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INNOVATION AND INVENTION IN SOUTHERN AFRICA: THE EXAMPLE OF DEVELOPING THE "RO-BUST," AN INTERNATIONAL AWARD WINNING INVENTION AND OTHER INNOVATIVE TECHNOLOGIES

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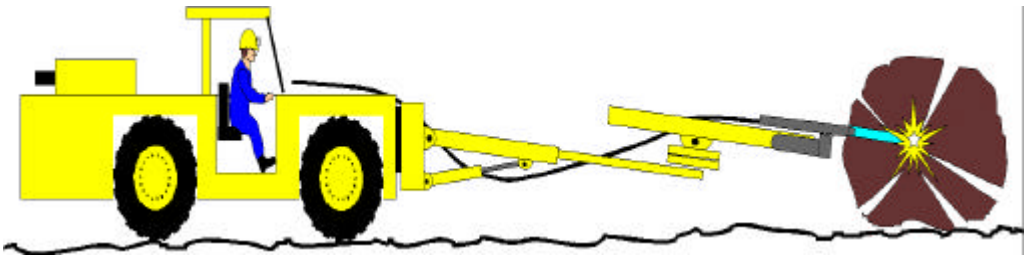
Ro-Bust™

HYDRO-FRACTURING

ROCK BREAKING TECHNOLOGY



SWARTKLIP PRODUCTS
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INTRODUCTION

1. Mining methods have been dominated by the drill-and-blast method from way back into the previous century. Over the years there have been steady improvements to this and its associated technologies, which include explosives, detonation and timing equipment, drilling systems and the integration thereof. However, in underground mines, the drill-and blast method by virtue of its inherent dangers and cyclic nature (drill; evacuate; blast; ventilate; structure support; muck) does not lend itself to continuous mining, forming a barrier to the next quantum step to improved productivity, safety and costs.

2. The competitive mining environment together with new emphasis from governments, environmentalists, unions and shareholders is changing the mining paradigm and new solutions are being sought. Automation of mining processes and safer and more efficient methods need to be employed such that equipment can be operated and maintained with minimum exposure of personnel to difficult or hazardous conditions, and, naturally, that profits are increased.

3. Over the last short while Swartklip Products, of Cape Town, has developed the new propellant-based Hydrofracturing technology, for breaking hard rock, which is being applied to meet the above criteria. Together with joint venture partners Swartklip is launching two new "continuous mining" products for the local and overseas markets.

4. Hydrofracturing technology offers the mining industry a "non-explosive," highly efficient, fast and safe solution to breaking of hard rock. It is a dust free, low noise, harmless fly-rock, no seismic effect, non-toxic, process, that lends itself to continuous mining and automation.

BACKGROUND OF THE HYDRO FRACTURING TECHNOLOGY

5. Swartklip Products, a division of Denel, developed and marketed the Boulder Buster™ hand tool, with considerable success, over the past seven years. The Boulder Buster™ is now sold to 18 countries and the increased environmental and safety focus of the European and North American companies have played a significant role in the market pull for this and subsequent products.

6. Through this product, *Hydro-Fracturing* Technology was developed and it's potential for innovative applications recognized. Due to its "hands-on" operation however, the Boulder Buster™ as it is, does not lend itself easily to mechanized applications and is seldom used in continuous production processes.

7. A few years ago, Swartklip embarked on a program to investigate the possibility to utilize the Boulder Buster™ principle for hard rock mining. From this program two projects were started:

- the **Rock Splitter** project which is a continuous mining system for narrow tabular ore bodies such as the South African gold mines,
- and the **Ro-Bust™** project, which is a fully mechanized secondary rock, breaking system for the massive ore body mining market worldwide.

HYDROFRACTURING SYSTEMS

BOULDER BUSTER ™

8. The Boulder Buster™ is a simple piece of equipment (hand tool) focused on the niche secondary breaking market where oversize is a sporadic problem.

