Performance update of hot dip galvanizing in the corrosive environment of South African gold mines

by R.E. Wilmot*

Synopsis

This paper is based on the experiences, over many years,of numerous authors in the South African mining industry and of the hot dip galvanizing process and its application as a corrosion protection system. The paper sets out the extensive development, financial resources and stringent operating requirements of the South African mining industry. After many years of research and operational experiences, hot dip galvanizing and, when necessary, duplex systems, have been found to meet the demanding requirements of this particular industry.

The paper sets out the requirements from the standpoint of corrosion criteria and is followed with a case where the corrosion protection properties of hot dip galvanizing are demonstrated. This case history traces the early investigation of the expected corrosive conditions in a new mining operation and concludes with two follow-up visits to the mine in order to examine actual performance of the corrosion protection system after ten years in service.

Introduction

The original paper under this title was presented at the European General Galvanizers Association International Conference (Intergalva 2003) in June 2003. The paper presented on that occasion was co-authored by:

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I was given responsibility for the presentation of the paper at Intergalva 2003. I thank my co-authors and acknowledge their valuable contributions, not only for the previous paper, but also for the vast amount of work relating to hot dip galvanizing in the mining industry.

A brief review of the paper that was presented at Intergalva 2003 would be useful as an introduction to what follows[1].

A brief background review

South African gold and platinum mines generally employ vertical shafts, extending to depths of between 500 m and 3 000 m, or alternatively, inclined shafts that extend to lengths of up to 1000 m. Irrespective of the type of shaft used, environmental conditions encountered are usually highly corrosive and become more corrosive the deeper one proceeds. These conditions are due to the presence of corrosive waters, high levels of humidity, corrosive fumes and gases, and corrosive and abrasive ores.

In addition, thriving corrosion cells develop due to the accumulation of debris at catch points and crevices, including internal surfaces of various hollow steel components.

Once a shaft and its related equipment are commissioned, extraction of ore becomes the measurement criteria, with maintenance downtimes becoming an unwanted distraction from this primary objective. Maintenance is restricted to about 8 hours per week and mandatory safety inspections are normally included in the time. It is for these reasons that the materials of construction must meet the demands of longevity and a maintenance-free life.

Performance of hot dip galvanized steel

The original paper highlighted the 'good to excellent[1]' performance of hot dip galvanizing, used since the late 1970s. The use of hot dip galvanized steel has gained greater acceptance due its unique properties when used in conjunction with carbon steel. Hot dip galvanizing is not simply another coating, but rather a material of construction that provides corrosion control by means of a stable 'barrier protection', combined with 'cathodic

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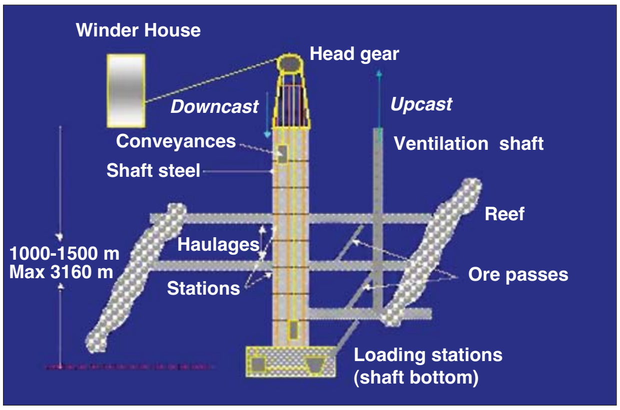

Figure 1—Vertical mine shafts

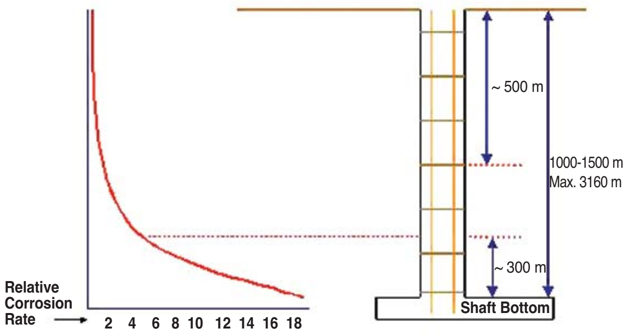

Figure 2—Corrosion profile of vertical shafts

pH range 2.8 to 9.0

Chlorides + Sulphate range 100 to 2000 p.p.m.

