Jaw Crusher Capacities, Blake and Single-Toggle Or Overhead Eccentric Types

by D. H. Gieskieng

THE advent of curved jaw crusher wearing plates made an approach other than segmental layout analysis desirable for prediction of capacities. For some time it had been known that the drawing board capacities of crushers using these plates had to be considerably modified by complicated experience factors to achieve agreement with results. Because these apparent capacities could be readily increased severalfold by minor crushing chamber shape changes, it was necessary that the utmost precaution be taken in predicting capacities of jaw plates modified for nonchoking, special wear characteristics, or any other reason.

To this end the laboratory and field tests outlined by the author in a previous paper[1] were made on Blake-type jaw crushers. The results of these tests were summarized in a simple first degree equation applicable to crushers using either straight or curved jaw plates. This equation first outlines the maximum capacity potential of a given crusher, then reduces this figure in accordance with installation circumstances by means of a realization factor.

It was found subsequently that this equation, with the addition of an eccentric throw factor, is applicable to standard types of single-toggle or overhead eccentric jaw crushers as far as maximum capacity potential is concerned. However, these crushers have realization factor curves somewhat different from those outlined for the Blake type.

While this paper is concerned principally with standard type single-toggle crusher capacities, the evaluation of data obtained with these machines is simplified by comparative reduction to the 10 x 7 in. Blake-type equivalents upon which the summary of the preceding paper was made. Convertibility of data from one type of crusher to the other also tends towards confirmation of both. The agreement of these data is sufficient to be considered complimentary. Consequently the feed factors, f, previously reported for Blake crushers are slightly adjusted to an average with the single-toggle crusher results.

Blake-type equation:

$$C = f \cdot d \cdot w \cdot y \cdot t \cdot n \cdot a \cdot r \quad [1]$$

Single-toggle type equation:

$$C = f \cdot d \cdot w \cdot y \cdot t \cdot n \cdot a \cdot e \cdot r \quad [2]$$

where C is the capacity in short tons per hour through the crusher, f is a feed factor, dependent upon the presence of fines in the feed, and the surface character of the jaw plates used.

Values of f:

	Smooth Plates	Corrugated Plates
With normal fines	0.0000414	0.0000319
Fines scalped out	0.0000368	0.0000252
Large pieces only	0.0000312	0.0000215

d is the apparent density of the broken product in pounds per cubic foot. (If the true specific gravity of the feed is known, 40 pct voids may be assumed and d becomes 37.4 times sp gr).

w is the width of crushing chamber in inches.

y is the openside setting of the crusher, in inches. In the case of corrugated jaw plates it is measured from the tip of one corrugation to the bottom of the valley opposite.

t is the length of jaw stroke in inches at the bottom of the crushing chamber. It is the difference between open and close-side settings.

n is rpm, or crushing cycles per minute.

a is the nip-angle factor. It is unity for 26° and 3 pct greater for each less nip-angle degree. A nip-angle of 20° has an a value of 1.18, and an angle of 30° has an a value of 0.88, see Fig. 1.

r is the realization factor. It is unity for perfectly uniform choke feeding and usually less for actual operating conditions according to the method of feeding used and the probabilities of hang-ups involving the size of feed and crusher opening. Approximate values are given by the curves in Fig. 2. These values are further reduced by intermittent feeding.

e is the throw or diameter of gyration of the single-toggle crusher eccentric in inches.

As evident in Fig. 1A, variation of feed size will generally have little effect on nip-angle if both jaw plates have flat areas.

Jaw plates having continuous curvature, as in Fig. 1B will have different nip-angles, depending upon the size of feed. For test work as described in this paper this effect was accounted. For general compilation of capacities for average feeds it is suggested that the nip-angle be taken at the various settings computed, at an arbitrary level, such as is indicated in Fig. 1C.

Data Evaluation

To bring the Blake and single-toggle type crusher capacity test results to common terms for evaluation, all data are converted to terms of 10 x 7 in. Blake-type performance at conditions of 100 lb per cu ft, 10 in. chamber width, 250 rpm, 0.65 in. stroke, 3-in. openside setting, and 18° nip-angle. (The nip-angle of the 10 x 7 in. Blake is 18° at 3-in. setting.) The single-toggle crusher performances are also divided by the eccentric throw to bring this effect to unity.

