

# A study on the combustion of 5,5'-azobis-tetrazole aminoguanidine / strontium nitrate as a gas generating agent

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## Abstract

Experimental work has been carried out in search for the potential of 5,5'-azobis-tetrazole aminoguanidine (ABAG) / strontium nitrate  $\text{Sr}(\text{NO}_3)_2$  mixture as a gas generating agent for airbag inflators. Altering the reducer/oxidizer ratio, linear burning rate, closed vessel test, 60-liter tank test, thermal analysis and qualitative and quantitative analyses of the combustion gases of the mixtures have been carried out, and the results have been compared with those of 5-amino-1H-tetrazole (5-ATZ) /  $\text{Sr}(\text{NO}_3)_2$  mixture. The linear burning rate of ABAG /  $\text{Sr}(\text{NO}_3)_2$  mixture reached its maximum when the mixture was ABAG rich. Internal pressure of the closed vessel reached its maximum when the mixture was ABAG rich, but the combustion temperature reached its maximum at a stoichiometric ratio. According to 60-liter tank test, the internal tank pressure of ABAG /  $\text{Sr}(\text{NO}_3)_2$  was greater than that of 5-ATZ /  $\text{Sr}(\text{NO}_3)_2$  and the hazardous gases such as HCN, CO, and  $\text{NO}_2$  were found in the combustion gases of ABAG /  $\text{Sr}(\text{NO}_3)_2$  but the concentration of CO and  $\text{NO}_2$  gases were less than those of 5-ATZ /  $\text{Sr}(\text{NO}_3)_2$ . A new decomposition reaction of  $\text{Sr}(\text{NO}_3)_2$  was suggested.

**Keywords:** 5,5'-azobis-tetrazole aminoguanidine (ABAG), Strontium nitrate, Combustion.

## 1. Introduction

In the past, sodium azide had been used as the main component of gas generating agents for automobile airbag inflators, but because it is highly toxic and harmful to dispose, reducer component has shifted from sodium azide to non-azide chemical compound, and at present, a mixture of 5-amino-1H-tetrazole (5-ATZ) and oxidizer has been commercialized. The authors are searching for new tetrazole compounds that are superior to 5-ATZ. In this study, we selected ABAG which contains two tetrazole rings in one molecule and which is expected to produce large amount of gas as the reducer; and selecting  $\text{Sr}(\text{NO}_3)_2$  as the oxidizer, we have studied on the combustion characteristics of the mixture. Here, linear burning rate, closed vessel test, 60-liter tank test, qualitative and quantitative analyses of products have been examined to study on the burning characteristics of the mixture. Comparing such characteristics of ABAG /  $\text{Sr}(\text{NO}_3)_2$  mixture with those of the already-commercialized 5-ATZ /  $\text{Sr}(\text{NO}_3)_2$  mixture, we have examined the practicality of ABAG /  $\text{Sr}(\text{NO}_3)_2$  mixture as a potential gas generating agent.

## 2. Experimental

### 2.1 Samples

As a reducer of the non-azide gas generating agent, non-toxic ABAG (Toyo Kasei Kogyo Co., Ltd.), as shown in Fig. 1, was used.  $\text{Sr}(\text{NO}_3)_2$  (Kanto Chemical Co., Inc., JIS special grade reagent, purity > 98 %) was used as an oxidizer.  $\text{Sr}(\text{NO}_3)_2$  was crushed in a ball mill (Irieshokai Co., Ltd., V-2, 100 r.p.m, 900 ml pot, 15 mm diameter porcelain balls) for approximately one hour and the particle diameter of  $\text{Sr}(\text{NO}_3)_2$  was controlled within 75 – 149  $\mu\text{m}$  by using Japanese Industrial Standard (JIS) sieves. The particle diameter of ABAG was controlled under 45  $\mu\text{m}$ .

The mixtures were mixed at a designated mixing ratio for 30 minutes at 80 r.p.m. through a rotary mixer (Tsutsui Scientific Instruments Co., Ltd., S-3) and were coated with 0.2 wt% polyvinyl alcohol (PVA, Kanto Chemical Co., Inc.) to produce mixtures as given in Table 1. The mixtures were then dried through a vacuum dryer (Kuramochikagaku Co., Ltd., RG-501) at 333 K and 10 Pa for 24 hours. Table 1 gives the oxygen balance, density, porosity, together with the estimated gas volume and the

