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COMPRESSED GUN COTTON

FOR

MILITARY USE.

TRANSLATED FROM THE GERMAN of MAX VON FÖRSTER

WITH AN INTRODUCTION

ON

MODERN GUN COTTON,

ITS

MANUFACTURE, PROPERTIES AND ANALYSIS.

BY

Lieut JOHN P. WISSER, U. S. A.

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INTRODUCTION.

Gun cotton, although the first discovered of the sudden explosives, the most thoroughly investigated and the safest, has not been employed to the extent to which its properties seem to entitle it. The accidents of the explosion of the earlier large factories of gun cotton, the rapid discovery and introduction of other sudden explosives, especially nitro-glycerine and its derivatives, the failure for some time to produce a pure material, and finally the unsuccessful attempts to introduce it in artillery, led to its abandonment to a large extent.

The great problem in military engineering to-day is the development of a proper system of fortification to resist the great power of modern ordnance. In anticipation of the solution of this problem, a new development is taking place in artillery: the use of the sudden explosives in charging projectiles. Gun cotton appears to be particularly adapted for this purpose, and would seem to be entitled to a fair test.

The experiments of Lieutenant Von Förster constitute a valuable addition to the literature of this explosive, and the material used is superior in quality to that generally described in scientific works. In order to complete the subject of gun cotton, and to make clear the value of these experiments and of the improvements in the qualities of the explosive, a brief outline of the process of manufacture now in use, and a summary of the properties of the best form produced, is here presented, and, in addition, a new method of analysis applicable to compressed as well as to fibrous gun cotton.

MODERN GUN COTTON,

ITS

Manufacture, Properties and Analysis.

BY

Lieut. JOHN P. WISSER, U.S.A.

HISTORY.

The first step in the discovery of gun cotton was the discovery by M. Braconnot, in 1833, of xyloidine, obtained by the action of nitric acid on starch. This substance was found to explode by ignition and by percussion. In 1838 the French chemist Pélouze observed that when concentrated nitric acid acts on paper, linen, or cotton wool, the cellulose is converted into an explosive substance, which he supposed to be identical with xyloidine.

But little attention was paid to these substances till the close of the year 1845, when Schönbein, of Basle, announced the discovery of an explosive cotton, which might be used as a substitute for gunpowder. His investigations on ozone led him to believe that a mixture of sulphuric and nitric acids would contain a radical like ozone and therefore possess strong oxydizing properties, and in applying his theory he discovered several compounds, among which gun cotton, on account of its explosive properties, interested him most, and in 1846 he sent specimens to his English friends, set to work to apply it in guns, and took out a patent on the process of making it, keeping the process a secret in the meantime. But soon afterwards, Otto, of Brunswick, and Böttger, of Frankfort, seeing the relation between cotton and starch, and between the properties of this new substance and those of xyloidine, discovered gun cotton independently, and made the discovery public. They prepared it by acting on cotton wool with strong nitric acid; but soon after Knop showed that it was preferable to use a mixture of nitric and sulphuric acids.

Immediately after its discovery many investigations were carried on and experiments made, with a view to its application as an explosive agent, and its manufacture commenced on a large scale. But in a short time two great accidents occurred, owing to the limited knowledge of the properties of this explosive and the precautions required in its manufacture, which temporarily caused its manufacture to be entirely abandoned. Hall Bros., of Faversham, England, who added the manufacture of gun cotton to their gunpowder works, had an explosion in 1847, which blew up the factory, killing every man at work in the place; and on the 17th of July, 1848, 16,000 kilograms of gun cotton exploded at Bouchet, near Paris, France. Committees appointed in France and Germany to investigate the manufacture and application of this explosive, decided against continuing any further experiments.

Two men, however, continued their investigations, the Austrian artillery officer, General Von Lenk, and Sir F. A. Abel, chemist to the English war office.

General Von Lenk discovered the cause of previous failures, developed a safe and profitable mode of preparation, and, under the auspices of the Austrian Government, commenced an extensive series of experiments on the best methods of applying it to gunnery. The development of the manufacture in Austria attracted the attention of the other European Governments, and Major Young was sent from England to learn what the Austrian Government would communicate. In 1862 a committee was appointed by the British Association to inquire into the application of the new explosive to warlike purposes; General Von Lenk furnished it with a complete description of his process, and F. A. Abel joined the committee and placed at its disposal the information obtained from Austria and the results of his own researches. Not long after, a government factory was commenced at Waltham Abbey, and Messrs. Prentice & Co. adopted Abel's method in their works at Stowmarket, England, but the latter works exploded in 1871, on account of the incomplete washing of the gun cotton.

To-day gun cotton is used almost exclusively by the nations of Europe as the charge for torpedoes and submarine mines, and in the United States as the charge for torpedoes in the navy. It is manufactured in England at Waltham Abbey, in France at the works of Moulin-Blanc, in Germany for the use of the navy and the pioneers, at Kruppamühle, Walsrode and Düren, and in the United States at the Naval Torpedo Station, Newport, R. I. The result of experiments made at Lydd, in 1885, with hollow projectiles loaded with gun cotton and other sudden explosives, were very unsatisfactory; the gun cotton shells were not exploded by the primer. So that to-day the matter still remains in doubt, and extensive experiments, conducted with great care and in accord with scientific principles, will be required to convince the military world of the applicability of gun cotton as a charge for shells.

CHEMICAL COMPOSITION.

The chemical composition of gun cotton has been the subject of much investigation and discussion. According to the original analysis of Schönbein's gun cotton by Walter Crum it was assumed to be *tri-nitro-cellulose*, formed from cellulose by the following simple substitution, three atoms of hydrogen being replaced by three molecules of nitryl (NO_2):

$C_6H_{10}O_5 + 3HNO_3 =$
cellulose.

$C_6H_7(NO_2)_3O_5 + 3H_2O.$
gun cotton.

The subsequent analyses by Abel and others confirmed this conclusion as to its chemical composition, but owing to the fact that no substitution compounds had been obtained, its true *molecular* formula could not be determined.

On account of the discovery of a nitrate of cellulose intermediate between the mono and the di-nitrate, the molecule of cellulose was regarded as—

$$C_{12}H_{20}O_{10},$$

and gun cotton, therefore, was called the *hexanitrate of cellulose*:

$$C_{12}H_{20}O_{10} + 6HNO_3 = C_{12}H_{14}(NO_2)_6O_{10} + 6H_2O.$$

Recent investigations on its substitution compounds indicate that it is the *nitric ether of cellulose*,

$$C_{12}H_{14}O_4(NO_3)_6$$

cellulose being regarded as a hexatomic alcohol,

$$C_{12}H_{14}O_4(OH)_6,$$

and in the action of nitric acid six molecules of hydroxyl (OH) are replaced by six molecules of (NO_3):

$$C_{12}H_{14}O_4(OH)_6 + 6HNO_3 = C_{12}H_{14}O_4(NO_3)_6 + 6H_2O.$$

The simplest expression for the explosion of gun cotton is represented by the equation:

$$C_{12}H_{14}O_4(NO_3)_6 = 7H_2O + 3N_2 + 3CO_2 + 9CO,$$

but, as in the case of gunpowder, a number of secondary reactions probably take place, so that the results of the analysis of the products of explosion do not correspond with this simple theory.

MANUFACTURE.

The accidents attending the earlier attempts to manufacture gun cotton led

General Von Lenk to carefully determine the character of this explosive and the causes of the accidents. The results of his investigations may be summed up as follows:

1. The cotton wool must be thoroughly freed from fatty or waxy matter by treatment with alkali, and must then be thoroughly desiccated.

2. The strongest acids procurable in commerce must be employed, 1 part, by weight, nitric acid of specific gravity 1.485 and 3 parts sulphuric acid of specific gravity 1.84, the total weight of the acid mixture being 300 times that of the cotton.

3. After the first immersion, which lasts but a few minutes, the cotton must be steeped in a fresh mixture of acids in the same proportion.

4. The steeping must be continued for forty-eight hours.

5. The gun cotton must then be squeezed and thoroughly purified by washing in a stream of running water for

several weeks, dipped in a solution of potassium carbonate and again washed.

Unless these precautions are observed the products are not uniform; nitric acids forms substitution products with fats, hence the necessity for cleansing the wool; weak acids produce a variety of other compounds, hence the necessity for using the strongest; and if any acid is left in the gun cotton it is liable to spontaneous decomposition, hence the necessity for careful washing.

The sulphuric acid acts simply to absorb the water already present in the commercial nitric acid and also that produced in the change, and thus serves to keep the nitric acid concentrated.

Lenk's process has been improved by Abel and others, and very great attention has been paid to the manufacture of gun cotton of late years, with a view to producing a perfectly uniform product, which might be employed as a substitute for gunpowder.

The cotton employed is the waste from spinning machines, which is picked as free as possible from foreign matter, thoroughly cleansed with caustic alkali, and brought into a uniform and open condition by being passed through a carding engine. The rolls thus obtained are dried in a triple cylinder; the cotton is placed in the central chamber, steam circulates in the surrounding one to produce a high temperature, and a blast of air enters the outside chamber at bottom, is heated in traversing the chamber, and then passes through the cotton in the central chamber and dries it. The dried cotton is then placed in tins and covered.

The acid mixture consists of 3 parts by weight of sulphuric acid, sp. gr. 1.84, to 1 part nitric acid, sp. gr. 1.52. The acids are placed in separate stoneware cisterns with taps, and allowed to run simultaneously, in slow streams, into another stoneware cistern, furnished with a tap and an iron lid with an opening for an iron stirrer. The mixture is allowed to stand for several hours to become cold.

About 12 gallons of the acid mixture is

drawn off into a deep stoneware pan standing in cold water. The cotton, when cold, is weighed out in quantities of 1 lb. each, carried to the dipping pan and immersed, a pound at a time, in the acid, and stirred about for two or three minutes. It is then placed on a grate or perforated shelf, attached to the pan, the excess of acid is squeezed out with the stirrer and the cotton allowed to drain. Enough acid is drawn from the cistern to replace that which has been absorbed by the cotton, and more cotton is treated in the same way.

The cotton is next transferred to pots well covered, standing in a shallow trough containing water, and is covered with about 10 or 15 times its weight of acid, and allowed to remain about 12 hours.

The large excess of acid is driven off by a centrifugal machine of iron gauze, revolving at first slowly then at 800 revolutions a minute, for about ten minutes, the waste acid being collected by a jacket surrounding the revolving portion. The gun cotton is now washed by a stream of water falling in cascade from a height, being thrown on the falling stream, carried down with it and whirled about in the water in the washing vessel, so that it comes in contact with a large quantity of water, and its temperature is not raised appreciably. It is again drained in the centrifugal machine and the washing repeated. It is then soaked in stirring tanks for two or three weeks, and afterwards boiled in large vats by the injection of steam. The purified gun cotton is transferred to the beating tank, a contrivance for beating it into pulp, consisting of a drum with a large number of closely set ridges on its surface, revolving over a fixed ridge in the tank, similar to the rag engine of paper mills. The pulp is removed to a poacher, where it is agitated for about forty-eight hours with a large quantity of warm water by means of a wheel, the water being drawn off and renewed until the gun cotton answers the heat test which is now applied. The pulp is then transferred to a vat and mixed with a little lime, carbonate of soda or ammonia. It is then drained and a measured quantity placed in the cylinder of a hydraulic press, through the perforated bottom of which most of the water is drawn off by a suction pump, and the press is then applied. It is pressed again in a more powerful press, and is thus obtained in the form of disks or cylinders of various sizes, having a density of 1.1 or 1.2, which are afterwards soaked in water until they contain about 25 per cent. of that liquid.

The cylinders made in England are about 3 inches long, 2.5 inches in diameter and weigh ½ lb. The gun cotton used in the navy of France for charging torpedoes is pressed in the form of prismatic disks or cylinders, weighing from 0.645 kilograms to 2.538 kilograms; for mining the French use cylinders 30 mm. high, and 25 mm. in diameter, with a central canal 5 mm. in diameter, weighing 25 grm. dry.

Granulated gun cotton is made by placing the pulp from the poacher in a centrifugal machine, where its water is reduced to 33 per cent., and the gun cotton is made fibrous, and then passing it through sieves, which break it into granules. It is then revolved for half an hour in a drum, mounted on a horizontal axis, for fifteen minutes, the drum revolving fast enough to cause the granules to roll rapidly down its surface, but not so fast as to carry the granules around with it.

Tests.—The finished gun cotton is examined by the following tests:

1. The density must be over 1.

2. The moisture is determined by drying it at 60° C.

3. The combustion of 2 grm. of gun cotton must leave a residue less than 0.08 grm. in weight.

4. The gun cotton should dissolve entirely in acetic ether, which would leave any unconverted cotton undissolved.

5. Fifty grains of the gun cotton should suffer little loss in weight when digested for two or three hours with four ounces of a mixture of 1 volume alcohol

(40′) and 2 volumes rectified ether, which would dissolve any collodion cotton.

6. Four grains are heated in a test tube placed in an oil bath, and containing a slip of paper moistened with a solution of potassium, iodide and starch. No tinge should be imparted to the paper till the temperature of the oil reaches 88° C.

7. Four grains, heated as above, should give no visible brown fumes below 175° C.

8. One grain is heated in a test tube, placed in an oil-bath, till it explodes, which should not happen below 179° C.

PROPERTIES.

The manufacture of gun cotton has been so greatly improved of late years that the gun cotton of to-day is a superior material to that usually described even in scientific works.

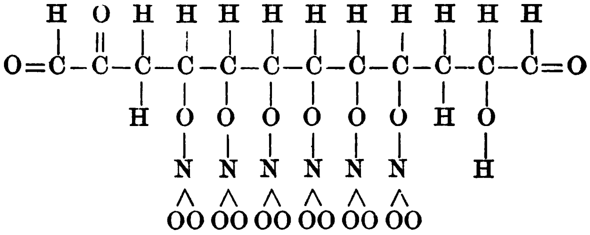
Gun cotton resembles cotton wool in appearance, but is harsher to the touch ; it becomes powerfully electric when rubbed, crackling and phosphorescing, and emitting sparks in the dark. It remains unaltered in contact with water, and can be worked and stored in the wet state without danger. On ignition it burns quietly when dry and leaves no residue; wet gun cotton is not combustible.

Gun cotton is insoluble in alcohol and ether or a mixture of the two, but is dissolved by acetic ether and by a mixture of ordinary ether with ammonia. Strong sulphuric acid dissolves it without carbonization, strong potash lye will also dissolve it, especially if heated to 70° C. A solution of potassic sulphydride reduces it to cellulose. When properly prepared it remains unaltered—it has been kept stored in Austria for twelve years without change, and that which was thrown away in the campaign in Italy in 1859 was afterwards found unaltered, although it had been exposed to the hot sun for many weeks.

Dry gun cotton inflames by percussion, but is never exploded, even by the passage of a bullet fired at short range, unless confined. Its explosive effect is greatest when detonated by means of a primer of mercuric fulminate, in which case no confining is necessary. The rate of propagation of the detonation in a mass of dry compressed gun cotton is about 5500 meters per second.

Wet gun cotton is not affected by percussion, and can be detonated only by the detonation of an amount of dry gun cotton bearing a certain ratio to the weight of wet gun cotton employed. Its explosive effect is much greater than that of dry gun cotton.

