

The Hydraulic Mining Cartridge*

A Mechanical Device for Use Where Explosives Are Impossible

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THE difficulty of removing rock and other material, in places where the shock attendant upon blasting operations would be damaging and dangerous to surrounding strata or foundations, is one which has not hitherto been thoroughly overcome.

The enormous initial power generated by the sudden decomposition of explosive substances has enabled great quantities of natural or artificial beds to be displaced, and a great portion of the work of the civil and mechanical engineer is involved either directly or indirectly in operations of this kind. The objection to the use of explosives, however, in many circumstances, is that the effect of blasting can seldom be harnessed or controlled so as to prevent the disintegration of the material beyond the area which it is desired to dislodge. In the case of many metalliferous mines, and sometimes of quarries, this is not a great drawback as it may not only be unnecessary to limit the operation of the "shot," but it may be actually desired to have the material in a pulverized condition. Even in this case, however, it should be remembered that this is not an economical means of

to operate at the back of the hole first, the wedge being drawn towards and not driven from the front. Except in the case of the simpler forms it may be said that no mechanical wedges are now being used with success for excavating purposes of any kind.

The Hydraulic Mining Cartridge.—The hydraulic mining cartridge differs from all other mechanical substitutes for blasting. It is not worked on the principle of the wedge, and consequently the power expended in forcing a wedge into the hole is saved. Instead of employing

done by having the piston (e) operated by the piston rod (f) which passes through a supplementary or hollow rod (g) and has an appropriate handle for operating the piston within the pump cylinder. By these means the piston may be quickly reciprocated by the user moving the small handle until the desired quantity of water has been supplied or until the pressure to be exerted over the rod (f) is beyond the power of the user, when the supplementary rod (g) may be brought into use to finish the operation, this advancing by screw motion, and great pressure being obtainable in this way.

Method of Working.—After the rock or coal has been prepared with one or more loose sides and the drill hole of 3 inches, 3½ inches, or 4½ inches, has been drilled to a suitable depth (say three or more feet), the cartridge is pushed in with liners if necessary. The water tank is filled and hung on the pipe, the rubber suction pipe coupled, and the taps turned. The small handle and then the large one are operated as already described. The pressure being fully on, the enormous power of the apparatus is soon apparent, for the rock or coal is heard to

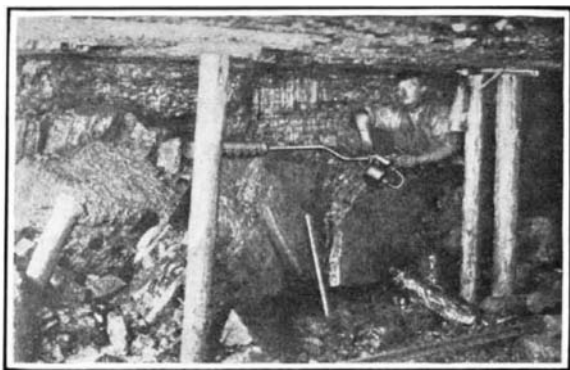


Fig. 3.—Operating the hydraulic cartridge in a coal mine.

obtaining such a result, for pulverization by explosives involves enormous waste of power as it usually represents great excess of explosive charge; in other words, the use of explosives must involve either the risk of accident through an insufficient charge or the production of misapplied energy.

It is for the purpose of avoiding these drawbacks and in order especially to take greater advantage of natural lines of cleavage or of bedding in the material to be dislodged that efforts have from time to time been made to provide what may be termed more rational or scientific means in the shape of mechanical substitutes for blasting.

The simplest form of mechanical means for breaking ground is, of course, the wedge, and this is used in varying lengths and shapes, in metalliferous and in coal mining, in all parts of the world. Various improvements on the simple wedge have been used at various times, viz., the stub and feather and the multiple wedge. The former consists of a steel "stub" or wedge driven in between two tapered liners of steel called "feathers" which have their thin end near the front of the hole. The multiple wedge is placed in a hole previously drilled and has liners also, but a pair of "feathers" may be inserted between them, driven up as far as possible, and then a second or a third "feather" may be used until the rock or coal is broken down. In coal mines, special efforts have been made to devise mechanical wedges capable of breaking down coal, notably those invented by Bidder, Burnett, Shreeve and Hall, and these have been used to a greater or less extent in a few mines. In some of these the wedge was driven in by means of a screw and handle, like a hand drilling machine, and in one case by hydraulic power.

