# Water-treatment practice in South African gold mines

### by R.T. WHITE*

**SYNOPSIS**

The usual figures quoted for water usage in South African gold mines are 1 ton of water used per ton of rock broken, which represents a consumption of 4000 litres of water every second. Owing to the limited sources of underground water, the high cost of surface-water supplies, and the environmental problems of effluent disposal, water is recycled continuously for underground use.

This paper reviews the various types of water treatment and why water needs to be treated. The uses of lime and some flocculants are considered, since much of the mine service water requires only simple neutralization and clarification. Where mining depths necessitate the installation of underground refrigeration plant, more stringent water requirements must be met, and where plant performance is to be maintained, the prevention of system scaling and corrosion is necessary. The families of chemicals added to provide such protection are outlined, together with a description of the mechanisms of control.

**SAMEVATTING**

Die gebruiklike syfers vir waterverbruik in die Suid-Afrikaanse goudmynbedryf is 1 ton water per ton gebreekte klip, wat verteenwoordig 'n verbruik van 4000 liter water elke sekonde. Vanweë die beperkte bronne van ondergrondse water, die hoë koste van bogrondse watervoorrade, en die omgewingsprobleme in verband met die wegdroeing van uitvloeisel, word water voordurend vir ondergrondse gebruik gehersirkuleer.

Hierdie bespreking noem die moontlike soorte waterbehandeling en verduidelik waarom water behandel moet word. Die gebruik van kalk en sommige uitvlokmiddels word in oënskou geneem aangesien baie van die gebruiksmyn-water slegs eenvoudige neutralisasie en verheldering vereis. Waar die myndiepte die aanbring van ondergrondse koelinstallasies vereis, moet daar aan strenger watervereistes voldoen word, en om die volgehoue werkverrigting van die installasie te verseker moet skaalvorming en korrosie van die stelsel voorkom word. Die soorte chemikalieë wat bygevoeg word om sodanige beskerming te verleen, word uiteengesit, tesame met 'n beskrywing van die beheermeganismes.

## Introduction

This paper deals with a study of underground waters and their treatment, and does not refer to the water-treatment procedures used by the gold-mining industry to provide water for reduction works or for final discharge to a water course.

The major uses of underground water are for cooling, drilling, water jetting, and the provision of hydraulic emulsions. The water used in underground workings originates from the surface of the mine (e.g. from surface dams or a potable supply), or from underground fissures within the mine. The supplies from the surface are generally of good quality, whereas fissure waters have a high content of total dissolved solids (TDS) and are invariably acidic. The reason for the high TDS levels is to be found in the geochemical history of these waters. In general, waters in the Orange Free State have higher chloride levels (more than 2000 mg/l) than those in the Witwatersrand area[1] (approximately 1000 mg/l). Vast volumes of water are used by the gold-mining industry in South Africa (1 ton of water per ton of rock broken, or 4000 litres of water every second). Because the consumption and the costs of surface supplies are so high, water is continuously recycled within the underground workings wherever possible. This recycling, together with the ingress of contaminants from working areas of the mine, would rapidly render the water underground unfit for use unless a sensible water-treatment policy were adopted within the overall framework of an integrated water-management scheme.

In the provision of water for a particular process, the type of water treatment to be used is dictated simply by the water's 'fitness for the purpose'; that is, the purpose for which the water is intended is the criterion for the degree of water purity required.

The major types of water treatment can be grouped as follows:

(1) biological treatment or sterilization,
(2) water conditioning,
(3) sequestration or anti-fouling, and prevention of scale, and
(4) corrosion inhibition.

### Biological Water Treatment

As there is always a danger that mine service water may be drunk by mining personnel, all the piped water in the mines is 'sterilized'. This water is non-toxic and should cause no ill effects if drunk in small quantities. Most bacteria and viruses are killed by chlorine, and a residue of 0,5 to 1 mg/l will usually destroy most organisms. Problems often arise in the treatment of water that is to be used in mine processes but is also required to be non-toxic. The provision of chilled potable water as an alternative supply minimizes these difficulties.

Biological fouling in water-reticulation systems in mines can be a major cause for concern, especially in refrigeration systems. Bacteria and dust are blown into open cooling systems, where the bacteria proliferate in the warm water. Excessive growth can cause biological slime to build up and to form a mat of dead or living organic detritus that is relatively immune to subsequent chemical treatment. Deposits of such slime can impair the efficiency of heat transfer in heat exchangers, and

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conditions can arise in which sulphate-reducing bacteria are able to flourish and to cause pitting on metal surfaces.

A wide range of chemicals is available for biocidal treatments, some of which are chlorine-releasing agents. The choice of treatment is dictated by the severity of the problem, but non-oxidizing biocides are often preferred to chloride. This is because many cooling systems run at pH values higher than 8, which greatly diminishes the activity of chlorine. In addition, chlorine is not specific to organic substances, but also oxidizes inorganic materials (such as $H_2S$ and $NH_3$), which means that a high concentration of chlorine is required for effective treatment.

