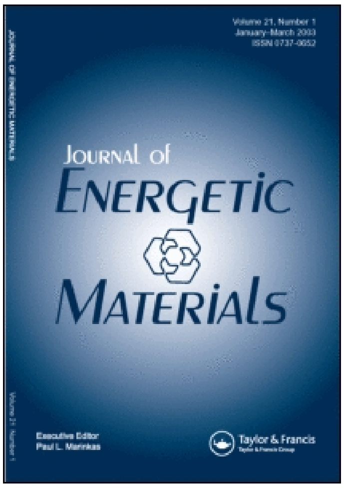

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DETONATION GASES AND RESIDUES OF COMPOSITE EXPLOSIVES

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ABSTRACT

Our previous work dealing with analyzing the reaction products of insensitive cast high explosives containing TNT, nitroguanidine (Nigu), ammonium nitrate (AN) and aluminium (Al) has shown that Al reacted incompleteley, especially in the case of high concentration of this metal.

In this paper, the influences of ambient gas or vacuum condition, of glass confinement and of the grain size of nitroguanidine on the product formation was investigated. Also the initiation behavior was analysed.

It was found that composition of the detonation gases is strongly dependent on the grain size of spherical nitroguanidine. Parameters responsible for the amount of unreacted Al are not only the oxygen balance but also the energy content of the high explosives.

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INTRODUCTION

Castable high explosives consisting of TNT, nitroguanidine (Nigu) or ammoniumnitrate (AN) with aluminium (Al) and castable plastic bonded high explosives containing ammonium perchlorate (AP), RDX and energetic plasticisers with high amounts of Al have become interesting on account of their insensitivity to external influences, for economic reasons and due to the easy availability of their components.

In particular, the production of spherical Nigu and phase-stabilized AN at the Fraunhofer-Institute ICT has improved the manufacturing conditions of those explosives /1/2/. Because of the nonideal behavior of explosives containing Nigu and AN, large charge diameters were necessary. For this reason it was not possible to use a detonation calorimeter /3/4/.

In order to learn more about the detonation reactions and to find out the amount of Al reacting during the detonation process of Nigu and AN containing explosives, we used a blasting chamber with a volume of 1,5 m^3 in which charges up to 300 g were initiated in inert atmosphere or in vacuum.

The analysis of the reaction products was done as a means to detect complete or incomplete reactions.

AIM OF THE INVESTIGATION

The investigations were done to determine the following influences:

- Influence of the booster on the composition of the reaction products, especially on the formation of NO and N_2O
- Influence of ambient gas or vacuum on the reaction products - Influence of glass confinement on the reaction products
- Influence of grain size of Nigu
- To find out the amount of Al reacted or unreacted in different charges

EXPERIMENTS

As mentioned before, a firing vessel of stainless steel with a volume of 1,5 m^3 was used. The static pressure for which the vessel was designed was about 4 MPa. In most cases, high explosive charges with a diameter of 50 mm and a length of between 85 and 95 mm were investigated. For initiation, a detonator Cap No 8 of Dynamit Nobel together with a 10 g RDX booster in each case was used.

In most cases an additional booster consisting of about 18 g of explosive sheets, having the same diameter as the explosive charge, was applied.

After the explosive charge was hung inside the vessel, the evacuation was started in order to replace air by argon as an ambient gas. After firing, the gas was analyzed by streaming it directly from the vessel through a chemiluminescence analyzer to measure the NO/NO_x content. Additional samples were taken in evacuated glass tubes for the mass spectrometric analysis. After opening the blasting chamber, the solid residue was collected as completely as possible in order to analyze carbon black and unreacted aluminium.

Charge components

The grain size of the spherical nitroguanidine (Nigu) was in most cases

72 %	500 - 1000 µm
28 %	125 - 250 µm

For some specific investigations we used fractions of

125 - 250 µm and
500 - 1000 µm

The bulk density of the spherical product is about 1.1 g/cm^3. The density of the spherules is between 1.72 - 1.76 g/cm^3. The grain size of ammonium nitrate (AN) was about 137 µm and of aluminium (Al) < about 15 µm. The phase-stabilized AN was produced by atomization of the melted product.

Confinement

Some shots were fired in order to determine the influence of a glass confinement on the detonation products. For these experiments two different glass thicknesses were used: 5 mm and 9 mm. These glass cylinders had a diameter of 52 mm and a length of 83 mm.

