Manufacturing and refurbishing of jaw crushers

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Manufacturing of Jaw Crushers

Origin

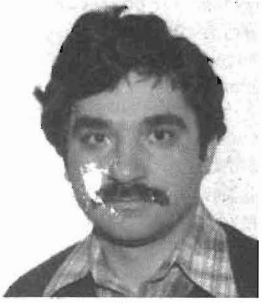
In 1858 Eli Whitney Blake invented the first successful mechanical rock breaker—the Blake-type jaw crusher. Blake adapted a mechanical principal, the powerful toggle linkage system used to transform rotating motion and energy into oscillating motion and tremendous compressive forces.

Today these same principals apply and the basic Blake-type jaw crusher is one of the leading machines of its class for heavy duty primary crushing service.

In 1881 Philetus W. Gates patented a design for a crusher, the forerunner of the modern gyratory crusher which dominated the field from the late 1800s to the early 1900s. In 1910 the largest gyratory crushers built had 48-inch openings. However, about this time the jaw crusher came to life when the Power and Mining Machinery Co. built an even larger sized opening crusher—a giant 84-inch by 60-inch jaw crusher for a trap rock quarry in Pennsylvania. A 24-inch gyratory crusher became the ideal sized secondary machine for this size jaw. From that time on jaw crushers were looked on favourably as primary breakers and lines were brought up to date to parallel the already developed gyratory lines.

F.W. Grieco

Frank Grieco was born in Noranda, Quebec. He studied business and administration at Laurentian University in Sudbury and completed his studies at Wilfred Laurier University in Waterloo, Ontario. Mr. Grieco worked for Inco and MacIsaac Mining and Tunnelling in all aspects of underground mining prior to joining P.R. Engineering Limited in 1973. As general manager of crusher sales and service, Mr. Grieco has travelled extensively throughout North America consulting on servicing and maintenance problems related to all makes of jaw crushers.



Joe Grieco

Joe Grieco was born in Noranda, Quebec. He graduated from the University of Toronto in civil engineering in 1970 and took post-graduate courses in mechanical and welding engineering. His work experience includes summers at Ontario Hydro and Ontario Department of Highways. Mr. Grieco is presently general manager of P.R. Engineering Limited, specializing in heavy fabrication and machining for the mining, steel, pulp and paper and automotive industries. P.R. Engineering also specializes in the refurbishing of used heavy-duty double toggle primary jaw crushers, as well as the design and manufacture of new Birdsboro Buchanan jaw crushers.

Keywords: Equipment, Maintenance, Crushers, Jaw crushers, Rock breakers, Refurbishing, Choking, Lubricating systems.

Function

Most heavy duty Blake-type jaw crushers work basically the same way. They are ruggedly designed and capable of crushing material in some cases in excess of 80,000 p.s.i. compressive strength. They are very simple machines with few moving parts and, with the exception of replacement of renewable parts, are relatively maintenance free. It is quite common to have these machines in production for 20 to 30 years.

The following will describe how these machines work.

Large-diameter high-inertia flywheels which are connected to the main eccentric shaft, rotate inside a connecting rod type mechanism called a Pitman. It transforms rotating motion into vertical oscillating motion. This vertical motion is in turn transformed into reciprocating motion by means of a system of 2 toggles, each connected to the Pitman. The rear toggle is connected to the fixed rear head, and the front toggle is connected to the swing jaw which is hinged at the top of the crusher. With each rotation of the eccentric shaft the swing jaw opens and closes on rock which is fed into the crusher chamber, crushing the rock in a series of bites. These bites, or strokes as they are called, usually vary between ½ inch to 1½ inch at speeds of 120 to 200 strokes per minute. The reduction ratio of feed input to discharge is usually about 8 to 1. Output capacities can vary from 100 tons/hour to 1200 tons/hour depending on the size of machine and its discharge opening. Horsepower requirements can vary from 75 hp to 400 hp.

The entire crusher chamber is lined with replaceable 14% manganese steel liner plates. This material is ideally suited for the job since it hardens as it wears during crusher operation. Manganese is also used in the high wear areas at each end of the toggle plates.

