The Manufacture of Explosives
A Theoretical and Practical Treatise on the History, The Physical and Chemical Properties, and the Manufacture of Explosives
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Oscar Guttmann, Assoc. M. Inst. C.E., F.I.C.
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3. COMPRESSED POWDER.

General Rodman, of the United States army, when experimenting with 15-inch and 20-inch cast-iron guns, found that he could considerably reduce the initial pressure in the by using discs, perforated with a number of holes, of compressed powder of a diameter equal to the calibre of the gun and between 1 inch and 2 inches thick. In a work published by him in 1861, he showed that at the beginning of the combustion such discs presented a minimum of free surface, which, as the powder burnt, continually increased through the constant enlargement of the holes, and on account of this constant increase of the area of burning surface the rate of production of the gases also constantly increased. This discovery of Rodman's was first practically used in the American civil war, during which the consumption of powder increased in such an extraordinary manner that the manufactories could not meet the requirements of the artillery, and making cartridges direct from the cake by means of pressing was tried. The cartridges so made did not answer the expectations, as interstices were wanting ; thus the powder only burned in layers, and the charge was blown out of the gun partially unconsumed. To overcome this defect the cartridges were perforated, both longitudinally and transversely, when good results were obtained, especially with guns of larger calibre.

About the same time granulated powder compressed into blocks was tried. It was a revival of a suggestion made by Paolo di San Roberto in 1852, whose idea was to utilize the low melting-point (230° F.) of sulphur to form the powder into blocks. These **[237]** blocks were made by putting powder into sheet-metal vessels surrounded by a jacket filled with boiling water ; the sulphur was softened, and the powder grains adhered to each other without losing their shape. The heated powder was then put into cylindrical moulds and pressed. In the resulting cartridges the grains were still perfectly recognizable, but adhered firmly to each other. They were hard as stone, black, and shining, and could be thrown to the ground without breaking. They gave very uniform results, both in guns and rifles, and the residue in the barrel was slight. This method of making compressed cartridges by softening the sulphur was soon given up, on account of its great inconvenience, but in nearly all countries attempts were made to utilize a binding agent, such as solutions of gum, sugar, or collodion, instead of heat. Brown patented a mixture made in the following way :—One part of gum arabic was to be dissolved in two parts of cold water, and a quarter part of saltpetre **in** 1/4 parts of water. Alcohol was to be added to both mixtures, and the whole stirred until an opaque liquid was formed. The powder grains were to be moistened with this solution and compressed in a mould.

During the American civil war, a Russian military commission visited the United States, and from what they learned of the behaviour of compressed powder, the manufacture of prismatic powder on a large scale was introduced by General Doremus. According to Doremus' original method, the granulated powder was made into cartridges of cylindrical shape by a light pressure, so as not to destroy the granular texture. In order to make the combustion keep pace with the increased surface, he made different sections of the same cartridges of varying densities. This was done by making the first part of the cartridge at a high pressure, and then making two more layers on to the same cartridge at lower pressures.

These cartridges were also tried for war purposes, and abandoned by all countries except France, which alone still uses compressed cartridges, though only in mitrailleuses. The mitrailleuse cartridge consists of a cardboard and galvanized iron case containing twenty-five metal cartridges, arranged in such a way that they place them-selves automatically in front of the twenty-five barrels of the mitrailleuse. Each cartridge contains six small discs of compressed powder about 3/8 inch thick, and 32 1/2 grains in weight. Over the powder is a ½ inch grease wad, and over this the projectile. On the other hand, compressed cartridges are used extensively for mining purposes in Great Britain, Austria, and Switzerland.

[238] In 1868, when Fenian disturbances were feared, the buck-shot cartridge, invented by Colonel Boxer, was adopted for the arms used by the Royal Irish Constabulary. Its charge consisted of fine-grained powder compressed into a cylinder, with an indenture on the top and bottom, and it was loaded with sixteen deer shots, the space between which was filled up with plaster of Paris.

The manufacture of compressed cartridges for mining purposes is almost entirely carried out by means of mechanical presses, but in large factories hydraulic presses, similar to those used for prismatic powder, are employed, which make one hundred cartridges at the same time. Figs. 113 and 114 show a cartridge press made by Charles Zimmermann, of Ehrenfeld, near Cologne, for the Swiss gunpowder factories.

