2. GYRATORY CRUSHERS

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History

The original patent for the gyratory crusher was granted to Philetus W. Gates in 1881. This first crusher was used by the Buffalo Cement Co. At the time these early gyratory crushers were developed all mining and quarrying, either underground or open pit, was done by hand; tonnages generally were small and product specifications simple and liberal. Likewise plants were small and demands for small product sizes practically nonexistent.

In addition to substantial amounts of hand labor, the available material handling equipment was small, simple, and not suited to handling large run of mine ore. Mine cars, cable ways, or belt conveyors transporting crushed material to the mill had limited capacity per hour.

At the turn of the century the largest Gates crusher, the No. 9, had a receiving opening of 21 x 48 in. with a three-arm spider and a 21 x 80-in. opening with a two-arm spider.

The steam shovel began to change the entire picture of open pit quarrying. As a result of the use of steam shovels around 1910 crushers with 48-in. receiving openings were built; thus it can be seen that the basic gyratory crusher was developed prior to World War I.

The improvement of the internal combustion engine and the use of pneumatic tires created a new set of operating conditions. Early mines were small, using shrinkage stoping and small mine cars. The capacity of material handling was small, limiting the size of the largest piece and the feed rate. Improved material handling resulted in more and more large open pit mines with large shovels and a tremendous increase in the size of off road or mine haul trucks or rail cars. Primary gyratory crushers also increased with receiving openings as large as 60 in. and connected hp of 1,000.

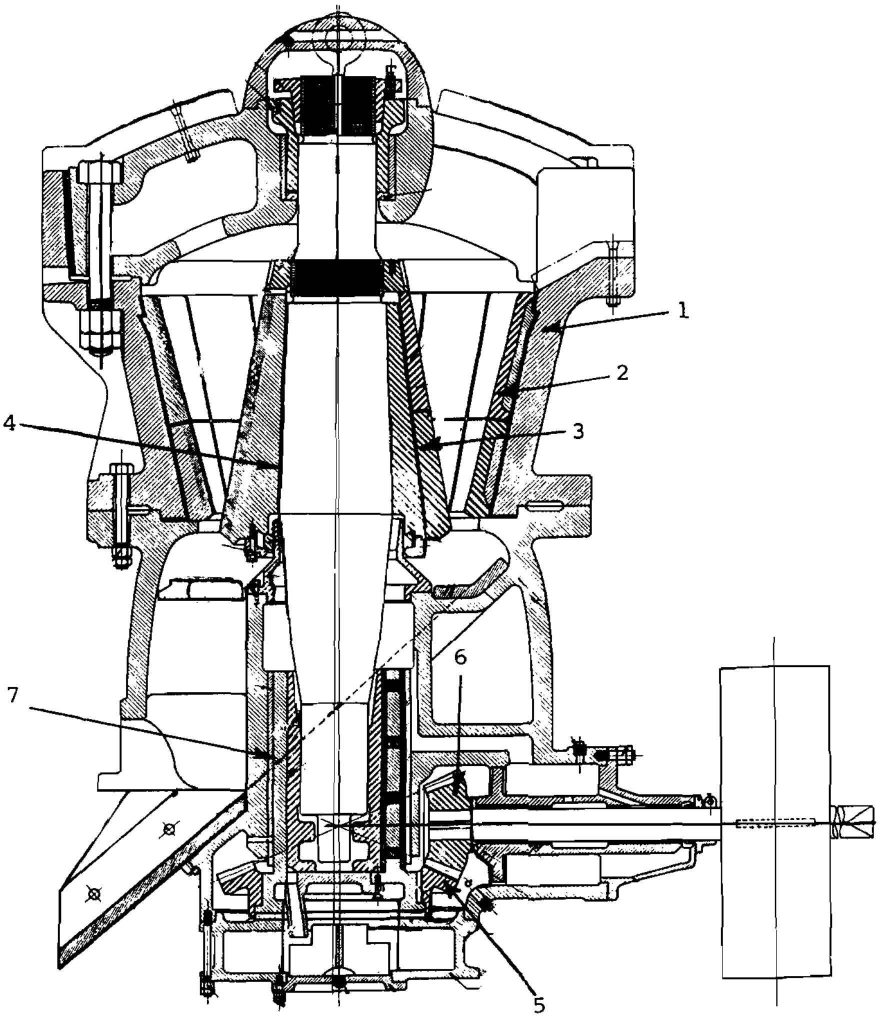

FIG. 22. Sectional view of short-shaft suspended gyratory crusher (courtesy of *Fuller Co.*). Legend: (1) main frame or top shell, (2) concaves, (3) mantle, (4) main shaft, (5) gear, (6) pinion, (7) eccentric.

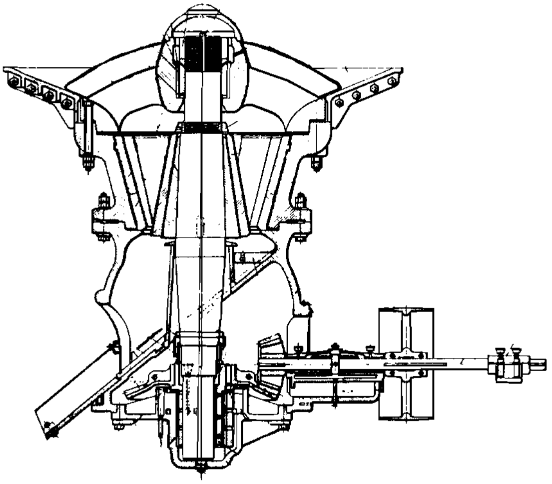

FIG. 23. Sectional view of long-shaft suspended gyratory crusher (courtesy of *Allis-Chalmers*).

When the feed to a gyratory crusher is run-of-mine it is normally referred to as a **primary** crusher. Similar crushers that are used following these units are known as **secondaries.** Two different types of secondary gyratories have been developed based on the crusher product requirements.

The development of concentration and cyanidation in the mining industry called for a finer product than was feasible in the early jaw and gyratory crushers. Manufacturers redesigned their gyratories to reduce the feed opening, decrease the closed-side setting, and increase the gyrations per minute. Examples of this crusher are the Allis-Chalmers Newhouse and Superior McCully Fine Reduction crushers, The Kennedy Van Saun Type "S", and the Traylor Type TF and TY. The Kennedy Van Saun "S" and the A-C Newhouse were known as **gearless** crushers as the drive motors are directly connected to the eccentric. This type of secondary gyratory crusher has been largely superseded by the cone crusher.

Another type of secondary crusher has been developed which follows large primary crushers to produce media for pebble mills. The crushing head and gyrations per minute are the same as those used on equivalent sized primary crushers. However, the concaves and crusher frame or shell are designed for a smaller feed opening and a finer crusher product. These crushers are frequently close-coupled with the larger primaries as at Reserve, Erie, and Eveleth or they may be some distance away as at Twin Buttes.

Over the years the gyratory crusher has developed into a number of forms. Essentially the surviving form of gyratory crusher which is used throughout the mining industry today is the hydraulically supported short-shaft crusher. Occasionally some plant operators will order the older spider-suspended short-shaft gyratory crusher. The following are either obsolete types of gyratory crushers, of which many are still in service, or are older designs with extremely limited capacity: long-shaft spider-suspended gyratory crusher, fixed-shaft gyratory crusher, and short-shaft gearless gyratory crusher.

Principles

The gyratory crusher, whether used as a primary or secondary, is essentially a gravity-type machine. Material flows vertically from top to bottom. It receives a large coarse feed, usually run-of-mine, and its product normally requires additional crushing before producing the final product. The gyratory crusher is a pressure crushing device as is the jaw crusher. The crushing action itself is simple. There is a fixed crushing surface known as the **concaves** which is basically the frustum of an inverted cone. A movable crushing surface called the **mantle,** also conical in shape, gyrates within the interior of the concave cone. As this is a gravity device the material flows from top to bottom.

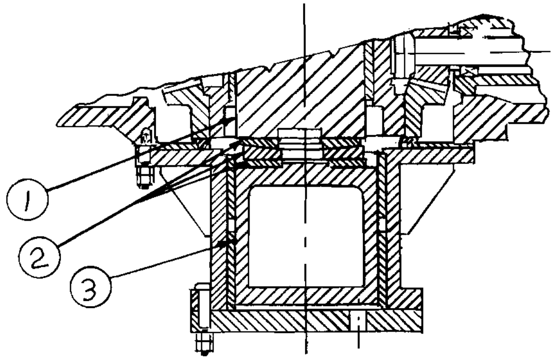

FIG. 24. Sectional view of hydraulic support assembly (courtesy of *Allis-Chalmers*). Legend: (1) main shaft, (2) thrust-bearing assembly, (3) hydraulic piston.

The gyratory crusher has been built in three types known respectively as the **suspended-spindle,** the **supported-spindle** and the **fixed-spindle** type. The second type, with the hydraulic piston as the supporting member, is the most used. These three types all have some common features, the principal ones being as follows. Referring to Fig. 22, the main frame or top shell (1) supports the concaves (2). The mantle (3) is gyrated by the mainshaft (4), which in turn is driven by a gear (5) and pinion (6). The gyrating motion is imparted by the eccentric (7).

There are two suspended-spindle gryatory crusher designs; the **short-shaft** and the **long-shaft** with the short-shaft (Fig. 22) being the modern design. The short-shaft gyratories are distinguished by having the eccentric located above the bevel gear. The main frame has two sections, the upper shell supports the concaves while the lower shell contains the eccentric and the pinion shaft. The bevel gear and pinion provide rotation for the eccentric. The crusher, as shown, is belt driven. The rotation of the mainshaft describes the surface of an acute cone, the apex of which is within the spider. The amplitude of the base is determined by the eccentric. The gyrating motion of the eccentric causes the main shaft, which is free to rotate around its own axis, to rotate slowly in the same direction as the travel of the eccentric when the crusher is empty and in the opposite direction when the crusher is working.

The older long-shaft gyratory crusher which has the gear above the eccentric (Fig. 23) has another difference in that the eccentric bearing is supported by a bottom plate A.

The majority of the current primary gyratory crushers are the hydraulically supported short-shaft type. Instead of being supported by threads at the top of the shaft, the mainshaft is supported by a hydraulic piston. The thrust bearing assembly between the mainshaft and piston is in three pieces: a bronze wearing plate, steel step washer, and bronze step which support the main-shaft assembly weight and absorb the vertical component of the crushing forces. As illustrated in Fig. 24 these are: (1) main shaft, (2) thrust bearing assembly, and (3) hydraulic piston.

The fixed-spindle gyratory (Fig. 25) differs from the other types in that the spindle is rigidly fixed top and bottom and the movement of the crushing head is essentially horizontal with the result that the eccentric throw is the same at the top of the chamber as it is at the bottom. The eccentric is very long and extends practically the entire length of the shaft.

External conditions impose limitations on the design of large crushers. The items affected are the main shaft, spider, and main frames or shells. Forge shops have definite limitations on the size

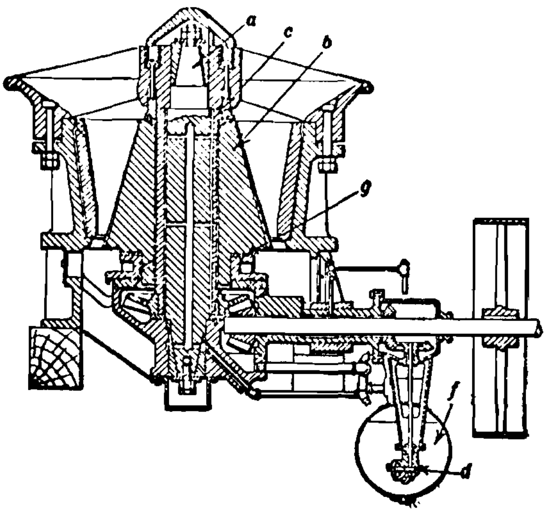

FIG. 25. Sectional view of fixed-spindle gyratory crusher (courtesy of *Barber-Greene*). Legend: (a) shaft, (b) head center or crushing cone, (c) eccentric sleeve, (d) lubrication pump, (f) oil well, (g) mantle.

and weight of forgings that they will handle. Similarly the foundries have limitations on the size of their casting pits and the tonnage of a single pour. Transportation companies have both clearance and weight limitations that determine the maximum dimensions and weight limitations of the principal castings.