The great explosive effect of nitroglycerine and gun cotton, as compared with gunpowder, is due to their composition. There are two great classes of explosives, mixtures and compounds. In mixtures the grains of the separate constituents, however finely divided, have a sensible magnitude, and the chemical action takes place between these grains and on their surfaces, so that the layers of the molecules are consumed in succession, hence the process must require a sensible time. In compounds the chemical action takes place in the molecules, which are infinitely smaller than the smallest grains obtained by mechanical processes, hence the action is essentially instantaneous. The following diagram, or structural formula, represents the manner in which the atoms of a molecule of gun cotton are connected one with another, and it is known that this molecule cannot be larger than the $\frac{1}{25,000,000}$ of an inch:



In the explosion, the hydrogen atoms combine with the oxygen atoms to form water, and the carbon atoms combine with the oxygen atoms to form carbon dioxide and carbon monoxide, all of which action takes place in the molecule. The action in the case of the rapid burning explosives is indeed so sudden that the great volume of gas produced does not give the air time to move aside, but lifts the entire column bodily, the air thus acting as a kind of tamping, which accounts for the enormous effects of nitroglycerine and gun cotton.

The temperature at which gun cotton explodes when heated is about 179° to 181° C., under the most favorable circumstances, but usually a much higher temperature is required. The temperature resulting from the explosion is about 4400° C. One gramme of gun cotton, on explosion, gives a quantity of gaseous products calculated to occupy at 0° C. and 760 mm. Bar., 753 c.c., which, at the temperature of explosion, would be expanded to 12,889 c.c. The quantity of heat generated has been determined as 1056.3 Centigrade units. The pressure produced by the detonation is estimated by Berthollet at 160 tons per square inch. The gases produced by the explosion of gun cotton, on analysis, have been found to contain in 100 volumes:

Aqueous vapor......	25.34	volumes.
Carbon monoxide.....	28.95	"
Carbon dioxide.......	20.82	"
Nitrogen.............	12.67	"
Hydrogen............	3.16	"
Marsh gas............	7.24	"
	98.18	

Normal gun cotton has about 2 per cent. of moisture, but is capable of taking up about 30 per cent. Its rate of combustion may be varied by spinning it into yarns and winding these with greater or less compactness.

Gun cotton is a powerful, reliable, safe, portable, and convenient explosive, especially valuable for submarine operations. There is less danger in its manufacture than in that of gunpowder or nitro-glycerine. It can be stored wet and is then perfectly safe. It leaves no residue and produces no smoke, and it is from five to ten times as effective as gunpowder when properly detonated.

Its principal disadvantages are, it requires more space in torpedoes than nitro-glycerine, being less dense and also less plastic, and cannot, therefore, be packed so easily and compactly, and when used as a charge for shells the point where the latter strike is not so readily seen, as no smoke is produced.

ANALYSIS.

The objects of the chemical analysis of gun cotton are to determine whether the freshly prepared material has the composition necessary for the production of the maximum effect in explosion, and to ascertain what changes have taken place in its composition by storage. The determinations to be made are:

Moisture,
Calcium carbonate,
Ash,
Nitrogen,
Nitrates, and
Cellulose.

The sample, in case of compressed gun cotton, is obtained by rubbing off a portion of the air-dried cake or cylinder by means of a coarse file, and passing it through a fine sieve. The powder is then placed in an exsiccator for several days before use.

Moisture.—About 5 grm. of the gun cotton are placed in a weighed shallow platinum dish and dried in the drying oven at 60° C. for 120 hours.

Calcium Carbonate.—A weighed quantity of gun cotton is placed in a beaker, and an accurately measured quantity of dilute hydrochloric acid, the strength of which has been previously determined by alkalimetry, is added, and after acting for a short time the liquid is filtered and the residue well washed. The free acid in the filtrate is then determined by means of a titrated solution of soda, which had been so constructed that a given volume neutralized an equal volume of the original dilute hydrochloric acid used. The difference between the volumes of acid and soda used will give the volume of acid to decompose the calcium carbonate, from which the percentage of the latter may be calculated.

Ash.—The residue of gun cotton left after the determination of the calcium carbonate, is dried and a weighed portion digested in concentrated nitric acid in a weighed platinum dish, evaporated carefully to dryness, and the residue ignited. The increase in weight gives the ash.

Nitrogen.—The nitrogen is best determined by the "Reversion-Nitrometer" of Lubarsch.* It consists of a gas burette A, a reservoir B, and a filling tube C.

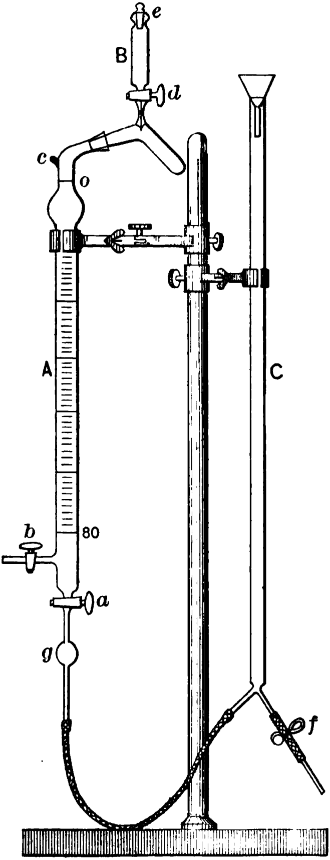
The gas burette is bent obliquely at the top, and just below the bend is enlarged to a globe containing about 25 c.c. The 0 of the scale is just above the globe, the divisions beginning just below the globe with 30 c.c. and the graduation, in ½ c.c., continues to 80 c.c. Five centimeters further down, the burette is closed by the stop-cock *a*, and between this stop-cock and the end of the gradua-

* Manufactured by Mr. Geissler, Berlin, N. W., Philippstrasse, 22.

tion is a side tube with stop-cock *b*. Below the stop-cock *a* the burette narrows to the tube with a small bulb *g*, to which is attached the heavy rubber tube which connects the burette with the filling tube.

Into the mouth of the burette is carefully fitted, by grinding the surfaces of contact, the reservoir B. The latter consists of a short tube, closed at one end, bent at its middle at an angle of about 120°, to the outer part of the angle of which is fused the separatory funnel *d e*, about 6 c.c. in capacity. The lower point of the funnel projects into the reservoir. The funnel may be shut off from the reservoir by the stop-cock *d*, and its upper end is closed by the the ground glass stopper *e*. The capacity of the reservoir, when attached to the burette, amounts to 25.7 c.c., that of the point of the funnel, below the stop-cock *d*, to 0.2 c.c.

The filling tube C branches at its lower end, one branch being closed by the clamp *f*, the other being attached to


e
B
d
c
o
A
C
b
80
a
g
f

the heavy rubber tube which connects it with the burette. The filling tube is usually held tight by its clamp, whereas the burette rests loosely with its globe on the clamp.

The principle on which the method of analysis is founded is shown by the following reaction:

$$C_{12}H_{14}O_4(NO_3)_6 + 9\,H_2SO_4 + 18\,Hg = C_{12}H_{20}O_{10} + 9\,Hg_2SO_4 + 6\,H_2O + 6\,NO.$$

The apparatus is dried, the reservoir is placed in the burette and fastened by passing a rubber band around the projection *c* and the narrow tube at *d*, the burette and filling tube are connected by a dry rubber tube, the stop-cocks *a* and *b* are closed and *d* opened. The filling tube is then half filled with mercury, and by gradually opening the stop-cock *a* it is allowed to rise till close up to the side tube *b*, and the level in the filling tube is then made the same as that in the burette. By squeezing the rubber tube and alternately raising and lowering the burette all enclosed air is removed, and the stop-cock *a* is then closed. The side tube is then connected with the carbon dioxide apparatus and the stop-cock *b* opened. The carbon dioxide is prepared in the ordinary Kipp apparatus from marble, which has been boiled in water and pure hydrochloric acid, and is dried by two wash-bottles containing sulphuric acid and two calcium chloride tubes. In a short time the apparatus is entirely filled with carbon dioxide.

Meanwhile about 0.3 grm. (not over 0.35 grm.) finely pulverized gun cotton are weighed in a small glass flask, the reservoir is removed, and the gun cotton carefully poured into it. The reservoir is replaced and secured, and the stream of carbon dioxide continued until the empty flask is weighed. The stop-cock *b* is then closed, *a* opened and mercury poured into the filling tube till its level is accurately at the 0 of the scale. The stop-cocks *a* and *d* are then closed, and the reading of the thermometer taken. Pure concentrated sulphuric acid is then poured into the funnel *d e*, the stop-cock *a* is opened and the filling tube lowered till the level in it is 5 or 6 centimeters lower than in the burette, or the requisite amount of mercury is let off at *f*.

The stop-cock *d* is carefully opened and sulphuric acid allowed to flow down upon the gun cotton until it is nearly all out of the funnel, when *d* is closed and the stopper *e* carefully inserted. In a few minutes nitric acid is evolved, and the reservoir, after removing the rubber band, is carefully turned in its ground fitting 180°, and the rubber band replaced. The reaction now begins, and the burette is removed from its clamp every five minutes, and by gradually inclining it a portion of the liquid is allowed to run into the reservoir, and the whole well shaken. The mercury which rises in the filling tube, after replacing the burette, is let off by the clamp, so as to have but little excess of pressure. Towards the end of the operation, which usually requires about half an hour, the mercury is nearly all driven out of the burette, and before each shaking the stop-cock *a* must be closed, to prevent sulphuric acid or gas bubbles from getting into the rubber tube. The shaking is accomplished by holding the upper part of the burette with the right hand, the thumb on the catch *c*, the fingers at *d*, the left hand keeping the stop-cock *a* in place. After each shaking the burette is replaced in its clamp, the stop-cock *a* opened only after the mercury and acid have completely separated. Finally, the level of the mercury in the filling tube is made higher than that in the burette by $\frac{1}{7}$ the number of divisions of the scale occupied by the sulphuric acid column,* the comparison being easily accomplished by turning the clamps till the tubes stand side by side, and applying a horizontal straight-edge. The volume of nitrous oxide is noted, the stop-cock *a* closed and the burette again shaken. After the liquids settle the stop-cock *a* is opened, the level again adjusted,

* To counterbalance the weight of the column of sulphuric acid ; mercury is about seven times heavier than the acid.

and this operation is repeated till two consecutive results are equal. The apparatus is then allowed to stand for 15 minutes, and the readings of the burette, the barometer and the thermometer are noted.

There are two corrections to be applied, a fixed and a variable one.

The fixed correction is the capacity of the tip of the separatory funnel, 0.2 c.c., which must be subtracted.

The variable correction is due to the difference in volume of the carbon dioxide due to the difference in temperature at the beginning and end of the operation. Subtractive, if the latter temperature be the higher, additive, if it be the lower.

Nitrates.—The lower nitrates of cellulose are determined by the following process:

A weighed quantity of gun cotton (about 5 grm.) is placed in a wide cylinder, provided with a glass stop-cock, and digested with the requisite quantity (about 200 grm.) of a mixture of absolute alcohol and rectified ether in the proportion of 1:3 for twelve hours, and repeatedly shaken. After settling, the clear liquid is passed through a weighed, crimped filter of Swedish filter-paper. The residue in the cylinder is treated with a quantity of a mixture of alcohol and ether equal to that first used, but in the proportion of 1:2, for six hours. After settling, the clear liquid is again passed through the filter, and the residue digested with a new mixture in the proportion 1:1. It is then twice washed with pure alcohol, twice with dilute alcohol, and finally several times with pure water. The residue is then brought on the filter, and after draining is dried in the air-bath at 60° C and weighed. The loss in weight represents the lower nitrates present.

The residue on the filter is pure hexanitrate of cellulose, and can be analysed as described under *Nitrogen.*

The filtrate contains the soluble nitrates. This is mixed with several litres of water, well stirred, the precipitate collected on a filter, washed, dried and weighed. The nitrogen in the soluble nitrates may be determined as before.

Cellulose.—The unaltered cellulose remaining in the gun cotton may be determined in two ways, directly and indirectly.

The direct method consists in boiling a weighed quantity of finely-divided gun cotton for 15 minutes in a concentrated solution of sodium stannate, prepared by fusing sodium hydrate with tin and leaching the fused mass. The cellulose nitrates are dissolved and the pure cellulose remains. The latter is filtered, washed, dried at 100° C and weighed. The sodium stannate must be freshly prepared.

The indirect method consists in a simple calculation. If we designate the percentage of nitrogen found by analysis by N, and the percentage of cellulose by x, we have the proportion:

$$(14.14-N) : 14.14 :: x : 100,$$
$$\therefore x=100\ (1-N : 14.14.)$$

The gun cotton used in the analysis must be the pure hexanitrate, obtained as described under *nitrates*, which contains also the unaltered cellulose. Perfectly pure hexanitrate of cellulose contains 14.14% nitrogen.

COMPRESSED GUN COTTON

FOR

MILITARY USE,

WITH

Special Reference to Gun Cotton Shells.

TRANSLATED FROM THE GERMAN of MAX VON FÖRSTER.

PREFACE.

In continuation of our previous experiments,* we have made further investigations with compressed gun cotton, with reference to its explosive force, using larger quantities of the explosive and confining it in a closed space.

We have endeavored to establish relations in the experiments similar to those existing in military practice. With reference to the application of compressed gun cotton for military purposes, we have considered the value of the use of paraffin in connection therewith, as well as the coating of the gun cotton by dipping it in a solvent; and finally we have instituted extensive experiments on the explosion and firing of gun cotton shells, with special reference to granulated gun cotton for charging the shells.

* Experiments with Compressed Gun Cotton. Van Nostrand's Engineering Magazine, August, 1884.

In the recent work of Lieutenant-General Brialmont, *La fortification du temps présent, Bruxelles, 1885*, attention is called to the importance and effect of gun cotton shells, and a shell filled with gun cotton in the form of disks is described in full, so that we feel convinced that the record of our experiments in this direction will be of interest.

Our experiments with shells were carried on for several years entirely at our own suggestion and at our own expense, with the exception of the experiments of firing and exploding six caliber steel shells, which were conducted in our presence by a foreign artillery.

A part of the results of our experiments was made public by the following patents taken out in Germany, in conjunction with W. F. Wolff:

1. No. 22,418. Method of exploding compressed gun cotton under water. September 1, 1882.

2. No. 24,674. Projectile containing a charge of compressed gun cotton. January 14, 1883.

A shell, the head of which may be unscrewed and the shell filled with gun cotton in the form of disks, and containing a primer, independent of the fuse, placed near the bottom of the shell.

3. No. 26,014. Method of coating pieces of compressed gun cotton, compressed nitrated wood and other forms of cellulose. partially or entirely, by treatment with a solvent thereof. March 9, 1883.

4. No. 33,867. Method of filling hollow projectiles with compressed explosives in a granulated form. May 2, 1885.

Our experiments, so far as the objects acted on are concerned, could be carried on only to the extent possible in a manufactory, but the results, we hope, will furnish data for all sorts of objects.

We are able, however, to furnish several examples of experiments with explosives on sunken ships and wrecks, carried on by us under the direction of the imperial admiralty, the imperial pilot command of Wilhelmshaven, and various other commands, as well as of private persons, which illustrate the effect of compressed gun cotton in submarine explosions in its larger relations.

