Recovery of energy from the water going down mine shafts

by A. WHILLIER*, Pr. Eng., Sc. D. (M.I.T.) (Fellow)

SYNOPSIS

The influence of energy-recovery systems on the rise in temperature of water going down mines is examined. It is concluded that the cost benefit of such systems, deriving partially from the reduced temperature rise in situations where cold water is sent underground from surface, would more than justify the installation cost.

SAMEVATTING

Die invloed van energieherwinningstelsels op die temperatuurstyging van water wat in die myne afgaan, word ondersoek. Die gevolgtrekking wat gemaak word, is dat die kostevoordeel van sulke stelsels, deels op grond van die kleiner temperatuurstygings op plekke waar koue water van die oppervlak af ondergronds gestuur word, die installeringskoste heeltemal sal regverdig.

Introduction

A consequence of the use of mine service water for the distribution of coolness to the stoping areas of deep mines is that in many instances some of the refrigeration plant can be located beneficially on the surface. Two drawbacks of surface-located refrigeration plant are the high cost in pumping the service water back to surface, and the rise in temperature of the water (by $g/Cp=9{,}79/4{,}19=2\frac{1}{3}$ °C per km of depth) resulting from the dissipation by friction of the potential energy of the water into thermal energy.

It has been suggested that some of the potential energy of the downgoing water could be recovered in a simple water turbine, so as to at least halve the net pumping power demand. Such an arrangement would have the added advantage of halving the increase in temperature of the water, giving a substantial increase in cooling available in the stopes.

The additional cost involved in an energy-recovery system arises from the need for a high-pressure pipe with a larger diameter in place of the conventional small low-pressure pipe for the downgoing water. This is in addition to the cost of the turbine itself.

This paper gives an outline of the influence of such energy-recovery systems on the temperature rise of the water, and of the cost benefits arising from their use. The nomenclature is given at the end of the paper.

Mollier Diagram for Water

A portion of a Mollier diagram for water, in which the energy content (enthalpy) is plotted against entropy, is shown in Fig. 1. In this diagram, three lines of constant pressure are shown rising up towards the right, and being intersected by almost vertical lines of constant temperature. The three isobars correspond to water at ambient pressure, 1000 m deep and 2000 m deep respectively. The isobars are almost straight, having a slope equal to T, the absolute temperature. The vertical distance separating these lines is about 9,8 kJ/kg. The entropy is not given since it is not required in any of the calculations.

The isotherms on such a Mollier diagram are vertical at temperatures between 3 and 4 °C (where water has its maximum density) but slope increasingly to the left at higher temperatures. At 15 °C, the deviation from true vertical is about 0,1 °C over a depth of 1000 m. For the purposes of this report, these small deviations of the isotherms from the vertical will be neglected. (The effect becomes significant only when it is desired to deduce the efficiency of water pumps or turbines from measurements of the change in temperature across such devices.)

In order to illustrate the use of the Mollier diagram, an example will be considered in which water at 10 °C is assumed to flow down a pipe to a depth of 1000 m. This water on entering the pipe would be represented by the point a in Fig. 1.

Heat transfer between the water and its surroundings will be neglected, since the effect of such heat transfer on the temperature of the water would be additive, and therefore corrections for any assumed rate of heat transfer can be made later if needed.

Ideal Frictionless Flow

If the flow of water down the pipe were frictionless (or if there were no flow), the pressure increase, Δp, corresponding to a change in depth Δz would be

$$\Delta p=\rho\, g\, \Delta z. \qquad (1)$$

The average density of the water in the pipe would be about 1001 kg/m^3, and, with the value of g for South Africa taken as 9,79 m/s^2, the increase in pressure corresponding to a depth of 1000 m is about 9,8 MPa (98 bar or 1421 lb/in^2). The absolute pressure of the water at the bottom of the pipe would hence be 9,8+0,1=9,9 MPa (99 bar).

Since in this case the flow is assumed to be frictionless and adiabatic (no exchange of heat with the surroundings), the process would be isentropic, and therefore would follow a vertical line in Fig. 1 from point a to point f. The temperature of the water at point f is practically identical to the temperature at point a.

The increase in energy content of the water for this process would be

$$\Delta h=h_f-h_a=g\,\Delta z=\bar{v}\,\Delta p, \text{ i.e.} \qquad (2)$$

$$\Delta h=9{,}79 \text{ kJ/kg per 1000 m depth.}$$

*Environmental Engineering Laboratory, Chamber of Mines of South Africa, Johannesburg.