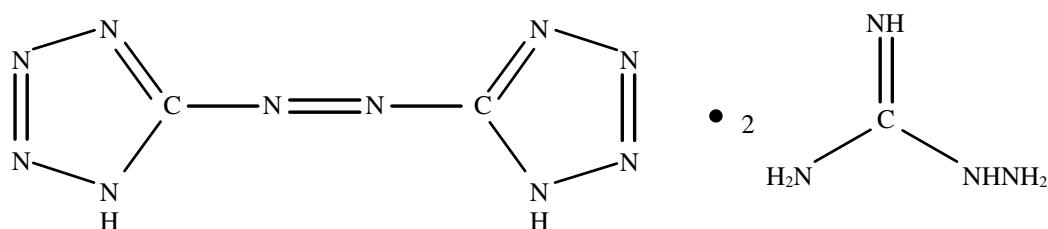


Fig. 1 Chemical structure of ABAG.

Table 1 Physical and theoretical properties of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures.

ABAG (wt%)	30	33.11	40	50	60
Sr(NO <sub>3</sub> ) <sub>2</sub> (wt%)	70	66.89	60	50	40
Oxygen balance <sup>*1</sup> (g)	+3.55	0	-7.87	-19.28	-30.70
Apparent density (g cm <sup>-3</sup> )	2.37	2.32	2.21	2.08	—
Porosity (%)	5.72	3.24	3.67	5.59	—
Generated gas <sup>*2</sup> (cm <sup>3</sup> g <sup>-1</sup> )	330.8	335.1	488.9	685.0	816.2
T <sub>f</sub> (K)	2742.0	2938.0	2769.7	2354.8	1974.2

<sup>\*1</sup> The amount of oxygen per 100 g mixture.

<sup>\*2</sup> It is assumed that H<sub>2</sub>O is liquid.

Table 2 Theoretical amount of generated gas of stoichiometric ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures.

	Density (g cm <sup>-3</sup> )	With H <sub>2</sub> O <sup>*1</sup>		Without H <sub>2</sub> O <sup>*2</sup>	
		(mol cm <sup>-3</sup> )	(mol g <sup>-1</sup> )	(mol cm <sup>-3</sup> )	(mol g <sup>-1</sup> )
ABAG / Sr(NO <sub>3</sub> ) <sub>2</sub>	2.32	4.90×10 <sup>-2</sup>	2.11×10 <sup>-2</sup>	3.17×10 <sup>-2</sup>	1.37×10 <sup>-2</sup>
5-ATZ / Sr(NO <sub>3</sub> ) <sub>2</sub>	2.15	4.60×10 <sup>-2</sup>	2.14×10 <sup>-2</sup>	3.22×10 <sup>-2</sup>	1.50×10 <sup>-2</sup>

<sup>\*1</sup> It is assumed that H<sub>2</sub>O is gas.

<sup>\*2</sup> It is assumed that H<sub>2</sub>O is liquid.

adiabatic flame temperature ( $T_f$ ) from ICT chemical equilibrium calculation<sup>1)</sup>. The heats of formation of Sr(NO<sub>3</sub>)<sub>2</sub> and ABAG employed for the calculation were -978.22 and 598.73 kJ mol<sup>-1</sup>, respectively. Table 2 gives the theoretical amount of generated gas for stoichiometric ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures. There was relatively small difference between ABAG and 5-ATZ in terms of theoretical amount of generated gas. The strands (5 × 5 × 70 mm) were prepared by compressing 4 grams of mixture at approximately 0.6 GPa for 5 minutes. Each strand was restricted with epoxy resin (Semedain Co., Ltd., 1500). The weight percentages of ABAG ( $\xi$ ) were 30, 33.11 (stoichiometric ratio), 40, and 50 wt%.

## 2.2 Measurement of linear burning rate

The combustion tests were performed by using a chimney-type strand burner (Kyowagiken Co., Ltd., SCTA-50), under 1 - 4 MPa nitrogen atmosphere at approximately 298 K. The strand was ignited with a heated nichrome wire (diameter 0.6 mm). Pressure ( $P$ ) was measured through a strain-gauge pressure transducer (Kyowa Electronic Instruments Co., Ltd., PG-100 KU) and after amplification through a signal conditioner (Kyowa Electronic Instruments Co., Ltd., CDV-230 C), the output

was recorded on a digital data recorder (Keyence Co., Ltd., GR-3000). The testing apparatus is described elsewhere<sup>2)</sup>. The linear burning rate ( $r$ ) was obtained from the duration of burning time by observing the pressure change inside the burner. The pressure started rising when the strand started burning and the pressure rise ceased at the termination.

