



## Power of TATP based explosives

Robert Matyáš, Jakub Šelešovský\*

*Institute of Energetic Materials, Faculty of Chemical Technology, University of Pardubice, CZ-532 10 Pardubice, Czech Republic*

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### ABSTRACT

The power of various explosive mixtures based on triacetone triperoxide (3,3,6,6,9,9-hexamethyl-1,2,4,5,7,8-hexoxonane, TATP), ammonium nitrate (AN), urea nitrate (UrN) and water (W), namely TATP/AN, oil/AN, TATP/UrN, TATP/W and TATP/AN/W, was studied using the ballistic mortar test. The ternary mixtures of TATP/AN/W have relatively high power in case of the low water contents. Their power decrease significantly with increasing the water content in the mixture to more than 30%.

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### 1. Introduction

The power of explosives (sometimes called performance, strength, working capacity or blasting ability) is an important parameter for their usage. It provides an information about the ability of the explosive to do work such as blasting down rock or propelling a chunk of metal [1]. The power of explosives is determined by the work done in the expansion of the gases produced. The factors which determine the explosives power are mainly the heat of detonation and the amount and composition of the gas produced [2].

The power of explosives can be measured by several tests (ballistic mortar, Trauzl lead block, underwater explosion, cylinder test). The Trauzl block test was often used in the past. However it has some disadvantages such as using of toxic lead, rupturing of a lead block or high cost. Nowadays a ballistic mortar is the preferred test for the explosive power measurements. Ballistic mortar test is also one of the methods recommended for the testing of explosive power of organic peroxides by the "Orange Book" [3].

The ballistic mortar is a heavy steel mortar attached to a pendulum. The defined amount of a tested explosive (10 g) is inserted into the mortar, enclosed by a steel projectile and fired. The maximal swing of a pendulum is a measure of explosive power. The testing device is described e.g. in [3] and the whole test is commented by

Sučeska [4]. The power of the tested explosive is expressed as the relative value, in comparison with the standard explosive (TNT or blasting gelatine). The relative power of some standard explosives can be found in [1].

The ballistic mortar is often used for the evaluation of the relative power of commercial explosives. The values of relative power of various commercial explosives are stated in [5]. The relative power of aluminized slurry explosives can be found in patent literature, e.g. [6]. The commercial explosives are usually mixed to have oxygen balance near zero. The zero oxygen balance (OB) ensures low toxicity of gaseous products as well as high power. The relationship between oxygen balance and relative power of explosives is also mentioned in [7].

The application of ballistic mortar for the evaluation of the hazard of organic peroxides is published in [8]. Five kinds of commercially used organic peroxides and the hydrogen peroxides were subjected to various tests including detonability, thermal stability and energy release tests. The values of relative power ranged from 0% TNT for dicumyl peroxide, 15.8% TNT for dibenzoyl peroxide, 16% TNT for t-butyl peroxide, 18 and 26% TNT for methyl ethyl ketone peroxide (with 9 and 11% of active oxygen respectively), 27% TNT for diisopropyl peroxydicarbonate, up to 42% TNT for hydrogen peroxide (70% in water).

Yoshida et al. [9] used the ballistic mortar with the modified measuring procedure to evaluate the explosive hazard of commercial organic peroxides. The authors were able to determine if the sample propagate the explosion and to measure the explosive power: 0% TNT for cumyl hydroperoxide (80% in cumene), dibenzoyl peroxide (75% in water), dicumyl peroxide and dilauroyl peroxide;

\* Corresponding author. Tel.: +420 466 038 018; fax: +420 466 038 024.

E-mail addresses: [mail@robertmatyas.cz](mailto:mail@robertmatyas.cz) (R. Matyáš), [jakub.selesovsky@gmail.com](mailto:jakub.selesovsky@gmail.com) (J. Šelešovský).

25% TNT for dibenzoyl peroxide, 38% TNT for di-*t*-butyl peroxide and 40% TNT for *t*-butyl peroxybenzoate. The assessment of the the shock sensitivity of the sample is also described.