Design Features

As mentioned earlier, most Blake-type jaw crushers are designed in much the same manner, however, over the years—certain refinements have been made to make these machines more efficient and productive. Traditionally the bearing surface on the main eccentric shaft was made of a babbitt material. Although many crushers today still use babbitt, manufacturers are

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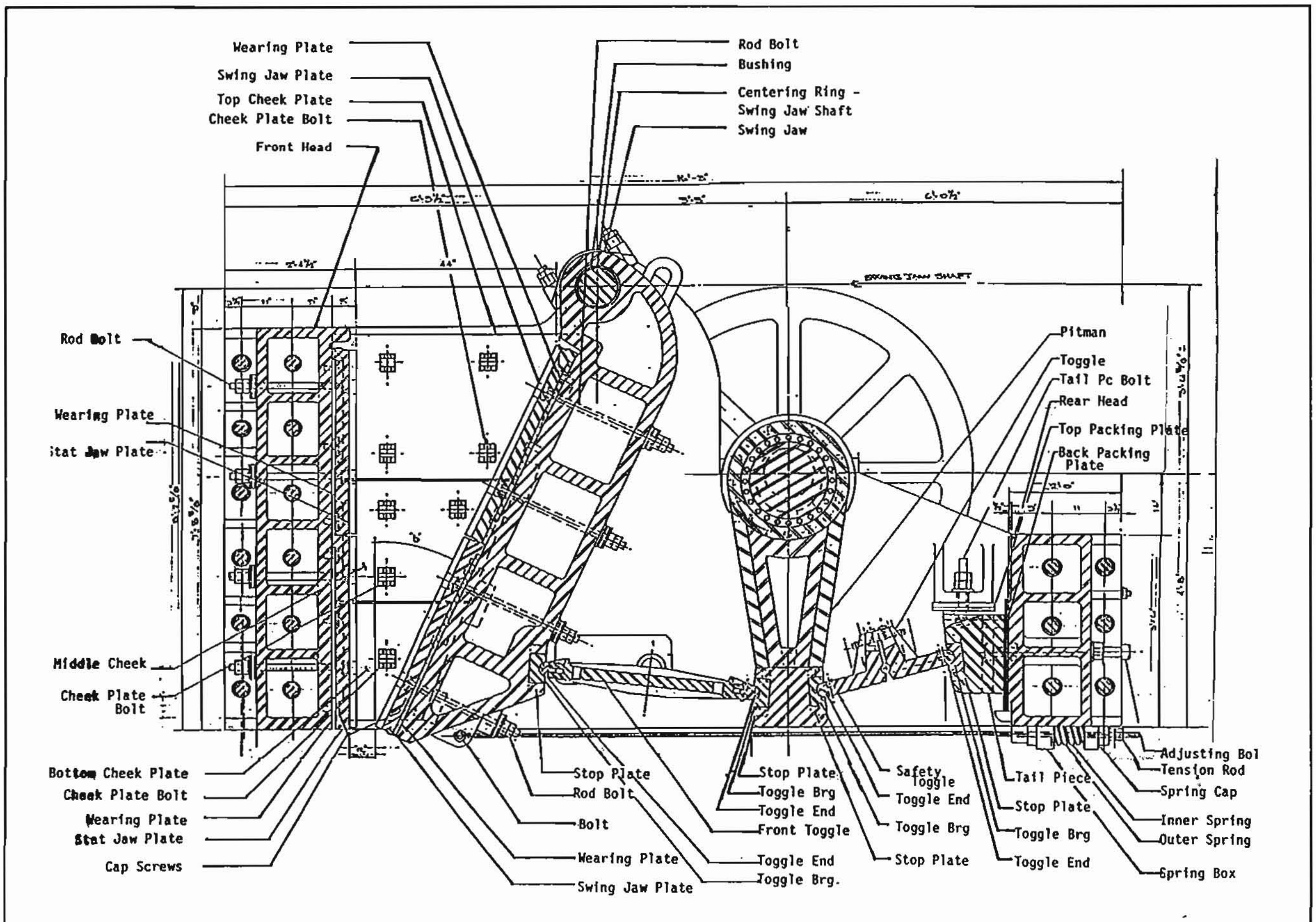

FIGURE 1. Standard Blake-type jaw crusher.

building the newer machines with anti-friction self-aligning roller bearings, which some believe reduces horsepower requirements and prolongs bearing life.

