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SEALING OF HOT, HIGH PRESSURE WATER IN A DEEP UNDERGROUND GOLD MINE - A CASE STUDY

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ABSTRACT

A development end, 3300m underground at Kloof Mine No. 4 Shaft, South Africa, developed a slight flow of hot water from the face. This area had previously been cover drilled according to standard procedures. An alert miner informed his supervisor of his concern for the slight seepages of hot water emitting from his blast holes. A decision was made to halt further blasting operations.

A decision was made to diamond drill to probe for the source of this water from a position in the left-hand sidewall, 3m back from the development face. The water was unexpectedly intersected at a hole depth of 4m at a pressure of 25MPa, 58°C and at a flow rate exceeding 80000l/hr.

The hot water spray/steam and released gasses, displaced the breathable air and forced the evacuation of workers.

The paper details the events and the techniques employed to seal the water and allow work to continue.

LOCALITY

The incident being discussed occurred at Kloof Mine, South Africa, a division of Gold Fields Limited. Gold Fields today is the fourth largest gold producer, with over 3 million ounces produced in 1998. The Kloof Mine for the six-month period at December 1998 milled 1.025 million tons of ore and produced 428000 ounces of gold for the same period.

The Mine is situated near Carletonville in the West Witwatersrand gold field. The reefs being mined are the VCR (Ventersdorp contact reef), the Kloof reef and the Libanon reef.

SHAFT SYSTEM

The Mine is long established and the shafts extend to 3723m below surface. The development end where the water intersection occurred is the 41 Level 56 hangingwall drive South at 3300m below surface. The development end at 15 September 1998 was approximately 3000m in a NE direction away from the No. 4 sub shaft station. This is illustrated in the portion of the mine section (Figure 1).

Working conditions at the site was 32ºC. Virgin rock temperature is 58ºC.

DEVELOPMENT PRACTICES

The drive was being developed by the Mine with concurrent cover drilling being undertaken on a contract basis by Cementation Mining.

The drive is a 3m x 3m cross-section tunnel, driven at a gradient near to the horizontal for drainage. It is standard practice to probe ahead by means of EXT (38mm diameter hole) diamond core drilling on either side of the drive centre line for a distance of approximately 120m. If water of insignificant quantities is found then the drive is normally advanced to within 20m of the position reached by the cover drilling. If water is intersected then grouting is done, otherwise not.