The angle of nip in gyratory crushers has definite limitations. In the older straight element crushing chamber, the angle ranges from 20° to 24°. On large primary crushers, using curved or nonchoking concaves and where gravity is of marked aid to nip with the large pieces at the mouth, the angle runs from 25° to 30°.

The parameters used in the basic design of a gyratory crusher are nip angle, feed rate, feed opening, closed-side setting, work index, and horsepower. The combination of the nip angle, feed opening, and closed-side setting determine the length of the crushing chamber and indirectly the length of the main shaft. The crusher manufacturer usually develops a pattern of sizes that determine the relation of feed opening to large-mantle diameter such as 42–65, 54–74 in., etc. with the first number designating feed opening or gape and the last number the mantle diameter. These elements establish the basic design of the crusher including the volume of the crushing chamber. The other three elements are variables within the limitations of the crushing chamber. Once the gyrations per minute have been established, the tons per hour can be calculated. Finally a known or assumed work index determines the required horsepower.

Mechanical Features

General

The majority of gyratory crushers that are currently manufactured are large units, i.e., 42 in. and larger gape, and are of the short shaft type. Generally the units are of the hydraulic supported type although there are specific applications where the spider suspended type is more desirable. The discussion of the mechanical features will be based on this type of crusher. The principal mechanical features are shown in Fig. 26.

The Nordberg short-shaft spider-suspended gyratory crusher with its characteristic shrink tie rods is shown in Fig. 27. It also features a built-in permanent lifting pin as part of the main shaft rather than using a removable eye bolt. The Traylor spider-suspended short-shaft gyratory crusher is shown in Fig. 28. It is also available as a hydraulically supported unit.

Housing

Frames or Shells. The crusher frames or shells of large gyratory crushers are made of cast steel. The original crushers used cast iron frames, a few of which are still used in the smaller crusher sizes. These frames are made in two or more shells depending on the size of the crusher. Available transportation clearances determine the maximum allowable size of these large castings. Special applications require additional sections and in some instances the shells have been split vertically.

Bottom shells have the eccentric bearing hub cast integral with the shell. Most bottom shells are designed for a vertical straight through discharge. Some manufacturers still offer the diaphragm and discharge spout design as an alternative. The hubs and bottom shell sides are normally protected from wear by steel or cast manganese liners. Originally the gyratory crusher only had straight bottom shells. Abrasive material produced excessive wear on the bottom shell so the design was modified to eliminate the impact of material on the bottom shell.

Spider. There are two types of spider designs in current use and both provide the support for the spider bushing. The type manufactured by Allis-Chalmers features a 360° circular rim with the two spider arms cast integral and secured to the upper top shell by a tapered fit and through bolts. This spider is of annealed cast steel. The Traylor spider is of the cast steel bar type. It is of box-section design with a heavy hub in the center. The ends of the arms are tapered and machined to fit into the pockets cast integral with the top shell, bolts at the end pass through the spider and the rim of the top shell, firmly seating and holding the spider in the tapered pockets. The Nordberg design is similar to that of Traylor. There is a tongue and groove fit between the spider and the top shell plus through bolts between the spider and the top shell that absorb the crushing thrust in all directions.

Spider Cap and Arm Shields. The spider cap (7 in Fig. 26) and the spider-arm shields are protective items. The cap is made of cast steel and is designed to withstand the shocks from material dumped into the crusher. The spider arm shields are made of either high carbon or manganese cast steel.

Spider Bearings. Spider bearings differ in detail in different makes of crushers. The same principles are used for either the hydraulic-supported or spider-suspended crushers. Either design transmits the horizontal forces of the main shaft to the spider. In addition the spider bearings of the suspended crusher support the main shaft and transmit vertical mainshaft thrust forces to the spider.

Main Shaft Assembly

The main shaft assembly (Fig. 29) illustrates the current Allis-Chalmers design. It has the following principal component parts: integral main shaft, mantle, head nut, main shaft sleeve, and main shaft step. The main shaft is the lever by means of which the crushing force transmitted through the eccentric bearing is applied to the rock. It must, therefore, be made of great strength and capable of withstanding a continuous succession of shock loads. The Allis-Chalmers shaft is of the integral type that eliminates the head center used by other manufacturers. It is made of forged steel, annealed, and machined outside for mantle fit. The lower end of the shaft is fitted with a bronze polished step bearing. The upper bearing journal is fitted with a replaceable alloy steel sleeve.

The **head center** used by other manufacturers is of low carbon cast steel taper bored to fit the shaft at the bottom and zinced in place. It is carefully turned on the outside to receive the mantle.

The **head nut** is of cast steel and is of the self-lightening type. Where frequent mantle changes are expected, as in the case when crushing abrasive ore, the two-piece head nut is used. Its purpose is to protect the main shaft threads. The inner nut is a shrink fit. The outside diameter of the inner nut is threaded to suit the thread of the outer head nut. Once the inner head nut is assembled to the shaft, there are only two reasons for its removal: (1) if the threads become damaged and (2) if the head center must be removed from the shaft for any reason. (The integral main shaft does not have a

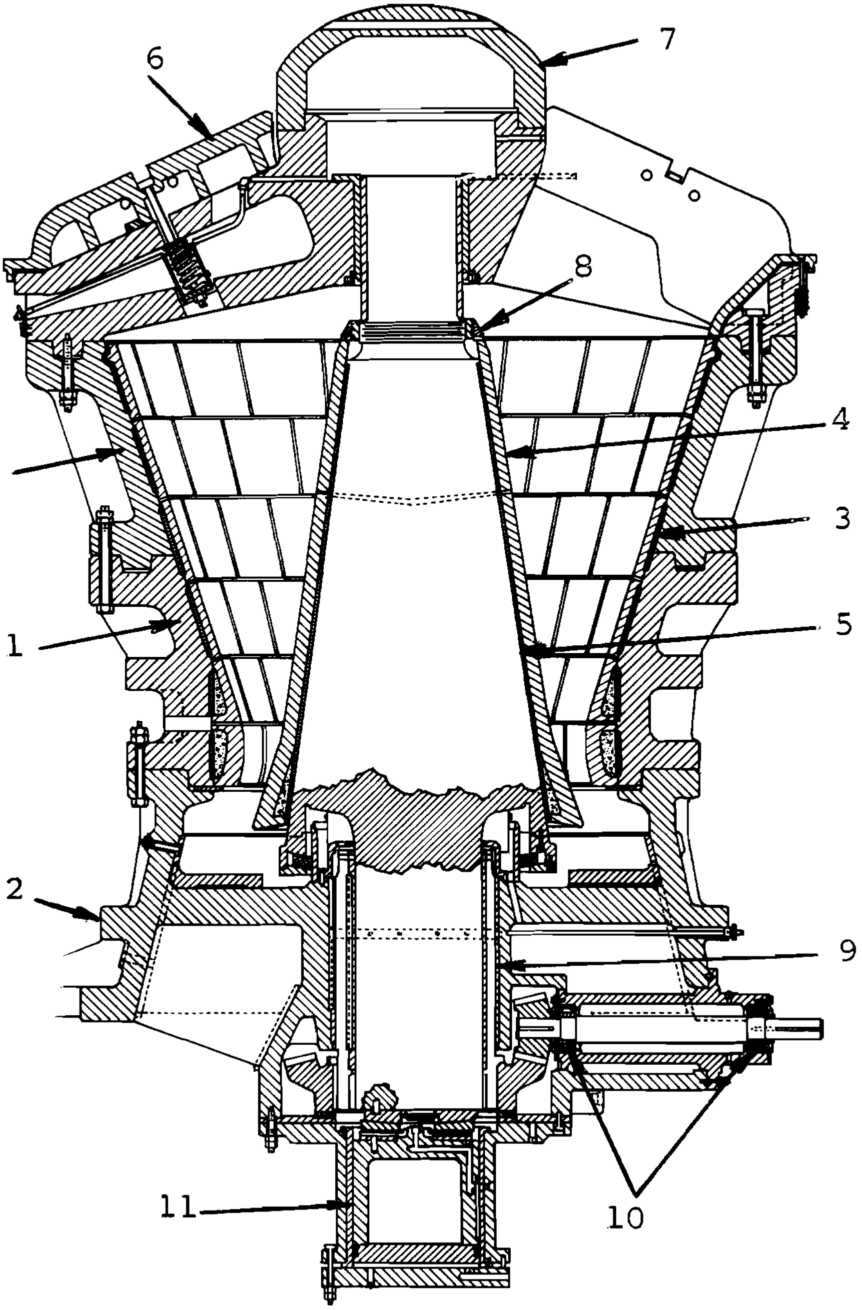

FIG. 26. Sectional view of hydraulic-supported short-shaft gyratory crusher (courtesy of *Allis-Chalmers*). Legend: (1) top shell (large crushers have two-piece top shells), (2) bottom shell, (3) concaves, (4) mantle, (5) main shaft, (6) spider, (7) spider cap, (8) two-piece head nut, (9) eccentric, (10) pinion-shaft bearings, (11) hydraulic-support piston.

head center). The outside diameter of the inner nut is small enough that the mantle will clear it for replacements.

Crushing Chamber

General. The heart of any mechanical crusher is the chamber design. Rock to be crushed is fed into the converging space between the concaves and the mantle (see 3 and 4 in Fig. 26). The concaves are stationary while the mantle or main shaft assembly is caused to gyrate (oscillate in a small circular path) within the crushing chamber, progressively approaching and receding from each element of the stationary concaves. This action of the gyratory crusher is fundamentally a simple one. Many engineering hours and extensive use of the

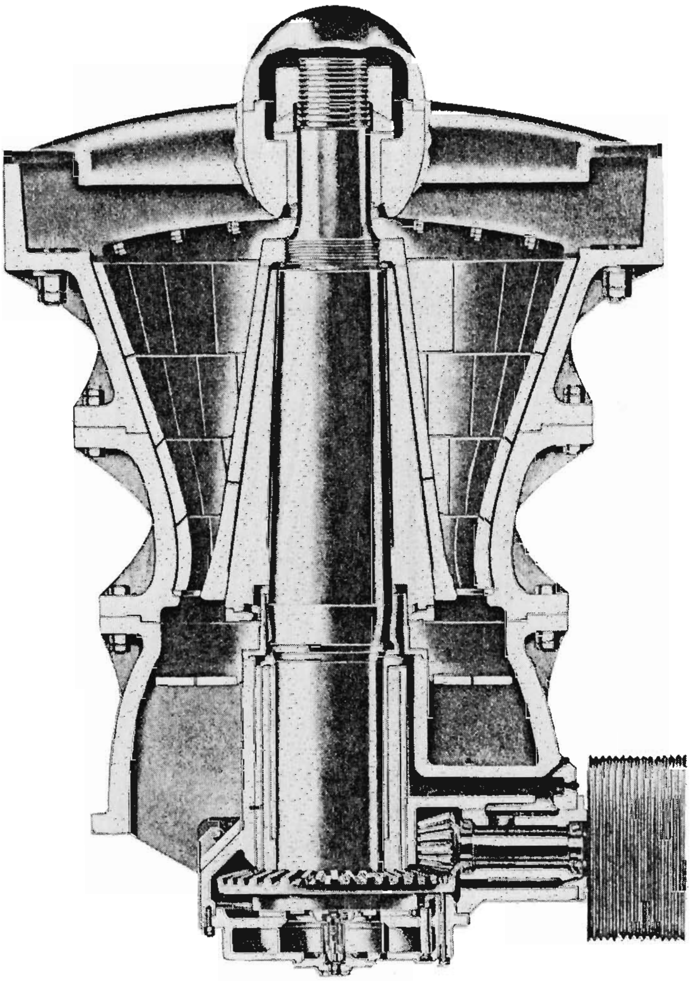

FIG. 28. Traylor Type TC short-shaft suspended gyratory crusher (courtesy of *Fuller Co.*).

computer are involved in the design of a crushing chamber that will provide maximum service life of the mantle and concaves as well as to maintain the setting and capacity of the chamber throughout the useful life of the manganese liners.