As outlined,[1] laboratory and field tests made on Blake-type crushers ranging from 10 x 7 in. to 60 x 48 in. were summarized along the foregoing conditions of speed, stroke, etc. This resulted in groups of data which correspond to feeds with fines, feeds

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with fines scalped, and feeds consisting of large pieces only. The results of this Blake-type summary are averaged with the single-toggle type data as converted to Blake-type equivalents, and this average forms the basis for calculation of the revised feed factors, f, i.e., considering corrugated jaw plates and feeds with fines.

$$f = \frac{19.3}{100 \times 10 \times 3.0 \times 0.65 \times 250 \times 1.24} = 0.0000319$$

where the numerator is the 10 x 7 in. Blake-type equivalent tonnage and the denominator corresponds to density, width, setting, stroke, speed, and nip-angle at the conditions which produced this tonnage.

Crushability-Capacity Effect

In the Blake-type crusher tests,[1] no capacity variation was noted for materials of different crushabilities, even though a wide range of materials was tested. These feeds had impact strengths ranging from 2.8 to 31 ft lb per in. of thickness as measured by the Bond method,[2] (potash, coke, soft hematite, limestones, traprock, taconites.)

The single-toggle crusher tests upon which this present paper is based indicate a trend in crushability-capacity effect. From Table I, which gives single-toggle to Blake-type equivalents, it is evident that feed *A*, a relatively soft gravel, resulted in capacities about 10 pct higher than those obtained with considerably tougher feeds *B* and *C*. A few tests not listed were run with very friable dry bituminous coal, which further indicated a crushability-capacity trend for single-toggle type crushers.

The simplicity of the capacity equations is maintained without loss of practical accuracy by averaging the single-toggle crusher results obtained with tough feeds (*B*, *C*, and *D*), and average feeds (*A*). It is evident that very little error is introduced for most feeds by doing this (5 pct or less). If softer than average feeds are contemplated for single-toggle crushers, up to about 10 pct additional capacity might be expected.

It is believed that the single-toggle crusher crushability-capacity trend is largely caused by the eccentric action which results in a rubbing motion between the jaw plates (attrition). With tough feeds this effect is apparently negligible as far as capacity is concerned. Feed factors computed from the traprock and taconite tests came within about 3 pct of feed factors previously reported for general feeds with Blake-type crushers.

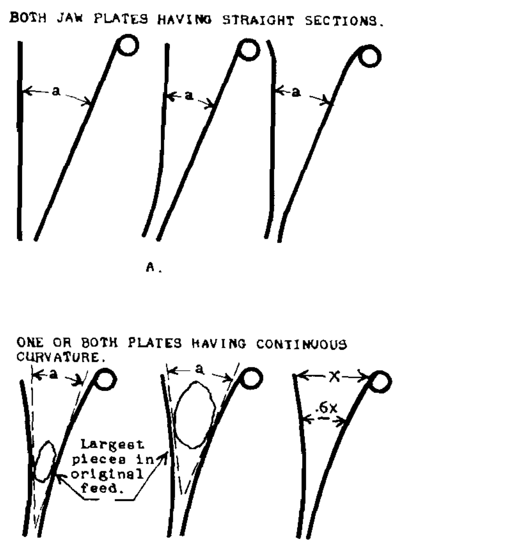

Fig. 1—Location of nip-angle measurement in Blake-type or single-toggle type jaw crushers.

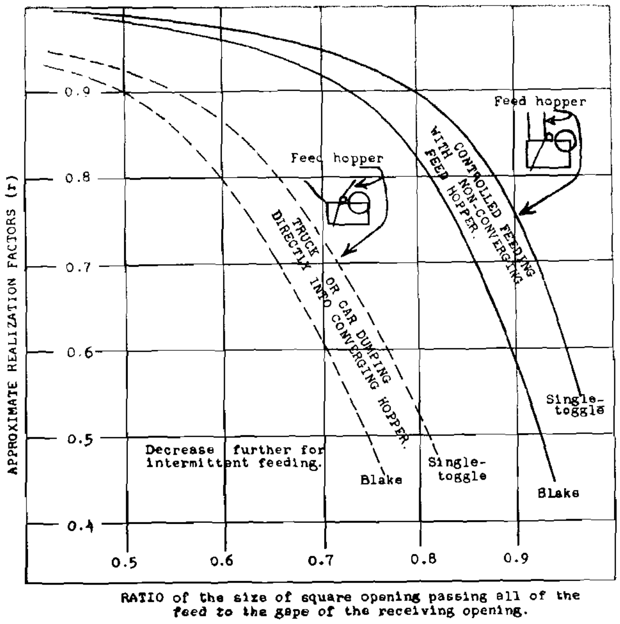

Fig. 2—Realization factors (r).

