THE DETERMINATION OF THE RELATIVE SENSITIVENESS OF EXPLOSIVE SUBSTANCES THROUGH "EXPLOSIONS BY INFLUENCE."[1]

BY CHARLES E. MUNROE.

THE determination of the sensitiveness of explosive substances has already been made by a number of different methods, but it is yet a question as to the real value of these results. Thus, we have the methods by percussion, by heat, by friction, and the like. It has occurred to me that a much more delicate and reliable method would result from the employment of what has been termed by Berthelot "explosion by influence." What is meant by this term is the explosion of a secondary mass through the explosion of a primary mass which is separated from the secondary mass by a definite interval. Numerous observations have been made, as notably in the Danish experiments, in explosions of this kind taking place under water, and a great many instances are recorded of similar explosions being brought about on the surface of the earth; but the submarine experiments were made with a limited number of substances confined in envelopes which materially modified the results, while the earth experiments were made under continually varying conditions. In the experiments which I have to record I have employed a continuous and, as nearly as may be, homogeneous medium, through which the effect of the explosion of the primary mass is conveyed to the secondary mass, while I have used definite and moderate quantities of explosives under constant conditions of confinement—circumstances which are easily repeated, while the attending phenomena are easily observed.

The method pursued was as follows:

The initial and secondary masses were placed upon a wrought iron armor plate nine feet five inches long, three feet four inches wide, and one inch thick, which rested upon a second plate of the same material and dimensions. These plates had been made for use on vessels of war, and consequently they contained several lines of rivet holes and also were curved to

[1] Read at Newport General Meeting.

the shape of the vessel. This of course affected the rigidity of the system, and it was expected that it might introduce irregularities into the results, but firing trials made under otherwise similar conditions showed that for the masses of explosives used the results were uniform at all points.

The initial mass consisted of 100 grams of explosive, while the secondary mass varied from 30 to 100 grams, it being evident that the weight of the secondary mass had no effect on its sensitiveness, and that it was essential only to have a sufficient quantity to produce a positive and visible effect on the firing plate in case it was exploded.

In the experiments for testing the relative sensitiveness of different explosives when referred to a common standard, 100 grams of United States service gun cotton was selected for the initial mass because it was the most accessible, convenient, and constant one at hand, but apart from these considerations there is an advantage in using this as the initial mass, since it has been shown by Abel that gun cotton is the most efficient detonating priming agent among explosive substances.

The gun cotton, as issued from the Naval Torpedo Station where it is manufactured, is in the form of blocks two and nine-tenths inches in diameter, three and seven-eighths inches in diagonal (the corners being chamfered), and two inches in height, and it is made by compressing pulped gun cotton in molds by means of a hydraulic press, the pressure applied being about 6,500 pounds per square inch. The gun cotton when so pressed has a gravimetric density of 1.2871. It should be added that the blocks are pierced through the center with a hole seven-sixteenths inch in diameter in which the detonator is to be inserted for firing. This gun cotton was steam-dried before using, and pieces of 100 grams weight were cut off by cutting transversely to the vertical axis, so that the diameter of the base of these pieces was that of the blocks from which they were taken, or 7.4 centimeters.

As all the other explosives were in the form of either a powder or paste, it was necessary to provide containers for them, and these were made from well calendered manilla paper. When these explosives were used for the initial mass the boxes had the same form and dimensions as the service block of gun cotton, except that the corners were not chamfered, and hence the area of the surface in contact with the plate was very closely the same as for the gun cotton. When these explosives were used as secondary masses they were enclosed in similar open paper boxes, but they were but 5.58 centimeters in diameter. In all cases the explosive was evenly distributed over the bottom of the case and brought well in contact with it, so that the area of the face of these different explosives in contact with the firing plate was as nearly as possible identical. It is evident from this description that the explosives were tested when unconfined except by atmospheric tamping.

In making the test it was of course necessary to proceed in a purely tentative manner. A point was selected upon the plate where no breaches of continuity were apparent for a considerable range, the initial mass was placed upon the plate and at the outset of each series two secondary masses (one being placed on either side of the initial or primary mass and at unequal distances from it) and the primary one detonated. When this was detonated it produced a well marked impression on the iron, and the same effect was observed in the case of the secondary masses when they were detonated, the effect, however, being in all cases diminished as the secondary mass approached that point at which it ceased to be detonated. The observations were most easily made when gun cotton was used for both the primary and secondary charges, for when the secondary charge was not far beyond the limit at which secondary charges could be detonated, it burst into flame and was tossed into the air in this inflamed condition through the disturbance produced in the atmosphere by the detonation of the initial mass.

