EXPLOSIVES.

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THIS subject of *Explosives* is one in which we are all rightly and justly interested and one which the majority of consumers are to-day studying as hard and thoroughly as the manufacturer, both from a humanitarian and economic standpoint; or first, to produce the safest for use, at the same time protecting the lives of the users, and second, to supply the best at minimum cost. The consumer is making it a study with the idea of determining what kind of explosive and which explosive is better adapted for the work in hand. The manufacturer studies the subject with the idea of supplying that explosive which will fill the various conditions and demands not only for the present time but also future demands.

From the time of the invention of gunpowder, or approximately in 1250, the study of explosives has been the problem for generations. With the new kinds of High Explosives, "Permissible" Explosives, Sporting Powders and Detonating Agents, the problem is one of greater moment and continues to be studied with increased care, and by a larger number of expert chemists. Perhaps a short historical retrospect will be very useful in order to fully appreciate this fact.

Gunpowder was known in a crude form by the Chinese for many centuries, but the earliest date of which there is record and which can be considered authentic in any way is 1264, when Roger Bacon made known the results of his tests. I believe, however, that the Western World only used this gunpowder for throwing projectiles. Not until 1629 was gunpowder used as a blasting agent, at which time Casper Weindl invented the use of gunpowder for blasting purposes. A demonstration was made at Schemnitz in Hungary, where it was shown conclusively that its use would materially aid in mining and quarrying operations. Until the beginning of the Nineteenth Century, however, no other explosive was introduced into practice with success. In

1788 Bertholet and Lavoisier tried the effect of adding potassium chlorate, and in 1861 Designolle made a powder from potassium picrate and saltpetre but without much success. In 1846 Schoenbein invented gun-cotton and in 1847 Sobero discovered nitroglycerin. The Austrian Government, which was the only one to try gun-cotton in guns, stopped the experiment abruptly in 1867, due to their having an explosion in the magazines at Hirtenberg. Not until 1863 was nitroglycerin available for general use owing to its extreme sensitiveness and to the inconvenience of handling it in its liquid state. Alfred Nobel, the great Swedish chemist, at this time found by using infusorial earth, known as Kieselguhr, as an absorbent for the nitroglycerin, it would overcome these objections to a large extent, and in 1867 he introduced this mixture under the name of dynamite. About this time the success of dynamite was assured by the discovery of the detonating effect of fulminate of mercury in the dynamite by Brown, a chemist in the English War Office. Gelatin dynamite was next produced when Alfred Nobel discovered that nitro-cotton was easily dissolved in nitroglycerin, forming an explosive gelatinous mass which he called blasting gelatin.

Such was practically the state of affairs as concerns explosives up to the year 1886. About this time it was recognized that most explosions in coal mines were due to the ignition of fire-damp by the firing of shots, and it was also recognized that it would be possible to produce explosives which could be used in coal mines and which would considerably reduce this danger.

From 1886 the strides made in the investigations, inventions and productions of different kinds of explosives have been very rapid. In fact, all explosive manufacturers produce two or three of the following kinds of explosives: Straight Nitroglycerin Dynamites, Gelatin Dynamites, Ammonia Dynamites, "Permissible" Explosives, Low-freezing Dynamites, Non-freezing Dynamites and Detonators of different varieties. It is left, however, to the largest manufacturers of explosives to produce all of the different kinds just mentioned.

According to the Standard Dictionary, "an explosive is any substance that may cause an explosion by its sudden combustion or decomposition." A distinction, however, should be made be-

tween explosives in general and those which are applicable to blasting purposes: a mixture of oxygen and hydrogen gases, or of fire-damp and air, or coal dust, or flour dust and air, etc., may be termed explosive, as when mixed in the proper proportion they may be exploded by a spark, flame, or by having the temperature raised by any other means.

Another very good definition of an explosive is, "Such a substance as can in an extremely short time and in a small space develop a very large amount of heat and gas exerting enormous pressure on the surrounding bodies, and is able by the expansion of highly heated gases to perform considerable work."

Some of the important qualifications of an explosive for blasting purposes are the following:

1. Sufficient stability.
2. Difficulty of detonation by mechanical shock, that is, not too sensitive.
3. Handy form.
4. Absence of injurious effect on the health of those using it.
5. Sufficient strength of action.
6. Sufficient density.
7. Comparative "flamelessness" and low heat of detonation for coal mining.

Explosives may be divided into two general classes:

1. *Low* explosives or direct exploding materials, such as blasting powder.
2. *High* explosives or indirect exploding materials, such as dynamite, gun-cotton, gelatin dynamite, ammonium nitrate, picric acid, etc.

