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A comparison of crushing machines

Clyde Willis Hall
Walter Henry Wager

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A COMPARISON OF CRUSHING MACHINES

BY

CLYDE WILLIS HALL

AND

WALTER HENRY WAGER

A THESIS

Submitted to the faculty of the
SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI
In partial fulfillment of the work required for the
Degree of
BACHELOR OF SCIENCE IN MINE ENGINEERING

Rolla, Mo.
1914

Approved by..............................

Assistant Professor of Ore Dressing.

17342
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<td>Blue prints</td>
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Introduction:

Much has been written on the comparative efficiency of the various sorts of crushing machines used in the art of Ore Dressing, but it must be confessed that the subject has by no means been reduced to one of the exact sciences as yet. This is rather a sad condition of affairs, for as is of course apparent to the most casual observer, the whole fabric of ore dressing rests and depends to a large degree on the efficiency and economy of the crushing machinery. Inefficient crushing means high costs, irrespective of the thoroughness and cheapness with which the ensuing operations are carried out.

Numerous and varied experiments have been carried out for the purpose of determining some means of comparing the work done by the various types of crushers, and Richards, in his admirable Text Book of Ore Dressing, gives the results of personal investigations on the subject. Of the multifarious and ingenious formulae and theories advanced, only two have stood the test, those of Stadtler and of Rittinger. While neither of these two is scientifically exact, involving as they do, an empirical coefficient, yet they are the best we have at present.

The following investigations were conducted with a view of determining the comparative value and usefulness of the two methods, and while the work is far from being conclusive, yet there are points which will well repay consideration.
Outline of work:

Lots, each of Zinc Ore, Granite, Hematite Calcite and Chert were crushed to approximately one inch. This was passed over a 5/8 inch screen and the oversize was saved for the experiment. A screen analysis was made of this material and the average diameter determined.

We then crushed 100# thru a small Dodge breaker, 100# thru large rolls, 16 x 36 inches, 50# thru small model Blake, and 75# thru a small model Gyratory machine all set at 1/4 inch.

During the process of crushing the net power to run each machine was determined by getting watts (volts x amps.) to run line shaft, watts to run empty machine plus line shaft and watts to run machine loaded and subtracting watts used in running empty machine from watts used in running machines loaded and dividing by 746 to get net horse power used.

The time required to crush a given quantity was tested and the capacity in tons per 24 hours was calculated.

After crushing, a screen analysis of each product was made and the average diameter calculated.

After the experimental work was completed the following determinations were made:

(a) Reduction in area
(b) The efficiency of each machine for each rock figured from both Stadler's and Rittinger's theories. Curves were plotted, the cumulative percent against the average size, for each rock, thru each machine.
3.

Some of these test runs were made under difficulties. For example: inadequate means of feeding rolls, belts slipping and etc. The observations might, therefore have been more accurate under more ideal working conditions.

Explanation of Tables:

Table 1- Contains a screen analysis, size of screen opening, average size of openings, reciprocal of average size, percent of rock on each screen and percent the totals are times reciprocal for the different rocks, what might be called work units and are used in determining the efficiency of each machine by Rittinger's theory.

Table 2- is merely a continuation of 1.

Tables 3 and 4 are the same as 1, and 2, with exception of the column which contains efficiency units for each machine the percent is multiplied by the efficiency units. The totals are work units and are used in determining the efficiency of each machine by Stadler's method.

Tables 6 to 10 are used in calculating the average size of the discharge.
Data and calculation:

<table>
<thead>
<tr>
<th>Material</th>
<th>Screen Analysis of Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Ore</td>
<td>4# on 1 in</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>5/8</td>
</tr>
<tr>
<td>Chert</td>
<td>1#</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>5/8</td>
</tr>
<tr>
<td>Granite</td>
<td>17#</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>5/8</td>
</tr>
<tr>
<td>Calcite</td>
<td>29#</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>5/8</td>
</tr>
<tr>
<td>Hematite</td>
<td>22#</td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
</tr>
<tr>
<td></td>
<td>5/8</td>
</tr>
</tbody>
</table>
Table No. 5.