We have used exclusively gun cotton prepared in the powder and gun cotton works of Wolff & Co., Walsrode. This gun cotton is used in all arms of the German Army, and has been tested by the German Navy, accepted, and a considerable quantity stored; it is supplied to many European and foreign armies and navies, and must therefore be regarded as fulfilling all the requirements of the best compressed gun cotton, and the results obtained must be regarded as applying to all good gun cotton. The gun cotton, unless otherwise specified, has a specific gravity of 1.1, and contains, on an average, 12.6 per cent. nitrogen, calculated on the weight of the absolutely dry gun cotton, just as it is, that is, including chalk and foreign ingredients.

It is well known that wet gun cotton is detonated by means of a corresponding weight of dry gun cotton, and we have done this even when it is not particularly stated.

The dry gun cotton we have detonated by means of a primer containing 1 grm. mercuric fulminate from the Linden Primer Factory, in Egestorf, Linden, near Hanover. These primers act very satisfactorily, even after having been five years in store.

Compressed Gun Cotton for Military Use.

Experiments Relative to the Force Exerted in the Explosion of Compressed Gun Cotton.

A. Dry and Wet Gun Cotton, not Confined, Placed on Lead Cylinders and Detonated.

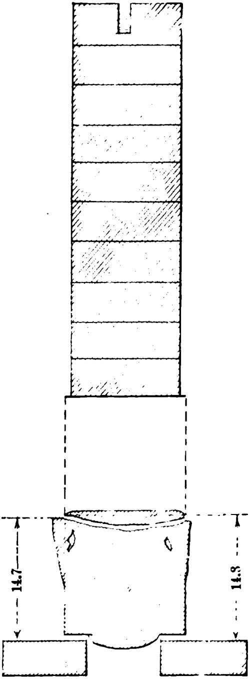
Experiments Nos. 1–4.—360 grm. gun cotton, placed on lead cylinders 46 mm. in diameter and 100 mm. in height, destroyed the latter—the dry gun cotton to one-half its depth, the wet gun cotton almost completely.

Experiment No. 5*a*.—6,500 grm. dry gun cotton disks, 14 cm. in diameter, and, in toto, 43 cm. high.

Experiment No. 5*b*.—6,500 grm. wet gun cotton disks, same weight dry plus 25 per cent. water and of the same dimensions.

Base consisting of two superposed

A 5a.



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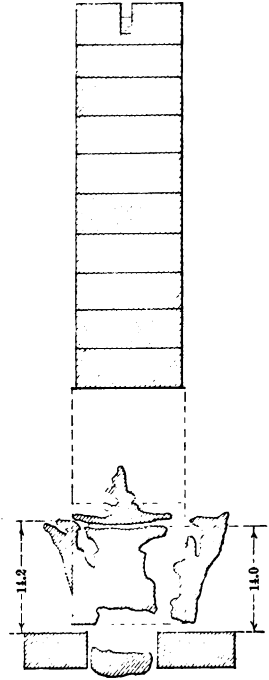
A 5b.



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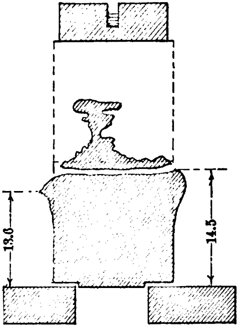
A 3.



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blocks of rolled lead, 15 c.c. in volume. The lower block stood on a perforated iron plate.

The dry gun cotton destroyed the upper, the wet also the lower block.

Experiment No. 6.—A gun cotton disk, 14 cm. in diameter, 6 cm. in height, weighing 920 grm., dry, containing a primer, and placed on blocks similar to those in *5a* and *5b*, destroyed them to at least the same extent, so that a charge of 900 grm. acted quite as effectively, if not more so, on the support directly underneath, as a charge of 6,500 grm., the surfaces of contact in the two cases being equal. In this experiment the result may perhaps be attributed to the effect exerted by the primer on the development of the explosive force of the gun cotton.

In the succeeding experiments the weight of the gun cotton employed was so far reduced that the object against which the force was exerted, the resistance of which was considerable, was not entirely destroyed. The charges, which were still considerable, acted in such wise that funnels with raised rims were formed in the blocks, while the upper surface of the blocks surrounding the funnels remained intact. To determine the effect, the rim was cut through vertically down to the unaffected upper surface of the block, and thus the level of the upper surface was marked on the interior of the funnel. The volume of lead displaced from the core of the block was then measured by filling the funnel to the mark with water from a glass tube graduated in cubic centimeters.

The greater the number of cubic centimeters of lead displaced, the greater the explosive force of the gun cotton.

The blocks of lead were so large (12 cm. cube), that a considerable weight of gun cotton could be employed.

GUN COTTON CARTRIDGES.—38 *mm. in diameter*, 50 *mm. high*, 63 *grm. in weight.*

Experiment No. 7.—1 dry cartridge displaced........................ 27 c.c.

Experiment No. 8.—1 wet cartridge, detonated by a superposed dry cartridge like No. 7, displaced...... 36 c.c.

Experiment No. 9.—8 dry cartridges, like No. 7, placed one above the other, displaced.................. 33.5 c.c.

GUN COTTON CARTRIDGES.—60 *mm. in diameter*, 50 *mm.* high, *of various weights.*

Experiment No. 10.—1 dry cartridge, specific gravity 1.1, 153 grm. in weight, displaced................. 60 c.c.

Experiment No. 11.—1 dry cartridge of the same dimensions, specific gravity 1.28, 178 grm. in weight, displaced...................... 90 c.c.

Experiment No. 12.—The experiment was repeated. Weight of cartridge, 175 grm., displaced.............. 90 c.c.

Experiment No. 13.—1 cartridge, as in 11 and 12, but with 18 per cent. water, containing an excavation sufficiently large to receive a dry priming cartridge weighing 32 grm., of specific gravity 1.1; the dry weight of the total amount of gun cotton employed was therefore the same as in 11 and 12, the volume as in 10, 11 and 12. Lead displaced.. 148 c.c.

Or, 2½ times as much as in 10, and 1⅗ times as much as in 11 and 12.

Experiment No. 14.—As in No. 13, but the priming cartridge weighed only 12.5 grm., specific gravity 1.1, so that 12.5 grm. gun cotton were wanting; the lower result is not, however, attributable to this. Lead displaced........................ 110 c.c.

Experiment No. 15 —Cartridge as in 13 and 14, the priming cartridge, however, composed of 8 pieces, placed one on the other, 38 mm. in diameter, and weighing 63 grm. each. Primer placed in the uppermost cartridge. Lead displaced... 143 c.c.

Although, as previously shown, the action of the last cartridge in long charges, here the eighth, is less, in comparison, than that of the first, nevertheless the eighth cartridge served effectually as a priming cartridge, and forced the gun cotton detonated by it to a full development of its explosive force.

Experiment No. 16.—3 cartridges, applied as before, 60 mm. in diameter, 50 mm. high, specific gravity 1.1, total weight 410 grm., all three dry, displaced........................	120 c.c.
Experiment No. 17.—3 similar cartridges, but of specific gravity 1.3, weight 488 grm., dry, displaced...	200 c.c.

Results.—Gun cotton with a specific gravity considerably above 1.1 gives higher power, and the latter increases more rapidly than the absolute weight of the gun cotton used.

It is therefore, in general, advantageous to use gun cotton of the highest possible specific gravity (when the space available for the charge is limited), although the following experiments, conducted with shells, as well as those in which the charges are not in direct contact with the object, show that, under circumstances other than those thus far considered, the superiority of the gun cotton of higher specific gravity is less noticeable.

Effect of gun cotton against objects with which it is not in direct contact, but separated therefrom by an air space.

In order to obtain data for the comparison of the following experiments, the preliminary test described under 1 was made.

1. A cylinder of gun cotton, 60 mm. in diameter, of specific gravity 1.2, 181 grm. in weight, was placed on a piece of wrought iron, 30 mm. thick and detonated.

The effect was as follows:

A trough-like depression was produced in the iron, of the diameter of the piece of gun cotton, 8 mm. deep in the center. Besides, the effect on the lower surface of the iron was very much more marked, —the iron was nearly perforated.

2. A cylinder 60 mm. in diameter, of specific gravity 1.3, 181 grm. in weight, placed 34 mm. above a piece of iron similar to that in 1, hence, separated from it by an air space of 34 mm., made an impression 55 mm. in diameter and 3 to 4 mm. deep.

3. A cylinder 60 mm. in diameter, specific gravity 1.1, 156 grm. in weight, applied as in 2, made an impression 55 mm. in diameter, 1½ to 2 mm. deep.

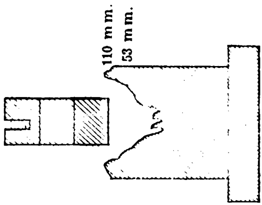
Moreover, the iron received a crack in 2 and 3, running in the direction of the fibers, which penetrated to the under side.

The effect, considered as a whole, diminished in such a way that the ratio of 1 to 2 was as that of 2 to 3, the diminution in effect being quite considerable.

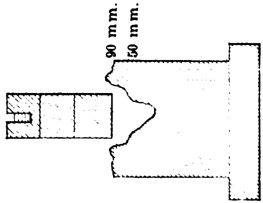
4. A piece of gun cotton, as in 2, specific gravity 1.3, was placed at a distance of 100 mm. from the iron, and made only traces of impressions on it.

5. A piece of gun cotton, as in 3,

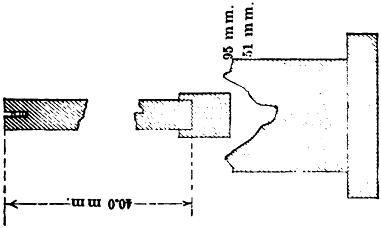
A 17.



A 16.



A 15.



specific gravity 1.1, also 100 mm. from the iron, made also only traces of impressions, but even less distinct than in 4. The difference between 4 and 5 is, however, not great.

6. A charge of 254 grm. gun cotton was hung to a pine 9 cm. in diameter, at a distance of 20 cm. from the trunk and 35 cm. above the ground. On the ground under the charge was placed an oak board 25 mm. thick. The detonation peeled the bark off the pine and split a piece lengthwise from the board.

7. Another charge was similarly arranged, but of 400 grm. weight, and at only 15 cm. distance from the tree. The latter was broken and a piece was split from the board as before.

Results.—In case of an open space between the charge and the object to be destroyed, the effect is thereby greatly diminished; and in case the open space is considerable, no great difference in action is observed between gun cotton of specific gravity 1.3 and that of specific gravity 1.1.

B. Experiments with Gun Cotton enclosed in Cast Iron Shells.

The gun cotton was in the form of disks, 139 mm. in diameter and 50 mm. high, with a specific gravity of 1.1. The shells were provided with a cavity corresponding to the diameter of the disks, the side walls were 32 mm. thick, the bottom 60 mm. and the head 120 mm.

The shells were placed upright on two superposed lead blocks, each 15 c.c. in volume, such as were used in former experiments, and which were, as in the previous experiments, set on an iron plate provided with a central opening. The upper block was always more or less disturbed. The effect could be more accurately measured by the depression made in the lower block, and by the amount of lead which was forced from the bottom of the lower block into the opening of the iron plate below.

Experiment No. 1.—The shell was filled with 5,200 grm. dry gun cotton, the primer was in the upper gun cotton disk, hence on the side farthest removed from the object.

Experiment No. 2.—The shell was filled with gun cotton, containing 20 per cent. water, but of the same weight dry as No. 1. The upper piece of gun cotton was dry, and served to detonate the wet portions.

Experiment No. 3.—The charge of the shell consisted of wet gun cotton, containing 20 per cent. water, reamed out about the long axis of the shell to a diameter of 50 mm. In the head was placed a piece of dry gun cotton for detonation.

By analogy of gun cotton charges not confined, it was presumed that a very energetic effect would be produced on the object by the open central canal.

Experiment No. 4.—The shell was filled with wet gun cotton, containing 20 per cent. water; the lowermost disk, weighing 930 grm., was dry, however, and contained the detonating primer.

As shown in the diagrams B. 1, 2, 3, 4, the effect in 3, with a hollow charge, was the weakest; next in order came No. 1, the dry, then No. 2, the wet, and the effect was greatest in No. 4, in which the piece of gun cotton detonated by the primer was almost in direct contact with the object on which it was to act.

It has often appeared from the experiments that gun cotton detonated by the mercuric fulminate primer is more energetic in its action than such as, instead of being detonated directly by the primer, is detonated by other gun cotton; in this phenomenon, the distance, to which the primer acts directly, plays an important part; as soon as this distance is passed, we assume that the gun cotton is no longer exploded by the primer, but by other gun cotton.

With a view to a closer examination of the effect of the primer on the energy of the explosion, the following experiment was made:

Experiment No. 5.—Four blocks of lead, each 15 c.c. in volume, such as were used in previous experiments, were bored through the center, the diameter of the opening being 23 mm., one block not quite through, however, but only half way. The four blocks were placed one above the other, and fastened lengthwise by iron rails; the block bored only half way through at the bottom.

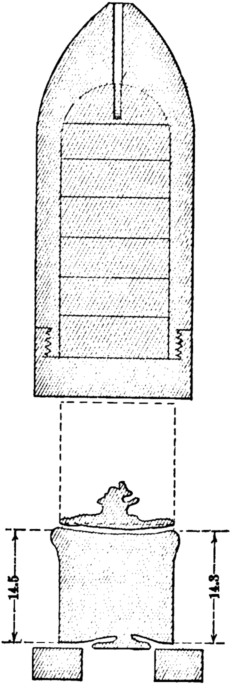
The channel in the four blocks, 52.5 c.m. deep, was charged with a charge of gun cotton, composed of several cartridges, 22.5 mm. in diameter and 45 cm. in length, so that the lower cartridge reached the bottom; into the upper cartridge, which was bored out for this purpose, was placed a 1 grm. primer with fuse attached, and the upper block closed with a leaden stopper, bored out for the passage of the fuse.

After the explosion of the cartridge the blocks were separated quite regularly into four parts, but when these parts were put together, a hollow space was seen to be formed therein by the explosion, which, in the upper quarter, where the primer had been placed, was 230 mm. in diameter, and in the lower quarter, or the one farthest removed from the primer, was 130 mm. in diameter. The spheres corresponding to these diameters are to each other as 6:1, so that it is apparent that the effect of the part detonated by the primer is six times as great as that of the lower part of the cartridge detonated by the progression of the explosion of the gun cotton.

We come to the conclusion, from these experiments, that it must be possible, by altering the physical condition of the gun cotton, or by a different method of detonation, to obtain a considerably increased effect.

The detonation of the primer develops the gases generated from the gun cotton in a very energetic form; the latter lose their force, however, against the elastic gun cotton which they meet, and cannot develop gases of the same energy as they themselves possess. Thus far it has been impossible for us to continue the experiments, using hollow lead blocks, nor to repeat them with gun cotton of specific gravity 1.3, and nitroglycerin, which is not elastic; neverthe-

B 2.