## 2.3 Measurement of burning pressure and burning temperature in the closed vessel

The orifice of the chimney-type strand burner was closed to act as a 4-liter closed vessel<sup>3), 4)</sup>, and the pressure-time change was measured at an initial pressure of 2 MPa helium gas and at an initial temperature of 298 K. The procedures for the ignition of the strand and the measurement of the pressure within the chamber ( $p_v$ ) were the same as those of the linear burning rate measurement. The gas temperature in the vessel was obtained with K-type thermocouple (diameter 1 mm). The output of the thermocouple was recorded on a recorder (Keyence Co., Ltd., GR-3000).

## 2.4 60-liter tank test

Fifteen of 1 g cylindrical pellets, each pressed at approximately 10 MPa for 1 minute, were installed in a simulated

inflator which was mounted inside the 60 liter tank<sup>3), 5)</sup>. After purging the atmosphere inside the tank with N<sub>2</sub>, the pellets were ignited by using a primer (Nihon Kayaku Co., Ltd.) and 1 g of B / KNO<sub>3</sub> igniter (Nihon Koki Co., Ltd.), at an initial tank temperature of 296 K. The internal pressure of the tank ( $p_T$ ) was measured by a strain gage pressure transducer (Kyowa Electronic Instruments Co., Ltd, PGM-10 KC). The temperature inside the tank ( $T_T$ ) was measured by using a 50 μm K-type thermocouple. After amplification by using a signal conditioner (Kyowa Electronic Instruments Co., Ltd., CDV-230C), the data were recorded on a recorder (Keyence Co., Ltd., NR-2000).

## 2.5 Qualitative and quantitative analyses of combustion products

Solid combustion products that resulted from the burning of the strand were analyzed by a wide angle X-ray diffractometer (XRD) (Mac Science Co., Ltd., M21-SRA) and the spectra were compared with standard samples for identification. Gaseous products of 4-liter closed vessel test and 60-liter tank test were analyzed by gas chromatography (GC) (Shimadzu Corp., GC-8A) and FT-IR gas analyzer (Temet Co., Ltd., DX-4000). In GC analysis, WG-100 (GL Science Co., Ltd.) was used as the column packing, and using helium at a flow rate of 40 ml min<sup>-1</sup> as the carrier gas, and the column temperature and injection temperature both set at 323 K, N<sub>2</sub>, CO<sub>2</sub>, and O<sub>2</sub> gases were analyzed. In the FT-IR analysis, helium was used as the carrier gas, and CO<sub>2</sub>, CO, NO<sub>2</sub>, NO, NH<sub>3</sub>, CH<sub>4</sub>, and HCN were analyzed. H<sub>2</sub>O evolved in the combustion gas was assumed to be in liquid state. The concentration of each gas measured by FT-IR was calibrated assuming that the concentration of CO<sub>2</sub> measured by GC was equal to that measured by FT-IR gas analyzer.

## 2.6 Thermal analysis

Under the heating rate of 20 K min<sup>-1</sup> in helium atmosphere (flow rate 20 ml min<sup>-1</sup>), thermogravimetry (TG) and differential thermal analysis (DTA) were conducted by using DTG-50H (Shimadzu Corp.). The mass spectrometry (MS) was conducted by using QP-5000 (Shimadzu Corp.) connected with DTG-50H to perform qualitative analysis of gaseous products of the pyrolysis.

## 3. Results and discussions

### 3.1 Linear burning rate

Observed values of  $r$  at various  $\xi$  are given in Fig. 2.  $r$  have followed Viele's formula  $r = a P^n$ , where  $a$  is a constant and  $n$  is the pressure exponent of  $P$ .  $n$  was within the range of 0.55 – 0.73 and it was 0.58 for the stoichiometric mixture. In comparison with 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixture whose  $n$  varied within the range of 0.2 – 0.8<sup>2)</sup>, it was found that the variation of  $n$  was smaller and less dependent on pressure. Although there was almost no difference at low pressure region,  $r$  for 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> was larger at higher pressure region because of its larger  $n$ . Figure 3 shows the relationship between  $r$  at 3 MPa, the heat of explosion ( $\Delta H$ ) estimated by the chemical equilibrium calculation<sup>1)</sup>