HDG will tolerate

- ❖ pH levels 6.0 to 12.5
- ❖ Chloride levels 1000p.p.m. in hard water > 100 p.p.m. calcium carbonate

Calcium salt deposits protect zinc surfaces

Zinc rarely susceptible to pitting corrosion

Figure 3—Analysis of mine water

protection' and at the same time superior bonding resulting from the metallurgical reaction between the carbon steel and molten zinc. Enhanced abrasion resistance is likewise improved by the same metallurgical reaction, which results in the formation of a series of hard zinc/iron alloy substrate layers, which are harder than the parent steel that is being protected. A further benefit of this material of construction, usually overlooked when predicting service life, is that the corrosion resistant properties of the zinc iron alloys are up to 30% greater than that of pure zinc in most environments.

The successful use of hot dip galvanized steel for shaft steelwork has taken place over 20 to 30 years. A great deal has been achieved by the galvanizing industry in this period to reach the point where this material can now be confidently selected and used for major new mining projects. Some of the milestones and achievements along the way have been:

- ➤ Controlling or avoiding distortion during galvanizing of large steel members with critical tolerances, e.g. guides, buntons and station supports, by design and modifications to the galvanizing process itself
- ➤ Coordination with steel suppliers to ensure the optimal grade and composition of steel to yield zinc coating thicknesses that minimize potential coating brittleness, while still providing adequate corrosion protection
- ➤ Developing the supply of hot dip galvanized fasteners to promote the availability of all required sizes, types, strengths and shapes of fasteners
- ➤ Developing a suitable specification for high strength bolts, and practical guidelines for the tensioning of these bolts to ensure optimal grip and to minimize relaxation affects
- ➤ Assisting in the development of suitable duplex coatings for specific applications and severe corrosive conditions
- ➤ Improving various aspects of the supply chain that often negated the efficient use of hot dip galvanized steel, e.g. using portable zinc spray units for site repairs, tracking of components at all stages of the galvanizing process and project execution, assisting users and fabricators at the project design and planning stages, optimizing transport and off-loading arrangements and undertaking full assembly 'mock-ups' prior to installation in the shafts.

By including the galvanizer as a member of the project team from the design and specifying stage through to final erection, apparent limitations to the use of the process have and can be overcome. This is evident in the highly successful completion of several major mining projects in recent years. The implementation of efficient teamwork and good communication in the supply of a corrosion protection service to complex multidiscipline, yet highly interrelated, projects have produced the required results. As is the case for hot dip galvanized steel, any alternative material has to provide a 'package' of properties to satisfy all safety, production, supply chain and project management requirements.

3000m Depth x 10 m Diameter

• Streamlined & joint bunton support	2800 Tons
• Shaft guides	2000 Tons
• Station structural steel	850 Tons
• Pump columns & piping	600 Tons
• Heat exchangers & ventilation ducting	350 Tons
• Miscellaneous steel work	100 Tons
TOTAL of STEEL to Equip a 3000m shaft	6700 Tons

Figure 4—Equipping a mine shaft

The original paper included a case study of Moab Khotsong Gold Mine, situated in the Klerksdorp area. Included in this paper is a return follow-up visit to the same shaft in order to monitor progress on the continued effectiveness of the corrosion protection system.

A brief description of this shaft is of particular interest as it exemplifies the use of hot dip galvanized steel as a material of construction in an aggressive corrosive mining environment.

Statistics of No.11 shaft Moab Khotsong Mine

Shaft sinking started in 1992 and progressed at a rate of 4 metres per 24 hours. The shaft, as it is today, is 10.6 metres in diameter and 3 160 meters in depth or a total volume of 275 000 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 km per hour). Each winder cost R120 million (US$ 14million) is computer controlled and will automatically bring the shaft cage to rest within 10 mm of the selected level. The shaft houses five sets of hoists, for the conveyance of personnel, as well as ore hauling skips.

Follow-up visits January 2003 and September 2006

Moab Khotsong No.11 shaft is now fully operational and being subjected to the full service conditions as well as 10 years of a highly corrosive mining environment.

Site visits in January 2003 and again in September 2006 were undertaken to examine the hot dip galvanized shaft steelwork, consisting of shaft guides, buntons and various other steel structures, after a period of 9 to 10 years in actual service conditions. Figure 6 illustrates our findings, from which it can be seen that the hot dip galvanized coating is performing exceptionally well. Coating thicknesses were found to be in the order of 150 to 180 µm. At certain isolated spots, the zinc coating had been mechanically damaged, causing the coating to chip and exposing the zinc iron layer. In these isolated spots no corrosion creep was evident while a portion of zinc iron alloy (25 to 35 µm) was still providing protection to the steel structure. Slight rust staining indicates that the zinc iron alloy is active and continues to provide corrosion protection. The benefit of zinc is that corrosion creep is prevented due to cathodic protection, or the fact that

Figure 5—Hot dip galvanized steelwork waiting to be transported underground (1992)