## Water Conditioning

Water conditioning can be regarded as the alteration of a particular water's properties by a major change in its composition. Conditioning of the underground waters of a mine comprises two processes: neutralization and clarification.
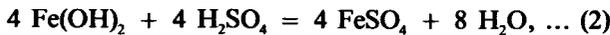
### Neutralization

The acidity of the water is due chiefly to the oxidation of pyrite, which is considered[2] to occur in two distinct stages.
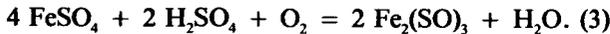
In the first stage,

$$4 \ FeS_2 \ + \ 12 \ H_2O \ + \ 14 \ O_2 \ = \ 4 \ Fe(OH)_2 \ + \ 8 \ H_2SO_4, \ \text{..............} \ (1)$$
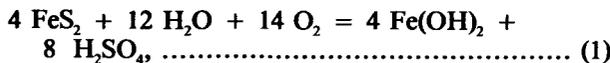
and the iron hydroxide reacts with the acid and dissolved oxygen to produce ferrous and then ferric sulphate as follows:

$$4 \ Fe(OH)_2 \ + \ 4 \ H_2SO_4 \ = \ 4 \ FeSO_4 \ + \ 8 \ H_2O, \ ... \ (2)$$

and

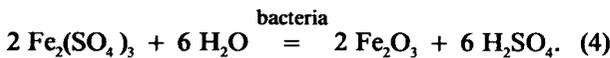$$4 \ FeSO_4 \ + \ 2 \ H_2SO_4 \ + \ O_2 \ = \ 2 \ Fe_2(SO)_3 \ + \ H_2O. \ (3)$$

The purely chemical action ends at this stage, producing greenish water with a pH value of 3,6 to 4.

If this water is not treated, certain bacteria (*Thiobacillus thio-oxydans* and *Thiobacillus ferro-oxidans*) start proliferating, and carry on the second-stage reaction:

$$2 \ Fe_2(SO_4)_3 \ + \ 6 \ H_2O \ \overset{\text{bacteria}}{=} \ 2 \ Fe_2O_3 \ + \ 6 \ H_2SO_4. \ (4)$$

The water then assumes a reddish-brown colour due to the ferric oxide rust ($Fe_2O_3$), and has a pH value of 2 or less. The amount of lime needed to neutralize this acid after reaction (4) is four times larger than that needed after reaction (3). Neutralization should therefore be effected before the bacteria can act and, preferably, as early as possible in the system.
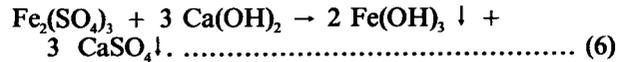
The acidification of mine water is responsible for much of the mineralization of the water since, in addition to producing sulphate, acid water accelerates the breakdown of silicate and carbonate minerals, which increases the concentration of silica, aluminium, calcium, magnesium, and manganese ions in the mine water.

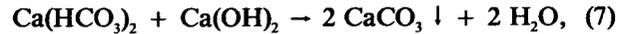The general method of neutralization employed for mine water is the addition of lime, normally in conjunction with additions of chlorine, to suppress reaction (4). Slaked lime is particularly effective if the acidic species are present in high concentrations, since the precipitation of calcium sulphate results in a marked decrease in TDS levels. The reactions involved are as follows:
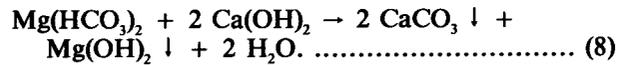
$$H_2SO_4 \ + \ Ca(OH)_2 \ \rightarrow \ CaSO_4 \ \downarrow \ + \ 2 \ H_2O, \ \text{.......} \ (5)$$

and

$$Fe_2(SO_4)_3 \ + \ 3 \ Ca(OH)_2 \ \rightarrow \ 2 \ Fe(OH)_3 \ \downarrow \ + \\ 3 \ CaSO_4 \downarrow. \ \text{..........................................} \ (6)$$

With the rise in pH, precipitation of the carbonates is also possible, thus:

$$Ca(HCO_3)_2 \ + \ Ca(OH)_2 \ \rightarrow \ 2 \ CaCO_3 \ \downarrow \ + \ 2 \ H_2O, \ (7)$$

and

$$Mg(HCO_3)_2 \ + \ 2 \ Ca(OH)_2 \ \rightarrow \ 2 \ CaCO_3 \ \downarrow \ + \\ Mg(OH)_2 \ \downarrow \ + \ 2 \ H_2O. \ \text{..............................} \ (8)$$

Additions of lime are usually controlled by pH measurements, and values in the range 6,5 to 7,5 are generally acceptable.

### Clarification

It is clear from these reactions that neutralization is effected by precipitation. Clarification of mine waters often occurs concurrently with neutralization. In addition to the natural turbidity of the water, the 'flocs' formed during neutralization are often finely divided, and small doses of coagulant are necessary to induce precipitation and settling. The following dosages are typical:

| Alum | 20 mg/l |
| Copperas | 20 mg/l |
| Ferric-floc | 10 mg/l. |

Coagulants are chemicals that produce one or more of the following actions:
(a) neutralization of the repulsive forces round the suspended solids, which enables the Van der Waals' cohesive forces to hold the particles together once they collide,
(b) the precipitation of 'sticky' flocs, such as metal hydroxides, which entangle the suspended solids and colour (such as yellow boy), and
(c) bridging of the suspended solids by natural or synthetic long-chain polymers of high molecular mass.

