

ABOUT TO RELEASE THE SWINGING SHOE OF THE PENDULUM FRICTION APPARATUS

# A. Pendulum-Type Testing Apparatus<sup>\*</sup>

Testing Potassium Chlorate Explosives at the U. S. Bureau of Mines

By S. P. Howell

IT has long been known that many commercial explosives may be exploded by severe and prolonged friction. It is also well established that some explosives are more sensitive to friction than others.

Certain kinds of potassium chlorate explosives have long been regarded as very sensitive to friction, as evidenced by the following quotations from Berthelot, Gody, Dupré, and Brunswig. Berthelot says:<sup>1</sup>

"Berthollet, after having discovered potassium chlorate and recognized the oxidizing properties so characteristic of this salt, thought of utilizing it in the manufacture of service powders. He made several attempts in this direction, but immediately suspended them after an explosion which happened during the manufacture carried on at the Essonnes powder factory—an explosion in which several persons were killed around himself. The same attempt has been revived at various periods, with certain variations in the composition.

"But in every case explosions, followed by loss of lives—such, for instance, as those which happened during the siege of Paris in 1870 and at L'Ecole de Pyrotechnie in 1877—happened before long in the course of its manufacture.

"It is thus clear that potassium chlorate is an extremely dangerous substance, which is only natural, because its mixture with combustible bodies is sensitive to the least shock or friction."

Gody says:<sup>2</sup>

<sup>\*</sup>Technical Paper 234, U. S. Bureau of Mines.

<sup>1</sup>Berthelot, M.P.E., *Explosives and their power*, translated by C. N. Hake and William Macnab, 1892, p. 518.

<sup>2</sup>Gody, L., *Traité théorique et pratique des matières explosives*, 3rd ed., 1907, p. 240.

"Berthollet missed losing his sight from the explosion of a chlorate explosive during imprudent manufacture in a mortar. . . .

"The mixture of combustible material with potassium chlorate must be made with the minutest precautions, as the least shock or friction may cause an explosion."

Dr. Dupré, as cited by De Kalb,<sup>3</sup> says:

"Chlorate of potassium, on account of the readiness with which it lends itself to the production of powerful explosives, offers a great temptation to inventors of new explosives, and many attempts have been made to put it to practical use, but so far with very limited success. This is chiefly owing to two causes. In the first place, potassium chlorate is a very unstable compound and is liable to suffer decomposition under a variety of circumstances, and under comparatively slight causes, chemical and mechanical. All chlorate mixtures are liable to what is termed spontaneous ignition or explosion in the presence of a variety of materials, more particularly of such as are acid, or are liable to generate acid; and all chlorate mixtures are readily exploded by percussion, such as a glancing blow which might easily and would often occur in charging a hole. In the second place, there is some evidence to show that the sensitiveness to percussion and friction increases by keeping, more especially if the explosive is exposed to the action of moist and dry air alternately."

Brunswig,<sup>4</sup> a more recent authority, in speaking of chlorate powders says:

"These powders have received little attention on account of

<sup>3</sup>De Kalb, Courtenay, *Manual of explosives*, 1900, p. 16.

<sup>4</sup>Brunswig, H., *Explosives*, translated and annotated by C. E. Munroe and A. L. Kibler, 1912, p. 302.

their greater sensitiveness toward shock and friction. In more recent times, however, the preparation of chlorates and perchlorates by electrical methods has made these substances easy to obtain, and it has been discovered that the addition of fatty oils to chlorate mixtures decreases their sensitiveness.

"Various annual reports" of His Majesty's inspectors of explosives, Great Britain, record fires and explosions with various potassium chlorate explosives during the operation of sifting, mixing, ramming with wooden rammers, and ramming with bronze rammers."

A certain potassium chlorate explosive that is used in the United States and is designated "Chlorate explosive B" in this paper has come under suspicion because of premature explosions that occurred while it was used in bituminous coal mines. The details of these accidents are as follows:

1. While inserting copper needle in a charge in a tamped bore hole the charge exploded. Miner not injured.

2. This accident occurred less than one hour after accident 1, but in another room of the mine. The charge exploded while the copper needle was being inserted in the charge in a bore hole. Miner not injured.

3. While pushing a 12-inch cartridge into bore hole, with copper needle inserted about 6 inches in it, and just before charge reached back of bore hole, the charge exploded. Miner severely burned and hand badly lacerated.