The fly-wheels (a_1), with handle (a_2), are fixed on the same shaft as the pulley (a). This shaft drives the eccentrics (a_4) through a double pair of cog-wheels. The eccentric lifts the guide-bar (b), and with it the piston (c). A hopper (E) filled with gun-powder is pushed on to or from the cylindrical mould (f), as required, by means of the tappet-driven lever motion (d). As the guide-bar (b) goes down, the hopper (E) moves back, and the piston (c) compresses the powder in the mould, whilst the lower piston rests firmly on the cross-bar (i_3), which is carried by means of the adjust-able nuts (i_2) on the two side bolts. As the eccentric continues to revolve, the piston (c) is lifted, when the cross-bar (ii) carried by the rods (G) catches the lower piston (i) and lifts the cartridge out of the mould (f), keeps it suspended for some time, during which time they are removed, and then lets the piston (i) descend again. For this purpose the cross-bar (H) is provided with a slot. The tappet (k) puts H in position for lifting the piston (i), whilst the upper one (1) throws it on one side, and allows the piston to fall. The same movements of the hopper, piston, etc., are then repeated. With the press here illustrated, a central hole is made through the cartridge by means of the pin (k_1) carried on the cross-bar (m).

Another press for the same purpose is illustrated in Fig. 115. In this form a circular table *(A)* containing six holes, serving as moulds, is made to rotate. A cross-head (s) carries two carriages (c and c,), to which are attached the pistons (D). The carriages move in V grooves, and are pushed up and down by means of rolls and lever arms (E), actuated by eccentrics. One of these pistons is longer than the other ; the shorter one compresses the cartridge, and the longer one pushes it out of the mould. Below the table is an iron plate (F) with an opening opposite to the pressing-out **[240]** piston, under which is a steep shoot (G) passing through the bottom part of the press to the outside. A fast and loose pulley drive the shaft, and with it the eccentrics, by means of cog-wheels. Two armed levers (s) transmit the pressure by means of cams to the piston carriages. Above the front hole is fixed a short iron filling-funnel (I), which is connected by means of a piece of hose-pipe with a hopper for the powder. The hopper is fixed to the ceiling.

The working of the press is as follows :—At each revolution of the pulley the table is moved round so as to bring a fresh hole under the filling-funnel and the pistons, and then held in place by a catch (K). The empty hole under the funnel is filled with powder, while at the same time the powder in the hole under the pressing piston is compressed into a cartridge. The pressing piston is then lifted, and the pressing-out piston descends, pushing out the cartridge in the hole under it into the shoot. As soon as the pressing-out piston has risen clear of the revolving table, **[241]** the latter advances again by one hole, and the same action is repeated.

Presses constructed in a similar way, but with filling hoppers which advance automatically, have been built in England.

It is a matter of history that in the American civil war in 1860 the Confederates protected their war-vessels with iron plates in order to avoid the deadly effect of projectiles from the naval guns. This had the natural effect of causing the projectiles and the calibre of the guns to be increased in order to penetrate the armour ; and since that time the competition between armour plates and guns has been continued, and has led finally to the use of armour plates of enormous dimensions and of 100-ton guns.

The ordinary powder cannot be used for the increased charges demanded by larger guns, since with them the suddenly-developed gas pressure is too high, and would destroy the gun. The rate of combustion of the charge had therefore to be slackened. This led to the manufacture of large grains, and later on to the prismatic powder. The idea upon which the use of compressed powder is based is the following :—If a fine-grain powder is used for large charges, the greater part of the charge is burned at the moment of ignition on account of its very large surface. Therefore, a considerable maximum pressure will result, leading to very violent effects, whilst the average force developed will be small in comparison with the first part. The opposite takes place if so-called " progressive powder” be used, as is the case with all compressed powders. At the commencement of combustion they only present a small surface and develop no more gases than are required to overcome the inertia of the projectile, but their **[242]** quantity increases constantly during combustion, thus causing a gradually increasing pressure. As has been said above, every compressed powder which burns in layers will give progressive action, and the rate of combustion can also be regulated by various means. The following kinds of compressed powders are in use :—

The prismatic powder, Figs. 116 to 118, which is compressed into regular hexagonal prisms, pierced as a rule with one or seven holes. The object of the hexagonal form is to facilitate the **[243]** arrangement of the prisms side by side and the introduction of the powder into projectiles as bursting charges. The other kinds are pebble and cylindrical powders, which will be referred to later on.

