Design of Detonator Plant

Part II. Tenement-Room Structure of Blow-out Type

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I. Introduction

Formerly, factories of explosives had mainly adopted a manual system, which, after the Second World War, developed into mechanization or semi-automation and in the last few years stepped out into the way to automation. In factories of detonators a tenement-room structure(adjoining room structure) of blow-out type [1] as shown in Fig. 1, has been adopted.

In this experiment, a model of about one-tenth of the real size was tested to obtain a standard tenement-room of blow-out type which had operational shields and a barricade. And an aspect of sympathetic detonation was studied by a high-speed camera.

II. Conclusions

1. To prevent the sympathetic detonation to the adjoining room, the construction should afford an expansion of shock waves produced by an initial stage of explosion.

A blow-out type without an overhead operational shield and a half blow-out type with an overhead operational shield, whose horizontal length is a half of the room depth, have fewer possibilities of sympathetic detonation than a closed type with an overhead operational shield of full horizontal length.

A longer distance from the room edge to the barricade relates to a less possibility of sympathetic detonation. In the case of mercury fulminate the distance effect is remarkable.

2. Diazodinitrophenol (DDNP) is more liable to induce a sympathetic detonation than does mercury fulminate.

3. DDNP's liability for sympathetic detonation was ascribed to the high explosion pressures, the big flame and its long duration.

4. The low density(1.63)[2] of DDNP makes it easy to scatter or disperse DDNP in air by blast waves. Thereafter, in the dispersed phase the ignition starts and leads to detonation.

III. Experimental

Construction: The model two-room tenement of blow-out type was made of steel plates (10mm in thickness), and was about one-tenth of the real size, i. e. 330mm in frontage, 295mm in depth and 335mm in height. (Fig. 1)

The overhead operational shield was attached to each room at the position of 230mm in height with various slants, 0°, 15°, etc. and in horizontal lengths of 115mm and 295 mm. The case of no shield was also tested.

Method: DDNP, mercury fulminate or black powder, was put on a rubber sheet which covered an iron stand (30mm in width, 110mm in height and 150mm in length) in each room. The stand was located about 10mm apart from the wall. The distance from the room edge to the barricade was varied to be 10cm, 20cm, or 30cm. Or the barricade was also tested.

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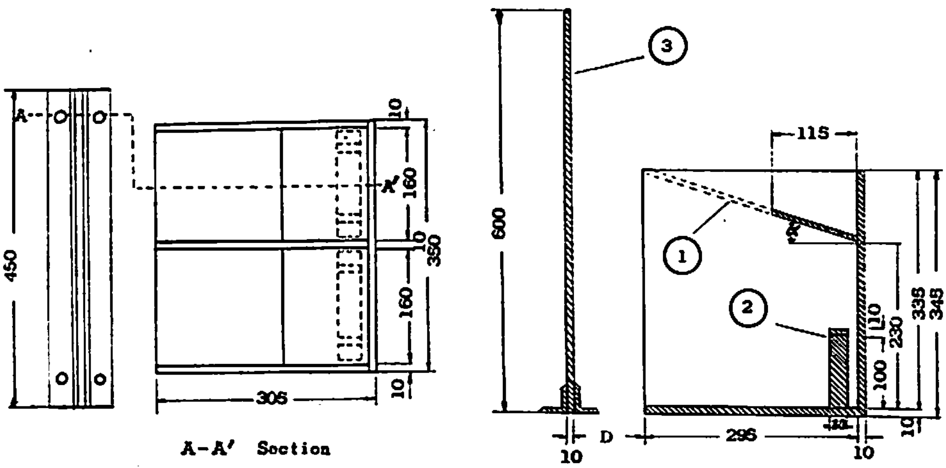


① : operational shield ② : stand ③ : barricade

Fig 1 The model two-room tenement of blow-out type

Table 1 Critical charges to induce sympathetic detonation at the model two-room tenemeut of blow-out type.

