

AMMONIUM NITRATE-FUEL-SURFACTANT EXPLOSIVE

Kumao Hino* and Mutsuo Yokogawa*

§ 1, Introduction

In 1955 H. B. Lee and R. L. Akre¹⁾ introduced a blasting agent composed of Ammonium nitrate (AN) and solid carbonaceous fuels into the blasting operation in the U. S. A. and since then rapid development in research and practice has been achieved mainly in the U. S. A. by various research and production groups.

This type of explosives has been in general used in rather bigger bore hole diameters (4 inches), because this is the most common practice in the U. S. A. and the bigger is the diameter of a blasting cartridge, the better is its detonation ability due to the so-called "diameter-effect" of the detonation of explosives.

In Japan the present authors have conducted research on AN-fuel explosives since 1956 and it was concentrated on AN-fuel explosives of smaller diameter because in Japan only cartridges of smaller diameters have industrial applications and naturally if we find better compositions for smaller diameters then the increase of diameter of cartridges brings about only improvement in detonation ability and no further problem.

In the earlier stage of the research various fuels have been extensively investigated and AN-coal tar mixture (A-1) proved to be of

considerable detonation ability.

In the second stage various inorganic catalysers which can promote the rapid reaction between AN and fuels have been extensively investigated and AN-coal tar-potassium bichromate mixture (A-2) proved to be of remarkably better detonation ability while it was found later that the mixture A-2 has two defects, that is, (1) considerable oxidation of wrapping materials takes place during storage (2) considerable expansion or swelling of the cartridge takes place after storage.

Then in the third stage various organic catalysers especially the so-called surface active agents or surfactants have been extensively investigated and AN-fuel-surfactant explosive (A-3) proved to be of the same detonation ability with that of A-2 and of much better storage properties than A-2.

As to the way of mixing, the heavy edge runner mill, which is usually used in the manufacture of the conventional Ammonium nitrate explosives such as the mixtures of AN, TNT and NaCl proved to give the best result while the roller mill proved to be less efficient as the time of crushing is quite short in the latter in comparison to the former in which we can realize any longer duration of crushing and mixing according to the requirements.

The practical minimum diameter of a cartridge which detonates with a stable velocity without any confinement is found to be about 20—24 millimeter for A-2 and A-3 while it

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* Nippon Kayaku Co., Ltd. Asa, Sanyo-cho, Yamaguchiken, Japan

1) Hugh B. Lee and Robert L. Akre: U. S. P. 2,703,528, March 8, 1955.

is about 40–50 millimeter for A-1.

§ 2. Measurement of the detonation ability

Various ways of measuring the detonation ability or sensitivity have been suggested by various authors. For example, Brinkley²⁾ and Gordon used the method of micro-scale test and Primacord test.

In the present paper the detonation ability has been expressed by the critical diameter or the practical minimum diameter for two reasons that is (1) the practical reason: the main objective of the investigation was to find a composition which can detonate with the diameter as small as possible (2) the theoretical reason: the critical diameter plays an essential role in the theory of the so-called “diameter effect” suggested by one of the present authors³⁾.

In this method a cylindrical charge of an explosive wrapped with a thin paper shell whose length is 230mm is placed on a sand bed and the total body of an industrially standard No. 6 detonator is inserted into the axis of the cartridge of various diameters and is fired electrically. Detonation or non-detonation of the cartridge is determined by observing the crater produced in sand and the residue of the cartridge after the detonation of the detonator.

In general at least 10 shots are fired for each diameter of the cartridge. The diameter at which 100% detonation takes place is defined as the “practical minimum diameter” $2R_m$ and the diameter at which 50% detonation occurs is defined as the “critical

diameter” $2R_c$ while the diameter at which we have 0% detonation is defined as the “failure diameter” $2R_f$. The distribution of the propability $X\%$ of the detonation with respect to the cartridge diameter $2R$ is described by a typical S-shaped sensitivity curve as is illustrated in Fig. 1.

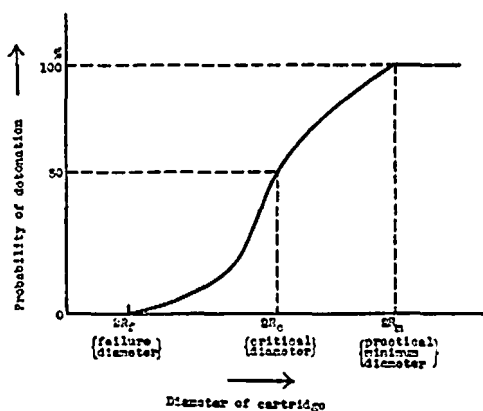


Fig. 1.