With these powders the projectile at the beginning of its movement has only a low velocity imparted to it on account of the small quantity of gases developed at the start. The projectile consequently takes the rifling properly and obtains a regular motion, which is of importance, as a uniform direction of flight and a uniform velocity depend upon the uniform movement of the projectile in the barrel.

[243] The first compressed powder, properly speaking, was the Mammoth powder of General Rodman, some of which had a diameter of 3 inches. Lord Armstrong used large-grained powder (" R. L. G.") for his guns in 1860. In order to slacken the rate of combustion the grains were polished with black-lead in wooden drums. The size of the grains with the " R. L. G." No. 2 powder now in use is such that they remain on sieves of 6 meshes per square inch and pass through one of 3 meshes per square inch.

Some time later pebble powder was made by compressing the cake to the density of 1·8, and breaking it in pieces, which were sorted through sieves of between 1/2 inch and 1 inch mesh. Later on cubical powder was made by means of a cutting machine, a process which is still used in some factories. A machine for this purpose, made by the Grusonwerk, is shown in Figs. 119 and 120. It consists of a strong cast-iron frame (A) with a movable table (n), on the lower surface of which, in the centre, is a rack which is geared into a cog-wheel (c) fixed to a shaft. At the end of the latter is a ratchet-wheel and pawl actuated by a lever (E) with **[244]** a counter-weight (F). The lever is moved by an eccentric fixed on a shaft with pulleys fitted on the lower part of the frame. The main shaft (G) is also on the lower part of the frame, and has an eccentric at each end, which is connected by means of rods (H) with a brass knife (1) guided at each end in slots on the upper part of the side frames. At each revolution of the shaft the knife is lifted, the table advanced one tooth, the knife brought down, and a strip of the powder cut off. After the whole cake on the table has been cut into strips they are placed on it again in a longitudinal direction and cut into cubes.

At Waltham Abbey an apparatus invented by Major Morgan was used for cutting cubical powder, the principle of which is shown in Fig. 121. It consists essentially of two pairs of phosphor- bronze rolls, which are placed at right angles to each other at different heights, on the circumference of which knives are fixed. The powder cake enters the upper pair of rolls, and is there cut into longitudinal strips, and pushed along a table by a conveyor on to an endless band. This moves at right angles to the conveyor, and carries the longitudinal strips to the lower pair of rolls, which break them into cubes. If a fixed board under the lattice band were used, the second longitudinal strip would fall on to the first, and so on, and the consequence would be an accumulation of strips on the lower endless band. In order to avoid this, the board is arranged to move backwards and forwards between certain limits. The mechanism to effect this is illustrated in Fig. 122. As will be seen, the bottom part of the board has a fixed slotted bar. An endless chain, moving over two correspondingly **[245]** shaped rolls, has a pin on one of its links, which engages in the slotted bar. It will be readily seen that as the chain continuously travels the board first obtains a movement to the left, `and as soon as the pin has reached the roll it is moved to the right. The consequence is that the strips on the endless band lie side by side instead of one above the other.

One hundred and sixty grains of cubical powder go to a pound. They measure between 1/2 inch and 5/8 inch on each side, and have a density of about 1·800. Larger cubes are used for the largest guns.

In whatever manner the cubical powder is made, it is always rounded after cutting, so that when it is stored or carried, no (lust or waste will be produced. For this purpose the powder is rotated in a cylindrical reel, by means of which the sharp corners are rubbed off, and at the same time the fine stuff and dust produced are removed. After drying, the powder is again treated in a reel with black-lead. Similar powders are made in almost all Government factories.

In 1860 it was again Rodman who suggested the compression of powder into plates by hydraulic pressure, in such a way that when the plates were laid one on top of the other they formed a cylindrical charge. Each of these plates was perforated, and in this way he made charges up to 75 lbs. weight; but this was attended by considerable difficulties, particularly in the pressing out of the moulds of such large and thick discs.

