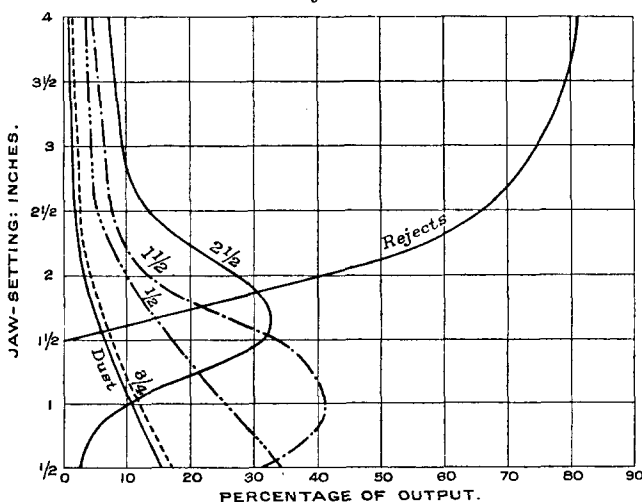


### Correspondence.

Mr. H. V. BUDGEN observed that the Authors had given curves Mr. Budgen. showing the percentages of the different grades of road-stone produced by various machines, but widely different curves appeared to have been found for the same material. That appeared to

Fig. 58.



indicate that either different machines or different jaw-settings were used in order to obtain the products represented, for example, by curves 1 and 5 of Fig. 6. The value of the Paper would be very greatly enhanced if the Authors would indicate the size of the machine and the setting employed for each of the performance-diagrams.

The Authors had said very little about the setting of the various machines, but the operator of a crushing plant sometimes wanted to increase the output of one particular grade at the expense of another. In order to ascertain the effect of an alteration in the setting of the machines, Mr. Budgen had instigated some field tests on dolerite. Fig. 58 showed the variation in product resulting from adjustment of the setting of a 16-inch by 9-inch crusher. Fig. 59 showed the results obtained from a 20-inch by 6-inch granulator fed with 2 1/4-inch and 1 1/2-inch stone, while Fig. 60 showed the result from the same machine when fed with stone ragged down to about 4 inches.

Mr. Budgen.

Unfortunately he had not been able to arrange for the hand-screening of the samples, which were mechanically screened, but he had used them in the absence of better material.

Fig. 59.

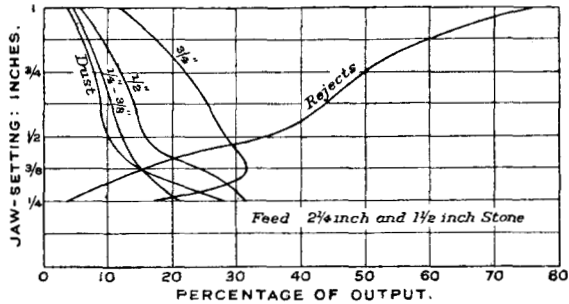
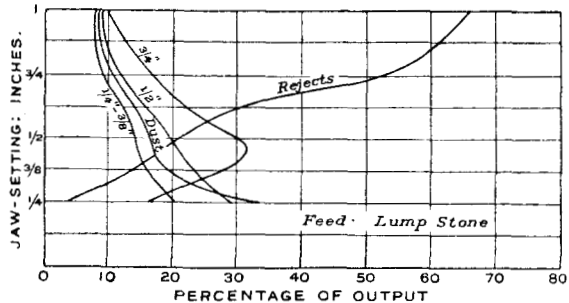


Fig. 60.



As illustrating the way in which requirements varied, he would instance the following percentages of different sizes required when feeding tar-macadam and asphalt plants:—

	Size.	Percentage.
(a) Mixing base-coat macadam . . . . .	2 1/4-inch	60
	1 1/2 - 1/2 inch	35-40
	Filler	0-5
(b) Mixing topping . . . . .	3/4 - 1/2 inch	70
	1/2 - 1/4 inch	25-30
	Filler	0-5
(c) Mixing single-coat macadam . . . . .	2 1/4-inch	30
	1 1/2-1 inch	30
	3/4 - 1/2 inch	35-40
(d) Mixing single-coat asphalt-macadam . . . . .	Filler	0-5
	1 1/2-inch	10
	1 "	30
	3/4 "	20
	1/2 "	18
	3/8 "	12
	1/4 "	10

It was not suggested that it was possible to design any plant so flexible as to produce the various grades in the required proportions without a surplus of some sizes and a deficiency of others, but it was suggested that that surplus or deficiency could to some extent be controlled by adjustment of settings.