The main components—the side frame and the front and rear heads which were previously made of cast steel, are now fabricated using high-quality steel and advanced welding technology. This improved more efficient construction had led some manufacturers to fabricate the swing jaw and Pitman as well.

In all crushers there is an area in the crusher known as the choke point. This is the level in the chamber where the capacity of the crusher is at a minimum, i.e. the bottleneck of the crushing chamber. Several jaw plate designs have been developed to minimize this choking problem. Choices include curved corrugated jaw plates, flat jaw plates, corrugated jaw plates or a combination flat-corrugated jaw plates.

Another problem that existed in standard Blake-type jaw crushers was a phenomenon called slippage. This occurs when crushed material tends to move upward rather than downward. This problem is a function of the type of material being crushed and the nip angle or crushing angle. Standard crushers have nip angles which vary between 25 degrees and 30 degrees. However, by increasing the crusher chamber length, nip angle can be reduced in some cases to less than 20 degrees. When combined with the improved non-choking jaw plates a more efficient crusher results.

The addition of automatic lubricating systems on crushers has ensured that lubrication is properly distributed to critical areas at all times. The system can be monitored against faulty operation and interlocked with bearing temperature sensors to trigger alarms at the first sign of trouble.

Improved toggle systems allows for the automatic lubrication of renewable toggle ends which increase toggle end and toggle seat life.

Discharge settings, which have to be adjusted from time-to-time to take up the wear of jaw plates, toggle ends and seats, or to respond to mill requirements—can now be accomplished hydraulically. This replaces the more rigorous jacking bolt method.

New safety systems have been developed and improved as a result of joint efforts on the part of operators and manufacturers. During normal crushing, two factors can lead to the destruction of expensive crusher parts; the introduction of an uncrushable item, e.g. tramp iron or mine timbers, and a phenomenon called packing. This is caused when a large amount of fines enters the crushing chamber and reduces the 40% voids normally present in broken rock. If these fines drop into the final sizing zones, an uncrushable situation results in the crushing chamber.

Three typical safety systems used today are the shatter-type the shear-type and the hinge-type safety toggles.

The shatter-type safety toggle has a cored hole running through the entire length of the toggle plate. Ideally, at a certain overload, the core would break rendering the toggle useless thereby stopping the crusher. Screams of "built in obsolescence" were heard by manufacturers. Some ingenious operators would repair the toggle by welding the core and putting it back into operation, of course only to break again.

Another system was developed—the shear-type safety toggle. This consisted of a toggle made up of two wedge-shape plates perfectly machined on the mating faces and bolted together by means of tapered fitted bolts. With a crusher overload, the bolts would shear at a determined stress, the two plates would come apart and the crusher would stop. This development was an improvement over the shatter type system. A welder was no longer required to fix the broken parts and, with the exception of the bolts, the parts could be used again.

The third system is the hinge-type safety toggle. This toggle is made up of two angle shaped pieces which can pivot or hinge about a shaft running the full length of the toggle. The lines of force on the toggle which is held together by bolts, are below the hinge centre thus placing tension on the upper portion of the toggle. Because these reduced section bolts are under tension, an exact breaking load can be calculated. When the bolts are overstressed and break, the toggle remains in the crusher and simply hinges about the central shaft. This action puts the crusher in neutral and crushing ceases. New bolts are inserted and the crusher is back in operation with minimal downtime.

Problems Associated with Jaw Crushers

Foundations

Here we refer to the entire crusher room layout. A typical layout in the crusher room is one that is based on the manufacturers, minimum clearances required for maintenance.

The room should be spacious and well illuminated. Fifteen- to twenty-foot clearances on all sides of the crusher should be a minimum. If a 25-ton overhead crane is a minimum requirement —install a 30- or 35-ton crane. Time and money are saved when an entire assembly can be removed for maintenance with one lift rather than several lifts. Special attention should be given to the layout of observation platforms, feeder substructures, motor layout and wheel guard arrangements so that dismantling of these parts for maintenance is kept to a minimum. The higher initial costs will pay off in the long run with increased efficiency and moral among operators and maintenance crews.