Explosive	Overhead operational shield: Horizontal length (cm)	Overhead operational shield: Slant (c)	Distance between room edge and barricade (cm)	Donor charge* (g): Critical charge averaged	Donor charge* (g): Deviation
DDNP Δ=0.476	295	0	10	6.85	1.669
			20	6.97	0.599
			30	6.20	2.033
			no barricade	8.70	1.790
	295	15	10	4.57	0.779
			20	5.50	0.916
			30	7.10	0.855
			no barricade	8.90	1.097
	no shield		10	6.83	0.839
			20	14.19	1.887
				12.96	0.698
			30	9.50	2.206
				9.57	1.034
			no barricade	12.92	11.052
	115	0	10	5.56	1.054
			20	8.50	1.411
			30	9.35	1.749
			no barricade	11.37	1.098
	115	15	10	6.03	1.098
			20	8.52	1.310
			30	11.07	1.369
			no barricade	12.10	1.137
Δ=0.574	no shield		10	8.88	1.055
			20	13.20	5.234
			30	9.35	3.353
			no barricade	10.28	2.632
$Hg(ONC)_2$ Δ=1.515	115	0	10	9.07	4.145
			20	17.50	7.115
			30	28.93	2.062
			no barricade	42.90	4.307
	115	15	10	9.16	4.725
			20	16.50	6.256
			30	26.75	1.997
			no barricade	38.70	9.287
	no shield		10	14.42	12.437
			20, 30, no barricade	non detonation at 55g	

* Donor and acceptor are the same quantity.

The sample was fired by a fuse head, and it was observed how the adjoining room got a sympathetic detonation. Critical charge to induce the sympathetic detonation was determined after thirty-time successive tests by K. A. Brownlee's up and down method.[3]

Results: the relations between the critical charge of sympathetic detonation and the distance of the barricade from the room edge are shown in Table 1.

(1) The length of overhead operational shield: the blow-out type without an overhead operational shield has slightly less tendency to induce a sympathetic detonation than does the half blow-out type with an overhead operational shield of one-half horizontal length, and shows more striking tendency to prevent a sympathetic detonation than does the closed type with an overhead operational shield of full horizontal length (295mm).

(2) Slant of the overhead operational shield: the difference in the effect of slant on preventing a sympathetic detonation could not be found. But so far as concerned with DDNP the shield of fifteen degree slant seems to be more or less effective in preventing a sympathetic detonation than does the horizontal overhead shield when the distance between the room edge and the barricade is long. On the contrary, for mercury fulminate the horizontal overhead operational shield seems to have an effect of preventing a sympathetic detonation than does the shield at a slant of fifteen degrees.

(3) The distance between the room edge and the barricade: as the distance between the room edge and the barricade becomes longer, the possibilities of sympathetic detonation become generally fewer. But the blow-out type without a shield shows the least possibility when the distance between the room edge and the barricade is 20cm. As for mercury fulminate the above-mentioned distance effect was found remarkable. In the case of DDNP ($\Delta=0.476$) another test model which had no overhead operational shield, and whose frontage was directly closed by an acryl plate gave the same critical charge (8.88g with a deviation of 1.925g) as that (8.70g with a deviation of 1.790g) of the fourth line in Table 1. This is easily understood, because both of the models have almost the same construction except the direction of openings.

(4) Samples: DDNP having the lower bulk density ($\Delta=0.476$) has slightly fewer possibilities of sympathetic detonation than that of the high bulk density ($\Delta=0.574$) has. Mercury fulminate has fewer possibilities, and more remarkable effect of distance between the barricade and the room edge than DDNP has. Glanular black powder (B. P.) does not induce sympathetic explosion even when the charge exceeds 200g, and the charge in the adjoining room remains unchanged. (Granular black powder is composed of 70% potassium nitrate, 16% charcoal and 10% sulphur.)

Mechanism of sympathetic detonation of DDNP was considered as follows: DDNP produced blast wave pressure measured by a piezoelectric gauge was higher than that of mercury fulminate. Since the pressure is generally considered as a cause of sympathetic detonation, the measured pressure seemingly supports that DDNP is more liable to induce a sympathetic detonation than mercury fulminate. But the difference between the distance effect of DDNP and that of mercury fulminate cannot be explained merely by the measured pressures. The cause of sympathetic detonation in this case should be considered elsewhere.

The explosion heat of DDNP (1,017.1cal/g) is greater than that of mercury fulminate (408.9cal/g). The explosion temperature of

DDNP calculated by the hydrodynamic theory of detonation[4] is lower than that of mercury fulminate. Meanwhile, Y. Mizushima[5] measured the temperatures of explosion flame of DDNP and mercury fulminate by means of the spectrum line reversal method to be 1,890 ±70°K and 2,500±200°K respectively. So the DDNP's greater tendency to the sympathetic detonation cannot be explained by the difference in the explosion temperatures.