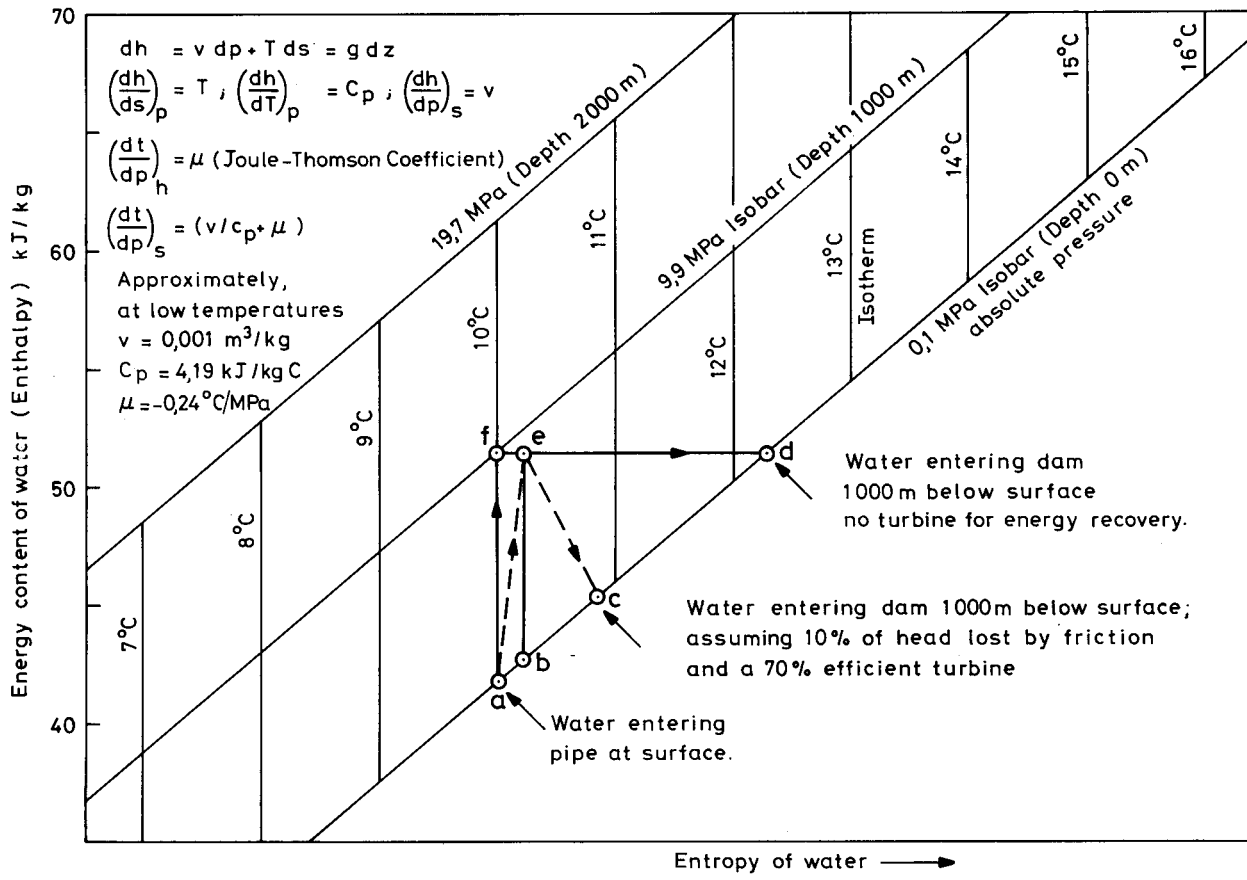


Fig. 1—Mollier diagram for water

Frictional Flow

If the water at high pressure in the bottom of the pipe were permitted to escape through a valve into a dam, the high pressure would create a very high velocity through the valve, which in turn would be dissipated in the dam by turbulence and friction. This frictional dissipation process from high pressure to low pressure (often referred to as expansion, particularly where gases are involved) is a process of constant energy content of the water, or constant enthalpy, represented by a horizontal line in Fig. 1 from *f* to *d*.

At point *d* the water is again at ambient pressure, which is assumed to be 100 kPa (1 bar or 0,1 MPa). It will be seen that the temperature of the water has now increased by 2,33 °C in going from point *f* to point *d*. This increase in temperature can be calculated by considering the isobar from *a* to *d*, since, *for constant pressure*, the enthalpy and temperature are related by the specific heat at constant pressure, *Cp*, as follows

$$(\Delta h)_p = Cp\ \Delta t \quad (3)$$

The increase in enthalpy between *a* and *d* is the same as the increase between *a* and *f*, namely 9,79 kJ/kg, so that the rise in temperature from *a* to *d*, if the specific heat of water at this temperature is assumed to be 4,19 kJ/kg C, is

9,79/4,19=2,33 °C.

If it is recollected that this calculation is for a depth of 1000 m, it will be seen that the rise in temperature of water flowing down a vertical pipeline and ending at ambient pressure in a dam at the bottom is 2,33 °C per kilometre of depth.

It is irrelevant whether the frictional dissipation takes place continuously down the pipeline, which would occur if the pipeline were operated at terminal velocity, or whether the dissipation occurs entirely at the exit end of the pipeline as was assumed above.

Recovery of Energy

When energy is to be recovered from the water going down a shaft, the pipeline must be sized so as to keep the velocity of the water at about 3 m/s if the friction losses are to be kept reasonably small. If, for example, the friction losses are 10 per cent of the total head, the pressure of the water reaching the bottom of the pipe would be equivalent to a head of 900 m and the temperature would have increased by 0,233 °C. This condition is represented by point *e* in Fig. 1.

If this water were passed through a perfect turbine, the water would return to ambient pressure along a line of constant entropy ending up at point *b* in Fig. 1. If, on the other hand, a turbine of say 70 per cent efficiency were used, the final condition of the water would be as represented by point *c* in Fig. 1.

The turbine efficiency, η_T, is defined as

$$\eta_T = (h_e - h_c)/(h_e - h_b). \quad (4)$$

The temperature of the water leaving the turbine at a condition corresponding to point *c* can be read off Fig. 1,

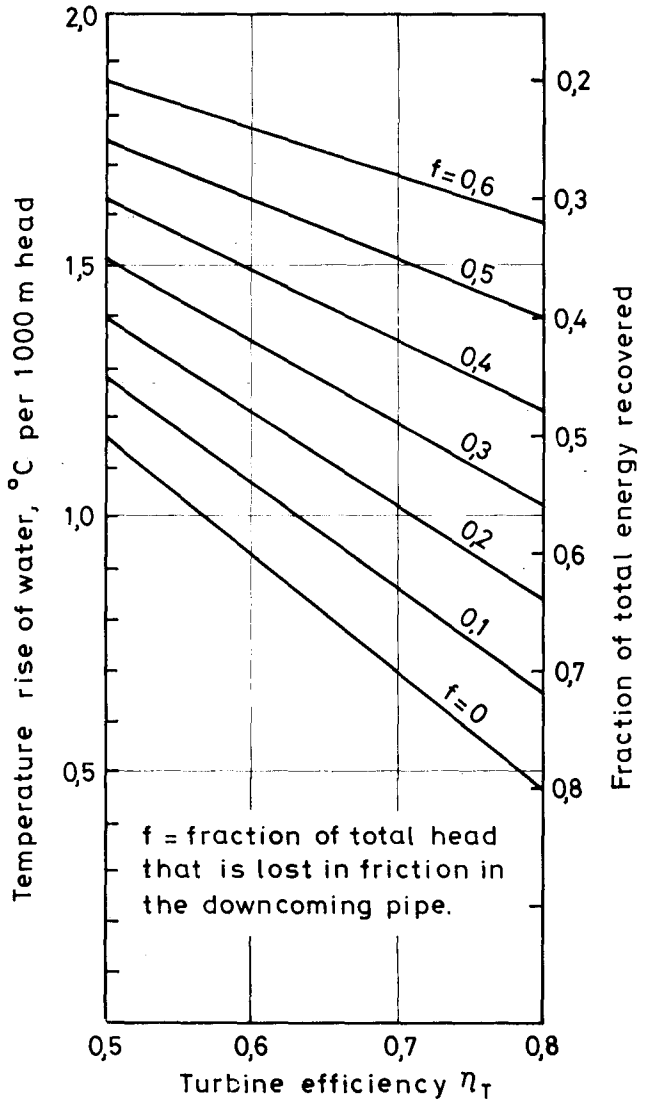


Fig. 2—Influence of energy recovery on temperature rise of the water

or it can be calculated from equation (5):

$$(t_c - t_a) = [f + (1-\eta_T)(1-f)]\,[0{,}00233\,H], \quad . \; . \; . \; . \quad (5)$$

where η_T = efficiency of the turbine,

f = fraction of the total head that is lost in friction,

H = total head in metres, and

$g/Cp = 0{,}00233\,°C/m$.

For the above example with $\eta_T = 0{,}7$, $f = 0{,}1$, and $H = 1000$ m, equation (5) gives the temperature rise as 0,862 °C, which is only 37 per cent of the original rise of 2,33 °C.