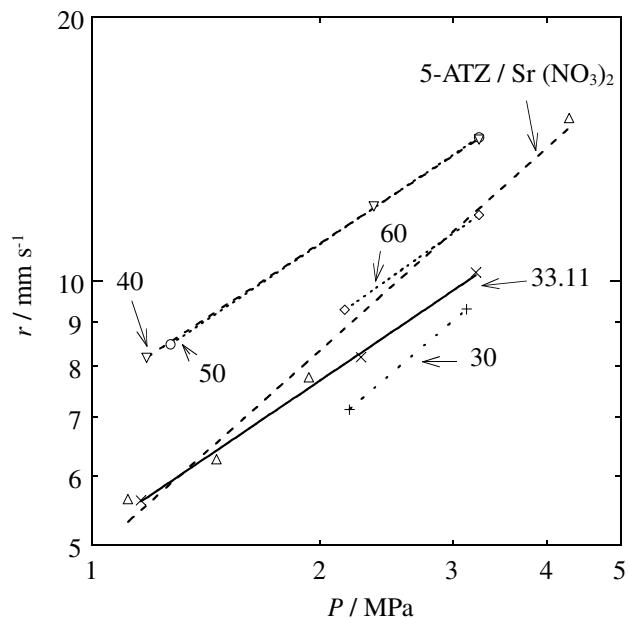


Fig. 2 Linear burning rates of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures. Numbers indicate the content of ABAG.

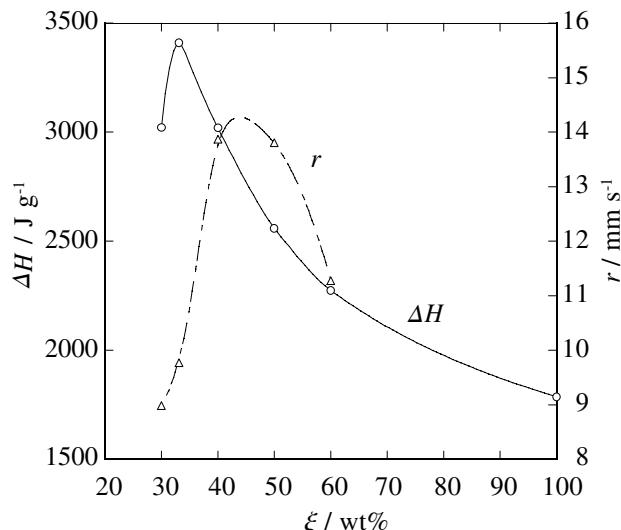


Fig. 3 Relation between linear burning rates at 3 MPa, estimated heat of explosion, and content of ABAG.

and  $\xi$ . Although  $\Delta H$  reached its maximum at the stoichiometric ratio ( $\xi = 33.11$  wt%),  $r$  were higher at ABAG rich composition  $\xi = 40$  and 50 wt% as compared to the stoichiometric ratio. This suggests that the combustion reactions did not proceed ideally. This may be because ABAG decomposes at a lower temperature than Sr(NO<sub>3</sub>)<sub>2</sub>, as can be seen in Fig. 9a and 9b. For the stoichiometric mixture, it is suggested that the decomposed products of ABAG have escaped from the reaction phase, causing the gas phase near the burning surface to be reducer lean so that the stoichiometric reaction could not take place. Detecting a large amount of unreacted oxygen gas (Table 3) confirmed this theory. It suggests that reaction which leads to the fastest  $r$  is obtained at a reducer rich region.

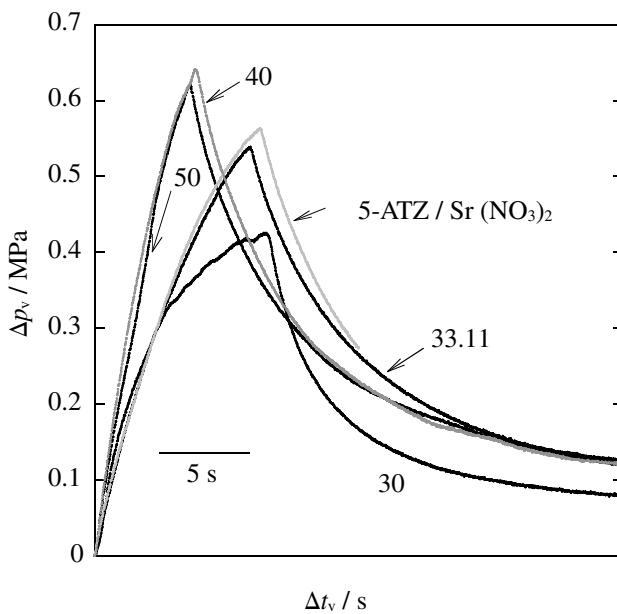


Fig. 4 Pressure-time history of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures for the closed vessel test.