These machines are not now in use and it may be taken that they have proved to be impracticable. This is no doubt due to the great pressure put upon them, even under favorable conditions, and the difficulty of devising and supplying a hydraulic pump capable of working at high pressure for a considerable time. It must also be remembered that a mechanical wedge must perform more work than that required to wrest the rock or coal from its position, as a certain amount of power is consumed in overcoming the friction of the sides of the wedge as it is driven up. Again, it is a disadvantage to have the material at the front of the hole breaking away as the wedge enters—the full weight of the falling material should, if possible, be utilized to assist the operation. With this object in view, machines have been designed

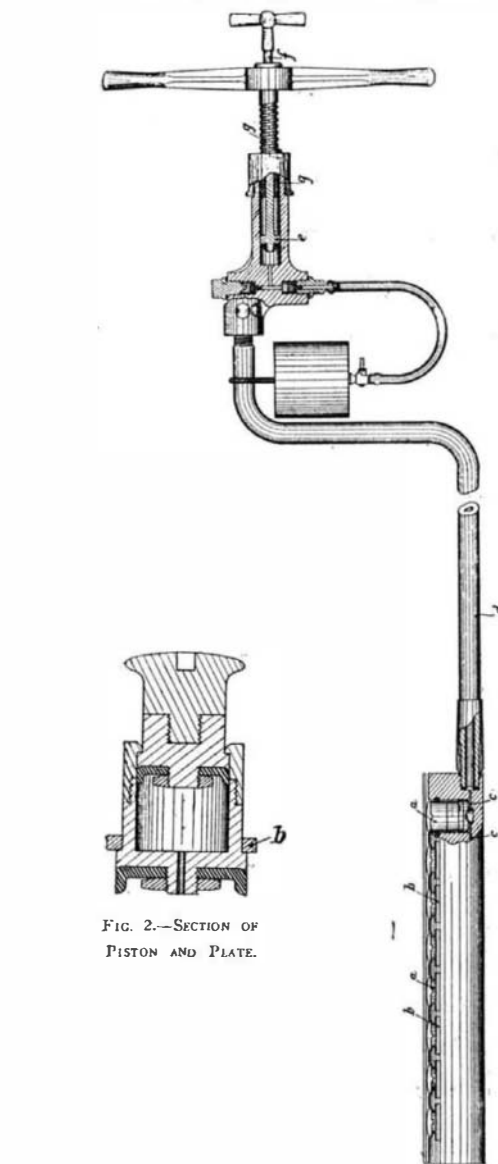


Fig. 1.—Sectional elevation of the hydraulic mining cartridge.

a wedge, the disrupting effect is obtained by means of a number of small rams or presses working at right angles from a strong cylinder of steel. (Fig. 1.) In order to make these rams more effective in their operation, by obtaining a greater travel from their original position, they are made of a duplex or telescopic form, one part sliding and fitting upon the other (Fig. 2). In some cartridges these pistons operate from each side of the cylinder alternately, thus greatly increasing the travel. To retain the rams in position, a sliding plate is used fitting in grooves in the barrel (b Fig. 1); this is so formed and secured that it is perfectly rigid and firm when the machine is in operation, but is readily removable if it is desired to detach or replace any of the rams. By a suitable arrangement of passages (c Fig. 1) a communication is made between each of the rams, whereby simultaneous action is obtained. Machines are made of various diameters, viz., 2½ inches, 3¼ inches, and 4 inches, and of various lengths, say with 8, 6 or 5 rams, the smaller diameters having the larger number of rams. Pressures of 3, 4, or 5 tons per square inch are usual, so that machines are made to withstand great stresses.

The Pump.—The cartridge is operated by means of a pump (Fig. 1) to which it is directly connected by a pipe (d). The pump is of special design. At the commencement of the supply of water it is desirable that the latter should be supplied in such quantities as to fill up quickly all the spaces within the rams and passages, while at the same time allowing the operator, when the rams begin to move and the pressure to increase, to supply a less quantity of water, but at a greater pressure, to complete the final operations of the rams. This is



Fig. 4.—Effect of hydraulic cartridge on rock in mines.

be rumbling and cracking. This is allowed to continue until the breaks are of such a size that the mass can be pushed or pulled over and usually is in such condition as to be easily and safely handled.