The smaller is the value of R_m , R_c or R_f respectively the better is the detonation ability of the cartridge.

§ 3. Effect of the specific surface of AN

Both theory and experience indicate that the smaller is the particle size of AN, the better is its detonation ability. In Table 1. the particle size and the specific surface of AN of various origins have been summarized. No. 1. is the ordinary AN used in the manufacture of the conventional explosives No. 2, is the product prepared by the heavy edge runner mill from No. 1. (The weight of a runner 155Kg, two runners are used, revolution per minute of the vertical axis 21, weight of charge 4–5Kg, mixing at 50°C for 30 minutes and another at 90°C for 30 minutes.)

No. 3. is prepared by the so-called atomizer mill (high speed rotor 8,800 revolution per minute, the opening of a screen sieve 5mm, capacity 20–30Kg per hour) made by

2) S. R. Brinkley and W. Gordon: Explosive Properties of the AN-fuel oil system. Congress International de Chimie Industrielle, Liège, 1958.

3) K. Hino: Theory and Practice of Blasting (1959) published by Nippon Kayaku Co., Ltd. p. 73.

K. Hino & S. Hasegawa: Theory of the variable reaction zones in the detonation of solid explosives. Congress International de Chimie Industrielle, Liège, 1958.

Table 1.

| Sample | Ammonium nitrate | Apparent density | Specific surface | Mean particle diameter | Tyler mesh | Water content |
|--------|----------------------------|-------------------|--------------------|------------------------|----------------|---------------|
| No. 1. | Industrial grade I. II. | g/cm ³ | cm ² /g | μ | 200mesh pass % | % |
| | | 1.09 0.98 | 500 795 | 54.0 42.3 | 13.6 6.0 | 0.06 0.03 |
| No. 2. | Edge runner 90°C 50°C | 1.03 1.05 | 1,100 1,150 | 31.5 30.0 | 46.0 53.2 | 0.03 0.04 |
| | | | | | | |
| No. 3. | Atomizer mill I. II. | 0.87 0.89 | 1,820 1,900 | 19.2 18.5 | 96.0 97.8 | 0.09 0.07 |
| | | | | | | |
| No. 4. | Low-density | 0.67 | 2,160 | — | 0 | 0.05 |

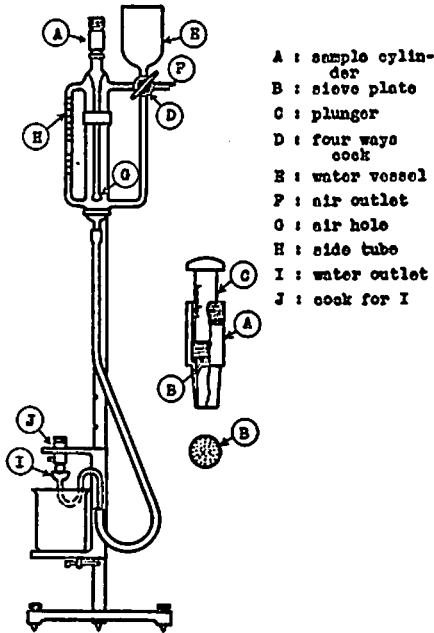


Fig. 2. Air permeability method.

Fuji-Sangyo Co., Ltd. No. 4. is the so-called low density AN prepared by Sumitomo-Kagaku Co., Ltd. The specific surface of AN particle and the mean particle size have been measured by the Air permeability method, the apparatus being made by Shimazu-Seisakusho Co., Ltd.

It was found that when the mean particle diameter is greater than 40μ (micron) it was impossible to realize the practical minimum diameter smaller than 35—40mm. The low-density AN (No. 4) gives better detonation sensitivity while the low-density of the product makes its brisance much lower.

§ 4. Selection of fuel

The practical minimum diameters obtained for various fuels are summarized in Table 2.

