Hot Dip Galvanized Case Study No. 14
Moab Khotsong (Vaal Reefs No. 11 Shaft)

The Application

After an extensive investigation during the course of 1996, the shaft engineer elected to use hot dip galvanized steel for corrosion control of all shaft guides and cross shaft steel structures (buntons).

The shaft guides were extensively rusted as a result of being exposed to atmospheric conditions for the past two years. The rusted condition, once cleaned would in all likelihood result in an excessively thick hot dip galvanized coatings that could be prone to mechanical damage and potential flaking. Coating thicknesses were therefore limited to a maximum average coating thickness of 300µm. Hot dip galvanized coatings, of recently manufactured buntons, were between 250 to 280µm.

Stringent straightness tolerances in both planes of the buntons and shaft guides were required. Straightening after hot dip galvanizing in a special manufactured jig was used to achieve specification requirements.

Fixing method of shaft guides, buntons and angle cleats called for a Huck type of fastener, which unfortunately were only mechanically plated with coating thicknesses of only 25µm. It was therefore decided, once assembled, all fasteners would be generously over coated with two coats of a coal tar epoxy to increase corrosion control and thus to achieve a balanced design. Coal tar epoxy was selected for its resistance to wet conditions that would be encountered in the mine.

Hot dip galvanized shaft guides laid out at the mine waiting installation during the course of 1997

Hot dip galvanized buntons with cold tar epoxy used to overcoat the fasteners and seal crevices

Hot dip galvanized shaft guides being unslung onto the cage for transport down the mine for installation

HOT DIP GALVANIZERS ASSOCIATION SOUTHERN AFRICA

Environmental Conditions

Corrosion of shaft steelwork is generally influenced by numerous factors some of which are summarized below.

❖ Corrosive Waters

Underground water usually has high chloride and sulphate ion concentrations, high total dissolved-solid contents, variable pH values (ranging from acid to alkaline), high conductivity and high scaling tendencies. They are also most likely to contain organisms which can promote microbial corrosion. It is often extremely difficult to predict actual corrosion rates since many of these factors can interact with one another positively or negatively (e.g., low pH water may be relatively harmless on account of a high scaling tendency).

❖ Humidity and Temperature

Most underground workings are humid on account of the high ambient temperatures and the presence of large quantities of water, especially if the mine uses water for drilling and cooling. Deep level mines, in particular, can be extremely hot and humid, by virtue of the rock temperatures (a rock-face temperature of 60°C is not uncommon in many South African gold mines) and the presence of large quantities of fissure and mine-service waters.

❖ Contaminated Underground Atmospheres

Underground atmospheres often contain corrosive gases and fumes arising from the use of nitrogen-based explosives. The atmosphere in the shaft will largely depend on whether the shaft is ventilated in an up-cast or down-cast manner. Up-cast shafts provide for more corrosive conditions since the contaminated underground atmosphere is drawn up the shaft, while in downcast shafts, incoming fresh air is able to dilute the corrosive atmosphere.

❖ Corrosive Ores and Dusts

A wide variety of chemical species can be leached out of the ore when it is exposed to water. These chemicals commonly include chlorides, sulphates, nitrates, silicates and many others, depending on the nature and characteristics of the ore. The high surface areas of a large number of small ore particles have a greater tendency for leaching than large particles, making the accumulation of moist dusts on unprotected steel surfaces a major corrosion problem. The dissolved chemical species will normally increase the corrosivity of the water by increasing its conductivity and by providing reactants for the corrosion mechanisms. In some types of water, the dissolved species may increase the scaling tendency of the water, which may serve to lower the water's corrosivity by its ability to deposit protective scales. An important feature of water in underground mining is the high degree of variability in composition and nature from one area to another.

❖ Abrasion

The shaft environment is normally extremely abrasive toward most common materials of construction and most types of protective coatings. For this reason, protective coatings on steel must be highly durable and be able to provide some form of resistance to under creep corrosion mechanisms at points where the coating is damaged. Abrasion is often coupled with corrosion and the synergy, or combined effect, of the two processes can result in very high overall rates of wear. Many conventional abrasion-resistant carbon steels have a relatively poor performance in shafts on account of the corrosion component in the wear mechanism.

❖ Mechanical Damage and Accumulated Debris

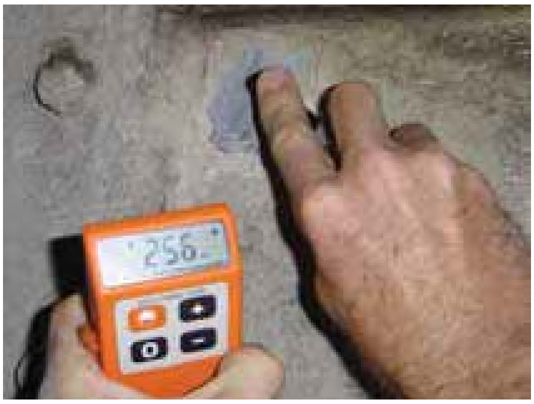
Mechanical damage is often very high on account of falling rocks; protective coatings, in particular, can be extremely vulnerable to this type of damage.
In most deep level mines, the lowest 300m of the shaft are considerably more corrosive than elsewhere. Rock and other particle debris and water can be trapped and accumulate in grooves and crevices and together with the hot and humid atmosphere, localised corrosion sites, known as crevice corrosion, develops within such “micro-climate” conditions.

The Site

The Moab Khotsong operation is situated near the towns of Orkney and Klerksdorp, about 180 km south-west of Johannesburg.
The shaft is 10.6metres in diameter and 3160 metres in depth or a total volume of 275000 cubic metres. It is currently one of the deepest “single drop” shafts in the world serving 12 levels on the way down. Using the above shaft-sinking rate of 4 metres per 24 hours, it took approximately 790 actual working days of 24 hours per day (2.2 years actual working time) to complete. The three level personnel conveyance “cage” takes approximately 4 minutes to travel from the surface to the lowest level, reaching a top speed of 19 metres per sec (68.4 kms per hour). Each winder is computer controlled and will automatically bring the shaft cage to rest within 10mm of the selected level. The shaft houses five sets of hoists, for the conveyance of personnel, as well as ore hauling skips.

Findings

Installation of the shaft steelwork took place from early 1997 and a survey of the coatings and this case study was undertaken in September 2006, about 9 years after installation. The hot dip galvanized coating on some of the station steelwork and some pipework was showing signs of corrosion but the main water pipes, shaft guides and buntons are in remarkable condition, despite the rather heavy calcareous layer that has over the years been deposited on the components and had to be removed in order to measure the coating thickness. The coating inspections took place on four different levels in the mine.



The coating thickness on shaft buntons at four different levels were inspected and found to be similar and were in a range of 250 to 300µm

The calcareous growth had to be removed prior before coating thicknesses could be accurately measured

Conclusion

Although the conditions underground can alter over the years for a number of reasons, the coating on the shaft guides and buntons has resisted the arduous mining conditions and will provide the expected life originally predicted at about 25 years with no maintenance. The mechanically coated Huck type bolts will in the medium term have to be addressed in order to realise the desired life of the mine.