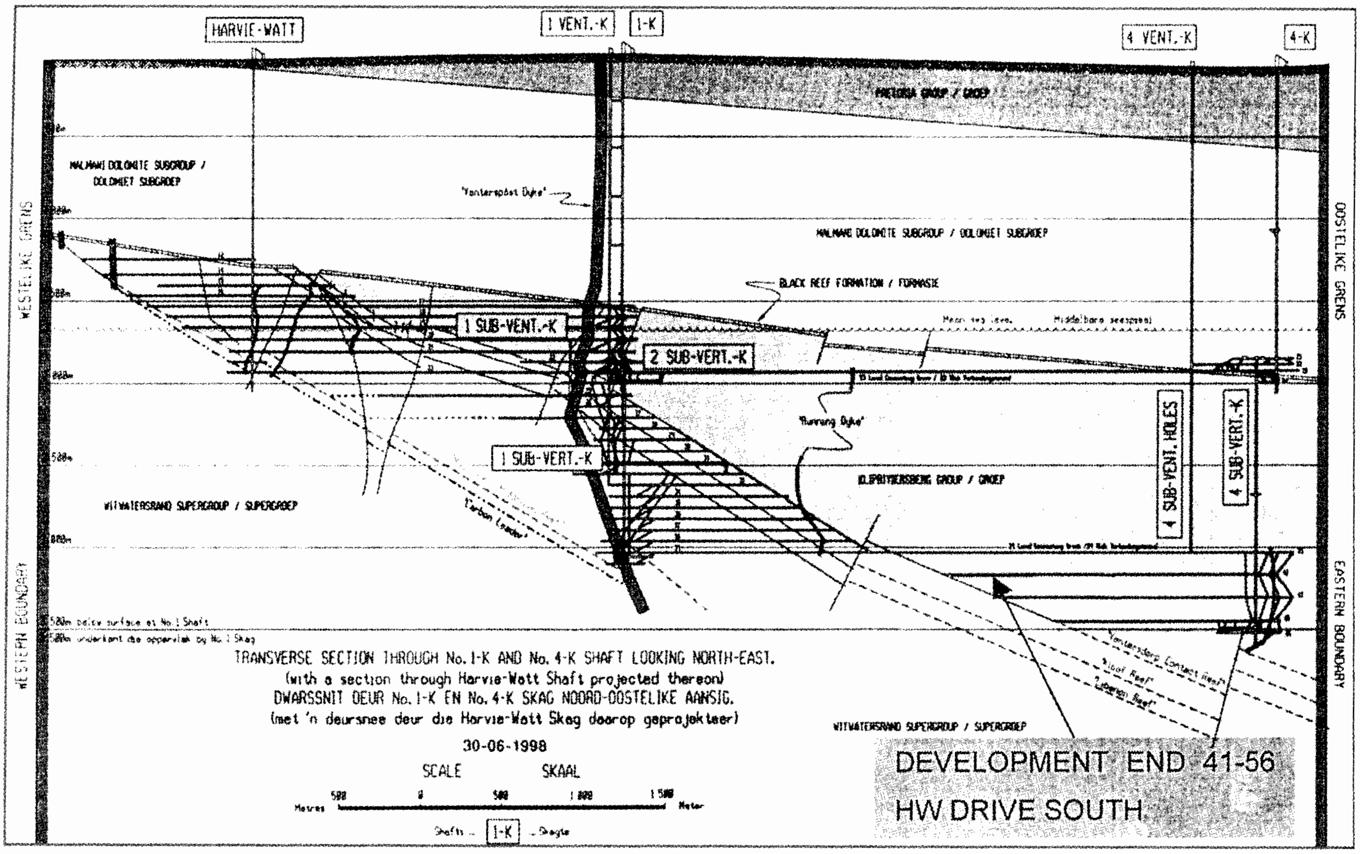

Figure 1. Kloof Mine Section through No. 1-K and No. 4-K Shaft looking North East.

GEOLOGY

The development is in the hanging wall above the reefs in undisturbed quartzite of the Klipriviersberg Series with some known dykes and faults present. In fact the cover drilling revealed a faulted zone ahead of the advancing drive end. The cover holes are shown in plan and section in Figure 2. The previous two cover holes were dry, while the furthest produced 2500 l/hr which was not considered significant.

THE CASE HISTORY

Initial signs

When the miner, working on advancing the development end, after the end was lashed and cleaned from the previous blast, noticed damp "patches" on the face and small inflows of water, he notified his supervisor who inspected the situation and stopped the advance of the face.

Action taken

It was decided to call in the drilling crew to probe for water with a horizontal diamond drill hole from a position 3 m back from the face 45º offline in the left-hand side sidewall. Normally forward drilling is done from a blasted cubby but in this instance, drilling was done from a sidewall position without the blasting of a cubby. As shown in Figure 2 the first hole advanced 4 m, before it intersected water with potentially disastrous consequences.