With regard to the features of various machines, standard designs of single-toggle breakers were expensive for bearing renewals, and it seemed that roller-bearings were really necessary for that class of machine. The curved jaw-faces in the Telsmith-Wheeling crusher appeared to be a very desirable feature for a secondary machine, as the wear on the jaws was thus distributed over a larger area instead of being concentrated at the point of outlet, where the wear in the case of straight jaws was excessive. The Authors had not attempted to compare one class of machine with another, but for the production of cubical chippings he considered that the single-toggle breakers yielded the best if not the cheapest sample; he would be glad of the Authors' opinion on that point. He had recently heard the view expressed that perfectly plain jaw-faces would be as effective as the usual corrugated ones. Did the Authors agree with that view, and had they tried such faces? Some makers still made cast-iron jaw-breakers and it seemed to him that in the smaller sizes they should not be despised. Their greater weight gave them a stability and resistance to vibration greater than those of the steel machines.

He agreed with the Authors' remark at the top of p. 78 that it was difficult to estimate the duty done by a secondary machine. In some records relating to the wear on jaws, which he was collecting from a number of plants over a wide area, he was calculating the secondary-crusher duty on the following basis:—

*Case 1.*

All sizes above  $\frac{3}{4}$  inch passing to granulator, remainder direct to bins; 76 per cent. of the output is the product of crusher plus granulator.

*Case 2.*

All sizes above 1 inch passing to granulator; 75 per cent. of  $\frac{3}{4}$  inch and smaller sizes is the product of crusher plus granulator, the remainder being the product of crusher only.

*Case 3.*

All sizes above  $\frac{3}{4}$  inch passing to granulator (except  $2\frac{1}{4}$  inch); 62 per cent. of  $\frac{3}{4}$  inch and smaller sizes is product of crusher plus granulator, the remainder being the product of crusher only.

Mr. Budgen.

*Case 4.*

Sizes above  $2\frac{1}{4}$  inch (namely, rejects only) passing to granulator ; 37 per cent. of  $\frac{3}{4}$ -inch and smaller sizes is product of crusher plus granulator, the remainder being the product of crusher only.

By recording the grades sent to the granulator daily he hoped to obtain some fairly reliable comparisons of jaw-duty on different stones. The plants under investigation each had an output of 80 to 100 tons per day.

Mr. Clements.

MR. E. W. F. CLEMENTS observed that a point deserving greater attention from the manufacturers of the larger gyratory crushers was the method of lubricating the suspension wearing-ring, at the top of the main shaft. Grease would not always reach the parts that it was desired to lubricate, and oil had a tendency to run down the mantle, and, by mixing with the ore, would upset floatation processes where only small quantities of reagents were used. Filling the cap with wool soaked with a mixture of grease and cylinder oil was a partial but by no means perfect remedy.

It was noticeable that the illustrations showed flat belt drives on most of the crushers. Short endless V-belts were becoming far more popular for such work owing to the saving in space and the flexibility which they afforded. Concaves on the heavier types of gyratory crushers were zincked in place, and when setting-in to take up wear, difficulty was frequently experienced in extracting the first segment, owing to the spreading of the manganese steel. Hammers and wedges were generally used, with oxy-acetylene burners in the worst cases. Some form of jack, operating through holes in the main bowl-frame, would probably save considerable time and money. It was a pity that no mention was made in the Paper of the various methods of feeding mineral to crushers ; the subject was interesting, and perhaps the Authors would add some information on that subject. With reference to the secondary crushers, the type shown in *Fig. 21* was obsolescent except in small plants, and was being replaced by types such as that shown in *Fig. 34*.

With the older types of rolls, the main difficulty was to exclude abrasive matter from the inner sides of the bearings. Occasional lapping-away of the shaft had been successfully made good by filling up the grooves by electric welding, the shaft afterwards being machined. The tendency of roll-shells to groove was not always counteracted by the fleeting motion sometimes fitted, and when a very even product was required it was often worth while to dress the tires frequently with a grinding wheel mounted on a slide-rest.