Terms. Before proceeding further with this discussion of the crushing chamber it is well to define the important terms to make clear the sense in which they are used throughout this chapter.

Choking means a complete, or practically complete, stoppage of the downward flow of material in the crushing chamber. It may be the result of an external condition, such as a **backup** of material occasioned by an obstruction in the discharge chute, in which case choking is followed by packing in the crushing chamber. Or choking may be the result of a condition existing within the crushing chamber, such as too close a discharge setting, too many fines in the feed, or sticky material. When so caused, packing precedes and brings about the choke up.

The **choke point** in a crushing chamber is that level in the chamber where the capacity of the crusher is a minimum; that is, it is the bottleneck of the crushing chamber. It follows that it is the point where choking is most likely to occur, particularly so if the choke is promoted by a condition existing within the crusher. Note that the existence of a choke point does not imply that choking will necessarily occur; in fact, as will be explained later, all compression-type crushers have a choke point at some level within the crushing chamber.

Ratio-of-Reduction. Precisely, this term refers to the size of the largest cube that the crusher will receive, divided by the size of the largest cube that the crusher will discharge. Actually, we are not dealing with exact cubes when we crush rock or ore; therefore it is more convenient, at least when discussing gyratory crushers, to relate the **ratio-of-reduction** to the screen analyses or estimate of the size of the feed vs. the size of the product. One rule of thumb is to state that the ratio of reduction is F80/P80 where F80 is the square opening that 80% of the feed will pass and P80 is the square opening that 80% of the product will pass.

Fig. 30 shows both the straight and nonchoking types of concaves. These are sections through any vertical, radial plane in a crushing chamber. Essentially all current designs of gyratory crushers are of the nonchoking type.

Crushing Action. In order to understand the crushing action in the chamber of a gyratory crusher, it is helpful to consider the process as though each step took place in an orderly and ideal fashion. It is hardly necessary to add that the action never does take place in just that fashion; nevertheless, the concept is fundamentally a correct one, and the average performance of the crusher follows the

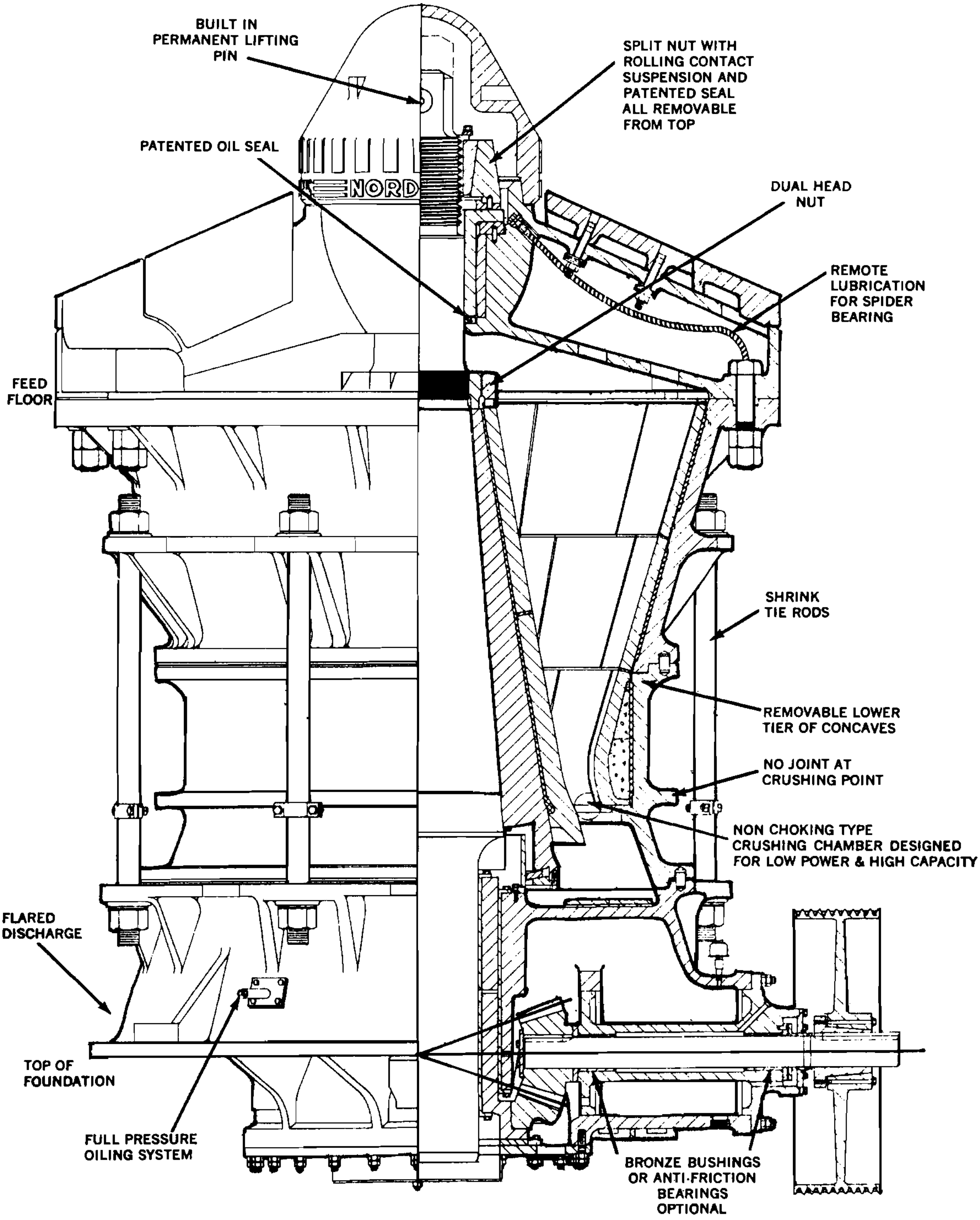

FIG. 27. Spider-suspended short-shaft gyratory crusher (courtesy of *Rexnord*).

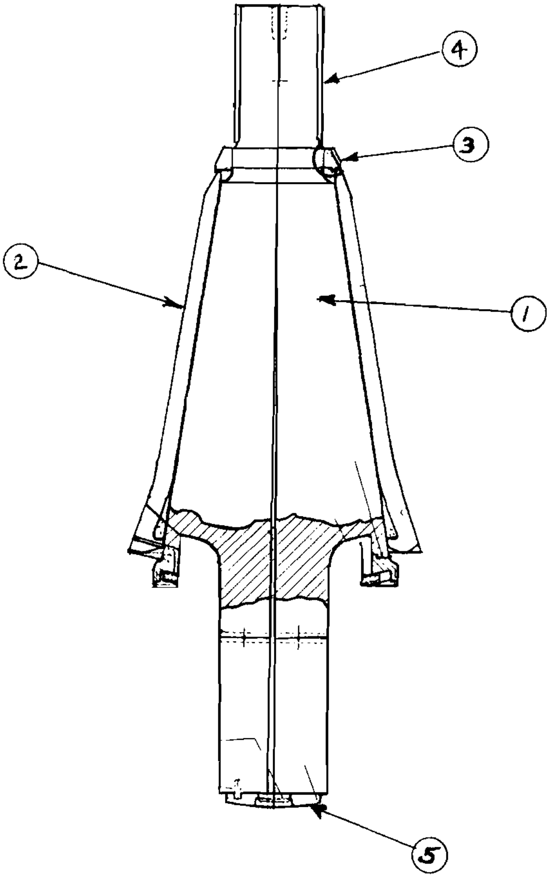

FIG. 29. Main shaft assembly (courtesy of *Allis-Chalmers*). Legend: (1) integral main shaft, (2) mantle, (3) head nut, (4) main shaft sleeve, (5) main shaft step.

pattern so closely that it is possible to predict, within surprisingly close limitations, what any particular design of crusher will do.

Initially visualize the crushing chamber filled with a friable material which will act just the way we want it to, with a head of material (choke feed) above the receiving opening so that no up-surge of load will occur during the closing stroke of the crusher mantle. Now, consider any horizontal plane through this body of material as, for example, the plane at the receiving opening, represented by line 0 in Fig. 29.

Start with the mantle in the close-side position. As the mantle recedes on its opening stroke, the body of material moves downward until, at the end of the stroke, the plane has moved to position 1. Note that the open-side mantle position is the same as that of position 0 from concave to close-side mantle position. On the next closing stroke postion 1 is compressed by the amount of mantle movement at that level, and on the next opening stroke it moves down to position 2 and so on through the chamber until it becomes short enough to pass through the open-side discharge setting.

Visualize this process as being the movement of the trapezoidal areas enclosed by each adjacent pair of horizontal lines and the two crushing faces. Better still, consider it as a movement of annular volumes whose cross-sections are the areas just mentioned. This later conception is essential in visualizing the action of nonchoking concaves and flared crushing chambers.

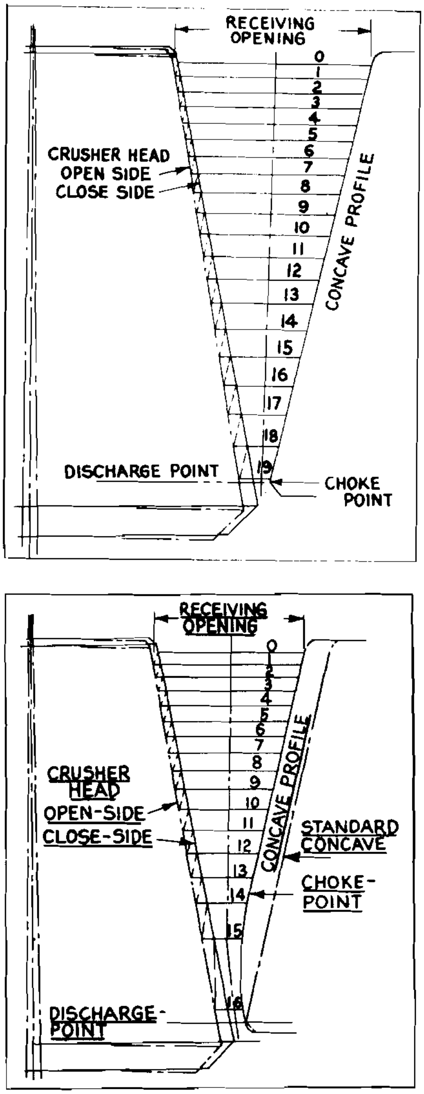

FIG. 30. Straight vs. nonchoking concaves (courtesy of *Allis-Chalmers*).

In the straight concave diagram of Fig. 29, the broken line through the center of the crushing chamber is the line of mean diameters of the compact areas. When the profiles of both crushing faces are straight lines, as is the case with straight concaves, this mean diameter line is also straight, and its slope depends upon the relative tapers of the mantle and concaves.

It is apparent that although the distance between successive horizontal planes increases gradually as these planes move downward (due to the increase throw of the mantle), the areas and hence the volumes, successively **decrease**. If we conceive the volume 0–1 as consisting of a mixture of rock and air, that is, containing a certain percentage of voids, then it is evident that when this volume has moved to positions 18–19, the percentage of these voids will be considerably diminished. If it should happen that the voids have reached such a low proportion when the material drops from 17 to 18 and

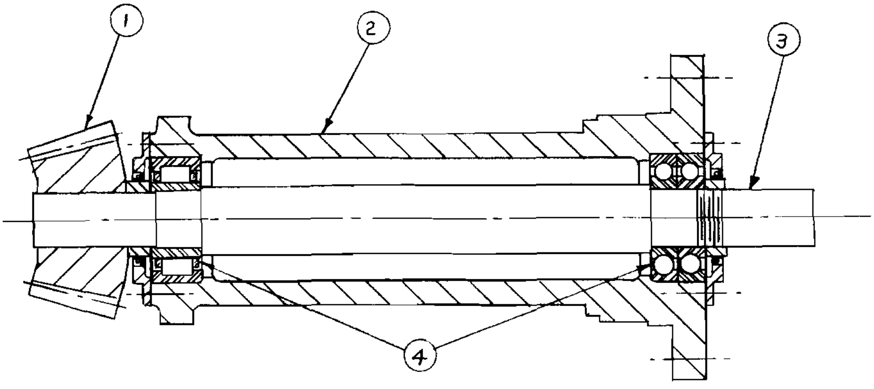

FIG. 31. Pinion-shaft assembly (courtesy of *Allis-Chalmers*).