In order to facilitate calculations, equation (5) has been plotted in Fig. 2 for various assumed values of f and η_T. The left-hand scale in Fig. 2 indicates the actual rise in temperature of the water per 1000 metres of depth, while the right-hand scale indicates the fraction of the total energy that is recovered for different combinations of f and η_T.

Additional Cooling in Stopes

In addition to the saving in the net power costs for pumping, an energy-recovery system has a benefit in making more cooling available in the stopes. This can be illustrated by consideration of a case where the water goes down 2000 m before reaching the stoping horizon of a mine. The temperature of the water would increase by $2 \times 2{,}33 = 4{,}66$ °C if no energy-recovery system were used, but by only 1,73 °C on the assumption of a pressure-recovery system with $f = 0{,}1$ and $\eta_T = 0{,}7$. The difference $(4{,}66 - 1{,}73) = 2{,}93$ °C represents additional cooling that would be available for the stopes. Thus, if the water is sent down the shaft at 10 °C and is pumped out of the mine at 30 °C, the increase in cooling is (2,93)/(30—14,66) or 19 per cent. On the other hand, if the water were sent down the mine from the surface at 0 °C, the additional cooling would amount to (2,93)/(30—4,66) or 11,6 per cent. Both represent a very considerable increase in the cooling that would be available at the stopes.

Cost Benefit

In order to illustrate the cost benefit of a pressure-recovery system, an example will be considered with the following assumptions.

Effective depth to stoping horizon	2000 m
Water flow-rate down shaft (24-hour average)	100 l/s
Fraction of energy recovered	0,6
Annual cost of 1 kW (electric)	R60
Annual value of 1 kW of cooling	R100

Theoretical power $= m\,g\,H = 100$ l/s $\times 9{,}79 \times 2000/1000 = 1958$ kW

Rate of recovery of energy $= 0{,}6 \times 1958 = 1170$ kW

Value of energy recovered, at R60 p.a. per kW is $1170 \times 60 =$ R70 488 p.a.

From Fig. 2, the rise in temperature of the water with 60 per cent recovery of energy is 0,93 °C per kilometre or 1,86 °C for a depth of 2 km.

Temperature-rise without energy recovery $= 2 \times 2{,}33 = 4{,}66$ °C.

Additional cooling in stopes resulting from the lower temperature of the water is

100 l/s $\times 4{,}19 \times (4{,}66 - 1{,}86) = 1170$ kW.

Annual value of the extra cooling = R117 000 p.a.

The total annual cost benefit of energy recovery (at 60 per cent efficiency) is as follows:

R70 488 + R117 000 = ≈ R187 000 p.a.

Note At a 50 per cent recovery of energy, the cost benefit would be R58 740 + R97 394 = ≈ R156 000.

These annual cost benefits would justify an expenditure of about R500 000 on the energy-recovery system, which is far in excess of the actual cost of such systems.

Conclusion

The examples given in this report suggest that the investment in energy-recovery systems in shafts where cold service water is sent underground from surface would be well justified.

Nomenclature

Cp Specific heat of water at constant pressure, 4,19 kJ/kg °C

f Fraction of head dissipated in friction

g Local gravitational acceleration, 9,79 m/s^2
H Vertical depth of pipe, m
h Enthalpy (energy content) of water, kJ/kg
p Pressure, Pa or MPa
t Temperature, °C
$\bar{v}$ Average specific volume of water, m^3/kg
z Vertical distance, m
η_T Efficiency of energy-recovery turbine
ρ Average density of water in the pipe, kg/m^3

Acknowledgement

This report arises from work carried out as part of the research programme of the Research Organisation of the Chamber of Mines of South Africa.

Company Affiliates

The following members have been admitted to the Institute as Company Affiliates.

AE & CI Limited.
Afrox/Dowson and Dobson Limited.
Amalgamated Collieries of S.A. Limited.
Apex Mines Limited.
Associated Manganese Mines of S.A. Limited.
Billiton Exploration S.A. (Pty) Limited.
Blackwood Hodge (S.A.) Limited.
Blyvooruitzicht G.M. Co. Ltd.
Boart International Limited
Bracken Mines Limited.
Buffelsfontein G.M. Co. Limited.
Cape Asbestos South Africa (Pty) Ltd.
Compair S.A. (Pty) Limited.
Consolidated Murchison (Tvl) Goldfields & Development Co. Limited.
Deelkraal Gold Mining Co. Ltd.
Doornfontein G.M. Co. Limited.
Durban Roodepoort Deep Limited.
East Driefontein G.M. Co. Limited.
East Rand Prop. Mines Limited.
Engineering Management Services (Pty) Ltd.
Envirotech (Pty) Ltd.
Free State Saaiplaas G.M. Co. Limited.
Fraser & Chalmers S.A. (Pty) Limited.
Gardner-Denver Co. Africa (Pty) Ltd.
Goldfields of S.A. Limited.
The Grootvlei (Pty) Mines Limited.
Harmony Gold Mining Co. Limited.
Hartebeesfontein G.M. Co. Limited.
Highveld Steel and Vanadium Corporation Limited.
Hubert Davies Heavy Equipment (Pty) Ltd
Impala Platinum Limited.
Ingersoll Rand Co. S.A. (Pty) Ltd.
Johannesburg Consolidated Investment Corp. Ltd.
Kinross Mines Limited.
Kloof Gold Mining Co. Limited.
Lennings Holdings Limited.
Leslie G.M. Limited.
Libanon G.M. Co. Limited.
Lonrho S.A. Limited.
Loraine Gold Mines Limited.
Marievale Consolidated Mines Limited
Matte Smelters (Pty) Limited.
Natal Cambrian Collieries Limited.
Northern Lime Co. Limited.
O'okiep Copper Company Limited.
Otjihase Mining Co. (Pty) Limited.
Palabora Mining Co. Limited.
Photometric Sorters.
Placer Development S.A. (Pty) Ltd.
President Steyn G.M. Co. Limited.
Pretoria Portland Cement Co. Limited.
Prieska Copper Mines (Pty) Limited.
Rand Mines Limited.
R. J. Spargo Limited
Rooiberg Minerals Development Co. Limited.
Rustenburg Platinum Mines Limited (Union Section).
Rustenburg Platinum Mines Limited (Rustenburg Section).
St. Helena Gold Mines Limited.
Shaft Sinkers (Pty) Limited.
S.A. Land Exploration Co. Limited.
Stilfontein G.M. Co. Limited.
The Griqualand Exploration and Finance Co. Limited.
The Messina (Transvaal) Development Co. Limited.
The Randfontein Estates Gold Mining Co.Witwatersrand Ltd.
The Robbins Co. (Africa) (Pty) Ltd.
The Steel Engineering Co. Ltd.
Trans-Natal Coal Corporation Limited.
Tvl Cons. Land & Exploration Co.
Tsumeb Corporation Limited.
Union Corporation Limited.
Vaal Reefs Exploration & Mining Co. Limited.
Venterspost G.M. Co. Limited.
Vergenoeg Mining Co. (Pty) Limited.
Vlakfontein G.M. Co. Limited.
Welkom Gold Mining Co. Limited.
West Driefontein G.M. Co. Limited.
Western Areas Gold Mining Co. Ltd.
Western Deep Levels Limited.
Western Holdings Limited.
Winkelhaak Mines Limited.

