

## CHAPTER VII

### DYNAMITE AND OTHER HIGH EXPLOSIVES

#### Invention of Dynamite

Dynamite and the fulminate blasting cap both resulted from Alfred Nobel's effort to make nitroglycerin more safe and more convenient to use.<sup>1</sup> Having discovered that nitroglycerin is exploded by the explosion of a small firecracker-like device filled with black powder, he tried the effect of mixing the two materials, and in 1863 was granted a patent<sup>2</sup> which covered the use of a liquid explosive, such as nitroglycerin or methyl or ethyl nitrate, in mixture with gunpowder in order to increase the effectiveness of the latter. The amount of the liquid was limited by the requirement that the mixtures should be dry and granular in character. The explosives were supposed to be actuated by fire, like black powder, but the liquid tended to slow down the rate of burning, and they were not notably successful. The same patent also covered the possibility of substituting a part of the saltpeter by nitroglycerin. Because this substance is insoluble in water and non-hygroscopic, it acts as a protective covering for the salt and makes the use of sodium nitrate possible in these mixtures.

Nobel's next patent,<sup>3</sup> granted in 1864, related to improvements in the manufacture of nitroglycerin and to the exploding of it by heating or by means of a detonating charge. He continued his experiments and in 1867 was granted a patent<sup>4</sup> for an explosive prepared by mixing nitroglycerin with a suitable non-explosive, porous absorbent such as charcoal or siliceous earth. The resulting material was much less sensitive to shock than nitroglycerin. It was known as *dynamite*, and was manufactured and sold also

<sup>1</sup> For an account of Nobel and his inventions see de Mosenthal, *Jour. Soc. Chem. Ind.*, 443 (1899).

<sup>2</sup> Brit. Pat. 2359 (1863).

<sup>3</sup> Brit. Pat. 1813 (1864).

<sup>4</sup> Brit. Pat. 1345 (1867).

under the name of Nobel's Safety Powder. The absorbent which was finally chosen as being most satisfactory was diatomaceous earth or kieselguhr (guhr or fuller's earth). Nobel believed that dynamite could be exploded by a spark or by fire if it was confined closely, but preferred to explode it under all conditions by means of a special exploder or cap containing a strong charge of

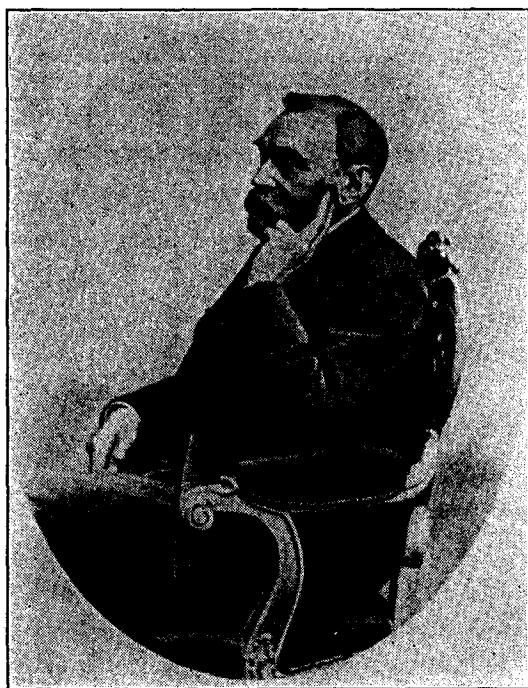


FIGURE 83. Alfred Nobel (1833-1896). First manufactured and used nitroglycerin commercially, 1863; invented dynamite and the fulminate blasting cap, 1867; straight dynamite, 1869; blasting gelatin and gelatin dynamite, 1875; and ballistite, 1888. He left the major part of his large fortune for the endowment of prizes, now known as the Nobel Prizes, for notable achievements in physics, in chemistry, in physiology and medicine, in literature, and in the promotion of peace.

mercury fulminate, crimped tightly to the end of the fuse in order that it might detonate more strongly. He stated that the form of the cap might be varied greatly but that its action depended upon the sudden development of an intense pressure or shock.

Dynamite with an inactive base (guhr dynamite) is not manufactured commercially in this country. Small quantities are used for experimental purposes where a standard of comparison is needed in studies on the strength of various explosives.