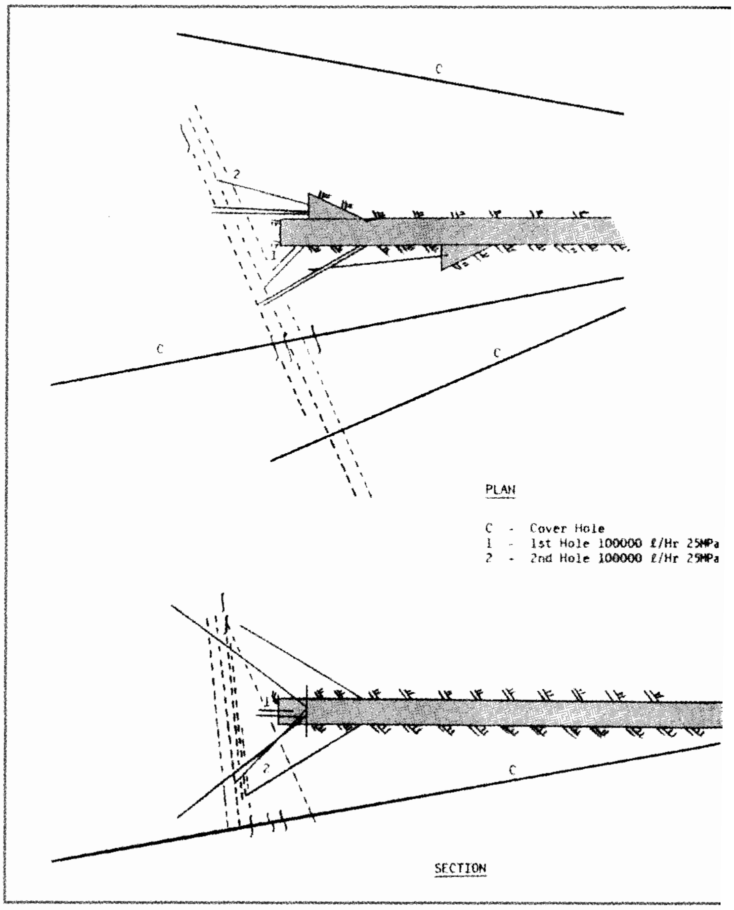

Figure 2. Plan and section of 41-56 HW Drive South showing all probe holes and fault zor

Standard drilling techniques

Machine employed

A compressed air powered Kempe U39 drilling machine mounted on a steel pipe frame was employed. An example of the machine is shown in the photograph Figure 3.

Figure 3. Drilling underground with a Kempe U39 machine.

Anchoring techniques

The standard procedure of using 2 No 1,5 m long 30 mm diameter mild steel wedge end-anchored rock bolts were employed. A 76 mm casing hole was drilled to a depth of 2,4 m and desludged. The hole was cased with 50 mm high pressure diamond drill casing 2,4 m long. A 50 mm high pressure valve was screwed securely on to the casing and grouted in. The casing and valve clamp was fastened by the wedge anchor bolts.

The casing pipe grout was allowed to harden, redrilled and pressure tested prior to the drilling cycle proceeding.

Drill rig arrangement (Figure 4)

After the casing clamp, a stuffing box fitted with a 25 mm high pressure valve was installed. A safety bar, strike block and chuck system with the machine mounted on the machine clamp all to the standard procedure was employed.

Because no high pressure, high volume water had previously been intersected on Kloof the single chuck system was standard at the time.

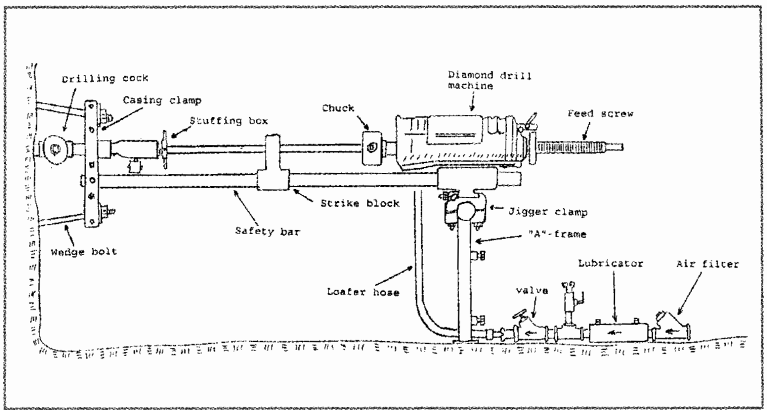

Figure 4. Diamond drill rig for normal conditions.

FOLLOWING INTERSECTION OF HIGH PRESSURE WATER

While probing for the source of water from this first hole, water was unexpectedly intersected less than 3 m from the corner of the tunnel face. There was initially no indication that water had been intersected as the stuffing box was torqued up and the drill rods rear end was equipped with a core stopper. Upon loosening the chuck, the rods were pushed clear out of the hole and jammed in the machine's chuck.

The water intersected was in the region of 80000 - 100000 l/hr at 25 MPa and at a temperature of 58ºC. The pH was measured on various occasions and varied between 11.5 and 8.5.

The heat of the intersected water rushing from the hole against the drill rig, created a major spray and made breathing impossible. All the breathable air was displaced by the large amount of spray and steam in the vicinity of the hole. It is possible that dissolved gases came out of solution immediately following the depressurisation of the water. Several attempts were made to enter the site through the water spray with no success.