Gravity-fed water systems in mines

by A. WHILLIER*, Pr. Eng., Sc. D. (M.I.T.) (Fellow) and
J. VAN DER WALT*, Pr. Eng., B.A. Hons. (Bus. Admin.), Ph.D. (Eng.) (Visitor)

SYNOPSIS

South African mines often experience significant losses in production because of recurring shortages of water at work places as the result of underground dams running dry. Similar shortages have occurred during fire-fighting operations, and now, with the use of cold service water to aid in the cooling of mines, it is even more necessary that such shortages should be prevented.

This paper draws attention to the primary cause of such water shortages, and an outline is given of some of the fundamental hydraulic principles that must be followed in the design of gravity-fed water-supply systems on mines.

SAMEVATTING

Suid-Afrikaanse myne ondervind dikwels betekenisvolle verliese in produksie vanweë herhaalde watertekorte by werkplekke omdat ondergrondse damme opdroog. Dergelike tekorte het al tydens brandbestrydingswerk voorgekom en met die gebruik van koue dienswater om met die verkoeling in myne te help is dit tans nog meer noodsaaklik om sulke tekorte te voorkom.

Hierdie referaat vestig die aandag op die primêre oorsaak van sulke watertekorte en gee in hooftrekke 'n paar van die grondliggende hidroulikabeginsels wat by die ontwerp van watervoorsieningstelsels met swaartekragtoevoer in myne toegepas moet word.

Introduction

It is common for South African mines to experience significant losses in production because of recurring shortages of water at work places as the result of underground dams running dry. Similar shortages have been experienced during fire-fighting operations. Now, with the advent of cold service water to aid in the cooling of mines, it is becoming even more necessary to prevent shortages of water.

Usually, such shortages are attributed to the small diameters of pipes carrying the water down the shaft. However, in most instances it is not the size of the pipes in the shaft that is at fault (in fact they are often too large), but rather that the piping arrangement for getting the water from the dams into the vertical pipes in the shaft is hopelessly inadequate. The reason for this is that the construction of the dams and of the pipes leading from the dams does not always follow sound hydraulic practice.

Sound practice for conveying water down pipes in shafts requires proper recognition of the following principles.

(a) The water tends to flow down the pipe at such a velocity that the frictional loss of head just balances the available vertical head. Thus, the speed of the water increases until the friction head loss (expressed as metres of water gauge per metre length of pipe) approaches $\sin \phi$, where ϕ is the angle of inclination of the shaft. For vertical shafts, $\sin \phi = 1$, and the limiting velocity occurs when the frictional head loss is 1 m of water per metre length of pipe. (Further discussion in this paper will refer only to vertical piping systems.)

(b) Any restriction in the approach pipe leading to the shaft will tend to cause a negative gauge pressure in the pipe column. In other words, the water flowing down a vertical pipe tends to draw water into the approach pipe.

(c) When the pressure in the approach pipe is sub-atmospheric (that is, when the gauge pressure is negative), there is a tendency for air to be drawn into the pipe through a vortex at the entrance to the pipe.

(d) If the absolute pressure anywhere in the pipe column approaches the saturation pressure of the water (5 kPa at a water temperature of 33 °C, 1 kPa at 7 °C), some of the water at that position will vaporize, with a large increase in volume. An instant later, this water and steam will have entered a zone where the pressure is slightly higher than the vapour pressure, and the vapour will condense instantaneously with a consequent inrush of water to fill the 'hole' created by the condensing vapour. This phenomenon, which can be heard easily at some distance from the pipe, is known as cavitation and can cause very high pressure surges in pipelines, often fracturing the pipes. It also severely restricts the flow-rate of water in the pipe.

(e) To avoid any possibility of negative gauge pressures, the approach pipe system leading from the dam to the shaft must be designed so that the available head of water in the dam is able to accelerate the water to the required velocity and to overcome frictional losses in this pipe at least as far as the shaft. This requires that the diameter of the approach pipe leading from the dam to the shaft should be considerably greater than the diameter of the pipe down the shaft. It also requires that a tapered inlet be provided at the entrance to the pipe so as to avoid a *vena contracta* at this point, since the velocity of the water in the *vena contracta* is about 40 per cent greater than the nominal velocity of the water in the pipe.

(f) Care must be taken that pipe sections on different elevations leading to the shaft are sized on the basis of the available upstream head of each section, and not on the basis of the total head for the entire pipeline.

*Environmental Engineering Laboratory, Chamber of Mines of South Africa, Johannesburg.