The next important event in the development of these explosives was Nobel's invention of *dynamite with an active base*,<sup>5</sup> an explosive in which the nitroglycerin was absorbed by a mixture of materials which were themselves not explosive separately, such as potassium, sodium, or ammonium nitrate mixed with wood meal, charcoal, rosin, sugar, or starch. The nitroglycerin formed a thin coating upon the particles of the solid materials, and caused them to explode if a fulminate cap was used. The patent suggested a mixture of barium nitrate 70 parts, rosin or charcoal 10, and nitroglycerin 20, with or without the addition of sulfur, as an example of the invention. Nitroglycerin alone was evidently not enough to prevent the deliquescence of sodium and ammonium nitrate in these mixtures, for a later patent<sup>6</sup> of Nobel claimed the addition of small amounts of paraffin, ozokerite, stearine, naphthalene, or of any similar substance which is solid at ordinary temperatures and is of a fatty nature, as a coating for the particles to prevent the absorption of moisture by the explosive and the resulting danger from the exudation of nitroglycerin.

Dynamite with an active base is manufactured and used extensively in this country and in Canada and Mexico. It is known as *straight dynamite*, or simply as dynamite, presumably because its entire substance contributes to the energy of its explosion. The standard 40% straight dynamite which is used in comparative tests at the U. S. Bureau of Mines contains<sup>7</sup> nitroglycerin 40%, sodium nitrate 44%, calcium carbonate (anti-acid) 1%, and wood pulp 15%. Since the time when this standard was adopted, the usage of the term "straight" has altered somewhat in consequence of changes in American manufacturing practice, with the result that this standard material is now better designated as 40% straight nitroglycerin (straight) dynamite. This name distinguishes it from 40% l. f. or 40% low-freezing (straight) dynamite which contains, instead of straight nitroglycerin, a mixture of nitric esters produced by nitrating a mix-

<sup>5</sup> Brit. Pat. 442 (1869).

<sup>6</sup> Brit. Pat. 1570 (1873).

<sup>7</sup> C. A. Taylor and W. H. Rinckenbach, "Explosives, Their Materials, Constitution, and Analysis," *U. S. Bur. Mines Bull.* 219, Washington, 1923, p. 133.

ture of glycerin and glycol or of glycerin and sugar. Practically all active-base dynamites now manufactured in the United States, whether straight or ammonia or gelatin, are of this l. f. variety. American straight dynamites contain from 20 to 60% of mixed nitric esters absorbed on wood pulp and mixed with enough sodium or potassium nitrate to maintain the oxygen balance and to take care of the oxidation of part or occasionally of all the wood pulp.

*Judson powder* is a special, low-grade dynamite in which 5 to 15% of nitroglycerin is used as a coating on a granular *dope* made by mixing ground coal with sodium nitrate and sulfur, warming the materials together until the sulfur is melted, forming into grains which harden on cooling and are screened for size. It is intermediate in power between black powder and ordinary dynamite and is used principally for moving earth and soft rock in railroad work.

Nobel's inventions of *blasting gelatin* and *gelatin dynamite* are both covered by the same patent.<sup>8</sup> Seven or 8% of collodion cotton dissolved in nitroglycerin converted it to a stiff jelly which was suitable for use as a powerful high explosive. Solvents, such as acetone, ether-alcohol, and nitrobenzene, facilitated the incorporation of the two substances in the cold, but Nobel reported that collodion cotton dissolved readily in nitroglycerin without additional solvent if the nitroglycerin was warmed gently on the water bath. A cheaper explosive of less power could be made by mixing the gelatinized nitroglycerin with black powder or with mixtures composed of an oxidizing agent, such as a nitrate or chlorate, and a combustible material, such as coal dust, sulfur, sawdust, sugar, starch, or rosin. A typical gelatin dynamite consists of nitroglycerin 62.5%, collodion cotton 2.5%, saltpeter 27.0%, and wood meal 8%. A softer jelly is used for making gelatin dynamite than is suitable for use by itself as a blasting gelatin, and somewhat less collodion is used in proportion to the amount of nitroglycerin.

All straight nitroglycerin explosives can be frozen. Straight dynamite when frozen becomes less sensitive to shock and to initiation, but blasting gelatin becomes slightly more sensitive.

<sup>8</sup> Brit. Pat. 4179 (1875).

When the explosives are afterwards thawed, the nitroglycerin shows a tendency to exude.

