ENGINEER DEPARTMENT, UNITED STATES ARMY.

PROFESSIONAL NOTES

BY

CAPTAIN EDWARD MAGUIRE,
CORPS OF ENGINEERS, U. S. A.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1884.

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Office of the Chief of Engineers,
United States Army,
Washington, D. C., May 20, 1884.

Sir: Capt. Edward Maguire, Corps of Engineers, has submitted to this office a short series of papers containing information procured by him while on leave of absence in Europe during the summer of 1883.

The papers contain information which it is thought will be useful to officers of the Army generally, and I respectfully recommend that authority be granted to have them printed, with the accompanying plates, at the Government Printing Office, and that 1,000 copies be obtained for the Engineer Department upon the usual requisition.

The papers are transmitted herewith.

Very respectfully, your obedient servant,

John Newton,
Chief of Engineers, Brigadier and Brevet Major General.

Hon. Robert T. Lincoln,
Secretary of War.

Approved.

By order of the Secretary of War:

John Tweedale,
Chief Clerk.

War Department, *May* 28, 1884.

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United States Engineer Office,
Buffalo, N. Y., December 24, 1883.

General: I have the honor to forward herewith a short series of papers containing information procured by me while on leave of absence in Europe during last summer.

I submit them simply as possible additions to the professional notes collected in the office of the Chief of Engineers. The subjects of which they treat were interesting to me, and I hope may prove so to some one else.

I found that an officer traveling in Europe without official letters has but few opportunities of seeing or learning anything of military or any other governmental work.

I am indebted for politeness to Geheim-Finanzrath Claus Köpcke and to Wasserbau-Director M. W. Schmidt, of Saxony; to Capt. I. Trauzl, formerly of the Austrian Engineers, and to the secretary of the American legation at Paris. To our minister to Austria, Judge Alphonzo Taft, I am particularly indebted for great courtesy. He did all that he could to assist me in making my visit to Vienna profitable and pleasant.

Very respectfully, your obedient servant,

Edw. Maguire,
Captain of Engineers, U. S. A.

To the Chief of Engineers, U. S. A.,
Washington, D. C.

PERFORATION OF ARMORED WALLS.

[From the French of M. Rodier, capitaine d'artillerie de la marine, 1882.]

The English and French formulæ for the perforation of armored walls are given in Vol. III of the Mémorial de l' Artillerie de la Marine, 1875, pp. 84 *et seq.*

They are accompanied by—

(1.) Tables containing numerical data and results of computations, which are useful for solving problems relating to the perforation of walls.

(2.) Three plates of curves giving graphical solutions of a great number of problems.

(3.) Numerous examples of the use of the curves and tables.

Since that time numerous experiments have been made in France by the Department of the Marine and progress has been made. At the Polygon of Gavre the thickness of wrought-iron plates, which in 1875 did not exceed 30 centimeters, has since attained 44 centimeters, and in the firings the ratio of the thickness of the plate to the diameter of the projectile has risen from 1 to 1.5. Furthermore, guns of greater caliber than those employed up to that time have been adopted. Finally, metallurgical industry has made great advances in the manufacture of plates as well as in that of projectiles.

The new conditions of fire against armored walls have led Mons. Hélie to modify somewhat the constants of the formula for perforation in use at Gavre, and so the curves and tables mentioned above are no longer entirely in accordance with the actual state of things; furthermore, they are not sufficiently extended, to be serviceable in every case which may arise in consequence of the increase in the caliber of the guns and in the thickness of the plates.

We will give, under a new and simple form, tables, to replace the former ones, deduced from the results of the most recent experiments at Gavre, and which apply to all thicknesses of plates and all calibers of guns actually in use.

The following will explain the method pursued in the calculations of the tables.

It is known that the various formulæ for the perforation of isolated plates, of backed plates, and of even wood walls may be placed under the following form:

$$\frac{p\ V^2}{a} = K.\ E^x$$

in which—

p	= the weight of the projectile.
V	= that component of the velocity of the projectile which is normal to the plate at the point of impact.
a	= the diameter of the projectile.
E	= the thickness of the plate.
K and x	= two quantities to be determined by experiment and which depend upon the form of the head of the projectile, and on its quality as well as upon the quality of the plate.

If, now, we represent by n the ratio of the weight of the projectile to that of a spherical shot of the same caliber, the formula becomes

$$n\ V^2\ a^2 = K'\ E^x$$

from which we see that with reference strictly to the perforation of plates of the same thickness,

(1.) *For projectiles having the same form of head the product* $\sqrt{n}\ Va$ *is constant.*

(2.) *For similar projectiles* (n *constant*) *the product* Va *is constant; that is to say, the velocity is inversely proportional to the caliber.*

It is, then, evident that if in a table we write in the first column the increasing thicknesses of the plates, and opposite to them the velocities necessary for a projectile of 1 decimeter, for example, to perforate plates having those tabular thicknesses, we may by simple divisions obtain the velocities necessary for a similar projectile of any caliber whatever to perforate the same thicknesses.

Conversely, knowing the thickness of the plate and the caliber, we may obtain the velocity.

We may also just as simply obtain the caliber, knowing the velocity.

That being the case, we will examine, in reference to the ogivo-cylindrical projectiles of the Navy, which may be considered as similar, the case of different walls which may be encountered, and we will give for each an example of the use of the tables, so as to pass in review the different problems which may present themselves for solution.

But first we will recall the two following hypotheses, verified by experiments at least within the limits of practice, and which are useful for the solution of problems of perforation.

(1.) The resistance of a wall is independent of the velocity of the projectile, so that the perforation should in all cases absorb the same amount of living force. Thus V being the velocity of impact, W the velocity necessary strictly for perforation, U the velocity remaining after the perforation, we have

$$V^2 = W^2 + U^2.$$

(2.) When a shot having a velocity, V, strikes a wall in a direction making with the normal an angle, i, the normal component of the velocity is $V \cos. i$. If V' be the normal velocity necessary strictly for perforation, the shot will pass through the wall only when

$$V \cos. i > V'.$$

In what is to follow, weights will be expressed in kilogrammes, velocities in meters, the thicknesses and diameters in decimeters.

We may, without appreciable error, substitute for the diameter of the shot the caliber of the gun.