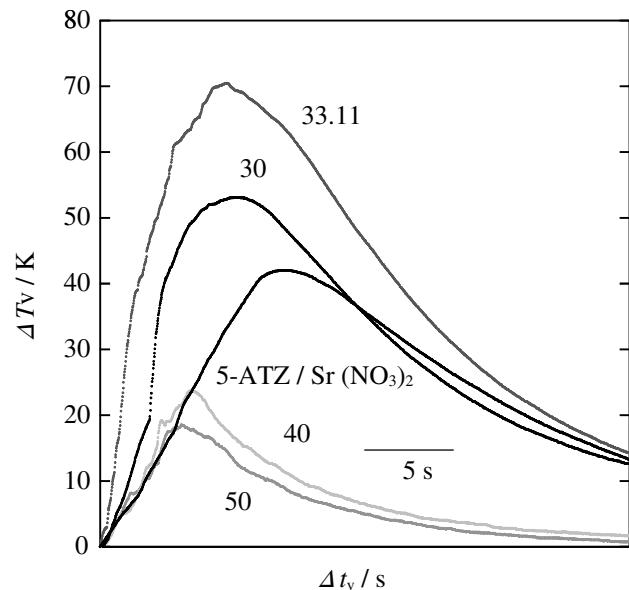


Fig. 5 Temperature-time history of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures for the closed vessel test.

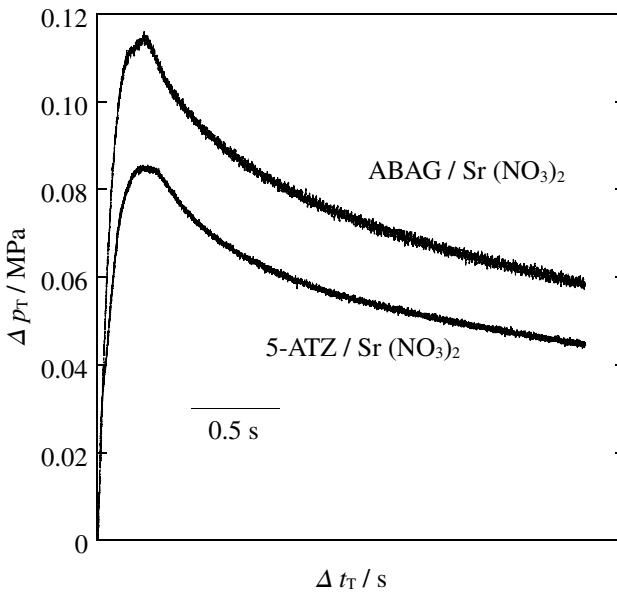


Fig. 6 Pressure-time history of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures for the 60 L tank test.

### 3.2 Closed vessel test

The net pressure increase ( $\Delta p_v$ ) – time ( $\Delta t_v$ ) history inside the closed vessel is shown in Fig. 4. The reducer rich mixture ( $\xi = 40$  and  $50$  wt%) had a higher rate of pressure increase ( $\Delta p_{v,\max} / \Delta t_{v,\max}$ ) and the maximum pressure ( $\Delta p_{v,\max}$ ) than those of the stoichiometric mixture. Here,  $\Delta t_{v,\max}$  is the time difference between ignition and the time when  $\Delta p_{v,\max}$  was observed.  $\Delta p_{v,\max} / \Delta t_{v,\max}$  increased for high reducer content because of an increase in the volume of the generated gas (Table 1) and  $r$  (Fig. 2). The net temperature rise inside the closed vessel ( $\Delta T_v$ ) is shown in Fig. 5. The maximum temperature ( $\Delta T_{v,\max}$ ) was found to be the highest for the stoichiometric mixture.

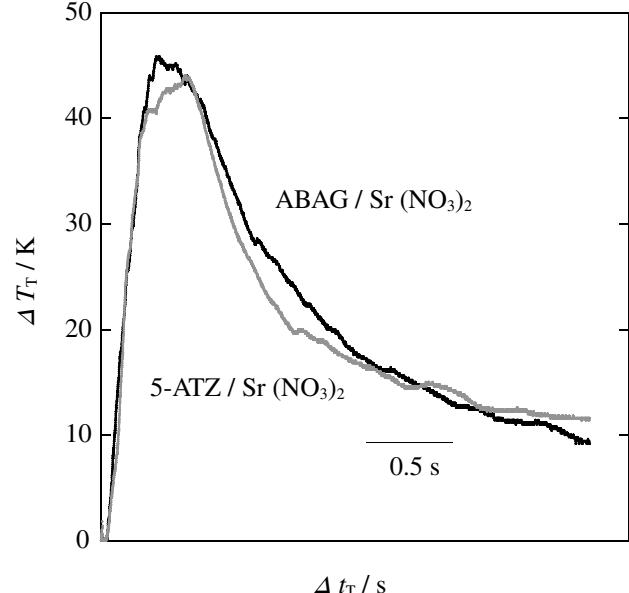


Fig. 7 Temperature-time history of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures for the 60 L tank test.