### Invention of Ammonium Nitrate Explosives

In 1867 two Swedish chemists, C. J. Ohlsson and J. H. Norrbin, patented an explosive, called *ammoniakkrot*, which consisted of ammonium nitrate either alone or in mixture with charcoal, sawdust, naphthalene, picric acid, nitroglycerin, or nitrobenzene. Theoretical calculations had shown that large quantities of heat and gas were given off by the explosions of these mixtures. The proportions of the materials were selected in such manner that all the carbon should be converted to carbon dioxide and all the hydrogen to water. Some of these explosives were difficult to ignite and to initiate, but the trouble was remedied by including some nitroglycerin in their compositions and by firing them with fulminate detonators. They were used to some extent in Sweden. Nobel purchased the invention from his fellow-countrymen early in the 1870's, and soon afterwards took out another patent<sup>9</sup> in connection with it, but still found that the hygroscopicity of the ammonium nitrate created real difficulty. He was not able to deal satisfactorily with the trouble until after the invention of gelatin dynamite. In present manufacturing practice in this country the tendency of the ammonium nitrate to take up water is counteracted by coating the particles with water-repelling substances, oils, or metallic soaps.

In 1879 Nobel took out a Swedish patent for *extra-dynamite* (ammon-gelatin-dynamit), one example of which was a fortified gelatin dynamite consisting of nitroglycerin 71%, collodion 4%, charcoal 2%, and ammonium nitrate 23%. Another contained much less nitroglycerin, namely, 25%, along with collodion 1%, charcoal 12%, and ammonium nitrate 62%, and was crumbly and plastic between the fingers rather than clearly gelatinous.

In these explosives, and in the ammonium nitrate *permissible* explosives which contain still less nitroglycerin, it is supposed that the nitroglycerin or the nitroglycerin jelly, which coats the particles of ammonium nitrate, carries the explosive impulse originating in the detonator, that this causes the ammonium nitrate to decompose explosively to produce nitrogen and water

<sup>9</sup> The above-cited Brit. Pat. 1570 (1873).

and oxygen, the last named of which enters into a further explosive reaction with the charcoal or other combustible material. Other explosive liquids or solids, such as liquid or solid DNT, TNT, or TNX, nitroglycol, nitrostarch, or nitrocellulose, may be used to sensitize the ammonium nitrate and to make the mixture more easily detonated by a blasting cap. Non-explosive combustible materials, such as rosin, coal, sulfur, cereal meal, and paraffin, also work as sensitizers for ammonium nitrate, and a different hypothesis is required to explain their action.

### Guhr Dynamite

Guhr dynamite is used rather widely in Europe. It is not hygroscopic. Liquid water however, brought into contact with it, is absorbed by the kieselguhr and displaces the nitroglycerin which separates in the form of an oily liquid. The nitroglycerin thus set free in a wet bore hole might easily seep away into a fissure in the rock where it would later be exploded accidentally by a drill or by the blow of a pick. Water does not cause the separation of nitroglycerin from blasting gelatin or gelatin dynamite. It tends to dissolve the soluble salts which are present in straight dynamite and to liberate in the liquid state any nitroglycerin with which they may be coated.

Guhr dynamite, made from 1 part of kieselguhr and 3 parts of nitroglycerin, is not exploded by a blow of wood upon wood, but is exploded by a blow of iron or other metal upon iron. In the drop test it is exploded by the fall of a 1-kilogram weight through 12 to 15 cm., or by the fall of a 2-kilogram weight through 7 cm. The frozen material is less sensitive: a drop of more than 1 meter of the kilogram weight or of at least 20 cm. of the 2-kilogram weight is necessary to explode it. Frozen or unfrozen it is exploded in a paper cartridge by the impact of a bullet from a military rifle. A small sample will burn quietly in the open, but will explode if it is lighted within a confined space. A cartridge explodes if heated on a metal plate.

The velocity of detonation of guhr dynamite varies with the density of loading and with the diameter of the charge, but does not reach values equal to the maxima under best conditions for nitroglycerin and blasting gelatin. Velocities of 6650 to 6800 meters per second, at a density of loading of 1.50 (the highest

which is practical) have been reported. Naoúm,<sup>10</sup> working with charges in an iron pipe 34 mm. in internal diameter and at a density of loading of 1.30, found for nitroglycerin guhr dynamite a velocity of detonation of 5650 meters per second, and, under the same conditions, for nitroglycol guhr dynamite one of 6000 meters per second.