Matyáš [10] measured the relative power of organic peroxides (15% TNT for dibenzoyl peroxide, 41% TNT for methyl ethyl ketone peroxide and 76% TNT for hexamethylenetriperoxide diamine). He also states the relative power values for the mixtures of organic peroxides with ammonium nitrate (balanced to almost zero OB). These mixtures have sufficiently higher power than pure peroxides (106% TNT for MEKP/AN mixture and 116% TNT for the HMTD/AN mixture).

Properties of TATP (triacetone triperoxide, 3,3,6,6,9,9-hexamethyl-1,2,4,5,7,8-hexoxonane) and its mixtures are extensively studied at the Institute of Energetic Materials, University of Pardubice. The thermal stability of raw TATP [11], the spontaneous transformation of TATP to DADP [12], the detonation velocity and the cylinder test of TATP/ammonium nitrate/water mixtures [13] have been already published. The influence of the reaction conditions of TATP synthesis on the composition of product [14] is ready for publishing.

We would like to continue the TATP studies, expand the data published by Zeman et al. [15] and also fill the gap in the field of the power of mixtures of primary explosive with oxidizer and other compounds. The attention is paid to the relation between the power of the mixture and its composition in this article.

## 2. Experimental

**Caution:** TATP is a primary explosive sensitive to impact, friction, electric discharge and flame. The synthesis and handling of TATP (even when wet) are dangerous operations that require the safety precaution for handling of primary explosives! Some mixtures of TATP/AN/W can be more sensitive to impact than pure TATP!

### 2.1. TATP preparation

51 ml (0.5 mol) of 30% hydrogen peroxide was mixed in 250 ml beaker with 29.2 ml (0.4 mol) of acetone. The reaction mixture was then cooled below 20 °C when 8.8 ml (0.1 mol) of 35% hydrochloric acid was added slowly. The temperature was kept below 20 °C and the mixture was stirred during the acid addition. The water cooling bath was removed after one hour and the reaction mixture was allowed to stand for 24 h at room temperature without stirring when TATP formed as a white crystalline material. The resulting precipitate was then filtered using plastic Büchner funnel, washed once with distilled water, once with 1% solution of sodium carbonate and then repeatedly with water until neutral. The particle size of prepared TATP after 24 h of drying (at room temperature) was 50–150 μm.

Due to the safety concerns TATP for the preparation of TATP/W and TATP/AN/W mixtures was not dried but used moist as obtained from filtration. TATP was dried only for preparation of dry mixtures TATP/AN, TATP/UrN and some of the TATP/W mixtures.

### 2.2. Preparation of TATP mixtures

Preparation of TATP mixtures was carried out behind the safety shield (bulletproof glass). The mixtures were carefully mixed by wooden spatula on the paper (for dry mixtures) or plastic foil (for wet mixtures) pad. The operator and the working table were earthed.

#### 2.2.1. TATP/AN and TATP/UrN mixtures

Ammonium nitrate was produced by Synthesia Ltd., Pardubice, Czech Republic; sieved and the fraction below 0.5 mm was used

**Table 1**  
The relative power of TATP/AN mixtures.

m/m TATP (%)	m/m AN (%)	OB (%)	RP (% TNT)
2	98	16.6	83.3
4	96	13.1	95.4
6	94	9.7	98.7
8	92	6.3	96.5
10	90	2.9	97.6
11.7	88.3	0.0	106.9
15	85	−5.7	99.4
20	80	−14.2	94.6
40	60	−48.5	79.4
60	40	−82.7	69.7
80	20	−116.9	61.4
100	0	−151.2	62.0

for preparation of the mixtures. Urea nitrate was prepared from the water solution of urea and nitric acid. It was used in dry fine form for the preparation of mixtures. Freshly prepared dry TATP was very carefully mixed with dry ammonium nitrate or dry urea nitrate. Mixtures with detonators were wrapped into a plastic foil and sealed.