Calculation of average size of feed:

\[
\text{Percent} \times \text{size} = \text{Average size.}
\]

<table>
<thead>
<tr>
<th>Percent</th>
<th>Size opening</th>
<th>Av. size: %</th>
<th>% &amp; size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0</td>
<td>7.5</td>
<td>73.5</td>
<td>64.3</td>
</tr>
<tr>
<td>7.5</td>
<td>625</td>
<td>667</td>
<td>19.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td>84.8</td>
</tr>
</tbody>
</table>

Calcite

<table>
<thead>
<tr>
<th>Percent</th>
<th>Size opening</th>
<th>Av. size: %</th>
<th>% &amp; size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0</td>
<td>7.5</td>
<td>73.5</td>
<td>64.3</td>
</tr>
<tr>
<td>7.5</td>
<td>675</td>
<td>687</td>
<td>15.3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td>85.7</td>
</tr>
</tbody>
</table>

Hematite

<table>
<thead>
<tr>
<th>Percent</th>
<th>Size opening</th>
<th>Av. size: %</th>
<th>% &amp; size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0</td>
<td>7.5</td>
<td>73.5</td>
<td>64.3</td>
</tr>
<tr>
<td>7.5</td>
<td>625</td>
<td>687</td>
<td>14.55</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>100</td>
<td>88.8</td>
</tr>
</tbody>
</table>
6.
Explanation of calculation of Net Horse Power and Efficiency

This explanation is by example and covers page 6 to 25 inclusive:

Chert thru Gyratory - page 6

Unloaded
amps - 7 volts - 230

Loaded
amps - 12 volts - 230
time 5 min - amt. 69#
Subtract line shaft in each case, i.e.
7 - 6 is 1 amp to run empty machine
12 - 6 is 6 " " loaded machine

Then

6 x 230 is 1380 watts to run loaded machine
1x 230 is 230 " " empty
\[
\frac{1150}{746} = \text{net watts to carry load.}
\]

\[
\frac{1150}{746} = 1.5 \text{ H. P. Net Power.}
\]

The efficiency or work units are found by multiplying the difference of the totals of the discharge and feed by the tons per horse power day ex:

Page - 6 difference of total is 1430;
tons per H. P. day is 6.2
Then 1430 x 6.2 is 8,866 - efficiency in work per H.P. Day.
Data & Calculation on:

Chert thru Gyratory.

Amps to run line shaft 6.

Unloaded:

Amps. is 7 volts is 230

Loaded:

Amps. is 12 volts is 230

Time 5 min. Amt. 69#

Net H. P. is 1.5

Capacity is 9.4 tons /24 hrs. or
6.2 tons /H. P. Day used below in calculating Efficiency.

For screen analysis see table No. 2.

Calculation of Efficiency - Rittinger.

Totals from table No. 2.

| Discharge | 1547.70 |
| Feed | 117.75 |
| **Total** | **1480.00** |

1430.00 x 6.2 is 8,800 Efficiency.

Calculation of efficiency - Studler.

Totals from table No. 4

| Discharge | 760.35 |
| Feed | 105.83 |
| **Total** | **651.50** |

651.50 x 6.2 is 4,030 Efficiency.

Data and calculation on

Calcite thru Gyratory.

Amps. to run line shaft 6.5
Unloaded

amps is 7.5 volts is 230

Loaded

amps is 9.5 volts is 230

Time 2 min. Amt. is 99#/h

Net HP is .46.

Capacity is 35.6 tons per H day - used below in calculating efficiency.

For screen Analysis see table No. 2.

Calculation of efficiency - Rittinger.

Totals from table No. 2.

<table>
<thead>
<tr>
<th>Discharge</th>
<th>2009.42</th>
<th>2008.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>112.90</td>
<td>1896.52</td>
</tr>
<tr>
<td></td>
<td>1896 x 77.3</td>
<td>146,500 efficiency</td>
</tr>
</tbody>
</table>

Calculation of efficiency - Stadler.

Totals from table No. 4

<table>
<thead>
<tr>
<th>Discharge</th>
<th>653.50</th>
<th>292.50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>73.50</td>
<td>580.00</td>
</tr>
<tr>
<td></td>
<td>800 x 77.3</td>
<td>44,800 efficiency</td>
</tr>
</tbody>
</table>

Data & Calculation on:

Hematite thru Gyratory.

Amps. to run line shaft - 7

Unloaded

Amps. 8 volts - 230

Loaded

Amps. 10 volts - 230
9.

Time 2½ min. amt. 47#

Net H.P. is .62

Capacity is 13.5 tons / 24 hrs.

or 21.8 tons per H.P. day-used below in calculating efficiency.

For screen analysis see table No. 1

Calculation of efficiency - Rittinger.