FIGURE 84. Determination of the Velocity of Detonation of Dynamite by the Dautriche Method. (Courtesy Hercules Powder Company.) Compare Figure 9, page 17.

Dynamites, like guhr dynamite and straight dynamite, which contain nitroglycerin in the subdivided but liquid state communicate explosion from cartridge to cartridge more readily, and in general are more easy to initiate, than blasting gelatin and gelatin dynamite in which no liquid nitroglycerin is present. A cartridge of guhr dynamite 30 mm. in diameter will propagate its explosion through a distance of 30 cm. to a similar cartridge.

<sup>10</sup> Phokion Naoúm, "Nitroglycerine and Nitroglycerine Explosives," trans E. M. Symmes, Baltimore, The Williams and Wilkins Company, 1928 p. 277.

### Straight Dynamite

Straight dynamite containing 60% or less of mixed nitric esters—but not more because of the danger of exudation—is used extensively in the United States, but has found little favor in

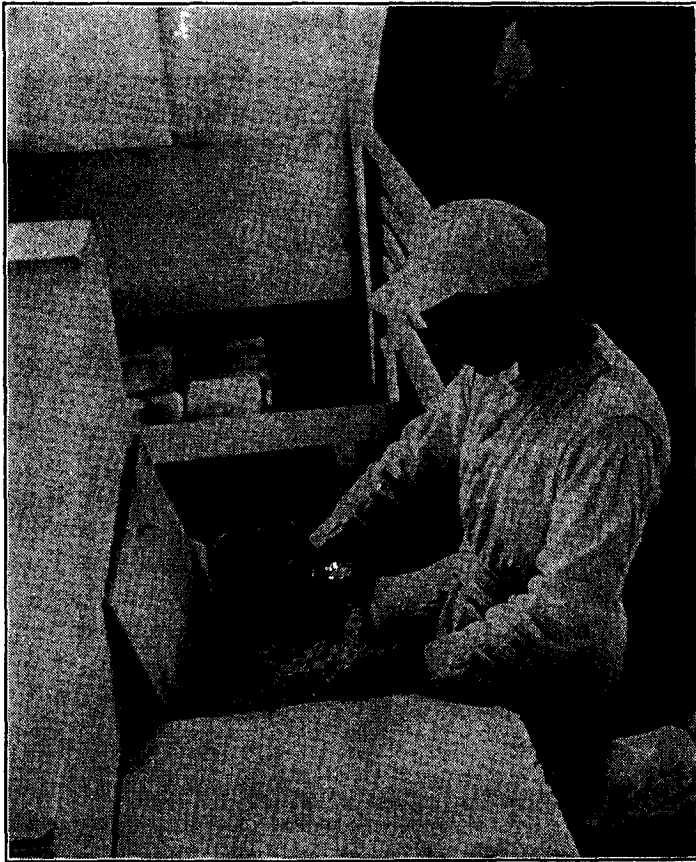


FIGURE 85. Dynamite Manufacture. (Courtesy Hercules Powder Company.) Rubbing the dry ingredients of dynamite through a screen into the bowl of a mixing machine.

Europe. It is made simply by mixing the explosive oil with the absorbent materials; the resulting loose, moist-appearing or greasy mass, from which oil ought not to exude under gentle pressure, is put up in cartridges or cylinders wrapped in paraffined paper and dipped into melted paraffin wax to seal them against moisture.

The strength of straight nitroglycerin dynamite is expressed by the per cent of nitroglycerin which it contains. Thus, "40% straight nitroglycerin dynamite" contains 40% of nitroglycerin,



but "40% ammonia dynamite," "40% gelatin dynamite," etc., whatever their compositions may be, are supposed to have the same strength or explosive force as 40% straight nitroglycerin dynamite. Munroe and Hall<sup>11</sup> in 1915 reported for typical straight nitroglycerin dynamites the compositions which are