Mr. Curtis.

MR. A. L. CURTIS remarked that few realized the importance of

crushed rocks and aggregates in primary industries. He proposed Mr. Curtis. to consider the efficiency of crushers (which should not be confused with their capacity) in reducing rocks of definite structure and strength to the various sizes demanded by the industries concerned.

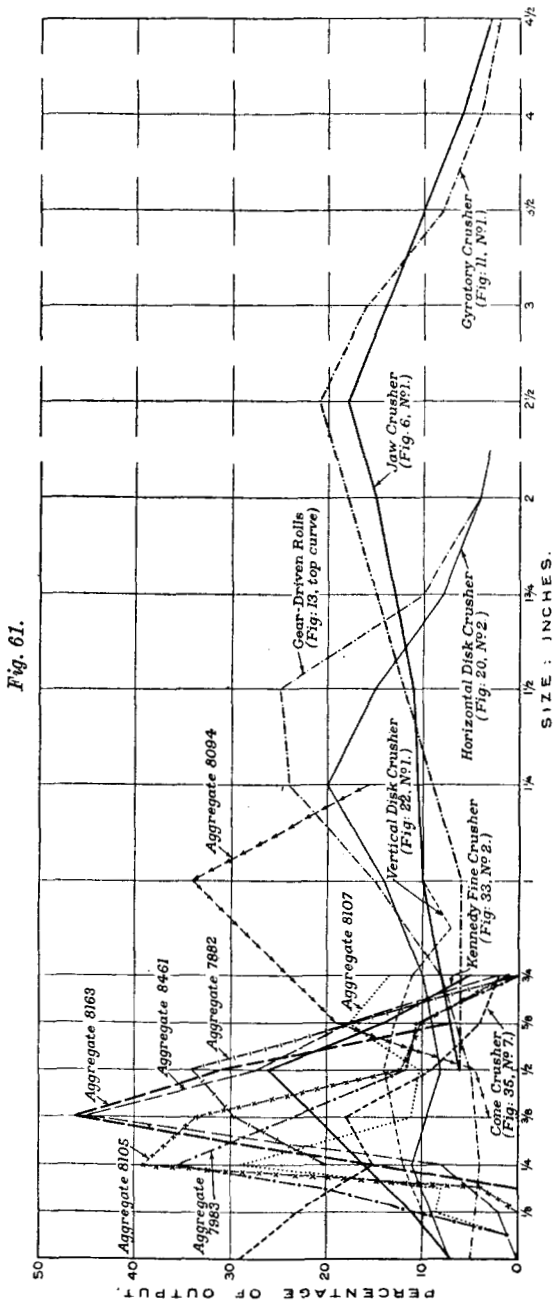
The size-distribution diagrams given in the Paper were important. When determining grain-size percentages from a given crusher it was usual to screen out the largest pieces first, leaving the finest material for the last operation, which was the simplest method. The ordinary method of plotting grain-size-percentage curves from such materials, however, was to show total percentages passing different-sized sieves, whereas in practice the percentage weights retained on different sieves were measured.

It would be interesting to know if the granites which gave the test results shown in *Figs. 6, 11, 13, 20, 22, 33* and *35* were all of the same variety, toughness, strength, and hardness; allowance had at present to be made for the lack of that information.

He would suggest that further deductions could be made from the composite chart of the Authors' curves on crushed granites shown in *Fig. 61*, p. 134. That chart served to illustrate the efficiencies of the several types of crusher dealt with, together with other curves prepared from crushed materials obtained in general practice. Curves No. 1 of *Fig. 6* and No. 1 of *Fig. 11*, when compared in *Fig. 61*, showed that there was little difference between the performance of the improved design of Blake's jaw crusher and that of the gyratory type, which was supposed to show an advantage over it. In both cases crushing fell at a point about half-way between the larger and finer particles crushed. The upper curve of *Fig. 13*, as re-plotted in *Fig. 61*, showed that crushed granite produced by gear-driven rolls fitted with toothed shells had a somewhat similar range to that produced by the previous two types, but such crushers, compared with disk crushers of the horizontal and vertical types, again lacked efficiency in a similar way to the jaw and gyratory types.