The most commonly used coagulants are aluminium sulphate, ferric sulphate, and ferrous sulphate. They are acidic in nature, and react with the natural or added alkalinity of the water to produce sulphates of calcium, magnesium, or sodium, as well as a gelatinous precipitate. The precipitate is assumed to be a hydroxide but has, in fact, a complex formula of varying composition.
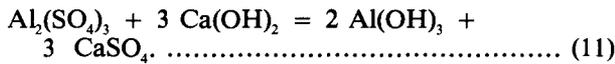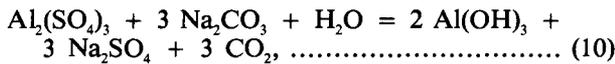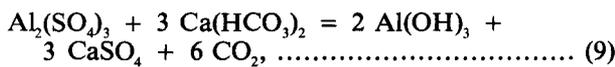
Neutralization of the negative ionic charges of the suspended particles and mechanical entanglement are involved in coagulation by the positive aluminium and iron salts. An optimum pH value is required, which

depends upon the minerals present in the water as well as on the type of coagulant used. For example, in sulphate solutions, the maximum rate of precipitation is at a pH value of approximately 6, whereas a value of 8 is required for chloride solutions. The alum floc re-dissolves at a pH value of between 10 and 11. The addition of aluminium or iron salts lowers the pH value. Additions of caustic soda, lime, or soda ash are often required to maintain the optimum pH value for coagulation.

In general, successful coagulation involves the following main factors:

(i) the presence of a minimum quantity of aluminium or iron ions to form an insoluble floc,

(ii) the presence of a strong anion such as $SO_4^{2-}$ or $Cl^-$, and

(iii) the control of pH within a definite range.

As indicated, the common coagulants are alum, ferrous sulphate, and ferric sulphate. Alum, i.e. $Al_2(SO_4)_3$, reacts with natural or added alkalinity as follows:
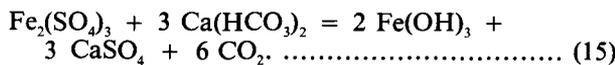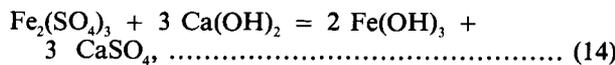
$$Al_2(SO_4)_3 + 3\ Ca(HCO_3)_2 = 2\ Al(OH)_3 + 3\ CaSO_4 + 6\ CO_2, \dots\dots\dots\dots\dots\dots \quad (9)$$

$$Al_2(SO_4)_3 + 3\ Na_2CO_3 + H_2O = 2\ Al(OH)_3 + 3\ Na_2SO_4 + 3\ CO_2, \dots\dots\dots\dots\dots \quad (10)$$

$$Al_2(SO_4)_3 + 3\ Ca(OH)_2 = 2\ Al(OH)_3 + 3\ CaSO_4. \dots\dots\dots\dots\dots\dots\dots\dots \quad (11)$$

For ferrous sulphate (Copperas), i.e. $FeSO_4 \cdot 7\ H_2O$, added alkalinity is normally required to produce the ferric hydroxide floc. This reaction occurs at a pH value of about 8,4 after the reaction of ferrous hydroxide with lime. Chlorine can also be used to oxidize ferrous hydroxide. The reactions are as follows:

$$FeSO_4 + Ca(OH)_2 = Fe(OH)_2 + CaSO_4, \dots\dots \quad (12)$$

and

$$4\ Fe(OH)_2 + H_2O = 4\ Fe(OH)_3 + H^+. \dots\dots \quad (13)$$
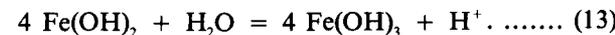
For ferric sulphate (Ferric-floc), i.e. $Fe_2(SO_4)_3$, the main reactions are

$$Fe_2(SO_4)_3 + 3\ Ca(OH)_2 = 2\ Fe(OH)_3 + 3\ CaSO_4, \dots\dots\dots\dots\dots\dots\dots\dots \quad (14)$$

$$Fe_2(SO_4)_3 + 3\ Ca(HCO_3)_2 = 2\ Fe(OH)_3 + 3\ CaSO_4 + 6\ CO_2. \dots\dots\dots\dots\dots \quad (15)$$

For all three major coagulants, the alkali normally added to give the optimum pH value is hydrated lime, soda ash, or caustic soda.

In waters low in turbidity, coagulation is more difficult than in waters that are highly turbid. The addition of clays to increase the turbidity results in better settling of the floc, and broadens the range in pH of the coagulants. This is generally not necessary in the mining environment.

Where difficulties are encountered in clarification, polyelectrolytes are often used. These are water-soluble polymers of high molecular mass that are classified as anionic, cationic, or non-ionic, depending upon whether negative, positive, or both types of ion are produced in the water. Polyelectrolytes can be used to broaden the range in pH over which the usual coagulants operate, and are normally used in very small dosages (less than 1 mg/l).

## Anti-fouling Treatments

If underground heat-exchange equipment is in use, precautions have to be taken to prevent the build-up of scale in exchanger tubes and the deposition of corrosion products and inorganic minerals. The increased use of costly mine-refrigeration equipment in South Africa's deep mines has led to more stringent control of water quality. Included in this control is the use of chemicals that clean the surfaces of heat exchangers.