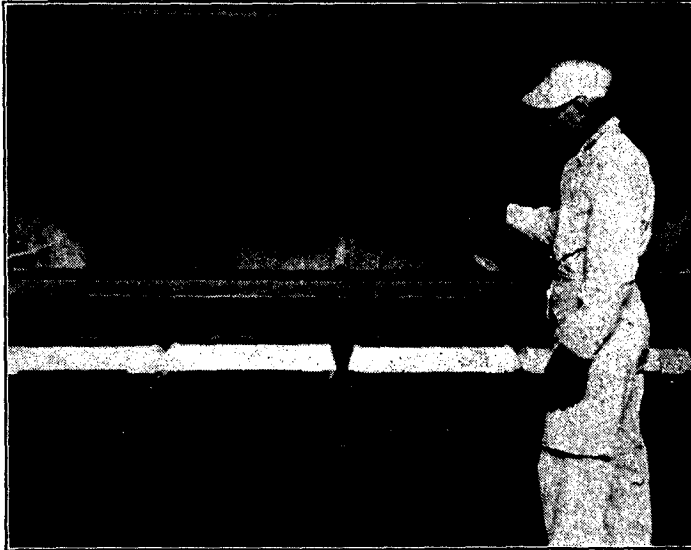


FIGURE 86. Dynamite Manufacture. (Courtesy Hercules Powder Company.) Hoppers underneath the mixing machine, showing the buggies which carry the mixed dynamite to the packing machines.

shown in the following table. Although these dynamites are not now manufactured commercially in the United States, their explosive properties, studied intensively at the U. S. Bureau of

	STRENGTH									
	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%
Nitroglycerin . . . . .	15	20	25	30	35	40	45	50	55	60
Combustible material	20	19	18	17	16	15	14	14	15	16
Sodium nitrate . . . . .	64	60	56	52	48	44	40	35	29	23
Calcium or magnesium carbonate . . . . .	1	1	1	1	1	1	1	1	1	1

Mines and reported as a matter of interest, do not differ greatly from those of the l. f. dynamites by which they have been superseded in common use. The combustible material stated to be used in these compositions consists of a mixture of wood pulp,

<sup>11</sup> Charles E. Munroe and Clarence Hall, "A Primer on Explosives for Metal Miners and Quarrymen," *U. S. Bur. Mines Bull.* 80, Washington, 1915, p. 22.

flour, and brimstone for the grades below 40% strength, wood pulp alone for the 40% and stronger. In commercial practice the dope sometimes contains coarse combustible material, like rice hulls, sawdust, or bran, which makes the explosive more bulky and has the effect of reducing the velocity of detonation. Tests at the U. S. Bureau of Mines on standard straight dynamites in cartridges  $1\frac{1}{4}$  inches in diameter showed for the 30% grade a velocity of detonation of 4548 meters per second, for the 40%

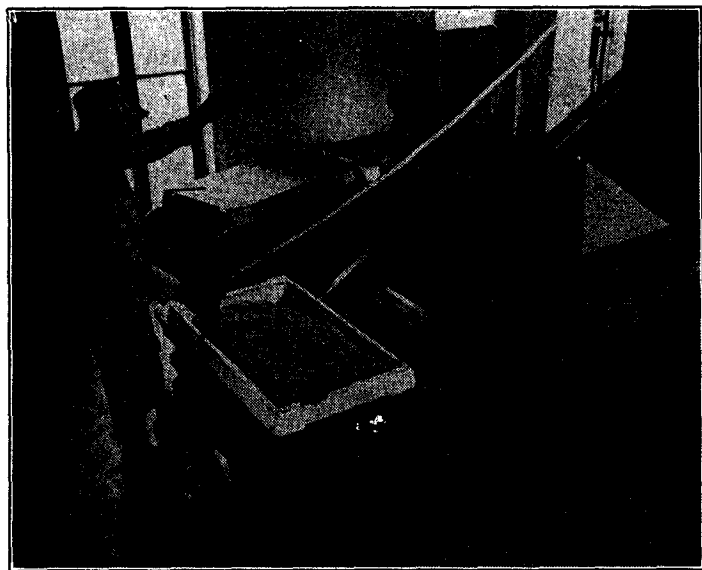


FIGURE 87. Dynamite Manufacture. (Courtesy Hercules Powder Company.) Dumping the mixed dynamite onto the conveyor belt which raises it to the hopper of the semi-automatic packing machine.

grade 4688 meters per second, and for the 60% grade 6246 meters per second. The 40% dynamite was exploded in one case out of three by an 11-cm. drop of a 2-kilogram weight, in no case out of five by a 10-cm. drop. Cartridges  $1\frac{1}{4}$  inches in diameter and 8 inches long transmitted explosion from one to another through a distance of 16 inches once in two trials, but not through a distance of 17 inches in three trials. The 40% dynamite gave a small lead block compression of 16.0 mm., and an expansion (average of three) in the Trauzl test of 278 cc.<sup>12</sup>

<sup>12</sup> Clarence Hall, W. O. Snelling, and S. P. Howell, "Investigations of Explosives Used in Coal Mines," *U. S. Bur. Mines Bull.* 15, Washington, 1912, pp. 171, 173.