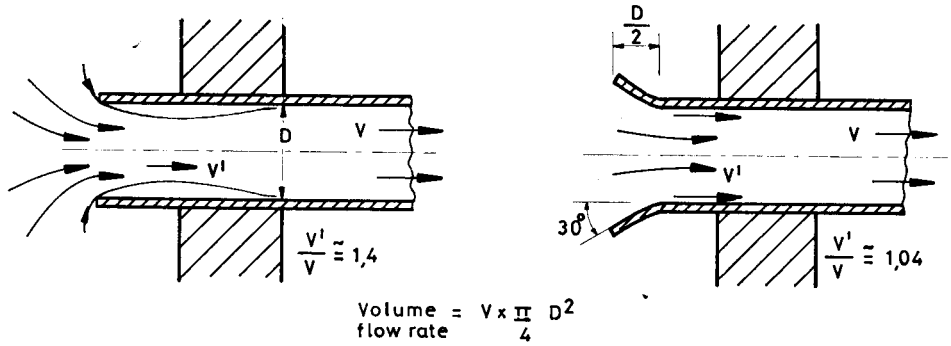


Fig. 1—Effect of shape of pipe inlet on the vena contracta

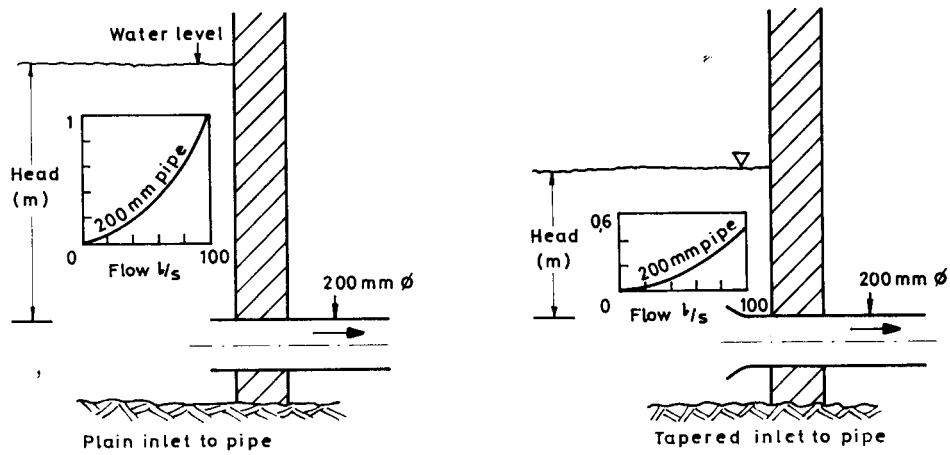


Fig. 2—Minimum water depth (above top of pipe) to achieve the flow-rates indicated

Estimation of Water-flow Capacities

A useful rule-of-thumb guide to the sizing of pipes is that the water flow-rate in litres per second at a nominal velocity of 2 m/s is equal to the square of the pipe diameter expressed in inches. Thus, a 100 mm (4 inch) pipe will carry 16 l/s, while a 200 mm (8 inch) pipe will carry 64 l/s, both at 2 m/s.

Effect of the Vena Contracta

If the water flows at a rate of 100 l/s from a dam through a 200 mm pipe in which the entrance shape is as illustrated in Fig. 1, the nominal velocity in the pipe would be $(100/1000)/(\pi/4\times0{,}2^2)=3{,}18$ m/s, and the head necessary to accelerate the water to this velocity, $(V^2/2g)$, would be $3{,}18^2/(2\times9{,}79)=0{,}52$ m. Thus, if air is not drawn into the pipe, the depth of water in the dam would have to be more than 0,52 m above the *top* of the pipe. This is illustrated in Fig. 2.

If the pipe does not have a shaped inlet, the water velocity at the *vena contracta* would be about 40 per cent greater than the nominal velocity, or 4,45 m/s, and the corresponding head, $V^2/2g$, necessary to accelerate the water to this velocity would be 1,01 m. Thus, in this case the depth of water in the dam to avoid air being drawn into the pipe would have to be at least 1,01 m above the top of the pipe.

It is well known that, during periods of heavy demand for water in mines, the levels of dams fall to a few centimetres above the pipe inlets, so that the rate of water flow is reduced considerably, resulting in shortages of water. The problem is not that the water is drawn too rapidly from the dams, but rather that the feeding of water into the dams is too slow because of inadequate design of the inlet opening in the pipes all the way up the shafts, often starting at the main supply dam at the top of the shaft.

The calculations above indicate that, for the example considered and for a straight inlet to the pipe, the water level must remain at a height greater than about 1 m above the top of the outlet pipe if full flow is to be maintained to the lower levels. Thus, the effective storage or surge volume in the dam is reduced considerably, being only the volume of water above this 1 m level to the top of the dam wall. It will be apparent therefore that, with the usual design of pipe inlets, the useful storage volume in mine dams is considerably smaller than the total volume of water, being unfortunately closer to half the total volume of water in the dam.

The shape of the tapered inlet is not very critical, provided that it gives a *smooth transition* on the inside. A typical inlet cone might have a 30° slope, and a diameter 30 to 40 per cent larger than, or even double, that of the pipe itself.

Benefits of a Goose-neck Inlet

Better use can be made of the total volume in storage

dams if a tapered goose-neck inlet is provided to all the pipes going out through the dam wall. This is illustrated in Fig. 3, where, for the example shown, the flow of 100 l/s could be maintained with the level of water only 135 mm above the goose-neck inlet pipe.

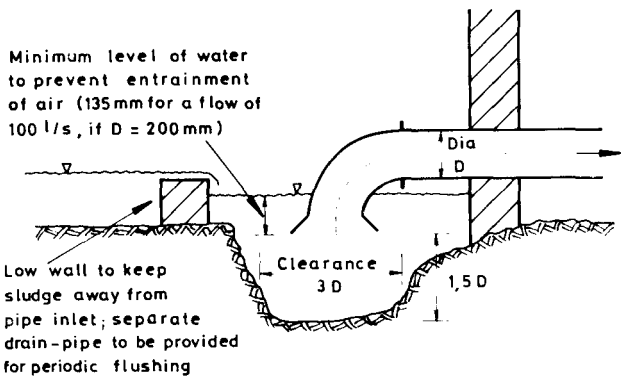


Fig. 3—Benefit of a tapered goose-neck inlet

In the case illustrated, where the maximum diameter of the tapered inlet is assumed to be 1,4 D, the velocity of the water at this point is $3{,}18/(1{,}4)^2=1{,}62$ m/s, giving a velocity head, $V^2/2g$, of 0,135 m.

It must be emphasized that, because of turbulence, wave action, and possible swirling, in practice air would be drawn into the pipe somewhat before the level of the water had dropped to the value indicated. However, the point to emphasize here is that, with a tapered goose-neck inlet, almost the entire volume of the dam could be utilized for surge capacity, and full flow could be maintained in the outlet pipe at practically all times.

The provision of a simple sludge trap in the form of a low-level wall inside the dam, as illustrated in Fig. 3, should be noted.

Design for Peak or Average Flow

The decision as to whether to design for peak flow or 24-hour average flow or some intermediate value depends on the size of the dams at the various levels. The average water demand can be determined most easily from pumping records, and it is usually safe to assume that peak flow-rates will not exceed two to three times the average flow-rate.

When refrigeration is to be used to cool the service water, it is desirable that the storage volume of dams should be equivalent to at least one-third of the total amount of water used per day, in order to even out the loads on the refrigeration plant. Thus, it is important to utilize the full volume of dams.

Prevention of Swirl

Swirl will seldom be a problem if tapered goose-neck inlets are used. However, if swirl is detected in dams, it can be suppressed fairly easily such as by the use of short, vertical sheetmetal grid plates arranged horizontally above the inlet pipe.

Necessary Head

In order to avoid negative gauge pressures in the pipeline, and hence to avoid surging, cavitation, swirl, and air entrainment, it is essential that the available head at the dam is sufficient to overcome friction losses in the pipeline leading to the shaft, and also to accelerate the water to the terminal velocity in the pipe going down the shaft. A useful guideline is that the diameter of the pipe leading from the dam to the shaft should be at least twice the diameter of the pipe going down the shaft.

