BREAKER TECHNOLOGY, LTD.
an Astec company

Increasing Efficiency and Safety with Underground Scaling

Clearing away loose rock from the rock surface has always been a safety issue. The very operation itself indicates danger. Reviewing scaling efficiency through operation methodology and modern technology in equipment design with the focus on safety in the mine is the intent of this paper. The information within is the culmination of information from documents on the subject of scaling, accident reviews on injuries due to falling material, and information from mining operations throughout the world.

Scaling is the removal of insecure material from the back, sidewalls and face. Making the drift/tunnel safe for the next operation is the main purpose in scaling. How that is done varies throughout the world; that in itself is one of the problems. Another problem is the use of equipment that is designed for another function and the long term effect on them. I think we first need to look at some of the factors that affect scaling and its level of efficiency and safety. By no means is this everything as there are always some unknowns that also add issues or the mining methods themselves may lend a hand in creating faults requiring scaling. What is listed has the greatest effect in my opinion.

The geological structure does have an affect on scaling efficiency and safety especially after blasting where there is rock deformation and damage within the fragmentation envelope. The following descriptions were taken from a Mining worksheet for the Engineering Programme at Concordia University.
- Igneous Rocks are crystalline solids which form directly from the cooling of magma. Igneous rocks are given names based on what they are made of or composition and the size of the crystals and/or texture of the rock. As an example basalt and granite are igneous rock. The solid mass of igneous rock creates the greatest amount of problem for scaling due to the jointing variables found in the rock.
- Sedimentary Rocks are called secondary because they are often the result of the accumulation of small pieces broken off of pre – existing rocks. The sedimentary rock covers the igneous rock in most parts of the world. Examples of sedimentary rock are sandstone, limestone and shale. Within the sedimentary you have three types, Clastic, Chemical and Organic; I won't go into their individual detail. Sedimentary rock has more natural crevices/fault lines making it the best for scaling.
- Metamorphic rock gets its name from "meta" (change) and "morph" (form). Any rock can become metamorphic by changing its environment such that its stability and equilibrium is affected. This rock form can also have a negative affect on the scaling operation.

The type of jointing common to solid rock masses may vary; a paper by Paavo Harkko on scaling principles describes the four major joints very well. From the following

descriptions and the photos of each, you can see why the different joints would affect the scaling operation. I have used rock forms above ground to help visualize the variables.
- Cubic jointing – the joints extend in three directions almost perpendicular to each other and each roughly the same joint frequency.
Slab jointing – the joint interval in one joint direction is denser than in the others, giving an appearance that is often similar to that found in sedimentary rocks.
- Wedge jointing – two or more joint directions are better developed than others. At least two tend to cut at different angles forming wedge shaped sections.
- Mixed jointing – the joints are usually not linear and lead in different directions without any particular direction prevailing.

The different methods of scaling in themselves can negatively affect the scaling operations efficiency and the safety of the miners. I would like to now review these different methods used to give an understanding of each and to look at issues within each method. The first method used was/is manual scaling which is tapping with a scaling bar (sounding) and using the bar to pry at the material with the idea of it falling away from the operator. This method does require the miner to force the bar into a crevice or fault, twist the bar and pry down at the same time; it is very physically demanding for the miner. The miner must be lifted to the surface to be scaled in the high cut operations; this could be extremely high creating a safety issue. Of course operating at heights requires the use of a tie off for the miner to reduce the chance of falling from the platform.
There are a variety of conveyances used such as LHD buckets, modified forklift trucks, high reach platforms, manbaskets or scissorlits. The problem with this method is extreme danger to the miner especially when scaling a back. With this method the miner has no idea as to the physical size of the material or if the material behind is secure. When you consider the jointing variables in solid rock it is difficult for the miner to know what direction the jointing is taking. The scaling bar method tends to be more effective in sedimentary rock that has natural points of entry for the bar rather than the solid rock mass. The use of lifting equipment rather than a mechanized Scaler seems a waste of equipment that could be used for another operation that would benefit the mine. The theory being it is only for a short time so we can afford to have it assisting with that operation. Is it just about the loss of time with the alternate equipment or should it also be about the equipment not being designed with the effects of scaling in mind? They are not designed with the idea of allowing tons of material to be dropped on them; that is usually not a factor in the FEA design criteria. The standard manbasket has a lift capacity of 1000 pounds usually and a scissorlift is designed for a lift capacity or point loading of 6000 pounds.
A bolter is commonly used world wide and it can certainly maneuver the boom on its knuckle joint to work a back, face or sidewall. The procedure used is “tapping or rattling”. This is where the drill bit taps the surface skimming the full area bringing down faults. When you consider a bolter is designed to apply direct force hydraulically against the sidewall or back basically simulating a steel column holding a position against a hard surface for a period of time. While the drill operates or the bolt is inserted during its normal operation and you consider the strength of the system holding it in place would you not think that scaling would have a negative affect on the equipment? It stands to reason there would be more vibration