Munroe and Hall<sup>13</sup> also reported the following compositions for typical ordinary and low-freezing ammonia dynamites, the combustible material in each case being a mixture of wood pulp, flour, and brimstone. Low-freezing dynamites at present in use in this country contain nitroglycol or nitrosugar instead of the above-mentioned nitrosubstitution compounds. In Europe dinitrochlorohydrin, tetranitrodiglycerin, and other nitric esters are used.

Strength	Ordinary					Low-Freezing				
	30%	35%	40%	50%	60%	30%	35%	40%	50%	60%
Nitroglycerin.....	15	20	22	27	35	13	17	17	21	27
Nitrosubstitution compounds.....	..	..	..	..	..	3	4	4	5	6
Ammonium nitrate.....	15	15	20	25	30	15	15	20	25	30
Sodium nitrate.....	51	48	42	36	24	53	49	45	36	27
Combustible material....	18	16	15	11	10	15	14	13	12	9
Calcium carbonate or zinc oxide.....	1	1	1	1	1	1	1	1	1	1

Three of the standard French ammonia dynamites, according to Naoúm,<sup>14</sup> have the compositions and explosive properties listed below.

Nitroglycerin .....	40	20	22
Ammonium nitrate .....	45	75	75
Sodium nitrate .....	5	...	...
Wood or cereal meal .....	10	5	...
Charcoal .....	...	...	3
Lead block expansion .....	400.0 cc.	335.0 cc.	330.0 cc.
Lead block crushing .....	22.0 mm.	15.5 mm.	16.0 mm.
Density .....	1.38	1.20	1.33

Taylor and Rinckenbach<sup>15</sup> report typical analyses of American ammonium nitrate dynamite (I below) and ammonium nitrate sodium nitrate dynamite (II below). These formulas really represent ammonium nitrate permissible explosives, very close in their

<sup>13</sup> *Op. cit.*, p. 23.

<sup>14</sup> *Op. cit.*, p. 285.

<sup>15</sup> *Op. cit.*, pp. 136, 138.

compositions to Monobel (III below) which is permissible in this country for use in coal mines. Naoúm<sup>16</sup> reports that this

	I	II	III
Nitroglycerin .....	9.50	9.50	10.0
Ammonium nitrate .....	79.45	69.25	80.0
Sodium nitrate .....	...	10.20	...
Carbonaceous combustible material <sup>17</sup> .....	9.75	9.65	...
Wood meal .....	...	...	10.0
Anti-acid .....	0.40	0.50	...
Moisture .....	0.90	0.90	...

Monobel (density about 1.15) gives a lead block expansion of about 350 cc. and a lead block crushing of 12 mm. He states that



FIGURE 88. Dynamite Manufacture. (Courtesy Hercules Powder Company.) Cartridges of dynamite as they come from the semi-automatic packing machine.

Monobel belongs to the class of typical ammonium nitrate explosives rather than to the dynamites, and points out that no specific effect can be ascribed to the 10% nitroglycerin which it contains, for an explosive containing only a small quantity, say 4%,

<sup>16</sup> *Op. cit.*, p. 286.

<sup>17</sup> The carbonaceous combustible material contains 0.40% grease or oil which was added to the ammonium nitrate to counteract its hygroscopicity. Note that the figures in the first two columns of the table represent results of analyses; those in the third column represent the formula according to which the explosive is mixed.

of nitroglycerin, or none at all, will give essentially the same performance. But the ammonium nitrate explosive with no nitroglycerin in it is safer to handle and more difficult to detonate.