Totals from table No. 1:

<table>
<thead>
<tr>
<th>Feed</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>114.5</td>
<td>1352.08</td>
</tr>
</tbody>
</table>

\[
\frac{12.54}{114.50} \cdot 21.8 \text{ is } 27.060 \text{ efficiency}
\]

Calculation of efficiency - Stadler

Totals from table No. 3

<table>
<thead>
<tr>
<th>Discharge</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>753.9</td>
<td>78.2</td>
</tr>
</tbody>
</table>

\[
\frac{753.9}{675.7} \cdot 21.8 \text{ is } 14.780 \text{ efficiency.}
\]

Data & Calculation on

Zinc ore thru Gyratory

Amps. to run line shaft - 7

Unloaded

Amps - 8 volts - 230

loaded

Amps - 11 volts - 230
10.

Time 5 min. - Amt. is 94#

Net H.P. is 95.92

Capacity is 13.5 tons / 24 hrs.
or 14.2 tons per H.P. day - used below in calculating efficiency

For Screen Analysis see table No.1.

Calculation of efficiency - Rittinger

Totals from table No. 1.

\[
\begin{align*}
\text{Discharge} & : 2,084.00 \\
\text{Feed} & : 118.85 \\
\end{align*}
\]

\[
\begin{align*}
\frac{1885.15}{1965.15} \times 14.2 & \text{ is } 37.910 \text{ efficiency.}
\end{align*}
\]

Calculation of efficiency - Stadler.

Totals from table No. 3.

\[
\begin{align*}
\text{Discharge} & : 555.7 \\
\text{Feed} & : 108.6 \\
\end{align*}
\]

\[
\begin{align*}
\frac{427.1}{427} \times 14.2 & \text{ is } 67.065 \text{ efficiency.}
\end{align*}
\]

Data & Calculation on Granite thru Gyratory.

Amps to run line shaft - 3

unloaded

Amps is 7. Volts is 230

loaded

Amps is 12. Volts is 230

Time 5 mins. - Amt. is 75#
11.

Net H. P. is \( \frac{92}{2} \times 6^\frac{3}{4} \).

Capacity is 10.8 tons per 24 hrs. or 11.88 tons per H.P. day - used below in calculating efficiency.

For screen analysis see table No. 1.

Calculation of efficiency - Fittinger.

Totals from table No. 1.

| Discharge | 1359.30 | 1.70 |
| Feed | 115.65 | 1.50 |

\(-\frac{1358.15}{1243.65} \times 11.4\) is 14.260 efficiency.

Calculation of efficiency - Stadler

Totals from table No. 3.

| Discharge | 775.9 | 8.50 |
| Feed | 187.7 | 2.00 |

\(-\frac{747.28}{788.2} \times 11.4\) is 8.980 efficiency.

Hematite thru Blake.

Amps to run line shaft is 7

Unloaded

Amps is 8 volts is 228

Loaded

Amps is 11 volts is 228

Time is 2 min. - Amt. is 40#.

Net H.P. is \( \frac{92}{2} \times 6^\frac{3}{4} \).

Capacity is 14.4 tons / 24 hrs. or 15.8 tons / H.P. day - used below in calculating efficiency.
12.

For screen analysis see table No.1.

Calculation of efficiency - Rittinger.

Totals from table No.1.

\[
\begin{align*}
\text{Discharge} & : 4112.47 & \text{Feed} & : 114.50 \\
\hline
& 1010.20 & & 1018.75 \\
\end{align*}
\]

\[
1010.20 \times 15.6 \text{ is } 15.770 \text{ efficiency.}
\]

Calculation of efficiency - Stadler

Totals from table No. 3.

\[
\begin{align*}
\text{Discharge} & : 804.5 & \text{Feed} & : 78.2 \\
\hline
& 506.3 & & 55.24 \\
\end{align*}
\]

\[
606 \times 15.6 \text{ is } 94.2\% \text{ efficiency.}
\]

Zinc ore thru Blake.

Amps to run line shaft is 7.

Unloaded

\[
\begin{align*}
\text{Amps} & : 8 & \text{volts} & : 230 \\
\end{align*}
\]

Loaded

\[
\begin{align*}
\text{Amps} & : 11.5 & \text{volts} & : 230 \\
\text{Time} & : 3 \text{ min.} & \text{Amt.} & : 55# \\
\text{Net H.P.} & : 1.08 \\
\text{Capacity} & : 13.2 \text{ tons} / 24 \text{ hrs.} \\
\text{or} & : 12.2 \text{ tons} / \text{H.P. day} - \text{used below in calculating efficiency.}
\end{align*}
\]

For screen analysis see table No.1.