Table 2.

| Fuel | | Explosive | | | |
|-----------|-------------------|-------------------|---------------|----------------------------|--|
| Origin | Kind | Apparent density | Water content | Practical minimum diameter | Composition of Explosives |
| Petroleum | Kerosine | g/cm ³ | % | mm | { AN 93.4% Fuel 3.6% Surfactant 3.0% |
| | Light oil | 0.90 | 0.30 | 30 | |
| | B heavy oil I | 0.89 | 0.28 | 25 | |
| | B heavy oil II | 0.96 | 0.28 | 34 | |
| | C heavy oil | 0.96 | 0.28 | 38 | |
| Coal | Creosote oil | 1.03 | 0.24 | 35 | { AN 92.6% Fuel 4.4% Surfactant 3.0% |
| | Anthracene oil I | 1.01 | 0.26 | 28 | |
| | Anthracene oil II | 1.00 | 0.27 | 25 | |
| | Painting tar | 1.01 | 0.25 | 28 | |
| | | 0.97 | 0.25 | 25 | |
| | Light oil | 0.91 | 0.30 | 45 | { AN 94.7% Fuel 5.3% |

Table 3.

| Fuel | Characteristics |
|-------------------|---|
| Light oil | Ignition point 80°C. First distil 198°C. Redwood viscosity (50°C) 30 sec. Chemically neutral. |
| Anthracene oil I. | Distillate from coal tar (300°C)- Ignition point 205°C. Redwood viscosity (50°C) 62 sec. Chemically neutral. |
| Painting tar | Refind tar used for painting. Distillate from coal. Creosote oil 70—65%. Pitch 30—35%. Black viscous fluid. Engler viscosity 12.5°C. |

The characteristics of the fuels are shown in Table 3.

The sample described in Table 2 were prepared by mixing the fuel with finely pulverized AN (No. 3. in Table 2) by a simple mixer (but not the edge runner mill) at room temperature of 10—15°C. As the painting tar is highly viscous in this case the mixing was conducted at temperature 20—25°C.

Table 2. indicates that as the fuel coal tar gives the highest detonation ability or the lowest practical minimum diameter. Light oil gives the same result while it was excluded from further use due to its ignition hazard in handling.

§ 5. Selection of the surface active agent or surfactant

According to the present idea³⁾ on the diameter effect of detonation, including the critical diameter or the practical minimum diameter, the effective detonation heat, which determines the stable detonation velocity at a given diameter, can be increased if the reaction velocity between the oxidizer (AN) and the fuel is increased. Reducing the particle size of AN or increasing the specific surface of AN can be one way of achieving this objective while the use of the catalyser to the reaction between AN and fuel pre-

sents another solution to the problem. Potassium bichromate proved quite effective in this respect while its undesirable properties manifested during storage excluded it from the practical application. Another solution to the problem is to find some agents which can combine AN and the fuel to more intimacy than a mere mechanical mixing. AN is drastically hygroscopic that is it has big affinity to water while oil or coal tar repels water, therefore, in general, it is rather difficult to mix the two components (the oxidizer and the fuel) on molecular scale. Thus the mere mechanical mixing which has been extensively used in the preparation of AN-fuel explosive is not enough to secure a reliable detonability. If we can find some adequate surface active agents or surfactants they have on the one hand an atomic group which has affinity to water, called hydrophilic group, and on the other another atomic group which has affinity to oily matters, called lypophilic group. Thus the surfactant of this kind forms a close bridge between the oxidizer AN and the fuel coal tar on molecular scale which in turn brings about the rapid explosive reaction between the oxidizer and the fuel.

In the present paper the effectiveness of the surfactant has been examined according to the following procedure: 0.5 weight percent of the surfactant was added to the base charge composed of 93.3% AN and 6.2% coal tar and the three components were mixed by a heavy edge runner mill. The product was tested one night after the preparation with respect to caking and the practical minimum diameter. In Table 4 A indicates the best result and B indicates the good one while C indicates the unsatisfactory result. A for the detonation ability detonates with the diameter around 20—24mm.