Crushers apparently had two definite functions in industry, the first being to reduce the size of hand-broken or as-quarried pieces of rock as far as possible preparatory to further treatment, and the second being to grade rock or mineral to a definite grain-size by crushing without too much auxiliary screening. He was not so much concerned with the first of those functions as with the second, in the production of standard sizes of crushed rocks or minerals for use as aggregates in concrete. Careful crushing and grading of rocks used in concrete mixtures played an important part in the ultimate strength of the concrete, which was therefore closely related to the performance of the crusher. *Fig. 61* included curves showing the size of crushed rocks used as aggregates in concrete-mixtures con-

Mr. Curtis.



taining 4 parts aggregate, 2 parts building sand, and 1 part Portland Mr. Curtis. cement. The better-graded aggregates A, B, and C were reduced in vertical disk crushers, and closely approached the particle-sizes laid down in the specification for concrete; the size-distribution curves illustrated the efficiency of that type of crusher for producing such materials. The curves for aggregates D, E, F, and G showed indifferently-crushed particles, and those aggregates gave lower crushing strengths than A, B, and C, as below:—

## CRUSHING STRENGTHS AT 28 DAYS.

A	Aggregate	8,461 . . . . .	5,600 lbs. per square inch.
B	„	8,163 . . . . .	5,400 „
C	„	7,882 . . . . .	4,417 „
D	„	8,094 . . . . .	4,000 „
E	„	8,105 . . . . .	3,870 „
F	„	8,107 . . . . .	3,500 „
G	„	7,983 . . . . .	3,250 „

It would be seen from those figures that the grain-size of the aggregate affected the strength of the concrete. If an improved Blake jaw crusher were set to crush a smaller-sized rock than that referred to by the Authors in *Fig. 6* (curve No. 1), he would not expect to get particles showing the same gradation as those from other types of crusher. A similar argument applied to the gyratory crusher, which, in the Authors' tests, was apparently working under the same conditions. The same held good—though to a lesser extent—with the gear-driven rolls (*Fig. 13*, top curve) and the horizontal disk crusher (*Fig. 20*, No. 2); the nearest approach was that obtained from the Kennedy fine-crusher (*Fig. 33*, No. 2). It would seem from the above that vertical disk crushers produced a group of definite-sized particles better graded than those from the gyratory, reciprocating-jaw, or other types. The most important duty of crushers used in building construction was the production of aggregates for use in making concrete; their product should be so graded that little or no screening was necessary to produce a standard aggregate. He had found it possible to produce by crushing and grading an aggregate which would increase the strength of concrete by about 25 per cent., as was shown by the curves A, B, C, D, E, F, and G of *Fig. 61* and the crushing strengths cited above. Unfortunately, those concerned with aggregates did not fully appreciate the accurate grouping of crushed particles, with a view to establishing a more rigid specification for grain-size, so that the strength of concrete varied greatly. Slight alterations in the design and adjustment of crushers might be necessary to furnish the ideal crushed material.

Professor  
Louis.

Professor HENRY LOUIS observed that for over 50 years he had been closely connected with the production and use of various forms of machinery for the comminution of rocks, both in coarse comminution as leading up to finer work, as was usual with gold ores and metalliferous ores generally, and in coarse comminution as a final process, as, for instance, the reduction of limestone and iron-ores for treatment in lime-kilns and blast-furnaces and the production of road-metal. As the Authors did not purport to describe all forms of appliances for comminution, his remarks would be complementary to their Paper, rather than critical. He would use the word "breaking" for the coarser comminution (down to about 2 inches); "crushing" for finer comminution (down to about 0.1 inch) and "grinding" for still finer work, where required. He did not suggest that those terms were exact, but it was important to make a distinction. His recollection of the earliest forms of Blake rock-breaker, with which *Fig. 1* seemed to agree, was that the swinging jaw was usually made of one chilled-iron casting; replaceable faces were introduced later, and faces made in two or more parts divided horizontally, side-plates, and renewable toggle-seats were introduced later still. The Authors did not mention "pin-plates" in that connection; they were plates of ordinary steel about 1 inch thick with holes drilled in them into which short pieces of round tool-steel were driven. The Authors appeared to have overlooked the most serious drawback of the Blake rock-breaker and Gates-type gyrating rock-breakers, namely, that the swinging jaw or gyrating portion was attached to a fulcrum on top and therefore had its maximum motion at the bottom, thus delivering an irregularly-sized product. To overcome that difficulty two rock-breakers have been devised in the United States; the Dodge rock-breaker (with which the Bartsch rock-breaker of Germany was practically identical) had its swinging jaw pivoted at the bottom, and the Forster rock-breaker had a lateral motion, the swinging jaw in both cases forming one arm of a bell-crank lever, the other arm being very long so as to give the necessary breaking stress. At one time it was quite common to use rock-breakers in tandem, the upper one being either of the Blake reciprocating or Gates gyrating type, and the lower one being usually a Dodge breaker, so that the product should be more uniform. The Authors described a number of what they called "single-toggle" jaw machines, but a toggle-joint really consisted of the two toggle-plates and a connecting-rod between them, whereas the mechanism which the Authors described was not a toggle-joint at all. He thought that it should be described rather as a radius-plate than as a toggle-joint, as the difference was important.