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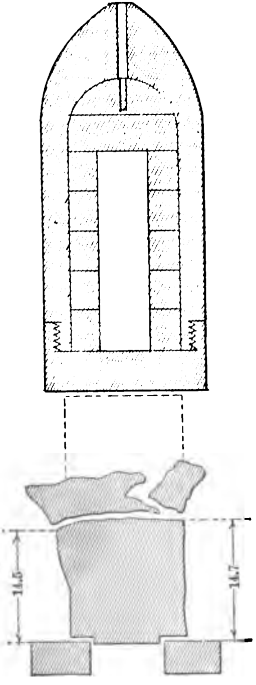

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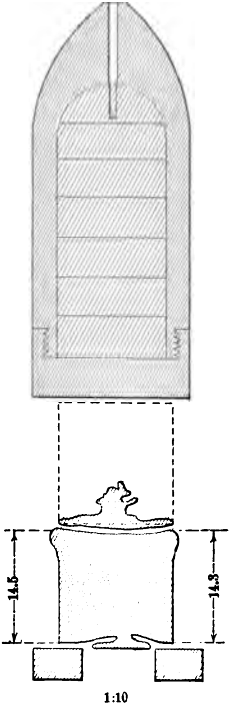

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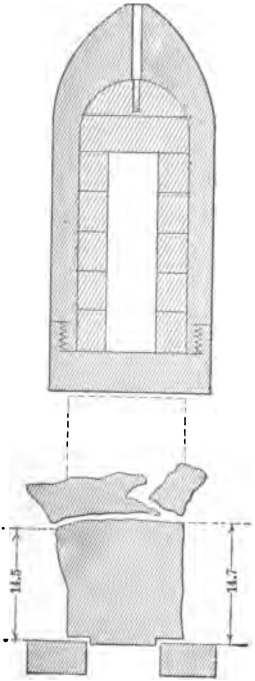

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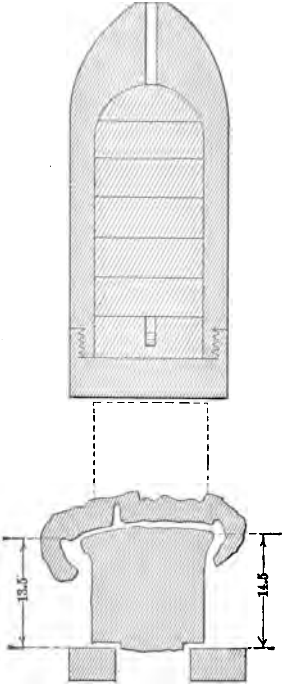
B 4.



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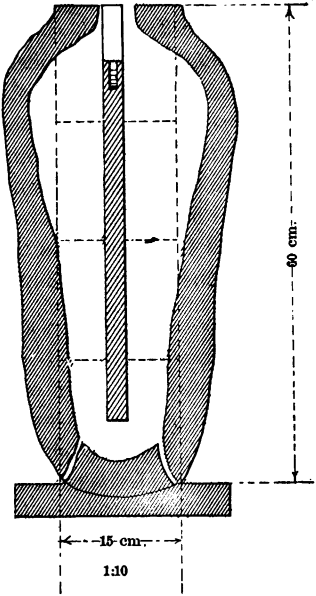
B 5.



be placed on a piece of armor plate, or a piece of wrought iron of sufficient resistance, and detonated, its form will be accurately reproduced on the underlying object, and the action extends beyond this limit only so far as the parts of the iron plate, affected directly, tear along with them the parts lying adjacent. The gases produced by the detonation occupied, therefore, in the first instant, and indeed during their entire action, exactly the same form as, and no more space than, the piece of gun cotton previously occupied. How instantaneous the action is is shown by the following experiment:

If a coin be placed between a gun cotton cartridge and a wrought-iron plate, the figures and letters in relief on the coin will appear in the iron as depressions after the explosion; if, instead of the coin, a green leaf be inserted, the entire skeleton of the leaf will appear on the iron plate after the explosion. The more prominent, as well as the finer veins, protect the underlying iron, the more delicate parts of the leaf, lying between the veins, cannot afford the same protection; hence the depression under the latter is the greater.

C. Explosion of Shells on Rails.

We exploded a number of shells on objects such as occur in actual practice, and used principally granulated gun co tton for the exposive charge.

15 cm. cast-iron shells, 2½ calibers long, containing a cavity 2 liters in capacity, were filled with granulated gun cotton. After being charged the spaces between the grains were filled with liquid paraffin, as will be described in detail further on. The dry as well as the wet grains were coated by means of acetic ether. The explosive charge consisted of:

Experiment No. 1.—Dry granulated gun cotton, 1,200 grm.

Experiment No. 2.—Wet grains, containing 25 per cent. water, and 250 grm. dry grains.

Experiment No. 3.—Wet grains, containing 25 per cent. water, and 150 grm. dry grains.

Experiment No. 4.—Wet grains, containing 25 per cent. water, and 100 grm. dry grains.

Experiment No. 5.—Grains entirely coated with paraffin and 300 grm. dry grains.

Experiment No. 6.—Grains entirely coated with paraffin, and 200 grm. dry grains without paraffin, gelatinized.

Experiment No. 7.—Wet grains, containing 25 per cent. water, and a dry priming cartridge 31 mm. in diameter, weighing 35 grm.

Experiment No. 8.—Dry grains, and a priming cartridge weighing 35 grm.

Experiment No. 9.—Grains entirely coated with paraffin, 150 grm. dry grains without paraffin, and a priming cartridge weighing 35 grm.

Experiment No. 10.—A half shell, cut lengthwise, filled with 1,000 grm. gun cotton in large prisms (volume of each, 140 c.c.).

Experiment No. 11.—Two prisms, each weighing 154 grm., as in 10, placed directly on the base of a rail.

Experiment No. 12.—One such prism, as in 11, placed on a rail.

Explosions 11 *and* 12 without the employment of a shell.

Each shell received a priming cartridge 16 mm. in diameter, 9 grm. in weight, for the reception of which a space was left in the filling; in the priming cartridge was placed the primer, containing 1 grm. fulminate.

The shells were placed on three iron rails, placed with the head down, as close together as possible, as shown in the diagram (C. 12).

All the shells exploded with perfect accuracy. The effect in all the shells was approximately the same, the rails were generally broken; when this did not take place completely, a similarly great energy exhibited itself in some other manner.

The effect in No. 10 was not greater than in the preceding ones, showing that the grains are quite as effective as the gun cotton in disks.

In 11 the rail was cut smoothly in two twice, in 12 once; in comparison with the preceding explosions the effect was greater, showing that by confining the gun cotton its effect is not increased, on the contrary, the direct instantaneous action on the object is rather weakened, a phenomenon explained by the fact that the 20 mm. thick wall of the shell removes the charge that far from the object. We call attention to the fact that we speak of the *direct* action on the object; *total* effect, acting also at a distance, must be distinguished therefrom; in the latter such small distances as 20 mm. can have no effect. This distinction also accounts for the fact that, in all experiments in which the force can act only in one direction on an object in direct contact, only relatively correct results are obtained, and that our experiments, too, at times conducted by placing the gun cotton directly on the object, and at other times confining it, furnish no uniformly accurate results.

Moreover, if 9 cylinders of gun cotton produce no more effect on the object than one cylinder (see Experiments A. 5*a*, 5*b* and 6), it does not follow that in the first case more total energy, corresponding to the weight, was not developed. At all events, even considering exclusively the effect, wet gun cotton will have preference over dry, in case it is desired to destroy, by means of externally applied unconfined charges, such objects as walls, arches, iron plates, etc., where the surface of contact between the gun cotton and the object to be destroyed is the largest possible.

Experiment No. 13.—A shell, filled with grains entirely coated with paraffin. A priming cartridge, 31 mm. in diameter, 65 grm. in weight, placed in a space left vacant for it in the filling, failed to detonate the filling of the shell. There was a partial combustion of the charge.

Experiment No. 14.—A shell, filled with grains entirely coated with paraffin, and containing a priming cartridge 31 mm. in diameter, but weighing 100 grm., detonated perfectly.

In case grains composing the filling of the shell are not bound together by means of melted paraffin, a very much heavier, and therefore larger, priming cartridge is necessary for detonation than if this is the case.

Experiment No. 15.—A 21 c.m. cast-iron shell was filled with 4,200 grm. dry granulated gun cotton, and placed on a support formed of a double row of rails. Five iron rails were placed side by side on two wooden skids, four rails were placed between the first named rails. The skids were 1 meter apart, the rails therefore had a bearing of 1 m.

The shell was covered with earth to a depth of ½ m. The action was very considerable; all the rails were broken, most of them at several points, and in addition a depression was formed in the ground ½ m. deep. A bomb-proof covering can, therefore, no longer be made in this way.

D. Action of Gun Cotton and Gun Cotton Shells in Earth.

Experiment No. 16.—A 15 c.m. shell, filled as above with granulated gun cotton, buried 1 m. deep in the earth, produces in light soil as well as in somewhat heavy soil (sandy clay) a cone:

60 cm. deep and 2 m. in diameter.

Experiment No. 17.—A 15 cm. shell, filled with 2,100 grm. ordinary gunpowder, produces a cone:

50 cm. deep, 2 m. long, and 1½ m. broad.

Experiment No. 18.—A 15 cm. steel shell, 6 calibers long, filled with 8.9 kg. granulated gun cotton, wet, containing 25 per cent. water, 1 kg. dry grains, and a priming cartridge weighing 35 grm., so buried that the head was 1 m. under the surface, the base ½ m., made a funnel:

1.3 m. deep and 4 m. in diameter. (See diagrams).

E. Comparative Experiments with Granulated Gun Cotton and Gun Cotton Disks.

The earth in which the explosions took place was light, clayey, sandy soil.

Experiment No. 19.—A tin canister, 3 calibers long, 7½ liters in capacity, filled with:

6300	grm.	wet granulated gun cotton,	8 mm. cube.
800	"	dry " " "	
50	"	priming cartridge,	
5620	"	= total dry weight,	

was buried so that one end was 1.2 m. nnder the surface, the other 0.9 m.; it formed a cone in the explosion,

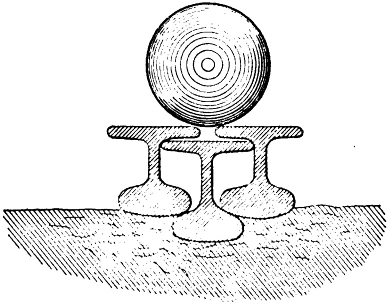
1.10 m. deep, and 3.30 m. in diameter.

Experiment No. 20.—An explosive charge of the same form as in Experiment 19, but composed of disks of wet gun cotton, 8.3 kg. in dry weight, and furnished with a 50 grm. priming cartridge, was buried as in Experiment 19; it formed a cone in the explosion,

1.30 m. deep and 4.10 m. in diameter.

Experiment No. 21.—A tin canister, 6 calibers long, 15 liters in capacity,

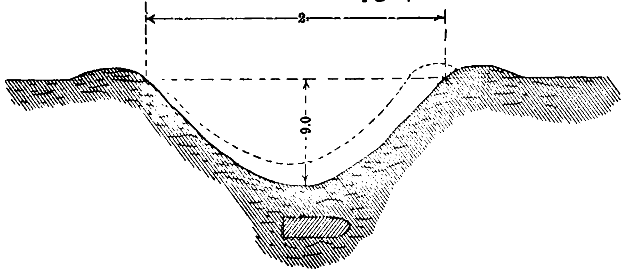
C. 12.



D. 16 and 17.

CONES OF EXPLOSION.

15 cm. shell filled with ordinary gunpowder.



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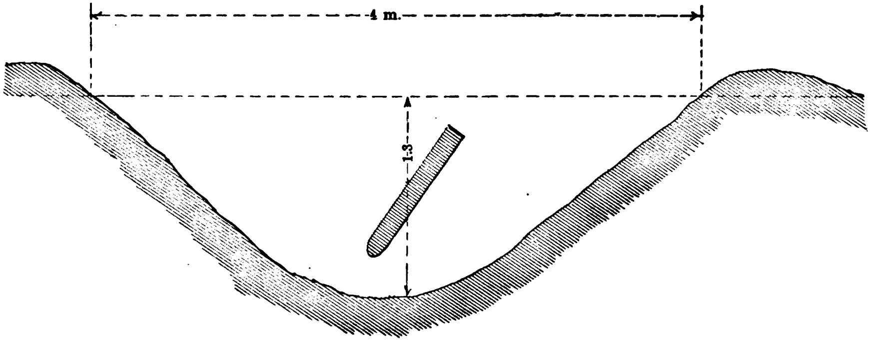
D. 18.

A 15 cm. steel shell, 6 calibres long, with 8 kg. granulated guncotton.



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filled with 11,150 grm. dry granulated gun cotton (8 mm. cube in volume, cubic weight 0.75) and a priming cartridge weighing 50 grm., was buried so that one end lay 1.2 m. deep, the other 0.6 m., and formed, in the explosion, a cone:

1.58 m. deep and 4.45 m. in diameter.

Experiment No. 22.—An explosive charge, composed of wet gun cotton disks, 16.6 kg. in dry weight, provided with a priming cartridge weighing 50 grm., buried as in Experiment 21, formed a cone, in the explosion,

1.56 m. deep and 5.1 m. in diameter.

A piece of wrought iron 3 cm. thick, 10 cm. square in surface area, which, in the first two explosions lay close under one corner of the charge, in the second two explosions 15 cm. below the charge and parallel to its side wall, separated from it by earth, was, in Experiments Nos. 19, 21 and 22, compressed to an equal degree, but in No. 20, somewhat more than in the others. In Experiments 19 and 20, the iron lay, as remarked, immediately against the charge, and, under these circumstances, the disks were more energetic in their action than the grains.

Experiment No. 23.—A piece of iron rail, 0.5 m. long, 10 cm. broad in the base, 12 cm. high, was placed in a ditch 1.25 m. deep, resting on two pieces of fir, 10 square centimeters in cross-sections, so as to leave 25 cm. between bearings. Earth was thrown over the rail to a depth of 25 cm. above the head. A tin canister, like the one employed in Experiment No. 19, filled with 5,620 grm. dry grains and a 10 grm. priming cartridge, was placed on the earth with its axis perpendicular to that of the rail, and the ditch filled up to the surface. The canister was exploded—it cut the rail squarely across, dividing it into three parts, and besides, the base of the rail was driven 1 cm. deep into the wood. The pieces of wood were otherwise uninjured. The cone of explosion was:

1.10 m. deep, 3.10 m. in diameter.

The pieces of rail and the strips of wood were found at a depth of 1.50 m. under the surface.

Experiment No. 24.—A charge of wet gun cotton disks, of the same dimensions as the above-described tin canister, 8.3 kg. in dry weight, and provided with a 50 grm. priming cartridge, was applied as in Experiment No. 23 and exploded.

The iron rail was broken in almost the same manner as in No. 23, except that there were only two pieces, in each of which a piece was broken off from the head of the rail near the middle. The base of the rail did not penetrate into the wooden supports, but the latter were cut squarely and smoothly in two. They evidently offered less resistance than in Experiment No. 23. With the exception of this break the strips of wood sustained no injury.