The approximate terminal velocity and corresponding flow-rate of water going down pipes in vertical shafts is as indicated in Table I. As there are few shaft systems at present using more than 150 l/s on the 24-hour average, it would appear that pipes of 150 mm diameter down shafts should suffice if the capacity of the dams is sufficient to meet peak demands. Indeed, in many mines 100 mm pipes would suffice in the shafts, provided that they were fed from the dams through 200 mm approach pipes and provided the dams had adequate surge capacity.

TABLE I

TERMINAL FLOW IN VERTICAL PIPELINES

Nominal pipe diameter, mm	Approximate terminal velocity, m/s		Corresponding flow-rate, l/s	
	New pipe	Old pipe	New pipe	Old pipe
50	6	4	12	8
100	10	6,7	80	54
150	12	8	216	144
200	15	10	480	320

Regulation of Flow

Any attempt to regulate the flow down the shaft by throttling at the inlet will result in severe surging as a result of cavitation, unless the pipe is vented. The flow of water down pipes in shafts should preferably be regulated either

(a) by means of a valve at the bottom of the pipe, in which case the pipeline must be designed to withstand the full static head, or

(b) by means of an *on–off* control at the top of the pipe, together with an air vent to allow air to enter the pipe when the water flow is shut off, in which case the outlet at the bottom of the pipe column must be open at all times unless the pipeline is designed to withstand the full static head.

In the case of an *on–off* control at the top of the pipe column with the bottom end open at all times, there can be only two stable flow situations. One is with zero flow, and the other with full flow at the terminal velocity. The flow in such a pipeline must hence be intermittent, with the relative duration of the *on* and *off* periods depending on the average demand for water at the bottom end of the pipeline.

Because of the increase in resistance of a pipeline with time (due to scaling or roughening as a result of corrosion), the relative duration of the *on* periods will increase steadily during the life of the pipeline. Thus, in the case of a mine requiring a 24-hour average flow of 100 l/s and provided with a 150 mm pipeline controlled from the top end, the *on* periods will constitute about 100/216=46 per cent of the total time when the pipe is

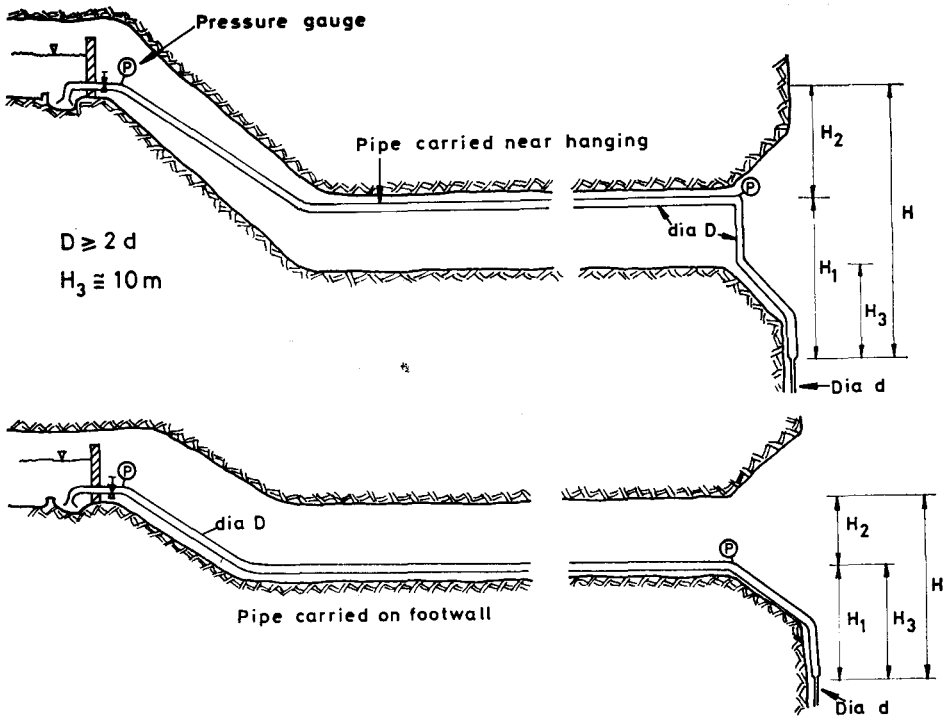


Fig. 4—Height of underground dam to ensure full flow of water

new, whereas, as the pipe ages, the *on* periods will increase towards about 100/144=69 per cent of the time. The feed to the shaft pipe would have to be designed to provide water at the rate of 216 l/s (for a 150 mm pipe, see Table I) without the development of negative gauge pressures in the pipeline.

Returning again to the example of a 150 mm pipeline down the shaft, the terminal velocity in the pipe when new will be about 12 m/s. The corresponding velocity head, $V^2/2g$, is 7,35 m, so that, referring to Fig. 4, the minimum value of the head, H_3, above the entrance to the 150 mm pipe must be 7,35 m if negative gauge pressures are to be avoided. If the diameter, D, of the supply pipe from the dam is 300 mm, the head loss in this pipe at a flow-rate of 216 l/s would be about 3 m per 100 m length. If the length of this 300 mm pipe, including the short portion down the shaft, is 150 m, the frictional head loss in the pipe would be H_2=4,5 m, and the total head, H, (see Fig. 4) necessary to ensure no negative pressures in the pipeline would be 7,35+4,5= 11,85 m. It should be evident from this example that dams must be developed at a level somewhat above that of the station footwall, so as to avoid the need for pumps to transfer the water out of dams to the shaft.

In practice it will be found that slight negative heads (up to a few metres) do not cause surges, giving a small safety factor in these calculations. Furthermore, as a further safety precaution, the measurement of the head H is taken from the bottom of the dam without allowance for the depth of water.

This example, and other similar calculations, lead to the rule-of-thumb recommendation that the diameter of the supply pipe leading from the dam to the shaft should be at least twice the diameter of the pipe down the shaft, and that, before joining the smaller shaft pipe, it should extend down the shaft for a distance of about 10 m below the station footwall. (Referring to Fig. 4, the diameter, D, should not be less than $2d$, and the distance H_3 should not be less than 10 m.)

Over-sized Shaft Pipes

When pipes down shafts are over-sized in relation to the pipes feeding water to them, several practical difficulties arise. For example, in pipelines in which the flow is regulated from the top, severe surging occurs unless a continuous bleed of air is allowed into the pipe at the top. This continuous bleed of air results in accelerated corrosion of the pipelines internally because of the ready availability of oxygen in the warm, damp environment. Such corrosion not only shortens the useful life of such pipes but also causes frequent blockages at places in the pipe circuit where scale and debris can accumulate. The need for this continuous bleed of air falls away if the approach pipe is properly sized.

The rate of flow of water down such over-sized pipes is determined almost entirely by the design of the inlet pipe and is hence not increased by having a larger pipe down the shaft. Thus, in situations where shortages of water occur, the mere provision of a larger pipe in the shaft will not markedly increase the water flow down the shaft.