### Blasting Gelatin

Blasting gelatin exists as a yellowish, translucent, elastic mass of density about 1.63. Strong pressure does not cause nitroglycerin to exude from it. Its surface is rendered milky by long contact with water, but its explosive strength is unaffected. It is less sensitive to shock, blows, and friction than nitroglycerin, guhr dynamite, and straight dynamite, for its elasticity enables it more readily to absorb the force of a blow, and a thin layer explodes under a hammer more easily than a thick one. Blasting gelatin freezes with difficulty. When frozen, it loses its elasticity and flexibility, and becomes a hard, white mass. Unlike guhr dynamite and straight dynamite, it is more sensitive to shock when frozen than when in the soft and unfrozen state.

Unlike nitroglycerin, blasting gelatin takes fire easily from a flame or from the spark of a fuse. Its combustion is rapid and violent, and is accompanied by a hissing sound. If a large quantity is burning, the combustion is likely to become an explosion, and the same result is likely to follow if even a small quantity of the frozen material is set on fire.

Pulverulent explosives or explosive mixtures are easier to initiate and propagate detonation for a greater distance than liquid explosives, especially viscous ones, and these are easier to detonate and propagate more readily than colloids. The stiffer the colloid the more difficult it becomes to initiate, until, with increasingly large proportions of nitrocellulose in the nitroglycerin gel, tough, horny colloids are formed, like ballistite and cordite, which in sizable aggregates can be detonated only with difficulty. Blasting gelatin is more difficult to detonate than any of the forms of dynamite in which the nitroglycerin exists in the liquid state. Naoúm<sup>18</sup> reports that a freshly prepared blasting gelatin made from 93 parts of nitroglycerin and 7 parts of collodion cotton is exploded by a No. 1 (the weakest) blasting cap and propagates detonation even in 25-mm. cartridges across a gap of about 10 mm. A blasting gelatin containing 9% of collodion cotton requires a No. 4 blasting cap to make it explode and propagates

<sup>18</sup> *Op. cit.*, p. 316.

its explosion to an adjacent cartridge only when initiated by a No. 6 blasting cap.

Blasting gelatin and gelatin dynamite on keeping become less sensitive to detonation, and, after long storage in a warm climate, may even become incapable of being detonated. The effect has been thought to be due to the small air bubbles which make newly prepared blasting gelatin appear practically white but which disappear when the material is kept in storage and becomes translucent and yellowish. But this cannot be the whole cause of the effect, for the colloid becomes stiffer after keeping. The loss of sensitivity is accompanied by a rapid dropping off in the velocity of detonation and in the brisance. According to Naoúm,<sup>19</sup> blasting gelatin containing 7% collodion cotton when newly prepared gave a lead block expansion of 600 cc., after 2 days 580 cc., and one containing 9% collodion gave when freshly made an expansion of 580 cc., after 2 days 545 cc.

Blasting gelatin under the most favorable conditions has a velocity of detonation of about 8000 meters per second. In iron pipes it attains this velocity only if its cross section exceeds 30 mm. in diameter, and it attains it only at a certain distance away from the point of initiation, so that in the Dautriche method where short lengths are used lower values are generally obtained. In tubes of 20–25 mm. diameter, and with samples of a sensitivity reduced either by storage or by an increased toughness of the colloid, values as low as 2000–2500 meters per second have been observed.

### Gelatin Dynamite

Blasting gelatin is not used very widely in the United States; the somewhat less powerful gelatin dynamite, or simply gelatin as it is called, is much more popular. Gelatin dynamite is essentially a straight dynamite in which a gel is used instead of the liquid nitroglycerin or l. f. mixture of nitric esters. It is a plastic mass which can be kneaded and shaped. The gel contains between 2 and 5.4% collodion cotton, and is not tough and really elastic like blasting gelatin. Correspondingly it is initiated more easily and has a higher velocity of detonation and better propagation. The gel is prepared by mixing the nitroglycerin and collodion cotton, allowing to stand at 40–45°C. for some hours or over

<sup>19</sup> *Op. cit.*, p. 322.

night, and then incorporating mechanically with the dope materials which have been previously mixed together. Munroe and Hall<sup>20</sup> in 1915 gave the compositions listed below as typical of gelatin dynamites offered for sale at that time in this country. Instead of straight nitroglycerin, i. e. mixtures of nitric esters are now used.