Explosive Charges Investigated

The following explosive charges were tested:

- 40 TNT/ 60 Nigu
- 60 TNT/ 40 Nigu
- 50 TNT/ 30 Nigu/ 20 Al, Ar, with and without booster
- 50 TNT/ 50 Nigu/ Vacuum, Ar, Ar-Glass Tube
- 50 TNT/ 50 Nigu/ Ar, with and without glass confinement
- 50 TNT/ 50 Nigu/ Ar, with different glass confinement
- 50 TNT/ 50 Nigu/ Ar, with different grain size of Nigu
- 50 TNT/ 50 AN/ Ar and Vacuum
- 50 TNT/ 25 AN/25 Al, Ar, Reproducibility

The influence of oxygen balance on the reaction of Al was tested with the following compositions:

50 TNT/ 25 AN/ 25 Al
75 Comp.B/ 25 Al
75 PBX/ 25 Al

RESULTS

Initiation with and without additional booster

The first shots were done using explosive charges containing 40 % TNT and 60 % Nigu. At first, for the initiation cylindrical RDX boosters of 10 g were applied. The detonation gases analyzed have shown that large amounts of nitric oxide were formed (See Table 1) which exhibits relatively high amounts of N_2O and HCN. This means the detonation reaction was not complete enough. It must be supposed that the booster was too weak or that the Nigu content was too high.

Therefore, at first we changed the mixture and used 60 % TNT and 40 % Nigu. In this case the N_2O content decreased. But when analyzing the solid residue we found small amounts of unreacted products, for example, 1,5 % TNT and 1,0 % Nigu, See Table 2).

To improve the initiation conditions we started new experiments by the use of an additional booster having the same diameter as the explosive charge (See trial no. 1/55 in Table 2). The result was that neither TNT nor Nigu could be found in the solid residue. Additionally, the NO content was strongly reduced from 2400 - 2600 ppm to 190 ppm. Also the HCN content was reduced to a smaller degree.

With charges containing 20 % Al the initiation could be improved in the same way as we see in Table 3 by comparing trial no. 1/18 with 1/71. Not only the amounts of HCN and NO could be reduced drastically, but also the gas formation could be increased as shown by the argon concentration.

Table 1

INITIATION WITHOUT ADDITIONAL BOOSTER

TRIAL No.	1/8	1/9
COMPOSITION (wt.%)	40 TNT 60 NIGU	40 TNT 60 NIGU
CONDITIONS	Ar	Ar
BOOSTER (g RDX)	10	10
GASES, VOL%		incomplete reaction
H_2	4.7	3.4
N_2	43.4	47.3
CO	21.5	20.3
CO_2	20.3	24.6
N_2O	4.2	2.6
HCN	5.7	1.1
CH_4	0.5	0.6
Ar, VOL%	91.5	97.3
ppm NO	4000	1350

INITIATION WITHOUT AND WITH ADDITIONAL BOOSTER

TRIAL No.	1/14	1/13	1/55
COMPOSITION (wt.%)	60 TNT 40 NIGU	60 TNT 40 NIGU	60 TNT 40 NIGU
CONDITIONS	Ar	Ar	Ar
ADDIT. BOOSTER	-	-	18 g
RESIDUE (g)	?	?	54
GASES, VOL%			
H_2	5.9	6.1	6.7
N_2	42.9	39.4	39.4
CO	23.0	23.1	30.1
CO_2	20.5	21.6	19.7
N_2O	1.1	1.3	-
HCN	5.1	7.1	3.6
CH_4	1.4	1.4	0.5
Ar, VOL%	89.7	90.8	89.7
ppm NO	2400	2600	190

Table 3

INFLUENCE OF ADDITIONAL BOOSTER

TRIAL No.	1/18	1/71
COMPOSITION (wt.%)	50 TNT 30 NIGU 20 AL	50 TNT 30 NIGU 20 AL
CONDITIONS	Ar	Ar
ADDIT. BOOSTER	-	+
RESIDUE (g)	?	111
%AL unreacted	?	8.7
GASES, VOL%		
H_2	22.3	27.6
N_2	28.1	25.5
CO	34.4	39.5
CO_2	5.3	3.2
HCN	9.4	4.1
CH_4	0.5	0.2
Ar, VOL%	90.2	86.3
ppm NO	1240	34

Influence of argon as an ambient gas and vacuum conditions

Further experiments were performed with 50 % TNT and 50 % Nigu, comparing argon as an ambient gas with vacuum. We see that the concentration of H_2 and CO are much higher and CO_2 and HCN much smaller under vacuum compared with argon (See Table 4).

We found that the carbon-containing residue 's much smaller in vacuum than in argon as an ambient gas. Therefore, the gas formation is higher in the vacuum tests.