Calculation of efficiency - Rittinger.

Totals from table No.1.
Discharge - 9100.00  2/19/71
Feed    - 310.85  1/23/83
\[\frac{9100.00}{1000.25} = \frac{9100}{1000} = 9.1 \] x 12.2 = 24.403 efficiency.

Calculation of efficiency - Stadler.

Totals from table No. 3.

\[\begin{array}{ccc}
\text{Discharge} & 815.6 & 844.39 \\
\text{Feed}       & 108.6  & 72.84 \\
\end{array}\]
\[\frac{815.6}{72.84} = 11.29 \]

\[\frac{705}{12.2} = 58.09 \text{ Efficiency.}\]

Granite thru Blake.

Amps. to run line shaft 7.

Unloaded
Amps. 8 volts is 230

Loaded
Amps. is 11.5 volts is 230

Time 2\(\frac{3}{4}\) mins. Amt. is 60#

Net H.P. is 1.08

Capacity is 15.7 tons /34 hrs.

or 14.5 tons /H.P. day-used below in calculating efficiency.

For screen analysis see table No.1.

Calculation of Efficiency - Rittinger.

Totals from table No.1.

\[\begin{array}{ccc}
\text{Discharge} & 1995.50 & 19/14/79 \\
\text{Feed}       & 115.65  & 1/15/85 \\
\end{array}\]
\[\frac{1995.50}{1799.25} = 1.13 \]
Calculation of Efficiency - Stadler

Totals from table No. 3

Discharge - 914.9
Feed - 87.7

\[
\begin{array}{c}
\text{Efficiency} \\
60.29 \\
849.20
\end{array}
\]

\[
-735.2 \times 14.5 \text{ is } 1.066 \text{ Efficiency.}
\]

Calculation thru Blake.

Amps. to run line shaft is 7

Unloaded
Amps is 8 volts is 230

Loaded
Amps. is 10 volts is 230

Time 5 min. - Amt. is 99.5#

Net H. is .62

Capacity is 14.4 tons /24 hrs.

or 23.2 tons /H.P.day - used below in calculating efficiency.

For screen analysis see table No. 2.

Calculation of Efficiency - Rittinger.

Totals from table No. 2

Discharge - 2851.20
Feed - 112.90

\[
\begin{array}{c}
\text{Efficiency} \\
2.85725 \\
1.31
\end{array}
\]

\[
2.74415
\]

\[
2733.30 \times 232 \text{ is } 62400 \text{ Efficiency.}
\]

Calculation of efficiency - Stadler.

Totals from table No. 4.
Discharge - 931.35 958.24
Feed - 23.5 50.20
937.85 x 23.2 is 22,266 Efficiency.

Data & Calculation.

Chert thru Blake.

Amps. to run line shaft - 7.

Unloaded
Amps. - volts 230

Loaded
Amps - 11 volts 230

Time 3 min. - amt. - 59#

Net H.P. is .95

Capacity is 3.5 tons per 24 hrs.

or 3.3 tons per H.P. day - used blow in calculating efficiency.

For screen analysis see table No. 2.

Calculation of Efficiency - Rittinger.

Totals from table No. 2.

<table>
<thead>
<tr>
<th>Discharge</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>2155.05</td>
<td>117.70</td>
</tr>
<tr>
<td>2037.35</td>
<td>20.55</td>
</tr>
</tbody>
</table>

2037.35 x 0.79 is 74.16 efficiency.

Calculation of Efficiency - Stadler.

Totals from table No. 4

<table>
<thead>
<tr>
<th>Discharge</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>760.4</td>
<td>188.9</td>
</tr>
<tr>
<td>461.5</td>
<td>725.04</td>
</tr>
</tbody>
</table>

725.04 is 2.582 Efficiency.
15.

Hematite thru Rolls.

Amp. to run line shaft is 45.7

Unloaded -

Amps. is 53.7  volts is 228

Loaded

Amps. is 68  volts is 228

Time is 3/4 min. - Amt. is 70#

Net H.P. - 6.78

Capacity is 67.2 tons/24 hrs.

or 3.5 tons/H.P. day - used below in calculating efficiency.

For screen analysis see table No.1.

Calculation of Efficiency - Rittinger.

Totals from table No.1.