Line of least resistance.—It is easy to understand that when a shot is fired in rock or concrete, the direction of the breakage will be chiefly in the line of the weakest part. If the material is of uniform strength this direction would be a straight line from the explosive to the nearest unsupported edge. But stratified beds, seams of coal, and walls of stone or brick, are not usually of uniform strength; rock and coal beds contain breaks, cleats, and faces, while concrete beds are invariably irregular in constitution or structure. It follows, therefore, that the line of least resistance is not necessarily the shortest line from the charge to the surface. The difficulty and danger of explosive firing is that whatever this line may be, it is not often possible to make use of it; the pressure generated, though not equally effective, is equally applied in all directions owing to the instantaneous character of the decomposition. This involves high temperature in the explosive gases, a large portion of the heat being absorbed and wasted in the portions which are not capable of being blown down. When mechanical means are employed the time involved in the operation allows the whole of the power to be exerted and applied in the desired direction without waste of heat energy. Not only is power lost in heat energy in the case of explosive compounds, but the result often proves that there has been counter action whereby the rock displacement is reduced through one line of force operating against another, closing in or reducing the area of broken ground.

In practice it is found possible so to arrange the hydraulic cartridge holes as to enable much greater areas of material to be moved than could be done with a safe quantity of explosive, while in some cases the displacement has been greatly extended by the use of small-sized bore holes toward which the slowly developing line of least resistance can assert itself. In other words the power exerted by the rams can be controlled, after a little experience, so that the full pressure can be usefully applied.

Use in Mines.—The appliance was originally introduced into mines in order to supply the acknowledged need of a different method for bringing down coal in mines in the best possible condition after it had been undererred by hand or machine. The use of high explosives for this purpose, apart from the element of danger, has

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always been considered undesirable by mining experts, because in using them coal is shattered and wasted and dust made. Now that coal has to be won from greater depth than formerly, and the distances and areas underground increase, the dangers and extent of explosion have proportionately increased, as many recent colliery disasters have shown. The mines in which the cartridge has been chiefly adopted may be divided into two classes:

(a) Where the coal is so friable as to render the use of explosives impossible for commercial reasons.

(b) Where the condition of the mines in regard to gas,

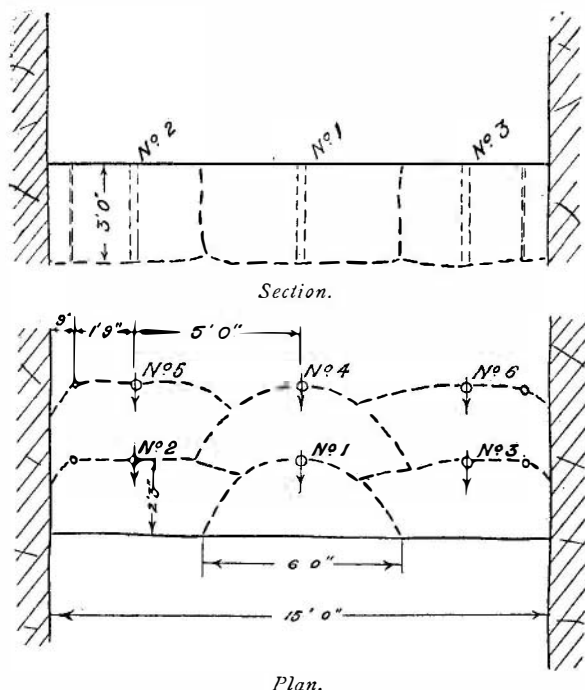


FIG. 5.—TRENCH EXCAVATION.

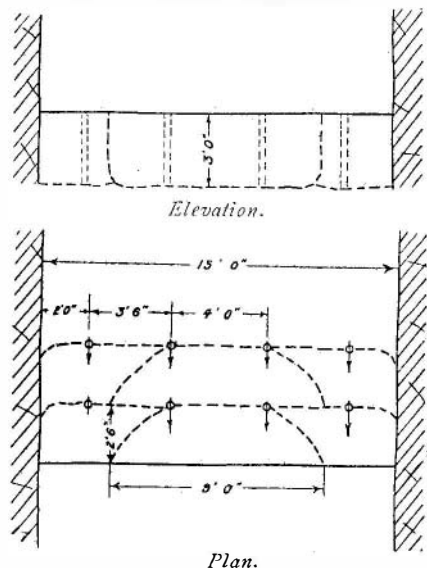


Fig. 6.—Trench excavation.

etc., renders shot firing an exceedingly dangerous proceeding.