passing through the equipment during scaling than when operating normally as the tapping operation would not require full hydraulic loading to the surface you are scaling. The FEA design criteria for a bolter does not take into affect dropping material onto the boom or drill which could happen during scaling. When you consider the time lost in moving the bolter out and bringing in secondary equipment for scaling you can see the bolter seems like the best time saving way to go.

The Tools of the Trade supplement "A Bolter is meant to bolt: a Scaler is meant to scale" found in a recent CIM magazine makes a strong statement. Goldcorp's Musselwhite mine advises they had discovered that the bottleneck was the bolting process because the bolters were performing a dual role. Mr. Jeff Lewicky, Mine Superintendent for Musselwhite mine advised "It was taking a long time and costing us a lot of money on maintenance. Rock bolters were not designed to scale". Mr. Lewicky further explains "We've reduced our bolting time from six or seven hours to three to four hours". When you consider the dollar savings in time, maintenance costs and increased utilization as a bolter the use of a bolter as a bolter bears value.

Now let us look at Mechanized Scalers designed for scaling, allowing the operator to use sight and sound to determine what is to be scaled. These units take a variety of shapes and sizes all offering either mechanized or hydraulic systems for scaling. Not necessarily totally efficient or safe depending on the base construction and design of operation. I have also looked into the basic designs of different manufactured units with an eye to operator comfort for scaling for long periods of time, the units mechanical and hydraulic systems and how they can lend themselves to efficiency issues. Efficiency is not just defined by the scaling operation but the base design of the unit could add to down time and higher maintenance costs that take away from the potential overall efficiency.

A description taken from the US patent for a Mine Scaling Vehicle states " a mine scaling vehicle for use in removing loose materials from the roof and walls of underground mines includes an articulated frame with a turntable mounted on a forward portion of the frame and a drive system mounted on the back portion of the frame".

- A typical mechanized Scaler should have a swing area capable of covering the full width of the drift in one position, commonly 25 degrees either side of centre. The boom should be telescopic to allow you to scale from one position for as long a distance as possible without moving the machine. These abilities will eliminate the necessity to continually move the machine forward for the next section. Mounting a fixed blade under the boom allows the machine to clear debris in front reducing the time to bring an LHD in to clear a path. Lights are a major point as each drift will reflect differently. In some mines it seems you can never have enough lights. The light power must illuminate the working area as if you were above ground in sunlight. The shadows created by low light intensity are potential hazards/faults that cannot be seen clearly by the operator and may go untouched. The cabin must be mounted in such a way as to minimize vibration to the operator having the unit vibration tested is advisable. Visibility for the operator at the working surface especially the back can be difficult requiring the need for a tilting cabin. There are issues with the hydraulic circuit that I will discuss further in the hydraulic breaker section of this paper.

The attachments used with the mechanical Scaler are very important to the effectiveness of the unit. Let's review the attachments that are commonly used to give you a better understanding of how they work and some of the issues common with them.

- The mechanical pick mounted to a boom that is either fixed in length or telescopic is the first of the tools used to replace a man on a pry bar. Mechanical picks efficiency is limited by the fact it basically is a scrapping tool that must be forced into natural crevices/faults and then levered down. That is why it is more effective in sedimentary rock due to the natural faults. This action can cause lifting and dropping of the engine end when the loose material releases that causes maintenance issues with axles and oscillating components, not to mention the affect on the operator. The hydraulic strength required for this operation is transferred through the carrier and boom as there is no effective way to cushion the affects. The pick tends to get jammed on a regular basis adding time to the process. This tool does not allow for shaping of the corners which is important to strengthen the back to the side walls. As Paavo Harkko said in his article on scaling principles "By adding a hydraulic actuator to the pick it could be more effective," with a rotary actuator the corners can be worked more efficiently. The pick is the most inefficient of tools for the Mechanical Scaler and does create more downtime for the long term.