For the stoichiometric mixture, gas generating properties of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> were slightly better than those of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub>.  $\Delta p_{v,\max}$  and  $\Delta p_{v,\max} / \Delta t_{v,\max}$  of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> were 0.533 MPa and 62 kPa s<sup>-1</sup>, respectively, and those of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> were 0.563 MPa and 60 kPa s<sup>-1</sup>, respectively. On the other hand,  $T_{v,\max}$  of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> was higher than that of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub>. Theoretically,  $T_f$  of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> was 2938 K which is higher than 2788 K for 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub>.  $T_f$  decreased with an increase in  $\xi$  as shown in Table 1 because of an incomplete combustion, which caused decrease in  $\Delta T_{v,\max}$  for  $\xi = 40$  and  $50$  wt%.

**Table 3** Combustion gases detected in the closed vessel test and calculated values for stoichiometric ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures.

Combustion gas	CO <sub>2</sub> (mol%)	N <sub>2</sub> (mol%)	O <sub>2</sub> (mol%)	NO (ppm)	NH <sub>3</sub> (ppm)	CH <sub>4</sub> (mol%)	HCN (ppm)	CO (mol%)	NO <sub>2</sub> (ppm)
Found	7.9	7.5×10	1.3×10	1.4×10 <sup>2</sup>	2.8×10 <sup>2</sup>	1.4×10 <sup>-3</sup>	2.2×10 <sup>2</sup>	4.0	4.0
Theoretical*	7.7	9.2×10	6.5×10 <sup>-5</sup>	2.5	9.8×10 <sup>-3</sup>	0.0	0.0	3.4×10 <sup>-3</sup>	3.1×10 <sup>-4</sup>

\* It is assumed that H<sub>2</sub>O is liquid.

**Table 4** Concentration of harmful gases detected in the 60-liter tank test of stoichiometric ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures.

	CO (mol%)	HCN (ppm)	NO <sub>2</sub> (ppm)
ABAG / Sr(NO <sub>3</sub> ) <sub>2</sub>	0.4	8.4×10	7.1×10
5-ATZ / Sr(NO <sub>3</sub> ) <sub>2</sub>	0.6	1.5×10	5.7×10 <sup>2</sup>

### 3.3 60-liter tank test

Each example of typical pressure-time history within the 60-liter tank for ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> and 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> at stoichiometric ratio is shown in Fig. 6. For ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixture,  $\Delta p_T$  has reached 0.1 MPa at 120 ms and the maximum pressure inside the 60-liter tank ( $\Delta p_{T, \max}$ ) was approximately 0.12 MPa at 220 ms after ignition. As for 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> mixture,  $\Delta p_{T, \max}$  was 0.09 MPa at 220 ms after ignition. In spite of the theoretical volume of generated gas of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> being larger than that of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub>,  $\Delta p_{T, \max}$  of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> was larger than that of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub>.

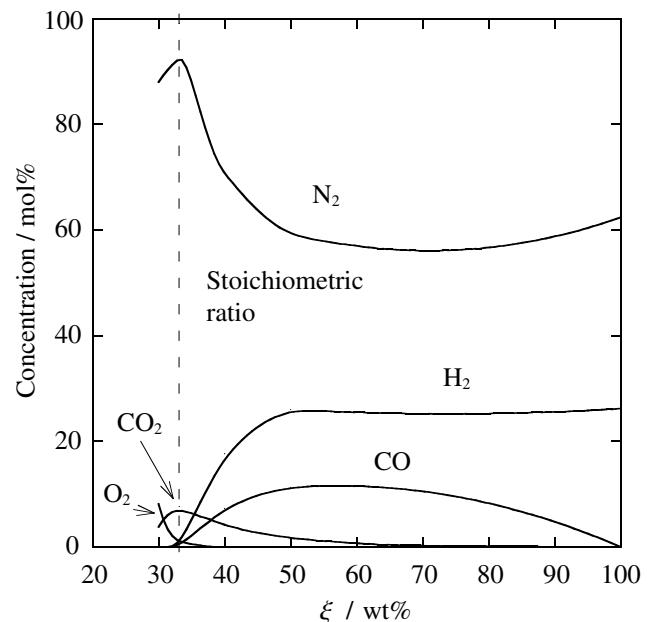
The possible explanation for this could be that  $r$  of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> is larger than that of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> so that the generated gas is more efficiently heated in the case of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixture. The superiority of gas generating ability of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> as compared with 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> was also confirmed in 60-liter tank test as well as in the closed vessel test.