A brief note on grout versus heavy timbers between the crusher concrete foundation and the crusher base plate. A good crusher foundation is paramount for trouble-free operation. When the foundation deteriorates a very expensive repair is in order. Compared to heavy timbers, high-strength grout is not as resilient. The relative damping effect of heavy timbers is an inexpensive way to preserve the concrete foundation and has been used quite successfully.

Feed Arrangement

The feeder should be long enough to give the crusher operator time to spot trouble coming from the ore pass, and react before the feed drops into the crusher. At the feeder design stage care should be taken to ensure that the carbon steel parts of the crusher, (the tops of each side frame, front head and swing jaw) are adequately protected from the abrasive action of the feed.

Scalping is always recommended from both a production and maintenance point of view. Typically the bars should be set so that the spacing is equivalent to the discharge setting of the crusher. The crusher works more efficiently with minimal fines and the possibility of packing in the crusher chamber is greatly reduced.

Choke feeding also increases crusher efficiency. Capacity is increased and the effect of rock crushing rock prolongs jaw plate life. However this type of feeding does require more horsepower and produces more fines. Therefore be on guard for crusher chamber packing.

The feed should be over the stationary jaw with the discharge end of the feeder at a height and distance from the feed opening that will enable elongated rock to tip into the crushing chamber instead of bridging across the moving jaw. Ideally, when economics allow, a pneumatic rock breaker should be mounted close to the crusher opening to effectively deal with bridging in the crusher chamber.

Operational Problems

Pound-for-pound, primary jaw crushers are probably one of the most ruggedly built pieces of equipment on a mine or quarry site. Consequently they are often abused and taken for granted. In mining, when surface calls for finer product size because of sensitive problems in the secondary crushing or grinding circuit, it is invariably the primary jaw crusher that is required to accommodate the new conditions.

Reduction ratios can vary depending on the hardness of the rock. For extremely hard rock, the ratios should be kept to approximately 6 to 1 or 7 to 1. For hard to medium rock, the ratios can increase to 8 to 1 or 9 to 1. Operating with larger ratios puts extra strain and wear on the crusher and greatly increases power requirements.

No matter how careful a crusher operator is, bridging will take place in the crushing chamber. One unorthodox and widely used method of solving this problem is to blast in the crusher chamber. The biggest problem lies in the individual's interpretation of how much blasting compound to use. As a result of blasting in the crushing chamber we have had to repair cracked side frames and broken swing jaws and Pitmans—all very expensive components to repair and the cause of considerable downtime.

As jaw plates, toggle ends and toggle seats wear, the crusher setting has to be adjusted to take up this wear. In most crushers this involves moving the tail piece ahead. By doing this, the geometry of the rear toggle is changed and its angle becomes steeper. This results in an increased stroke. A stroke in excess of 1½ inch is extremely hard on the crusher and safety toggle. Additionally, there is more chance of packing taking place in the crusher chamber. It should be remembered that if the crusher setting is adjusted the stroke must be adjusted to no more than ¾ inch to 1½ inch depending on the size of machine.

Replacement of worn parts is cheap insurance against major component failures. For example, jaw plates and cheek plates if not replaced after their useful life, will lead to irrepairable damage to side frames, swing jaw and front head. Babbitt bearings which are not regularly reset or which are allowed to wear through to the steel, cause severe damage to an expensive shaft. Toggle seats and toggle ends if ignored can result in the replacement of an expensive toggle body, or in some cases misalignment of the crusher. If a safety toggle breaks often—take a look at the cause of these failures before simply strengthening the toggle.

One of the most important systems on a crusher is the lubrication system. When bronze bushings, babbitted bearings or antifriction roller bearings are properly lubricated they will give years of trouble-free service.

It is advisable that the alarm system be interlocked with bearing temperature sensors, feeder, and crusher motor. If a problem arises (faulty lubrication system, or a hot bearing), the system should stop the feeder first then the crusher so that the crusher is given a chance to clear its charge before it stops.

Finally most modern sectionalized crushers are held together by bolting. Because of the nature of a jaw crusher operation, bolting should be properly torqued at assembly and maintained that way at all times. This check should be high on the list of daily preventative maintenance operations.