The cone of explosion was:

1.5 m. deep and 3.5 m. in diameter,

hence, somewhat larger than in Experiment No. 23. The pieces of rail and the

of wood were found buried at a
of 1.65 m.

charges Nos. 23 and 24 broke up
ron rails at a depth of 45 cm.
them, and threw out cones of ex-
n to a depth of 40 and 80 cm. re-
vely. The pieces of rail and the
en supports were found pressed 90
to the ground, and the sandy earth
round to dust to the same depth.

s experiment shows that gun cot-
both forms acts not only when in
contact, but with great force even
nsiderable distance.

m the comparative experiments it
rs that in sum total the action of
volumes of granulated gun cotton
un cotton disks is the same; the
in weight of over a third has
ect, especially when considerable
ts are used, and the object to be
yed is not in direct contact with
arge.

ether, with other objects and under
circumstances, the excess of weight
charge when disks are used over

that of grains, will be made effective remains undetermined, but we believe from all the preceding experiments that we are forced to the conclusion that this can only take place to a slight extent.

We are furthermore of opinion that it is very doubtful whether, by the use of heavier and more sudden explosives, as, for instance, explosive gelatine, mixtures of the nitrates of benzole and aniline with nitric or hyponitric acid, in shells, a greater effect will be obtained.

In actual firing, the shells will rarely be in direct contact with the object which they are to destroy, but will more generally be some distance from it; *e. g.*, in case of arches and armor plates they will not lie in contact therewith along their entire length, but will either not be in direct contact at all or but very slightly, and at the smaller distances is just where the degree of suddenness of action of an explosive is most apparent.

In case of shells with thick cast-iron walls, the increased suddenness of action will probably have no other effect than to pulverize the walls to dust—an effect in many cases not at all desired.

It will be necessary, however, to test the various explosives under circumstances which resemble actual practice, in order to obtain comparative results of their power and action.

We will quote here a few examples from the above mentioned work of Lieutenant General Brialmont:

Ordinary 21 cm. steel shells, containing a charge of 14½ kg. of gunpowder, fired at an elevation of 45° from the Krupp 21 cm. forged mortar, penetrated from 2 to 2.60 m. into the sandy earth of the firing ground at Meppen, and threw out elliptical cones of explosion—

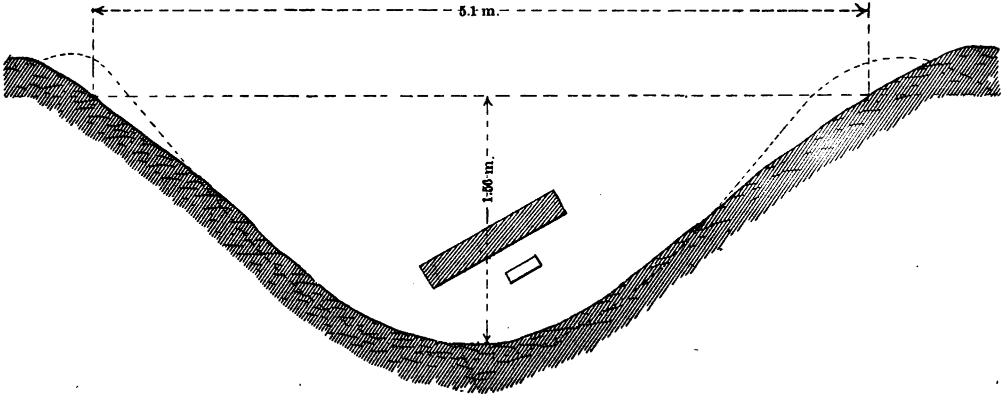
1.20 to 1.40 m. deep.
3.20 to 4.80 m. long.
3.20 to 4.00 m. broad.

Fired at 28° and 60° elevation, the action was less. A steel torpedo shell, 6 calibers long, containing a charge of 36 kg. of gunpowder, fired at 35° elevation, produced a cone of explosion,

E. 21 and 22.

CONES OF EXPLOSION.

16 kg. guncotton in disks, equal quantity granulated guncotton.

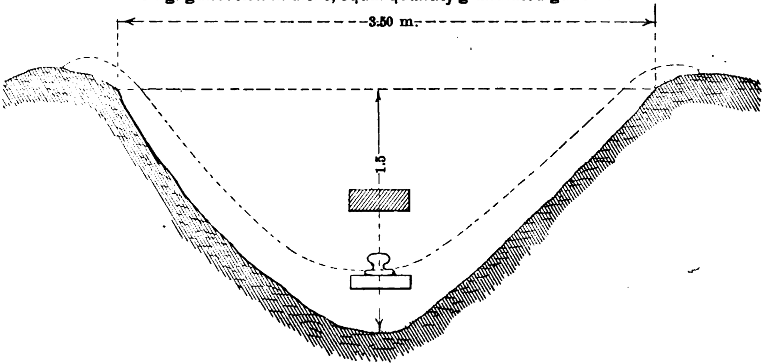


1:50

E. 23 and 24.

CONES OF EXPLOSION.

8 kg. guncotton in disks, equal quantity granulated guncotton.



1:50

2.40 m deep and 4.80 m. in diameter, corresponding to a mean displacement of 15 cubic meters of earth.

Arches, constructed of the best béton, 1.45 m. thick, require the following thicknesses of sandy earth to protect them against various projectiles fired from the 21 cm. mortar:

1.00 to 2.20 m. deep,
3.20 to 5.00 m. long,
2.60 to 5.00 m. broad,

corresponding to a mean displacement of earth of 7 cubic meters.

The 21 cm. steel gun cotton shells penetrate 4 m. deep, lying nearly horizontal, and throw out cones of explosion,

Ordinary shells,....	: 2.50 m.
Steel shells, charge 14½ kg. gunpowder....................	: 3 to 3.50 m.
Torpedo shell filled with gun cotton.........................	: 5 m.

But this thickness of earth covering of 5 m. cannot be attained in practice, as the fortification works will have to be too high and too costly. It is, therefore, proposed to omit the earth covering entirely and to replace it by a layer of granite or porphyry 0.80 m. in thickness, or by a bed of Portland cement 1 m. to 1.20 m. in thickness.

The experiments in Silberberg in 1869 showed, however, that even this covering will not suffice against the projectiles of the forged mortar charged simply with gunpowder, as these projectiles produced depressions of $\frac{1}{2}$ to $\frac{2}{3}$ m., so that a second shell striking the same point would penetrate the arch.

Lieutenant General Brialmont thinks, therefore, that it is not possible to propose anything definite on this subject as yet, but considers it preferable to construct the arches of the best béton, made 1 to 1.50 m. thick, and covered with at least 3 m. of earth. In case this is not sufficient, a part of the earth must be replaced by béton, or the earth covering must be increased, or an arch of sheet-iron may be inserted under the béton arch, which last is the simplest and cheapest method.

This, it is evident, approaches the armored turret.

We believe, however, that even this may be greatly damaged by means of large charges of gun cotton.

From all this it is evident that Lieutenant General Brialmont considers the power of the gun cotton shell, and its effect on the future construction of earthworks, as very great.

SUBMARINE EXPLOSIONS WITH COMPRESSED GUN COTTON.

Explosion of the Iron Tug-boat Mathias Stinnes I., Sunk in the Rhine near the Railroad Bridge of Rheinhausen, below Duisburg.

Conducted by the author and engineer MATH. ROSSENBECK.

The tug-boat was a strong iron vessel, dating from the earliest times in which such vessels were built, constructed especially solidly in all its parts.

She lay with the stern 200 m. from the railroad bridge, which stood on massive piers, and 100 m. out from the right bank of the Rhine, extending thence with its entire length down stream almost in the direction of the current. The stern at mean low water was about 2 m., the bow about 6 m. under water.

The vessel was to be cleared away to a certain depth of water, so that evidently the stern and center had to be removed. The current is so strong that a diver cannot descend without assistance.

A wooden Rhenish flat boat was therefore so arranged that an iron cylinder was laid square across its deck, containing on the end extending over the flat boat an iron ladder, which could be turned in its support. When the ladder hung free vertically it was held by a hand-screw, but it could also be rested on the sunken vessel, on parts which had fallen off, or on the flatter parts of the river bottom, and rose in all cases 2 m. above the shaft. On the ladder a shield $\frac{2}{3}$ m. broad was fastened, which diverted the current from it. The ladder and shield could be raised and lowered by means of a hand-screw. By means of the ladder the diver could reach the vessel, and, protected by the shield, could work readily, mostly with the left arm.

A second flat-boat of the largest kind was provided with a solid deck and a crane, by means of which and an iron chain the parts separated by the explosions were raised.

Although large charges could not be used on account of the proximity of the railroad bridge, on which account heavy shocks had to be avoided, they would have been of no avail, but would more likely have been detrimental.

No charge, however large, even if 1,000 kg. of the most powerful explosive had been detonated at once, would have destroyed the vessel in such a way that the separated parts could be raised and removed. It would have left a conglomeration of parts of the vessel which, adhering firmly, would not have permitted the removal of the separate parts or the work of the divers.

The question was how to remove separate parts by charges not too great, and then to raise these parts by means of the crane on the flat-boat. Wooden chests were therefore charged with 10 kg. compressed gun cotton, and used either separately or occasionally two at the same time.

The diver descended to the vessel, placed the charge in position, which often required hours on account of the strong current, ascended ; the ladder was raised, the flat-boat went out to the middle of the stream, and the explosion was effected by electricity.

The boat returned, the diver descended, fastened a chain to the loose parts of the vessel, an operation which again required several hours, on account of the exceedingly great difficulties, and an attempt was then made to raise the parts, which generally succeeded. Often the attempt failed, however, as the parts were still fast bound to the vessel, and the strong crane could not tear them away.

The iron planks, the ribs, the wheel,

gradually the boiler, parts of the wheels, parts of the shaft and the machinery appeared in turn. The shaft was a cylinder of the best steel, 15 cm. thick, and was acted on by a double charge, hence by 20 kg. gun cotton, cutting it across in several places.

Great as was the action of the gun cotton, over 100 explosions, in which 1,200 kg. gun cotton were used, were found necessary to clear the water to the required depth. The greater part of the stern of the vessel was removed, the rest was forced into the sand of the stream by the force of the explosions; the bow of the vessel till beyond the wheel shaft was little disturbed; it lay, however, below the required depth of water.

It is shown again, in this example, that the annihilation of the vessel by means of charges of explosives is entirely out of the question; iron constructions are particularly difficult to remove, unless they are raised after the explosion or the force of the explosion pushes them into the ground.

To sink a floating vessel is quite another matter.

Charges of 20 kg. of gun cotton, applied externally to a suitable part of the vessel, and lying in direct contact, will burst through the sides of the vessel, but whether they will so disturb it as to make it sink is a question. So far as relates to its action at a distance, we have observed that in explosions in deep water, at a distance of 100 m. from a charge as much as 100 kg. in weight, only a light shock is given to floating material, such as vessels, and that, on the contrary, the shock produced by such an explosion is transmitted through the solid earth to considerable distances, 500 to 800 m., to other solid substances standing on the ground, such as buildings, for instance.

Wooden vessels are easily destroyed by explosion, because after the explosion they are removed by the water, by ebb and flood tide, or by other currents.

We have destroyed a large number of such sunken vessels on the coasts of the

North Sea, and at the mouths of the Jade and Weser.

Charges of 100 kg. of gun cotton each, placed in long chests, were lowered to the wreck, or, when possible, fastened by divers to the side-walls of the wrecks, and exploded.

In the case of small vessels, two or three well-applied charges are sufficient; in the case of larger vessels, considerably more are required.

Explosions at the Adlergrund.

In the Baltic Sea, between Bornholm and Rügen, lies the Adlergrund, a shoal formed by large rocks lying on the bottom of the sea. At the shallowest places the royal government, with a view to increasing the depth of water, had some of the rocks removed by vessels furnished with cranes.

Divers went down, fastened chains about the rocks, or attached clamps to them; the rocks were then raised. In order to break up the rocks and to render more easy the attachment of the lifting machinery, many charges of 10 kg. gun cotton each were placed on the bottom of the sea, to a depth of 4 to 6 m., and detonated. These explosions usually loosened from two to four blocks, each about 2 cubic meters in volume, and forced them completely out of their original position, so that they could be easily raised.

Rock-blasting in the Rhine, with a View to Deepening the Channel between Bingen and Coblenz.

In many places rocks at the bottom of the Rhine form shoals which impede navigation, the best known and most dangerous of which is the "Bingerloch." From rafts and vessels a series of holes is bored in the rocky bottom, 1 to 2 m. deep, according to the amount of rock material to be removed; these are filled with gunpowder, tamped with sand, and the charge fired. After 10 or 20, or even more blasts, vessels provided with diving-bells are run over the spot, the diving-bell is lowered, and, by means of picks and bars, the rocks are broken loose, and are then raised through the diving-bell to the surface and loaded into vessels held ready for the purpose.

We are of the opinion that if, in place of the gunpowder, *sudden* explosives are used, the work of removing the débris, which now involves the principal cost, will be greatly simplified and rendered cheaper. It is also necessary with gunpowder to deepen the bore-holes considerably below the point to which it is desired to remove the rock; fired with sudden explosives, the rock will be removed to the bottom of the boring, whereas by the use of gunpowder the lower third of the bore-hole remains intact. The sudden explosives are not used, because people still fear those who decry them, saying that a part of the explosive may remain unexploded, and when the diving-bell is lowered and the workmen proceed to loosen the rocks, may give rise to after-explosions, produced by the shocks in striking it, which may cause serious accidents.

This may be true of nitro-glycerine preparations, which are not rendered inexplosive by penetrating water, but in the case of gun cotton the cartridges, as the author has stated in his previous article, may be easily so arranged that, after a certain time, say 24 hours, they will become thoroughly wet and rendered inexplosive and perfectly safe, as well from the explosive priming cartridge, which may still remain, as from the shocks of the tools.

Although advantages are gained by the use of compressed gun cotton in such work, we are nevertheless of the opinion that neither gun cotton nor any other sudden explosive can act so as to dispense with the boring of the bore-holes.

Externally applied charges do not, even in case of considerable depth of water, which acts as a kind of tamping, act so strongly, but that the cost of explosives will be too great.

We can conceive of an advantageous

method of carrying on the work with externally-applied charges, without the use of bore-holes, only in case large surfaces of rocks are to be removed to but slight depths, perhaps to 10 or 15 cm., in which case bore-holes would even act disadvantageously. The entire work of preparing the borings and the removal of the rocks is saved, and thus, in spite of the large amount of explosives employed, a relatively cheaper and more rapid work is obtained.

Paraffining Gun Cotton.

1. *Paraffining Dry Gun Cotton so that the Paraffine penetrates the piece and takes the place of the water, which is always present in wet Gun Cotton.*

Wet gun cotton, in store, will dry in time unless it be packed air-tight, and must therefore be moistened from time to time.

To save this labor, it has been proposed to replace wet gun cotton by paraffined dry, on the ground that paraffine does not evaporate.

This would be a very practical suggestion if the paraffine were capable of replacing the water. But this is by no means the case; paraffined gun cotton is rather a substance intermediate between wet and dry, without the good properties of either.

The principal advantage of wet gun cotton, containing 25 per cent. of water, is, it is not combustible. This property deprives it, in handling, storing and transportation, of the character of an explosive, and it is a great advantage to be able to store gun cotton in this condition, especially when large quantities are on hand.