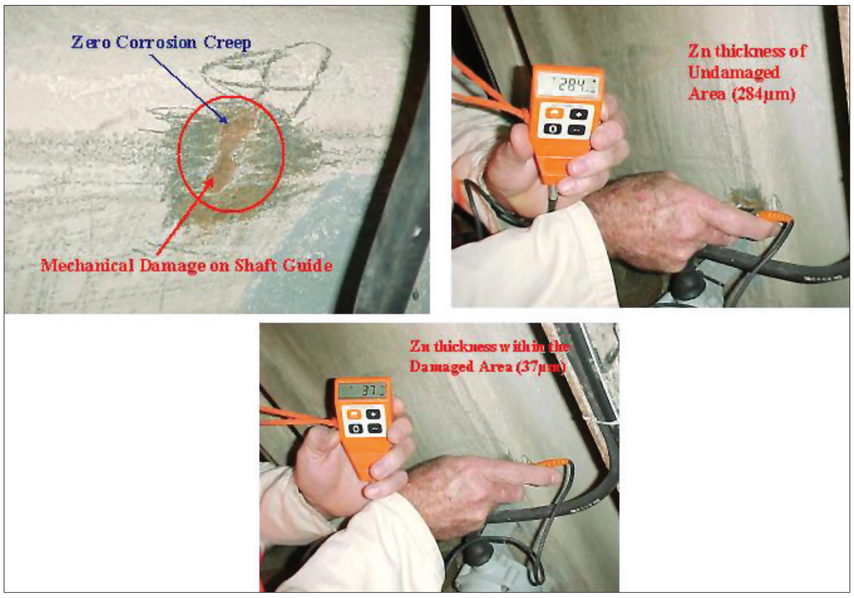

Figure 6—Performance of hot dip galvized coating

zinc will sacrifice itself to protect the carbon steel. (Zinc the 'anode' is electro-negative to carbon steel being the 'cathode').

The photographs in Figures 7 to 9 were taken during the visit in 2003 and demonstrate the ability of zinc to prevent corrosion creep by cathodic protection.

During September 2006, my Association colleague, Terry Smith, returned to the mine and recorded the photographs during the course of a routine shaft inspection. One is able to achieve a glimpse of the environment found within a typical deep mining shaft. Note the extent of the debris and poultice development that has taken place on the shaft steelwork. This, together with the continual wet environment, containing various corrosive elements, contributes to the development of ideal corrosive conditions.

Conclusion

South African gold mines require between 15 to 20 years to explore, plan, and develop, and large financial resources before a gram of gold is produced. Leading up to the day when the first gold is produced, large facilities and equipment are installed, upon which the mine will be dependent for its entire life. Such equipment must therefore provide long-term maintenance-free service. After many years of research and actual experience, most of the gold and platinum mines in South Africa have now opted for hot dip galvanizing and, when necessary, duplex corrosion protection systems. At the last update some 40 South African mines, of various descriptions, are specifying hot dip galvanizing and when required, duplex coatings, for their corrosion protection system. This represents a conservative estimate of 250 000 tons of hot dip galvanized steel.

It has been proven that hot dip galvanizing remains in the forefront of corrosion protection systems for not only the mining industry, but for many other industries as well as domestic requirements. Hot dip galvanizing may be one of the oldest, but it remains the most economical and viable protection system available today.

Figure 7—Examination of a shaft guide. Removal of the encrusted poultices and measuring the underlying hot dip galvanized protective coating reveals a coating thickness of 430 µm

Figure 8—Another shaft guide. This measuring taken on the side gives 181 µm of hot dip galvanized coating

Figure 9—Examination of a shaft bunton. The underlying hot dip galvanized coating measured 256 µm

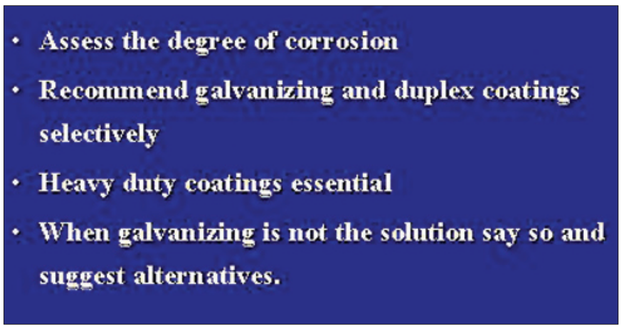

Figure 10—Hot dip galvanizing in mines: summary

Acknowledgements

Anglo Gold and the shaft engineer at Moab Khotsong.

References

1. Andrew, R.H.C. *Practical Guidelines for Corrosion Protection in the Mining and Metallurgical Industry*, NACE International. 2003.
2. Porter, F. Corrosion Resistance of Zinc and Zinc Alloys. *Zinc Handbook*. Marcell Dekker, New York, 1991.p. 62. ◆