When non-detonating or sub-detonating explosives were used for the secondary charges, impressions were produced so long as explosion was effected, but the impressions produced, at least near the extreme limit, were due only to the removal of scale from the plate by the shock of the explosion and to the deposition of soot and other products. When beyond this limit the explosive was found scattered upon the plate together with fragments of the containers.

As in the course of these experiments we appeared to approach the limit, single secondary charges only were used with each initial charge in order to simplify the observations. It should be added that the points measured were from the inside edge of the primary mass to the inside edge of the secondary mass before explosion.

The results obtained were as follows:

GUN COTTON ON GUN COTTON.

Initial mass, gun cotton.	Secondary mass, gun cotton.	Distance.	Result.
100 grams.	100 grams.	10 cm.	Detonated.
100 "	100 "	10 "	"
100 "	60 "	10 "	"
100 "	100 "	10.5 "	Failed.
100 "	60 "	11 "	"
100 "	100 "	11 "	"
100 "	100 "	12 "	"
100 "	100 "	17.3 "	"
100 "	100 "	35 "	"
100 "	100 "	70 "	"

GUN COTTON ON JUDSON POWDER, R. R. P.

Initial mass, gun cotton.	Secondary mass, gun cotton.	Distance.	Result.
100 grams.	30 grams.	20 cm.	Detonated.
100 "	30 "	20 "	"
100 "	30 "	25 "	"
100 "	30 "	25 "	"
100 "	30 "	26 "	Failed.
100 "	30 "	27 "	"
100 "	30 "	30 "	"

GUN COTTON ON EMMENSITE, NO. 259.

Initial mass, gun cotton.	Secondary mass, Emmensite.	Distance.	Result.
100 grams.	60 grams.	10 cm.	Exploded.
100 "	60 "	11 "	"
100 "	60 "	12 "	"
100 "	60 "	13 "	"
100 "	60 "	14 "	"
100 "	60 "	15 "	"
100 "	60 "	16 "	"
100 "	60 "	17 "	"
100 "	60 "	20 "	"
100 "	60 "	25 "	"
100 "	60 "	30 "	"
100 "	60 "	31 "	Failed.
100 "	60 "	35 "	"
100 "	60 "	35 "	"
100 "	60 "	40 "	"

GUN COTTON ON EMMENSITE (259) II.

Initial mass, gun cotton.	Secondary mass, Emmensite II.	Distance.	Result.
100 grams.	60 grams.	30 cm.	Exploded.
100 "	60 "	31 "	"
100 "	60 "	31 "	Failed.
100 "	60 "	32 "	"

This Emmensite II is a portion of No. 259 which had been subjected to temperatures of 120° F. and 60° F. alternately for varying periods during sixty-three days.

The firing plate was exposed to the sun, and on the day of these experiments it was so hot that one could hardly hold the naked hand upon it, while in the previous experiments, the sky being overcast, the plate was not noticeably warm.

GUN COTTON ON FORCITE NO. 1.

Initial mass, gun cotton.	Secondary mass, Forcite Powder.	Distance.	Result.
100 grams.	30 grams.	40 cm.	Detonated.
100 "	30 "	50 "	"
100 "	30 "	60 "	"
100 "	30 "	60 "	Doubtful.
100 "	30 "	61 "	"
100 "	30 "	62 "	Failed.
100 "	30 "	65 "	"
100 "	30 "	70 "	"

The forcite was well pressed down in the bottom of the paper box and the bottom of the latter appeared to be moistened by exuded nitroglycerine. The forcite, except in being transferred from the cartridge cases, was in the same condition as when purchased from the company.

GUN COTTON ON ATLAS NO. 1.