18 to 19, that the closing stroke on 18–19 completely eliminates all voids, we have a choked condition at that point. Such a condition is untenable because downward movement of the material ceases, and the crusher either stalls or fails at some point.

It is apparent that the choke point in the straight concave crushing chamber discussed previously is at the discharge level, or immediately above it. It is equally clear that the unit pressures in such a chamber increase progressively from the top down, reaching the maximum value at the choke point, where the voids are at a minimum. It follows that the amount of wear on the mantle and concaves must increase progressively toward the lower part of the chamber. As a matter of fact, when the crusher setting and other conditions are such that the machine is operating at anything approaching a choking condition, wear is very rapid in the region of the discharge point, as compared to the rest of the chamber, so much that a **ski-slide** condition arises and is likely to progress to a troublesome degree.

Nonchoking Concaves. The nonchoking concave diagram shown in Fig. 29 has been arranged so that it has the same discharge setting as the straight concaves even though a closer setting is normally permissable with the nonchoking concave design.

The eccentric throw is considered the same for both chambers. The concaves in the upper portion of the chamber parallel those of the straight concave design. Successive drops of material in the upper portion of the chamber are similar. This is true to line 13 of the nonchoking concave chamber. Then we note a difference in the diagram; the drop per stroke increases much more rapidly than in the case of the straight concaves until at stroke 16 the line has arrived at discharge level. The choke point has been raised to 13–14 instead of being at the discharge level. From the choke point on down to the discharge level, each successive volume is greater than volume 13–14, and greater than the volume immediately preceeding. Therefore, the shape of the crushing chamber in the zone below the choke point is favorable to choke free operation.

It should be made clear at this point that even though the design is called **nonchoking** it does not afford absolute insurance against choking inasmuch as a choke point exists in the crushing chamber. The description of this chamber as nonchoking is perhaps slightly misleading even though the danger of choking is minimized.

The **ratio-of-volume** reduction between volumes 0–1 and 18–19 in the straight concave chamber is obviously greater than the ratio between volumes 0–1 and 13–14 in the nonchoking chamber. Actually the ratio in the former case is about 4:1 and in the later about 1.75:1. Therefore, if we assume an equal percentage of voids in the feed for both cases, it is apparent that the nonchoking design will not, when the choke point is reached, have compacted the material to as low a percentage of voids as the straight concave design. Also the actual volume of 18–19 in the straight concave chamber is substantially smaller than that of volume 13–14 in the nonchoking chamber. Inasmuch as these volumes pass the choke point in the same time period, the capacity through 13–14 zone is obviously the greater of the two.

The nonchoking chamber design is the preferred design for most crushing installations for the following reasons:

1) The nonchoking concave chamber permits the use of smaller discharge settings in any given size of crusher.

2) Capacities are considerably higher, particularly so in the range of finer settings.

3) The wear of the mantle and concaves is more evenly distributed in the lower part of the crushing chamber.

4) The crusher product is more uniform and will generally contain less fine material.

5) Power requirements are very definitely in favor of the nonchoking chamber design.

Drive Mechanism

Pinion-Shaft Assembly. Fig. 31 represents a typical pinion-shaft assembly. The alloy or high carbon steel pinion (1) with straight or spiral teeth is mounted on the turned steel shaft (3). The pinion-shaft bearings (4) are normally of the anti-friction type as shown. One manufacturer offers bronze bushings as an optional item. The pinion-shaft housing (2) is designed so that the assembly can be removed from the crusher without dismantling.

Eccentric Assembly. The eccentric assembly is shown in Fig. 32. The crushing force is transmitted through the eccentric to the main shaft. Crushing forces are high, thus requiring a large bearing area. The eccentric (1) is of annealed cast steel and is fitted with an inner wearing sleeve (2). The eccentric turns in a bronze bottom shell bushing (3). The eccentric gear (4) is of high carbon or alloy steel with machine cut teeth. The gear teeth are of either the straight or spiral type.

Lubrication

Efficient lubrication systems are the key to trouble free gyratory crusher operation. Bearings and gears must receive an adequate supply of clean lubricants at the proper viscosity and operating temperature. Items that require lubrication on current gyratory crushers are the following: (1) spider bearing, (2) eccentric bearing, (3) gear and pinion, and (4) pinion-shaft bearings.

Spider Bearings. Spider bearings are normally independently manually lubricated. The lubricant can be grease or oil. Automatic spider lubrication systems are available with their installation generally restricted to large mining installations.

Eccentric and Gear. This is the principal lubrication system in a gyratory crusher. The favored system is an external one which has two distinct advantages:

1) The oil is filtered while hot, cooled, and supplied to the crusher in adequate amounts to insure proper lubrication of all working surfaces in the bottom shell.

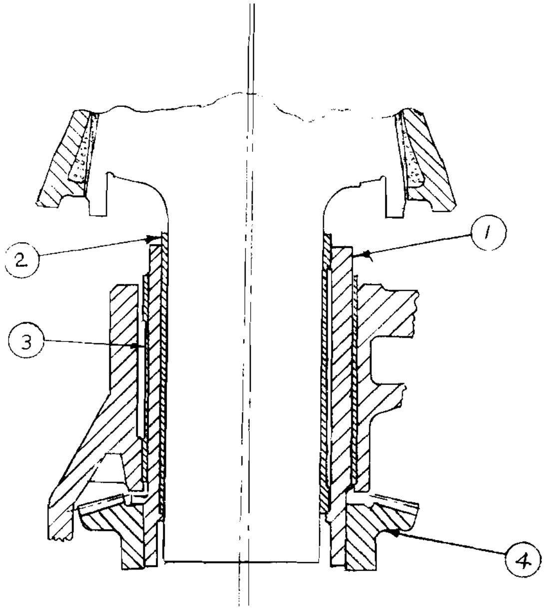

FIG. 32. Eccentric assembly (courtesy of *Allis-Chalmers*). Legend: (1) eccentric, (2) inner wearing sleeve, (3) bronze bottom shell brushing, (4) eccentric gear.

2) When maintenance and repair become necessary on the lubrication system, the components are readily accessible without the removal of any crusher part.

Fig. 33 illustrates a typical external lubrication system. In this system oil is pumped from the storage tank (1) by a motor-driven gear pump (2); then filtered by a full pressure filter (3); cooled in a water-to-oil cooler (4); and then delivered to the split-flow crusher supply lines (Fig. 34). An alternate method of cooling is to use a radiator-type air-to-coil cooler equipped with a motor driven fan.

The split flow oil system operates as follows: The upper inlet supplies oil to the bottom shell bushing, the eccentric, and to the spiral bevel gear. The oil in the lower inlet enters the crusher at the hydraulic cylinder and flows upward between the main shaft and the bore of the eccentric sleeve. A portion of this oil flows through radial holes in the eccentrics and join the oil that entered through the upper inlet. The balance overflows through return oil holes.

Pinion-Shaft Bearings. Two methods are used to lubricate the pinion-shaft bearings. One system uses a third split flow line. This oil enters the pinion-shaft bearing chamber through the passage provided. It cannot escape from this chamber to return to the reservoir except through the pinion-shaft bearings which are, therefore, continually working in oil. The other method is self-contained and pool lubricated. This latter system is used only with anti-friction bearings which operate best with only small quantities of lubrication oil.

Manufacturers' Information

General

Four tables have been prepared from manufacturers' catalogs. Table 14 covers the short shaft gyratory crushers, which design is now used almost exclusively for primary crusher applications in the size ranges shown. The long-shaft and fixed-spindle crushers shown in Tables 15 and 16 are no longer manufactured. There are, however, a large number of these crushers still in use. Table 17 presents the data for the fine-reduction gyratory crushers, the application of which is also accomplished by the cone crushers.

Sizes and Capacities

Size. Except for Table 15, the size designation of the gyratory crusher represents the feed opening and the maximum diameter of the head. For example in Fig. 35 the crusher has a 42-in. receiving opening and a 65-in. maximum diam crushing head.

Speed. The pinion rpm shown in the tables is the speed normally recommended by the manufacturer. The speed shown can be increased or decreased slightly subject to the limitations established by the specific manufacturer.

Motor Horsepower. Except for Table 14 the motor horsepower shown is an average. The horsepower of Table 14 is the design horsepower or the maximum connected horsepower that can be used with a specific crusher.

Capacities. The following comments apply to the capacities shown in Table 14: Allis-Chalmers, "Capacities shown are based on a clean, dry, friable feed of ore or stone weighing 100 pcf and containing a minimum quantity of fines;" Rexnord, "Crusher capacities are based on average operating conditions and when handling a free running, dry, friable material weighing 100 pcf (crushed)."

Application

General

The majority of gyratory crushers are used as primaries, i.e. they receive the initial feed from the mine or quarry. The same type of crusher with chamber modifications is used as a secondary crusher, particularly when following a large primary crusher. The fine-reduction gyratory crusher can also be used for tertiary crushing. The cone crusher has largely replaced the gyratory for secondary and tertiary applications.

There are two parameters used to determine the size of a primary crusher, namely the size of the feed and the tons per hour capacity. The feed opening of a gyratory crusher has two designated dimensions, A and B, as shown in Fig. 36. The largest dimension of the feed should be less than the A dimension in order to prevent bridging as there is no way to predict how the rock will enter the crushing chamber. A good rule of thumb to follow is that 80% of the feed to the crusher should have a maximum one-way dimension that is less than two-thirds of the nominal feed opening or A dimension.

Feed Arrangements

Primary gyratory crushers may be either direct fed or the fines are removed by scalping ahead of the crusher. Whenever there is a large quantity of fines in the original feed, scalping should be given serious consideration. The type of quarry haul equipment affects the efficiency of scalping. Side-dump rail cars and trucks dump their material onto the grizzly with a minimum of bed depth. On the other hand, the large 50-ton-plus end-dump trucks have relatively small width to height ratio so that scalping is not normally efficient due to the great bed depth and short retention time involved when the material passes over the grizzly. The grizzly openings should be selected to avoid a concentration of near size particles which will quickly plug up the openings.

While it is true that direct feeding is used with large end-dump quarry haul trucks, there are other situations that also make this method desirable: (1) when the ore breaks blocky with a minimum of fines and general retention of smaller pieces with the oversize, (2) when cut-off from one type of ore to another has to be quick and clean (for example, a change from sulfide flotation to oxide leach ore). Structural circumstance and capital costs may dictate the use of the more economical direct feeding method.