Finally we will assume $N = 2.80$. It is generally assumed, it is true, that the weight of the ogival projectile is three times that of the spherical shot of the same caliber, the latter being the ordinary cast-iron shot of an average density of 7.1. That is true for medium calibers if we suppose the spherical shot to have a windage equal to that formerly assumed for spherical shot of smooth-bore guns. But if we suppose the diameter of the spherical shot to be exactly equal to the caliber of the gun the ratio of the weights descends from 3.0 to 2.80.

In what follows steel or compound armor will not be considered, the data at hand, even at the present time, not being sufficient for the deduction of a law of penetration.

1. Unarmored wood walls.

The first experiments made at Gavre with ogival shot on an oak wall and with a 14-centimeter gun, gave rise to the following formula:

$$\frac{p\,U^2}{a} = 9025\ E^2,$$

which is still used by the Commission of Gavre.

Applying this formula to the 10-centimeter gun, and assuming $p = 2.80$ times the weight of a spherical shot of the same caliber, we have

$$U = 29.44\ E.$$

Table No. 1 contains for every 5 centimeters of the value of E, from 1 to 12 decimeters, the corresponding values of U and U^2.

Examples of the use of Table No. 1.

(1.) Required the caliber of the ogival projectile capable of strictly perforating, in a normal direction, with a velocity of impact of 350 meters, a wood wall 8 decimeters thick.

Let a be the caliber sought expressed in decimeters.

According to the table the wall in question is perforated by the projectile of 1 decimeter caliber, when the latter has a normal velocity of 235.5 meters.

We have, then,

$$a \times 350 = 235.5 \times 1$$
$$a = 0.673 \text{ decimeter.}$$

(2.) Required the velocity necessary for a 24-centimeter ogival projectile to perforate normally and successively two wood walls 70 and 90 centimeters thick, respectively.

The velocities U' and U'' necessary for the 1-decimeter projectile to pass through each of those walls are given in Table No. 1.

To successively pass through the two walls that projectile should have a velocity given by the formula

$$U = \sqrt{U'^2 + U''^2}$$

since the living force expended in the passage is independent of the velocity.

Hence it results that the 24-centimeter projectile requires a velocity

$$x = \frac{\sqrt{U'^2 + U''^2}}{2.4}$$

As Table No. 1 contains the values of U^2 the result is almost immediate, and we find

$$x = 140 \text{ meters.}$$

(2.) Wrought-iron armor plates.

It is a well known fact that the depth of penetration of a projectile in a medium of very great thickness is less than that thickness of the same medium which can be strictly perforated by the same projectile. For this reason, in determining the thickness to be given to an earthen parapet, it is a generally admitted rule that the thickness should be 1.5 times the penetration in the earth forming the parapet. The thickness to be given to wood walls in order that the projectile may be completely arrested is $1\frac{1}{3}$ times the penetration of that projectile.

It is known, further, that the living force necessary for a projectile to perforate a plate with a backing is greater than the sum of the living forces required for the perforation of each separately.

In firing at an armored wood wall it is difficult to determine exactly the increase of resistance due to the union of the plate and backing; but generally the resistance of the wood is very small in comparison to that of the armor, and we may, with sufficient accuracy, assume as the resistance of the plate the difference between the total resistance of the wall and the known resistance of the wood-backing supposed isolated.

That is the method constantly employed by the Commission of Gavre.

Assuming such to be the case, now, if we consider armored wood walls, the resistance of which has been determined at Gavre, and after having deducted the resistance of the backing, we calculate the coefficients K and x of the formula

$$\frac{pV^2}{a} = K \cdot E^x$$

We may form the following table:

Thickness of plates in decimeters	1.2	1.5	2.0	2.2	2.5 and 3.0
Values of x	1.71	1.58	1.44	1.40	1.36
Values of $\frac{K}{10^3}$	2.335	2.371	2.654	2.371	2.757

Monsieur Hélie satisfied these different results by the following formula:

$$\frac{p\ V^2}{a} = 2755600\ E^{\frac{4}{3}}$$

But the results since obtained with the 44-centimeter plate have led to a slight modification of the coefficients and to assuming definitively

$$\frac{p\ V^2}{a} = (1635)^2\, E^{1.4}$$

Assuming as before $a = 1$ decimeter and $p = 2.80$ times the weight of a spherical shot of the same caliber, we shall have

$$V = 506.7\ E^{0.7}$$

by means of which we have calculated Table No. 2.

It happens sometimes that the armor consists of several superposed plates. Let E', E'', E''' be the thicknesses of the plates composing the armor, V', V'', V''' the velocities with which the projectile perforates each plate supposed isolated, V the velocity which the projectile should have to perforate the armor.

Assuming that the living force necessary for the perforation of the armor is equal to the sum of the living forces necessary for the perforation of each of the individual plates, we shall have

$$V^2 = V'^2 + V''^2 + V'''^2$$

But this expression will give too small a value for V, for the reason that no account is taken of the relations which in an armored wall exist between the different parts; if those relations are unimportant in so far as they concern the backing or the thin iron plates which form the frames on account of their feeble resistance, such is not the case when we consider the plates themselves.

In the most ordinary case the armor is composed of only two plates; the comparative experiments made at Gavre with 32-centimeter projectiles on 44-centimeter plates and on two 22-centimeter plates united by a system of bolts supply the data for calculating the thickness of a single plate, equivalent to a system of two superposed plates.

Let

E', E'' = the thickness of the two plates
E = the thickness of the single plate.

Monsieur Hélie, taking the results of the above-mentioned experiments, deduced the following formula:

$$E = (E' + E'')\left(1 - 0.102\,\frac{E''}{E'}\right)$$

which is to be used for the case of an armor formed of two superposed plates.

Examples of the use of Table No. 2.

(1.) Required the thickness of a wrought-iron plate which can be strictly perforated by a 42-centimeter ogival projectile, having a normal velocity of impact of 455 meters.

This 42-centimeter projectile should have the same perforative force as a 10-centimeter projectile having a velocity,

$$V = 455 \times 4.2 = 1911 \text{ meters.}$$

Table No. 2 gives 67 centimeters as the thickness sought.

(2.) Required the velocity of impact necessary for a 27-centimeter ogival projectile to pierce a 20-centimeter wrought-iron plate under an angle of incidence of 30°.