This will come into play, particularly in case fire breaks out in the magazine or in its vicinity; even if the supply of gun cotton is destroyed, as will be the case if large quantities of other combustible substances are present, and the flame is therefore very persistent, danger there cannot be.

Although spontaneous decomposition is not absolutely impossible, yet wet gun cotton will have the preference over all other explosives formed by the nitration of organic substances, which are all combustible, in that spontaneous combustion, at all events, cannot take place.

The property of incombustibility is that which above all renders wet gun cotton particularly suitable for military use, and especially in submarine mines, since, in this case, large quantities of the explosive will be accumulated in one place, and, in case large quantities of explosive burn, there is great danger arising from this very fact; moreover, by the gradual rise in temperature an explosion may even take place.

Paraffined gun cotton, however, is not incombustible; in fact, any little flame will set fire to it, and it will burn almost as rapidly as dry gun cotton.

The rapidity with which the flame spreads and develops is the true criterion of the degree of danger, which may result from its combustion, to a magazine filled with explosive.

As a further test of paraffined gun cotton, the following experiment, made at the factory at Walsrode, may serve:

Pieces of gun cotton, not thoroughly freed from acid, were paraffined. After a period of two years the gun cotton showed signs of decomposition, green flecks and curdy spots began to appear, the mass became soft and liquid; the appearances were the same as in the case of poor, dry, unparaffined gun cotton. In case of wet gun cotton this phenomenon was not observed.

But not only does the paraffining not prevent decomposition, it must, according to all appearances, induce a spontaneous decomposition. Paraffined gun cotton was prepared by drying wet gun cotton and digesting it in a bath of paraffine at 65° C until the entire piece was permeated by the paraffine. This requires from ½ to one hour, according to the size of the pieces. If the paraffine bath is at a lower temperature, a longer time will be required.

This process may injure the gun cotton every time.

It is a determined fact that at temperatures of $+65°$ C. nitrous acid is evolved from gun cotton; it is detected by means of the reaction with potassium iodide and starch paper. The paraffine causes this nitrous acid, as well as that which may be evolved in the course of the year, during the storage of the gun cotton, to be retained. In case of dry or wet gun cotton, not inclosed air-tight, the gases developed can escape.

The discovery has often been verified in the factory at Walsrode that, according to the potassium iodide and starch test, gun cotton of slight stability, which is permitted to give off its vapors freely, becomes more stable after a number of years. The acid developed partly combines with the chalk and partly volatilizes, so that a more stable gun cotton remains. Very slight traces of nitrous acid are evolved from all gun cotton even at comparatively low temperatures. If gun cotton be digested in warm water, or for a longer time in cold water, nitrous acid may be detected in the water by the addition of sulphuric acid and zinc iodide and starch solution.

We made the following experiment:

Gun cotton was washed at the laboratory until the wash water no longer gave any reaction for nitrous acid; then the gun cotton was left in the drying oven at +30°C. for eight days and again washed. The washings again gave the reaction for nitrous acid.

The same experiment, repeated with the same gun cotton, invariably gave the same result.

Hence, we must conclude that all gun cotton contains nitrous acid.

Moreover, all commercial nitre, as used in the manufacture of gunpowder, contains nitrous acid.

We applied to one of the most celebrated factories of chemicals for fused nitre, free from nitrous acid, and were told that they had not succeeded in preparing it.

We then prepared it in our own laboratory, by careful fusion and refusion, under certain required conditions, and preserved it in a well-closed glass flask.

When examined after an interval of several months, the nitre again contained nitrous acid.

Professor Himly, of Kiel, often expressed himself to the author to the effect that: "All nitro-compounds are unstable, all organic substances are easily decomposed, only inorganic substances should be used for explosives." True as this is theoretically, it is nevertheless not verified in practice.

In all cases, however, it will be well, even with gun cotton, not only to exercise great care in the manufacture, but also not to rely too much on its safety in preparing charges for blasting, as is too often done.

We call attention, moreover, to the fact that, when the nitrous acid has combined with the chalk to form calcium nitrite, as long as no more is evolved than the chalk can combine with, it cannot injure the gun cotton. Nevertheless, it again makes its appearance when tested with solution of potassium iodide and starch, or zinc iodide and starch, because the calcium nitrite is dissolved by the water in which the gun cotton is digested; and when sulphuric acid is added the nitrous acid is liberated and detected by the reagent. A gun cotton may therefore be free from acid, and yet, when tested, give the reaction for nitrous acid. From all this we conclude that it is useless to attempt to prepare gun cotton free from nitrous acid. But such gun cotton is not to be confounded with that which contains considerable quantities of free acid, even nitric acid. Such gun cotton, instead of improving with time, will deteriorate and rapidly decompose.

Any indication that gun cotton, even only moderately free from acid, but chemically altered, decomposes with the production of light, we have never observed.

Returning to paraffined gun cotton, we do not mean to state that a good gun cotton must necessarily decompose to such an extent as to be dangerous, but only that it is better to avoid the process of paraffining, if possible; furthermore, we do not say in general that it is injurious to preserve a good gun cotton air tight, but rather have frequently verified the fact that a good gun cotton, stored air-tight for years, has lost nothing of its permanence, as determined by the potassium iodide and starch test; we simply believe that for all gun cotton it is better, if practicable, to store it without inclosing it air-tight.

If we return now to the physical properties of paraffined gun cotton, we shall see that its only similarity to wet gun cotton is in being less sensitive to a shock than dry, on account of which property paraffining has been mainly advocated; it is, however, much more sensitive to a shock, and especially to ignition by a shock, than gun cotton with 15 per cent. water.

In this connection we made the following experiment:

Shots were fired at short distances from the Mauser Infantry arm against disks of gun cotton 15 cm. in diameter and 5 cm. thick. Gun cotton with 15 per cent. water stood three hits; paraffined gun cotton was ignited the third hit.

The shocks to which the gun cotton designed for use in submarine mines is liable, even dry gun cotton can endure; for that purpose it will not, therefore, be necessary to paraffine the gun cotton. The charges of the Fish torpedo are an exception, as they are often exposed to the enemy's fire, but for this very reason paraffined gun cotton cannot be used.

Having shown that paraffined gun cotton is too sensitive to shock, it should be stated, on the other hand, that it has lost the power of being detonated by the detonation of a primer containing 1 grm. mercuric fulminate. It can be detonated only by means of dry gun cotton.

As paraffine does not evaporate it forever prevents the use of gun cotton permeated with it for priming cartridges, while wet gun cotton need only be dried to be used for this purpose.

We repeat, therefore, that, in our opinion, paraffined gun cotton is not an advantageous form of the explosive.

In the work "The Modern High Explosives" of Manuel Eissler, Mining Engineer, New York, 1885, gun cotton is very unjustly dealt with, as it is stated there that in England, experiments had been made showing that gun cotton is so sensitive to a shock, that in a system of submarine mines charged with gun cotton, the explosion of one mine caused the neighboring ones, and thus successively the entire series, to explode, and that it would therefore be easy, by means of a countermine, to explode an entire system of mines charged with gun cotton, and thus render it harmless.

It is a well-known fact that there is no navy in Europe which does not use compressed gun cotton almost exclusively for charging submarine mines, except in so far as old powder mines are still on hand, and just because it is so little sensitive to shock.

In describing the chemical properties and the investigations of gun cotton, Mr. Eissler has also shown that he does not understand its character and properties.

2. *Paraffining dry gun cotton externally, so that the paraffine penetrates several millimeters, and forms with the gun cotton a coating, which protects the inner dry portion of the cartridge against external action, especially of moisture.*

The operation is especially adapted for the preparation of priming cartridges. The opening for the reception of the primer is closed with a sheet of paper before the cartridge is dipped in the paraffine, and the cartridge is thus protected against moisture in general during years of storage.

An improvement of the process consists in coating the walls of the cavity which serves for the reception of the primer, by means of acetic ether. The cartridge is thereby rendered impervious to water for a considerable time, even after the sheet of paper is broken, and the primer is placed in position, preparatory to using the cartridge, even under water.

The detonating power of the cartridge is not diminished by the thin coating of dissolved gun cotton; it will detonate even under water, in spite of the fact that water penetrates between the primer and the walls of the cartridge.

In the case of charges for submarine mines, however, the use of paraffine offers no advantages. However carefully the paraffining is performed, it is not possible to ascertain whether the paraffine may not have penetrated too far into the cartridge; it is possible that the cartridge has lost the power of being detonated by the primer, but we are not able to determine this with certainty.

Moreover, cartridges paraffined in this way will, according to our experience, become cracked, thus allowing moisture to penetrate. The piece of gun cotton is not an unalterable mass; it changes its form with changes of temperature and with changes in the hygrometric state of the atmosphere; hence, small cracks will be formed, and in time large ones, too.

These possibilities will be ground sufficient for not applying paraffine in any manner to cartridges used in submarine mines. These cartridges must be preserved against moisture by the mode of packing, during storage and use.

We add, in this connection, that cartridges which are air-dried, and are preserved in a dry and airy magazine, will be detonated at all seasons, in every kind of weather, by a 1 grm. primer; it is therefore not necessary to take such extreme precautions with it, provided only that good 1 grm. primers are used.

3. *Paraffining Wet Gun Cotton.*

Pieces of gun cotton, with 25 per cent.

water, may be coated externally with a layer of paraffine several millimeters thick, but the paraffine cannot penetrate on account of the presence of the water.

At ordinary temperatures the layer of paraffine is tolerably firm and prevents the piece from drying, to a certain extent, and gives it a tolerably permanent form.

By changes of temperature, and by frost, innumerable cracks are rapidly formed, however, and portions begin to crumble, causing the two advantages just mentioned to be rendered nugatory.

According to experiments made at the factory at Walsrode, it appears that of the most carefully-prepared wet pieces of gun cotton, paraffined externally, several withstood the effects of the first winter, none the second; the crevices became so numerous that there was no longer any impediment to the evaporation of the water, and the form of the piece of gun cotton was no more permanent than in pieces without the layer of paraffine.

Not unimportant is the fact that the layer of paraffine increases the size of the pieces, and a given space will therefore contain less gun cotton.

In the case of pieces of gun cotton, 140 c.c. in volume, the increased space required amounts to 12 per cent., and, besides, 12 per cent. paraffine, *i.e.*, a considerable weight of a substance, which, together with the wood of the packing boxes, forms a combustible material, penetrates into the wet gun cotton.

Small pieces will evidently not be very suitable for this process.

If the layer of paraffine be less than 2 mm. thick, it will not subserve its purpose even for a short time. In conclusion, it will be exceedingly difficult and expensive to paraffine a large quantity of wet gun cotton, externally, so that the pieces are well coated with paraffine, and that the layer of paraffine will not diminish the facility with which the wet gun cotton may be detonated.

By experiment it was found that the detonation of wet, externally paraffined pieces of gun cotton was not effected by a priming cartridge of 150 grm., when the pieces are not in contact, but separated 10 mm. from each other. In case of charges not inclosed, failures to explode, or partial explosions, may easily take place.

The result is that we must also regard wet, externally paraffined gun cotton, on account of its increased cost and disadvantages, as not advantageous.

Coating Gun Cotton by Immersing it in a Solvent.

This process has proved a success in the experiments, extending over three years, and conducted in every possible direction. The coating lasts well, cracks or peelings occur only to an inconsiderable extent. A portion of wet gun cotton thus coated was preserved in well-closed cases, another portion in open cases under water. Although a few pieces contained cracks, the form and density of the pieces, obtained by pressure in the manufacture, was preserved. The time, during which the moisture is retained by the gun cotton varies mainly with the mode of packing it; impermeable the coating is not, but still it protects in a great degree as well against the penetration of water in the case of dry gun cotton as against the evaporation of it in wet. The principal advantage lies in its rendering the pieces as tough as wood, and whoever has had occasion to observe the condition of even well-pressed and well-packed gun cotton, after transportation over long distances, will appreciate this advantage.

Moreover, the coating prevents the formation of mould, although in the case of wet gun cotton the formation of mould is favored by the very mode of storing it, and goes on in spite of the fact that the gun cotton is enclosed, as when it begins on the sides of the packing chests and extends to all the material stored in the chests, in which case the pieces of gun cotton cannot remain free from it, whether coated or not. Are they coated, however, the mould will not penetrate the pieces, but remains outside on the coating. It may easily be removed by wiping the pieces. It cannot therefore injure either the structure or the composition of the gun cotton.

We will remark, in this connection, that when wet gun cotton, on which mould has formed, is placed in an airy store-room, in which it can dry, the growth of the fungus is stopped. Moreover, we moistened gun cotton, which seemed to be especially threatened with the formation of mould, on account of the climate or the mode of storage, with carbolic acid, with good effect.

The coating will commend itself more especially in the case of gun cotton intended for use in submarine mines or the Fish torpedoes, which must endure transportation and always a long term of storage, and which may possibly have to endure unpacking and repacking in the vessels used for holding it in the mines.

The coating is also suitable for the gun cotton used for explosion by the land forces, and which, in the event of war, must endure long-continued transportation, and often unpacking and repacking.

In case of granulated gun cotton, intended as a charge for shells, the coating is indispensable. All granulated powder will jolt in the shell when fired, friction on the walls of the shell is unavoidable, and thereby ignition of the powder and premature explosion of the shell may be produced.

In case of granulated gun cotton this is true in a higher degree than ordinarily.

We therefore fill up the interstices in the granulated gun cotton, with which the shell is charged, with liquid paraffine, which forms of the entire filling, after solidification, a compact, no longer compressible, body, excluding the possibility of a jolting of the charge or a movement of the separate parts.

The coating of the separate grains prevents the paraffine, while liquid, from penetrating into them, and it is necessary to prevent this, because grains of gun cotton permeated with paraffine require a priming cartridge so large that it cannot be conveniently applied or cannot be applied at all.

Every granulated gun cotton is particularly subject to conversion into dust; the coating prevents this, and it is thereby made capable of being transported and of being used in warfare.

The facility of detonation, in case of coated gun cotton, is in no wise diminished; dry gun cotton remains subject to detonation by a primer to the same degree, and wet gun cotton to the detonation of the dry and the adjacent wet gun cotton.

Nor can there be any ground for the opposite view, since no foreign body is carried into the gun cotton or added to it by the coating; a very small portion of the piece of gun cotton on the surface, about as thick as a sheet of thin paper, is simply dissolved by the solvent, and remains, after the evaporation of the solvent, as a thin, closely-adhering pellicle. This pellicle consists of dry gun cotton, and it has therefore been said that the process of coating by means of acetic ether renders wet gun cotton combustible.

Occasionally, too, the word "ether" has led to the belief that, after the completion of the fabrication of the coating, combustible vapors of ether may remain.

The latter is of course not at all the case. The ether used for solution evaporates very rapidly, and the above-mentioned hard, dry pellicle remains. The amount of dry gun cotton thus produced is, however, exceedingly small; in a prism 230 c.c. in volume it amounts to 1 grm., and in case of one of 140 c.c. it is still smaller; therefore less than ½ per cent.

A chest containing 50 kg. of wet gun cotton will therefore contain ¼ kg. of dry gun cotton, a quantity involving no danger whatever, and which, in comparison with other combustible material present in the storage of wet gun cotton, is insignificant.