Of course the question of cost enters very largely into the matter. As is usually the case when a new appliance is introduced, its qualities are quickly estimated from the effects upon the working expenses. At a later stage it will be seen that its effect upon the working cost is slight, while its general advantageous effect upon the selling price of the coal is quite striking. During the past ten years the appliance has been employed in mines in Great Britain, the United States, Russia, Japan, Germany and Austria.

In removing coal a series of holes is drilled in the top of the seam, adjoining and running parallel with the roof. These holes are at intervals determined by working conditions, usually from 6 feet to 10 feet apart and from 3 feet to 5 feet deep. The operator begins at the first hole and pumps off each in succession, usually leaving the supporting sprags to be removed by the collier, who fills the coal thus broken and prepares the coal behind for a repetition of this process. One operator can pump from 30 to 40 shots per working shift of eight hours, using only one machine, which lasts with repairs from three to four years. This procedure is adopted where a large wall of coal has been opened out, and where the coal is got in pillars and headings the process is somewhat modified. The coal across the face of the heading in undercut (almost universally now by a percussive machine operating from a fixed standard) and a vertical slot or "shearing" is cut up the center of the coal, thus providing a loose end. One hole on each side of the "shear" is then sufficient to bring down the coal. The holes are placed as near as practicable to the fast side in order to bring the coal down as near the "fast-corner" as possible. (Figs. 3 and 4 show the cartridge in use in mines.)

Among the mines in which these machines are at present in use are the following:

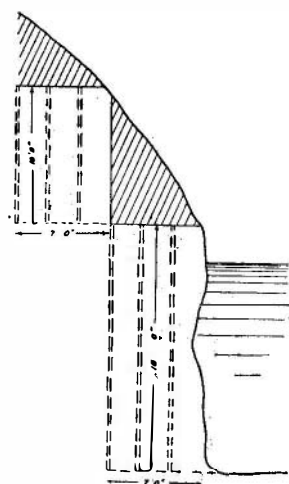
Colliery No. 1.—At this colliery an average of over 1,000 explosive shots per week were formerly fired in coal in the various mines. By the introduction of the hydraulic cartridge the whole of the explosive shots have been discarded and there is not now a single shot in coal in any seam. In one seam alone a total of 28,500 hydraulic cartridge thrusts were made in one year, by which it is estimated that 92,626 tons of coal were produced, or about $3\frac{1}{4}$ tons per thrust. The seam was 3 feet thick and four cartridges were in daily use.

Colliery No. 2.—In a seam using five hydraulic cartridges 450 tons of coal are produced per day, of which 75 per cent is large coal and 25 per cent small. When the coal in this seam was brought down by explosives the percentage of large coal was 65 per cent and the percentage of small was 35 per cent. The average price of large coal was 13s., and of small coal 7s. per ton. The profit obtained by the use of the cartridges on this seam on 450 tons is therefore £14 5s. per day. Fifteen machines are employed at this colliery, making a total advantage over explosives of £42 15s. per day. Moreover, an extra 6d. per ton is obtained for the coal brought down with hydraulic cartridges, on account of its greater hardness and freedom from dust.

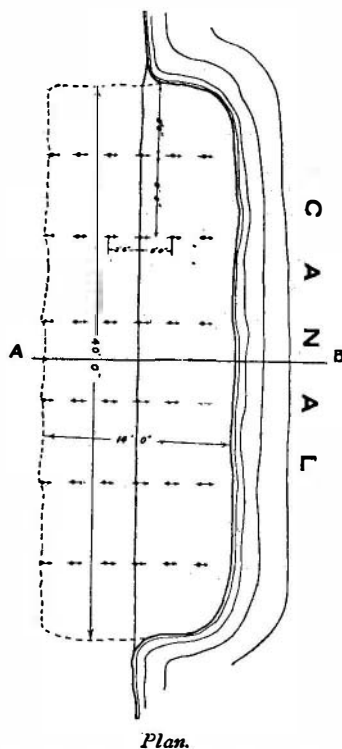
Use in Reservoirs, Docks, Harbors and Canals.—The operations in these places have all certain features in common which allow of their being classed together, and they may be divided into three classes.