Most waters used in reticulation systems contain potential scale producers or mineral constituents that can lead to fouling. Scale deposits occur when the solubility product of a particular compound is exceeded, whereas fouling is generally considered to be caused by the production and accumulation of loose mineral deposits such as silica and debris due to corrosion. Scale-forming minerals are particularly troublesome in cooling circuits since their solubility decreases rapidly with increasing temperature (Fig. 1).
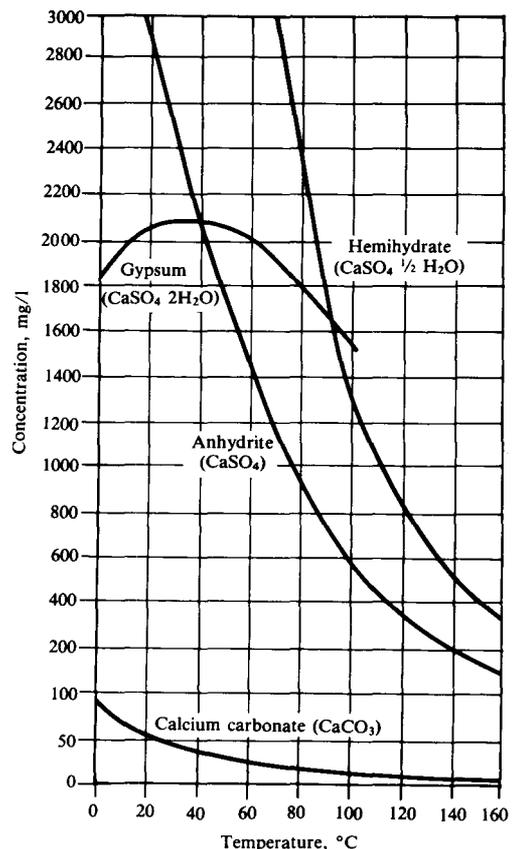


Fig. 1—Effect of temperature on the solubility of scaling salts

As already mentioned, water is recycled underground, and this recycling leads to an increase in the TDS levels. This is particularly true for cooling-water circuits, where evaporation further concentrates potential scale-forming minerals. The methods of control employed underground are as follows:

(1) the practice of blow-down, in which the TDS-loaded water is removed from the system and replaced with 'fresh' water, so reducing the overall concentration of TDS in the system,

(2) clarification, usually of the incoming stream by methods mentioned earlier,

(3) the use of chemical dispersants and crystal modifiers to prevent the precipitation of scale and to re-dissolve the precipitants, and

(4) control of the pH value of the water in the vicinity of 8,0, at which level the water will be under equilibrium conditions in terms of its carbonate content and is therefore considered to be neither aggressive nor precipitative.

If supersaturation of a particular mineral is allowed, active nuclei are formed that grow into crystals, resulting in the laying down of scales on the surface of the metal. The addition of certain surface-active agents to the water reduces the number of active nuclei available to further scaling ions, and thus reduces the formation of crystals and therefore of scale. Before 1945, organic materials such as tannins and lignins were added to cooling waters. The theory on which this was based was that certain organic materials would deform the precipitating crystals by being incorporated into them and, as a result, the crystals would not 'stick' to the hot surface. This treatment met with limited success. Molecules such as polyphosphates, phosphonates, and polycarboxylic acids are highly surface-active and, as such, are strongly attracted to the active nuclei of incipient crystals. These surface-active molecules and the crystallizing substances therefore compete for the active growth sites. Usually the scale inhibitor is adsorbed, and further crystal growth is prevented. This explains why very small amounts of inhibitor can prevent the formation of scale in the presence of high concentrations of scale-forming salts.
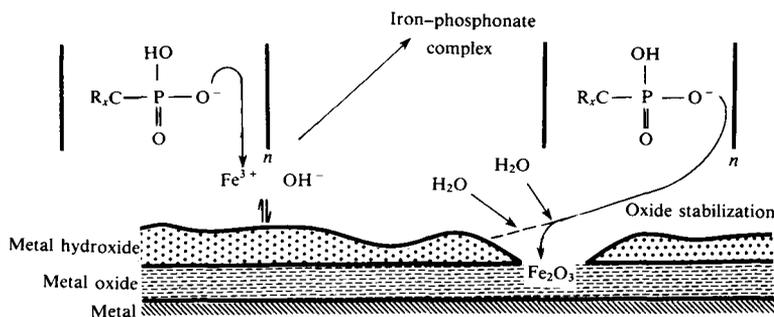
When TDS concentrations are exceptionally high, these scale inhibitors act in the same way as the tannins and lignins, producing softer scales that are usually dispersed by the movement of water. Typical scale inhibitors are the organic phosphorus compounds such as the phosphonates, polymethacrylates, and polymaleates.

All these inhibitors also possess dissolving, sequestering, or chelating properties. Therefore many deposits that arrive at the metal surface are returned to the bulk solution as a stable colloidal suspension. The proposed action of these products is illustrated in Fig. 2.
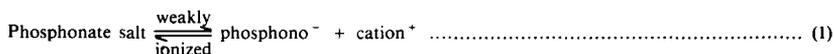
### Corrosion Inhibitors

A corrosion inhibitor[3] can be defined as a substance that, when added to a corrosive environment in small concentrations, reduces the aggressive nature of the environment by a reaction at the metal–solution interface.