Whenever crushers are directly fed by trucks or trains, the plant layout should provide an adequate impact area or stone box so that the larger pieces of stone do not discharge directly onto the spider cap or arms. The impact of these large pieces falling directly on the body of the crusher creates numerous problems that reduce the overall service life of the crusher. When falling on the spider and spider cap, they accelerate the wear on these items and produce shock stresses on the spider and eccentric bearings. Heavy impact stresses

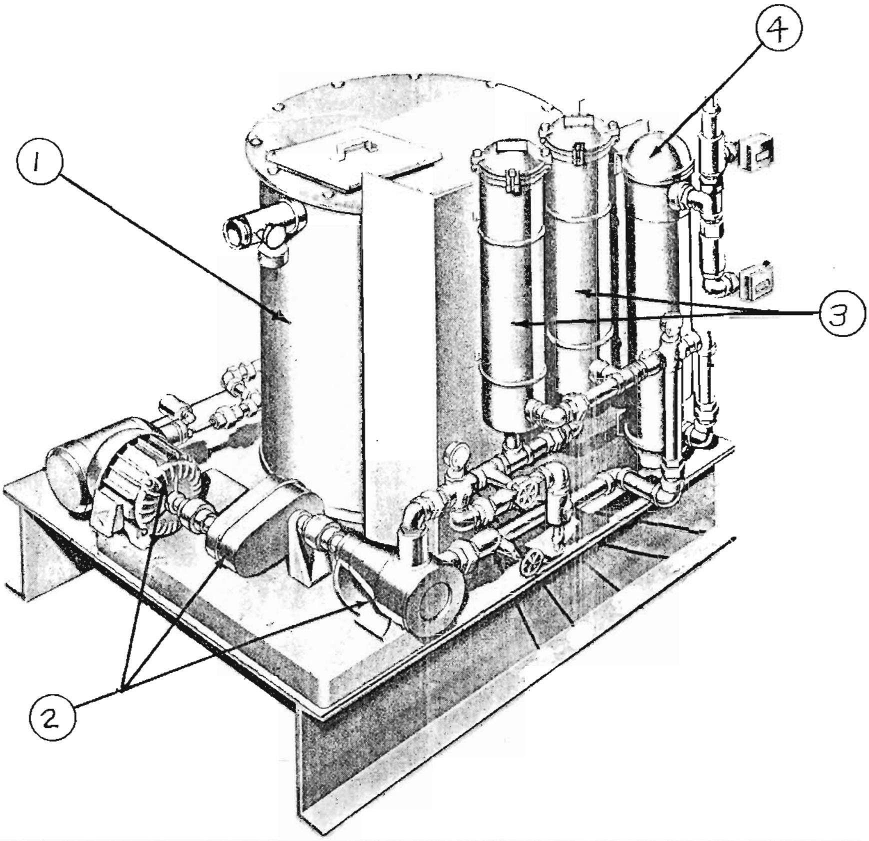

FIG. 33. External lubrication system (courtesy of *Allis-Chalmers*). Legend: (1) storage tank, (2) motor-driven gear pump, (3) pressure filter, (4) water-to-oil cooler.

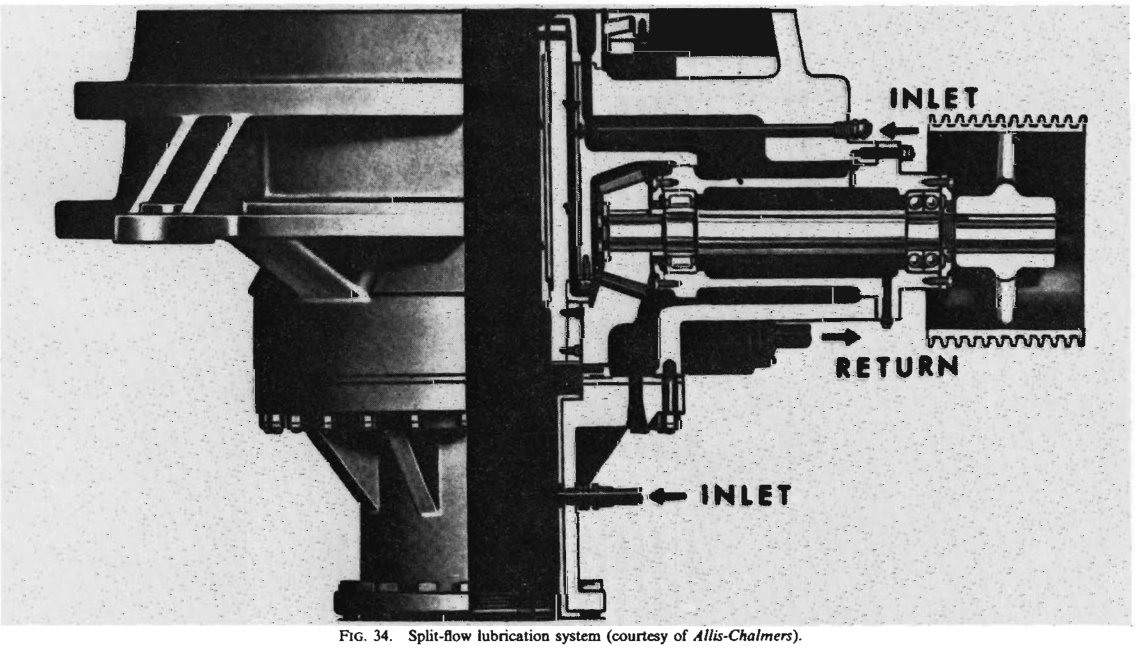

FIG. 34. Split-flow lubrication system (courtesy of *Allis-Chalmers*).

Table 14. Data on Short-Shaft Gyratory Crushers Selected from Manufacturers' Catalogs

Make	Size	Approx. shipping weight in lb	Pinion rpm	Motor hp	Approximate capacity tons (2,000 lb) per hr at discharge openings shown for material weighing 100 lb per cu ft																				
					Open side setting of discharge opening in in.																				
					2	2½	3	3½	4	4½	5	5½	6	6½	7	7½	8	8½	9	9½	10	10½	11	11½	12
Traylor (Fuller)	30–60	200,000	425	200	345	420	495	560	625		765		910												
Allis-Chalmers	30–55	148,000	600	300		420	510	570	650	730	810	900													
Traylor (Fuller)	36–60	280,000	375	250		505	595	665	750		915		1070		1220										
Allis-Chalmers	36–55	163,000	600	300					600	680	760	850													
Traylor (Fuller)	42–66	315,000	375	250			675	770	860		1045		1220		1395		1550								
Allis-Chalmers	42–65	266,500	514	400						880	1000	1120	1250	1450	1650										
Nordberg (Rexnord)	42–70	251,800	380	300							780	870	950	1040	1120	1200									
Traylor (Fuller)	48–70	500,000	340	350				945	1050		1380		1500		1710		1910		2100						
Allis-Chalmers	48–74	504,000	514	500							1700	1850	2000	2150	2300	2500	2700								
Nordberg (Rexnord)	48–80	489,000	330	500									1515	1610	1720	1830	1940	2060							
Traylor (Fuller)	54–74	600,000	340	400					1250		1520		1790		2015		2250		2500		2700				
Allis-Chalmers	54–74	534,000	514	500								1800	1950	2100	2250	2400	2550								
Nordberg (Rexnord)	54–80	525,000	330	500									1440	1535	1640	1740	1850	1950							
Traylor (Fuller)	60–89	800,000	300	500							2150		2500		2925		3200		3450		3800		4100		
Allis-Chalmers	60–89	881,000	514	600									2500	2670	2840	3100	3260	3430	3600						
Traylor (Fuller)	72–90	980,000	300	700									2600		3050		3350		3600		4000		4300		
Nordberg (Rexnord)	60–102	1,200,000	300	800													2800	3040	3275		3740		4215		4685
Allis-Chalmers	60–109	1,277,000	450	1000														4300	4620	4940	5260	5580	5900	6250	6600
Traylor (Fuller)	84–110	1,300,000	275	1000											3500		3875		4250		4625		5000		

Table 15. Data on Long-Shaft Suspended-Spindle Gyratory Crushers, from Manufacturers' Catalogues

Old No.*	Size of receiving opening, in.	Approximate hourly capacities† to open settings stated, in. — Minimum Size	Minimum Tons	Maximum Size	Maximum Tons	Weight, lb, avg.	Rpm	Installed hp, avg.	Fall through crusher, ft-in.
0	2½ × 28	⅜	0.6	. . .	. . .	1,000	700	3	1–7
1	5 × 50	1	5	1¾	8	7,000	600	5	4–9
2	6 × 50	1	6.5	1¾	10	10,250	500	8	5–4
3	7 × 56	1¼	11	2½	20	17,000	475	12.5	5–10
4	8 × 68	1½	20	3½	48	23,000	450	16	6–9
5	10 × 80	1¾	30	3	60	37,000	400	25	7–10
6	12 × 88	2	50	4½	120	48,000	375	35	8–9
7½	14 × 104	2½	80	4	120	68,000	350	62	9–6
8	19 × 138	3	125	5	295	106,000	375	82	11–9
21	21 × 152	3	160	5	300	160,000	325	125	13–6
24	24 × 168	3½	210	5½	370	175,000	350	138	14–5
26	26 × 200	4	310	5½	450	143,000	340	200	14–10
36	36 × 272	4½	550	7	940	405,000	300	240	18–1
42	42 × 272	5½	700	9	1,300	425,000	300	255	—
48	48 × 332	5½	1,158	9	1,900	470,000	275	300	21–9
60	60 × 420	7	1,678	10	2,400	750,000	220	350	29–3
72	72 × 484	9	2,572	12	3,432	1,000,000	175	400	34–7

* Modern practice numbers the crusher by inches gape.

† Based on run-of-quarry limestone scalped to the open setting stated; crushers fitted with straight-element mantles and concaves.

Table 16. Data on Fixed-Spindle Gyratory Crushers from Manufacturer's Catalog

Size	Size of receiving opening, in.	Approx. shipping wt. in lb	Pinion	Avg. Motor	Approximate capacity tons (2,000 lb) per hr at discharge openings shown for materials weighing 100 lb per cu ft* — Open side setting of discharge openings in in. — 1¼	1½	1¾	2	2½	3	3½	4
8B	8 × 82	12,500	750	22.5	32	35	38					
10B	10 × 102	19,000	700	27.5		40	46	54				
13B	13 × 118	29,000	560	45				75	85	95		
16B	16 × 148	44,500	500	67.5					128	140	153	
20B	20 × 176	62,500	440	87.5						210	235	348
25B	25 × 212	108,000	480	112.5							265	383

* The capacities shown are based on crushing clean, friable limestone.

at the top of the crushing chamber increase manganese expansion which can knock out concaves and seriously damage the mantle. Regardless of whether the feed is run-of-mine or scalped the material should enter the chamber over the spider arms to distribute the feed evenly throughout the crushing chamber and the chamber choke fed as that is the most efficient method of operating a gyratory crusher.

Fig. 37 shows one method of providing a spider rim seal between the crusher and the foundation. There is always some movement or vibration of the crusher during operation. In addition, space must be provided for removal of the spider. The rim seal is installed to keep the fine material from falling through this opening. The leveling bar merely rests upon the spider rim.

Power Draw

The power draw or horsepower used by a crusher is essentially a measurement of the work done on the stone by the crusher. Essentially what we are saying is that it requires a certain amount of power to reduce a quantity of stone from a large size to a smaller size.

Table 17. Data on Fine-Reduction Gyratory Crushers from Manufacturer's Catalog

Size	Approx. shipping weight in lb	Pinion rpm	Avg. Motor hp	Approximate capacity tons (2,000 lb) per hr at discharge openings shown for material weighing 100 lb per cu ft* — Closed side setting of discharge opening in in. — ⅜	½	⅝	¾	⅞	1	1⅛	1¼
5–36	25,000	695	100	35	49	63	81	79	85		
7–36	25,000	695	100		73	80	88	96	104	112	116
8–48	55,000	575	150		84	92	100	110	120	129	138
17–48	55,000	575	150			113	121	130	139	145	152
10–66	145,000	490	250			200	227	258	298	332	367
16–66	145,000	490	250				250	280	312	345	380

* The capacities shown are the maximum specified by the manufacturer and are for mixed feeds up to 50% of the feed opening. Capacities, particularly at fine setting, will vary with hardness and toughness of the material crushed.

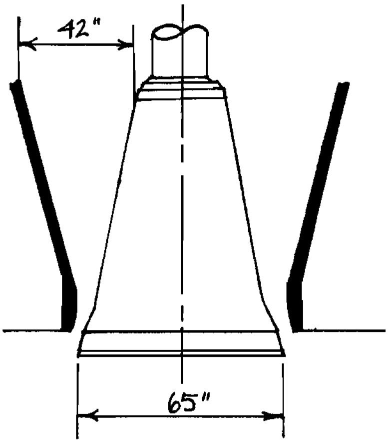

FIG. 35. Size designation of gyratory crushers.

The power requirement will vary depending on the characteristics of the stone. However, it is independent of the method of crushing. In other words, two equally efficient crushers receiving identical feed and producing an identical product at the same rate (tph) will draw the same horsepower. It is true that machine efficiency affects the total horsepower draw of a crusher. However, the work done on the stone itself will be the same regardless of the method of crushing.