Other potassium chlorate explosives containing potassium chlorate and sugar also exploded prematurely in coal mines in the United States. The details are as follows:

4. A 7-inch by 1-inch charge had misfired in a 5½-foot bore hole, presumably on account of using wet squibs. The stemming was then drilled out about 3 feet and copper needle inserted to reform the needle hole. The needle went into the clay stemming easily and the miner "did not have to exert any strength to force it." He was turning the needle around to form the hole for the squib and just as the needle went through the stemming it turned to go a little bit faster, then the shot went off prematurely. The miner lost the thumb and index finger of his left hand, besides being lacerated about the chest and arms, and his face was slightly cut.

5. While a miner was tamping several inches of stemming on the explosive it exploded. No injury reported.

6. After putting in several handfuls of stemming on the explosive it exploded. The cartridge had been broken when being inserted. No injury reported.

7. Exploded while pushing the copper needle into the explosive. No injury reported.

In view of the frequency of these accidents and the seeming ease with which they took place, not being explainable by the sensitiveness of the explosive itself to friction, it was considered advisable to determine, if possible, the cause of the excessive sensitiveness to friction.

As the coal in the mines in which these accidents occurred contains pyrite-bearing bands, it was thought that the pyrite might be a general cause of the accidents, as practically all

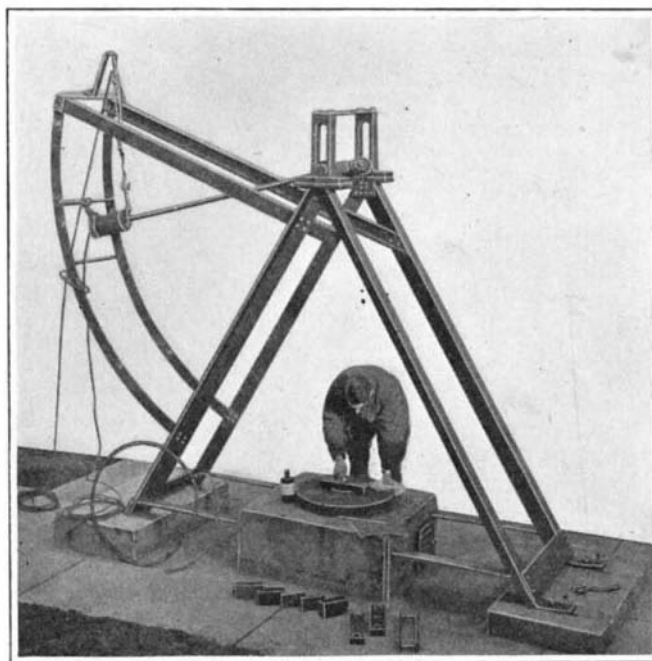
bituminous coals, and especially those of the Middle West have these pyritiferous bands.

At the suggestion of Clarence Hall, chief explosives engineer of the Bureau of Mines, the experiments described below were made to determine the effect of pyrite-bearing coal on sensitiveness to friction of potassium chlorate explosives.

Chlorate explosive B, which failed to pass the pendulum friction test with the wood-fiber shoe dropped from the 1½-meter position, gave no unfavorable results in 10 trials when the wood-fiber shoe was dropped from the 1-meter position. Under the same conditions, but mixed with small pieces of pyrite-bearing bituminous coal, the explosive ignited in each trial. It was found also that ignition occurred when the height of fall was reduced to ½ meter and even to ¼ meter.

Similar tests made with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignitions.

In order to determine whether the friction of a moving copper-wire needle in a bore hole would be sufficient to cause an ignition of chlorate explosive B, the following test was made.



PREPARING FOR A TEST WITH THE PENDULUM DEVICE

A hole one-half inch in diameter and 4 inches deep was drilled in a block of bituminous coal. A 2-gram charge consisting of 4 parts of chlorate explosive B, 1 part coal dust, and 1 part pyrite of the same granulation as the explosive was placed in the bore hole. The friction from the movement of a No. 8 (B. & S. gage) copper needle within this mixture caused ignition.

Repeated with three other chlorate explosives of the same general type, this test gave the same results.

Similar tests with FFF black blasting powder and 40 per cent nitroglycerin dynamite gave no ignition.