(5) A sample loaded in a spherical shell, made of cellophane of twenty micron thick with a fuse head in the centre, was suspended at the centre of a wooden frame of $1m^2$. The photographs are shown in Fig. 2. The area of the flames measured by a planimeter is given in Fig. 3. The mean area of DDNP flame increases remarkably as the quantity of charge increases. The area is larger than that of black powder, deflagration flame of which was formerly considered to be the largest of explosive flames. The mean area of mercury fulminate flame becomes large as the charge increases, but in a far smaller scale compared to DDNP.

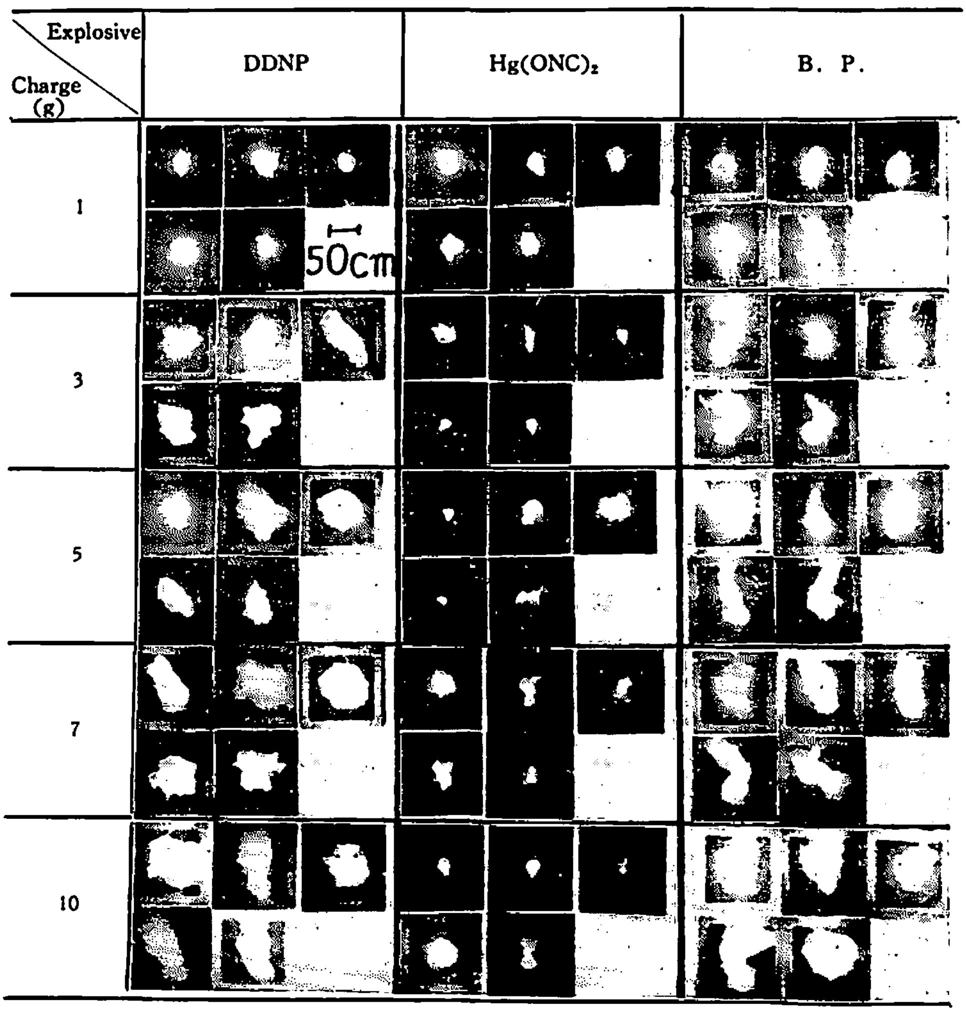
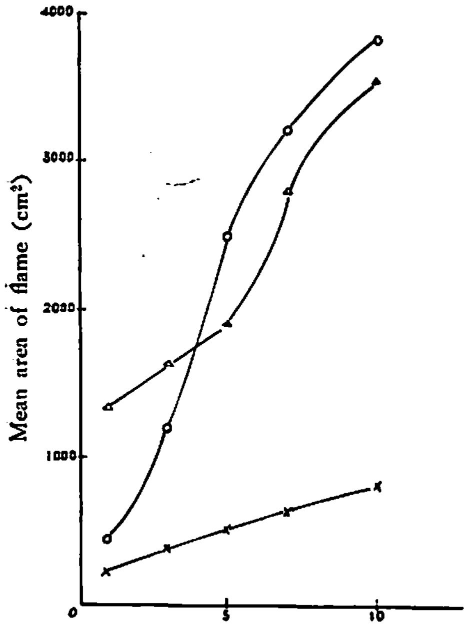
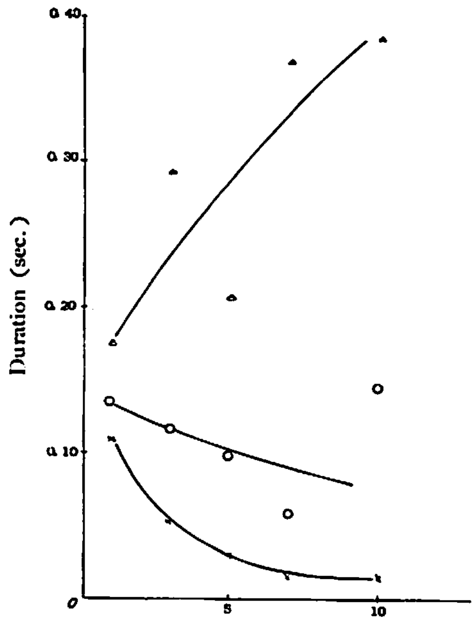