Fig. 3 is a schematic diagram of the corrosion of steel in an aerated aqueous environment. The general corrosion reaction of a steel in aerated neutral water comprises two half reactions: an anodic dissolution reaction supported by the cathodic reduction of dissolved oxygen. The anodic reaction may produce ferric ions in solution, or these may combine with the local alkalinity produced by the cathode reaction to form insoluble hydroxides. This cathodic precipitation is in itself an inhibitive action, but



The reactions are as follows:

$$\text{Phosphonate salt} \underset{\text{ionized}}{\overset{\text{weakly}}{\rightleftharpoons}} \text{phosphono}^{-} + \text{cation}^{+} \quad \text{....................} \quad (1)$$

$$\text{e.g. } KA \rightleftharpoons A^{-} + K^{+}.$$

Sequestration then occurs as follows:

$$\text{Fe(OH)}_3 \underset{\text{equilibrium}}{\overset{\text{dynamic}}{\rightleftharpoons}} Fe^{3+} + OH^{-}, \quad \text{....................} \quad (2)$$

and Reaction (2) drives Reaction (1) thus:

$$Fe^{3+} + n A^{-} \rightarrow Fe[A]_n \text{ (soluble)}. \quad \text{....................} \quad (3)$$

Passivation occurs as follows:

$$Fe \xrightarrow{\text{oxidized}} Fe_2O_3, \quad \text{....................} \quad (4)$$

$$Fe_2O_3 + nA^{-} \rightarrow Fe_2O_3[A]_n \text{ (stabilized oxide)}. \quad \text{....................} \quad (5)$$

**Fig. 2—Proposed dissolving properties of scale dispersants**

the porosity of the precipitate allows continued, although slow, corrosion to occur.

There are three major types of corrosion inhibitors:
(1) passivation or anodic inhibitors,
(2) precipitation or cathodic inhibitors, and
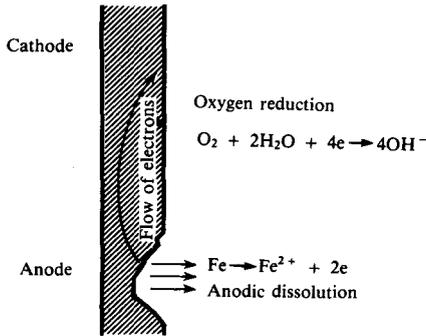(3) adsorption inhibitors.



Fig. 3—Corrosion reactions

## Passivation Inhibitors

This family of inhibitors, which includes chromates and phosphates, acts by preventing the anodic corrosion reaction, as illustrated in Fig. 4. They become incorporated into the oxide film of the metal, thus stabilizing it and stifling further dissolution.
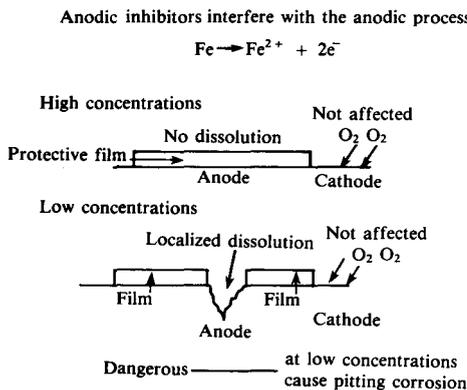


Fig. 4—Corrosion inhibitors: passivation or anodic (after Harris and Marshall[4])

The reaction of chromate with ferrous ions produces a mixture of chromium and iron oxides, which forms a protective oxide film over the anodic sites on the metal surface. If a passivation inhibitor is not present at a concentration level sufficient to block off all the anodic sites, as shown in the lower illustration of Fig. 4, then localized corrosion such as pitting corrosion can become a serious problem. This is why these inhibitors are regarded as dangerous. The concentration required to provide protection rises with the presence of anions such as chlorides and, to a lesser extent, sulphates.

## Precipitation Inhibitors

Precipitation inhibitors block the cathodic reaction by deposition at the cathode as a result of locally elevated pH (Fig. 5). Zinc salts are members of this family and, as can be seen, pitting is avoided even if complete

coverage is not attained. Precipitation inhibitors are safer than the passivation types, and act by blocking the cathodic sites. This is generally achieved by precipitating an insoluble compound onto the cathode, as shown in Fig. 5. Zinc ions are used as precipitation inhibitors because zinc hydroxide is precipitated at cathodic sites as a consequence of the locally high pH values that occur at these sites. The cathodes become blocked, and the reduction reaction of dissolved oxygen is therefore suppressed. This is in effect what was described in the precipitation of ferric hydroxide, only now the precipitate is non-porous. As can be seen, pitting is avoided even if complete coverage does not occur. This is because the current density generated over a large number of anodes when supported by relatively few cathodes is insufficient to cause overly rapid local dissolution.
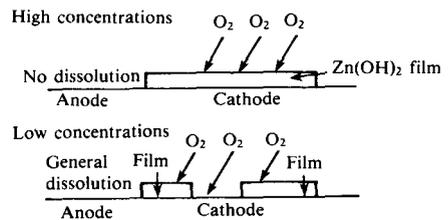


Fig. 5—Corrosion inhibitors: precipitation or cathodic (after Harris and Marshall[4])