Discharge - 1222.30  1226.8
         Feed  114.50  114.5

\[
\frac{11/2.7 \times 15.4}{1107.80} = 11 \frac{2}{3}
\]

\[
\frac{1107.80 \times 9.8}{9.8} = 109.10 \text{ Efficiency.}
\]

Calculation of efficiency - Stadler.

Totals from table No.3.

Discharge - 651.7  74.0
         Feed  78.9  55.7

\[
\frac{685.36 \times 15.4}{612} = 10.5 \frac{4}{5}
\]

\[
\frac{612 \times 9.2}{9.2} = 68.5 \frac{3}{6}
\]

Granite thru Rolls.

Amp. to run line shaft is 44

Unloaded
Amps. is 52  volts is 228

Loaded

Amps. is 74  volts is 228

Time is 3/4 min. - Amt. is 88#

Net H.P. is 6.72

Capacity is 84.5 tons per 24 hrs.

or 12.6 tons /H.P.day - used below in calculating efficiency.

For screen analysis see table No.1.

Calculation of Efficiency - Rittinger.

Totals from table No.1

<table>
<thead>
<tr>
<th>Discharge</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1569.00</td>
<td>115.65</td>
</tr>
<tr>
<td>1260.25</td>
<td>1260.25</td>
</tr>
</tbody>
</table>

\[
\frac{1569.00}{1260.25} \times 12.6 = 16.520 \text{ Efficiency.}
\]

Calculation of Efficiency - Stadler.

Totals from table No.3

<table>
<thead>
<tr>
<th>Discharge</th>
<th>Feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>995.5</td>
<td>615.6</td>
</tr>
<tr>
<td>683.91</td>
<td>615.6</td>
</tr>
</tbody>
</table>

\[
\frac{995.5}{683.91} \times 12.6 = 16.520 \text{ Efficiency.}
\]

Zinc ore thru Rolls.

Amp. to run line shaft is 44.

Unloaded

Amps is 52  volts is 228

Loaded

Amps is 72  volts is 228
Time is 1 min. - Amt. is 92#

Net H. is 6.11

Capacity is 66.2 tons/24 hrs.

or 10.8 tons/H.P.day - used below in calculating efficiency.

For screen analysis see table No.1.

Calculation of Efficiency - Rittinger:

Totals from table No.1.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discharge</td>
<td>1485.00</td>
</tr>
<tr>
<td>Feed</td>
<td>118.85</td>
</tr>
<tr>
<td>----------</td>
<td>---------</td>
</tr>
<tr>
<td>x 10.8</td>
<td>1387.15</td>
</tr>
</tbody>
</table>

\[ \text{Discharge - Feed x 10.8} = 1387.15 \]

\[ \text{Efficiency = 1387.15} \]

Calculation of Efficiency - Stadler

Totals from table No.3.

<p>| | |</p>
<table>
<thead>
<tr>
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<tr>
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<td>---------</td>
</tr>
<tr>
<td>x 10.8</td>
<td>731.02</td>
</tr>
</tbody>
</table>

\[ \text{Discharge - Feed x 10.8} = 731.02 \]

\[ \text{Efficiency = 731.02} \]

Chert thru Rolls.

Amps to run line shaft is 44.

Unloaded -

Amps. is 52  volts is 228

Loaded

Amps. is 74  volts  228

Time is 1 min. - Amt. is 93#
Net H.P. is 6.72

Capacity is 67 tons/24 hrs.

or 9.89 tons/h.p. day - used below in Calculating efficiency.

For screen analysis see table No. 2.

Calculation of Efficiency - Rittinger.

Totals from table No. 2

\[
\begin{array}{c}
\text{Discharge} - 1652.32 \\ 
\text{Feed} - 120.87 \\
\hline
1723.19
\end{array}
\]

\[
\frac{1723.19}{17200} \times 9.89 \text{ is } 15.28\% \text{ Efficiency.}
\]

Calculation of Efficiency - Stadler.

Totals from table No. 4

\[
\begin{array}{c}
\text{Discharge} - 762.85 \\ 
\text{Feed} - 77.82 \\
\hline
840.67
\end{array}
\]

\[
\frac{840.67}{68412} \times 9.89 \text{ is } 5.66\% \text{ Efficiency.}
\]

Calcite thru Rolls.

Amps. to run line shaft is 44.

Unloaded

Amps. is 52 volts is 228

Loaded

Amps. is 62 volts is 228

Time is 3/4 min. - Amt. is 100#

Net H.P. is 6.72

Capacity is 96 tons per H.P. day - used below in calculating efficiency.
19.