By direct exploding materials are meant those which can be made to develop their force by direct means, such as ignition; whereas the indirect exploding materials require an intermediate agent to develop their full force, such as a blasting cap or electric fuze.

In the case of a low explosive, such as blasting powder, the force is developed by first burning some of the powder, the fire being transmitted from grain to grain, a certain amount of pressure and heat are developed, when the whole amount of powder is brought into sudden decomposition. This fact is readily shown by burning a small quantity of blasting powder unconfined, and then burning it confined, the pressure being an

important factor in bringing about the explosion of blasting powder. The finer the grain of the powder the greater proportionately is the amount of burning surface, and consequently, the quicker the complete transformation of the solid into the gases.

To the high explosive class belong all those explosives commonly known as dynamite, and which or may not have nitroglycerin as the explosive basis of the substances, such as: ordinary nitroglycerin dynamite, the ammonium-nitroglycerin compounds, gelatin dynamite, low-freezing dynamite, and the Judson powders. To this class belong all of the "Permissible" Explosives.

Whereas a perfect explosion of a low explosive results from burning, a perfect explosion of a high explosive is the result of the detonation of the explosive. This may be considered the result of a certain kind of shock causing the instantaneous destruction of the very delicately balanced forces which preserve the chemical and physical equilibrium of the explosive compound.

Defective blasting caps and electric fuzes are often causes of imperfect explosions of high explosives. Another cause, and one of frequent occurrence, is where dynamite is loaded in the same bore-hole with blasting powder without a detonator, the blasting powder being fired by the use of a squib or safety fuse. Another cause is where the fuse is laced through the cartridges of dynamite, which is very apt to set the dynamite on fire.

Before the sale of an explosive is undertaken those who manufacture and sell explosives should make such tests as will determine the characteristics of that particular explosive. Some of these points to be determined about any explosive are:

1. Sensitiveness.
2. Comparative strength.
3. Waterproof qualities.
4. Effects of temperature on the explosive.
5. Nature of gases resulting from detonation.
6. Velocity of detonation—that is *quickness*.
7. Height and duration of flame.
8. Temperature of detonation.
9. Heat of detonation.

There are many tests which have been devised and have been and are used to determine these various characteristics of

explosives as far as is possible before the explosive is taken into actual work in a quarry or mine. Only those in the explosive business seem to fully realize the difficulties in the way of a proper comparison of the value of two or more explosives. All of the points which I have just mentioned have their material effect on the value of an explosive, and much can be, and is, learned by study of an explosive at the laboratory, but the actual use of an explosive in practical work is necessary before a definite knowledge of the explosive can be obtained.

In this connection there is a point to which I wish to call your particular attention, and that is to the fact that the strength of a high explosive does not entirely depend upon the percentage of nitroglycerin in the explosive. Suppose you were making a test of two explosives, each containing the same percentage of nitroglycerin. One of these explosives may be found to be very much stronger than the other, depending entirely on the other components of the explosive. This method of grading explosives by the percentage of nitroglycerin contents is still in general use and is very unfortunate both for the consumer and the reliable manufacturer of explosives. The consumer desires an explosive having the proper strength and action to do the work he has to do, without regard of the percentage of nitroglycerin in the explosive.

In the manufacture of explosives very careful attention is given to the method of manufacture. The purity of the raw materials, the intimate mixing of the ingredients, cartridge-making and packing are all essential points to be thoroughly studied in order to produce the best explosives.

Since 1886, in England and on the continent of Europe a study has been and is being made to-day of explosives suitable for use in gaseous and dusty coal mines. As a result of these investigations many explosives are manufactured for this class of work more suitable and which can be used with more comparative safety than blasting powder or dynamite. In the United States this is a newer problem, and yet according to Explosive Circular No. 3 issued by the United States Geological Survey of the Department of the Interior, on May 16, 1910, there are manufactured forty-five "Permissible" Explosives suitable for use in gaseous or dusty coal mines.

Where large quantities of fire-damp are found, it is ex-

tremely dangerous to use either blasting powder or ordinary dynamite for *this* reason. Blasting powder produces a very long flame of considerable duration and ordinary dynamite produces a very hot flame when exploded. Because of this and the explosive character of a mixture of fire-damp and air, or coal dust and air, or of all three of these occurring in coal mines, demands are made for the development of explosives which are not liable in their use to cause an explosion of any of these mixtures.

From laboratory tests it has been determined that certain gaseous mixtures require certain temperatures to ignite them. It has been found with considerable accuracy that fire-damp mixtures ignite at a temperature in the neighborhood of 650 degrees C., or 1202 degrees F. It is also necessary to heat the fire-damp mixtures up to the ignition point during a certain length of time. Consequently, the explosion of fire-damp depends on at least two factors, namely, *time* and *temperature*.