Greater differences in crushability-capacity effect than those just discussed for single-toggle type crushers have been reported by investigators working with small Dodge-type crushers. However, these crushers have rubbing motion between the jaws at the discharge, Fig. 3, and in addition have very little jaw stroke at the discharge. The crushing done by attrition between the jaws thereby assumes increasing importance with more friable feeds, as there is longer retention time in the crushing chamber caused by the small stroke and resulting discharge capacity deficiency. Comparing various data reported for Dodge-type crushers, it was found that the so-called crushability-capacity effect was very much greater with a jaw stroke of 0.04 in. than it was with 0.20 in. A further contributing effect to this tendency is believed to be illustrated in Fig. 4 of the preceding paper[1] which indicates that discharge capacity falls off more than proportionately for jaw strokes less than about ¼ in.

Reduction of data from one type or size of jaw crusher into the equivalent performance of another crusher has been accomplished by ratios of all of the various equation factors involved. The individual

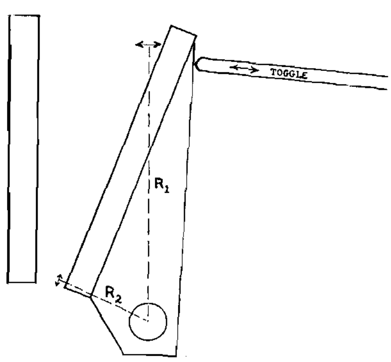

Fig. 3—Dodge-type jaw crusher showing relative swing jaw motion at feed and discharge ends.

Table I. Single-toggle Data Conversion to Blake-type Comparison Equivalents

Single-Toggle Crusher Size and Eccentric Throw, In.	Open and Closed Settings	Nip-angle	10x7 in. Blake-type comparison equivalents. 100 lb, 250 rpm, .65 in. stroke, 3 in. openside setting, 18° nip-angle, 10 in. width	
CORRUGATED JAW PLATES				
Feeds with Fines				
4¾ x 3⅛				
½ ecc.	0.932/0.616	16.7°	19.8 A	18.8 B (2)[a]
	0.563/0.250	19.2°	21.0 A (2)	19.5 B (2)
6⅝ x 5⅝				
¾ ecc.	1.385/0.817	19.4°	21.2 A	20.4 B
	1.037/0.470	20.9°	21.9 A	18.5 B
			20.1 Avg 18.5 Prev. Blake	
			19.3 Avg Feed factor 0.0000319	
Feeds with Fines Scalped				
4¾ x 3⅛	0.938/0.622	16.6°	16.6 A	16.3 B
½ ecc.	0.563/0.250	19.2°	14.6 A (2)	13.9 B (2)
6⅝ x 5⅝	1.250/0.676	20.0°	16.1 A	13.2 B
¾ ecc.	1.000/0.435	20.9°	16.7 A	14.1 B
	0.846/0.278	21.7°	13.6 A	13.1 B (2)
36 x 25				
1¼ ecc.	3.91/3.04	26.0°		15.4 C
			15.0 Avg 15.4 Prev. Blake	
			15.2 Avg Feed factor 0.0000252	
Feeds Consisting of Large Pieces Only				
6⅝ x 3⅛				
¾ ecc.	1.715/1.147	17.9°	13.9 A (3)	13.0 B (2)
			13.5 Avg 12.5 Prev. Blake	
			13.0 Avg Feed factor 0.0000215	
SMOOTH JAW PLATES				
Feeds with Fines (−2.25 In. Slot Size)				
24 x 10				
¾ ecc.	1.64/1.10	7.5°	24.4 D	
	1.19/0.65	12.0°	24.0 D	
	0.79/0.25	12.5°	22.8 D	
			23.7 Avg 1.2[b]	
			24.9 Avg 25.0 Prev. Blake Feed factor 0.0000414	
Feeds with Fines Scalped (−3 In. Slot Size)				
24 x 10				
¾ ecc.	1.64/1.10	11.0°	21.9 D	
	1.19/0.65	12.5°	21.8 D	
	0.79/0.25	14.5°	20.3 D	
	Density	**Impact Strength**	21.3 Avg	
Feed A gravel	105 lb per cu ft	15.0	1.1[b]	
Feed B traprock	105 lb per cu ft	27.0	22.4 Avg	
Feed C taconite	130 lb per cu ft	20.3	22.0 Prev. Blake	
Feed D traprock	107 lb per cu ft	23.7	22.2 Avg Feed factor 0.0000368	

[a] (2), (3) indicates average of two or three tests.
[b] 5 pct added to compensate for average feeds not tested.

analysis of the extent of most of these factors is outlined in the preceding paper.[1]

Direction of Flywheel Rotation

The top of the flywheels of almost all single-toggle crushers rotate towards the crushing chamber, and this rotation is considered to be normal. Capacity eqs 2 and 3 and subsequent discussion are based upon this rotation unless otherwise noted.