In 1872 Professor Wyschnegradski invented a press for the manufacture of prismatic powder, which is still used in all Government factories. **It is** the so-called cam-press, and is illustrated in Fig. 123. It consists of three cross-heads, an upper, a central, and a lower one. The upper and lower cross-heads are connected with each other by means of bars, and they move an upper and lower traverse by means of eccentrics and cog-wheels in such a way that the two traverses approach each other up to a certain point and **[246]** then move upwards. Each traverse has six pistons perforated longitudinally by seven holes. The steel moulds for the compression of the powder are placed in the centre cross-head. On the lower traverse are fixed seven steel needles, which are slightly tapered, and about 0·2 inch in diameter. They pass through the perforations of the lower pistons up to the surface of the centre cross-head. The powder is introduced from a brass box which moves to and fro on the centre cross-head, and has seven tubes for measuring the powder. The charger moves with the machine, and as soon as it is brought over the moulds, the powder from the measures falls into them. The charger then moves away, the two pistons approach each other, and the eccentrics are so arranged that after the upper pistons have reached their lowest positions, the bottom piston continues to move upwards. The upper traverse is then lifted quickly by means of a large eccentric, the lower **[*247]*** pistons push out the compressed prisms, and the charger coming forward, pushes them over an incline towards the attendant.

A similar press built by the Grusonwerk of Buckau is illustrated in Fig. 124, the general arrangement of which can be well seen from the drawing.

In Great Britain and France prismatic powders are now almost exclusively made by hydraulic pressure. Before considering the various systems of presses, it is advisable to make a few general remarks on hydraulic presses.

On the 30th of April, 1795, Joseph Bramah took out a patent in England for a hydraulic press. It was based upon the principle that if pressure is exerted upon one part of a fluid enclosed in a vessel, it will be uniformly transmitted in all directions, so that **[247]** every part of the walls of the vessel is subjected to the same pressure as that exerted on the particular part. If, now, in such a vessel a tightly-fitting ram be placed, each part of the outer surface of the ram that is inside the vessel will be subjected to the same pressure.

Supposing that in Fig. 125 A be such a vessel, B such a piston, and c the piston of a pump, and also that the force acting upon the piston of the pump be of such magnitude that it will exert a pressure of 4000 lbs. on it ; further suppose that the piston of the pump have a diameter of 3 inches (or a sectional area of 7 square inches in round figures), and the ram in the vessel a diameter of 24 inches (or a sectional area of 452 square inches), then when the pump forces water into the vessel each square inch of the water surface in the pump will be submitted to a pressure of 4000/7 or 556 lbs. per square inch, and this pressure will be uniformly transmitted to the surface of the water, and in consequence also on to the lower surface of the ram (n). The latter, therefore, will be subjected to a pressure of 452 x 556 =251,312 lbs., and at the same time will be lifted by the water forced in by the pump ; it will therefore be able to transmit the pressure to other objects. If the piston of the pump have a diameter of 2 inches only—i.e. an area of 3·14 inches—then each square inch of water surface will have a pressure of 1274 lbs. on it. The pressure exerted on the piston in the vessel will then be 452 x 1274 = 575,848 lbs.

[249] The total pressure exerted on to the ram of the press is there-fore inversely proportional to the square of its diameter. It does not make any difference whether the piston of the pump or the ram of the press be flat or rounded or quite round, since the pressure always corresponds to the area, which depends upon the diameter of the piston and not upon the surface of the semi-circular end.

The amount the ram of a hydraulic press is lifted depends upon the quantity of water introduced. If, in our example, we suppose that the piston of the pump has a stroke of 15 inches and makes 60 strokes per minute, then 15 x 7 = 105 cubic inches per second will be forced into the press, and the ram will be lifted 105/452=0·232 inch per second. With a pump piston of 2 inches diameter, and the same number and length of strokes, only 15 x 3·14 = 47 cubic inches of water will be pumped in, and the ram will only rise 47/252=0·014 inch per second. The total pressure exerted by the piston can be used at its upper surface in any desired manner, whatever its form or however large it be; for instance, a plate may be put on the top. If, on the other hand, a press piston for cartridges were put on the top of the ram of the press, then the total pressure acting upon the ram would also act upon the cartridge piston. Supposing that the cartridge piston have a circular section of 6 inches diameter, corresponding to an area of 28·27 square inches, then this piston will, by using a 3-inch pump, be subjected to a pressure of 251/28 x 312/27= 8890 lbs. per square inch, and by using a 2-inch pump to a pressure of 575/28 x 848/27=20,370 lbs. per square inch. If, instead of the one large piston, several small ones be placed upon the ram, then the pressure exerted in this case depends on the sum of their areas.