Refurbishing of Jaw Crushers

Over the years, mining has gone through many cycles. The roller coaster effect of mineral prices has forced many operators to seek alternative ways of cutting costs. A popular alternative is the rebuilding of existing equipment or the replacement of worn out equipment with refurbished used equipment. One good reason for choosing refurbishing over new, is the advent of sophisticated machine tools, improved welding technology, and accurate non-destructive testing methods all of which help ensure the reliability of refurbished equipment.

Before considering refurbishing, a study should be made to determine which is the best approach—to go new or to refurbish. Some of the major considerations are as follows:

1) The cost of rebuilding older machinery versus the cost of purchasing new.
2) The life expectancy of the new machine versus the rebuilt machine.
3) The productivity of the new machine versus the rebuilt machine.
4) Interchangeability with existing present equipment.
5) The trade-in or resale value of the old machine prior to rebuilding.
6) Availability of new machines versus the availability of parts to rebuild.
7) Are you rebuilding into obsolescence?

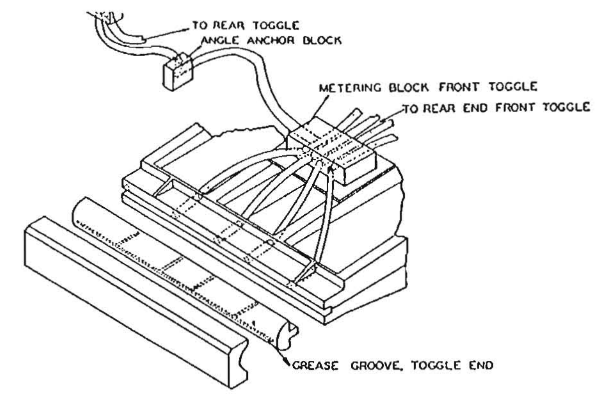

FIGURE 2. Automatic lubrication system for toggle bearings.

8) Availability of suitable rebuilding facilities.
9) The availability of capital money to purchase new equipment.
10) Tax write-off considerations—a rebuilding program can generally be written off as an operating expense—new machine purchases involve capital investment.
11) Considerations for amortization of a new machine versus possible write-off of an old machine prior to rebuilding.

Primary jaw crushers are good candidates for refurbishing. They are so ruggedly built that in many cases they are still operating after 20 to 30 years and often outlive the plant for which they were originally purchased.

During the course of operation, a crusher undergoes wear in many areas which do not adversely affect the operation of the machine. However, if the machine is dismantled for any reason, these areas become visible and accessible.

Complete refurbishing of jaw crushers involves four major operations:
1) Investigation with nondestructive testing methods of all highly stressed, worn and suspicious areas.
2) Repair and strengthening of all major components.
3) Complete re-machining of all areas which were originally machined during the manufacturing of the new crusher.
4) Complete assembly, alignment and dowelling of the crusher.

Non-Destructive Testing

Two methods—ultrasound and liquid dye penetrant are used to detect cracks and flaws in castings, weldments and forgings. The swing jaw shaft and the eccentric shaft should be ultrasonically tested for fatigue. If they prove sound, they are then rebuilt and polished to original dimensions so that original bronze bushings and babbitt bearing sizes can be interchanged. Highly stressed areas include keys in both heads and keyways in the side frames. As well the lower portion of the Pitman and swing jaw should be investigated.

Several areas should also be investigated such as:
— face of front head and swing jaw;
— lower ribbed portions of the front head, rear head and 2 side frames; and
— flywheel spokes and rims.

Once these problem areas have been outlined, the next step is the repair and strengthening.

Repair and Strengthening

Repair all cracking. Major cracking should never be welded. The entire section containing the crack is replaced with new plate and welded with 100% penetration using proper preheat and post heat techniques.

The over-all length of the swing jaw and Pitman barrel in most cases is shorter than original. This is due to wear at each end which may cause excessive float in turn leading to uneven crushing and uneven toggle seat wear. These over-all lengths should be built up and machined back to original dimensions. Any wash out areas due to abrasive action of the feed at the top and lower cheek plate areas of the 2 side frames and top of the front head should be built and remachined.