Cornish crushing-rolls were at one time in very common use,

but the Authors did not appear to have mentioned the raff-wheel, which formed one of the most conspicuous parts of the machine. In discussing geared rolls, the Authors did not mention the use of the "hunting cog," which was a tooth inserted in one of the gear-wheels, so that the rates of revolution of the two rolls might differ by about 1 per cent., in order to prevent the same parts of the rolls always coming in contact with each other. They did not mention that many belt-driven rolls (in which he thought that the Krom roll was the pioneer) were drawn together instead of pressed together, as in the original Cornish rolls. Some valuable information regarding crushing rolls had been given by Mr. Philip Argall.<sup>1</sup> With regard to Edison rolls, the Authors did not seem to be aware that such rolls were set up at Dunderland in Norway 7 feet in diameter and 7 feet wide, breaking pieces of rock weighing up to 8 tons.<sup>2</sup> Possibly the most interesting experimental feature of those rolls was that they were drawn together by wire ropes, so as to relieve the very heavy friction that would otherwise come upon the bearings; the wire rope suffered severely in the process. Apparently the Edison principle was being revived in rolls which Messrs. Stewarts and Lloyds were installing at Corby. Broadly speaking, it might be doubted whether springs were really an ideal means for holding together rolls, as their use was bound to permit a certain amount of irregularity in the product; the feeder to the rolls should, in any case, always carry some magnetic device to keep out "tramp iron" such as pick-points, nuts and spikes, although the Authors did not mention that fact, which was evident to every practical miner. There was a whole series of mills for fine grinding which the Authors did not consider, including ball-mills, tube-mills, and stamp-mills ranging from the somewhat crude Saxon mill of the Middle Ages to the latest steam stamp of the United States.<sup>3</sup> The importance of those fine grinding appliances had grown immensely since the use of flotation in dressing metalliferous ores had developed so largely. The Authors did not refer to the large number of coal-comminution machines which were in use, including needle breakers, special toothed rolls, the Bradford breaker, which was largely used in the United States, and the Carr disintegrator, widely used for coal-crushing in Great Britain. In spite, however, of those gaps in the Authors' Paper, it nevertheless presented a very useful summary of the machinery described in it.

<sup>1</sup> "Sampling and Dry Crushing in Colorado," Trans. Inst. Min. Met., vol. x (1902), p. 234.

<sup>2</sup> W. Simpkin and J. B. Ballantine, "Dry Crushing of Ores by the Edison Process," Trans. Inst. Min. Met., vol. xiv (1905), p. 67.

<sup>3</sup> Henry Louis, "The Dressing of Minerals," London, 1909.

Mr. Main.

MR. S. A. MAIN remarked that the study made by the Authors of those characteristics of rocks likely to influence their abrasive effect on the wearing parts of crushers was, so far as he was aware, the first of its kind. The provision of the most suitable materials for those wearing parts could obviously best be effected only from a parallel study on the one hand of the nature of the products dealt with, and of their abrasive action, and on the other of the abrasion-resisting properties of the material of the wearing parts. In previous work attention had been focussed mainly on the latter, and the present research was therefore welcome, as inaugurating a study on better lines.