Gun cotton is generally packed in wooden chests, pitched inside. The wood of the chest weighs 15 kg., the tar ¼ kg. per 50 kg. of packed gun cotton—an amount of combustible material sufficient to produce a continuous heat, in case a fire breaks out in the magazine, adequate to vaporize gradually the water of the wet gun cotton, and thus convert it into dry gun cotton.

The ½ per cent. of dry gun cotton produced by the coating, will not alter these relations, since it does not fly about in the form of dust and come in contact with any light that may be carried about and thus take fire, as it is in a compact, not a pulverulent form, on wet gun cotton, combined with the latter in chests.

As already stated, we are of the opinion that keeping gun cotton moist prevents all danger in case of fire in the magazine, as it prevents a rapid development of the fire; we are, however, also of the opinion that, in all ordinary methods of packing or arrangement of the magazine, the stock of gun cotton may be considerably damaged by fire, and, in case of inadequate arrangements for extinguishing fire, may even be entirely destroyed, and any change in the wet gun cotton, such as the coating produced by acetic ether, which is insignificant in effect, will not alter the character of wet gun cotton in this respect.

The coated gun cotton long retains the odor of acetic ether. After some time, however, not a trace of the odor remains an indication that all the acetic ether has evaporated. No alteration in the gun cotton or in the pellicle is produced, however. We have found that no acetic acid is formed either in the pellicle, or immediately under it, or in the piece of gun cotton itself.

Should traces of acetic acid, formed by the mixture of vapors of acetic ether with atmospheric air, accumulate, however, due to the inclosing of freshly-coated gun cotton, no injury will result, as it is in no way injurious to gun cotton.

The process of coating gun cotton by dipping it in acetic ether is called "gelatinizing" gun cotton, and this expression is often used in the text.

Gun Cotton Shells.

It is well known that the effect of shells filled with ordinary gunpowder against stone arches, against iron coverings, against armored walls and armored turrets, is often very slight, and that attempts have been made for some time to introduce a more energetic explosive as a charge for shells. Compressed gun cotton must be recognized as best adapted for this purpose, as it belongs to the most energetic of the explosives now known, exists in the solid form, is convenient to handle, safe in transportation and storage, little sensitive to shock (not at all when wet), chemically stable even after long-continued storage, and has been known in the military world for 20 years, and is in use at present giving good results.

From these considerations we have endeavored to apply compressed gun cotton to produce an increased effect in the explosion of shells, and we have succeeded, by extensive firings and explosions at the factory at Walsrode, in discovering a method of filling the shells which promises to fulfill all the requirements, in that it not only renders possible the firing of the ordinary rifle shell for mortars or guns without exploding in the bore, but also insures the explosion of the shell at the target.

This filling of the shell—the gun cotton as well as the primer—endures all the shocks produced by the expanding gases in the bore of the gun ; there is no danger whatever that one of the two portions of the filling of the shell will explode prematurely by the shock received, and thus produce an explosion in the bore.

We have proved this by the following experiments :

1. By firing a considerable number of shots (over 200) with gun cotton shells with full charges, from an 8.8 cm. gun, with an initial velocity of 450 m. ;

By firing from the rifled 15 cm. mortar, with an initial velocity of 200 m. ;

By firing from a rifled long 15 cm. gun, with an initial velocity of 400, but in the case of the two last named guns with the 6-caliber steel shells as well as with the ordinary shells.

2. By firing shots with ordinary shells, in which separate parts of the filling were left, the others being omitted, so that every part might be tested separately against various objects.

Besides the immediate practical result, namely, that the shells were fired without exploding in the bore, it was computed in these experiments that the shock experienced by the shell with a high final velocity, in striking a solid object, was very much greater than that which it receives from the expansive powder gases in the bore of the gun. If it can, therefore, endure the former without exploding (*i. e.*, when the plunger, which is to cause the explosion of the shell on striking, is removed), even without separate parts of the charge or of the fuse being changed in form or position, it may be assumed with perfect certainty that it will endure the latter shock in the bore of the gun under all circumstances, and that, even when the plunger is in the fuse, explosions in the bore will not take place, as the plunger is the same as that which has been in use for some time in fuses and found perfectly safe. Besides the plunger, the fuse contains the primer, necessary for the detonation of the gun cotton. In the construction of this primer, which plays a most important part in the experiments with gun cotton shells, we have modified somewhat the form ordinarily used and rendered it particularly safe, and, as shown by the experiments, we have thoroughly tested it under all kinds of circumstances. Besides the primer described in our patent, we used another form, which guarantees all that is possibly required. After a combination of wet and dry gun cotton has been accepted as a charge for shells, the remainder of the question is simply one of a proper fuse, which we found extremely difficult to answer, but believe now to have thoroughly and completely solved.*

* In filling the shell a hollow space is left in the pro-

The experiments, which determined the capability of the charge of our shells to resist the effects of shocks, were as follows:

a. We fired charged shells, from which the plunger, which we consider as having no part in the experiments, had been removed, but which contained the rest of the fuse and the charge of gun cotton, against objects of great resistance at

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longation of the fuse-hole for the priming cartridge, in which is temporarily placed a hollow cylinder. After the paraffine congeals the cylinder is withdrawn and replaced by a tube of thin sheet brass. The diameter of the priming cartridge is the same as that of the fuse-hole. A diameter of 15 mm. and a length of cartridge of 42 mm. give it a weight of 7 grm., which is sufficient for the detonation of the charge. The priming cartridge is provided with a channel 8 mm. in width and 82 mm. deep.

The fuse is a percussion fuse, modified. The case of the fuse is lengthened and the end closed by a screw. In the hollow space, formed in lengthening it, is lodged the primer cap, containing 1 grm. mercuric fulminate. The plunger remains as before. The primer is provided with a strong case, surrounded by an india-rubber cap, to weaken the shocks transmitted to the primer. The primer projects nearly 22 mm. from the fuse, and this projection enters the channel in the priming cartridge.

In the other form of primer used the fuse was not altered, the primer being separate therefrom, and is protected from shocks by means of india-rubber.

short distances.* The shells reached the object with a high final velocity, 420 m.

The targets were earth walls, walls of strong wood, and wooden walls covered with wrought iron rails.

We found that our gun cotton shells endured the greatest striking force against these objects in the highest degree, without exploding, so long as the plunger was left out.

We increased the strength of the wrought iron rails, against which we fired, as much as the strength of the shells would permit, and found as a result that, as long as empty shells were not broken by the striking force, the shells containing gun cotton and primer remained intact also. When the shell breaks on striking the iron, and the parts of the charge, in pressing forward, are brought in direct contact with the iron, producing great friction, the gun cotton generally burns and the primer detonates.

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* We removed the plunger, because we used percussion fuses, which, if the plunger had been in place would have caused the primer to detonate on striking.

Nevertheless, many cases arose in which the shell broke, and the pieces were found 1 meter deep in the wall of the earth behind the rail, without any combustion or detonation of the charge having taken place.

b. Against the same objects we fired shells, which were provided only with the gun cotton charge, or only with the fuse, without the plunger, but with the primer.

The first lot of shells we opened by placing on them a gun cotton cartridge and detonating it; in case the charge of the shells did not also detonate, we were able to show that the separate grains of the charge of gun cotton suffered no compression, but were found perfectly intact, and that no jamming of the charge—either towards the base or towards the head of the shell—had taken place; everything had remained in place.

The last lot of shells, those in which the fuse and primer were present, we filled with peas instead of gun cotton, and with a wet priming cartridge; we opened them after the firing by cutting off the base with a boring machine, and were able to show that the primer had not been detonated.

We fired from the 8.8 cm. gun shells of the ordinary form, but made of steel, under the same circumstances as above described, and obtained very good results, but before making the results public we desire to continue the experiments.

While the experiments with partially charged shells showed that our filling is very safe against shock, the experiments with completely charged shells have shown that the arrangement of the primer functions very well, and that the charge of gun cotton always detonates entirely and with full effect. Partial explosions of the gun cotton charge did not occur in using granulated gun cotton.

The form in which we prefer to use the gun cotton for the charges of our shells is different from the disks of gun cotton heretofore in use.

A shell, filled with gun cotton in the form of disks, is described fully in the work of Lieutenant General Brialmont, "La Fortification du temps présent."

The disk form of gun cotton is not advantageous for the filling of shells, because the shells must be provided with a base or head, screwing off and on, so that the shell may be filled. We therefore prepare the charge of gun cotton not only in the form of disks, but also in the form of grains, so that the filling may take place through the mouth of the shell.

Each separate grain of this "gun cotton powder" has a specific gravity of over 1. The gravimetric density of the gun cotton powder is 0.7; 700 grm. (dry weight) will therefore fill a space of 1,000 c.c.

The grains are rectangular, 8 to 12 mm. in diameter in cross-section, and either cubical or elongated. They are gelatinized, or coated by dipping in acetic ether, and have thereby acquired a compact form, and are prevented from crumbling to dust.

After the grains are poured into the

shell, the latter is filled with melted paraffine, which, after solidifying, converts the whole filling into a solid mass.

In filling the larger shells we use wet grains as the principal part of the charge, adding at the end about 200 grm. dry grains, so as to entirely fill the shell.

In the use of powder of nitrated cellulose as a charge for shells, in the case of most of the different kinds of powder, partial explosions will probably frequently occur, and combustion or the carrying away of a part of the charge will often take place.

Gun cotton and other forms of nitrated cellulose are as a rule more difficult to detonate than is generally supposed.

We made the following experiments:

In a strong wooden chest, lined with tin, we placed uncompressed gun cotton containing 30 per cent. water, and pressed it as compactly as was possible without the use of machinery; the chest had an interior capacity of $\frac{1}{4}$ cubic meter and held 50 kg. gun cotton, dry weight.

A piece of compressed gun cotton, 500 grm. in weight, was placed in this chest, in the center of the wet, uncompressed gun cotton and detonated; the chest and its contents were burst asunder, without causing either a partial explosion or a combustion of the loose gun cotton.

A pile of such gun cotton was placed on the ground, and a piece of compressed gun cotton, 250 grm. in weight, placed on it and detonated; no explosion of the loose gun cotton took place, although it could not avoid the shock of the cartridge.

We must therefore regard loose, wet gun cotton as not belonging to the explosives. In one of its forms, as "collodion cotton," it is transported by the railroads at ordinary rates, and no danger will result to commerce, if compressed, wet gun cotton—which, so far as its properties in this regard are concerned, is nothing else than collodion cotton, although in its use as an explosive it is more advantageous—is transported by rail under the same privileges as collodion cotton. In order to make possible the fulfillment of the requirements, the amount of water now prescribed for collodion cotton must be reduced for compressed gun cotton to 25 per cent., as the latter cannot absorb 50 per cent. water.

Gun cotton with 25 per cent. water is a substance which cannot be exploded by any accidents possible on a railroad.

During the storage at the place where the gun cotton is to be used, the cartridges will dry of their own accord, and can then be detonated with a primer.

It will thus be possible to furnish the smaller purchasers with a suitable sudden explosive, and farmers, for instance, would be greatly benefited thereby, since a sudden explosive may be used with advantage, to blow up rocks and stumps of trees, in the construction of roads and in clearing land.

Uncompressed gun cotton in the dry state burns rapidly, explodes even, but does not detonate, and can, therefore, as is well known, be used as gunpowder.

The same is true of gun cotton powder. It offers, of course, no great resistance to the shock of the priming cartridge, nor does one portion of the powder to another. Gun cotton, itself easily detonated, if it be not in large, heavy pieces, but in small, light ones, will move aside from the shock of the detonated priming cartridge, and will be blown away or only slightly burned.

The finer the powder, the smaller and lighter the grain, the more is it subject to partial explosions and combustion, and the larger must be the priming cartridge, and the greater the degree of confinement of the charge, to produce perfect detonation.

It is very probable that most forms of granulated powder, composed of nitrocellulose in large masses, cannot be brought by practicable means to complete detonation.

The gun cotton manufactured by us at the Walsrode factory behaves differently. In the first place, the grains are not too porous and light, they have the same constitution as the large pieces of pressed gun cotton; in the second place, the grains are not too small, 6 mm. cube is the very smallest size, and we give them even, for reasons connected simply with the manufacture, the greatest possible size, *e. g.*, about 10x10 mm. in cross-section, 25 mm. in length.

In the third place, and this is very important, the paraffine, used to fill up the interstices in the shell, forms with the grains a compact mass, which acts as a whole exactly like a piece of compressed gun cotton.

In general a 1 grm. primer is sufficient for the detonation of this mass, when the grains are completely dry; are they wet or entirely paraffined, a priming cartridge of corresponding weight must be inserted.

While in the case of wet grains formed into a compact mass by inclosing them in the shell and filling up with paraffine, a priming cartridge 35 grm. in weight is sufficient; grains entirely paraffined, as we have seen, require a much heavier and larger priming cartridge; indeed, so large that it can hardly be applied in a shell. In case a 65 grm. priming cartridge is not sufficient, one of 100 grm., although it may produce detonation once in the experiments described, will not always do so with certainty, and combustion and partial detonations will be unavoidable in case of paraffined grains. Moreover, paraffining increases the size of the grains and diminishes, therefore, their gravimetric density.

These reasons, in connection with the decreased chemical stability, render grains entirely paraffined in every way disadvantageous.

In the case of the dry and the wet grains used by us, coated and formed into a solid mass by means of paraffine, a partial detonation never occurs, even when the charge is but very lightly inclosed, *e. g.*, in a box of thin tin, as shown by our previously described experiments, and as must be evident from the nature of the case.

It is unavoidable by using grains that

the weight of the charge is somewhat less than when disks of the same specific gravity as the grains are used, but our experiments have shown that the difference in effect of the two kinds of gun cotton is not great.

On the other hand, the filling of shells with granulated powder carries with it the advantage of much greater strength in shells made in one piece over shells composed of two parts, or, in case strength of shell is not particularly required, the possibility of making the walls of a steel shell thinner, or of making the shells of cast iron, even if not six calibers long, at least longer than ordinary shells, since cast iron always furnishes a sufficiently strong material for shells made in one piece. In this way a shell will be obtained especially effective and at the same time cheap, the only means of insuring the employment of gun cotton for shells to the greatest, and, as it appears to us, judging from its limited use, necessary extent.

Granulated gun cotton has, furthermore, the valuable property of supplying a material proper for all kinds of shells, no matter of what caliber or kind. Granulated gun cotton can be used in all sorts of shells.

The advantage offered by this universal explosive, as compared with gun cotton disks, which require for every kind of shell a different size, need not be dwelt upon; the effort to obtain ammunition of general application is sufficiently well known and regarded as indispensable.

Moreover, granulated gun cotton will permit the supply of steel and cast iron shells now on hand, which were designed for charging with gunpowder, to be converted into gun cotton shells, and thus give them not only a higher explosive power, but also so increase the number of pieces resulting from the explosion, that their effect must be exceptionally great.

The number of pieces resulting from the explosion of artillery projectiles has been increased, as is well known, by forming the interior core of the shell of many parts, which are held together by the outer wall of the shell, and also by constructing shrapnel; the former method can be used in but few kinds of shells, and therefore an increase in the number of pieces resulting from explosion, in the case of most of the ordinary shells now on hand, is greatly to be desired. The second method for obtaining a large number of pieces by the explosion, the use of shrapnel, has the disadvantage of requiring a number of special kinds of projectiles, and it is well known that we would gladly give them up if a good substitute could be obtained in some form of shell.