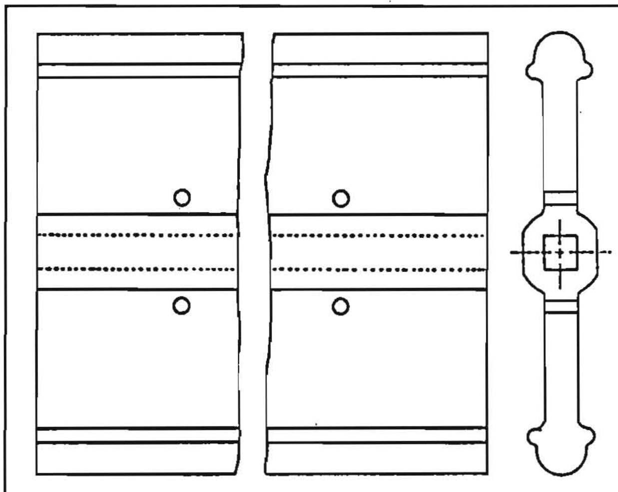

FIGURE 3. Safety toggle using cored cavity (obsolete design).

On older crushers with cast side frames, large observation port holes located in the frames in the area of the Pitman and front toggle were quite frequent. The frames can be reinforced by welding up these holes with plate and continuing the lateral ribs across the closed port holes. The swing jaw can be reinforced by welding plates on each side starting from just above the mid-length section down to the lower toe lug and toggle seat areas.

Crushers having side frames with integral babbitt bearings can be reconditioned to accept bearing inserts for ease of maintenance. In addition, crushers with 1 piece side frames can be split to accommodate restricted mine shaft dimension.

Complete Machining

The front face of the front head and swing jaw are machined to approximately 75 to 80% clean-up. Total material removal is usually no more than ¼ inch to ⅜ inch. This operation prepares the faces for the installation of mild steel replaceable ½ inch to ¾ inch thick wear plates. The mating surface of the front and rear heads, and side frames are machined to ensure 100% contact between these surfaces.

Cheek plate areas on the side frames are machined to 75% clean-up. The maximum material removal in this area is usually ¼ inch. Areas requiring more material removal should be built up with weld metal, and in more severe cases the section should be replaced with a new plate properly welded in place.

All keys and keyways are machined to produce a proper snug fit. Unless the keyways are cracked, it is usually cheaper to build up the keys and machine the keyways oversize to produce the proper key to keyway fit. Toggle seat areas are built up and machined to original dimensions.

The main frame bearing saddle and swing jaw frame saddles are all remachined to original dimensions. This procedure is carried out quite economically by simply dropping the centre lines of each bore and machining new bores with 90 to 95% clean-up to exact original dimensions.

The most critical aspect in the final machining procedure, is to have all bores perfectly parallel and square to each other and to the toggle seat areas. Keys and keyways must be machined exactly square and perpendicular to these bores and parallel to each other.

All babbitt bearings must be rebabbitted, machined and grooved to suit reconditioned shaft dimensions. Bolting should be entirely replaced.

Crushers with manual lubrication systems can be modified to accept automatic systems. This involves drilling grease ports in the swing jaw, bearing caps, bearing inserts, Pitman cap and Pitman bottom. Toggle bodies can be modified to accept reuseable lubricated toggle ends.

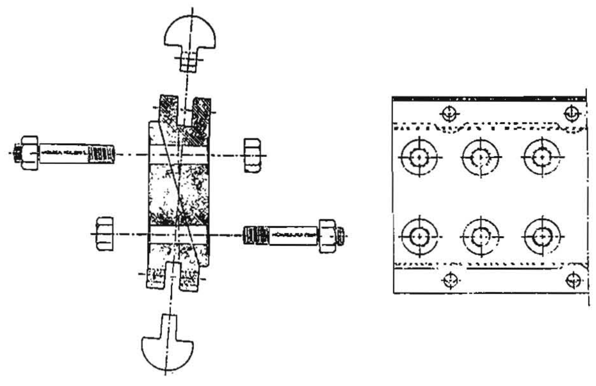

FIGURE 4. Shearing toggle with tapered pins and replaceable ends.