With reference to the possible influence of sharp edges on abrasion, in the attrition-test as applied in the Authors' research it was hardly to be expected that any marked change in the rate of attrition should occur at any particular period or stage of the test. Sharpness would not be removed at any definite time from the edges of all the rock fragments in a batch. Any effect of sharpness might therefore be expected to show itself in a tendency for the relative rates of abrasion of the materials to become more constant as wear proceeded. The results of Fig. 52, Plate 1, did in fact show a steady decline in the rate of attrition in all cases, such as might lead to the conclusion that blunting of the fragments was operative. Suitable replotting showed, however, that within the duration of the tests there was no tendency for the relative rates of attrition to settle down to definite proportions, even as between the two most friable rocks, where the abrasion had reached as much as  $4\frac{1}{2}$  per cent. and over. In arriving at that conclusion the rates of attrition had been compared on what appeared to be the most logical basis, namely, at an equal percentage of total wear for each material. The behaviour in that test of rock-samples taken in the form of naturally-rounded pebbles should, by the consistency or otherwise of their relative rates of wear, help to determine that question.

It seemed very desirable that the tests applied to rocks should be brought on to a more rational basis, as it was obvious that the relative characteristics of the rocks depended on the arbitrarily chosen bases of comparison. In the attrition-test, for example, the relative values determined on a basis of total wear after a given number of revolutions were very different from those obtained from a comparison of the number of revolutions to produce a given amount of wear. It was not suggested that the tests employed in rock-testing were any more empirical than many others in extensive use in other directions, as, for example, in the mechanical testing of metals, instanced by many types of hardness-test. Such empiricism was a constant hindrance to scientific progress, although

having undoubted uses in simplifying practical testing. It should **Mr. Main.** not, however, be regarded as beyond possibility to reconcile the requirements of scientific research and practical expediency, and it was to be hoped that that point would be kept in view. The introduction of the diamond pyramid hardness-test for metals had, owing to its rationality, proved to be a valuable development by removing many of the anomalies associated with the only semi-rational Brinell test. Similar rationalizing, to the extent to which it was possible, should prove of undoubted benefit in the study of rocks.

**Mr. ALFRED B. SEARLE** regarded the Paper as of great value, **Mr. Searle.** though the "scattering" of the results in Figs. 36 to 52, Plate 1, made it unwise to draw very definite conclusions. The results were, on the whole, in close agreement with those he had obtained in testing stones of various kinds during the past 30 years. The Author's analogy between the abrasion of rocks in use and the action of a grinding wheel was particularly apt, and made clear a factor which was often overlooked. Le Chatelier had suggested that the abrasive value of a rock was more closely allied to a modified form of crushing test than to that generally used, in which the "cracking strength" was obtained when the pressure was applied through a steel ball 1 centimetre in diameter.

The graphs showing the relation of "ring-size" to "percentage passing" were illuminating, but, unfortunately, they had been drawn in an unusual manner; it was more usual to show the "percentage passing" as the ordinate and the "size" as the abscissa. The similarity of some of the curves for stones widely different in nature was very striking, and so were the differences in the curves for rocks bearing the same name (for example, granite) but from different localities. The latter showed the importance of not relying too much on the "name" of a rock as a guide to its suitability for any purpose.

**Mr. E. G. WALKER** observed that the Authors devoted com- **Mr. Walker.** paratively little attention to the swinging-hammer type of crusher. Possibly that might be due to the comparatively limited extent to which the type had been used in Great Britain. The limited reference to it in the Paper, and the confining of that reference only to the older patterns, which, for heavy work, had been largely superseded, might well cause an erroneous impression to be disseminated as to its merits and the stage which has been reached in its development. The Williams crusher, described on pp. 65 and 66 of the Paper, had long passed the stage of development illustrated by *Fig. 26*. The modern Williams machine differed materially both in principle and detail from that figure. Although yoke hammers

Mr. Walker.