	STRENGTH						
	30%	35%	40%	50%	55%	60%	70%
Nitroglycerin .....	23.0	28.0	33.0	42.0	46.0	50.0	60.0
Nitrocellulose .....	0.7	0.9	1.0	1.5	1.7	1.9	2.4
Sodium nitrate .....	62.3	58.1	52.0	45.5	42.3	38.1	29.6
Combustible material <sup>21</sup> .....	13.0	12.0	13.0	10.0	9.0	9.0	7.0
Calcium carbonate .....	1.0	1.0	1.0	1.0	1.0	1.0	1.0

The three standard explosives which are used in Great Britain are called respectively blasting gelatin, gelatin dynamite, and *Gelignite*. *Gelignite*, let us note, is a variety of gelatin dynamite as the latter term is used in this country. It is the most widely used of the three and may indeed be regarded as the standard explosive.

	BLASTING	GELATIN	
	GELATIN	DYNAMITE	
Nitroglycerin .....	92	75	60
Collodion cotton .....	8	5	4
Wood meal .....	..	5	8
Potassium nitrate .....	..	15	28

The gelatin dynamites most widely used in Germany contain about 65 parts of gelatinized nitroglycerin and about 35 parts of dope or absorbent material. The dope for an explosive for domestic use consists of 76.9% sodium nitrate, 22.6% wood meal, and 0.5% chalk, and for one for export of 80% potassium nitrate, 19.5% wood meal, and 0.5% chalk. A weaker *Gelignite II* and certain high-strength gelatin dynamites, as tabulated below, are also manufactured for export.

	GELIGNITE	HIGH-STRENGTH GELATIN DYNAMITE		
	II	80%	81%	75%
Nitroglycerin .....	47.5	75	75.8	70.4
Collodion cotton .....	2.5	5	5.2	4.6
Potassium nitrate .....	37.5	15	15.2	19.3
Wood meal with chalk .....	3.5	5	3.8	5.7
Rye meal .....	9.0	..	..	..

<sup>20</sup> *Op. cit.*, p. 23.

<sup>21</sup> Wood pulp was used in the 60% and 70% grades. Flour, wood pulp, and, in some examples, rosin and brimstone were used in the other grades.

The gelatin dynamites manufactured in Belgium are called *Forcites*. The reported compositions of several of them are tabulated below. *Forcite extra* is an ammonia gelatin dynamite.

	FOR- CITE EXTRA	SU- PER- IEURE	PER FOR- CITE	FOR- CITE No. 1	FOR- CITE No. 1P	FOR- CITE No. 2	FOR- CITE No. 2P
Nitroglycerin .....	64	64	64	49	49	36	36
Collodion cotton .....	3.5	3	3	2	2	3	2
Sodium nitrate .....	..	24	..	36	..	35	..
Potassium nitrate .....	..	..	23	..	37	..	46
Ammonium nitrate .....	25	..	..	..	..	..	..
Wood meal .....	6.5	8	9	13	11	11	..
Bran .....	..	..	..	..	..	14	15
Magnesium carbonate .....	1	1	1	1	1	1	1

In France gelatin dynamites are known by the names indicated in the following table where the reported compositions of several of them are tabulated.

	Dynamite-gomme- extra-forte	Dynamite-gomme- potasse	Dynamite-gomme- soudé	Gélatine A	Gélatine B-potasse	Gélatine B-soudé	Gomme F	Gélinite
Nitroglycerin.....	92-93	82-83	82-83	64	57.5	57	49	58
Collodion cotton.....	8-7	6-5	6-5	3	2.5	3	2	2
Potassium nitrate.....	..	9-10	..	..	32.0	..	36	28
Sodium nitrate.....	..	..	9-10	24	..	34	..	..
Wood meal.....	..	2-3	2-3	8	8.0	6	10	9
Flour.....	..	..	..	..	..	..	3	3
Magnesium carbonate..	..	..	..	1	..	..	..	..

### Permissible Explosives

The atmosphere of coal mines frequently contains enough methane (fire damp) to make it explode from the flame of a black powder or dynamite blast. Dust also produces an explosive atmosphere, and it may happen, if dust is not already present,



.....  
tent lies between 5 and 14%. A mixture which contains 9.5% of methane, in which the oxygen exactly suffices for complete combustion, is the one which explodes most violently, propagates the explosion most easily, and produces the highest temperature. This mixture ignites at about 650° to 700°. Since explosives in general produce temperatures which are considerably above 1000°, explo-

<sup>22</sup> A few of the interesting and important publications of the U. S. Bureau of Mines are listed in the footnote, Vol. I, pp. 22-23.













