For a 1-decimeter projectile this velocity is equal to—

$$823 \times \frac{1}{\cos.\ 30^\circ} = 960.1.$$

We have then the equation

$$x \times 2.7 = 960.1.$$

Hence

$$x = 355 \text{ meters.}$$

(3.) Required the thickness of a single plate having the same resistance as three superposed plates of the respective thicknesses of 30 centimeters, 20 centimeters, and 20 millimeters.

We commence by determining, by means of the formula given above, the thickness of a single plate having the same resistance as two plates of 30 centimeters and 20 centimeters thickness, respectively. The calculation gives 4.66 decimeters as the required thickness.

According to Table No. 2 the 10-centimeter shot should have a velocity of 1,488 meters to pierce a plate of 4.66 decimeters, and a velocity of 164 meters to pierce a plate of 20 millimeters thickness.

Let V represent the velocity necessary for the same projectile to perforate the system of the three plates, and we have without sensible error, on account of the comparatively feeble resistance of the third plate,

$$V^2 = (1488)^2 + (164)^2 = 2241040,$$

and hence

$$V = 1497 \text{ meters.}$$

From Table No. 2 we see that a 47-centimeter plate is equivalent to an armor composed of the three plates of 30 centimeters, 20 centimeters, and 20 millimeters thickness.

3. Armored walls.

The resistance of an armored wall being equal to the sum of the resistances of its component parts, we may by means of the tables which give the resistances of the different parts, obtain the total resistance of the wall.

Among the different armored walls in use at Gavre there is a type known specially as the "Gavre Wall," and which consists of a wood wall 84 centimeters thick, protected by armor plates. This wall is one of the strongest and most frequently used in the experiments.

It has been deemed advisable, therefore, to calculate by means of Tables Nos. 1 and 2 a third table (No. 3) of perforations of this wall for every centimeter of thickness of plates from 1 decimeter to 1 meter by a 1-decimeter projectile whose weight is 2.80 times that of a spherical shot of the same caliber.

The velocities thus calculated will generally be a little greater than those necessary for the perforation of armored walls with wood backing assembled and framed in iron under the condition of taking into account the thickness of the frame. Consequently the use of Table No. 3 may be extended to the armored sides of ships without fear of underestimating. It may be extended also to walls whose armor is formed of several plates directly superposed or separated by a wood filling, but in those cases it will be necessary to substitute for the superposed plates the single plate which has the same resistance.

Examples of the use of Table No. 3.

(1.) Required the velocity necessary for a 37-centimeter ogival projectile to perforate a ship's side protected by a 45-centimeter wrought-iron plate.

According to Table No. 3 the 1-decimeter projectile requires for this perforation a velocity of 1,473 meters. The velocity sought is then

$$\frac{1473}{3.7} = 398.1 \text{ meters.}$$

(2.) Required the thickness of armor of a wall which will be strictly perforated in a normal direction by a 37-centimeter projectile having a velocity of 398 meters.

The thickness is that corresponding to a velocity of $398 \times 3.7 = 1473$ meters for a 10-centimeter shot, that is to say, according to the table, 45 centimeters.

(3.) Required the velocity necessary for a 34-centimeter ogival projectile to perforate normally an armor of superposed plates of 30 centimeters, 20 centimeters, and 20 millimeters thicknesses.

We commence by determining, by the process indicated in the preceding paragraph (third example), the thickness of a single plate having the same resistance as the three plates. The calculation gives 47 centimeters as the thickness sought.

According to Table No. 3 the velocity necessary for the 10-centimeter projectile to perforate a wall whose armor is 47 centimeters thick, is 1,517 meters. The velocity sought is then

$$\frac{1517}{3.4} = 446.2 \text{ meters.}$$

The tables are calculated for the oblong projectiles in use in the French Navy, whose weights are on an average 2.80 times those of spherical shot of the same calibers, but they may easily be extended to all oblong projectiles of any weight whatever by means of the remark given above.

"1. *For projectiles having the same form of head the product* $\sqrt{n}\ Va$ *is constant.*"

The product $\sqrt{n}\ Va$ being in effect constant for the same thickness of plate perforated, it results that, to solve the problem, it is sufficient to consider the projectile as one of those in use in the French Navy, and then multiply the result thus obtained by $\sqrt{\frac{2.8}{n}}$ if it be a question of velocity or caliber. If, on the contrary, it be a question of thickness of wall, we must first multiply the velocity by $\sqrt{\frac{n}{2.8}}$ and then make use of the tables as if we had to do with a French naval projectile.

In order to facilitate the calculations by a rapid determination of n, we have given in Table No. 4 the weights of spherical shot for each centimeter of caliber from 10 to 45 centimeters.

In order to calculaté the penetration of a projectile for any range we must determine its velocity of impact at that range, and for that purpose must make use of the tables or formulæ for remaining velocities.

TABLE No 1.—WOOD WALLS.

Values of E, in decimeters.	Values of U, in meters.	Values of U^2, in meters.	Values of E, in decimeters.	Values of U, in meters.	Values of U^2, in meters.
1.0	29.44	867	7.0	206.1	42,477
1.5	44.16	1,950	7.5	220.8	48,752
2.0	58.9	3,467	8.0	235.5	55,460
2.5	73.6	5,417	8.5	250.2	62,600
3.0	88.3	7,800	9.0	264.9	70,172
3.5	103.0	10,609	9.5	279.7	78,232
4.0	117.7	13,853	10.0	294.4	86,671
4.5	132.5	17,556	10.5	309.1	95,543
5.0	147.2	21,668	11.0	323.8	104,846
5.5	161.9	26,211	11.5	338.5	114,582
6.0	176.6	31,187	12.0	353.2	124,750
6.5	191.3	36,596			

TABLE No. 2.—WROUGHT-IRON ARMOR-PLATES.