Horsepower Calculations. For many years, there was no generally accepted method of predetermining the power required for a given crusher application. There was little or no factual data available as a guide. Now the Bond crusher Work-Index equation[11] is the generally accepted method used for calculating crusher horsepower. To calculate the approximate horsepower to crush material with a known work index, we have the equations:

$$(\text{hp/ton}) = \frac{\text{Wi}\,(13.4)(\sqrt{F} - \sqrt{P})}{(\sqrt{F})(\sqrt{P})} \qquad (1)$$

and

$$(\text{Total hp}) = (\text{Crusher capacity})\,(\text{hp/ton})\,(\text{factor}) \qquad (2)$$

where Wi = Bond crushing Work Index, kw-hr per ton; F = feed 80% passing size, μm; P = product 80% passing size, μm; crusher capacity = desired crushing rate, tph; and factor = 0.75 for primary crusher applications, 1.0 for secondary crusher applications (adjustment to horsepower calculations based on field experience).

As a typical example assume that a proposed copper ore mining facility has a design capacity of 1,550 tph with a Work Index of 19.4 kw-hr per ton. The primary crusher is a 54-in. gyratory designed to operate at 6-in. open-side setting. Feed will be direct from quarry haul trucks (use F equal to 36 in. or 914,400 μm based on an assumption that 80% of the feed is two-thirds of the feed opening). The desired product size is such that P is 5½ in. or 139,700 μm. Then using Eqs. 1 and 2 gives:

$$(\text{hp/ton}) = \frac{19.4(13.4)(\sqrt{914{,}400} - \sqrt{139{,}700})}{(\sqrt{914{,}400})(\sqrt{139{,}700})} = 0.423$$

and

$$(\text{Total hp}) = (1{,}550)(0.423)(0.75) = 492 \text{ hp}.$$

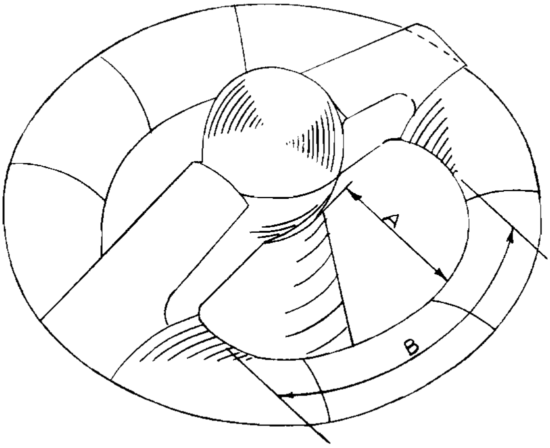

FIG. 36. Typical gyratory crusher feed openings.

Crusher size	Dimensions A, in.	 B, in
42–65	42	153
60–89	60	210

Throw and Speed

The combination of eccentric throw, gyrations per minute of the crushing head, and the design horsepower are interrelated and affect the capacity of a crusher. Over the years crusher manufacturers have standardized the characteristics of gyratory crushers so that for most crusher applications each crusher size has a single recommended throw and speed.

Eccentric throw is an important element as it determines the distance in the equation that work equals force times distance. For a given drive horsepower and pinion-shaft speed the smaller the eccentric throw, the more crushing force can be applied before stalling the crusher. Increasing the throw increases the capacity. When the speed is fixed the power will go up when the throw is increased as more work is required due to the increase in volumetric capacity. When gyratory crushers are selected on the basis of feed opening with relatively low tonnage requirements smaller than standard eccentric throws are used with a corresponding reduction in connected horsepower. The eccentric throw is adjustable by changing the eccentric sleeves.

As can be seen in Table 14 manufacturers have established standard speeds for the various sizes of gyratory crushers. Increasing the speed may either increase or decrease the capacity of the crushing chamber. As the crushed material progresses through the chamber with each gyration of the mantle, increasing the gyrations per minute will have the effect of increasing the capacity of the chamber up to the point where the time interval becomes the determining factor as far as the gravitational zone height is concerned. After this increasing the speed has the effect of decreasing the chamber capacity.

Nip Angle

Early gyratory crushers with straight-element crushing surfaces used nip angles of from 21° to 24° with an average near 22°. In present gyratory crushers where gravity is of marked aid to nip with the large pieces at the mouth, and with curved surfaces, the angle of nip ranges from 25° to 30°. In general, all other items being equal, the steeper the nip angle the greater the volumetric capacity of the crusher.

Drives

Gyratory crushers are driven by V-belts or direct connected. Drives under 300 hp are generally V-belt driven; 300 and 400 hp drives use either method with the present preference being to direct connect which provides less load on the pinion shaft and motor bearings as well as eliminating the adjustment of V-belts which is time-consuming on the large motors. Direct drives frequently include a floating shaft between the pinion-shaft and motor called a **jack shaft**

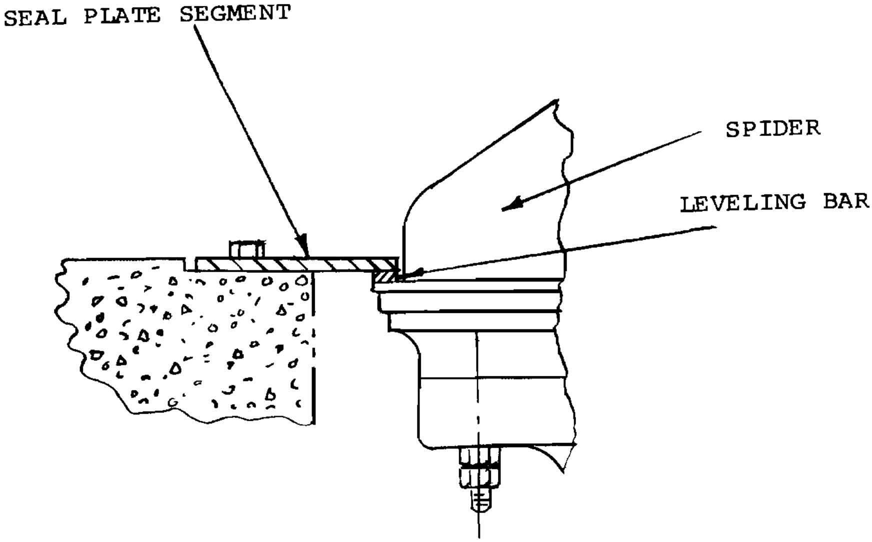

FIG. 37. Spider rim seal (courtesy of *Allis-Chalmers*).

to permit removal of the pinion-shaft housing assembly without removing the motor. Controlled torque couplings with zero-speed switches are optional items used on the larger crushers to protect the motor from severe surge loads such as large pieces of tramp iron in the crushing chamber.

Motors

It is recommended that the motors for gyratory crushers have 180% starting and 250% breakdown torque. When the crushing chamber is empty 100% starting torque is adequate. However, with the general adoption of the hydraulic-supported crushing head, a stalled crusher many times can be cleared by lowering the head and utilizing the 180% starting torque to restart the crusher. The 250% breakdown torque is to take care of intermittent peak power demand due to surge loads or unexpected hard material. Either a 1.0 or a 1.15 service factor can be specified. When the horsepower calculations indicate that the power draw is close to the rated motor horsepower then the 1.15 service factor should be specified.

Wound-rotor motors are generally specified for primary gyratory crushers because of their inherent high starting torque characteristics. The squirrel cage induction motor can be used if it has the specified starting and breakdown torques. Unless reduced voltage starters are used, the high starting inrush required by the squirrel cage induction motor may not be acceptable to the power company.

Crusher Product Disposition

Under Crusher Hopper. The crusher foundation should be designed so that there is adequate storage space underneath to clear the crusher chamber in the event the under crusher conveyor is shut down while the crushing chamber is full. A good rule-of-thumb is to provide space for at least two truckloads, as one truck may be dumping when the chamber is relatively full.

Both high- and low-level bin-level indicators are usually installed in the under crusher hopper. The high-level indicator is to prevent backup of crushed material into the body of the crusher while the low-level indicator is to keep the hopper from emptying so there is always a bed of material to protect the surface of the hopper discharge feeder.

Bin Discharge Feeders. It is possible to use a gravity discharge from under the crusher hopper to the primary conveying belt. This method is not considered practical for large crusher installations. Generally most facilities utilize a controlled rate discharge. Apron, belt, or vibrating feeders are used and the vibrating feeder may be of either the mechanical or electromagnetic type. The rate of discharge is regulated by varying the speed of the unit. Any of these types, when properly applied, operate satisfactorily.

Discharge Arrangements. Most primary gyratory crusher installations have capacities considerably greater than the remainder of the plant. This situation plus the possibility of shut down in the quarry make the inclusion of a stockpile immediately after the primary crusher desirable. The stockpile permits operation of the primary crusher less hours per day than the remainder of the plant.

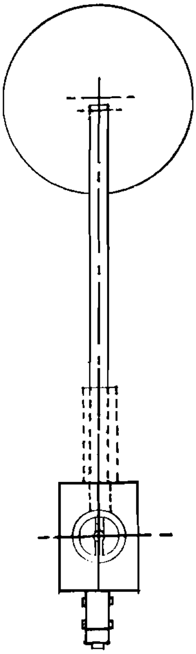

FIG. 38. Feed and discharge arrangement, single-truck discharge.

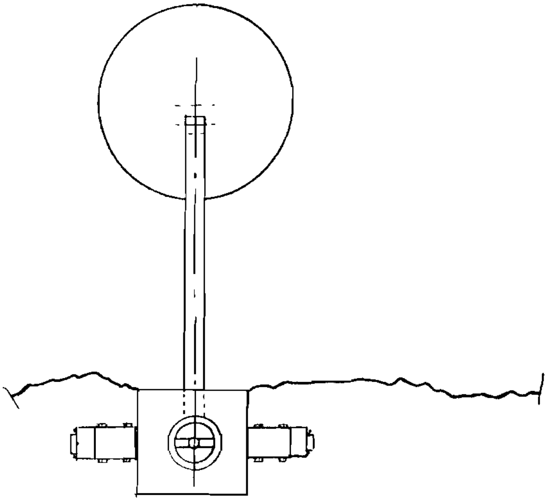

FIG. 39. Feed and discharge arrangement, two-truck discharge.

Primary crusher installations have many different arrangements determined by the topography of the area, the number of units involved, requirements for stockpiling two or more types of ore, and the type and capacity of the quarry or mine haul equipment.

The following plant layouts (Figs. 38 thru 41) are examples of some of the feed and discharge arrangements. All are based on the utilization of primary surge capacity or a stockpile. Fig. 38 uses a single-truck discharge with the dump axis (line through truck and crusher) parallel to discharge conveyor. It is a simple arrangement that permits the location of the pinion shaft and the opening in the crusher product hopper for removal of eccentric to be at right angles to the dump axis. Fig. 39 is a two-truck discharge arrangement with the dump axis at right angles to the discharge conveyor. This arrangement is frequently used when the discharge conveyor is at the quarry floor and the crusher is recessed into the face of the quarry. Fig. 40 is also a two-truck discharge arrangement with the dump axis at right angles to the discharge conveyors. It features two stockpiles with a shuttle transfer conveyor which is used when separate classification is required for two types or grades of ore. Fig. 41 has the dump axis parallel to the conveyors and features side-dump rail cars with a fixed grizzly ahead of the crusher.

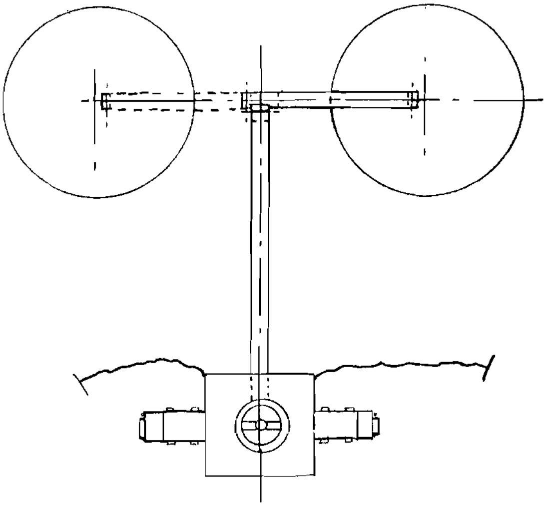

FIG. 40. Feed and discharge arrangement, two-truck discharge and two stockpiles.