(a) **In open Trenches.**—The difficulty of removing rock from confined spaces where it is necessary that no shock or vibration should be transmitted to surrounding strata is a very vital one. The introduction of the hydraulic cartridge into this class of work will, it is hoped, help to solve this question. During the past few years it has been thoroughly tested under most varied conditions and in all classes of deposits.

The work in trenches usually proceeds as follows: A number of holes are drilled (Fig. 5), say 2 feet 3 inches back from the edge of the rock, about 5 feet apart and 3 feet to 5 feet deep, according to circumstances. The holes are, when possible, bored by a power drill operating from a tripod. By these means suitable holes, of diameters up to about 5 inches, can be quickly drilled. The center hole is pumped first and provides a loose end for those on each side. These are pumped in turn until the fast side is reached, where it may be found advisable to drill a small 1-inch diameter hole, say 9 inches from the fast side, to enable the cartridge to break the rock as



Section on A B.



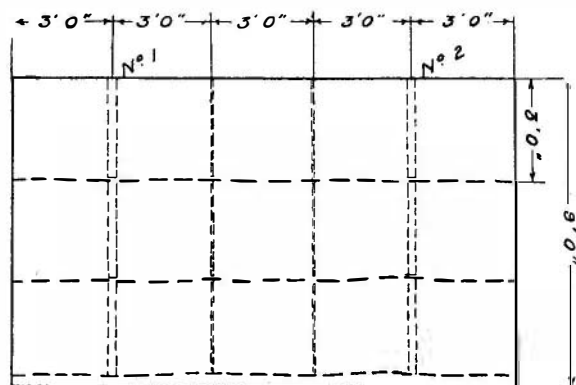
Plan.

Fig. 7.—Excavation of rock on the side of a canal.

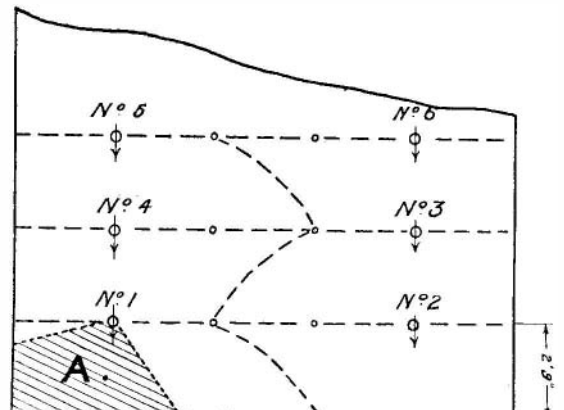
close to the fast side as possible. Sometimes this method is varied by pumping off two center holes simultaneously and placing the last holes 2 feet from the fast side, leaving out the small diameter holes. (Fig. 6.) In this case the holes could be 2 feet 6 inches from the front edge and two machines would be required.

Taking a trench 15 feet in width and holes 3 feet in depth, the first method would necessitate three cartridges and two 1-inch holes to get 100 cubic feet of rock, while the second method would require only four cartridge holes to remove 112 cubic feet. During the operation of the machine it is possible to see the rock slowly fracturing at each turn of the handle. Work of this character has been done by the cartridge in connection with the Derwent Valley Water Works, and the Cwm Taff Reservoir, Liverpool Corporation, and tests are now being made for the Abertillery Water Scheme.

(b) **Under Water.**—The appliance has been used in



End View.



Plan.

Fig. 8.—Concrete bed excavation.

many cases under water, chiefly to remove rock, either from the sides of canals, or from the sides of harbors and docks, where it was obviously impossible to use explosives, the machine being operated from the bank or from pontoons. A typical case will serve to illustrate the suitability of the cartridge for this class of work. The rock to be removed was partly projecting from the side of the canal, and it was necessary not only to remove the mass in the water, but also that upon the bank, as shown in Fig. 7.

The rock was New Red Sandstone and the depth to the bottom of the canal 18 feet. It was decided to remove the mass the full depth at one operation. A series of holes was accordingly drilled 6 feet apart, 2 feet 4 inches back from the edge, and 18 feet deep. These were pumped off in succession and the operation of the cartridge at this depth sufficed to break the rock right up to the bank in nearly every case. In one or two holes it was found necessary after operating in the bottom half to draw the machine up about 9 feet and operate again. During the operation divers were below water ascertaining the position and extent of the breaks and directing the operator above as to how to continue the thrusts. The portion shaded (Fig. 7) was removed by hand, and another series of holes was put down 10 feet deep, 6 feet apart, and 2 feet 4 inches from the edge, to break up that portion of the rock to be removed.