## Adsorption Inhibitors

These are generally organic derivatives, and are usually applied to steel in acid environments. However, several have shown the ability to displace oxides from a surface film in neutral waters, e.g. phosphonates. The protection offered by adsorption inhibitors, together with the structure of some examples, is illustrated in Fig. 6.
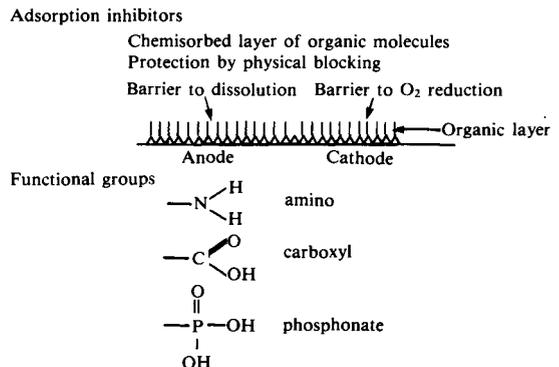


Fig. 6—Corrosion inhibitors: adsorption (after Harris and Marshall[4])

The parameters to be considered before inhibitors are used include the following:

(a) the compatibility of the inhibitor molecule with the system;

(b) the density of the inhibitor, which is important for proper mixing in the system;

(c) desirable effective solubility, i.e. some solubility is required for mixing in the system, although hydrophobicity is a prerequisite to ensure adsorption onto the corroding surface;

(d) surface-active characteristics, i.e. the inhibitor must disperse easily and be primarily hydrophobic in character, but not be so surface-active as to form soap micelles and therefore foam;

(e) the formation of sludges or precipitates due to the use of corrosion inhibitors in combination with additives such as dispersants, scale inhibitors, and biocides (because a reaction that produces any precipitate will clearly reduce the concentration of any of the reactants and therefore their effectiveness);

(f) the temperature of the system, since many inhibitors, especially many of the newer organic types, exhibit thermal degradation;

(g) the pH value of the solution;

(h) the diffusion rate through the boundary layer;

(i) undesirable ecological effects, e.g. due to the toxicity of chromates, which has resulted in the wide application of zinc and phosphates as substitutes for chromates as inhibitors; and

(j) costs, for which studies of the most economical chemicals to be used for treatment are imperative.

## Application of Inhibitors

Naturally, the various components of an industrial water system must be considered. The qualitative effects of these components on the efficiency of the inhibitor are as follows:

*Metal Cations.* In general, monovalent cations do not interfere with inhibition, unlike divalent cations, which form protective precipitates at moderate concentrations, but precipitate inhibitors such as phosphate and silicates at high concentrations.

*Alkali (OH⁻).* As indicated, corrosion is controlled by oxygen diffusion. Steel can be passivated, but amphoteric metals such as zinc, aluminium, and lead will corrode considerably above a pH value of 9.

*Chloride (Cl⁻).* Chloride ions are strongly adsorbed by steel, making it difficult to passivate, and the amount of inhibitor required rises in proportion to the chloride concentration.

*Sulphate.* Although not as severe in effect as chloride, sulphates can depassivate a surface by precipitation and cause certain inhibitors to coagulate.

*Sulphides.* Many metal ions are precipitated by sulphides, and oxidizing inhibitors are reduced by sulphide, requiring great concentrations for effectiveness.

*Oxygen.* The reduction of dissolved oxygen to less than 1 mg/l can support steel passivation. Organic inhibitors are generally not effective against oxygen-based corrosion unless passivating groups such as benzoates or sulphonates are present.

*Acids.* Corrosion rates are increased by an increase in the concentration of hydrogen ions, and passivating inhibitors cannot be used. Non-passivating inhibitors (e.g.

propargyl alcohol and pyridines) are preferred in pickling acids such as hydrochloric acid.

*Bicarbonate.* In hard water, deposited mineral scales will impede corrosion but, in soft water, excess carbon dioxide will produce acidic conditions requiring the addition of inhibitors.

Inhibition in cooling circuits requires more than the simple addition of inhibitors; the conditions must be favourable if the inhibitor is to work effectively. The factors that affect the inhibition of cooling waters include the following:

(i) oxygen saturation at the cooling towers,

(ii) ingress of water-soluble gaseous components (such as sulphur dioxide) owing to the scrubbing action of the towers,

(iii) pH (the optimum pH range must be maintained),

(iv) TDS of the make-up water,

(v) algae spores, which may proliferate readily (against which biocides, chlorine, chloramines, chlorophenates, and quaternary ammonium salts are effective),

(vi) contamination due to leakages (e.g. refrigerant),

(vii) sulphate-reducing bacteria that produce hydrogen sulphide under slime deposits and cause local corrosion, and

(viii) silt and solids.

Silt and solids present special problems because solids coagulate at high temperatures and settlement allows attack as a result of differential aeration. Dispersants are often added to keep the solids in solution, but pretreatment of the water is preferable.

Mixtures of inhibitors frequently provide better inhibition than similar concentrations of individual components. Harris and Marshall[5] have illustrated a method for the selection of inhibitors for various applications based upon the Ryzner index of the water, and the potential or existing problem. This is shown in Fig. 7.

## Conclusion

Water treatment in general and corrosion inhibition in particular require a knowledge and careful study of the system used and the water type. The water must be rendered biologically inactive to aid efficient neutralization. Clarification is rapid in a well-neutralized, balanced water. The removal of TDS aids the efficient use of scale dispersants, and all these methods if carried out with care provide a water that is amenable to a cost-effective programme of corrosion control.

## References

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2. KEMPE, J.O. Water pollution control in the mining industry. *Coal, Gold, Base Miner.,* Aug. 1981. p. 115.