Mine rescue personnel was called in for assistance with continuous unsuccessful attempts being made over a period of 12 hours. Finally the ventilation columns were extended and with the aid of icepacks and rescue packs, the area was entered and the valve closed.

The chemical properties of the water was analysed and is given below in Table 1.

Temperature	58.3ºC
pH	8.5
Conductivity	780 mS/m
Total dissolved solids	5070 mg/l

Table 1. Properties of a sample of water taken from the site.

A second hole was drilled at -45º at 4 m back from the face in the right hand sidewall and water was again intersected. Difficulties were experienced in extracting the drill string. Once again with the aid of Mine rescue personnel, it took 18 hours in total to extract the drill string with the double chuck system.

POSSIBLE CONSEQUENCES WHICH COULD HAVE ARISEN FROM THIS INCIDENT

- Injury to personnel;
- Heat exhaustion;
- Suffocation;
- Flooding of the Mine.

INSTRUCTIONS ISSUED TO OBVIATE A SIMILAR INCIDENT

The following instructions were issued:

- The area where the casing is to be drilled must be investigated for water seepages, faults, dykes, etc, rock quality and competence.
- The required casing and wedge bolts rating and lengths must be used.
- Water precaution safety equipment must be prechecked and tested.
- Double high pressure valves, double safety clamp and double supported safety bar to be employed in all cases where expected static head pressure exceeds 20 MPa.
- Double chuck (safety chuck) system to be used on all cover and exploration holes in known water areas.
- After casing installation and setting time, redrill to rock contact and pressure test to 2x static head.
- Redrill and deepen in stages of 0,5 m and pressure test to a depth of 4,0 m into the solid or as otherwise specified.
- The last three tests in succession must have zero acceptance and standing pressure at 2x static head before it can be assumed that the casing area is tight. Electro hydraulic pumps are recommended for water intersections at pressures in excess of 20 MPa.
- If the approximate point of a fissure intersection can be predetermined a water shut off valve can be fitted in the drill string at between 3,0 m and 6,0 m behind the drill bit.
- Sketch of drill rig and casing arrangement with full water precautions to be displayed on site and regular meetings to be held where standards and the importance thereof are discussed.

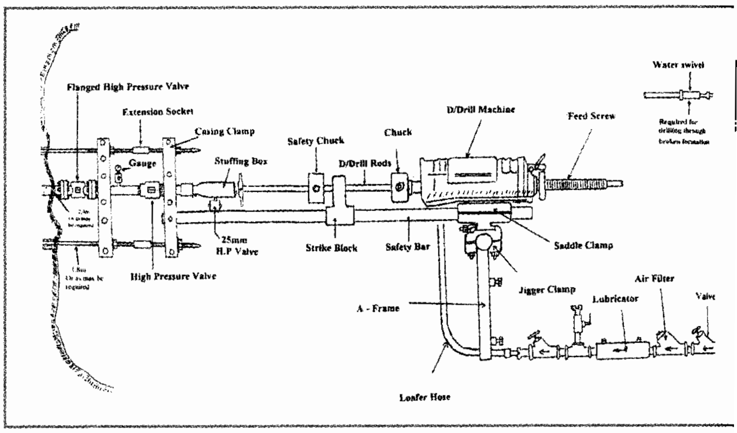

Figure 5. Diamond drill rig to cater for fissures under high pressure.

- Check lists and over inspections to be carried out by Driller, Foreman and Senior Cementation Mining personnel.

CORROSIVE WATER

Following these incidents certain items composing the drilling set-up bean to fail. Threaded connections on the high pressure piping corroded through within one week of use.

This led to the design of the systm being reassessed and changed to stainless 316L flanged connections.

The modifications to the system are shown in Figure 5.

SEALING OF THE WATER

To date the water has not been sealed. The plan has been to drill pressure relief holes into the fissure. Water colorant has been used to check for connection. Grouting will then be done from one hole to the next to push the water away from the excavaton shile the pressure is diminished by the relief holes. Once this is achieved, high pressure grout will tighten up the whole area.

CONCLUSION

Dealing with high pressure, hot corrosive water is dangerous. Careful procedures must be followed to avoid mishaps and accidents.

Design changes have made the system safer and capable of handling pressures not previously encountered.