The cast iron shell, filled with granulated gun cotton, offers, in this respect, great advantages, at least for the ammunition of fortification and siege guns, for it is not to be expected that gun cotton shells will be introduced in field artillery.

The following experiments present some idea of the number of fragments obtainable in the explosion of ordinary shells.

We exploded the shells in a space, specially constructed for the experiments, well closed, built of masonry and covered on the inside with boards, but containing an exit for the gases resulting from the detonation, to diminish the explosive force, and obtained:

From a cast-iron 8.8 cm. shell, weighing 7 kg., filled with ordinary gunpowder,
37 fragments, weighing in toto 6,160 grm.
Filled with granulated gun cotton,
200 fragments, each weighing over 10 grm.
600 " weighing from 1 to 10 grm.
From an 8.8 cm. steel shell weighing 6,640 grm., filled with granulated gun cotton,

23	fragments,	weighing	in toto	2,260 grm.
127	"	"	"	2,865 "
150	"	"	"	5,125 "

From a cast-iron 15 cm. shell, weighing 27 kg., filled with ordinary gunpowder,
42 fragments.
Filled with granulated gun cotton,
376 fragments, each weighing over 10 grm.
828 " weighing from 1 to 10 grm.

A large part of the cast-iron shell is broken into very small fragments. Pieces less than 1 grm. in weight have not been considered in our estimation, although they are entitled to consideration, as most of them received from the explosive charge alone so much energy that they penetrated boards 25 mm. thick, and, evidently, in actual practice against troops, some effect would still be produced by them. As regards fragments over 10 grm. in weight, which have sufficient energy for proper effect even at considerable distances, the charge of granulated gun cotton was nine times as effective as the charge of gunpowder—certainly a remarkable result.

Moreover, gun cotton shells, unless provided with a slow fuse to delay explosion, possess the special property of bursting immediately after the first impact, not after an appreciable time, as is the case with gunpowder shells.

We made the following experiments in this connection:

a. Two targets made of boards 40 mm. thick were placed, one behind the other, $\frac{1}{8}$ m. apart. A gun cotton shell penetrates the first target and bursts between this and the second.

b. A target of boards, 4 square meters in area, was fired at with an 8.8 cm. cast-iron shell, in such a way that the shell struck the ground 2 m. in front of the target. The shell burst before reaching the target, which was penetrated by 135 fragments.

c. Two targets, as above described, but separated by 2 m., were fired at by an 8.8 cm. powder shell so as to strike the center of the targets.

The shell pierced both targets and burst only in rear of the second in an earth wall.

The powder shell had the same percussion fuse as the gun cotton shell; the later bursting of the former cannot therefore be due to the fuse, as heretofore always assumed, but to the slower development of the powder gases of the charge, as compared to the gun cotton gases.

The property of gun cotton shells of bursting in this way at the first moment of impact, must give them, in a variety of cases, many advantages over gunpowder shells, *e. g.*, in the destruction of objects into which the shell cannot penetrate, such as heavy armor or solid masonry, when the shell strikes obliquely, in which case it will be deflected if charged with gunpowder and have no explosive effect, and also in case of objects which are so easily penetrated that the gunpowder shell will burst too late and generally behind them, such as gun-carriages, caissons and other wagon material.

By inserting a slow-burning composition in the fuse, by which the primer is detonated some time after the shock of striking, or by means of a time fuse, the bursting of the gun cotton shell may be delayed for any length of time. This delay will be necessary in the case of the bombardment of fortifications protected by an earth covering, in order that the latter may be penetrated before the shell bursts.

From data obtained at the cast-steel works of Friedr. Krupp, relating to experiments with guns and projectiles, we quote the following, as they appear to us to indicate in what cases a gun cotton shell may be of use.

Gun: 15 cm. gun, 35 calibers long.

Projectiles:

Kind.	Length of Projectiles.		Total weight, (including charge) kg.	Charge. kg.
	mm	calibers		
Steel armor shell........	500	3.35	51	1.5
Cast-iron ordinary shell.	596	4	51	3.4
Cast-steel ordinary shell.	670	4.5	51	6.2

Mortars are used for purposes other than those for which guns are designed, and the projectiles should be constructed with this difference in application in view. In general, the walls of the mortar projectiles may be much thinner than those of the projectiles used in guns, since the pressures of the gases in the bores of the respective pieces are as 1 : 2. Mortars are used exclusively for firing with great elevations.

They are intended:

1. To remove earthworks.

2. To fire on troops posted behind cover.

3. To destroy coverings.

1. In order *to remove earthworks* shells are required which penetrate as deep as possible before bursting, which hold a large charge and which possess the requisite strength, so that the powder may be consumed as completely as possible before the beginning of the explosive effect.

High elevations and percussion fuses, the action of which is delayed, must be employed. Cast-iron shells are less suitable for this purpose, as they must necessarily have thick walls, and can therefore contain only comparatively small bursting charges, and offer, besides, too little resistance to the gases of the charge, so that the bursting takes place before all the powder is consumed. Steel shells are much more effective in this case, because they are free from these objections.

If it be not desired to fire with full charges in the piece the walls of the steel shell may be made very thin. To obtain the normal total weight, the length may be increased. In this way we arrive at shells with great bursting charges, the so-called torpedo shells.

2. *To fire on troops behind cover* shrapnel are used.

3. *Destruction of coverings.* While in firing on earthworks, it is necessary to delay the action of the percussion fuse, in order to obtain great penetration before explosion, in firing on coverings it is desirable to have the explosion take place instantly after striking, because otherwise the projectile will burst in ascending arc, and the effect of explosion for the purpose sought will be lost. As is well known, it has not been possible to overcome this difficulty. This object can hardly be attained in a satisfactory manner, because, even with the most delicate fuse, a certain amount of time elapses and must necessarily elapse, be-

tween the striking and the bursting of the shell.

We deduce from these data the following:

The armor shells are capable of containing only a small charge, and the effect of even the largest calibered steel armor shells, with an initial volocity of 500 m. and more, obtained by the use of brown powder, will not be very greatly increased by ever so energetic à bursting charge, but still it will be increased, and at least clear out the opening produced by the shell.

The cast-iron and cast-steel shells contain a sufficiently large charge to produce the requisite effect.

The torpedo shell is the form most suitable for the application of gun cotton.

To remove earthworks the gun cotton shell is valuable, as its effect in earth is greater than that of the gunpowder shell. A delay in the action of the fuse is easily obtained.

To break down coverings the gun cotton shell is essential, as it alone can attain the object sought, namely, the condition that the shell must burst in striking; the gunpowder shell can never attain this object, since its bursting after striking must be ascribed, not to the fuse, but as first shown in our experiments,* to the gunpowder charge.

Even the cast-iron shells will be considerably improved by the gun cotton charge, since the slight resistance which they offer is not detrimental, and the thick walls, and consequent smaller charge, is not such a great disadvantage, considering the much greater energy of gun cotton.

But a steel shell with thin walls is always to be preferred.

As regards shrapnel, we remark that they may perhaps be entirely superseded by the cast-iron gun cotton shell, since the latter, as our experiments have shown, gives as great a number of pieces by explosion as shrapnel.

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* Experiments *a*, *b* and *c*, a few pages preced n.

We repeat that the ordinary cast-iron 15 cm. shell, filled with granulated gun cotton, gave

376 fragments, each over 10 grm. in weight.
823 " between 1 and 10 grm. in weight.

We hope that Mr. Fried. Krupp with the extensive means at his disposal in his establishment, will soon begin experiments with gun cotton shells, since it is evident that they are capable of at least supplying many very delicate wants in the effects of explosives. If they can offer advantages on account of a difference in the trajectory at the target, as we have seen to be the case in discussing their property of bursting instantly on striking, the question of obtaining a more energetic charge for shells than gunpowder is of the greatest importance, even if not in the same degree for all kinds of projectiles, and this question must come up for solution in the near future.

Should Mr. Krupp undertake the experiments, we are convinced that he will solve this, as he has all other questions relating to artillery that have come under his notice, in a brilliant manner, and if we, with our gun cotton factory, with our knowledge of explosives and of gun cotton in particular, derived from years of experience, can be of any service, we are always at his disposal.

Interesting cases, in which gun cotton shells may be used, are found in Major Schumann's work on armored gun carriages, in which it is stated:

"In England was adopted a method of armoring for sea-coast fortifications according to the so-called Sandwich system, a combination of 3 to 5 plates, generally 15 to 16 cm. thick each, with layers of wood between.

With the latest steel shells, which have been so greatly improved, it is to be expected that the penetration into the different layers will be sufficient to cause them, if charged with sudden explosives, to act with disastrous effect on the entire system.

The penetration of projectiles in massive forged iron armor, 40 to 60 cm. thick, will evidently be much less. There is, however, in case the plates are very soft, and therefore little inclined to crack, a not unimportant increase of effect to be expected from charges of sudden explosives, at least in case of those shots which strike near the edges of the plates.

The two latest improvements in projectiles join hands here.

The Krupp shells, which are made of excellent material and forged under the hammer over a mandrel, receive such a degree of toughness by this method of manufacture that they are stronger than solid shot. Their hardness is increased to such a degree that a projectile from the 15 cm. gun, 35 calibers long in the bore, for instance, penetrated two plates, each 18 cm. thick with a layer of wood, [illegible] cm. thick, between, and showed but a single slight alteration, in that the point was abraded about 1 mm.

The second improvement consists in

the use of sudden explosives in charging the shells, the hardness and strength of which allow them to penetrate sufficiently deep in vertical, soft forged iron plates, to make use of at least a part of the explosive effect of sudden explosives. In cases, therefore, where such armor plates can be struck with velocities which admit of the sufficiently deep penetration of such projectiles in soft forged iron, to allow sudden explosives to act with effect, means will have to be devised to prevent this penetration.

Examples of armor plates which may be struck directly are:

a. Armored ships.

b. Armored sea-coast fortifications.

c. Armored turrets in land fortifications.

The Schumann method of construction consists in preventing direct impact on the armor of land fortifications, with armor shells fired from long guns, by building the turret in the form of an umbrella, the armor plate of which the shells cannot strike in a direction perpendicular to the surface. They will strike at an acute angle and glance off without effect. The effect of explosion can be the only one that can act, but this will be too late, as the shell bursts too late, whether it be a gunpowder or a gun cotton shell."

From these constructions of Major Schumann it appears that he expects important results from the use of sudden explosives as a charge for armor shells, and we add, in reference to the technical construction, the following:

In case gun cotton, as a charge for armor shells, which therefore penetrate into the armor, detonates directly from the shock of the shell in striking the armor plate, and this without fuse and without primer—we do not doubt that the dry priming cartridge will partially burn or explode, the only question is, will it detonate in such a way as to cause the wet gun cotton to detonate at the same time?—then it will detonate before the shell has exerted its full energy, hence too soon. The development of the detonation of gun cotton as compared to that of gunpowder is, as we observed, instantaneous, and this will be true whether it is caused by the primer or by the shock.

A fuse, even a slow one, in projectiles which strike armor plate perpendicularly and penetrate into it, will break, hence no effect can be expected from delaying the bursting by making the fuse a slow one.

In case dry gun cotton is detonated by the shock, the bursting of the shell will take place too early; in case it does not detonate, but only takes fire and undergoes partial combustion, it would be possible—by arranging the primer in the shell so that it is not detonated too early by the shock in the bore of the gun and cause bursting in the bore—to delay the bursting of the shell, and the events taking place in the shell would succeed each other as follows:

The primer would be detonated by the burning dry gun cotton, and cause that part of the dry gun cotton which is not yet consumed to detonate.

Similar relations may be obtained by placing a primer in a piece of dry gun cotton, provided with a recess for the purpose, and igniting the piece of gun cotton at any point. In a large number of experiments, which we personally conducted, the gun cotton was always caused to detonate after ignition, and by the combustion in conjunction with the primer.

In shells we found the action similar.

We believe, moreover, that, by a special construction and application of the primer, it will be more difficult to cause it to detonate than to cause dry gun cotton to burn.

On the other hand, there is no danger whatever that, when the dry gun cotton begins to burn, the shell will burst before the primer is detonated.

It is therefore quite possible to make an armor shell, containing wet and dry gun cotton and a primer, but without a fuse, burst at the proper time, hence not too early, since the development of the flame of dry gun cotton and the transmission of the flame to the primer will require a certain amount of time.

We do not know whether this has been determined by experiments, but it is clear that in case of shells which do not penetrate into the armor plate, and are not designed to, the relations are much more favorable. These shells would be provided with as great a charge as possible, and with a fuse, of course not a slow one.

The shell will either strike the armor plate at an acute angle and glance off—in which case it will burst, contrary to the view of Major Schumann, quite close to the armor plate—or it will strike perpendicularly, so that it will be crushed or flattened, and thus in all cases be detonated, and at the proper time for the charge to act with full effect, since it bursts immediately after impact.

We believe, too, that the Schumann armored constructions are not safe against the effect of gun cotton shells as they are against gunpowder shells, and that therefore gun cotton shells will be of service against all kinds of armored constructions.

We return to the object of our experiments with gun cotton shells, viz., that, in opposition to the propositions to use a dynamite cartridge, thrown by means of compressed air from the bore of a gun, and in opposition to many other propositions, and the application of apparatus already on hand, to throw projectiles filled with sudden explosives, in all of which uncommon, complex and very expensive apparatus, difficult to transport, is required, we propose to fire at great ranges the ordinary shell as a gun cotton shell, specially provided with our mode of arrangement, from ordinary guns and mortars, with the gunpowder charges now in use. We lay particular stress on the simplicity of the application of our gun cotton shells, and, according to our view, we must add that, under all circumstances, at least on land, nothing should ever be used as a moving force for projectiles but the most compendious and cheapest source of such power—gunpowder.

Our constructions relate only to the filling of the shells now in use with gun cotton; no change of material other than the charge of the shell takes place; even the weight of the filled shell remains unchanged.

These results we have obtained:

1. By the manufacture of a special, new and effective granulated gun cotton.

2. By means of a special arrangement for filling the shells, viz., by filling out the interstices with paraffine.

3. By the construction of a suitable primer.

We are convinced that the gun cotton shell will be of great service, even if it will not accomplish wonders.

The effect of sudden explosives is overrated; on a small part of a heavy armored plate, for instance, one cannot obtain nearly the same effect with ever so energetic a sudden explosive as may be obtained with a steel shell from a 30 cm. or 40 cm. gun, but in the first place there are but few such guns, and in the second place they cannot be moved about on land. On land and in the attack and defense of fortifications the limit of producing increase in effect by increasing the caliber is soon reached, and nothing remains but to increase the effect of explosion, and we believe that shells containing sudden explosives will play an important part in the future, although they will not accomplish all that is expected by those who overrate the possibilities in the case; but just because these shells will not work wonders, we are of opinion that the sudden explosives must be applied so as not to alter the artillery material.

We submit these lines to the indulgent reader with the assurance that, although we have said much *pro domo*, we have also endeavored to carry out the experiments without prejudice and to draw the conclusions in the same spirit.

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