The result summarized in Table 4—1, 4—

Table 4-1. Anionic surfactant




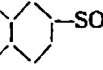
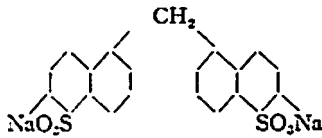
| No. | Chemical | Structure | Trade grade | Detonation | Caking | H. L. B. |
|---|--|---|---------------------------------|----------------------------|----------------------------|--|
| 1-2. Higher alcohol sulfonic ester (C ₃ -C ₁₈) | | | | | | |
| 1 | Sodium laurylsulfate (S. L. S.) | C ₁₂ H ₂₅ OSO ₃ Na | I II III | A A B | A A C | 40 40 40 |
| 2 | Sodium stearylsulfate | C ₁₈ H ₃₇ OSO ₃ Na | I II III | A B B | C C C | 38 38 38 |
| 3 | Sodium higher alcohol sulfate | | I II III IV V VI | A B B B B B | C C C C C C | 40~38 40~38 40~38 40~38 40~38 40~38 |
| 1-2. Aliphatic alcohol phosphate | | | | | | |
| 5 | Sodium alkylphosphite | ROP (ONa) ₂ | I II | A B | C C | |
| 5 | Alkylphosphate triethanolamine | $\begin{array}{c} \text{O} \\ \parallel \\ \text{R O}_2 \text{P OHN (C}_2\text{H}_5\text{OH)}_3 \\ \text{R} = \text{C}_{12}\text{H}_{25} \end{array}$ | | A | C | |
| 1-3. Aliphatic amide sulfonate | | | | | | |
| 6 | Sodium stearyl amide methylethylsulfonate | $\begin{array}{c} \text{C}_{17}\text{H}_{35}\text{CONC}_2\text{H}_5\text{SO}_3\text{Na} \\ \\ \text{CH}_3 \end{array}$ | | B | C | |
| 7 | Sodium aliphatic amide alkylethylsulfonate | $\begin{array}{c} \text{RCON-C}_2\text{H}_5\text{SO}_3\text{Na} \\ \\ \text{R} \end{array}$ | | A | A | |
| 1-4. Alkylaryl sulfonate | | | | | | |
| 8 | Sodium dodecylbenzenesulfonate (S. D. B.) | C ₁₂ H ₂₅ -  -SO ₃ Na | I II III IV | A A B C | A C C C | |
| 9 | Butylnaphthalenesulfonate | C ₄ H ₉ -  -SO ₃ Na | I II | C B | C C | |
| 10 | Alkylbenzenesulfonate | R-  -SO ₃ Na | I II III | B B B | A B A | |
| 11 | Alkyl naphthalenesulfonate | R-  -SO ₃ Na | I II III | A B B | C A C | |
| 1-5. Sodium Dinaphthylmethane disulfonate | | | | | | |
| 12 | (S. D. D.) |  | I II III | A B B | A A A | 80 80 80 |

Table 4-2. Cationic surfactant





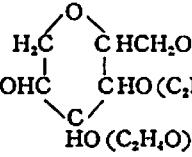
| No. | Chemical | Structure | Trade grade | Detonation | Caking |
|--------------------------------|--|--|---------------------------------|----------------------------|----------------------------|
| 2-1. Aliphatic amine | | | | | |
| 13 | Lauryamine acetate | $C_{12}H_{25}NH_2OCOCH_3$ | I II | C B | A A |
| 2-2. Quarternary ammonium salt | | | | | |
| 14 | Dioctadecyldimethyl ammonium chloride | $[C_{18}H_{37}]_2N(CH_3)_2 Cl$ | I II | C B | C A |
| 15 | Octadecyltrimethylammonium chloride | $[C_{18}H_{37}-N(CH_3)_3] Cl$ | | C | C |
| 16 | Dodecyltrimethylammonium chloride | $[C_{12}H_{25}N(CH_3)_3] Cl$ | | B | C |
| 17 | Quarternary ammonium salt | $[RR' R'' R''' N] X$ | I II III IV V VI | A C C C C C | C C C C B C |
| 2-3. Alkylpyridinium salt | | | | | |
| 18 | Tetradecyl-pyridinium chloride | $C_{14}H_{29}N-Cl$  | | B | C |
| 19 | Hexadecyl-pyridinium chloride | $C_{16}H_{33}N-Cl$  | | B | C |
| 20 | Alkyl pyridinium salt | $R-N-Cl$  | I II III | B B B | C C C |
| 21 | Stearylamide methylpyridinium chloride | $C_{17}H_{35}CONHCH_2-N-Cl$  | | B | C |

Table 4-3. Nonionic surfactant

| No. | Chemical | Structure | Trade grade | Detonation | Caking | H.L.B. |
|-----|----------------------------------|---|----------------|-------------|-------------|--------|
| 22 | Polyoxyethylene-alkylether | $RO(C_2H_4O)_n H$ | I II III | B B B | C C C | 12.8 |
| 23 | Polyoxyethylene-oleate | $C_{17}H_{33}COO(C_2H_4O)_n H$ | | B | C | 13.5 |
| 24 | Polyoxyethylene-alkylphenol | $R-\langle \text{C}_6\text{H}_4 \rangle-O(C_2H_4O)_n H$ | I II | B C | B A | |
| 25 | Polyoxyethylenesorbitan laurate |  | | B | C | 16.7 |
| 26 | Polyoxyethylenesorbitan stearate | $H(CH_2C_2)_n OHC$ | | C | C | 14.9 |
| 27 | Polyoxyethylenesorbitan oleate | $HO(C_2H_4O)_n H$ | | B | C | 15.0 |

$R=C_{17}H_{33-35}$ for oleate, stearate
 $=C_{11}H_{23}$ for laurate

2, and 4—3 indicates that the best surfactants are all Anionic ones and they are:
 (1) Sodium dinaphthylmethane disulfonate (S. D. D.)
 (2) Sodium laurylsulphate (S. L. S.)
 (3) Sodium dodecylbenzene sulfonate (S. D. B.)