Fig. 2 The size and shape of flame



○ : DDNP, × : $Hg(ONC)_2$, △ : B. P.

Fig. 3 The size of flame



○ : DDNP, × : $Hg(ONC)_2$, △ : B. P.

Fig. 4 Duration of flame

(6) The similar samples with above were fired in a bright and a dark field. The duration of explosion flame was recorded by an 8mm cinecamera at a framing rate 64. The duration is shown in Fig. 4. The duration of black powder flame becomes longer as the charge increases. The duration of DDNP flame becomes shorter as the charge increases and that of mercury fulminate flame becomes rapidly shorter than DDNP flame does. These facts show that DDNP and mercury fulminate have the tendency leading to the complete detonation above a definite critical charge corresponding to firing conditions. DDNP thus gives the long duration flame and a large critical charge to get detonation as compared with mercury fulminate. These properties of DDNP probably affect the induction of sympathetic detonation.

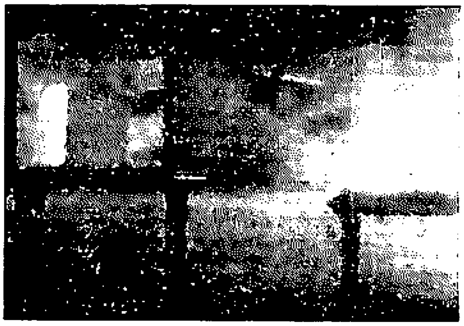
(7) The photographs of the front and side views of the model structure were simultaneously taken by a Kodak High speed Camera. In this case an acryl plate (60cm in height, 45cm in width and 1cm in thickness) was used as a barricade. Two series of photograph shown in Fig. 5. are as follows.

DDNP of 10g (Δ=0.476) located on the stand in each room of closed type. The slant of the overhead operational shield was fifteen degrees. The distance detween the room edge and the barricade was 20cm. The framing rate was 2,400 in a second. (Fig. 5-(a))

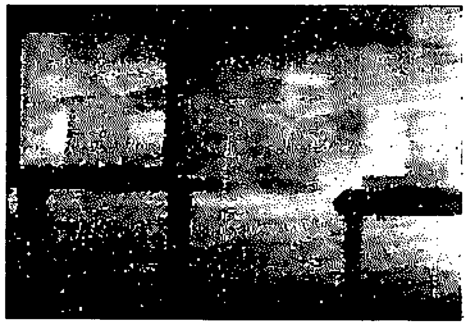
At 8.4 msec. after the initiation the largest explosion flame are seen in the initiation room. At 24.6 msec, in the adjoining room flame starts in the left corner and fine powder begins to disperse. At 39.6~40msec. DDNP on the stand explodes. At 47.1 msec. the maximum flame is seen in the adjoining room. The explosion flame in the initiating room

(1) After initiation, 1 frame (0.42ms.)

(2) After initiation, 20 frames (8.4ms.) Initiation room shows maximum flame.



(3) After initiation, 95 frames (39.6ms.) The just state preceding in which DDNP on the sample stand begins to explode.



(4) After initiation, frames (40.0ms.) DDNP on the sample stand begins to explode.