To determine the relative safety of explosives, the United States, as well as other countries, have established experimental stations. The apparatus used consists of an artificially constructed tunnel or gallery which can be filled with fire-damp and air, or other explosive gas or coal-dust mixture, and into which various sized charges of explosives can be fired from a mortar with or without tamping. The first fact established was that no explosive is absolutely safe, as all will ignite fire-damp when the charge per bore hole is sufficiently large, which is true even where the explosion temperature of an explosive is below 2000 degrees C., or 3632 degrees F.

Thus far we have dwelt only on the *temperature of detonation of explosives*, but after careful study of this subject it has been found that other factors in connection with the charge must be considered. These are the *rate or velocity of detonation*, the *length and duration of the flame*, the *heat of detonation* or the *quantity of heat produced*, the "*after flame*" ratio, or the relation between the rate of detonation and the duration of the flame, etc. All of these qualities have their effect on the safety of explosives in fire-damp, it having been shown that the lower they are, the safer the explosives. However, no limit can be placed on any of them, as excess in any other may counter-balance it. This point has been proven in the case of blasting powder, which

possesses all the necessary qualities for a safe explosive except the duration of the flame, which alone makes it very unsafe.

In looking over the field for the uses of explosives to-day, we find this list to be of much greater length than only a few years back. At one time we believed that explosives could be used only in quarries, mines of all kinds and railroad construction work. To-day we find that explosives are used in blasting stumps, boulders, tearing down buildings, breaking up hard pan and hard sub-soil, breaking up boilers and scrap iron, digging drainage ditches, breaking up log jams and ice jams, planting orchards and many other classes of work.

The E. I. du Pont de Nemours Powder Company of Wilmington, Delaware, are considered the largest manufacturers of explosives in this country. They manufacture all the different kinds of explosives for use in different kinds of work and have the largest force of expert chemists to carefully and thoroughly study the manufacture of explosives. They also maintain a Technical Division having a large field force to assist, wherever requested, in the better use of explosives in actual work.

All of the dynamites mentioned in this article are packed in cartridge form, the standard size of cartridges ranging from $\frac{7}{8}$ in. x 8 in. to 2 in. x 18 in., depending, of course, upon the kinds of explosives packed. As a general rule, they are packed in two sized cases, viz., 25-lb. cases and 50-lb. cases. The cases are made of one-half-inch lumber, lined with paper and a small amount of sawdust sprinkled in the bottom of each case according to regulations established by the Bureau for the Safe Transportation of Explosives.

Nearly all kinds of dynamite freeze at temperatures between 45° F. and 50° F. and they should be thoroughly thawed before using in order to obtain the full explosive effect. The low-freezing explosives, however, do not freeze much above the freezing temperature of water, yet these explosives should be thoroughly thawed when the temperature reaches the freezing point. The non-freezing explosives are, as their name suggests, truly non-freezing. As a general rule the "Permissible" Explosives used in the United States should be thawed before using if the temperature is below 50° F.

The thawing of dynamite is the cause of much loss of life, generally due to the fact that it is not given proper attention, as

many of the methods used are very crude. Too great care cannot be taken in the thawing of explosives, and it would be well for consumers of explosives to consult very freely with manufacturers on this important question.

In detonating dynamite, two methods are generally used; one by means of electricity and the other by use of safety fuse and blasting caps. Of these two methods the one most strongly recommended by explosive manufacturers for nearly all kinds of blasting is that by electricity, as it is the most effective, economical and safe system that can be used. This is especially true in coal mines, as when using safety fuze and blasting caps, the gas is apt to be ignited while lighting the fuse or by the spitting out of the fuse, while there is no danger in this respect when electricity is used.

Another very vital point to be considered in the use of explosives is the tamping material and the method of tamping the charge in the bore-holes. The best material to use is damp clay, for the reasons that it contains no gritty matter which will damage the fuze or electric fuze wires in tamping, and also it will pack well in the bore-hole and thus leave no air spaces. No inflammable material should ever be used. In tamping, the explosive should be well confined to obtain its maximum efficiency, and to insure the maximum resistance against the pressure of the gases of explosion.

Since 1886 as important results have been obtained in the manufacture, handling, storage and use of explosives as in the whole of the previous years. This is no doubt due to the enormous amount of scientific research and experiment devoted by manufacturers to the study of such questions and also demands made on manufacturers for different kinds of explosives. To-day every up-to-date manufacturer recognizes that only by the best scientific knowledge can he effect improvement or keep in line with modern developments of the industry.