The values H. L. B. (Hydrophilic Lypophilic Balance) shown in Table 4—1 and Table 4—3 indicate the degree of balancing between the hydrophilic and lypophilic groups within a surfactant and the bigger is the value the bigger is the affinity to water.

§ 6. Effect of the surfactant on the detonation ability

The relation between the content of the surfactant and the critical diameter is shown in Fig. 3.

C. M. C. indicates that there exist the "critical micelle concentration" which is commonly observed in the effect of the surfactant, that is, as the surfactant affects the reaction on the boundary between two components the phenomenon of saturation may be expected, therefore, only a small amount

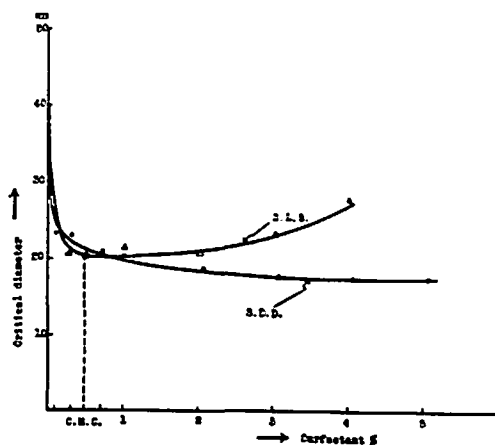


Fig. 3.

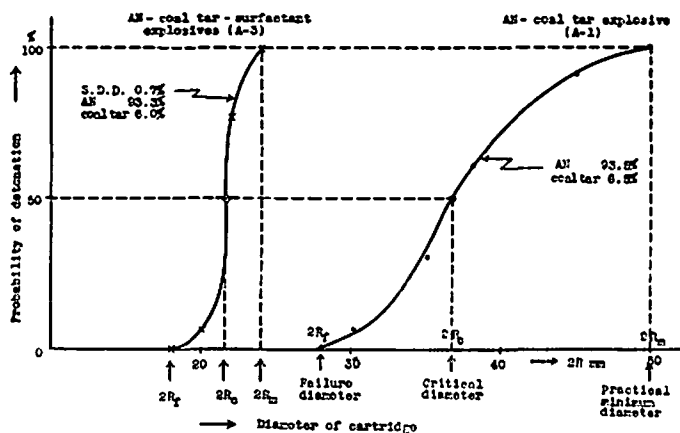


Fig. 4.

of the surfactant serves the purpose, which makes its industrial applications quite economical.

Fig. 4 illustrates how high is the detonation ability of the AN-coal tar-surfactant explosives compared with that of the AN-coal tar explosive.

§ 7. Effect of the surfactant on the reaction zone in the detonation

The detonation velocity D m/sec for various diameters of cartridges has been measured by the streak camera described in a previous paper⁴⁾ for the explosives A—1 and A—3 (Table 5 and Fig. 5). According to the theoretical analysis described in the same

Table 5.

(1) AN-coal tar explosive (A—1)

| Radius of charge R cm | Detonation velocity D m/sec. | D mean |
|-------------------------|--------------------------------|----------|
| 1.79 | 2,540 × × | |
| 2.01 | 2,940, 2,900, 3,010 | 2,950 |
| 2.26 | 3,220, 3,060, 3,060 | 3,110 |
| 2.52 | 3,110, 3,330, 3,250 | 3,230 |
| 2.83 | 3,330, 3,270, 3,370 | 3,330 |
| 2.96 | 3,390, 3,520, 3,440 | 3,450 |
| 3.22 | 3,370, 3,330, 3,360 | 3,350 |
| 3.43 | 3,210, 3,360, 3,320 | 3,300 |
| 3.69 | 3,300, 3,350, 3,310 | 3,320 |
| 3.96 | 3,440, 3,550, 3,450 | 3,480 |

4) Kumao Hino and Seiichi Hasegawa: The theory of the variable reaction zones in the detonation of industrial explosives. Journal of the Industrial Explosives Society, Japan Vol. 20, No. 1, 1959, pp. 2~11