In the Alexandra Docks at Newport, and in the new dock at Swansea, the appliance has been used to break up ledges of rock occurring in the vicinity of walls which would have been damaged by the use of explosives. The holes were put in and the cartridges inserted under water by divers and pressure was applied from the pump placed on a raft on the water.

(c) **Dock or Harbor Walls.**—Hydraulic machines have been used for some years at the Dover Harbor Works for the purpose of detaching the large concrete blocks used in the harbor walls. These blocks are of great size and weight. By inserting the drill hole along the bottom of the block and placing the cartridge about half-way under it, the whole mass is slightly lifted and tilted without breaking, and being thus released from its bed is easily lifted on to a wagon by a crane. Machines are being used for a similar purpose in other docks.

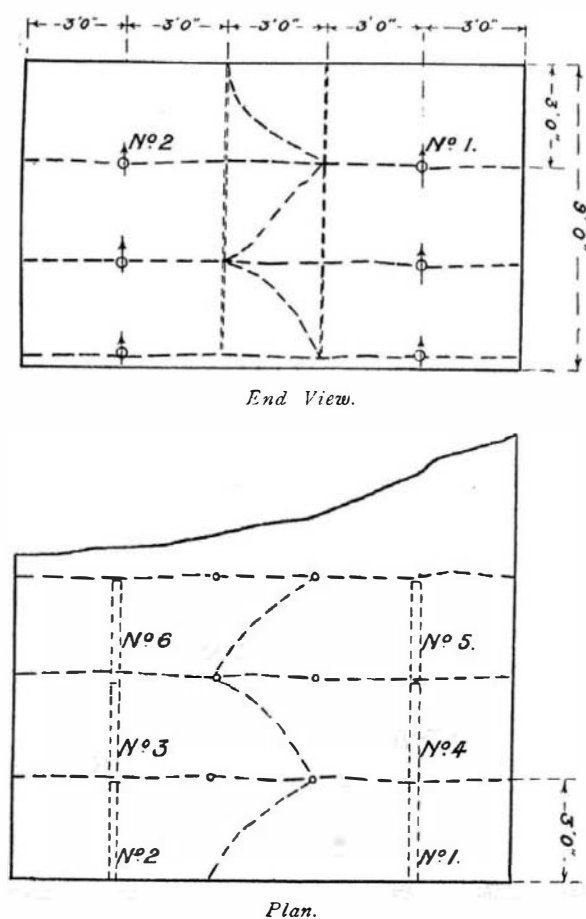


Fig. 9.—Concrete bed excavation.

Excavation of Foundations.—The question of the removal of concrete foundation beds by a method which would not involve explosive blasts and would avoid the slightest damage to machinery or buildings has been carefully studied recently by the writer, and had never been thoroughly solved until extended trials in all parts of the British Isles had been made.

The effect of powerful hydraulic pressure upon concrete is interesting. In the case of sandstone and shales there is comparatively slight crushing of the rock before the full pressure of the rams has the effect of causing the mass to bend; considerable pumping and consequent travel of the rams is then necessary before the rock finally begins to crack and break away; with concrete, however, there is usually a perceptible interval during which the rams are crushing or compressing the material and no movement is noticeable; after this is accomplished a few more thrusts of the rams cause the whole mass to break up without any indications of bending. It may still be necessary to continue to apply pressure and to increase the size of the breaks in the mass, but the greatest shattering effect will have been accomplished at the first disclosure of the cracks, the pressure required to break the mass afterwards gradually diminishing.

In such material, explosives invariably have the effect of "hacking a way through" by the shortest direction to the unsupported edge (Fig. 8), pulverizing the mass but failing to take advantage of pressure gently applied, by means of breaks which spread and widen, and to utilize the weight of the concrete itself to increase the scope of the operation. Numerous experiments in this class of work show that 60 to 70 cubic feet of concrete can easily be removed per thrust.

The general procedure in attacking beds of concrete may be divided thus:

1. By vertical cartridge holes.
2. By horizontal cartridge holes.

1. **By Vertical Cartridge Holes.** (Fig. 8.)—This method is most applicable to places where power can be easily obtained to bore the holes by tripod and power drills. The cartridge holes are drilled about 3 feet deep and 2 feet 9 inches back from the front edge of the bed. It has been found of great advantage to drill small diameter holes 3 feet away and in line, to which the fracture will break. In this way a bed 15 feet wide could be broken all across by two cartridges and two small diameter holes, amounting to 124 cubic feet of material.