3. WHITE, R.T. A review of corrosion inhibitors: theory and practice. Randburg, Council for Mineral Technology, *Report* M66. 1983. 27 pp.
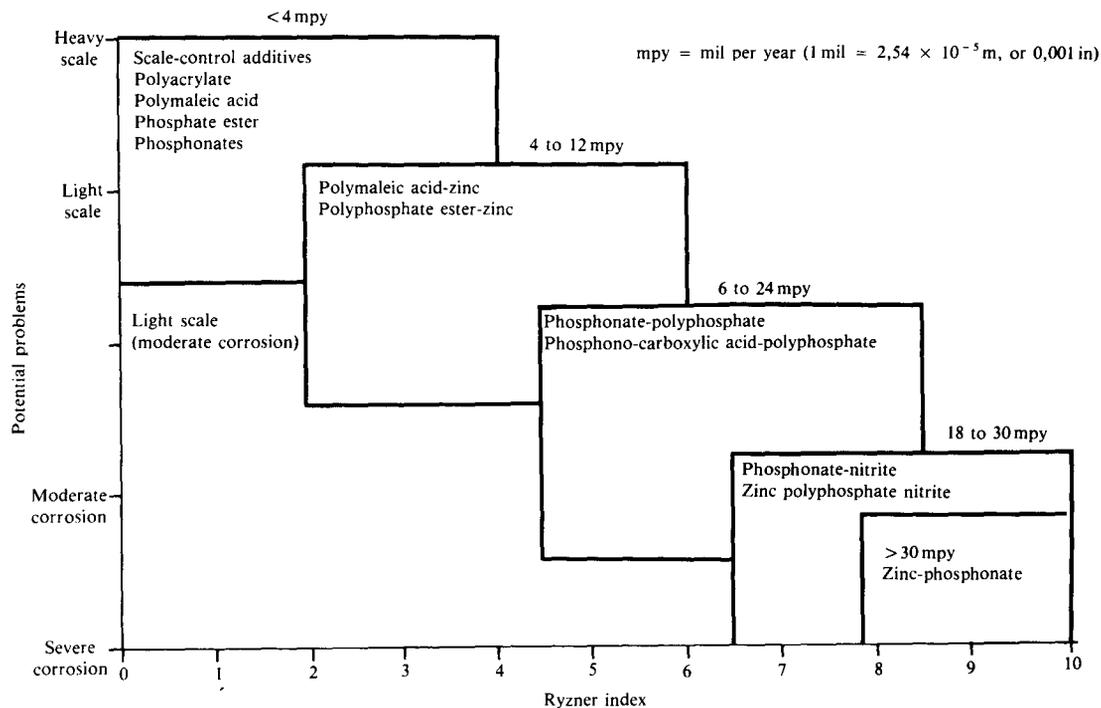
<4 mpy

Heavy scale

Scale-control additives
Polyacrylate
Polymaleic acid
Phosphate ester
Phosphonates

mpy = mil per year (1 mil = 2,54 × 10⁻⁵ m, or 0,001 in)

Light scale

4 to 12 mpy

Polymaleic acid-zinc
Polyphosphate ester-zinc

Potential problems

6 to 24 mpy

Light scale
(moderate corrosion)

Phosphonate-polyphosphate
Phosphono-carboxylic acid-polyphosphate

18 to 30 mpy

Phosphonate-nitrite
Zinc polyphosphate nitrite

Moderate corrosion

>30 mpy
Zinc-phosphonate

Severe corrosion

0    1    2    3    4    5    6    7    8    9    10

Ryzner index

**Fig. 7—A chart for the selection of inhibitors (after Harris and Marshall[5])**

4. HARRIS, A., and MARSHALL, A. The control of corrosion in industrial cooling water systems (1). *Corros. Prev. Control*, vol. 27, no. 3. Jun. 1980. pp. 18–21.

5. HARRIS, A., and MARSHALL, A. The control of corrosion in industrial cooling water systems (2). *Corros. Prev. Control*, vol. 27, no. 4. Aug. 1980. pp. 17–21.

# IPMI seminar

The International Precious Metals Institute will hold a Noble Metals Fabrication and Technology Seminar in Jerusalem, Israel, from 27th April to 5th May, 1985. The organizing chairmen, Drs Leah Gal-Or, John P. Nielsen, and Christof Raub, have planned five sessions of outstanding technical papers and one full day of plant visits. A hospitality programme of tours, receptions, and banquet has also been arranged for the delegates and accompanying persons.

A brief summary of the technical programme by session includes:

Session I *General Subjects*

'Dental Alloys – Precious Metals or Nickel?', 'Silver as Contaminate in Fine Gold', 'Electroforming of Gold Objects', 'Industrial Uses of Platinum Group Metals', 'Quality Control in Jewellery Manufacture and its Relationship to International Hallmarking Requirements', 'Inventory Management of Precious Metals'.

Session II *Precious Metals Investment Casting*

'Investment Casting of Jewellery Alloys – Problems and Solutions', 'The Mesh Monitor for Casting Characterization', 'The Razor-Blade Monitor for Casting Characterization', 'Casting Characteristics of Palladium Dental Alloys'.

Session III *Jewellery*

'Structure, Phase Transformations, Thermal and Mechanical History and Technological Properties of Some 18 Carat Gold Jewellery Alloys', 'Technical and Economic Advantages Achieved Through the Use of Brazing Pastes in Manufacturing Jewellery', 'Platinum Alloys for Jewellery Applications', 'Procedures for Small-scale Refining of Jeweller's Scrap', 'International Marketing of Jewellery and Non-Tariff Barriers'.