(2) AN-cal tar-surfactant explosive (A-3)

| Radius of charge R cm | Detonation velocity D m/sec. | D mean |
|-----------------------|------------------------------|--------|
| 1.02 | × 3,020 × | |
| 1.12 | 3,150, 3,340, 3,310 | 3,270 |
| 1.23 | 3,370, 3,430, 3,430 | 3,410 |
| 1.34 | 3,480, 3,500, 3,420 | 3,470 |
| 1.41 | 3,590, 3,510, 3,500 | 3,530 |
| 1.53 | 3,710, 3,800, 3,640 | 3,720 |
| 1.77 | 3,690, 3,740, 3,780 | 3,740 |
| 1.98 | 3,850, 3,840, 3,850 | 3,850 |
| 2.25 | 4,030, 4,020, 3,910 | 3,990 |
| 2.49 | 4,090, 4,080, — | 4,090 |
| 2.79 | 4,140, 4,130, — | 4,140 |
| 2.96 | 4,170, 4,010, 4,010 | 4,060 |
| 3.21 | 4,260, 4,030, 4,170 | 4,160 |
| 3.41 | 4,330, — 4,270 | 4,300 |
| 3.67 | 4,270, 4,280, 4,260 | 4,260 |
| 3.93 | 4,350, 4,380, 4,430 | 4,400 |
| 4.16 | 4,310, 4,180, 4,330 | 4,270 |
| 4.60 | 4,420, 4,450, 4,450 | 4,440 |

Table 6.

| | A-1 | A-3 |
|--|---------------|---------------|
| Critical reaction time t_c | 10.3 μ s | 7.9 μ s |
| First transition reaction time t_1 | 14.47 μ s | 12.49 μ s |
| Maximum reaction time t_m | 18.62 μ s | 18.48 μ s |
| t_m/t_c | 1.81 | 2.34 |
| Fraction of heat at critical diameter N_c | 0.66 | 0.54 |
| Fraction of heat at first transition N_1 | 0.918 | 0.85 |
| Critical reaction zone length X_c | 2.62cm | 2.57cm |
| Reaction zone length at first transition X_1 | 4.82cm | 5.10cm |
| Maximum reaction zone X_m | 6.48cm | 8.19cm |
| X_m/X_c | 2.47 | 3.19 |
| Critical radius R_c | 1.79cm | 1.08cm |
| First transition radius R_1 | 2.83cm | 2.49cm |
| upper limit radius R_m | 3.96cm | 4.6 cm |
| X_c/R_c | 1.46 | 2.38 |
| Critical detonation velocity D_c | 2,540m/s | 3,260m/s |
| Transition velocity D_1 | 3,330m/s | 4,090m/s |
| Maximum velocity D_m | 3,480m/s | 4,440m/s |

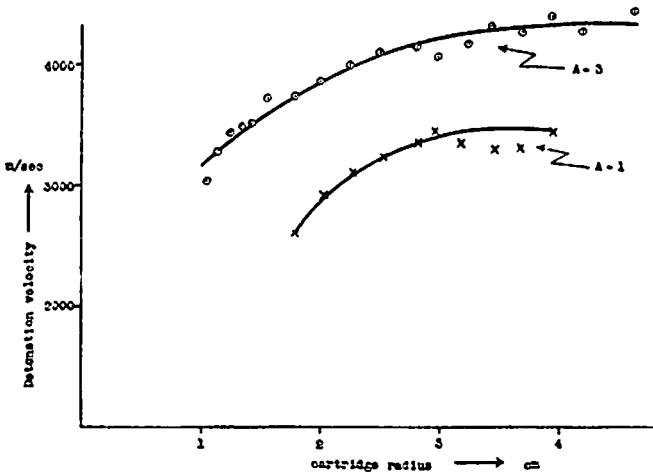


Fig. 5.

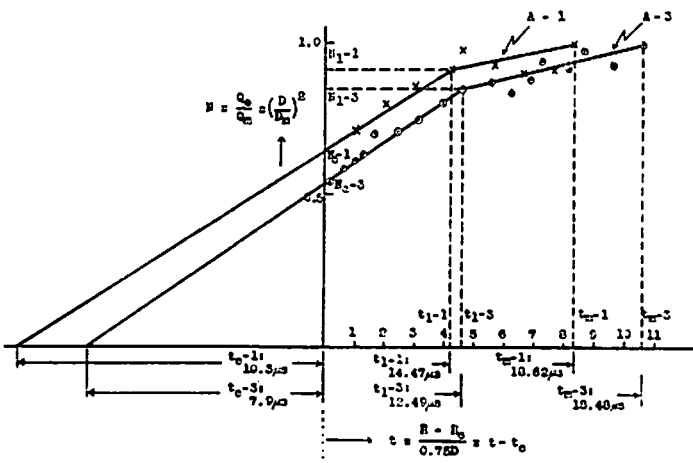


Fig. 6.