Initial mass, gun cotton.	Secondary mass, Atlas Powder.	Distance.	Result.
100 grams.	30 grams.	20 cm.	Detonated.
100 "	30 "	30 "	"
100 "	30 "	40 "	"
100 "	30 "	50 "	"
100 "	30 "	60 "	"
100 "	30 "	70 "	"
100 "	30 "	71 "	"
100 "	30 "	72 "	"
100 "	30 "	73 "	Doubtful.
100 "	30 "	73 "	Detonated.
100 "	30 "	74 "	Failed.
100 "	30 "	75 "	"
100 "	30 "	80 "	"
100 "	30 "	90 "	"

The wind was strong from the southwest during these experiments, and as double secondary charges were used in the earlier rounds, the more distant one being to southwest of the primary, there was an uncertainty in the first round at seventy-three and seventy-five cm. whether unexploded Atlas powder at the seventy-three cm. position to the northeast was a residue from this charge, or had been carried by the wind from the seventy-five cm. charge.

The Atlas charges were pressed firmly down in paper box and the latter appeared to be moistened by exuded nitro-glycerine.

GUN COTTON ON EXPLOSIVE GELATINE (CAMPHORATED).

Initial mass, gun cotton.	Secondary mass, Explosive Gelatine.	Distance.	Result.
100 grams.	10 grams.	10 cm.	Detonated.
100 "	10 "	15 "	"
100 "	10 "	18 "	"
100 "	10 "	20 "	"
100 "	10 "	21 "	Failed.
100 "	10 "	60 "	"
100 "	10 "	66 "	"

This explosive gelatine was made at the United States Naval Torpedo Station at Newport, R. I., March 31, 1889, and consisted of nitroglycerine 86.5 per cent., nitro-cotton 9.6 per cent., camphor 4 per cent., and was tested August 2, 1890.

GUN COTTON ON BELLITE.

Initial mass, gun cotton.	Secondary mass, Bellite.	Distance.	Result.
100 grams.	30 grams.	50 cm.	Detonated.
100 "	30 "	50 "	"
100 "	30 "	51 "	Failed.
100 "	30 "	53 "	"
100 "	30 "	55 "	"
100 "	30 "	60 "	"
100 "	30 "	100 "	"

This bellite was made January 21, 1890, by fusing together NH_4NO_3 five parts; $C_6H_4(NO_2)_2$ (1 : 3), one part, and was tested August 2, 1890.

GUN COTTON ON KIESELGUHR DYNAMITE NO. 1.

Initial mass, gun cotton.	Secondary mass, Kieselguhr dynamite.	Distance.	Result.
100 grams.	30 grams.	30 cm.	Detonated.
100 "	30 "	40 "	"
100 "	30 "	40 "	"
100 "	30 "	50 "	"
100 "	30 "	50 "	"
100 "	30 "	60 "	"
100 "	30 "	60 "	"

GUN COTTON ON KIESELGUHR DYNAMITE NO. 1. (CONCLUDED).

Initial mass, gun cotton.	Secondary mass, Kieselguhr dynamite.	Distance.	Result.
100 grams	30 grams	63 cm.	Detonated.
100 "	30 "	64 "	"
100 "	30 "	65 "	Failed.
100 "	30 "	70 "	"
100 "	30 "	70 "	"
100 "	30 "	80 "	"

This 75 per cent. Kieselguhr dynamite was made at the United States Naval Torpedo Station at Newport, R. I., in 1884, and tested August, 1890.

GUN COTTON ON RACKAROCK.

Initial mass, gun cotton.	Secondary mass, Rackarock.	Distance.	Result.
100 grams.	30 grams.	30 cm.	Detonated.
100 "	30 "	30 "	"
100 "	30 "	31 "	"
100 "	30 "	31 "	"
100 "	30 "	32 "	"
100 "	30 "	32 "	"
100 "	30 "	33 "	Failed.
100 "	30 "	33 "	"
100 "	30 "	40 "	"

This rackarock was made at the Naval Torpedo Station at Newport, R. I., in July, 1888, and consisted of $KClO_3$, seventy-nine parts; $C_6H_5(NO_2)$ (sp. gr. 1.33), twenty-one parts; and was tested August, 1890.

Summing up this data we find that the relative sensitiveness of these explosives to detonating gun cotton, all being in the open and on the same iron plate, is as follows:

RELATIVE SENSITIVENESS TO DETONATION BY GUN COTTON.