Tests made with reverse rotation on standard and inverted toggle single-toggle crushers indicate about 20 to 30 pct less capacity for average crushing conditions and nip-angles of about 20°. With small ratios of reduction or larger nip-angles the capacities obtained with reverse rotation approach those obtained with normal rotation.

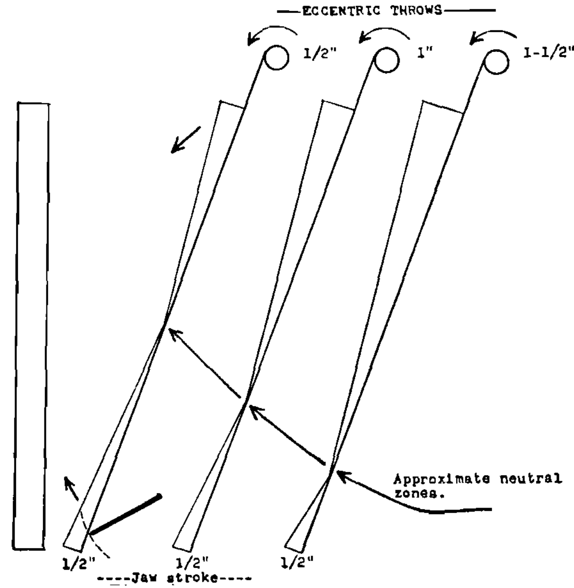

Fig. 4—Force feeding and uplifting action in single-toggle crusher.

A single-toggle crusher with a 26° nip-angle had 6 pct more capacity with normal rotation than with reverse when crushing normal feeds. However, in the particular pit where this machine was located, a large portion of stream-worn feed was present of a size corresponding to the neutral zone, Fig. 4. These boulders handicapped the crusher to such an extent that reversing the rotation and thereby dislocating the neutral zone improved the overall operation. This is believed to be an exception.

Toggle Arrangements

Standard: Almost all single-toggle crushers built today are arranged with the toggle slanting downward to the swing jaw, see Fig. 5a. This arrangement is considered standard and lends itself to strong construction as the toggle is in compression and the pressure reaction is in line with the crushing chamber.

In analyzing the jaw motion of these crushers, it may be seen that during about 50 pct of the time the opening and closing motion at the top and bottom of the crushing chamber is opposite. This results in a variable intermediate level having little crushing action, which may explain to some extent the applicability of the capacity equation to either the standard type of single-toggle or Blake-type crusher. This characteristic has some design advantage for choke feeding as the flow of material to the lower portion of the crushing chamber is limited, which tends to reduce packing tendencies in this critical region.

Inverted Toggle: Single-toggle crushers having an opposite toggle action to that of the so-called standard type are for convenience referred to as Inverted toggle crushers, Fig. 5b. This type is uncommon and the few known in the field are old.

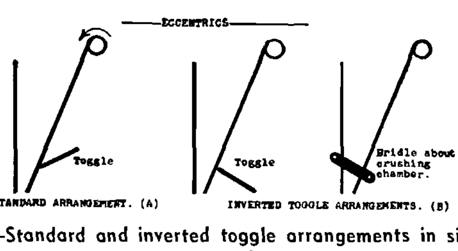

Fig. 5—Standard and inverted toggle arrangements in single-toggle crushers.