Assembly

Having machined and/or modified the main components, the crusher is ready for assembly.

The first step is to assemble the crusher box which consists of the 2 side frames and the front and rear head. The newly rebabbitted bearing inserts are installed. The eccentric shaft is blued and inserted into the bearing inserts and checked for contact by observing the resultant blue pattern. Alignment is ensured when a blue pattern appears across the bottom of each bearing. The crusher is then ready for dowelling at the junction of each side frame and the front and rear heads. Dowelling accomplishes two tasks; it takes the guess work out of alignment at installation and it ensures continued alignment during the operating life of the crusher.

The swing jaw and Pitman are installed to make certain proper clearances are maintained between the swing jaw barrel, Pitman barrel and the 2 side frames. Insufficient clearance will result in the generation of heat and in excessive wear; too much clearance will cause float and misalignment. Next the toggles are installed to ensure that they sit properly in the toggle seats. Flywheels are installed on the eccentric shaft and the crusher is turned over usually with the help of a crane. If the flywheels make one revolution and rock back and forth a few times before stopping, indications are that the machine is ready for operation.

Conclusion

All jaw crushers, no matter what their condition, can be refurbished to operate like new. If all four steps are carried out properly, a one-year new crusher warranty can be given with the refurbished machine.

The cost to recondition depends on the severity of component damage. Under normal circumstances costs range in the area of 60% to 70% of the cost of a new machine. The refurbishing operation should take 3 to 6 months.

GLOSSARY OF TERMS

Blocking means the blockading of the crusher receiving opening by a piece of rock or ore that is too large to enter the crushing chamber in any position.

Bridging means the blockading of the receiving opening by one or more pieces, any of which are small enough to enter the crushing chamber, but which are prevented from doing so, either because they fall so as to span the opening, or so that they mutually block each other from entrance.

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 "back-up" 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 chokeup.

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.

Choke-feed implies a completely filled crushing chamber (or as full as the design will permit), with a sufficient head of material above the receiving opening to keep the crusher full continuously. This contrasts with **regulated-feed**, which implies that the flow of material to the crusher is throttled to a point somewhat below the capacity of the machine, so that the crusher is never completely filled.

MOH scale is the relative hardness compared to 1-Talc, 2-Gypsum, 3-Calcite, 4-Fluorite, 5-Apatite, 6-Orthoclase, 7-Quartz, 8-Topaz, 9-Corundum and 10-Diamond.

Packing refers to a compacted or compressed condition of the material in the crusher, characterized by a complete or nearly complete absence of voids. Any condition which tends to retard the free movement of material downward through the crushing chamber tends likewise to promote packing.

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 it will discharge.

Scalping — removing from crusher feed all sizes smaller than product top size.

Tramp iron — bolts, shovel teeth, picks and other uncrushable metal that get into crusher feed.

Equipment Maintenance Council announces maintenance and computer seminars

The Equipment Maintenance Council will conduct a series of seminars entitled Equipment Maintenance Management and Computerizing Your Maintenance Operation. The week-long series will be held at two locations during the winter. "Equipment Maintenance" will be conducted on Monday through Wednesday of each seminar week; "Computerizing Your Maintenance Operation" will be held Wednesday through Friday of each seminar week.

"Equipment Maintenance Management" and "Computerizing Your Maintenance Operation" are scheduled for **December 9-13, 1985** in Los Angeles, California; and **January 20-24, 1986** in Tampa, Florida.

"Equipment Maintenance Management" will examine the following topics:

- Introduction to modern maintenance management
- Planning and scheduling your maintenance program
- How to establish an effective maintenance program
- Preventive maintenance supervisors and mechanics
- Predictive maintenance
- Training your maintenance supervisors and mechanics
- Using computer application to improve maintenance performance
- Motivation of maintenance personnel

The course is designed for individuals at all levels of equipment and fleet maintenance management. Ample time has been built into the seminar schedule to discuss participants' own maintenance concerns and how the information presented in the seminar can be put to work in participants' own operations.

For further details, contact: Equipment Maintenance Council, 1133 Fifteenth Street, N.W., Washington, D.C. 20005; (202) 429-9440.

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