When the approach pipe is correctly sized, the gauge pressure at the top of the vertical column will always be positive, so that no air can be drawn into the system and the flow down the vertical pipe will be at terminal velocity.

Pin-pointing Troubles

When difficulty is experienced with the water supply in mines, a few simple measurements with pressure

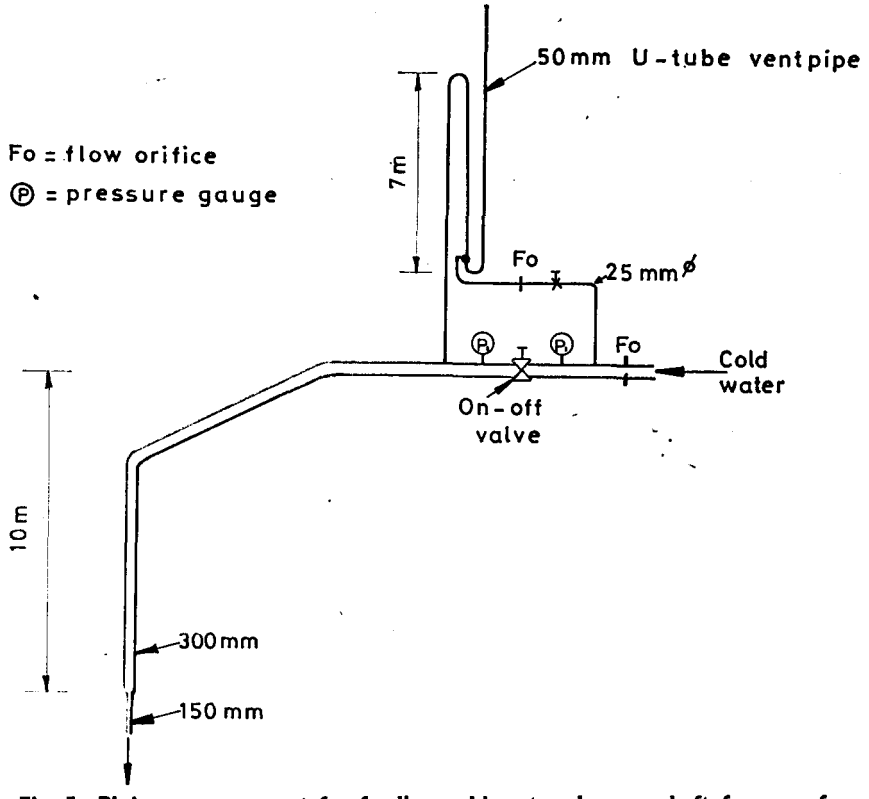
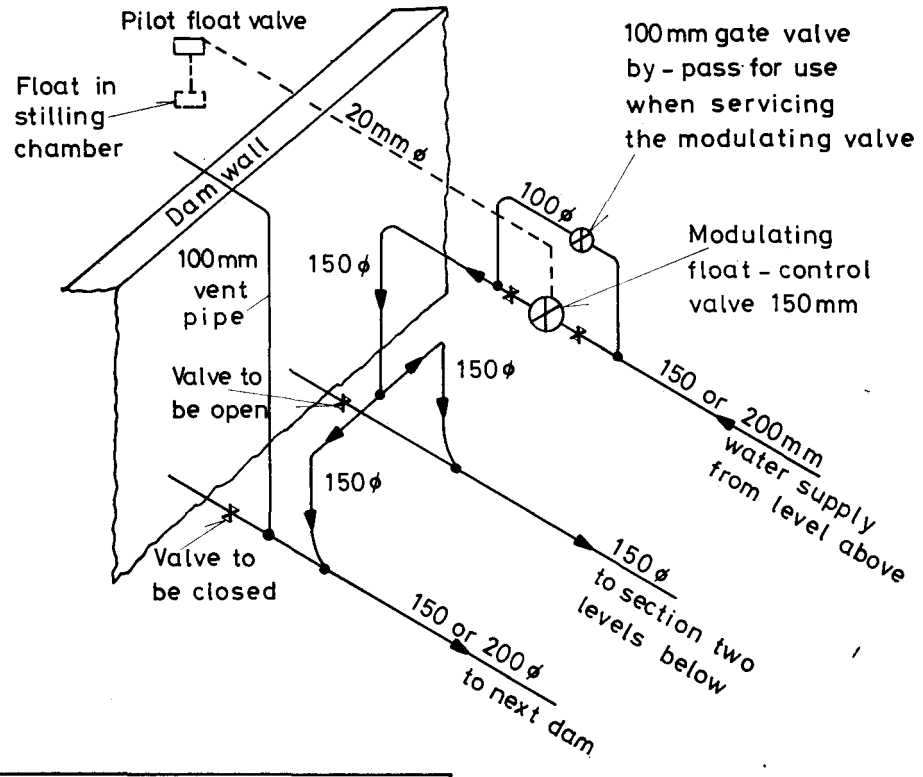


Fig. 5—Piping arrangement for feeding cold water down a shaft from surface



Valve size	Normal peak flow
100mm	50 to 60 l/s
150mm	120 to 130 l/s

For larger flows use two valves in parallel.

Do not oversize valves.

Fig. 6—Suggested piping arrangement at existing dams to ensure an adequate supply of water, and to prevent, at least partially, extensive production delays when water pipes are broken accidentally

gauges will often suffice to indicate the causes. For this it is imperative that suitable pressure tappings are provided on the pipes so that pressure gauges can be fitted quickly. Two important measuring points in the pipe leading to the shaft are indicated in Fig. 4. Another place is at the bottom of the pipeline in cases where flow regulation is provided at this position, or where the flow enters a pump or a heat exchanger such as a condenser. Measurements of these pressures, together with a knowledge of the relative altitudes of the measuring points from survey data, will usually indicate whether the difficulty is due to air entrainment, air accumulation resulting in pipelines running partially full, blockages, inadequate pipe diameters, poor inlet design, etc.

Intermittent Flow

When long pipelines carry cold water intermittently, or when the flow stops for considerable periods over weekends, the change in pipe temperature can give rise to difficulties as a result of thermal expansion. Thus, with a coefficient of thermal expansion of $10{,}7 \times 10^{-6}$ per °C, the change in length of a 1000 m long pipeline for a temperature change of 30 °C is 0,32 m. Provision must be incorporated in the support of the pipeline for this expansion and contraction.

One method for avoiding problems of expansion and contraction resulting from intermittent operation (particularly over weekends) is illustrated in Fig. 5, where a small continuous flow of water is provided down the pipe, the flow-rate being adjusted so as not to draw air down through the U-tube vent pipe. The height of the U-tube must be one to two metres less than the barometric head; typically it would be about 7 m, as illustrated. The U-tube has a second purpose in that it prevents the flow of air down the pipe during the off-periods, thus reducing internal corrosion.