9. Typical applications are:

- ❑ Secondary rock breaking
- ❑ Oversize on grizzlies and crushers
- ❑ Trenching
- ❑ Dimensional stone dressing
- ❑ Civil construction
- ❑ Swimming pool excavations

10. The hydro fracturing technology as utilized in the Boulder Buster™ works as follows:

- A hole is drilled ¾ through the rock or boulder to be broken
- The hole is filled with water
- The Boulder Buster™ barrel and beech body assembly is positioned into the mouth of the hole.
- A rubber mat is positioned over the breech body (prevents small fly rock and acts as recoil damper)
- A Boulder Buster™ cartridge is placed in the breech body
- The firing mechanism is screwed on.
- The operator hooks in a lanyard and walks away to fire the Boulder Buster™ from seven meters away (by tugging the lanyard).

11. On firing, the propellant cartridge is initiated. The propellant combusts rapidly causing a pressure pulse that is transmitted through the water in the form of a pressure wave. This pressure wave interacts on the small fractures at the bottom of the drill hole (resulting from percussion drilling) and propagates these fractures to the nearest free face or fault line in the rock. The pressure pulse also causes a static pressure to build up in the drill hole, which is used to heave or throw the fractured rock apart.

12. Bigger sized boulders (> one cubic meter) can be broken by dropping a **booster cartridge** into the drill hole before positioning the Boulder Buster™. The booster cartridge is also a soft case propellant cartridge fitted with a normal shotgun primer. When the pressure wave traveling from the tool hits the cartridge it initiates the cartridge and a second combustion takes place (extremely efficient as the water forms a perfect combustion chamber around the cartridge). It is this booster cartridge principle that is used as the basis for the **Rock Splitter** and **Ro-Bust** ™ systems.

ROCK SPLITTER

13. The **Rock Splitter** project is a joint venture with Boart Longyear to develop and market a continuous mining system for the hard rock tabular ore body mining market. The first prototype system is currently being tested at Vaal Reefs 9 shaft.

14. To break solid in-situ rock a different approach to boulder breaking is needed. The Rock-Splitter utilizes a two cartridge system (one in the impulse generator and one down the hole) to pressurize the drill hole with high-pressure pulses at both ends. As the holes are mostly horizontal a gel was developed to fill the hole and transmit the pressure wave.

15. The current system under test at Vaal Reefs is based on a double tube rail system with two carriages. The first carriage is fitted with two pneumatic drill feeds and drills to drill the holes. This facilitates accurate holes and improves productivity. The second carriage carries two Impulse Generators on pneumatic feeds, and follows close behind the drilling carriage. Drilling and breaking takes place concurrently with cleaning, roof support and other operations all being done in parallel enabling true continuous mining.

16. The existing project phase will prove the reliability and capability of the system under various rock conditions. This will be followed by a full-scale pilot project to prove the feasibility of the system.

17. To date the system has proven rock breaking in solid and fractured rock, with the ability to negotiate various reef conditions such as frozen and contact plane foot and hanging wall conditions. What was extremely promising was the ability to mine only the targeted stoop height and not to overbreak into weak hanging wall conditions.

RO-BUST™

18. The Ro-Bust project is a joint venture between Swartklip Products (Denel, South Africa) and McCarthy Industries (Denver, Colorado). The project started in November 1995 and rapid progress has been made to the point where we are now testing the first pre-production model.

19. The Ro-Bust technology is a new method of rock fragmentation, developed from Swartklip's Booster cartridge principle as used in the Boulder Buster™, combined with McCarthy Industry's rugged application system. This represents a true advancement to the state-of-the-art of secondary rock breaking.

20. This has developed rapidly over the last two years to the point where it is now being introduced for commercial application in the mining and civil construction industries. The initial commercial application of **Ro-Bust**™ have been undertaken at the Finch Mine of De Beers in South Africa beginning in May of 1997. Results are extremely positive. The system will be performing live demonstrations at the upcoming MineCon exhibition (September 2 to 5, 1997, near Pretoria). This followed closely by demonstration in Canada on a MaClean Engineering BlockHoler. The first focus of the technology is secondary rock breaking applications in underground block cave mining.