Values of E, in decimeters.	Values of V, in meters.	Values of V^2, in meters.	Values of E, in decimeters.	Values of V, in meters.	Values of V^2, in meters.
0.1	51	2,601	5.1	1,585	2,512,225
0.2	164	26,896	5.2	1,607	2,582,449
0.3	218	47,524	5.3	1,628	2,650,384
0.4	267	71,289	5.4	1,650	2,722,500
0.5	312	97,344	5.5	1,671	2,792,241
0.6	354	125,316	5.6	1,692	2,862,864
0.7	395	156,025	5.7	1,713	2,934,369
0.8	433	187,489	5.8	1,734	3,006,756
0.9	471	221,841	5.9	1,755	3,080,025
1.0	507	257,049	6.0	1,776	3,154,176
1.1	542	293,764	6.1	1,797	3,229,209
1.2	576	331,776	6.2	1,817	3,301,489
1.3	609	370,881	6.3	1,838	3,378,244
1.4	641	410,881	6.4	1,858	3,452,164
1.5	673	452,929	6.5	1,878	3,526,884
1.6	704	495,616	6.6	1,898	3,602,404
1.7	736	541,696	6.7	1,918	3,678,724
1.8	765	585,225	6.8	1,939	3,759,721
1.9	794	630,436	6.9	1,959	3,837,681
2.0	823	677,329	7.0	1,978	3,912,484
2.1	852	725,904	7.1	1,998	3,992,004
2.2	880	774,400	7.2	2,018	4,072,324
2.3	908	824,464	7.3	2,037	4,149,369
2.4	935	874,225	7.4	2,057	4,231,249
2.5	962	925,444	7.5	2,076	4,309,776
2.6	989	978,121	7.6	2,096	4,393,216
2.7	1,015	1,030,225	7.7	2,115	4,473,225
2.8	1,042	1,085,764	7.8	2,134	4,553,956
2.9	1,068	1,140,624	7.9	2,153	4,635,409
3.0	1,093	1,194,649	8.0	2.172	4,717,584
3.1	1,119	1,252,161	8.1	2,191	4,800,481
3.2	1,144	1,308,736	8.2	2,210	4,884,100
3.3	1,168	1,364,224	8.3	2,229	4,968,441
3.4	1,193	1,423,249	8.4	2,248	5,053,504
3.5	1,218	1,483,524	8.5	2,266	5,134,756
3.6	1,242	1,542,564	8.6	2,285	5,221,225
3.7	1,266	1,602,756	8.7	2,304	5,308,416
3.8	1,290	1,664,100	8.8	2,322	5,391,684
3.9	1,314	1,726,596	8.9	2,340	5,475,600
4.0	1,337	1,787,569	9.0	2,359	5,564,881
4.1	1,360	1,849,600	9.1	2,377	5,650,129
4.2	1,383	1,912,689	9.2	2,395	5,736,025
4.3	1,407	1,979,649	9.3	2,414	5,827,396
4.4	1,429	2,042,041	9.4	2,432	5,914,624
4.5	1,452	2,108,304	9.5	2,450	6,002,500
4.6	1,475	2,175,625	9.6	2,468	6,091,024
4.7	1,497	2,241,009	9.7	2,486	6,180,196
4.8	1,519	2,307,361	9.8	2,504	6,270,016
4.9	1,541	2,442,969	9.9	2,522	6,360,484
5.0	1,563	2,374,631	10.0	2,540	6,451,600

TABLE No. 3.—ARMORED WALLS.

Values of E, in decimeters.	Values of V, in meters.	Values of E, in decimeters.	Values of V, in meters.	Values of E, in decimeters.	Values of V, in meters.
1.0	564	4.1	1,382	7.2	2,033
1.1	595	4.2	1,405	7.3	2,052
1.2	627	4.3	1,428	7.4	2,072
1.3	658	4.4	1,450	7.5	2,091
1.4	687	4.5	1,473	7.6	2,110
1.5	717	4.6	1,495	7.7	2,129
1.6	746	4.7	1,517	7.8	2,148
1.7	767	4.8	1,539	7.9	2,167
1.8	804	4.9	1,560	8.0	2,186
1.9	832	5.0	1,582	8.1	2,205
2.0	859	5.1	1,604	8.2	2,224
2.1	887	5.2	1,626	8.3	2,243
2.2	914	5.3	1,647	8.4	2,262
2.3	941	5.4	1,668	8.5	2,280
2.4	967	5.5	1,689	8.6	2,298
2.5	993	5.6	1,710	8.7	2,317
2.6	1,019	5.7	1,731	8.8	2,335
2.7	1,045	5.8	1,752	8.9	2,353
2.8	1,071	5.9	1,772	9.0	2,372
2.9	1,096	6.0	1,793	9.1	2,390
3.0	1,121	6.1	1,814	9.2	2,408
3.1	1,146	6.2	1,834	9.3	2,426
3.2	1,170	6.3	1,854	9.4	2,444
3.3	1,194	6.4	1,874	9.5	2,462
3.4	1,218	6.5	1,894	9.6	2,480
3.5	1,242	6.6	1,914	9.7	2,498
3.6	1,266	6.7	1,934	9.8	2,516
3.7	1,290	6.8	1,954	9.9	2,534
3.8	1,313	6.9	1,974	10.0	2,552
3.9	1,337	7.0	1,993		
4.0	1,359	7.1	2,013		

TABLE No. 4.—WEIGHTS OF SPHERICAL SHOT OF DIFFERENT CALIBERS.

Caliber in decimeters.	Weight in kilograms.	Caliber in decimeters.	Weight in kilograms.	Caliber in decimeters.	Weight in kilograms.
1.0	3.718	2.2	39.585	3.4	146.114
1.1	4.948	2.3	45.231	3.5	159.390
1.2	6.424	2.4	51.391	3.6	173.446
1.3	8.167	2.5	58.086	3.7	188.305
1.4	10.201	2.6	65.340	3.8	203.989
1.5	12.546	2.7	73.173	3.9	220.522
1.6	15.227	2.8	81.607	4.0	237.923
1.7	18.264	2.9	90.667	4.1	256.218
1.8	21.680	3.0	100.374	4 2	275.426
1.9	25.499	3.1	110.749	4.3	295.572
2.0	29.740	3.2	121.817	4.4	316.676
2.1	34.428	3.3	133.595	4.5	338.762

DETERMINATION OF A GENERAL FORMULA FOR REMAINING VELOCITY.

In view of the discrepancies in the results given in the tables and by the various formulæ for remaining velocities, and also the complicated form of the latter, it is difficult to decide as to which one to adopt. A formula, simple in form and susceptible of quick and easy application, which will give sufficiently approximate results, would appear to be desirable. With this in view the following determination of such a formula was made.

