slightly higher. In the case of ANFO-T, in two of the three trials, the glove that contained the explosive mixture was broken during the placement of the explosive. As the trials with glove produce a higher pressure values, this fact allows us to confirm (as other authors suggest[6,8]) that: the confinement, however small it may be (latex glove), make the pressures generated higher and therefore, the TNT equivalent. In all other cases, variations are low, especially for the ammonal explosive.

Comparing explosive by explosive, it can be seen that ANFO in prilled form presents TNT equivalent values extremely different when using technical ammonium nitrate (ANFO-T) or fertilizer ammonium nitrate (ANFO-F) being the first one much higher, probably due to the difference in the porosity as other authors suggest[23]. The same happens when ammonium nitrate powder is used. The difference between fertilizer and technical grade is very pronounced. For the ammonal mixture, the equivalent obtained is the highest (near to 1) with technical ammonium nitrate powder. On the contrary, when working with fertilizer nitrate in prills, the equivalent does not reach 0.2 at best. When dealing with the use of the same explosive and the same mixture (ANFO), seems to confirm that the powder explosive generates higher pressures than in prills, mainly due to the more intimacy and homogenous mixing of components (nitrate and fuel).

The equivalents referred to the impulse are in general lower than the same for pressure (see Table 4). In most cases, the equivalent based on impulse is similar for all scaled distances. Regarding the explosive mixture, the highest values have been obtained by the ammonal (with technical grade). Looking at the powder mixture, the results are better than in prills for ANFO with technical grade, while when using FAN the results are similar and very low.

The most accurately measured blast parameter is usually the arrival time[11]. The trend is similar to the previous two parameters although with some variations. In this case, the highest values are always at the largest distance, and the tendency is to increase with distance.

The positive phase duration (Table 4) is the most subjective measurement due to difficulties in accurate determination of the time where the pressure change to negative values for real signals[11]. Viewing the results obtained, no defined pattern is appreciated. All the values are lower than the other parameters, and depending on the case, increasing or decreasing with the scaled distance. Also, for all ANFO's mixtures, the highest or the lowest value are obtained at 4.4 m/kg1/3.

For the shock front velocity (Table 5 and Fig. 5), it can be seen that the highest values are always at the largest scaled distance 5.2 m/kg$^{1/3}$. Furthermore, in some cases, the difference is around an order of magnitude. As the velocity depends on the arrival time, the trend followed in this parameter is the same. Again, the mixture of ammonal in technical grade and powder form registers the highest values, being all data above one.

Comparing the field test data obtained with respect to the representation of the UFC 3-340-02 values for hemispherical surface explosion (Fig. 6), it can be seen that all the parameters measured are in consonance with the TNT performance results, which means that they follow the tendency of the curves for each parameter. For pressure (P_{so}), impulse (I_{so}), and shock front velocity (u), all the data are under the curve while in case of arrival time (t_a) and positive phase duration (t_d) are over them. It means that all the mixtures are less powerful than the TNT except the ammonal mixture with technical ammonium nitrate powder (AMMONAL-T) which registers similar values than TNT.