21. The **Ro-Bust**™ is a Hydro-fracturing Secondary Rock-breaking System, which can be fitted to the boom of any suitable carrier vehicle; primarily for use in draw points of massive

ore-body mines and at ore-pass grizzlies of general mining operations. It can also be used in surface mines and construction; wherever oversize rock needs to be broken swiftly, safely and economically.

22. To exploit the potential of **Ro-Bust**™ for underground rock fragmentation applications, Swartklip/McCarthy has engineered a self contained and mechanized system capable of breaking a full range of rock types and strengths. The system integrates a percussive rock drill and Ro-**Bust**™ pulse generator onto an indexing mechanism, with all mounted to a heavy-duty boom. This boom assembly is mounted on a carrier, which is capable of moving freely about the work site to drill and break oversize boulders and perform specific excavation work on exposed rock surfaces.

♦ Ro-Bust™ Cartridge

23. Ro-Bust™ uses a small-charge (15g or 25g) propellant-based cartridge, employing the extremely efficient tensile breaking method. The cartridge has some unique safety features built in, making it safe to transport, handle and store (classed as a power-tool cartridge - 1.4S i.e., no detonation or fire hazard). Through critical design, conditions of burn-rate and gas release are controlled enabling *continuous* operation. Low gas release and the presence of water also mean low fly-rock and noise and no dust.

♦ Operation Sequence

24. The **Ro-Bust**™ technique first drills a short hole, then loads a patented propellant based power cartridge in the bottom of the drill hole, and immediately initiates the cartridge with a column of high velocity stemming water released from a patented accumulator. The cycle time, drill to break, is accomplished within three minutes. All functions are carried out by a single operator from the convenience of his cab or from remote controls at the rear of the vehicle. The resulting product is the safe reduction of oversize boulders (of up to ten cubic meters with one 25g cartridge) to manageable size fractions. Continually repeating this process, an operator can produce significantly more broken rock in a given time frame than by any other method, in a controlled and safer manner. The smooth integration of propellant cartridge and the delivery and initiation components of the **Ro-Bust**™ system permits efficient continuous breakage of the hardest of rock.

♦ Ro-Bust™ Rock Breaking Mechanism

25. **Ro-Bust**™ rock breaking mechanism is based on the Boulder Buster™ booster cartridge technology. The cartridge is the prime energy source, which on being initiated rapidly releases its energy at the bottom of a water-filled hole. The shock is transmitted into the rock propagating fractures from the hole surface to the extremities of the rock.

♦ **Initial Application of Ro-Bust**

26. The system is ideally suited for secondary breaking at the draw points of caving operations in massive ore body mines. The rugged system lends itself to remote operation and can be attached to any suitable mining vehicle. **Ro-Bust**™ is very economical and offers a safe, efficient and reliable method of breaking oversized boulders up to ten cubic meters with a single shot, all in a cycle time as little as three minutes. Operating efficiency is greatly enhanced with a typical performance of 100 boulders in an eight-hour shift.

27. Swartklip/McCarthy will introduce its **Ro-Bust**™ rock breaking technology, with a focus on two primary rock excavation applications where **Ro-Bust**™ has the greatest competitive advantage.

1. Oversized boulders
2. Slashing applications in drifting and tunneling

SPECIAL FEATURES OF HYDRO-FRACTURING - HYDRO-FRACTURING EFFICIENCY

28. The best way to compare one rock breaking method with the other is through efficiency of energy consumed. **Specific Energy** is the measure of energy used to break one cubic meter of rock. All processes can be related back to energy and Specific Energy allows one to compare explosives with say, a propellant, plasma, a drop-ball or water jet. Obviously, the smaller the particle size, in general, the higher the energy consumed. More work (energy) is needed to break down to fines than to split it into four, say.