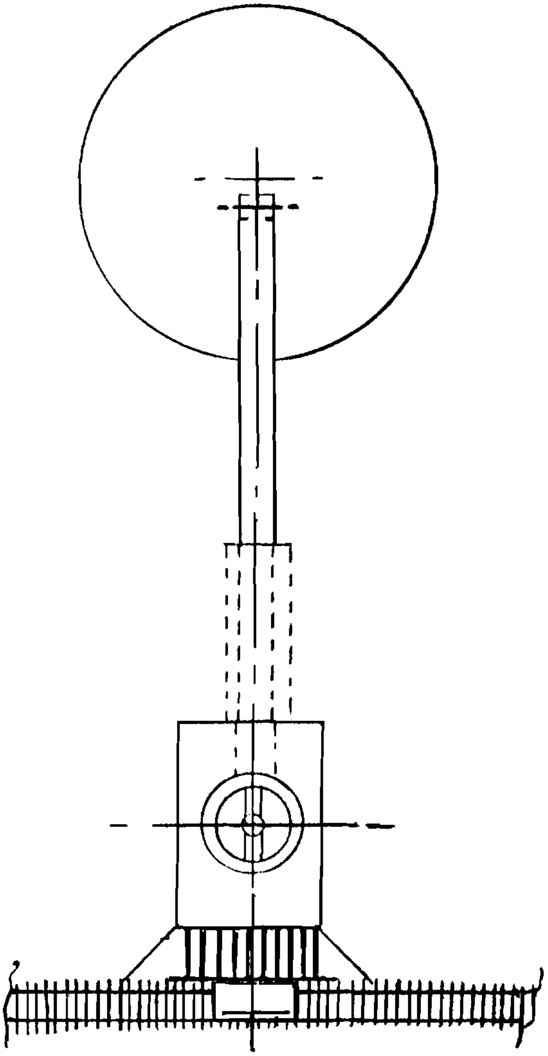

FIG. 41. Feed and discharge arrangement, side-dump rail car discharge.

Secondary Crushing

While the majority of gyratory crushers are used as primary units, their design characteristics are utilized for some secondary crushing applications in lieu of cone crushers. The gyratory crusher has a large feed opening, acute angle in the crushing chamber, and a long parallel zone compared to the cone crusher. Its two most common applications are following large primary crushers operating at maximum open-side setting or to produce a relatively large final product. For a given feed, the gyratory settings range from equivalent close-side settings of from 1 to 4 in. compared to the maximum close-side settings of from 1½ to 2½ in. available on cone crushers.

Table 18. Percent of Product Passing a Square Opening Equal to Open-Side Setting of Gyratory Crusher

Feed material	Run of mine	Scalped	Scapled and recombined with fines
Limestone	90	85	88
Granite	82	75	80
Trap rock	75	70	75
Ores	90	85	85

Crusher Product Curves

Crusher product curves, while based on screen analyses of actual crusher products, are still essentially estimates and guides. There are several reasons why these product curves are regarded as no more than a close approximation, including the variation in physical structure of the many materials that are crushed. Rocks exhibit a high degree of rugged individualism in their reaction to crushing. This reaction is frequently quite pronounced between different areas of the same quarry. The quantity of fines in the feed obviously affects the shape of the crusher-product curve. A choke or chamber-full crusher will usually produce a finer product than one operating with the chamber only partially full.

Fortunately, most materials do follow a definite gradation pattern and by averaging a large number of test results, it is possible to plot a group of curves that can be classed as fairly close approximations. Even though these curves are approximate, they are extremely useful in crushing plant design, in the preparation of flowsheets, and as the basis of calculating crushed-product size distributions.

Gyratory crushers are normally rated on the basis of the open-side setting. In order to select the particular curve of a group of curves, which will most nearly represent the product of a crusher having any given discharge setting, it is important to know approximately what percentage of the total output will pass a screen opening of equal dimension. Table 18 lists approximate percentages of product passing a square opening test sieve whose holes are equal to the discharge setting of the crusher. Most basic rocks or ores will be close enough in physical structure to one of the listed varieties so that the percentage can be used for them without serious error. The same statement applies to the product gradation curves to be discussed. It must be remembered that this information represents averages which are also subject to the variations in physical characteristics that occur in most quarries or ore bodies.

Figs. 42 and 43 show a family of curves for gyratory crushers. The method of using these curves is simple and requires little explanation. The vertical axis represents material size (in.) while the horizontal axis represents cumulative percentages passing the corresponding screen openings. In order to check the expected product from a crusher set at a predetermined discharge opening, first refer to Table 18 for the approximate percentage of product which will pass an opening

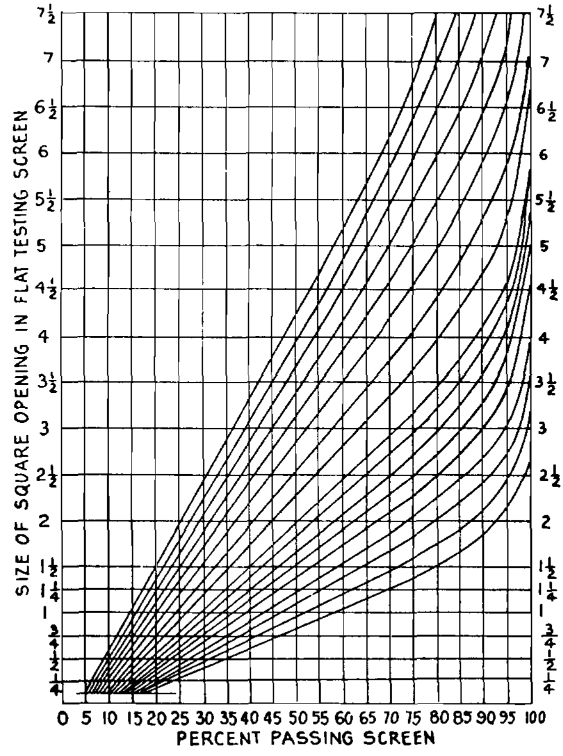

FIG. 42. Typical crusher-product size-distribution curves for open-side discharge opening under 7½ in. (courtesy of *Allis-Chalmers*).

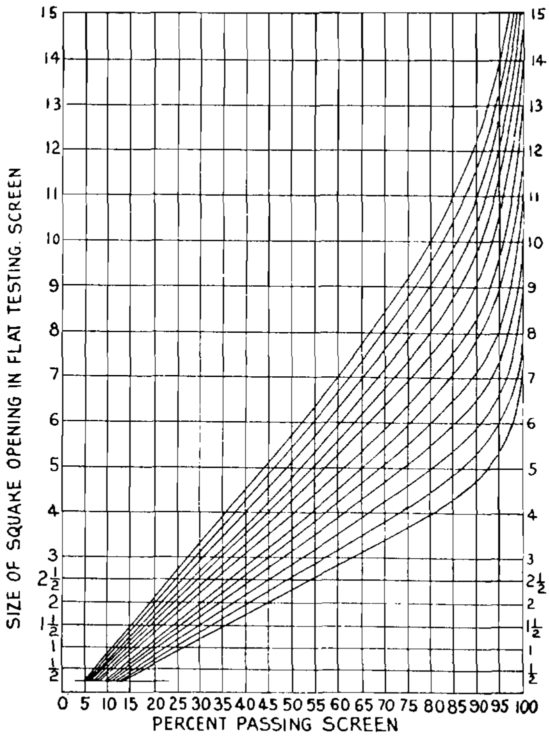

FIG. 43. Typical crusher-product size-distribution curves for open-side discharge opening over 7½ in. (courtesy of *Allis-Chalmers*).

Table 19. Gyratory Crusher Installation and Application Data

Install. key No.	Company division, group parent	Geographical location of crusher	Size of crusher,* in.	Mfr.†	OSS,‡ in.	Eccen. throw, in.	Gyr. per min	Motor hp	Crushing work index	Crushing rate, mtph	Avg. hp draw	Max. hp draw	Oprg. hr per day	Avg. %, lt
1	Anvil Mining Corp. Ltd.	Faro, Yukon Terr.	54–74	AC	5½	1⅝	N.A.	500	N.A.	N.A.	N.A.	N.A.	16	N.A.
2	Bougainville Copper Pty. Ltd.	Panguna, P.N.G.	54–74	AC	8	1⅝	135	500	13	3070	75	120	24	40
3	Canadian Johns-Manville Co. Ltd.	Asbestos, Que.	72–91	T	7¾	1¾	111	700	N.A.	2722	500	700	24	12
4	Cities Service, Pinto Valley Opr.	Miami, Ariz.	60–89	T	8	1½	113	500	6.0	3175	N.A.	N.A.	16	N.A.
5	Cleveland-Cliffs, Empire Mine	Palmer, Mich.	60–89	T	9½–11	1½	92	700	12	3251	300	600	8–24	20
6	Cleveland-Cliffs, Republic Mine	Republic, Mich.	48–81	T	7–7½	1½	93	350	N.A.	1320	250	350	N.A.	30
7	Cleveland-Cliffs, Sherman Mine	Timagami, Ont.	54–74	T	10½	1½	130	500	10.5	2450	250	350	16	5
8	Cleveland-Cliffs, Adams Mine	Kirkland Lake, Ont.	54–74	T	5½–7	1½	[illegible]	600	N.A.	2032	450	800	10	22
9	Amax, Climax Mine	Climax, Colo.	60–102	N	9	⅞	[illegible]	500	10	2268	275	450	12	47
10	Cia. Vale Do Rio Doce, Cave Mine	Itabira, Brazil	48–74	AC	8	1⅝	135	500	N.A.	2000	250	575	24	N.A.
11	Cia. Vale Do Rio Doce, Cave Mine	Itabira, Brazil	60–89	AC	8	1¼	110	500	N.A.	4160	250	575	24	N.A.
12	Cyprus Pima Mining Co., Pima Mine	Tucson, Ariz.	54–74	AC	7½	1⅝	135	500	17.5	2900	200	250	20	15
13	Ecstall Mining Ltd., Kidd Creek	Timmins, Ont.	54–74	AC	7¼	1⅜	135	600	20	953	530	600	16	N.A.
14	Erie Mining Co.	Hoyt Lakes, Minn.	60–102	T	8¾	1¾	103	900	14	4980	540	1080	24	N.A.
15	Erie Mining Co.	Hoyt Lakes, Minn.	36–70	T	3¼	1¼	154	400	14	1660	290	480	24	N.A.
16	Gaspe Copper Mines Ltd.	Murdochville, Que.	54–74	AC	6	1¼	135	600	N.A.	1270	N.A.	N.A.	16	N.A.
17	Gibraltor Mines Ltd.	McLeese Lake, B.C.	54–74	AC	8⅝	1⅝	150	600	9.0	2720	450	800	24	3
18	Goldsworthy Mining, Shay Gap Mine	Shay Gap, Western Australia	54–74	AC	5	1	135	425	18.2	1100	320	N.A.	20	7.9
19	Hanna Mining, Butler Bros.	Nashwauk, Minn.	60–102	N	6	1⅝	100	800	14	3048	500	725	12	28
20	Hanna Mining, National Steel	Keewatin, Minn.	60–102	N	7⅛	1⅝	100	800	14	3048	415	N.A.	N.A.	25
21	Lornex Mining Co. Ltd.	Highland Valley, B.C.	60–89	AC	9 13/16	1 13/16	110	700	13.1	3810	315	769	21	9.95
22	Inspiration Consolidated Copper Co.	Inspiration, Ariz.	54–74	AC	7	1⅜	135	450	N.A.	2722	100	180	21	N.A.
23	Meramec Mining Co., Pea Ridge	Sullivan, Miss.	42–66	T	4	1	N.A.	300	N.A.	958	145	470	15	10
24	Molycorp Inc., Questa Mine	Questa, N. Mex.	48–74	AC	6	1¼	120	400	14	1095	200	300	21	8
25	Mt. Newman Mining Co. Pty.	Newman, Western Australia	60–89	AC	8	1 13/16	110	700	13	5803	520	620	24	2
26	Mt. Newman Mining Co. Pty.	Newman, Western Australia	30–70	AC	4	1½	150	400	13	1870	220	260	24	10
27	Orinoco Mining Co.	Puerto Ordaz, Venezuela	60–89	AC	8	1½	110	500	N.A.	N.A.	N.A.	N.A.	24	10
28	Orinoco Mining Co.	Puerto Ordaz, Venezuela	30–70	AC	4	N.A.	150	300	N.A.	N.A.	N.A.	N.A.	24	10
29	Phelps Dodge Corp.	Morenci, Ariz.	60–89	T	6	1½	N.A.	500	12.5	3600	360	450	15	7
30	Phelps Dodge Corp.	Tyrone, N. Mex.	60–89	T	6½–7	1½	103	500	6–7	3650	300	500	14	40
31	Pickands Mather, Griffith Mine	Red Lake, Ont.	54–74	AC	8	1¼	135	500	15	1157	300	514	24	3
32	Pickands Mather, Savage River	Savage River, Tasmania	54–74	AC	7	1¼	135	400	12–14	1225	275	N.A.	20	12
33	Pickands Mather, Wabush Mines	Wabush, Lab.	54–74	AC	8	1¼	135	450	13.84	2350	335	402	24	N.A.
34	Western Mining Corp. Ltd.	Kambalda, West Australia	42–70	N	6	1¼	135	300	N.A.	1018	230	300	N.A.	N.A.
35	Kennecott Copper Corp.	Bonneville, Utah	54–74	AC	6½	1⅜	135	500	12	1416	N.A.	500	N.A.	5
36	Kennecott Copper Corp.	Magna, Utah	54–74	AC	6½	1⅜	135	500	12	1416	N.A.	500	N.A.	5
37	Kennecott Copper Corp.	Ray, Ariz.	54–74	AC	8	1⅝	135	500	12–16	2124	N.A.	500	N.A.	5