If a hydraulic pump be connected with the ram of a press used for compressing objects, the pressure will be exerted in jerks, because the working of a pump is not smooth. This causes unequal pressing, and sometimes more power is required. To avoid this, appliances called " accumulators" are used. They are really nothing but a hydraulic press, because the pressure exerted upon a piston is used to lift a certain calculated weight, which in its turn exerts the pressure upon the press by means of a branch-pipe.

There are two kinds of accumulators—those with a fixed cylinder where the ram is lifted, and those where the ram is fixed and the cylinder lifted. **In** Fig. 126 an accumulator made by Easton, Anderson, and Goolden, Limited, of Erith, is illustrated. The fixed **[250]** part of accumulators is firmly bolted to the ground by means of large bed-plates and foundation-bolts, and the movable part has a cross-head on to which weighting-plates are laid or suspended by means of bars. In order to facilitate putting on and taking off these weights, they have, as a rule, an opening cast in them from the centre to circumference, so that they can be pushed on to the ram instead of being slipped over it ; in this case the openings are, as a rule, placed at an angle of 90° from each other to prevent the plates falling off.

It is cheaper and more advantageous to use a wrought-iron shell, as in Fig. 126, instead of weight-plates, and to fill it with scrap-iron or with water.

Supposing that a pump with a piston of 3 inches diameter, as mentioned before, acts upon an accumulator, the piston of which is 12 inches in diameter, and consequently has an area of 113 square inches. If this piston be weighted with 50,000 lbs., and its own weight be 2000 lbs., then each square inch of the water surface in **[251]** the accumulator will be subjected to a pressure of 460 lbs. If now from another part of the cylinder a discharge-pipe be led to the ram of the press before mentioned, then each square inch of the ram will have the same pressure, and the total pressure in the press will be 452 x 460=207,920 lbs. ; but if the ram of the accumulator have a diameter of 2 inches only, or 7 square inches area, and the weight upon it be only 5000 lbs., then the pressure exerted by it will be 714 lbs. per square inch, and the total pressure on the press ram 322,728 lbs. It will be seen from this that the smaller the section of the accumulator ram the larger the pressure exerted by it, provided the load be the same. This property is made use of in compressing black powder, gun-cotton, and similar explosives, by first exerting a small pressure by means of a large accumulator, and then large pressure by means of a small accumulator. If the larger pressure were to be put on at once, the ram would be lifted too slowly, and at the same time the counter pressure of the body to be compressed would increase at such an extraordinary rate that the compression would be done very badly. It will be seen, when treating of gun-cotton later on, how necessary it is, in order to eliminate the water from a body to be pressed, that the pressure should be small at the be-ginning and be applied gradually. But it is also very important with rigid bodies such as black powder, because the air must escape gradually, and what little elasticity the body has must first be overcome before real compression can take place.

With accumulators, so far as their work on a press is concerned, it does not matter if the pressure of the water entering the accumulator varies, so long as it is sufficient to lift the weights ; and the more water enters the accumulator per second the quicker will this take place. The pressure exerted by the accumulator depends only on the area of the ram, and the load it carries, and the pressure it transmits to the press is not altered in the least if it is lifted at the same time by the water from the pump. The only requirement is that the areas of the pipes for inlet and outlet and the yield of the pump should be so chosen that the weights can never sink down to their lowest level.

From what has already been. said about the distribution of the pressure and the surface of the press-table, it follows as a matter of course that the mass to be compressed must be at the same level in all the moulds, and must have the same proportions ; otherwise it may happen that the total pressure exerted by the press acts in one mould only, and an excessive pressure is thus **[252]** given, which with explosives may be very dangerous. This is avoided by keeping each mould independent, and having for each a special pressing-piston, as is the case with Gruson's press, which will be described later, or as adopted in a press designed by the author, by making the moulds movable and independent of each other. This principle was invented by Otto Rost. Considering the tensile strength of cast-iron, which is the material generally used for the cylinders of presses, the diameter of the pistons is generally arranged so that the cylinder is exposed to a maximum pressure of 1500 lbs. per square inch. If higher, an exceptional thickness of metal for the cylinder would be required. The pistons are generally cast hollow to reduce their weight, and so relieve the pump of useless work. Since hollow rams have to be calculated as tubes subject to external pressure, and cylinders as tubes under internal pressure, and since also the bore of the ram is much smaller than that of the cylinder, the thickness of metal for rams is always smaller than that of the cylinders.