From the table of velocities, given on page 41 of Professional Papers

No. 25, Corps of Engineers, United States Army, we will deduce the equation for remaining velocity for each gun. Having obtained these equations the general equation for all of the guns will be of the same form as the individual equations, the coefficients being the means of those of the latter.

For example, the table gives for the 100-ton Armstrong gun—

	Feet.
Velocity at muzzle	1,832
Velocity at 600 yards	1,765
Velocity at 1,200 yards	1,699
Velocity at 1,800 yards	1,637
Velocity at 2,400 yards	1,577
Velocity at 3,000 yards	1,518
Velocity at 3,600 yards	1,462
Velocity at 4,200 yards	1,408
Velocity at 4,800 yards	1,355
Velocity at 5,400 yards	1,305
Velocity at 6,000 yards	1,259

Now let—

$V =$ the initial velocity,

$v =$ the remaining velocity,

$x =$ the range at which the projectile has a remaining velocity v.

Assume the general equation

$$v = V + Ax + Bx^2. \qquad (1)$$

Substituting in this equation the values given above we shall have the observation equations

$$
\begin{aligned}
1765 &= 1832 + 600\,A + 360000\,B \\
1699 &= 1832 + 1200\,A + 1440000\,B \\
1637 &= 1832 + 1800\,A + 3240000\,B \\
1577 &= 1832 + 2400\,A + 5760000\,B \\
1518 &= 1832 + 3000\,A + 9000000\,B \\
1462 &= 1832 + 3600\,A + 12960000\,B \\
1408 &= 1832 + 4200\,A + 17640000\,B \\
1355 &= 1832 + 4800\,A + 23040000\,B \\
1305 &= 1832 + 5400\,A + 29160000\,B \\
1259 &= 1832 + 6000\,A + 36000000\,B
\end{aligned}
$$

Performing the necessary operations we shall obtain the following normal equations :

$$
\begin{aligned}
-13791 &= 138600\,A + 653400000\,B \\
-644022 &= 6534000\,A + 31831568000\,B
\end{aligned}
$$

From which we have

$$B = +0.000006 \qquad A = -0.127$$

Substituting these values in the general equation (1) we have

$$v = V - 0.127x + 0.000006x^2$$

By a similar process we shall obtain a similar equation for each gun.

The equations are:
For 100-ton Armstrong:

$$v = V - 0.127x + 0.000006x^2$$

For 81-ton Woolwich:

$$v = V - 0.111x + 0.000006x^2$$

For 38-ton Woolwich:

$$v = V - 0.125x + 0.000006x^2$$

For 71-ton Krupp:

$$v = V - 0.114x + 0.000006x^2$$

For 51-ton Krupp:

$$v = V - 0.121x + 0.000006x^2$$

For 18-ton Krupp:

$$v = V - 0.131x + 0.000006x^2$$

Taking the mean of these equations we have as the general equation for all of the guns

$$v = V - 0.1215x + 0.000006x^2$$

In order to compare the results given by this equation with those given in the table on page 41 of Professional Papers No. 25, we have the following table. The upper line opposite each gun gives the latter results while the lower line gives the former. It will be seen that the results agree quite closely:

TABLE OF VELOCITIES.

[Velocities in feet per second. x = Range in yards.]

Gun.	At muzzle.	600 yards.	1,200 yards.	1,800 yards.	2,400 yards	3,000 yards	3,600 yards.	4,200 yards.	4,800 yards.	5,400 yards.	6,000. yards
100-ton Armstrong.	1,832	1,765	1,699	1,637	1,577	1,518	1,462	1,408	1,355	1,305	1,259
	....	1,761	1,695	1,633	1,575	1,522	1,472	1,428	1,387	1,351	1,319
81-ton Woolwich...	1,657	1,601	1,546	1,494	1,443	1,393	1,346	1,300	1,258	1,218	1,181
	....	1,586	1,520	1,458	1,400	1,347	1,297	1,253	1,212	1,176	1,144
38-ton Woolwich...	1,590	1,518	1,449	1,383	1,322	1,266	1,213	1,166	1,125	1,089	1,058
	... .	1,519	1,453	1,391	1,333	1,280	1,230	1,186	1,145	1,109	1,077
71-ton Krupp	1,703	1,646	1,590	1,536	1,484	1,434	1,385	1,338	1,293	1,251	1,211
	....	1,632	1,566	1,504	1,446	1,393	1,343	1,299	1,258	1,222	1,190
51-ton Krupp	1,645	1,580	1,517	1,457	1,399	1,344	1,292	1,244	1,198	1,159	1,124
	....	1,574	1,508	1,446	1,388	1,335	1,285	1,241	1,200	1,164	1,132
18-ton Krupp	1,688	1,614	1,544	1,477	1,412	1,351	1,294	1,241	1,192	1,149	1,113
	... .	1,617	1,551	1,489	1,431	1,378	1,328	1,284	1,243	1,207	1,175

Capt. Orde Browne has given the following simple rule of thumb: "The penetration of projectiles into wrought iron is one caliber for every thousand feet of striking velocity."

In the following table are given the penetrations for certain guns as determined by Browne's rule, the striking velocities having been determined by the general equation just deduced. Comparing the results there given with those given in Professional Papers No. 25, the value of the rule may be appreciated.

TABLE OF PENETRATIONS INTO WROUGHT IRON.

	100-ton Armstrong.	81-ton Woolwich.	38-ton Woolwich.	71-ton Krupp.	51-ton Krupp.	18-ton Krupp.
Caliber..........inches..	17.75	16.00	12.50	15.75	14.00	9.45
RANGE.						
At muzzle........inches..	32.52	26.51	19.87	26.82	23.03	15.95
At 600 yards........do....	31.26	25.38	18.99	25.70	22.03	15.28
At 1,200 yards......do....	29.50	24.32	18.16	24.66	21.11	14.65
At 1,800 yards......do....	28.99	23.33	17.39	23.69	20.24	14.07
At 2,400 yards......do....	27.96	22.40	16.66	22.77	19.43	13.52
At 3,000 yards... ..do....	27.01	21.55	16.00	21.94	18.69	13.02
At 3,600 yards. ....do....	26.13	20.75	15.38	21.15	17.99	12.55
At 4,200 yards......do....	25.35	20.05	14.82	20.46	17.36	12.13
At 4,800 yards .....do....	24.61	19.39	14.31	19.83	16.80	11.74
At 5,400 yards......do ...	23.98	18.82	13.86	19.25	16.29	11.40
At 6,000 yards......do....	23.41	18.30	13.46	18.74	15.85	11.10

VIENNA ELECTRICAL EXPOSITION, 1883.