Session IV *High Technology I*

'Gold and Platinum Metals in the Electronic Industry', 'The Recent Technology of Precious Metal Plating for the Connector Field in Japan', 'Sputtered Metallization for Hybrid Devices', 'Gold Contact Cladding Technique', 'Sputtering of Precious Metals for Seminconductor Applications'.

Session V *High Technology II*

'Previous Metal Dental Alloys', 'Hardening Mechanism in Gold–Copper–Silver Alloys', 'Electrodeposition of Platinum from Molten Salts', 'Laser Induced Plating of Gold on Metallic and Non-Metallic Substrates', 'Gold Wire Bonding for Microelectronics'.

A complete programme of the technical papers to be presented and their authors, along with information on travel arrangements, accommodation, tours, and fees, can be obtained from the Secretariat:

International Precious Metals Institute
Government Building, ABE Airport
Allentown, PA 18103, U.S.A.
Telephone: 215/266-1570.

# Ninetieth Birthday — 1894/95 to 1984/85

by DORIS GARDNER*

The current Council Session (1984/85) of The South African Institute of Mining and Metallurgy is the 90th Session of this august body.

## Inauguration

At the beginning of 1894, certain members of the profession who interchanged ideas among themselves felt that more benefit would be derived if a larger number of chemists and metallurgists were to meet for that specific purpose. To ascertain the general opinion of the practicability of forming a professional society, a dinner was held on 10th March, 1894, at the North-western Hotel in Johannesburg. Some 60 people were present, and the support for such a Society was so great that a meeting was called for 24th March of the same year.

Only 14 people attended that meeting but, in spite of this, a committee was appointed to draft the first Constitution and By-laws of the Society. The Constitution and By-laws were adopted at a meeting held on 14th April, 1894, at which 21 people were present. A further meeting was held on 21st April, 1894, and it was at this meeting that the first Office Bearers were elected from among the 34 foundation members.

The preparations were complete, and the Institute began its existence as the Society of Chemists and Metallurgists of South Africa, with the first President, Mr W. Bettel, giving his inaugural address at a meeting on 19th May, 1894.

## Early Years

The proceedings of the first Annual General Meeting, held on Saturday evening, 15th June, 1895, contain very interesting facts about the first year—not the least of which is the fact that a profit of £133.7s.3d. was made. The subscriptions at that time were two guineas, and the raising of the subscriptions to three guineas for members living within the toll gates was discussed. It is not known from the annual report whether the increase ever took place. In January 1897 the total membership of the Society stood at 111. The Council continued to meet on a regular basis until October 1899, when, with the outbreak of the Anglo-Boer War, no further meetings were held until 10th May, 1902.

## Change of Name

It appears that all the meetings held so far had taken the form of a discussion around one or more technical papers that had been read at the beginning of the meeting. At an ordinary monthly meeting held on 20th September, 1902, Mr D.J. Williams pointed out that papers were being read before Council that were neither chemical nor metallurgical, and he proposed that the name of the Society should be changed to include the word *mining*. The matter was referred to Council for a decision, and

was obviously discussed during a Council meeting because various names were put forward as suggestions to the meeting held on 15th November, 1902. A proposal was made that the name should be changed to The Chemical and Metallurgical Society and Mining Institute of South Africa, and it was agreed that this proposal should be put forward at a Special General Meeting.

This Special General Meeting was held on 20th December, 1902, and there was naturally a great deal of reluctance to change the name on the part of a number of members. Mr A. Whitby, who appeared to be the main person against the change, said, 'If we are to introduce mining proper into our deliberations, we must include a number of subjects which are far removed from the consideration of chemists and metallurgists. We have no concern with timbering, winding, drills, dykes, faults, or any of the thousand and one problems connected with mining, which come within the province of the engineer, surveyor, or geologist'. He stated further, 'We have been twitted with the name of the Cyanide Club, and some are inclined to consider it a term of reproach, but I argue that the Society has merely done the work called for'. In fact, the deliberations carried on for so long that the meeting ended without finality having been reached.

At the following monthly meeting, held on 24th January, 1903, it was proposed that a Special General Meeting should be convened to discuss a change in the Society's name to The Chemical, Metallurgical and Mining Society of South Africa. A vote was taken, and the Special General Meeting was convened for 21st February, 1903. This meeting was attended by 128 Members, and a ballot was held; the outcome was 92 for the motion and 36 against. The Society continued under this name until 1956, when a Special General Meeting was called on 27th June to consider once again a change in name. There were 58 members present, and it was proposed that the name should be changed to its present form, i.e. The South African Institute of Mining and Metallurgy. The motion was carried unanimously, and the meeting lasted 6 minutes.

## The Present Time

Today the Institute has a membership of more than 2400 and continues to grow in numbers. It is apparent that the initial aims of the first Council are being adhered to. These, as stated by Mr W. Bettel in his inaugural address, are 'to promote good fellowship among its members, and by social intercourse, interchange of ideas, and research, aided by the formation of a reference library . . . to keep abreast of scientific progress'.

'Happy 90th Birthday, SAIMM, and may you see many more'.

To celebrate the 90th Anniversary, a banquet was held at the Carlton Hotel on 22nd March, 1984, which was much enjoyed by all who attended.

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