Leakage round the ram is prevented by using a cup leather (Fig. 127). It is a ring made of leather, or hard rubber, bent in the shape of a U. It is put into a groove in the cylinder, with the opening downwards, and presses on one side against the cylinder, and on the other side against the ram. The water entering the cup leather forces its sides outwards, and the more the pressure increases the more tightly it is pressed against the rain. In order to hold it up to its work a metal ring or a rope is placed inside it.

Hydraulic presses, therefore, consist of a strong cylinder and a piston packed by means of a cup leather, carrying the press-table. They have also, as a rule, two, three, or four columns, which are rigidly connected at one end with the cylinder, and at the other end with a cross-head. According to the use to which such a press is to be put, modifications in details have to be made. Fig. 128 shows a prismatic powder press constructed by Taylor and Challen, of Birmingham, for the Royal Gunpowder Factory, Waltham Abbey. The base (ii) and the head (c) are connected in the usual manner by four columns (A). The head and base **[254]** are cast in one with the upper and the lower hydraulic cylinders respectively. The base carries a plate (D) on to which the phosphor-bronze needles (d), for forming the perforations in the prisms, are fixed. Above these the lower ram carries the pressing-table (E), on which the lower plungers (e) are so arranged that the needles (d) can pass through them. The mould-plate (F) is above the lower plungers, and contains 64 hexagonal moulds ; it is free to move vertically, and is guided by the pillars (A). To the rear of this stands a wooden frame (G), with rails on to which the charging-machine is run for filling. The top ram carries the upper plunger plate (x), on which are 64 corresponding but shorter plungers (h). They also have axial perforations to let the needles pass. The charger consists of 64 charging-tubes (i), above which 64 small funnels (k) are arranged. A plate (1) with 64 holes is arranged to move between the funnels and the charging-tubes, and another one (m) moves below the charging-tubes. For filling, the lower plate is so moved that the full parts of it stand opposite the bottom of the charging-tubes, and the same is done between the charging-tubes and funnels. The funnels are then filled with black powder, and the upper plate moved back, allowing the powder to fall into the charging-tubes and fill them. Then the upper plate is again closed, cutting off connection with the funnel, and the whole charger is moved on the rails into the press. As soon as it is in position with the charging-tubes standing exactly opposite the moulds, the lower plate is moved out by means of the lower lever, and the powder in the tubes falls into the moulds, which are closed at their lower end by the bottom plungers.

On compressing, the lower pressing-plate is first lifted, so that the plungers just close the moulds ; these are then filled as described above, and pressure is admitted simultaneously to the lower and upper press-plate. After the pressing is finished the upper press-plate is lifted, and the lower one is allowed to rise, so that the prisms are pushed off the needles and out from the mould-plate, from which they are taken away by hand.

The time of pressing, which varies according to the state of the weather and the density required, is from 10 to 20 seconds. The whole operation lasts about two minutes.

A hydraulic press for prismatic powder built by the Grusonwork at Buckau has several special features. It was constructed chiefly with regard to the manufacture of brown prismatic powder but, unlike most machines, it has the great advantage of allowing **[255]** independent pressing of single prisms, thus obviating the risk of all the pressure exerted by the press being concentrated on to one single prism, should one mould happen to be more fully charged than the others. At the same time, the press exerts its pressure for a longer period, thus allowing the use of a lower pressure.

The Gruson press (Figs. 129, 130, and 131) consists of a base (A_l) and a head (A). The base has 10 pressing-cylinders (B), each fitted with a ram (c), to which the lower plungers (D), made of phosphor-bronze, are attached. The upper plungers (E) are fixed on to the head. The mould-table (F) is movable, and is guided on the columns of the press. By this arrangement, as will be seen at once, each prism is compressed by itself.