29. The crushing and grinding processes produce very fine particles and can be seen to have high specific energies, ranging from 1 000 MJ/m³ for percussive drilling to 24 000 MJ/m³ for water jet piercing. Explosives when used externally (mudpack) would also fall into the crushing group.

30. The combination of drill and blasting places explosives at 8 MJ/m³—vastly more efficient—in a group together with hydraulic rock breakers and splitters (wedge). Although the nominal particle sizes are larger in this group, these processes still create a lot of fines.

31. The Hydro-Fracturing method by comparison, creates no fines, and hence has a specific energy of only 0,012 MJ/m³, hundreds of times less than drilling and blasting. This places Ro-Bust™ technology in the correct perspective and offers a state-of-the-art advance in rock breaking.

POWDER FACTORS

32. The powder factor is the average amount of “powder” required to fragment a given amount of rock (read in kg/m³). **Ro-Bust**™ powder factors for breaking hard boulders into optimal fragments, averages 0.010 kg/m³ in 300 Mpa granite to 0,0025 in typical cave mining rock.

33. However, as implied above, only through specific energy can direct comparisons be made. Energy densities (MJ/kg) vary greatly between explosives and hence also powder

factors. This means that a lower powder factor only tells one that the explosive has a higher energy density.

SEISMIC EFFECT

34. The small amount of propellant energy used (0,012MJ/m³) results in benign fly rock and very low seismic energy.

FLY ROCK

35. The Hydro-Fracturing technology imparts orders of magnitude less energy to the rock than explosives do, and generate only a fraction of the gas, resulting in virtually no fly rock. The rock is seen to fracture and then just fall apart.

NOISE

36. The momentary Ro-**Bust**™ noise levels at the operator's location are under 95dB (with the peak energy centered around 75Hz).

DUST

37. **Ro-Bust**™'s Hydro-Fracturing process breaks rock with energy levels some three orders of magnitude lower than explosives. The rock is broken into sizable chunks and no annular crushing of the rock takes place, and hence also no dust. The use of water in the firing cycle also contains any dust that could have remained from the drilling process.

TOXICITY

38. In tests by Comro no toxic gasses other than a very small quantity of CO was measured. In underground environments the amount released per shot is very low and will be dissipated or extracted by even the least efficient ventilation systems. The use of water in the firing cycle also helps control and filter the gas products that are generated.

SAFETY

39. All of the above features result in improved safety for the operator directly and for the mines as a whole. In general, the process allows the operator to observe the breaking and thus he learns very quickly to become more effective. Not like with explosives where additional charge is added to ensure success and safety and structural damage further impaired.

FUTURE DEVELOPMENTS

40. The development of propellant-based techniques, while very significant, does not, in themselves, result in an economical method on continuous rock excavation. However, the

lack of fly rock, noise, dust, and noxious fumes will allow the introduction of mechanized equipment able to remain at the work face through the entire rock excavation cycle. The initial **Ro-Bust™** product was developed to handle oversized boulders, benching and slipping (drift slashing) applications where breaking to a free rock face is available. The next generation of product development will move into equipment platforms that allow full-face development to progress.

41. ***Future developments of the technology platform will focus on the following applications:***

1. ***Remote operations - ensuring safer working conditions for personnel***
2. ***Seismic sensitive areas***
3. ***Areas in which ore dilution is critical***
4. ***Cities and built-up areas where explosives are prohibited (tunneling & trenching).***

SUMMARY

42. Propellant based Hydro-fracturing as a means to break hard rock has surfaced as a viable competitor in the mining and civil industries. The Rock-Splitter application thereof is at present being tested as a true continuous mining system in a South African gold mine; while the Ro-Bust™ is being introduced simultaneously to massive ore bodied mines in South Africa and North America.

43. This new technology raises new opportunities for the future of mining worldwide.

44. Swartklip Products believes that through exposure in commercial applications, the virtues of the many positive features will become accepted and ultimately adopted into new mining approaches.

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