It looks like argon provided confinement, because we know from earlier investigations that the better the confinement, the higher is the formation of carbon, CO_2 and H_2O.
In this connection we are not able to determine the effect of reshocking.

Influence of glass confinement

Some experiments with glass tubes were conducted to evaluate the influence of confinement. For these tests, two different wall thicknesses were used: 5 mm and 9 mm. The tubes were 83 mm in length and 52 mm in diameter. Comparing the results in Table 5 we see that the 9 mm confinement produced a higher CHN-containing residue and a higher CO_2 content, but a decreased amount of H_2, CO and HCN. On the other hand, between 5 and 9 mm wall thickness, there is only a moderate difference in CO_2 but a strong difference in the amount of HCN formed (See Table 6).

Table 4

DETONATION UNDER ARGON OR VACUUM CONDITION

TRIAL No.	1/1	1/2
COMPOSITION (wt.%)	50 TNT 50 NIGU	50 TNT 50 NIGU
CONDITIONS	Ar	VAC.
RESIDUE (g)	75	11
GASES, VOL%		
H2	3.2	18.9
N2	45.3	33.0
CO	25.1	42.9
CO2	22.4	4.6
(NH3)	-	>0.3
HCN	3.5	0.2
CH4	0.2	0.05
Ar, VOL%	88.7	82.8
ppm NO	40	40

Table 5

INFLUENCE OF GLASS CONFINEMENT

TRIAL No.	2/30	6/30
COMPOSITION (wt.%)	50 TNT 50 NIGU	50 TNT 50 NIGU
CONDITIONS	Ar	Ar
GLASS CONFINEMENT (mm)	-	9.0
RESIDUE (g)	17.9	31.5
GASES, VOL%		
H2	12.7	5.4
N2	39.9	46.6
CO	25.2	20.4
CO2	20.5	24.3
N20	-	1.0
NO	-	0.1
(NH3)	-	>1.0
HCN	1.4	0.3
CH4	0.2	0.9
Ar, VOL%	84.9	88.8
ppm NO	2	54

Table 6

INFLUENCE OF CONFINEMENT

TRIAL No.	48/20	6/30
COMPOSITION (wt.%)	50 TNT 50 NIGU	50 TNT 50 NIGU
GLASS CONFINE-MENT (mm)	5	9
GASES, VOL%		
H_2	4.3	5.4
N_2	47.3	46.6
CO	17.3	20.4
CO_2	22.3	24.3
N_2O	1.3	1.0
NO	0.7	0.1
NH_3	>3.0	>1.0
HCN	3.2	0.3
CH_4	0.6	0.9
Ar, VOL%	88.0	88.8
ppm NO	700	54

Influence of grain size of Nigu

The influence of the grain size was tested by using spherical Nigu with the following grain distribution:

a) 125 - 250 µm
b) 500 - 1000 µm

For this investigation, a charge consisting of 50 % TNT and 50 % Nigu was used. As can be seen in Table 7, the larger grain size did not react as completely as the smaller grain size of Nigu: Relatively high amounts of metastable decomposition products of Nigu were analyzed, for example, 4,5 Vol % N_2O, 4,0 Vol % NO and 4,6 % HCN.

These products are responsible for a considerable decrease of the heat of detonation as follows:

50 % TNT/ 50 % Nigu	Heat of detonation (kJ/kg) HCN included	without HCN
Nigu 125 - 250 µm	4567	4654
Nigu 500 - 1000 µm	4355	4480

Charges based on TNT and AN

The influence of argon or vacuum on the product formation from charges containing AN is not as pronounced as in the case of Nigu because of the higher oxygen content (See Table 8).

Table 7

INFLUENCE OF GRAIN SIZE OF NIGU

TRIAL No.	57/20	60/20
COMPOSITION (wt.%)	50 TNT 50 NIGU	50 TNT 50 NIGU
CONDITIONS	Ar	Ar
GRAIN SIZE OF NIGU (μM)	125-250	500-1000
GASES, VOL%		
H2	6.8	2.7
N2	48.0	44.6
CO	23.2	21.9
CO2	17.3	17.2
N2O	-	4.5
NO	-	4.0
(NH3)	>1.0	
HCN	3.4	4.6
CH4	0.3	0.5
Ar, VOL%	85.6	91.0
ppm NO	17	4200

Table 8

INFLUENCE OF CARRIER GAS AND VACUUM

TRIAL No.	1/34	10/15
COMPOSITION (wt.%)	50 TNT 50 AN	50 TNT 50 AN
CONDITIONS	Ar	VAC.
GASES, VOL%		
H2	8.2	12.4
N2	38.8	38.1
CO	27.0	33.5
CO2	24.8	16.1
HCN	1.0	-
CH4	0.3	0.02
Ar, VOL%	89.3	81.8
ppm NO	30	3