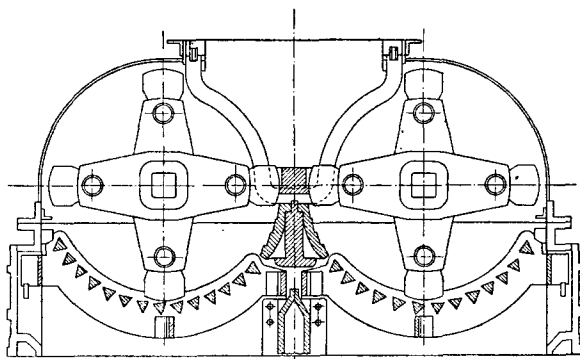
as described by the Authors were still used for certain materials, a number of different types of hinged and shaped beaters had been designed and used successfully, in order to deal with a large range of materials from the softest to the hardest. The straight grate-bars referred to on p. 66 had, for rock-crushing, been replaced by a segmental cage of the type shown in *Fig. 27*, so that the material was confined within a cylindrical space, having its centre-line along the axis of the shaft. The small inclined shoot shown in *Fig. 26* had been replaced by an inclined beater-plate. That type of machine now depended for its crushing efficiency on the effect produced by rapid successions of downward blows by the hammers on the materials resting on the beater-plate. The arrangement of the machine was closely akin to that shown in *Fig. 28*. Pieces of material not small enough to pass through the grid were carried round by centrifugal force until they were again dropped on to the beater-plate or the unbroken pieces of rock that were being fed into the machine. As compared with the jaw and gyratory crushers, the action of that type of machine was more closely akin to the breaking of stones by a hand-hammer.

The type of pulverizer shown in *Fig. 27* differed from the Williams and Pennsylvania types by reason of the fact that it depended largely for its crushing action upon the driving of the larger pieces of material against the lining-plates. The pulverizing-chamber shown above the horizontal axis of the machine was a substitute for the breaker-plates in other types. Machines of the "Lightning Crusher" type were very successfully used for crushing and granulating in Great Britain, but were generally used in smaller sizes. Their simplicity of construction made them very useful, and suitable for portable units such as were required for breaking concrete-aggregate. Such machines could deal with material containing a considerable quantity of moisture almost as easily as dry material. That was often a very great advantage, particularly when dealing with materials such as chalk, which would absorb water in such quantities as often to cause the clogging of machines of other types. Further, in cases where it was necessary to use dirty stone, they would usually be found simple to operate. Their use was not necessarily confined to small sizes, and in recent years they had been used very successfully for breaking hard stone for road-making purposes. Machines such as the K.B. rotary granulator, made by Edgar Allen & Co., Ltd., were in use in sizes that would break down soft materials such as limestone slag to a  $\frac{3}{4}$ -inch product at rates up to 60 and 70 tons an hour. Those machines required 100 to 120 HP. to drive them, and were comparable in size with the large machines of other classes.

The Authors had made no reference to the greatest advance which

had been made in the development of the hammer type of crusher, Mr. Walker, namely, the introduction of the twin-shaft type of machine, in which two sets of hammers were mounted on parallel shafts rotating in opposite directions. Those machines had been developed more in Germany than anywhere else, but had been applied with considerable success in the breaking of hard stones in other parts of the world. They were made in Great Britain by Edgar Allen & Co., Ltd. The principle of the machine was shown in *Fig. 62*. Two sets of rotating hammers, revolving in opposite directions with a suitable clearance between them, struck the rock, which was supported in a cage on bars between the two shafts. The broken rock was carried round by centrifugal force and discharged through the grid bars. The action of the machine was extremely simple, and the supporting of

*Fig. 62.*



the raw material by the cage ensured the blows of the hinged hammers being applied in the most effective way. Such machines had two outstanding advantages. In the first place, they could be used for the breaking of rock of the largest size that could be loaded into them down to  $\frac{3}{4}$ -inch or under in one operation, the limit of size of the feed being set by the size of the largest piece that could be put into the cage. He had seen one of those machines take in its normal feed limestone blocks weighing several tons and reduce them to material of 1 inch or smaller. Their other great advantage was that they would handle material that would clog crushers of other types. Some years ago he had had occasion to instal crushing and grinding machinery for dealing with a mixture of hard limestone and clay which occurred in the form of narrow alternating bands of the two materials. These bands occurred above thicker beds of limestone and beneath a more clayey overburden. In working the quarry

Mr. Walker.

the whole of the face, including the clay and the interstratified material as well as the uniform stone at the bottom, was brought down in one operation and passed through the crusher, the mixture containing up to 30 or 35 per cent. of clay. In wet weather the clay was fairly sticky, yet it was found possible to use the machine for breaking up the mixed material, which was fed directly to it without any preliminary separation. No difficulty was experienced from choking or clogging by reason of the presence of the clay in the mixture.