I had laid my plans to visit Vienna at such a time after the opening of the Electrical Exposition as to find it in full operation. I discovered, however, on reaching that city, that the opening day had been postponed to a week later than my arrival. I therefore had but little time at my disposal to devote to the Exposition. But even when it was opened the general display was comparatively small and, as far as the application of electricity to military purposes is concerned, the variety of apparatus was very limited. The Austrian War Department was behindhand, and there was very little that was new in its display. There was, it is true, a large assortment of fuses and batteries, but they were all of well-known models.

There was, however, on exhibition one of Baron von Ebner's Light-Projectors, and, in view of the important part which the electric light will play in future operations of war, it is thought that a description of some of the apparatus used for military purposes will not be out of place.

Fig. 1 is a drawing of von Ebner's apparatus. It consists of a large parabolic concave mirror having an electric lamp in its luminous focus. The lamp is connected with a spring clock-work at the back of the mirror, by means of which the carbon points are kept at the proper distance apart and the light thus regulated.

In order that there may be no loss of light through side radiation, a Fresnel lens, L, with three circular prisms, is placed in front of the lamp, and thus the rays are concentrated into a cylinder parallel to the axis of the mirror.

The mirror is supported by a strong iron frame on three wheels which run around a central turning point. The iron circle *U U U* on which the wheels run is divided into degrees in order to determine the horizontal pointing. The apparatus is revolved by means of the arm *G*.

The vertical inclination of the mirror is produced by means of a crank and endless screw, *K K*, which is geared into a toothed quadrant, *Z*. The inclination may be read on a graduated half-circle, *R*, which is attached to the right support. At the same place there is also a telescope clamped to the horizontal limb, with its axis parallel to that of the mirror, thus making it possible to observe the object illuminated by the mirror.

In 1878 experiments were made with such an instrument at Olmütz in connection with the siege manœuvres, and the results obtained were generally satisfactory, notwithstanding the fact that the light produced by an Alliance machine was relatively of very small power.

The effectiveness of such large projectors is beyond question, and yet they are more or less excluded from general use, partly on account of their great cost and partly on account of the difficulty of moving them, due to their great weight, five to six hundred weight. Furthermore, their size renders the possibility of their being hit by an enemy's shot far from uncertain.

For these reasons it is generally considered better to use small, handy reflectors of but little weight, such as Mangin's, Sautter-Lemonier's, Siemens's, &c., the positions of which may be constantly shifted, and consequently the chances of being hit much reduced.

Mangin's projector, Fig. 2, contains, in a well-ventilated cast-iron case, *T*, *T*, the aplanatic mirror *A*, which is silvered on the convex side, and a Sautter-Lemonier hand-lamp. On the front side at *G* is the projector-frame closed either by a pane of glass with parallel faces, or by a divergent lens.

The radii of curvature of the mirror, the power and refraction-co-efficient of the glass having been determined by mathematical calculations there was given to the mirror a rather large diameter, while at the same time there is less spherical aberration than is ordinarily the case with spherical mirrors of the same dimensions.

When the electric arc is placed in the luminous focus of the mirror a beam of almost perfectly parallel rays passes out from the projector. If the lamp be shifted from the luminous focus in either direction then the projector sends forth a divergent or only partially concentrated light. By the use of the divergent lens the light may be dispersed for only the breadth most frequently desired for lighting up the coast as well as surrounding objects. The whole apparatus may be turned in any desired direction and immediately clamped in any position.

This projector intensifies the light nominally two thousand fold, which amount, however, holds only for certain conditions and distances.

A full description of Siemens' projector is given in Sleeman's "Torpedoes and Torpedo Warfare."

Comparative experiments made by the Imperial Royal Permanent Artillery Commission in Pola with the Mangin and Siemens projectors showed that the latter caused a divergence of at least 5° 40′, while the Mangin apparatus gave a divergence of only 2 to 4°, as well as affording a somewhat better use of the light.

Bustyn's Auxilliary Projector is intended to extend the illumination of objects by a Mangin apparatus. By means of it pencils of light may be turned off at any desired angle from the main beam, and, without perceptible diminution of the latter, lateral objects can be illuminated and followed at the same time as the main object. It consists essentially of a metal tube, containing a plane mirror with a universal motion, placed in the side of the projector. The light obtained by reflection illuminates objects lying to the right or left of the main beam without interfering with the latter.

The following are some of the results obtained with a Mangin projector:

Experiments made at Fort Mont Valérien by a commission of French officers showed that, with a light of 19,000 standard candle power in a Mangin projector, houses, wagons, and military manœuvres were plainly visible at a distance of 5,000 meters. At a distance of 2,700 meters a single soldier could be distinguished and observed at bayonet exercise. The observer was in this case stationed near the projector. The lateral range of the light is, however, very considerably increased if the observer station himself at some distance from the instrument.

It was shown by experiments at Toulon that by the use of a divergent lens a field 200 meters broad at a distance of 3,000 to 5,000 meters was sufficiently illuminated to enable artillery to shoot into it. The barracks at Mont Faron, a distance of 9,500 meters, could be seen from Toulon by an observer standing near the projector.

The Sautter-Lemonier hand-lamp, Fig. 3, consists of a metallic case, $g\ g$, the upper plate of which makes an angle of 30 degrees with the horizon. Perpendicular to the plate are a conducting-rod, $Z\ Z$, and a spindle, $A\ A$; the latter is turned by the wheel B. The two carbon-carriers $K\ M$, which are supported by the rod Z, may be moved up and down on the spindle A by means of the nuts $D\ D'$.

In order to start the lamp the carbon points are first brought into contact by turning the wheel B and then by a reverse motion separated to a distance of 2 to 3 millimeters. An occasional movement of the carbon points towards each other as they diminish by combustion is sufficient to keep the light going.