2. **By Horizontal Cartridge Holes.** (Fig. 9.)—In this case the holes would be 3 feet deep and made to lift 3 feet of material per thrust, the vertical small diameter holes being put in as before. The amount of material moved per thrust is 67 cubic feet. The effect of lifting up is to break a larger quantity of material and in much larger pieces than is the case with vertical holes. With the latter the concrete is found to be very well broken up, and ready for handling without the further use of tools. Horizontal holes, on the other hand, are more suitable for beds where foundation bolts are embedded in the concrete.

There appears to be no class of work so suitable for this machine as the removal of concrete beds. The

following recent case is a typical example. At a municipal electricity works the cartridge was used to remove the main engine room foundation bed. Within a radius of 40 yards from the scene of operations, many of them within the same building, were very valuable Lancashire and water tube boilers, electrical and steam engines and the main switch board and cables. Needless to say the work had to be carried out with as little vibration or shock as possible. Explosives were out of the question, and the ordinary method of hammer and wedge would have proved an extremely long, tedious, and expensive process. The bed consisted of a solid mass 14 feet 6 inches wide, 26 feet long, and 10 feet deep, composed of hard cement concrete for the most part, and reinforced with numerous foundation bolts.

It was considered unnecessary to install power drills on the work and the holes in consequence were drilled by hand. The majority of these were horizontal and were put in by means of an ordinary twist drill and ratchet machine by two men. These men could drill fairly easily 3 feet per hour. One hydraulic cartridge only was employed. The general procedure was to keep the drillers at work putting in holes all round the side of the concrete, the machine following when two or more holes were ready. The holes were on an average 6 feet 6 inches apart, and from 2 feet 6 inches to 3 feet below the surface in the case of horizontal holes. The vertical holes were drilled only in special places to trim down the vertical edge, and in these cases the measurements were about the same. The employment of shot holes to form a breaking point was considered unnecessary. (Fig. 10 is a photograph of one of the horizontal shots.)

The debris thus broken was removed by a gang of six men who were kept busily employed with pick and shovel, and wedges were necessary only to break up the larger pieces to a suitable size for handling. It was found that the amount of material broken up in the course of three or four shots was quite sufficient, in consequence of the limited and cramped working area, to keep the men busily employed for the rest of the day. Had it been possible to place more men on the bed, there is no reason why a much better output should not have been attained, but in this case it would have been necessary to break open the wall in several places, which was not considered advisable. The whole bed, weighing approximately 200 tons of concrete, was removed in twenty working days. About sixty shots were necessary to complete the work, making an average of nearly $3\frac{1}{2}$ tons per thrust.

The cost of the work was as follows:

Labor per day, including operator, drillers, navvies, and foreman.....	£2 15 0
Amount of material removed—	
average 10 tons per day.....	4 9 per ton.

The above cases will be sufficient to show that with a mechanical substitute for blasting capable of exerting a total pressure of 150 or 200 tons upon rock, coal, concrete, masonry, etc., and in such manner as to cause no shock to the material in which it is operated, there should be possibilities of usefulness to engineers not previously contemplated.

Replying to the discussion, the speaker said that one speaker had referred to the use of black powder for blasting salt rock. That was really in line with the use of the hydraulic machine, which operated slowly and gradually. The old-fashioned explosives had the very distinct advantage that, owing to the length of time required before the gases attained their full temperature and pressure, it was possible to get the power exerted in a more effective way. He thought that if it were not for the element of danger associated with black powder, all users of explosives would agree that the old-fashioned slow-working explosives had always been most satisfactory. It was only carrying the principle a little further to apply it in the form of hydraulic power.

With regard to Mr. Jenkins' point, rotary drills had been used for making holes on many occasions, and it had been found that the diamond drill was quite satisfactory when used as a hand machine. It was very necessary to have a regular and smooth hole, and the diamond drill gave such a hole much better than any percussive drill could possibly do. It appeared to him that it would also have the effect of greatly reducing the amount of dust that would be made in the drilling of the hole, and not only would there be a smaller quantity of dust made, but that dust would be of coarser texture.