An unpublished report by Russell B. and Treadway B. Munroe, which was available to the Bureau of Mines, on the effect of metallic sulphides on a sodium chlorate

explosive showed that both antimony and lead sulphides increased the sensitiveness of the explosive to friction more than pyrite.

This conclusion is in part corroborated by the work of Cushman,<sup>6</sup> who shows that in priming compositions the compositions containing antimony or lead sulphides are more sensitive to impact than the composition containing pyrite.

To determine the sensitiveness of potassium chlorate explosives, the English have long used the broomstick test. This test consists in spreading a small quantity of the explosive on a soft wood surface and striking it a glancing blow with a broomstick. An explosive is considered as having passed this test if it fails to explode or crack when tested repeatedly.

A rawhide-mallet test has been used at the Bureau of Mines and elsewhere to determine the sensitiveness of explosives. A small portion of the explosive is spread on a smooth oak surface and struck a glancing blow with the mallet. The explosive is considered as having passed this test if there is no explosion or local crackling.

Obviously the broomstick test and the rawhide-mallet test lack the uniformity in execution that should characterize a scientific friction test, so in June, 1911, the Bureau of Mines

<sup>5</sup>32d annual report, 1907, pp. 114, 122; 33d annual report, 1908, p. 95; 34th annual report, 1909, p. 104; 36th annual report, 1911, p. 109.

<sup>6</sup>Cushman, A. S., Antimony sulphide as a constituent in military and sporting arms primers; *Jour. Ind. and Eng. Chem.*, vol. 10, 1918, p. 376.

designed a pendulum friction device. The first tests with it were made in September, 1911. Tests of a variety of explosives, including permissible explosives, commercial explosives other than permissibles, black blasting powder, and potassium chlorate explosives, showed that all explosives except a certain potassium chlorate explosive passed the test.

In October, 1911, a committee consisting of Dr. C. E. Munroe, C. P. Beistle, and Clarence Hall was appointed to pass upon the propriety of the pendulum friction test as a requirement for determining the permissibility of explosives for use in coal mines.

After studying the results of the preliminary tests, and witnessing tests of the pendulum friction device provided with a wood-fiber shoe, the committee recommended the adoption of the test. Their report was approved by Director J. A. Holmes on November 22, 1911.

In the opinion of the director and the committee, the failure of an explosive to pass the pendulum friction test as adopted by the Bureau of Mines should be considered an unfavorable physical characteristic because of the liability of such an explosive to explode in drill holes, by such friction as may be produced by a tamping rod. Moreover, they decided that the Bureau of Mines was not warranted in placing on the permissible list any explosive that failed to pass the pendulum friction test, but did pass other required tests.

The pendulum friction device adopted by the Bureau of Mines comprises a steel anvil and a swinging shoe. The anvil has a smooth face, 3.25 inches (8.3 cm.) wide by 12 inches (30.5 cm.) long, in the middle of which are three grooves for holding the charge of explosive. The shoe is  $3\frac{1}{4}$  inches (8.3 cm.) wide, its radius of swing is 6 feet 6.75 inches (2 meters), and the radius of curvature of its face is 10.5 inches (26.7 cm.). The shoe may be of steel, or of steel faced with hardwood fiber or other material, and may be dropped from heights up to 78.7 inches (2 meters). Added weights of 2.2 to 44 pounds (1 to 20 kg.) may be used.

In the official test adopted by the Bureau of Mines a steel shoe faced with hardwood fiber, 44 pounds (20 kg.) added weight and a fall of 59.1 inches (1.5 meters) are used. The shoe is squarely adjusted so that when there is no explosive on the anvil it will swing across the face of the anvil  $18 \pm 1$  times before coming to rest.

In making the test 7 grams of the explosive is spread in an even layer in and above the three grooves in the anvil. Each test consists of 10 trials. After each trial the remaining explosive is brushed from the anvil and shoe, and both are thoroughly cleaned with a solvent to insure the complete removal of the explosive. When the steel shoe is used, both the shoe and anvil after each trial are rubbed with carborundum cloth to remove any roughness caused by the preceding trial; thus any gritty material is thoroughly removed.

The usual tests are made at normal temperatures ( $14^{\circ}$  C. to  $30^{\circ}$  C.), the temperature of the anvil and of the shoe being controlled.