#### 2.2.2. TATP/AN/W

Freshly prepared moist TATP was carefully mixed with dry ammonium nitrate and the explosive mixture was immediately wrapped into the plastic foil together with detonator and sealed. The content of water (W) in the mixtures was calculated retrospectively after drying a small sample of TATP taken from wet TATP before preparation of mixture.

The mixtures with the high content of water (higher than 63%, m/m) were not prepared because it is not possible to ensure the homogeneity of such mixtures.

#### 2.2.3. TATP/W

These types of mixtures were prepared by two methods. The first method was to use the moist TATP directly after filtration of TATP during its preparation. The content of water in the mixtures was calculated retrospectively after drying a small sample of TATP taken from wet TATP before preparation of the mixture. Mixtures with detonators were wrapped into the plastic foil and sealed.

Dry TATP was used for the second type of samples. Calculated amount of water was carefully added to dry TATP and left to soak to the crystals. Mixtures with detonators were wrapped into plastic foil and sealed.

#### 2.2.4. AN/oil

Dry ammonium nitrate was mixed with paraffine oil OL-J46 (supplied by Paramo Ltd., Pardubice, Czech Republic). Mixtures with detonators were wrapped into the plastic foil and sealed.

**Table 2**  
The relative power of oil/AN mixtures.

m/m oil (%)	m/m AN (%)	OB (%)	RP (% TNT)
1	99	16.4	108
4	96	5.5	127
5	95	1.9	129
6	94	−1.7	126
8	92	−9.0	125
10	90	−16.2	124
15	85	−34.3	110
20	80	−52.4	95
25	75	−70.5	70
30	70	−88.6	17

**Table 3**  
The relative power of TATP/UrN mixtures.

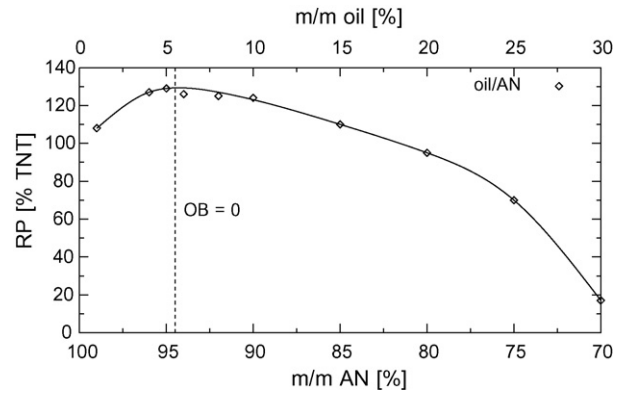
m/m TATP (%)	m/m UrN (%)	OB (%)	RP (% TNT)
0	100	-6.5	78
2	98	-9.4	81
4.1	95.9	-12.4	79
10	90	-21.0	70
15	85	-28.2	68
20	80	-35.4	66
40	60	-64.4	63
60	40	-93.9	61
80	20	-122.2	61
100	0	-151.2	62

**Table 4**  
The relative power of TATP/W mixtures.

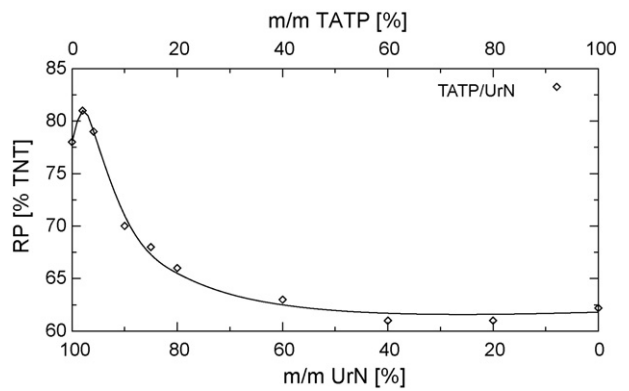
m/m TATP (%)	m/m W (%)	OB (%)	RP (% TNT)
100	0	-151.2	62.0
90.0	10.0	-136.1	54.8
71.6	28.4	-108.2	41.0
70.0	30.0	-105.8	37.2
60.0	40.0	-90.7	30.1
50.0	50.0	-75.6	19.3
40.0	60.0	-60.5	6.0