- Hydraulic breakers for scaling can provide a higher production rate or add to bigger problems for the mine. The hydraulic breaker must be adjusted to the material type it is to work with so you do not have over scaling. This will require the reduction in the hydraulic breakers energy at the working tool to prevent over scaling. You must also consider the approach angle of the breaker to the surface to be scaled which should be approximately a 30 degree angle. Any greater upward angle will have the unit doing production work not scaling. It is also advisable to have the breaker equipped for anti-blank firing for when the tool jams in a crevice. Without anti-blank it will continue to fire damaging the retainer pins and tool. The breaker should have a cushion chamber that reduces the vibration to the boom and carrier reducing maintenance costs and lost time. A bigger issue with breakers is that during the scaling operation contaminants work their way into the breaker as the tool end is exposed to the contaminants, naturally they end up in the hydraulic system. There is very little that can be done to stop this. A donut made from conveyor belting could be fit over the tool close to the bottom of the breaker. It is only effective if it remains in place. A tighter lip seal around the piston of the breaker will prolong the effects of the contaminants. Not all manufacturers offer this option. The best solution to minimize damage to the hydraulic system is to have a separate hydraulic circuit for the breaker with a gear pump. This will prevent contamination of the complete hydraulic system, reducing down time and keeping maintenance costs for the repair to a minimum. The gear pump is a workhorse that can withstand contaminants for a period of time before it shuts down. The attached schematic shows a hydraulic circuit that separates the breaker from the main.

- Hydraulic Feed Assembly for a Hydraulic Breaker controls the approach angle by its very design a feed is designed for the loads that would be applied. Mounting a breaker to a jumbo does not qualify as a feed design in my mind. This will minimize the potential for over scaling. The illustrated version has a hydraulic extension of eighteen inches for the breaker giving the operator better control and minimizes moving the base unit in the drift. The feed assembly allows the breaker itself to swing side to side 35 degrees either side of centre for a total of 70

degrees. This function enhances the swing of the boom that is already 50 degrees total swing thereby improving the overall coverage of the drift. The feed assembly also allows the breaker to shape the corners to strengthen the side wall to back. This option adds so much value to the hydraulic breaker designed scaling unit, with gains in time by not moving the vehicle and also by controlling the scaling operation with the additional feed function. Unfortunately it still has the contaminant problems as discussed in the hydraulic breaker summary.

- Vibratory Pick Assembly with a rotary actuator is without a doubt the most effective, efficient scaling tool available. The basic design combines the ability of a mechanical pick with a hydraulic breaker, this combination eliminates the prying loads back to the boom common with a breaker. Basically it is designed with a small hydraulic breaker mounted inside of a mechanical pick body, an extremely narrow design with a raised tooth. This design provides excellent operator visibility and dexterity during all scaling modes eliminating the guess work on where the tool is as compared to a conventional breaker or feed system. For the operator, they have the option of prying as a mechanical pick or activating/firing the breaker to clear any hard to remove areas. The prying tooth is a replaceable off the shelf product that comes in different widths, the advantage being a wider tooth tends to be more effective in softer rock like limestone, nickel ore or gold ore and the narrow tooth is more effective in harder material such as granite or lead/zinc operations.

As you can see from the illustration, the breaker is sealed inside the body eliminating the contaminant problem found with the hydraulic breakers. By eliminating the contaminant problem the second hydraulic circuit is no longer required therefore reducing the number of replaceable components. Troubleshooting of the hydraulics is now easier and reduction in inventory are two benefits with the vibratory pick design. The other added benefits are high productivity with the breaker inset in the body, while over scaling is almost eliminated with the profile design of the working tooth. The pick breaker design offers the best loading and does not require the same force to bring down a fault, saving on machine maintenance.

A dedicated Mechanized Scaler is purpose built for scaling large work areas that can be dangerous for the operator. The technological advances we have seen in the last five to ten years proves the design side is improving with a focus toward operator safety, not just efficiency. I think it is important that we as an industry look at establishing a standard for mechanized Scalers, something that would hold all manufacturers to the same level of design and quality. The hazardous nature of the operation dictates a need for a machine that should focus on safety first with an eye toward improved efficiency, increased production and improved availability.