Figure 7 shows the temperature-time histories for 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> and ABAG / Sr(NO<sub>3</sub>)<sub>2</sub>. At  $\Delta p_{T, \max}$ , the net maximum temperature ( $\Delta T_{T, \max}$ ) for 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub> and ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> were 337 K and 340 K, respectively.

### 3.4 Combustion products

Table 3 gives the observed concentrations of gases generated by the closed vessel test at 298 K and the calculated concentrations of the main products at 298 K that were derived from the chemical equilibrium calculation<sup>1)</sup>, for stoichiometric ratio of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixture. Main difference between the observed value and the calculated value was that 13 mol% of oxygen was observed. This indicates that the reaction was not stoichiometric. Harmful HCN was also observed, even though it was not found in the calculated products.

Figure 8 shows the calculated concentrations of N<sub>2</sub>, CO<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>, and CO gases at 298 K for ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures.



**Fig. 8** Predicted combustion products of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> mixtures at 298 K.

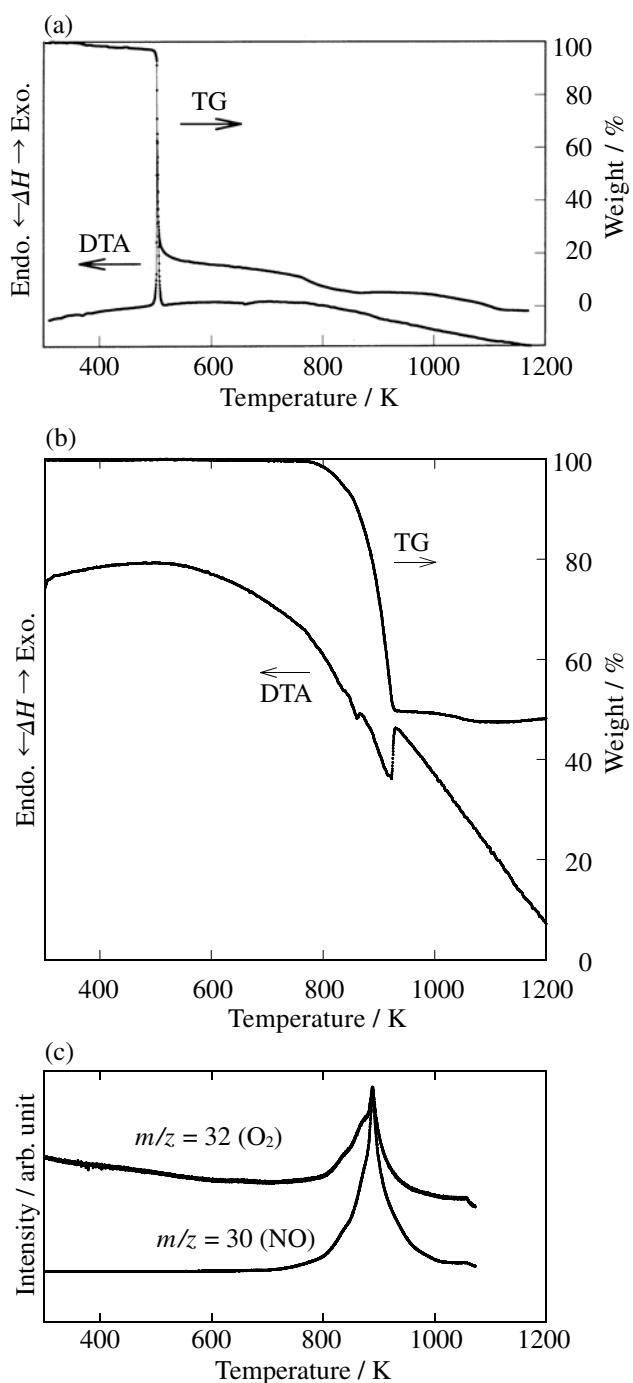
Table 4 shows the observed concentrations of harmful gases in 60-liter tank test. The concentration of HCN was larger but those of CO and NO<sub>2</sub> for ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> were less than those of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub>.