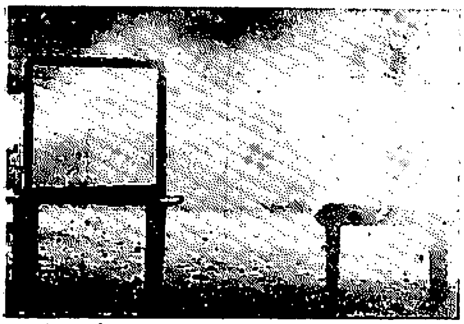
(5) After initiation, 113 frames (47.1ms.) Adjoining room shows maximum flame.

(6) After initiation, 271 frames (113ms.) Flame of initiating room disappears.

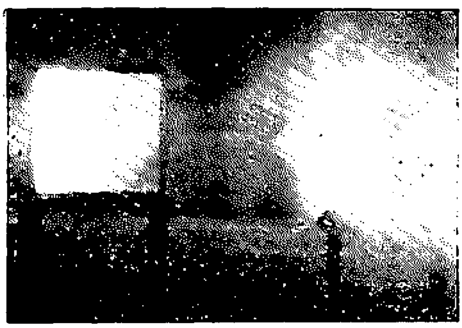
(7) Arter initiatiou, 390 frames (163ms.) Flame of adjoiniag room disappears.

Fig. 5-(a) Kodak High Speed Camera shows at 2,400 frames/sec. DDNP (Δ= 0.476, 10g) detonates the same charge in the adjoining room sympathetically. The rooms have an overhead operational shield of 15° slant. The distance between the room edge and the barricade is 20cm.

(1) After initiation, 2 frames (2.1ms.) Initiating room shows maximum flame



(2) After initiation, 107 frames (45.8ms.) The just state preceding the beginning of explosion in adjoining room, Acryl plate instead of barricade had already been broken to fragments.



(3) After initiation, 131 frames (56.0ms.) Adjoining room shows maximum flame.

Fig. 5-(b) Kodak High Speed Camera shows at 2,340 frames/sec. Mercury fulminate(Δ=1.515, 10g) detonates the same charge in the adjoining room sympathetically. The rooms have an overhead operational shield of 15° slant. The distance between the room edge and the barricade is 20cm.

disappears at 113 msec., and the flame in the adjoining room extinguished at 163 msec..

Mercury fulminate(Δ=1.515) of 10g located in each room of the closed type. The slant of the overhead operational shield was fifteen degrees. The distance from the room edge to the barricade was 20cm. The framing rate was 2,340 per sec.. (Fig. 5-(b))

At 2.1 msec. after the initiation the room shows the maximum flame. At 45.8 msec. the acryl plate (the barricade) was broken to pieces. In the adjoining room explosion starts at the middle point between the over head operational shield and the stand. At 56.1 msec. the flame reaches maximum.

The sympathetic detonation of DDNP is considered as follows.

DDNP yields the higher pressure, greater heat, wider flame and longer duration than those of mercury fulminate and has lower density (1.63g/cm^3)[2] than that (4.4g/cm^3)[2] of mercury fulminate.

The high-speed photographs show that the DDNP of small density in the adjoining room is liable to scatter or disperse in air by blast waves.

These properties of DDNP lead to its liability for the sympathetic detonation.

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火工品工場の危険工室の設計

第II報　放爆式連接危険工室設定に関するモデル実験

沢　田　維　男

放爆式危険工室の連接基準を得るため，約 1/10 の大きさの放爆式 2 連接工室の小型モデルを造り，1 工室が何らかの原因で爆発した場合，隣接工室が殉爆するか否かを，屋根方向の避害板の有無，長さ，角度および工室から土堤までの垂直距離を変化させて検討した。

1. 連接工室の殉爆防止には，ショック波，爆発波の乱れが少ない上方向に避害板のない放爆型，あるいは水平長で約 1/2 の半放爆型の方が，全長の密閉型のものより殉爆し難いようである。

2. 工室と土堤との距離も，同様な理由で距離が大きくなるほど殉爆し難く，土堤のない無限大の場合が最も殉爆し難いようである。

なお雷こうでは，特にこの距離効果の影響がいちじるしい。

3. 雷こうは DDNP に比し殉爆し難い。

4. DDNP が雷こうに比し殉爆し易い要因として，実験的に爆発圧力および爆発火炎が大きく，爆発火炎の持続時間が長いことが挙げられることを確めた。

5. DDNP は雷こうに比し比重が小さいので，爆発によるショック波の伝播反射，爆発波の膨脹収縮による 2 次的な薬の移動と爆発火炎の相互作用で殉爆を誘起し易いことが考えられる。