[256] The charging of the press is done by a movable slide (a), which slides on a prolongation of the mould-table, and can be pushed to and fro by a lever arrangement (x). The slide contains charging-tubes (I) opposite the moulds, and above them a filling-hopper (r). When pressing, water is admitted into the lower parts (K) of the cylinders in the head, and raises the mould-table, which in turn lifts the lower plungers by means of a cross-head (L) arranged below it. As soon as the upper plungers enter the moulds on the upward movement of the table, the compression begins. Water is also admitted to the lower cylinder through the main pressure pipe (M) in the base, when the compression of the powder from below begins. After the pressing is finished, water is admitted into the upper part (N) of the cylinder in the head, causing the mould-table to slide down. As soon as the lower plungers have come down so far that compression ceases, **[257]** the lower cylinders are stopped, whilst the table continues its downward movement and pushes the prisms out of the moulds. They are then pushed away on to the small table *(o)* by the filling-hopper as it moves forward. The continued downward movement of the table finally causes it to touch a lever arrangement (n), which connects the table with the lower cross-head. By this the lower plungers are brought back into their lowest position, which is determined by the collars turned on them. As soon as the funnel has finished charging, an automatic reversion takes place, and the whole process is repeated. The inlet and outlet of the water to the cylinder is regulated by a special valve, which is opened on one end by the eccentric of a rotating shaft, and on the other end by the movement of the mould-table.

In England granulated powder is used for making prismatic powder. The prisms are 1-· inches high, and have a density of 1·78 after drying. In Germany the prisms are 0·97 inch high, and measure 1·575 inches over the angles. Their weight is about 1·41 ounces, and their density 1·660.

The granulated powder used for the manufacture of prismatic powder contains about 4 per cent, of moisture when put into the hopper of the press. The more moist the powder, the more easily the pressing is done, but at the same time it must not be too moist, or saltpetre will effloresce on drying. In general, the height to which the moulds are filled depends to some extent on the moisture of the air, and it has, therefore, to be regulated accordingly.

After pressing, the prisms are dried in special drying-houses. As a rule trays are used, the bottoms of which are of narrow **[*258]*** wooden strips, with sufficient space between them to let the air pass from all sides, but not enough to allow the powder to fall through. At Waltham Abbey they are dried slowly for 140 hours, and after this they should not contain less than 1 per cent. moisture. At Spandau they are dried 48 hours at 122° F., when they should contain 0·75 per cent. moisture as a maximum.

Another kind of powder, made until recently in Great Britain, was the "Pellet" powder. The late Sir John Anderson, of Woolwich, invented a press for its manufacture, which is illustrated in Fig. 132. The pressing-table consists of a disc of about 6 feet diameter revolving about one of the columns. The disc has teeth round its circumference, and can be turned by means of a pinion and handle. It holds four round metal plates, placed symmetrically, which are about 2 inches thick and 1 foot 6 inches in diameter ; in each there are 200 cylindrical holes of inch diameter. Above each plate is a movable covering-plate, which can be pressed tightly against it, and into each of the 200 holes a small plunger [259] enters, which goes through the bottom part of the disc, and can be lifted from below by means of a hydraulic press. Two opposite plates are always pressed at the same time. As soon as the movable plates are lifted the moulds are filled with meal powder, the plates are cleaned, and the movable plates lowered and fixed so that they close the holes on the top. Then the plungers are pressed into the moulds, causing the layer of powder to be compressed to inch in height. After this has been done, the movable plates are lifted, and the plungers are pressed forward towards the surface of the plates, pressing out the pellets from the moulds. The disc is then allowed to make one quarter turn, and the pellets are taken off the two mould-plates. The above operations are then carried out with the two other plates. The pressure applied is half-a-ton per square inch. The pellet has the shape of a flat cylinder, one or both bases of which have a hollow in the middle in the form of a blunt cone (Fig. 133). In order to produce this the plunger has a corresponding projection. The diameter of the pellet is inch, its height inch, and the depth of the hollow ,'-a inch. The density is between 1·65 and 1·70, and the weight 100 grains.

[*260]* Compressed powder burns more slowly than ordinary large-grained powder, and is therefore less violent in its action. According to English experiments, its muzzle velocity is greater than that of large-grained powder and its pressure less by about one-half.

The Du Pont Powder Company, of Wilmington, Delaware, make a hexagonal powder known as "Du Pont" powder. It has the form illustrated in Fig. 134, in which two truncated hexagonal pyramids are connected by means of a cylindrical layer of powder. The compression is done in the following manner :—A lower plate in which a number of pyramidal recesses are cut is covered with powder. A second similar plate is laid over it, and the whole subjected to pressure. According to the thickness of the layer of powder, the cylindrical part connecting the two trunks will be thicker or thinner. After pressing, the cake is broken, thus causing the grains to be broken off on the edges of the cylindrical part. In America this powder is used on a large scale.

In Italy, powder of the form illustrated in Fig. 135 was used for some time under the name of " Fossano " powder.