An X-ray analysis of the solid combustion products has shown that the solid product was identified as SrCO<sub>3</sub>, in spite of the expected SrO. Probably SrO may have absorbed CO<sub>2</sub> to produce SrCO<sub>3</sub>.

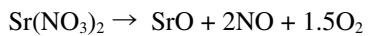
### 3.5 Thermal analysis

TG-DTA curves for ABAG are shown in Fig. 9a. The exothermic decomposition of ABAG was observed at 509 K and approximately 90 % of ABAG decomposed.

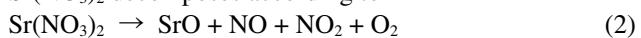
TG-DTA curves for Sr(NO<sub>3</sub>)<sub>2</sub> are shown in Fig. 9b. The small endothermic peak of the DTA curve that peaked at approximately 860 K was probably related to the melting of Sr(NO<sub>3</sub>)<sub>2</sub> (melting point: 843 K<sup>6)</sup>). The decomposition of Sr(NO<sub>3</sub>)<sub>2</sub> started at approximately 800 K, peaked at approximately 920 K, and ended at approximately 930 K which agreed with the generation of O<sub>2</sub> and NO, as shown in Fig. 9c. The percentage of mass loss of the TG curve was approximately 50 %, which agreed with the theoretical value of 51.0 %. According to MS analysis (Fig. 9c), O<sub>2</sub> and NO were found but NO<sub>2</sub> was not detected. The suggested decomposition reaction would be



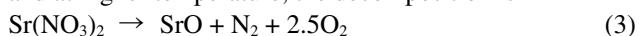
**Fig. 9** Thermal analyses of ABAG and Sr(NO<sub>3</sub>)<sub>2</sub>  
 (a) TG-DTA curves of ABAG  
 (b) TG-DTA curves of Sr(NO<sub>3</sub>)<sub>2</sub>  
 (c) mass fragmentogram of Sr(NO<sub>3</sub>)<sub>2</sub>.



Conkling<sup>7)</sup> mentioned that near its melting point, Sr(NO<sub>3</sub>)<sub>2</sub> decomposes according to



and at higher temperature, the decomposition is



The observed result did not agree with the reactions (2) and (3).

#### 4. Conclusions

Selecting ABAG as the reducer and Sr(NO<sub>3</sub>)<sub>2</sub> as the oxidizer for gas generator mixture, the following conclusions were obtained.

- 1) Linear burning rates depended on pressure, following Vieille's law.
- 2) According to 60-liter tank test, generated gas pressure of ABAG / Sr(NO<sub>3</sub>)<sub>2</sub> was greater than that of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub>.
- 3) The main gaseous products were N<sub>2</sub>, CO<sub>2</sub>, O<sub>2</sub>, and CO. Harmful gases such as CO, NO<sub>2</sub>, and HCN were found but the volumes of CO, NO<sub>2</sub> gases were less than those of 5-ATZ / Sr(NO<sub>3</sub>)<sub>2</sub>.
- 4) The solid product was found to be SrCO<sub>3</sub>.
- 5) The new decomposition reaction of Sr(NO<sub>3</sub>)<sub>2</sub> was proposed.

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## ガス発生剤としての5,5'-アゾビステトラゾール・アミノグアニジン／硝酸ストロンチウム混合物の燃焼特性

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5,5'-アゾビステトラゾール・アミノグアニジン(ABAG)と硝酸ストロンチウム  $\text{Sr}(\text{NO}_3)_2$  混合物のエアバッグ用ガス発生剤としての可能性を探求するため、組成比を変化させ、線燃焼速度測定、密閉容器試験等を行い燃焼特性を調べた。また、量論比混合試料について、60リットルタンク試験を行い5-アミノ-1H-テトラゾール(5-ATZ)と  $\text{Sr}(\text{NO}_3)_2$  混合物と比較した。線燃焼速度はVielleの式に従い、ABAG混合物はABAG過剰で最大燃速になった。密閉容器試験ではABAG過剰で最大圧力となり、燃焼温度は量論混合物で最大となった。60リットルタンク試験では5-ATZ混合物よりABAG混合物のほうが燃焼圧力が高くなった。また、ABAG混合物の燃焼生成気体には有害な HCN, CO,  $\text{NO}_2$  が同定されたが、HCN以外は5-ATZ混合物より少なかった。また、 $\text{Sr}(\text{NO}_3)_2$  の新しい分解反応式を提案した。

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