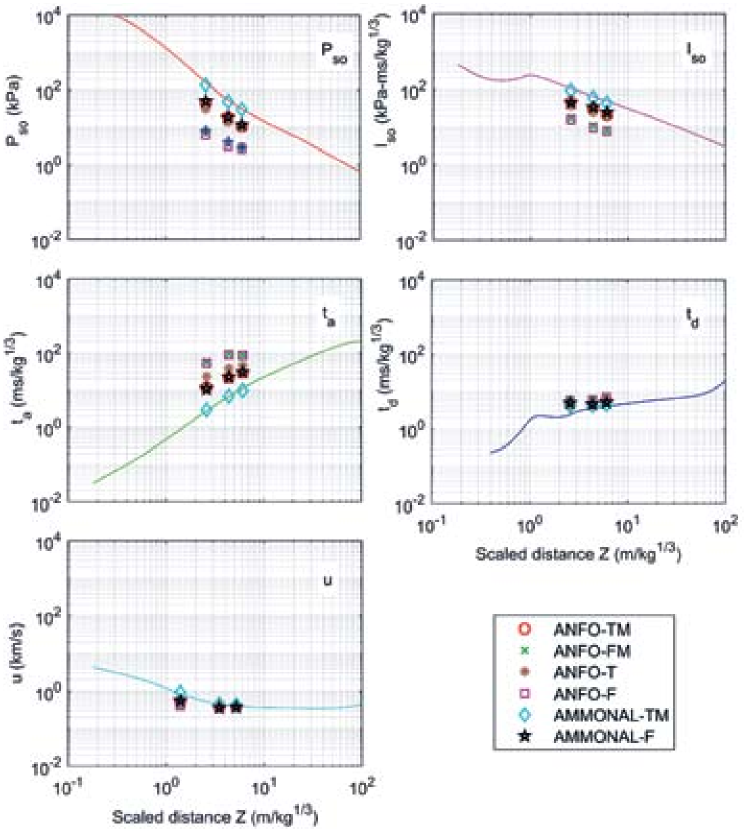


Figure 6. Field test data and UFC 3-340-02 values for hemispherical surface explosion.

4. CONCLUSIONS

Blast wave characterisation of improvised explosive device with homemade explosives has been carried out based on TNT equivalent. A series of airblast trials have been conducted, at small scaled distances, which can be used by the security forces for better understanding the possible IED effects.

For this characterisation, two main substances have been used: ANFO and AMMONAL. Of these, different mixtures have been tested, where the ammonium nitrate type and physical form have been modified.

TNT equivalent has been calculated for small devices of 1.5 kg initiated with detonation cord. Viewing the results, it can be concluded that ANFO with fertilizer ammonium nitrate does not detonate with this charge conditions. ANFO with technical ammonium nitrate produces an incident pressure bigger than 40 kPa at 3 m which can produce damage on people and structures. The IED with the mixture named AMMONAL produces a full detonation and has a TNT equivalent higher than the ANFO, being nearby to 1 when is powdered. Technical ammonium nitrate produces a TNT equivalent higher when working with its powder form than when it is prilled mainly due to the more intimacy and homogenous mixing of components (nitrate and fuel).

The TNT equivalent takes different values depending on the parameter used. The highest values and more consistent have been obtained when the equivalent is based on the peak pressure. This TNT can be useful to determine the potential damage for small devices with this kind of substances and initiation system. In addition, the experimental work presented could be used for calibration of models using hydrocodes such as LS-DYNA or other shock physics code. The calibrated models could then be compared to large scale data for validation. If successful, it would show that this small scale experimental tests can be used for the characterisation of HMEs.

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CONTRIBUTORS

Ms María Chiquito is PhD candidate at the School of Mines and Energy from the Universidad Politécnica de Madrid. She has a BSc in Civil Engineering and a MSc in Integrated Management of Quality, Environment and Workplace Risk Prevention. She was the responsible of Management Systems Department (Quality, Environment, Health and Safety and Research and Development) in a construction company during eight year.
Her contribution in this study has been on signal treatment, data analysis and manuscript redaction.

Dr Ricardo Castedo is Assistant Professor at the School of Mines and Energy from the Universidad Politécnica de Madrid. He holds a PhD in Geological Engineering with two research stays of 4 months at University of Leeds (UK) and University of Windsor (Canada).
His contribution in this study has been in the field tests, signal treatment, data analysis and manuscript redaction.

Dr Lina Mª López is Associate Professor at the School of Mines and Energy from the Universidad Politécnica de Madrid. She holds a PhD in Mining Engineering with two research stays at Mines Paris Tech (France) and New Mexico Tech (USA).
Her contribution in this study has been in the field tests, signal treatment and data analysis.

Dr Anastasio P. Santos is Associate Professor at the School of Mines and Energy from the Universidad Politécnica de Madrid. He holds a PhD in Mining Engineering with one research stays of a year at Ecole Centrale de Paris (France). He used to work for HUNOSA - Empresa Nacional del Uranio as a Mechanical Engineer during two year and he was the Leader of structural analysis Dept. during four year at TGI.
His contribution in this study has been in the field tests, instrumentation and data analysis.

Dr Juan M. Mancilla is presently working at the Compliance and Facilitation Directorate in the World Customs Organisation. He has been working as Captain of the Spanish Navy Forces and latter at the Counter Improvised Explosive Devices Centre of Excellence. He is now a PhD student at the School of Mines and Energy of the Universidad Politécnica de Madrid.
His contribution in this study has been in the field tests, explosives preparation and data analysis.

Dr José I. Yenes is now working at the Spanish Ministry of Defense and he is also teacher at the Army Polytechnic School. He spent seven year at the Counter Improvised Explosive Devices Centre of Excellence and conducted more than fifteen research projects.
His contribution in this study has been in the field tests and explosives preparation.