In comparing types of crushers it was difficult to select a specific criterion of performance, and practically impossible to set out in quantitative form the work that it was necessary to do upon the raw material as taken from the quarry-face to break it down to any specified size. It was, however, to be regretted that the Authors gave no information as to the performance of the various types of machines which they described, and made no reference to their power-consumptions or outputs. Such information would be of greater use than the graphical information of the gradings of the product given in the Paper. In the practical selection of machinery convenience of operation (and in many cases also convenience of transport) were quite as important as power-consumption. Simplicity in the arrangement of the plant would, therefore, frequently outweigh considerations of the cost of power, particularly when it was possible to employ single-stage instead of two- or three-stage crushing. The characteristics of the site upon which the plant was to be installed and the difficulties of erection were frequently very important factors in the lay-out of the crushing-plant.

He agreed with the Authors that it was very difficult to apply the results of existing experimental work on the abrasion of rocks to the mechanical design of a crusher. Most of the work quoted by them had been directed to the determination of the wearing properties of the rocks themselves when subject to the abrasive action of loads applied to them. Whilst that information might be of direct application to problems of grinding, it had but little connection with those of crushing. Neither the Dorry tests nor the scratch test were applicable to that problem, and although impact-tests of the type of the Page test were likely to give some better indication of the behaviour of a rock in a crusher, they did not give evidence of the effect on the crusher. Until more scientific evidence was accumulated the practical features of the design of crushers must continue to be based materially upon the accumulated experience of their performance on the large range of materials put through in practical working.

The AUTHORS, in reply, dealt firstly with certain questions asked The Authors. by Mr. H. V. Budgen. The inclusion of the sizes of the machines used for the various crushing-tests together with their settings would have complicated the diagrams. It was also well to point out that the character of the crushing-faces, whether plain or toothed, new or worn, together with the extent of the crushing-stroke near the sizing point, were all factors which had considerable influence on the product-size. It was undoubtedly true that the single-toggle breakers yielded a very regular and cubical product. In the Author's opinion that was due to the facts that the effective crushing stroke diminished from inlet to outlet and that the final sizing was effected by short glancing strokes. With regard to the relative efficiencies of plain and toothed or corrugated jaws, the Authors had experimented with both types and had found that, whilst jaws with fine-pitched teeth gave the better sample, it was possible by using curved jaws with plain faces to obtain a very fair product when the stone which was being crushed was not particularly "flaky." On abrasive materials the life of the small-pitched teeth necessary for chippings was very short, with the result that the jaws soon presented a bad surface due to irregular wear. In such cases correctly-designed plain jaws might prove economical.

Mr. Main had contributed an interesting discussion of the interpretation of the experiment on the influence of sharp edges in abrasion. The point raised by the Authors was that if the sharp edges had a material effect the slowing-down of the rate of attrition in the tough rocks would differ from the effect shown in the more fragile rocks. It had been found in naturally-rounded pebbles that an abnormally low rate of attrition of the rock occurred. That was in accordance with what would be expected from the character of the curves shown in Fig. 52, Plate I. It would appear that further evidence was to be looked for on that debatable point.

Several criticisms had been made of the Authors' interpretations of the data presented in Plate I, but none had dispelled the conviction that the relationships marked a definite clarification of the diverse features presented.

Professor Louis had referred to fine comminution, and Mr. Hancock in the discussion had raised the question of "grindability" and referred to the work of the United States Bureau of Mines on the subject. It had, however, been clearly indicated in the Paper that those subjects did not come within its scope.

Mr. Walker had interpreted the object of the sections dealing with the abrasive character of rocks in a manner opposite to that intended by the Authors. Their object had been directed not to the determination of the wearing properties of the rocks themselves when

**The Authors.** subject to the abrasive action of loads applied to them, but, as the title of the Paper indicated, to those characteristics of the rocks which were responsible for abrasion of the metal parts of the crushing machinery.

27 November, 1934.

Mr. JOHN DUNCAN WATSON, Vice-President, in the Chair.

The Discussion on the Paper by Messrs. Miller and Sarjant on the evolution of various types of crushers for stone and ore, and the characteristics of rocks as affecting abrasion in crushing machinery, was continued and concluded.