The lamp is arranged for uniform electrical currents. The positive carbon travels for a single turn of the spindle *A* twice the distance moved by the negative carbon, the thread of the nut *D* having twice the pitch of that of *D′*.

The centering of the light-arc is accomplished by means of the screw *C*. The upper or positive carbon may be given any desired position by means of the articulations *n* and *m* of the carrier.

A small screen, *S*, of blackened plate-brass serves to intercept the central ray; its proper place in the apparatus is fixed by means of a clamp on the rod *Z*.

The conducting wires are inserted through the opening $+p$ and a corresponding clamp-screw, $-p$, on the opposite side.

In the section of the Exposition set aside for Denmark there was an interesting display by the "First Division of the Royal Danish Torpedo-Corps." I was not allowed to look at the detailed drawings, but I obtained from the officer in charge of the apparatus the following general information:

1. The current-distribution table for electrical contact mines.

All of the mines in one set are connected with the firing-battery on the current-distribution table. The circuit is closed through the cable of the mine struck by a hostile ship. The firing-battery is two-fold. A small battery, the relay-battery, is connected with the cable when an attack is expected. At the instant of contact it operates a firing-relay, which breaks the relay-circuit, closes the direct firing-circuit, and then quickly breaks it again after the charge is fired. The whole operation is automatic. Each cable attached to the table is connected with a numbered dial, which indicates the mine struck.

The relay-battery is connected with the mine by means of the armature of the firing-relay. After the firing current has passed through the relay the latter returns to a state of rest, when it closes a local circuit for a small alarm-battery on the table; the bell connected with this latter battery rings and announces a contact.

For testing the electrical condition of the mines and cables use is made of a small testing-battery or several metal plates (carbon, copper, zinc) immersed in sea-water, a delicate alarm, a galvanometer, and a test-circle, that is to say, a circle of insulated contacts which can be connected with the axis of the circle by means of a movable radial arm.

In order that several mines, arranged in a group, may be operated by means of a single cable attached to the table, the branch-cable attached to mine struck must be cut out of the system after the explosion. For this purpose there is placed at the junction of the branch-cables a submarine relay whose armature is removed by a special cut-out battery as soon as the apparatus on the distribution table announces that an explosion has taken place. The cut-out battery is connected with the cable by means of a key firmly screwed to the table. If the key be pressed the cut-out battery is set in action through the connection established with the water in consequence of the explosion and closes the submarine relay belonging to it, by which means the corresponding cable is cut out of the system.

Leclanché batteries, either with or without earthen cells, are used for operating the mines.

2. Submarine relay.

By means of this electro-magnetic relay a cable, after the explosion of the mine to which it is attached, is cut out from the rest of the mines in the same group and from the entire system.

This cutting out is effected by means of a revolving contact-ring, which is held fast, when the relay is at rest, by a hook in such a manner that the group and mine cables are connected with each other through the coil of the relay. If the cut-out battery be set in action the armature of the relay is attached, the hook is freed, and a spring turns the contact-ring whereby the connection is cut out.

The relay stands in a water-tight box on the bottom of the sea.

3. Circuit closer.

The electrical circuit is ordinarily open in the sea-mine. A ship striking the mine closes the circuit by means of a circuit closer in the mine.

The closing is effected by means of about one cubic centimeter of mercury situated in the bottom of a small iron cylinder which forms one contact. The cover of the cylinder, which is insulated from it, forms the second contact. This apparatus is suspended in the mine-case by chains. If the ship upset the case the mercury runs out and makes the connection between the two contacts.

4. Platinum-wire fuse.

Platinum-wire fuses are used in the mines. The wire has a diameter of $\frac{1}{150}$ to $\frac{1}{200}$ millimeter, and can be brought to a red heat by a very light current, only 0.05 to 0.07 ampère.

5. Carbon mine.

The galvanized-iron mine-case and a carbon plate immersed in sea-water constitute, with the connecting cable, a galvanic cell which is capable of developing a current of sufficient strength to fire two of the fuses described above.

If the connection between the case and the carbon be maintained unbroken the combination constitutes a simple contact mine. In this state it is as dangerous to the defense as to the enemy. If, however, a polarized relay be inserted between the carbon plate and the cables of all the mines to be operated by it, the connections between the carbon and the mines may be made or broken at will; that is to say, the mines may be operated as if they were ordinary non-automatic contact mines. A number of mines may be operated by means of a single carbon plate.

The relay is therefore connected with the station by a leading cable. By a positive current sent through the cable and the coil of the relay the circuit through the carbon and the mine is closed and by a negative current it is opened.

By the aid of two plates (carbon and zinc), immersed in the water, and a galvanometer, the electrical connection between the carbon and the mines may be tested; that is to say, the operator may determine with certainty whether the mines are charged or discharged.

The apparatus (commutator, cut-out, tester, and galvanometer) needed for the service and testing of the relay are arranged on the service table for carbon mines.

6. Current distributor for observation mines and combined observation and contact mines. Truelsen System.

By the aid of this apparatus a large number of mines, especially observation mines, may be operated with only two cables.

At the bottom of the sea, in a water-tight iron case, lies a rheotome, whose arm can, by means of a galvanic current from the station, be brought into contact with the contact-plate corresponding to any particular mine. That is done through the operating-cable. The arm stands in continual contact with the firing-cable, so that the mine corresponding to the contact-plate against which the arm presses may be exploded.

A test may be made of the correct position of the arm by means of the operating-cable and a system of resistance-coils; a certain resistance corresponds to each contact-plate. A similar system of resistance-coils, but in inverse order, is placed at the station. The sum of the two resistances must always be the same when the arm is correctly placed. The resistances are determined by a differential-galvanometer.

With several water plates (copper, carbon, zinc), the electrical condition of the individual mines may be tested.

A dial at the station indicates the number of the contact-plate against which the arm presses.

The following is a translation of a portion of an article by Dr. Fr.

Wächter, published in No. 23 of the "Internationale Zeitschrift für die Elektrische Ausstellung in Wien, 1883":

The sea-mine apparatus of the Danish Navy consists of a large set of very ingeniously combined, but also very complicated instruments. The first to be mentioned is the current-distributor for observation, and combined observation and contact mines. This apparatus, which is mounted on a special table—the current-distribution table—operates a large number of mines by means of only two cables.