paper, the structure of the reaction zone has been calculated as is shown in Fig. 6 and Table 6. It may be seen that the detonation ability is greatly improved by the use of the surfactant and the critical reaction time reduced from 10.3 micro second to 7.90 micro second which indicates that the surfactant accelerates the explosive reaction between AN and coal tar to a great extent.

§ 8. Blasting properties of the AN-coal tar surfactant explosive

The blasting properties of AN-coal tar surfactant explosive (A-3) are compared with those of a Semi-gelatin dynamite whose compositions are: Nitroglyceline · nitroglycol

gel 10.5%. Nitro-compound 5.0%. Ammonium nitrate 76%. Wood meal 8.5%.

8-1. Sensitivity against the bit of a drill

Explosives were charged into a bore hole 7-10cm long drilled into granite. A chisel bit of tungsten-carbide gave a repeated strike to the explosive for 30 second at the rate of 2,000 strikes per minute. The total pressure applied to the explosive is around 170-220Kg. In ten trials semi-gelatine dynamite ignited five times while in A-3 no ignition occurred, that is, the AN-coal tar-surfactant explosive proved to be quite safe against the striking of a bit.

8-2. Explosion properties

The comparison of the explosion properties between the A-3 explosive and the semi-gelatin dynamites is summarized in Table 7.

Table 7.

| Explosion Properties | A-3 | Semi gelatin |
|---|-----------------------|-----------------------|
| Ignition point | 370-375°C | 295°C |
| Drop hammer test (5kg) (no-ignition height) | 30-33cm | 22cm |
| Loading density | 0.98g/cm ³ | 0.95g/cm ³ |
| Hess brisance (50g) | 13.6mm | 12.0mm |
| Trauzl block test (10g) | 320cm ³ | 350cm ³ |
| Ballistic pendulum (100g) | 72.8mm | 75.0mm |
| Gap test (multiple of diameter) | 2 | 6 |

8-3. Gaseous products after detonation

Two cartridges of 100g explosive wrapped by a parafinized paper whose diameter is 30mm were charged into a borehole of a steel mortar whose inner diameter is 55mm and length 550mm. The charge was fired by an industrial No. 6 electric detonator without stemming and the detonation products were discharged into a gallery with 2.15 meter diameter and 9.36m length whose volume is 35,800 liter. CO₂ content was analysed by alkali absorption (Rôken type

apparatus) CO content was measured by Graham method and nitrose gases were analysed by phenol-disulfonic acid method (by colorimetry). The result is shown in Table 8.

Table 8.

| Explosives | CO ₂ | CO | Nitrose |
|---------------|-----------------------|----------------------|------------------------|
| A-3 | 107.5l/Kg (0.065%) | 33.6l/Kg (0.024%) | 2.26l/Kg (14.24ppm) |
| Semi-gelatine | 151.0l/Kg (0.091%) | 32.4l/Kg (0.020%) | 2.20l/Kg (13.85ppm) |

§ 9. Blasting performance

A series of boreholes whose diameter is 55mm have been drilled in graphite schist and granite at Hikari quarry in Japan. The length of boreholes in about 5-7 meters. A-3 explosive cartridge with 40mm diameter and 225g weight per cartridge was tested in comparison with Ammon gelatin dynamite (Fuji dynamite). The industrial standard No. 6. electric detonator was used to initiate A-3 explosive. The weight of charge in a hole was about 4-5Kg and the total length of the charge in a hole was about 4-5 meters.

The result of the blasting proved quite satisfactory both from the standpoints of of fragmentation and the volume of rock broken.

§ 10. Acknowledgement

The authors thank Tsuguo Sawada for his help with the experiment in the earlier stage of the investigation and thanks are also due to S. Asaka, G. Okada, M. Morimoto, T. Hôjo and T. Murabayashi for their help with the experiment throughout the period of the research. They also would like to appreciate the advice given by Dr. Bernard Lewis and Dr. Stuart R. Brinkley, Jr.