As to the driving of headings, he must say that in ordinary tunneling he had not been entirely successful, chiefly because of the difficulty of obtaining a suitable drill for putting holes in easily and quickly. It was not possible to blast from the solid. If the rock was to be broken with a loose end at all, it was necessary to be able to put in small holes readily and easily in various directions. Having loosened one side, there was then no longer any difficulty.

With regard to the limit of 150 to 200 tons, he mentioned those amounts because they were approximately

those to which he had worked up to the present. By using the 3-inch machine he got, with full pressure on, about 120 tons. When using a 4-inch machine he generally used about five pistons instead of eight, and he got 170 or 180 up to 200 tons pressure with that particular size. There was no limit. It was possible to increase the pressure according to the length and size

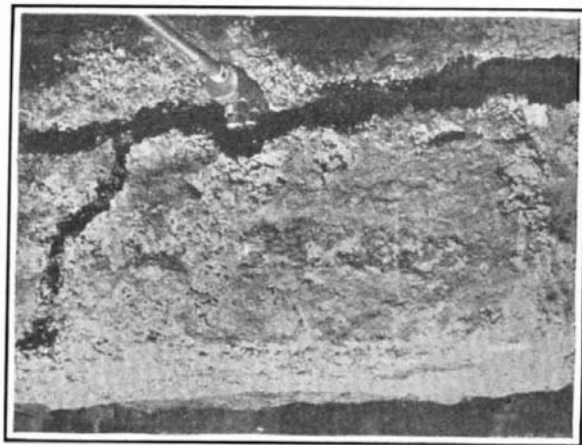


Fig. 10.—Hydraulic cartridge used in a bed of concrete.

of the machine, but there would arise a liability for the cartridge to become bent. There was no bending of the cartridge if the sizes of the machines used were limited as at present, provided that a regular hole was obtained. If the hole was not regular and smooth there would be the risk of some damage being done to the machine. He did not mean to say that there was a danger of bending the machine after the material had once been broken. When the back of the material was broken there was no danger to the cartridge. Very few machines had been bent or damaged in any way. That was probably due to limiting the length of the cartridge to 20 inches in the case of eight-piston machines and a few inches less in the case of a five-piston machine.

With regard to varying the intensity of the pressure, he thought that that was hardly necessary so long as the hole was drilled sufficiently deep. He did not like to have the end of the cartridge anywhere near the end of the hole. It should be right in. As long as it was right in the hole there did not seem to be any advantage to be gained by varying the pressure. He got the cartridge right into the hole, and then it was not necessary to make any change. Usually the pistons were out an equal distance throughout the full length of the cartridge, showing that the resistance had been the same throughout its length.

The Flight of a Golf Ball

SOME interesting statements concerning the flight of a golf ball were made in a case heard by Mr. Justice Warrington in the Chancery Court. The validity of the patent granted to William Taylor for his golf ball was challenged by Messrs. A. W. Gamage, Ltd., who claimed the revocation of the patent owned by Charles Stuart Cox and A. G. Spalding & Bros., who made the golf ball under the name of the "Dimple." In the specification of the patentee, he said his principal object was to obtain better results in the flight of the ball in the direction of a sustained hanging flight, giving a flat trajectory, with a slight rising tendency toward the end of the flight.

Prof. C. Vernon Boys said the form of the surface of the ball affected the flight very materially, and, from general experience, a smooth ball had been found not to be so good as one of which the surface had been roughed. The smooth ball had not an advantageous surface for getting a long travel. The character of marking which constituted Taylor's invention was an inverted bramble pattern, and consisted of isolated cavities, circular, evenly distributed, shallow, and their sides steep. Prof. Boys said he found by experiments that this form of surface gave an extremely satisfactory flight. The experiments consisted in driving the balls by means of a machine designed by himself and Mr. Taylor, and were carried out on Borstall Golf Course, on the road to Charnwood Forest. He did not find in the specifications of Willie Park and Fernie, on which Messrs. Gamage relied, Taylor's form of cavities.

In cross-examination as to the typical golf ball's flight, witness said the ball more than counteracted the action of gravity. His Lordship: The golf ball does not make a parabola? Prof. Boys: Not in the slightest degree; a good flight is very nearly straight for a long time, and then gradually rising and then falling. His Lordship, giving judgment, said that the main feature of the descriptive part of Taylor's specification was its vagueness. He held that the patent failed, and that there must be an order for its revocation. A stay was granted pending an appeal.—From the *English Mechanic*.