be broken in that way. It should be packed in a solid mass by slitting the paper cartridge shells and massing them together, taking care not to spread them over the surface of the boulder any more than absolutely necessary. A blasting cap crimped into fuse should be placed in middle of the charge and the whole covered with six inches of damp clay or sand. This should be pressed firmly over the explosive, care being taken not to cover the outer end of fuse. If the boulder is deeply embedded in the ground, it is best, before blasting, to dig away or loosen some of the earth surrounding it.

If the boulder is cracked or seamy, the charge should be placed in some depression and covered with a quantity of clay or sand, as described before. This gives the explosive greater power.

A test made by Bureau of Mines at Washington to determine the effect of drilling and tamping holes in boulders, showed that a 1-inch hole 12 inches deep, with 1 ounce of explosive, had practically the same effect as 1 pound of unconfined explosive laid on the rock. The conclusion is that where time is not the principal object it is more efficient to drill. However, the cost of drilling should be against the cost of explosive. Three sticks of dynamite will practically cost the same as a 6-inch hole.

Quarrying.—The rock in quarries is generally covered with layer of earth which it is necessary to remove before blasting or separate from stone after blasting. This stripping will vary with the character of soil, depth of cut necessary, and the distance to which the material has to be moved. In estimating cost, this may be considered as ordinary earthwork.

Drilling.—This may be done either by hand, by steam, or compressed air. The two first named methods are generally used in Ontario. However, portable air compressors run by gasoline are used extensively in the States. One at Yonkers, N.Y., with an air cylinder 8 x 10 inches gave 96 cubic feet of free air per minute at 165 revolutions with 80 to 100 lbs. air pressure. A hoisting attachment for pulling rock from trenches, etc., was also connected on rear of machine. The entire outfit weighed about 8,000 lbs. Three hammer drills were used, each averaging 50 ft. per day. The cost per foot was approximately 14 cents.

Limestone drilling by hand costs anywhere from 35c. to 45c. per foot. That by steam from 20c. to 30c. a foot. In granite these prices are increased 25 to 30 per cent. In limestone three men will probably not drill more than 15 ft. per day. The steam drill will average about 45 ft. per day. In granite and trap rock these are correspondingly decreased 25 to 30 per cent. The estimates given above are for 1¼ inches steel.

Blasting.—There are few operations in quarrying where a workman can display a higher degree of skill and effect larger economies than in the proper placing of bore holes, and in the proper adjustment of his charges to the work to be done. Against the firing of one hole the following may be charged: labor, power (steam or air) where machine drills are used, wear and tear on plant, explosives, and a general loss distributed among many items in the operation of the quarry.

For the most part, efficient work in blasting is a matter of experience and good judgment. This cannot be taught in books, but there are some general rules which are fundamental, and in proportion as these are understood and appreciated the work of quarrying will be conducted with greater system and economy. Unsystematic efforts are always wasteful and costly, and system implies the recognition of some definite principles, according to which the work is laid out and prosecuted.

(1) The strength and quantity of the explosive should be properly proportioned to the cohesive strength or resistance of rock.

(2) The "burden," the shortest line that can be drawn from the charge in the bore-hole to the outer free face of rock, should bear a proper relation to the strength of the explosive and to the resistance of the rock.

(3) If the working face of rock is so blasted as to leave two or more free faces, instead of one for future blasts, the explosive required to overcome the resistance of the rock will be reduced.

(4) A seam or fissure may become important help, if hole is properly located, but the opposite may occur if charge is improperly placed.

(5) Breaking to regular benches and faces is most economical method, rock can be carefully observed for seams and fissures, admitting of a more intelligent placing of subsequent bore-holes.

(6) Simultaneous firing is more economical in most cases than firing singly or in series, for the reason that the adjacent charges assist each other reducing the amount of explosive required and the total length of holes to be drilled for any given volume of rock.

(7) Careful charging and tamping is absolutely essential. The more compact the charge the more efficient the results.

(8) The object in quarrying is to rupture rock, not to hurl it some distance. Hence only enough explosive should be used to accomplish this. Where rock is thrown great distance it is evident that the proper relation did not exist between the charge and the burden and that too large a charge was used for the length of the line of least resistance.

The amount of explosive required depends upon: (1) Kind of explosive used. (2) Depth of bore-hole. (3) Line of least resistance. (4) What stone is being used for.

From Gillette we have that the amount of 40% dynamite required per cubic yard of rock excavated varies with the depth of hole, decreasing as the depth of hole increases. In open cut work he uses the formula $P = 3/d$, in which P is equal to the pounds of dynamite required for cubic yard of rock and d depth in feet.

With 40% dynamite, at 15c. per lb., and drilling at 25c. per ft., we find upon summing up that the cost in cents per cubic yard of rock excavation, solid measure, using these rules, is as follows:—

When d (in ft.)	1	2	3	4	6	8	10	12
Cost of dynamite per cu. yd.	26	18	15	13	11	9	8	7
Cost of drilling per cu. yd...	100	66	34	29	15	11	9	9
Total cost per cu. yd.	126	84	59	42	26	20	17	16

The holes are generally spaced equal to their depth, but after 5 ft. in depth, Gillette uses the formula $S = 10/4\ \sqrt{d}$; where S = spacing and d = depth.

OPERATION AND CARE OF MACHINERY. By W. Huber, B.A.Sc., assistant engineer, Ontario Office of Public Highways.

The two-fold effect of the introduction of various kinds of machinery into road building were stated to be (1) shortening the time required to make a finished road; (2) replacing a large percentage of labor of men and teams whose wages have been steadily increasing, thereby considerably reducing unit costs under favorable conditions. The author emphasized the importance of a careful selection of the machine, specially adapted for the work, of sufficient capacity and possessing the required degree of