There is also a difference in H_2, CO and CO_2 but with regard to the products of incomplete reaction ,only a higher HCN content was observed. Therefore, the difference in the heat of detonation is negligible compared with a difference of about 20 % in the case of 50 % TNT/50 % Nigu. The reproducibility of charges containing 25 % Al is shown in Table 9. In this case, a relatively good agreement of the residue between the three shots were found. With regard to the amount of unreacted Al, Table 10 shows that 9,9 % of the Al content was unreacted. On the other hand we found that Composition B and PBX, both containing 25 % Al, exhibited complete reaction of their Al. The reason for this behavior could be:

- the higher heat output of Comp. B/25 % Al and
- the much better oxygen balance of the PBX, containing RDX and ammonium perchlorate (AP)

Trial No	71/20	82/20	75/20
O_2 balance	- 51,8	- 53,4	- 38,6
Heat of detonation J/g	7213	8462	9011

These experiments show clearly that not only the oxygen balance but also the energy of high explosives are of influence for the aluminium reaction.

Table 9

REPRODUCIBILITY OF THE FORMATION OF UNREACTED AL OF TNT/AN/AL CHARGES

TRIAL No.	70/20	71/20	72/20
COMPOSITION (wt.%)	50 TNT 25 AN 25 AL	50 TNT 25 AN 25 AL	50 TNT 25 AN 25 AL
CONDITIONS	Ar	Ar	Ar
RESIDUE (g)	126.3	126.7	128.4
GASES, VOL%			
H2	19.5	17.6	17.1
N2	32.6	35.5	37.6
CO	44.1	41.9	41.0
CO2	2.7	3.5	3.4
HCN	0.86	1.10	0.62
CH4	0.14	0.18	0.10
Ar, VOL%	86.6	86.5	85.4
ppm NO	18	26	24

Table 10

FORMATION OF UNREACTED AL AS A FUNCTION OF COMPOSITION

TRIAL No.	71/20	82/20	75/20
COMPOSITION (wt.%)	50 TNT 25 AN 25 AL	75 COMP.B 25 AL	PBX with RDX, AP 25 AL
O2 BALANCE	-51.8	-53.4	-38.6
CONDITIONS	Ar	Ar	Ar
RESIDUE (g)	126.9	140.0	139.2
AL active (g/100g AL)	9.9	0.71	0.31
GASES, VOL%			
H2	17.6	21.2	20.1
N2	35.5	36.4	42.4
CO	41.9	40.2	32.0
CO2	3.5	1.1	5.2
NO	-	-	0.2
HCN	1.1	0.9	0.13
CH4	0.2	0.1	0.03
Ar, VOL%	86.5	84.4	85.1
ppm NO	26	17	124

CONCLUSION

The investigation of the detonation products of cast high explosives based on TNT/Nigu and TNT/AN has shown the following results:

- By measuring the initiation conditions the booster could be optimized especially with regard to a minimum formation of NO and N_2O. In the same way the energy output increased.
- The use of argon as an ambient gas improved very clearly the energy output compared with the detonation process in vacuum condition. This means that argon provides confinement.
- The tests performed with glass confinement also improved the energy formation by decreasing reaction products like NO and N_2O, which exhibit a positive heat of formation.
- The tests conducted with different grain sizes of nitroguanidine have pointed out the strong influence of grain size distribution. Spherical nitroguanidine with a grain size of > 500 µm formed detonation gases with increased content of N_2O and NO and therefore with a loss of energy. - Different from the commonly used tests, which measure the performance of high explosives, the chamber method, combined with analyzing the reaction products, is capable of finding out the reason for a low or poorly optimized energy output.

REFERENCES

1. W. Engel, "Darstellung von kugeligem Nitroguanidin",
Jahrestagung: Fraunhofer-Institut für Treib- und Explosivstoffe, 1981, pp. 21-29

2. W. Engel, "Beitrag zur Phasenstabilisierung von Ammoniumnitrat"
Explosivstoffe 21, 9, 1973

3. D.L. Ornellas, "Calorimetric Determination of the Heat and Products of Detonation for Explosives: October 1961 to April 1982",
UCRL-52821,
Lawrence Livermore National Laboratory, April 5, 1982

4. F. Volk, H. Bathelt, F. Schedlbauer and J. Wagner "Detonation Products of Insensitive Cast High Explosives"
The Eighth Symposium (International) on Detonation
July 15-19, 1985, Albuquerque, USA.