For screen analysis see tables No. 2.

Calculation of Efficiency - Rittinger.

Totals from table - No. 2.

\[
\begin{align*}
\text{Discharge} & = 3192.09 \\
\text{Feed} & = 118.09 \\
\text{Discharge} - \text{Feed} & = 3074.00
\end{align*}
\]

\[
\begin{align*}
\frac{\text{Discharge}}{\text{Feed}} & = \frac{3192.09}{118.09} = 26.605
\end{align*}
\]

\[
\begin{align*}
\text{Efficiency} = 100 \times \left(1 - \frac{\text{Discharge} - \text{Feed}}{\text{Discharge} + \text{Feed}}\right)
\end{align*}
\]

Calculation of Efficiency - Stadler.

Totals from table No. 4.

\[
\begin{align*}
\text{Discharge} & = 800.0 \\
\text{Feed} & = 35.0 \\
\text{Discharge} - \text{Feed} & = 765.0
\end{align*}
\]

\[
\begin{align*}
\frac{\text{Discharge}}{\text{Feed}} & = \frac{800.0}{35.0} = 22.857
\end{align*}
\]

\[
\begin{align*}
\text{Efficiency} = 100 \times \left(1 - \frac{\text{Discharge} - \text{Feed}}{\text{Discharge} + \text{Feed}}\right)
\end{align*}
\]

Granite thru Dodge.

Amps to run line shaft is 41.

Unloaded -

Amps is 45.7 volts is 228

Loaded

Amps is 49 volts is 228

Time is 4.5 min. - Amt. is 83#

Net H.P. is 1.02

Capacity is 13.8 tons/24hrs.

or 15 tons/H.P. day-used below in calculating efficiency.

For screen analysis see table No.1.
Calculation of Efficiency - Rittinger.

Totals from table No.1

\[
\begin{align*}
\text{Discharge} & : 1292.9 \\
\text{Feed} & : 115.65 \\
\hline
\text{Totals} & : 1177.25
\end{align*}
\]

\[1177.25 \times 13.5 = 16068 \text{ Efficiency}\]

Calculation of Efficiency - Stadler.

Totals from table No.3.

\[
\begin{align*}
\text{Discharge} & : 725.87 \\
\text{Feed} & : 60.29 \\
\hline
\text{Totals} & : 665.58
\end{align*}
\]

\[665.58 \times 13.5 = 7002.2 \text{ Efficiency}\]

Zine ore thru Dodge.

Amps. to run line shaft is 41.

Unloaded:

Amps is 45.7 volts is 228

Loaded:

Amps is 48.9 volts is 228

Time - 4 Min. - amt. is 86#

Net H.P. is .98

Capacity is 15.5 tons/24 hrs.

or 16.0 tons/H.P. day - used below in calculating efficiency.

For screen analysis see table No.1.

Calculation of Efficiency - Rittinger.

Totals from table No.1
Calculation of efficiency - Stadler.

Totals from table No. 3

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\[ \text{Discharge} \times 16.2 = \text{Efficiency} \]

Hematite thru Dodge.

Amps to run the shaft is 41
Unloaded -
Amps. is 48 volts is 228
Loaded
Amps. is 52 volts is 228
Time is 5.5 min. - amt. is 85#
Net H.P. is \( \text{calc.} \)
Capacity is 11.1 tons / 24 hrs.
or 9.04 tons / H.P. day-used below in calculating efficiency.

For screen analysis see table No.1.

Calculation of Efficiency - Rittinger.

Totals from table No.1

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</tbody>
</table>

\[ 23.94 \times 9.04 = \text{Efficiency} \]
Calculation of Efficiency - Statler.
Totals from table No. 4.

\[
\begin{array}{c|c|c}
\text{Discharge} & 585.4 & 736.00 \\
\text{Feed} & 78.2 & 55.34 \\
\hline
\text{Net} & 607.2 & 680.66
\end{array}
\]

Calcite thru Dodge.
Amps. to run line shaft is 41
Unloaded -
Amps is 45.7 volts is 228
Loaded
Amps is 47.7 volts is 228
Time is 5 min. amt. is 92#
Net H.P. is 275.61
Capacity is 13.25 tons/24 hrs.

or 2.72 tons H.P. day - used below in calculating efficiency.

For screen analysis see table No. 2.