The observations made are explosion, whether complete or partial; burning; local crackling, whether distinctly audible

or almost indistinguishable; and no local crackling. An explosive that gives no more unfavorable result than an almost indistinguishable local crackling with the wood-fiber shoe is considered as having passed the test.

As soon as tests showed that the steel shoe was more severe than the wood-fiber shoe, explosives were first tested with the steel shoe and usually were not tested on the wood-fiber shoe if they passed the test with the steel shoe. (*The Bulletin contains a number of tables which are omitted.*—EDITOR.)

#### SUMMARY OF RESULTS.

1. Tests with the steel shoe are much more severe than tests with the wood-fiber shoe.

Forty per cent straight dynamite passed the test at 2.0 meters fall and 20 kilograms added weight with the wood-fiber shoe, but failed with the steel shoe at 0.5 meters fall and 20.0 kilograms added weight, and 1.5 meters fall with no added weight. Moreover, the record shows that 40 explosives failed under test with the steel shoe but passed the test with the wood-fiber shoe, but for no explosive was the reverse true.

2. All the explosives tested with the wood-fiber shoe passed the test except 10 potassium-chlorate explosives and one perchlorate explosive.

3. Of 267 samples tested with the steel shoe, 55 failed to pass the test.

4. Black blasting and ignition powders, blasting gelatin, ammonia dynamites, and organic nitrate explosives (other than nitroglycerin) are not as sensitive to frictional impact as the nitroglycerin dynamites and the gelatin dynamites.

5. TNA, tetryl, 50/50 amatol, and 60/40 sodatol are more sensitive to frictional impact than TNT, picric acid, ammonium picrate, 85/15 amatol, 80/20 sodatol.

6. Tests of TNA, and of 40 per cent straight dynamite with the steel shoe, show that increasing the height of fall increases the severity of the test.

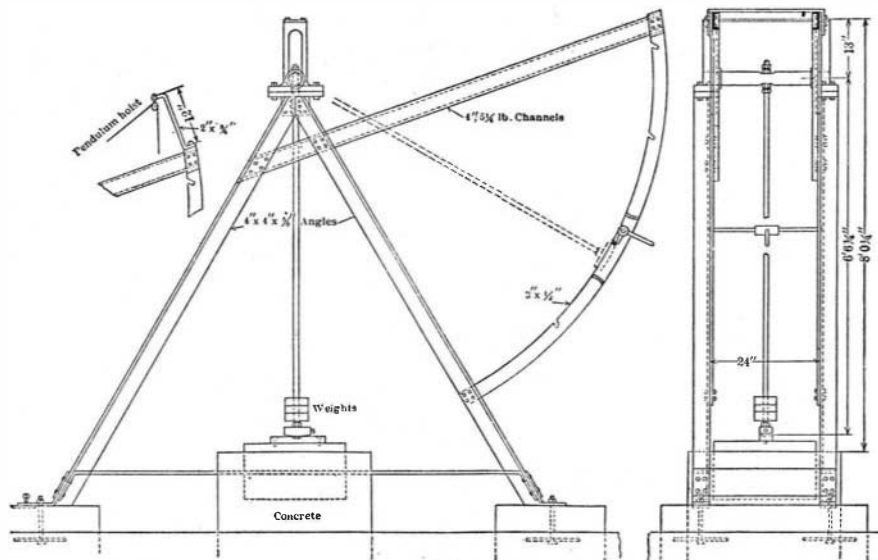
7. Tests of 40 per cent straight dynamite with the steel shoe show that decreasing the added weight decreases the severity of the test.

8. The tests at normal and high temperatures showed that no discrimination can be made on the basis of increasing the temperature.

9. Potassium chlorate explosives have proved extremely sensitive to frictional impact even when the wood-fiber shoe is used. But some were rendered sufficiently insensitive to friction by adding an adequate quantity of mineral oil, vegetable oils, and aromatic nitro compounds.

10. That the pendulum friction device, as adopted by the Bureau of Mines, is not too severe is indicated by the fact that one of the potassium chlorate explosives which passed the test has on more than one occasion exploded prematurely during manufacture and use. On the other hand, potassium chlorate explosives of the general type of E (potassium chlorate, sugar and gum arabic) which failed to pass the pendulum friction test exploded prematurely on several occasions in use.

11. The sensitiveness of potassium chlorate explosives to friction is increased by the presence of pyrite-bearing coal.



ELEVATION AND DETAILS OF THE TESTING MACHINE