硝安—燃料—界面活性剤爆薬

日野熊雄・横川六雄

硝安—燃料系爆薬の起爆感度を測定する試験法として実用的には小葉径で起爆する爆薬を求める事、又理論的には葉径効果を究明する事の二点より限界葉径試験を提唱しこれを採用した。

限界葉径の小さい硝安—燃料系爆薬を得るには

- 1) 硝安の粒度は平均粒子径で40ミクロン以下であること
 - 2) 燃料としてはコールタール、アントラセン油、軽油等の硝安と混合し易い燃料油を選ぶこと
- の二点が先づ必要である。更に両者の反応を促進せしめる爆轟促進剤が不可欠である。特殊な界面活性剤は

硝安—燃料油を分子的規模に於て結合せしめて両者の反応を著しく促進せしめる作用がある。

硝安—燃料—界面活性剤爆薬について各葉径に於ける爆速値を解析し爆轟反応帯構造を明かにすると共に界面活性剤の作用効果を究明した。

同爆薬の実用最小葉径は 20~24mm であり、爆轟性能、衝撃感度及び発破後ガス等について一般の工業用爆薬であるセミゼラチンダイナマイトと対比せしめ同爆薬が小葉径で且つ坑内用として実用し得る事を明かにした。

ニュース

ハイドロスパーク・フォーミング

最近の宇宙時代においてはロケット、人工衛星などがめざましい進歩を遂げてきているが、これらに使用する材料は高温に耐え、かつ強度の高いことが要求される。そこでそれら高強度の耐熱材料を加工するには在来の成型法では非常に困難となつて、瞬間的に高いエネルギーを放出する加工法が望まれてくる。それには爆薬または火薬のエネルギーを利用する爆発成型法が近來ソビエトをはじめ米国でも使用されはじめて来た。ここで述べるハイドロスパーク・フォーミングも電気的エネルギーをコンデンサーに一時たくわえ、次に水中で電極間に瞬時に放電することにより、金属の成型（主として薄肉管の成型）に必要なエネルギーを得る方法で、原理的にはこと新しくはない。電気放電によつて金属を加工する方法は、実験的には約半世紀以前から続けられてきたが、初期の時代はこの放電によるエネルギーを余り問題にしなかつた。しかし近來になつて高電圧、大容量のコンデンサーを用いることにより水中でそれが瞬間的に数万気圧の力を出すことを発見した。そこで最近になつて爆発成型に対抗する高エネルギー速度加工の一環としてこの加工法の原理とか応用について簡単に紹介してみる。（技術ジャーナル、35-9-9）

ロケット燃料用粘結剤

プラスチックの技術でビニール樹脂、可塑性、アルミ粉末および過塩素酸アンモンを強力で信頼性ある固形推進剤にすることができる。これはアメリカのアトランティックリサーチ社が開発したもので、180°Cに熱するとゴム状にとけるプラスチックである。ミサイルの粘結剤および燃料として有効である。

（ケミカル・エンジニアリング 6月27日 p. 68）
（日刊工業 35-8-15）

マンモス・ロケットの本命

アメリカが計画中のマンモス・ロケット、ノバの原動力になると考えられているのが、推力 150 万ポンド（680トン）の F-1 エンジンで、今までの最大を誇る H-1 エンジンの数倍ものサイズがある。RP-1 というケロシン系の燃料と液体酸素が推進剤に使われるが、それが実に 1 秒間に 3 トンという量で燃焼室に送られる。全力運転は近くエドワーズ空軍基地に建設中の施設が完成次第に行なわれることになつていながら、燃料ポンプと燃焼室はテストの結果が上々で、100 万ポンドまでの推力を出す試験も行なわれているので実用化は意外に近いだろうという。ノバにはこれを 4 基または 6 基たばねて、ブースターとして使おうというもの。製作はノースアメリカン航空のロケットデザイン部門。（技術ジャーナル、35-8-12）

固形プロペラント用新バインダー

固形プロペラント用の新しいバインダーが大型ロケット用として開発された。そのバインダーはカルボキシ基が端についている直鎖状ポリブタジエン（C. & EN, Aug. 1, Page 35）（年号の記載がない。）であつて、これは現在使つているポリブタジエンアクリリクアジッドコーポリマー（PABB）より機械的性質が優れていると、North American Aviation の Rocketdyne, Division ではいつている。例えばこの Flexadyne-Propellant は PABB の 2 倍の引張り強度がある。

PBAA は貯蔵安定性が良い。Flexadyne-Propellant はこの点について評価するには新し過ぎるが、現在迄のデータでは PBAA に比して変りはないようである。（C. & E. News Aug. 8, 1960 p. 53）

（木村清茂）