Source: Replies to questionnaire June to Nov. 1974.
Notes: * In inches of feed opening, diameter of mantle.
† Abbreviations: AC-Allis-Chalmers; N-Nordberg (Rexnord): T-Traylor.
‡ Open side setting
Average percent lost time.

Table 20. Gyratory Crusher Application Data Screen Analyses of Crusher Product

Install. key No.	Name	Open side setting	% Passing		Crusher product Square opening in flat sieve, in.					
			10 in.	8 in.	6	4	3	2	1	½
2	Bougainville Copper	8		100	98	96	94	85	55	34
3	Canadian Johns-Manville	7¾	100	97	90	85	82	75	55	34
8	Cleveland-Cliffs, Adams	5½–7			100	73	59	42	26	16
9	Amax, Climax Moly	9 max.				100	76	67	55	34
11	C.V.R.D., cave mine	8		94			84	72	58	52
12	Cyprus Pima Mining Co.	7½		98	90	74	70	62	45	
13	Ecstall Mining Ltd.	7¼			85	58	44	30	16	10
15	Erie Mining, Hoyt Lakes	3¼				72	55	37	20	12
20	Hanna Mining, Keewatin	7⅛			93	65	48	35	23	15
21	Lornex Mining Co.	$9\frac{13}{16}$			87	77	69	59	45	
24	Moly Corp., Questa Mine	6				85	73	60	47	32
25	Mt. Newman Mining	8		89	80	66	60	58	40	
26	Mt. Newman Mining	4				89	75	63	43	
32	Savage River Mines	7					85	76	55	
35	Kennecott, Bonneville	6½			85	60	45	30		
36	Kennecott, Magna	6½			85	60	45	30		
37	Kennecott, Ray	8		90	75	50	36	25		

@ Product of 36–79 secondary.
Note: Table 21 for manganese wear.

equivalent to the crusher setting. This locates the intersection of the two-axes, or a point, on the product curve for a specific application. If it falls between the curves already drawn interpolate.

For those not familiar with the use of product-gradation curves an example may be helpful. Assume that a tenative selection of a 6-in. open-side discharge setting has been made for a primary gyratory crusher to be used for crushing run-of-mine copper ore. Referring to Table 18 we find under the **run-of-mine** column that 90% of the crusher product should pass a 6-in. square opening. Then using Fig. 42 follow the horizontal line denoting the 6-in. product size over to the vertical line marking the 90% passing value. The point thus established does not fall directly upon any specific curve, but lies so close to one of them that it may be used without introducing any appreciable error in the calculations.

Further assume that the material is scalped at 2 in. ahead of a secondary crusher. In order to determine the quantity of material that requires secondary crushing, follow the curve down to the 2-in. size line. At this point 38% of the primary crusher output may be expected to pass the screen opening; 62% will be retained so that secondary crushing capacity must be provided to take care of 62 tons for each 100 tons fed to the primary crusher.

It will be noted that the product curves bend upward in very marked fashion above the 75–85% passing region. This reflects the tendency of practically all materials to slab or spall to some extent in the crusher. As a general rule, product gradation above the open-side setting of a crusher is uncertain and variable. The curves indicate an average condition. Essentially all primary crusher output larger than the open-side setting is recrushed in succeeding stages, so it is important to know how much will be recrushed and an indication of the top size.

Typical Installations

General

Table 19 provides general information dealing with various gyratory crusher installations throughout the world. In the first column there is a key number by which reference is made to specific installations in later tables. The next two columns give the company and specific location of each crusher which is not repeated elsewhere except with a single identifying name. The following columns, with the help of explanatory footnotes, describe the various crushers. The majority of the installations cover primary crushers with feed openings varying from 42 to 60 in. The same primary crushers have mantle diameters that vary from 66 to 102 in. The table also includes three gyratory crushers used as secondaries, namely Nos. 15, 26, and 28. The installed motors range from 300 to 800 hp.

It can be observed that there is considerable variation in the crushing rates for these crushers. The maximum shown is 7,200 mtph for Mount Newman (25) while the minimum for a primary crusher is 958 for Maramec Mining (23). The quantity of fines in the run-of-mine feed has a tremendous influence on the throughput of a primary gyratory crusher.

Crusher Product Size

Table 20 shows a listing of the screen analyses of a few of the crusher products represented in Table 19. This type of information is normally hard to get, the reason being that sampling coarse rock under normal operating conditions requires a very large sample for accuracy. In addition, the preparation of a screen analysis of a large sample is both time-consuming and expensive. As a general rule this type of information is normally only secured by the larger mining companies.

Crusher Liner Data

Liner life, including mantle and concaves, varies substantially with both the abrasive condition of the material being crushed and, obviously, the open-side setting of the crusher. Operating data for various gyratory crushers, regarding manganese liner life, are recorded in Table 21. Replacement procedures differ at various installations and these differences are covered by footnotes (Table 21).

Large primary gyratory crushers handling abrasive ores usually require quite frequent liner changes. Because of this situation, and to reduce downtime to a minimum, most operations have a spare main shaft on hand. New mantles are installed on the spare main shaft prior to the time the crusher is down for a change of liners. This procedure substantially reduces the overall downtime for major liner changes.

Table 21. Gyratory Crusher Application Data—Maganese Wearing Part Data

Install key No.	Name	Size of crusher[a]	Open side setting, in.	Mantle		Concaves	
				Wear, tons x 10^6	Time to change, hr	Wear, tons x 10^6	Time to change, hr
1	Avil Mining Corp.	54–74	5½	2.0	N.A.	3.0[b]	
2	Bougainville Copper	54–74	8	15.0	72[c]	15.0	72[c]
5	Cleveland-Cliffs, Empire	60–89	8	10.0	8[d]	12.0	72
6	Cleveland-Cliffs, Republic	48–81	7–7½	0.95	9[e]	0.95	36
7	Cleveland-Cliffs, Sherman	54–74	10½	2.5	12[e]	2.5–5.0[f]	80
8	Cleveland-Cliffs, Adams	54–75	5½–7	0.75	6[d]	0.75–4.0[g]	84
9	Climax Moly, Climax Mine	60–102	9	2.8	8	5.3	24
10	CVRD, cave mine	48–74	8	15.0	20	20.0	28
12	Cyprus Pima Mining	54–74	7½	7.0	8	12.0	32
13	Ecstall Mining	54–74	7¼	1.1	6	1.29	32
14	Erie Mining, Hoyt	60–102	8¾	3.0–12.0[h]	6	3.0–12.0[i]	33–55[k]
15	Erie Mining, Hoyt	30–70	3¼	0.63–10.8[m]	16	0.63–10.8[n]	16
16	Gaspe Copper Mines	54–74	6	1.15	16	1.5	36
17	Gilbraltor Mines	54–74	8⅝	3.5	24	6.0	36
18	Goldsworthy Mining	54–74	5	6.3	(0)	7.7	50
19	Hanna, Butler	60–102	6	3.6	48	7.2	48
20	Hanna, National	60–102	7⅛	4.0	36	8.0	75
21	Lornex Mining	60–89	9 13/16	10.8	N.A.	21.5	N.A.
22	Inspiration Copper	54–74	7	9.0	32	18.0	48
23	Meramec Mining	42–66	4	4.0	8	6.5	80
24	Moly Corp	48–74	6	N.A.	12	N.A.	48
25	Mt. Newman Mining	60–89	8	8.2	12	9.75	30
26	Mt. Newman Mining	30–70	4	2.8	10	3.3	30
29	Phelps Dodge-Morenci	60–89	6	13.0–22.0[p]	12	17.8	54
30	Phelps Dodge-Tyrone	60–89	6½–7	13.4	N.A.	25.5	N.A.
31	Griffith Mine	54–74	7¾–8¼	1.3–4.4[r]	24	1.3–5.3[s]	42
32	Savage River Mines	54–74	7	9.0	16	15.0	72
33	Wabush Mines	54–74	8	9.0	12	12.0	56
34	Western Mining	42–70	6	1.2	10	1.2	30
35	Kennecott Bonneville	54–74	6½	12.0	12	18.0	16
36	Kennecott Magna	54–74	6½	14.0	12	20.0	16
37	Kennecott Ray	54–74	8	10.0	12	13.0	16

NOTES

[a] In inches, Feed opening, diameter of mantle.

[b] Bottom three rows.

[c] 72 hr required to change both mantle and concaves.

[d] Based on using spare mainshaft with mantle pre-installed.

[e] Based on use of spare main shaft.

[f] 2.5 x 10^6 tons lower concaves, 5.0 x 10^6 tons middle and upper concaves.

[g] Lower concaves 0.75 x 10^6 hr, lower intermediate concaves 1.5 x 10^6 hr, upper intermediate and upper concaves 4.0 x 10^6 tons.

[h] Upper mantle 12.0 x 10^6 Tons, lower mantle 3.0 x 10^6 Tons.

[i]

Row	*Life in tons*
1	12.0 x 10^6
2	12.0 x 10^6
3	6.0 x 10^6
4	6.0 x 10^6
5	3.0 x 10^6

[k] Time to change:

Row #5	33 hr
Row 3, 4, & 5	53 hr
All five rows	73 hr

[m] Upper mantle 10.8 x 10^6 tons, lower mantle 0.63 x 10^6 tons.

[n] Upper row 10.8 x 10^6 tons, middle row 4.3 x 10^6 tons, lower row 0.63 x 10^6 tons.

[o] One to 5 days depending on other parts repaired during the shutdown.

[p] Upper mantle 22.2 x 10^6 tons, middle and lower mantles 13.0 x 10^6 tons.

[r] Upper mantle 4.4 x 10^6 tons, lower mantle 1.3 x 10^6 tons.

[s] Top two rows 5.3 x 10^6 tons, bottom two rows 1.3 x 10^6 tons.

3. COMPARISON OF PRIMARY JAW AND GYRATORY CRUSHERS

N. L. WEISS

General

The crushing of run-of-mine hard rock ores is the province of jaw and gyratory primary crushers described in the two preceding chapters of this section. While it is now seldom difficult to make a choice between the two to suit a specific set of circumstances, the governing factors merit a review, and that is the purpose of this chapter.

For every size of feed there is a crusher of either type that can handle it, and it is only when the desired crushing rate in **tons per hour** is considered together with the rock size that the preference for one type over the other is truly significant. When Taggart completed his *Handbook of Mineral Dressing** there were already in opera-

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* John Wiley & Sons, Inc., New York, 1945.