It consists of two similar current distributors, formed of as many contact plates, arranged in a circular manner, as there are mines to be operated. Over the contact plates moves a metallic arm in such a manner that it is never in contact with more than one plate at a time. Between each two contact plates is inserted a resistance-coil of Siemens' units, but the arrangement of the latter on the second distributor is in reverse order from that on the first.

Suppose, now, the contact plates arranged in a circular manner on the table and numbered from 1 to 30, from left to right; then we shall have between Plates 1 and 2 on the first distributor a resistance coil of 1 Siemens' unit; between 2 and 3 a coil of 2 Siemens' units, &c. On the second distributor the plates are numbered in the same order, but between 1 and 2 there is a coil of 31 Siemens' units; between 2 and 3 a coil of 30 Siemens' units, &c.

The first distributor is on the current-distribution table at the observation-station; the second is in a water-tight metal box on the bottom of the sea. The two distributors are connected by the so-called "Afficirungs" cable. If, now, the pointer at the observation-station be moved from the contact-plate 2 to 25, then the pointer of the rheotome at the bottom of the sea also moves from 2 to 25. In that case, then, only mine No. 25 is in the circuit, all the others being cut out. It may happen that the pointer jumps one or more contact-plates, or hitches, and in that case the number 25 of the station-distributor will not correspond to the same number of the submarine rheotome, but to a higher or lower, or at all events, some unknown number, and it would be necessary to raise the apparatus from the bottom of the sea to set it right. But to avoid that infeasible operation the above-mentioned resistance-coils between the contact-plates are used.

In consequence of the arrangement of the two distributors they must offer a constant resistance, no matter on which number the pointers may be, provided both are on the same number. If the pointers were on No. 5 the resistance would be $5 + 27 = 32$ Siemens' units; if on No. 8 the resistance would be $8 + 24 = 32$ Siemens' units, &c. Consequently a constant battery would always give the same result on the galvanometer.

As such a battery are used large copper and zinc plates immersed in sea-water; for measuring the strength of the current a differential-galvanometer is used.

With these the rheotomes are tested from time to time. If a wrong result be given it shows that the two pointers are not on the same numbers. In that case, by measuring the resistance, a calculation may be made of the error of the submarine pointer without the necessity of raising the apparatus. For such calculations a Siemens' universal-galvanometer is mounted on the current-distribution table.

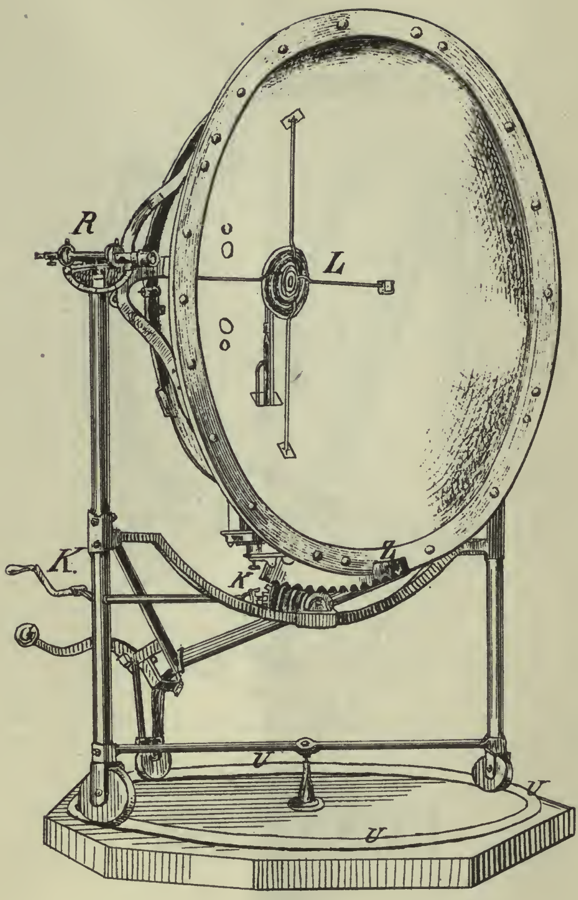

Fig. 1

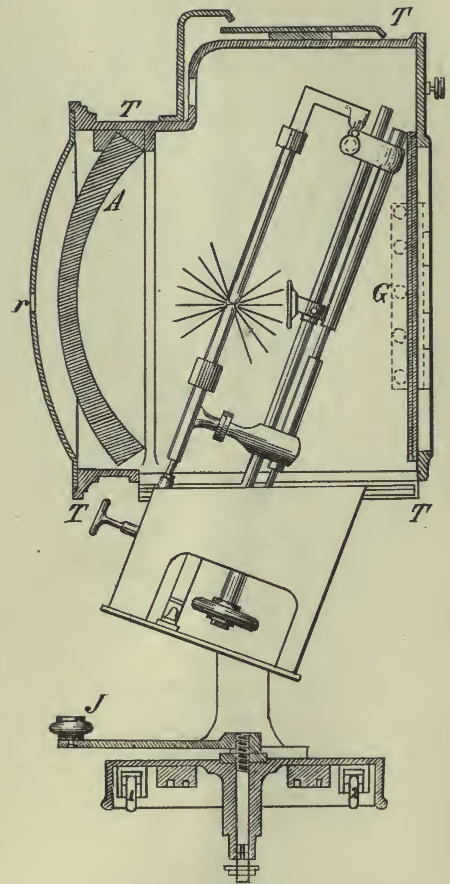

Fig. 2.

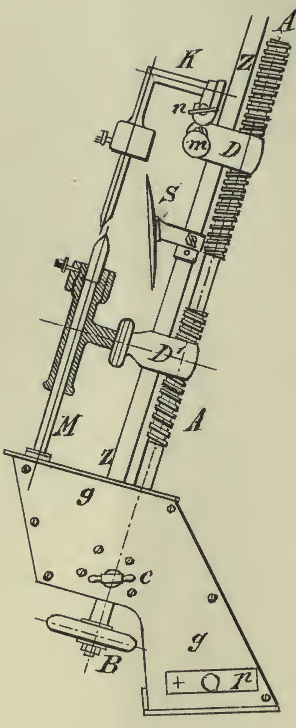

Fig. 3.