**Table 5**  
The relative power of TATP/AN/W mixtures.

m/m TATP (%)	m/m AN (%)	m/m W (%)	OB (%)	RP (% TNT)
100	0	0	-151.2	62.0
86.2	7.5	6.3	-128.8	61.1
70.3	15.0	14.7	-103.3	58.2
57.9	14.8	27.2	-84.6	53.1
54.6	25.0	20.3	-77.6	46.9
42.6	14.3	43.1	-61.5	30.7
45.9	45.0	9.1	-60.4	68.1
44.5	34.5	20.9	-60.4	59.1
42.2	21.2	36.6	-59.6	37.2
37.2	35.0	28.1	-49.1	48.0
32.0	26.8	41.2	-43.0	24.1
33.0	51.5	15.5	-39.5	78.7
29.8	62.1	8.1	-32.6	84.4
26.6	43.1	30.3	-31.6	47.7
22.4	15.0	62.7	-30.8	6.5
26.0	54.0	20.0	-28.5	81.0
11.3	78.8	9.9	-1.3	100.5
8.8	66.7	24.6	0.0	71.9
4.9	90.9	4.2	10.8	100.5



**Fig. 2.** The dependence of the relative power of oil/AN mixtures on their composition.



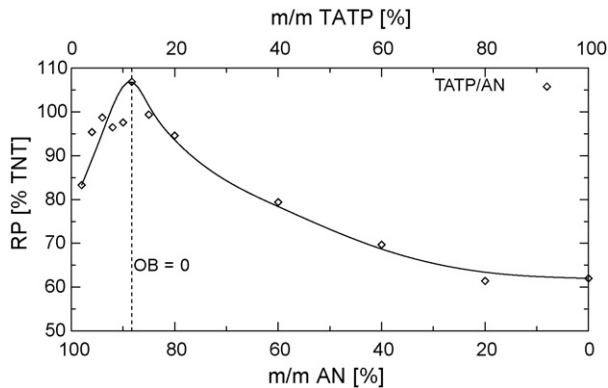
**Fig. 3.** The dependence of the relative power of TATP/UrN mixtures on their composition.

2.3. Ballistic mortar test

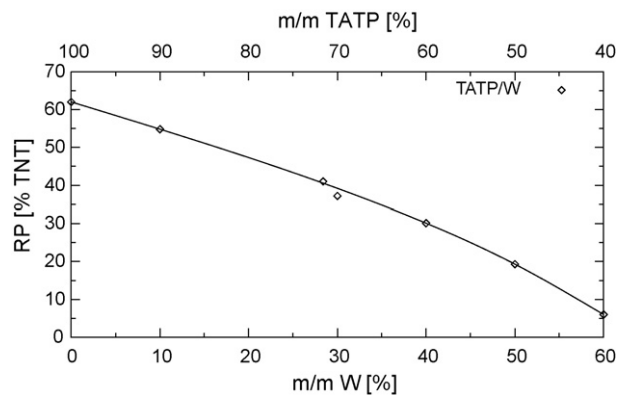
The measurements of the power of the samples were carried out in accordance with the procedure described in [16]. Values are reported as a relative performance of TNT. For each measurement, 10 g tested explosive was wrapped in a plastic foil and initiated by nonelectric detonator. Three tests were carried out for each sample. The averaged values are summarized in Tables 1–5.