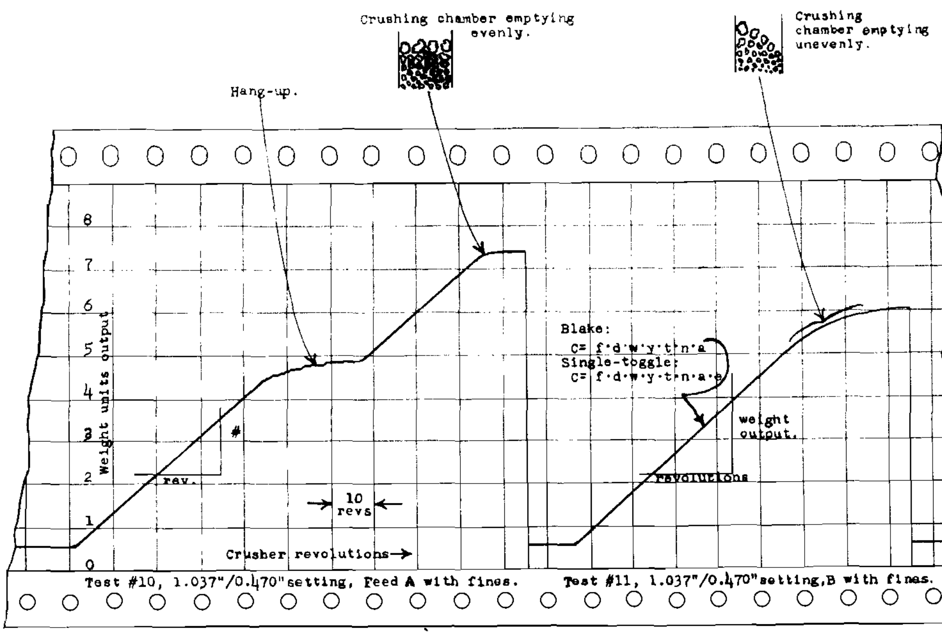

Fig 6 — Typical crushing test records made by synchronized recording device. Power input measured separately.

An inverted arrangement may consist of either a conventional toggle in compression arranged to slope upwards to the swing jaw or of a bridle consisting of hinged tension rods on both sides of the crushing chamber. The construction of either inverted toggle arrangement is not inherently as strong as the standard type. Also, the feed to the lower chamber tends to be excessive which necessitates relatively small strokes to avoid compaction of the feed and high crusher stresses.

An inverted toggle crusher was tested to round out the single-toggle investigation. The capacity characteristics of this crusher were found to be somewhat different than the standard type of single-toggle crusher. A preliminary capacity equation based upon these tests is as follows:

$$C = f \cdot d \cdot w \cdot y \cdot (t_1 + t_2)\ n \cdot a \cdot r \qquad [3]$$

where t_1 is the stroke at the discharge, and t_2 is the stroke at the top of the crushing chamber.

Eccentricity

Single-toggle crushers with normal flywheel rotation have a crushing action caused by the eccentric motion which is commonly termed forced feeding. With standard single-toggle crushers this crowding action extends only to the previously mentioned variable intermediate level having little crushing motion. Below this level an opposite or uplifting action takes place.

The observation that a force feeding action is capacity conducive, and that an uplifting action is not, is confirmed by the results obtained in the reverse rotation experiments. It may be seen that balancing of the effects of these two actions, as illustrated in Fig. 4, is largely accomplished by the presence of the factors *e* and *t* in eq 2; as the value of *e* increases the proportion of uplifting action decreases.

Since standard type single-toggle crushers having eccentric throws of ½ in., ¾ in., and 1¼ in. were tested, and the results successfully converted by ratios of these eccentricities, this eccentricity factor is apparently linear for all practical purposes.

In converting standard type single-toggle data to Blake-type equivalents, the former is divided by the eccentric throw to reduce the effect described above to unity.

Realization Factor

By means of apparatus which continuously recorded the crusher tests, it was possible to eliminate the vagaries of feeding conditions as illustrated in Fig. 6, and thereby reduce the first analysis to terms of characteristic maximum capacities at given conditions of setting, stroke, etc. Various field data were then compared to the resulting equations to determine approximately what percentages of the potential capacities were obtainable in practice with various feeding methods. The effect of various feeding methods is included as a realization factor, *r*.

Summary

This paper is concerned with the capacity characteristics of jaw crushers, and no attempt is made to discuss the other characteristics, such as power consumption or screen analysis of product. It is assumed that in applying the equation good installation practice is followed to the extent of scalping the feed when small settings are used and employing jaw plates having a proper nonchoking curvature if feeds having unusual packing tendencies are encountered.

Acknowledgment

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The opinions expressed on the controversial subject of crushing are those of the writer and do not necessarily coincide in all particulars with those of the Allis-Chalmers staff.

References

[1] D. H. Gieskieng: Jaw Crusher Capacities (Blake Type). *Trans.* AIME (1949) **184**, p. 239; Mining Engineering (July 1949) TP 2598B.

[2] F. C. Bond: Crushing Tests by Pressure and Impact. *Trans.* AIME (1946) **169**, p. 58; Mining Technology (January 1946) TP 1895.