	Cm.
Gun cotton	10
Explosive Gelatine (camphorated)	20
Judson, R. R. P.	25
Emmensite (No. 259)	30
Rackarock	32
Bellite	50
Forcite No. 1	61
Kieselguhr Dynamite No. 1	64
Atlas No. 1	74

These results are rather unexpected as it was supposed that the nitro-substitution explosives, emmensite, rackarock, and bellite would prove much less sensitive than camphorated explosive gelatine and Judson powder or even than gun cotton itself. The dynamites came out in their proper position according to theory, though the relative position of the different ones might vary with different manufactured lots.

It is very important for practical operations in countermining to know if a similar difference exists in the relative sensitiveness of different explosives to detonation by a single kind of priming substance, and this point should be thoroughly investigated.

Besides the above a few experiments were made to determine the greatest distance at which a unit mass of a substance could effect the explosion or detonation of a secondary mass of the same substance. The results are as follows:

EMMENSITE NO. 259 ON EMMENSITE NO. 259.

Initial mass.	Secondary mass.	Distance.	Result.
100 grams.	30 grams.	10 cm.	Exploded.
100 "	30 "	10 "	"
100 "	30 "	10 "	"
100 "	30 "	10 "	"
100 "	30 "	11 "	Failed.
100 "	30 "	15 "	"
100 "	30 "	15 "	"
100 "	30 "	20 "	"
100 "	30 "	20 "	"
100 "	30 "	30 "	"

ATLAS NO. 1 ON ATLAS NO. 1.

Initial mass.	Secondary mass.	Distance.	Result.
100 grams.	30 grams.	11 cm.	Exploded.
100 "	30 "	12 "	"
100 "	30 "	13 "	"
100 "	30 "	20 "	"
100 "	30 "	30 "	"

FORCITE NO. 1 ON FORCITE NO. 1.

Initial mass.	Secondary mass.	Distance.	Result.
100 grams.	30 grams.	11 cm.	Detonated.
100 "	30 "	14 "	"
100 "	30 "	14.5 "	"
100 "	30 "	15 "	"
100 "	30 "	15 "	Failed (?)

KIESELGUHR DYNAMITE NO. 1 ON KIESELGUHR DYNAMITE NO. 1.

Initial mass.	Secondary mass.	Distance.	Result.
100 grams.	30 grams.	11 cm.	Detonated.
100 "	30 "	15 "	"
100 "	30 "	20 "	"
100 "	30 "	25 "	"
100 "	30 "	30 "	"

These experiments were conducted like those in which gun cotton was used as the initial mass, except that both the initial and secondary masses were enclosed in paper boxes.

At this point I was compelled to cease the experiments and have not since been able to renew the work, but I believe that if these observations could be extended they would prove fruitful not only in interesting but practical results. However, the observer must have had a large experience in explosive work and the effects of explosives, or he will frequently be deceived as to the nature of the results obtained.

THE ACTION OF THE HALOID ACIDS IN GAS FORM UPON MOLYBDIC ACID.

By Edgar F. Smith and Vickers Oberholtzer.

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Debray (*Compt. rend.*, **46**, 1098, and *Ann. Chem.* (*Liebig*) **108**, 250) first called attention to the fact that a very volatile, crystalline compound of the formula $MoO_3.2HCl$ resulted upon exposing molybdic acid heated from 150° to 200° to the action of hydrochloric acid gas. It is true that the constitution of this volatile product may also be represented by the formula $MoO(OH)_2Cl_2$, which would make it a molybdenum hydroxychloride. Dismissing the question of constitution for the present and considering the point of easy volatility, it seemed to us that this behavior might be utilized for the separation of molybdic acid from tungstic acid, as the latter apparently does not enter into volatile combination with hydrochloric acid gas. We therefore exposed weighed amounts of sublimed molybdic acid to the action of the acid gas, and succeeded in expelling the molybdic acid completely from the porcelain boats containing it. Applying the same treatment to what we considered pure tungstic acid we were greatly surprised to find that very appreciable quantities of a sublimate similar in every respect to that of molybdenum hydroxychloride were expelled from the boat. An examination of this product proved it to be the molybdic acid compound. In short our tungstic acid was not pure. We, however, continued to heat portions of it in hydrochloric acid gas until a sublimate was no longer obtained, when on mixing molybdic acid in known amount with the residual tungstic acid we discovered that we could completely expel the former acid from the latter. Our next step was to observe the