3. Results and discussion

The dependence of the power on the composition was observed in case of all examined mixtures. If one compares the fuel-oxidizer



**Fig. 1.** The dependence of the relative power of TATP/AN mixtures on their composition.



**Fig. 4.** The dependence of the relative power of TATP/W mixtures on their composition.

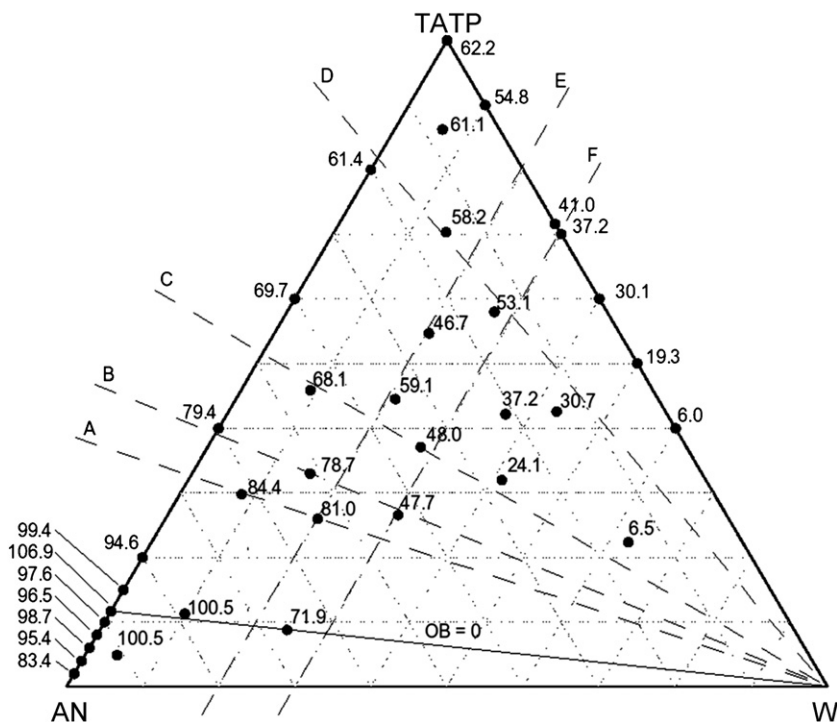


Fig. 5. The dependence of the relative power of TATP/AN/W mixtures on their composition.

mixtures (see graphs in Figs. 1 and 2), it is evident, that the maximal power is obtained near the zero oxygen balance. The zero oxygen balance have the mixtures of 11.7% TATP with 88.3% AN and 5.5% oil with 94.5% AN. The balanced (OB = 0) mixture oil/AN showed higher power than TATP/AN mixture.

The TATP/UrN mixture cannot be balanced to OB = 0, because both compounds have negative OB themselves. However also in this case the maximum on the dependence of power on composition was observed, which can be seen in Fig. 3. This maximum occurs at the composition of 2% TATP with 98% UrN and can be probably ascribed to the lower ability to initiate the pure UrN. In case of TATP/W mixtures, the power decreases with the increasing water content, as can be seen in Fig. 4.

The ternary diagram of the dependence of explosive power on the composition of TATP/AN/W mixtures is shown in Fig. 5. The highest values of the power were detected near the zero oxygen balance line (the line OB = 0). If one focuses on the mixtures with the constant TATP/AN ratio (in Fig. 5 lines A, B, C and D), it is possible to say that the small addition of water (up to cca 20 %) causes only slight decrease of the power. On the other hand drastic reduction of power occurs when more than 30 % of water is added. This transition tendency is indicated by the region between the lines E (20 % of water) and F (30 % of water) in the Fig. 5. This is an important discovery, if one wants to decrease an explosive power of a TATP/AN mixtures by adding the water, the water should be added in sufficient amount.

#### 4. Conclusion

The power of various explosive mixtures (TATP/AN, oil/AN, TATP/UrN, TATP/W and TATP/AN/W) was studied. The fuel-oxidizer mixtures (TATP/AN and oil/AN) have the maximal power near the zero oxygen balance (11.7% of TATP and 5.5% of oil). The mixture TATP/UrN is a mixture of two fuels and has also the maximum on the composition–power dependence (2% of TATP). This result is probably caused by the lower ability to initiate of the pure UrN.

The ternary mixtures of TATP/AN/W have relatively high power in case the water contents is below 20% approx. Their power decrease significantly with increasing of the water content in the mixture to more than 30%.

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