Calculation of Efficiency - Rittinger.
Totals from table No. 2.

\[
\begin{array}{c|c|c}
\text{Discharge} & 1523.45 & 1646.07 \\
\text{Feed} & 112.30 & 113.1 \\
\hline
\text{Net} & 1535.75 & 1559.17
\end{array}
\]

Calculation of Efficiency - Statler.
Totals from table No. 4.
Discharge - 787.8
Feed - 76.5
844.8

864.32
\( \frac{694.3 \times 17.2}{18756} \) is 11.930 Efficiency.

Chert thru - Dodge.
Amps. to run line shaft is 41.
Unloaded
Amps. is 45.7 volts - 228

Loaded
Amps. is 48 volts - 228

Time is 35 min. - Amt. is 68#/2

Net H.P. is .9372

Capacity is 14 tons/24 hrs.

or 15.1 tons/ H.P. day - Used below in calculating efficiency.

For screen analysis see table No.2.

Calculation of Efficiency - Rittinger.

Total from table No.2.

\[
\begin{align*}
\text{Discharge} & : 787.8 & & \text{Feed} : 76.5 \\
\text{967.00} & \times 15.1 & & \text{is 24.954} \text{ Efficiency.}
\end{align*}
\]

Calculation of Efficiency - Stadler.

Totals from table No.4
24.

Discharge - 660.38
Feed - 660.38

\[ \frac{660.38}{660.38} \times 19.6 = 12.949 \]

is 8.800 Efficiency.
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<th></th>
<th></th>
<th>BLAKE</th>
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<th></th>
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</table>

| or size  | 17.4%    | 17.4%  |       | 17.2%  | 17.6%  |       | 17.6%  | 17.5%  | 21.8%  | 21.8%  |

<p>| Average  | 100      | 100    |       | 100    | 100    |       | 100    | 100    | 100    | 100    |</p>
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Average size: 20.28
### Table No. 8

**Hematite**

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Table No. 9.

Granite.

| MATERIAL | GYRATORY | | | BLAKE | | | ROLLS | | | DODGE | | |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| AV. SIZE | PER CENT | PER CENT X SIZE | PER CENT | PER CENT X SIZE | PER CENT | PER CENT X SIZE | PER CENT | PER CENT X SIZE | PER CENT | PER CENT X SIZE |
| .35 | 22.78 | 7.926 | 17.90 | 6.270 | 37.50 | 137.25 | 49.37 | 17.80 |
| .248 | 42.70 | 10.600 | 41.70 | 10.346 | 34.10 | 8.456 | 21.69 |
| .128 | 13.32 | 1.700 | 13.34 | 1.710 | 9.08 | 1.160 | 8.43 | 1.080 |
| .073 | 6.64 | .485 | 10.00 | .730 | 7.98 | .582 | 8.16 | .617 |
| .039 | 5.33 | .208 | 5.83 | .227 | 3.41 | .133 | 4.82 | .188 |
| .022 | 4.67 | .103 | 5.42 | .119 | 4.54 | .100 | 3.80 | .084 |
| .010 | 2.66 | .027 | 2.91 | .029 | 1.04 | .010 | 1.82 | .036 |
| .007 | .62 | .004 | .62 | .004 | .52 | .004 | .60 | .004 |
| .006 | .62 | .004 | .62 | .004 | .80 | .005 | .36 | .002 |
| .004 | .40 | .002 | 1.04 | .004 | .69 | .003 | .30 | .001 |
| .002 | .26 | .002 | .62 | .001 | .34 | .001 | .36 | .001 |

Average size
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<th>Rolls</th>
<th>Dodge</th>
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<td><strong>PER CENT X SIZE</strong></td>
<td><strong>PER CENT</strong></td>
<td><strong>PER CENT X SIZE</strong></td>
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<td>.129</td>
</tr>
<tr>
<td>.022</td>
<td>1.76</td>
<td>.038</td>
<td>5.00</td>
<td>.110</td>
</tr>
<tr>
<td>.010</td>
<td>7.50</td>
<td>.075</td>
<td>3.17</td>
<td>.032</td>
</tr>
<tr>
<td>.007</td>
<td>.18</td>
<td>.001</td>
<td>.84</td>
<td>.005</td>
</tr>
<tr>
<td>.006</td>
<td>.36</td>
<td>.002</td>
<td>1.00</td>
<td>.006</td>
</tr>
<tr>
<td>.004</td>
<td>.22</td>
<td>.001</td>
<td>.83</td>
<td>.003</td>
</tr>
<tr>
<td>.002</td>
<td>.18</td>
<td>.001</td>
<td>1.25</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>22.878</td>
<td>22.464</td>
<td>23.887</td>
<td></td>
</tr>
<tr>
<td>22.878 is 22.464 is.22 23.887 is.24 24.767 is.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Average size for Gyratory, Blake, Rolls, and Dodge are 22.878, 22.464, 23.887, and 24.767 respectively.
Calculation of Reduction in Diameter.

The reduction in diameter is gotten by subtracting the average size of the discharge of each rock thru each machine. For Example: from table No.5 the average size of the feed of zinc ore is .84 and from table 7 the average size of discharge of zinc ore thru Gyratory is .20 - now subtract .20 from .84 equal .64 which is the reduction in diameter by the Gyratory.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Calcite</th>
<th>Zinc</th>
<th>Hematite</th>
<th>Granite</th>
<th>Chert</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gy.</td>
<td>.726</td>
<td>.65</td>
<td>.62</td>
<td>.665</td>
<td>.614</td>
</tr>
<tr>
<td>Bla.</td>
<td>.73</td>
<td>.647</td>
<td>.65</td>
<td>.68</td>
<td>.668</td>
</tr>
<tr>
<td>Rolls</td>
<td>.725</td>
<td>.62</td>
<td>.65</td>
<td>.64</td>
<td>.682</td>
</tr>
<tr>
<td>Dodge</td>
<td>.67</td>
<td>.62</td>
<td>.65</td>
<td>.68</td>
<td>.62</td>
</tr>
</tbody>
</table>

Note: This table explains the above and is merely a tabulation of the reduction in diameter.
## Table No. 11.

<table>
<thead>
<tr>
<th>Machine</th>
<th>Rock</th>
<th>Efficiency by Rittinger</th>
<th>Efficiency by Stadler.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyratory: Zinc ore</td>
<td>Granite</td>
<td>14,200</td>
<td>8,980</td>
</tr>
<tr>
<td></td>
<td>Hematite</td>
<td>17,000</td>
<td>14,968</td>
</tr>
<tr>
<td></td>
<td>Calcite</td>
<td>24,500</td>
<td>44,600</td>
</tr>
<tr>
<td></td>
<td>Chert</td>
<td>16,800</td>
<td>4,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11.15%</td>
<td>5.22%</td>
</tr>
<tr>
<td>Blake</td>
<td>Zinc ore</td>
<td>24,000</td>
<td>9,279</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>36,000</td>
<td>1,980</td>
</tr>
<tr>
<td></td>
<td>Hematite</td>
<td>15,378</td>
<td>1,210</td>
</tr>
<tr>
<td></td>
<td>Calcite</td>
<td>68,800</td>
<td>22,760</td>
</tr>
<tr>
<td></td>
<td>Chert</td>
<td>15,700</td>
<td>5,480</td>
</tr>
<tr>
<td>Rolls</td>
<td>Zinc ore</td>
<td>44,800</td>
<td>9,279</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>55,600</td>
<td>7,700</td>
</tr>
<tr>
<td></td>
<td>Hematite</td>
<td>56,210</td>
<td>10,554</td>
</tr>
<tr>
<td></td>
<td>Calcite</td>
<td>44,000</td>
<td>25,360</td>
</tr>
<tr>
<td></td>
<td>Chert</td>
<td>15,200</td>
<td>5,480</td>
</tr>
<tr>
<td>Dodge</td>
<td>Zinc ore</td>
<td>22,280</td>
<td>10,200</td>
</tr>
<tr>
<td></td>
<td>Granite</td>
<td>15,900</td>
<td>5,990</td>
</tr>
<tr>
<td></td>
<td>Hematite</td>
<td>9,800</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>Calcite</td>
<td>16,000</td>
<td>11,000</td>
</tr>
<tr>
<td></td>
<td>Chert</td>
<td>14,000</td>
<td>24,957</td>
</tr>
</tbody>
</table>

Note:

In the table are summarized the efficiency units for each rock thru each machine. The numbers are large but they can be used comparatively.

These efficiencies on work units are per unit of H.P. day.
Conclusion:

A glance at table No.11 will show the comparative efficiencies of each machine on each rock. Thus, the Gyratory on Zinc ore is the most efficient of all machines on this same ore.

In summing up, it seems that the way the machines rank in regard to power efficiency is:

1. Gyratory
   - Blake
2. Blake
   - Rolls
3. Dodge.