Inadequate Piping Systems

Where water supply difficulties occur in existing installations, it will often be possible to remedy matters by laying a new, larger approach pipe, and by combining all the pipe connections that are already built through the dam wall to feed into a common header immediately outside the dam. Usually it will also be necessary to fit tapered goose-neck inlet sections to all the pipes that carry water out through the wall in order to prevent air being drawn into the pipes, and hence enabling the full volume of the dam to be utilized for surge capacity. In the method illustrated in Fig. 6, the peak water flow-rates can be handled without having to pass through the pipes in the dam wall, and delays in production arising from broken pipes can be reduced significantly.

It is important to note that, with the arrangement of piping and valves shown in Fig. 6, the dam would serve essentially as an open stand-pipe since the level of the water would vary by only a few centimetres each day. The volume storage capacity of the dam would be utilized only in the event of a broken pipe.

Conclusion

It is believed that adherence to the fundamental design principles outlined in this paper will ensure adequate water supplies in mines under all conditions.

Atlas Copco bursaries

With effect from 1977, two bursaries for study tours of Swedish mines will be awarded annually to young mining graduates. One bursary is open to engineers in any country who have at least three years' practical mining experience; the second bursary will be awarded to an engineer who is undertaking research at a British university and has a minimum of one year's practical mining experience.

The awards, which were established by the Atlas Copco organization in collaboration with the Swedish Mining Association, will comprise a three- to four-week tour of Swedish mining operations in September 1977. Travelling expenses from any country will be paid for the first bursar, and from London for the second; accommodation expenses will be met for both.

As in the past, the Council of the Institution of Mining and Metallurgy will assume responsibility for the selection of the bursars, who will be required to submit, before 1st December, 1977, a written report on any aspect of Swedish mining practice that they find of particular interest.

Application forms, which are available from the Secretary, Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, England, should be returned before 1st May, 1977.

Hydrogen in metals

The second international congress on this subject is to be held in Paris from 6th to 10th June 1977. The congress is being organized by the I.S.M.C.M. (L'Institut Supérieur des Matériaux et de la Construction Mécanique). All correspondence concerning the congress should be addressed to the Secretariat General du 2 ème Congres, "L'Hydrogene dans les Metaux", I.S.M.C.M., 3 rue Fernand Hainaut, 93407 St Ouen Cedex, Paris.

Health hazards of South African mine water

by P. SMIT*, M.B., Ch.B., D.T.M.H., D.P.H. (Visitor)

SYNOPSIS

The water supply in South African mines is not as good as most mining engineers would like to believe, nor is sufficient care taken to ensure the safe dispensing, transportation, and consumption of water. As long as cases of dysentery and typhoid continue to occur in large numbers, it can be assumed only that the water supplies are not safe, or that the water-dispensing methods are poor. A dual water supply is a real health hazard. The ideal water supply is a single safe source for human consumption and industrial use.

SAMEVATTING

Watervoorsiening in Suid-Afrikaanse myne is nie so goed soos die meeste myningenieurs graag sou wou glo nie en daar word ook nie genoeg sorg aan die dag gelê om die veilige beskikking oor vervoer en verbruik van water te verseker nie. So lank daar steeds gevalle van disenterie en ingewandskoors in groot getalle voorkom, kan daar net aanvaar word dat die watervoorrade nie veilig is nie, of dat die metodes om oor die water te beskik, swak is. 'n Dubbele watervoorsieningstelsel is 'n wesenlike gesondheidsgevaar. Die ideale watervoorsiening is 'n enkele veilige bron vir menselike en nywerheidsgebruik.

Introduction

Mines obtain their water from fissures in the rock underground, or from surface when sufficient underground water is not available. Some mines have an excess of water and have to pump millions of litres to the surface, whilst others are short of water. Mines with excess water have a high dilution factor in their favour, whereas mines short of water have to re-circulate their industrial water, which often becomes heavily polluted. Occasionally, a good supply of fissure water is available in one area, where it can be conveniently led into a large dam underground and circulated throughout the mine for industrial use and occasionally for human consumption. This water must be checked and chlorinated. One mine in the Stilfontein district has this system, and all the water collecting at the bottom of the mine is pumped to the surface to a water-treatment plant. After treatment, it is used on surface and at times some is sent back into the mine if extra water is required. Thus, the mine has a single safe water supply both for industrial and human consumption.

However, most mines have to introduce potable water into the mines for human consumption. The distribution of this water is largely dependent upon the type of mining practised: concentrated long-wall mining frequently has the potable-water pipe close to the working area, whereas scattered short-wall mining does not always have safe water close at hand. In most cases, gold mines have dual water supplies, i.e., potable water for human consumption and fissure water for industrial use. The industrial water is available all over the mine, but the potable water is often some distance away from the work site.

The average water requirement is 3 litres per man per shift in South African gold mines, which have a hot working environment. The industrial water requirements vary from 1000 to 4000 kg for every 1000 kg of rock broken.

Hazards to Health

Public health authorities have always been very concerned about dual water supplies where one is inexpensive and inferior in quality but satisfactory for general garden and industrial use, and the other is of a high quality fit for human use. Even when the community served is careful and intelligent, the hazards are considerable because of the ever-present possibility of interconnection. In gold mines, there is the extra danger that potable water is not always available on site, and people are prepared to drink industrial water because they have found that it is not as bad as they have been told and, in any case, if water comes out of a pipe, they regard it as fit for drinking.

The industrial water at the mines at present is not very palatable, mainly because it is relatively warm, but cold industrial water is to be used in the near future to improve the environmental temperatures. The workers will then probably prefer to drink the cold water. The safest and most economical way of supplying safe water would then be to have water-purification plants on surface that are associated with water-cooling towers to provide cheap, safe industrial water.

The potable water supplied at South African gold mines is often accepted as such by mining engineers with very little thought that it can ever be dangerous. But pollution can take place; for example, by short circuiting with industrial water, by pollution during servicing, by poor control of the underground transportation of potable water in water tankers or carts. If the sources of potable water are a long distance from the working site, the water carrier is easily tempted to fill the tanker with water close at hand, which is usually industrial water. Sometimes a hose is attached to the potable water supply to make filling of the tanker easier. Unfortunately, the hose often lies in a drain or on the dirty floor and so easily pollutes the potable water being tapped. Sometimes the taps on the water carts become jammed, and this results in workers using a communal cup to scoop water out of the tank. It is easily appreciated that their hands are rinsed by the water in the tank, and in no time the water presents a real hazard. The habit of passing a can of drinking water through a stope at regular intervals with one or two cups is another insanitary practice that should be discouraged.

Some mines have problems with the dual water system

*Gold Fields of South Africa Limited, Johannesburg.

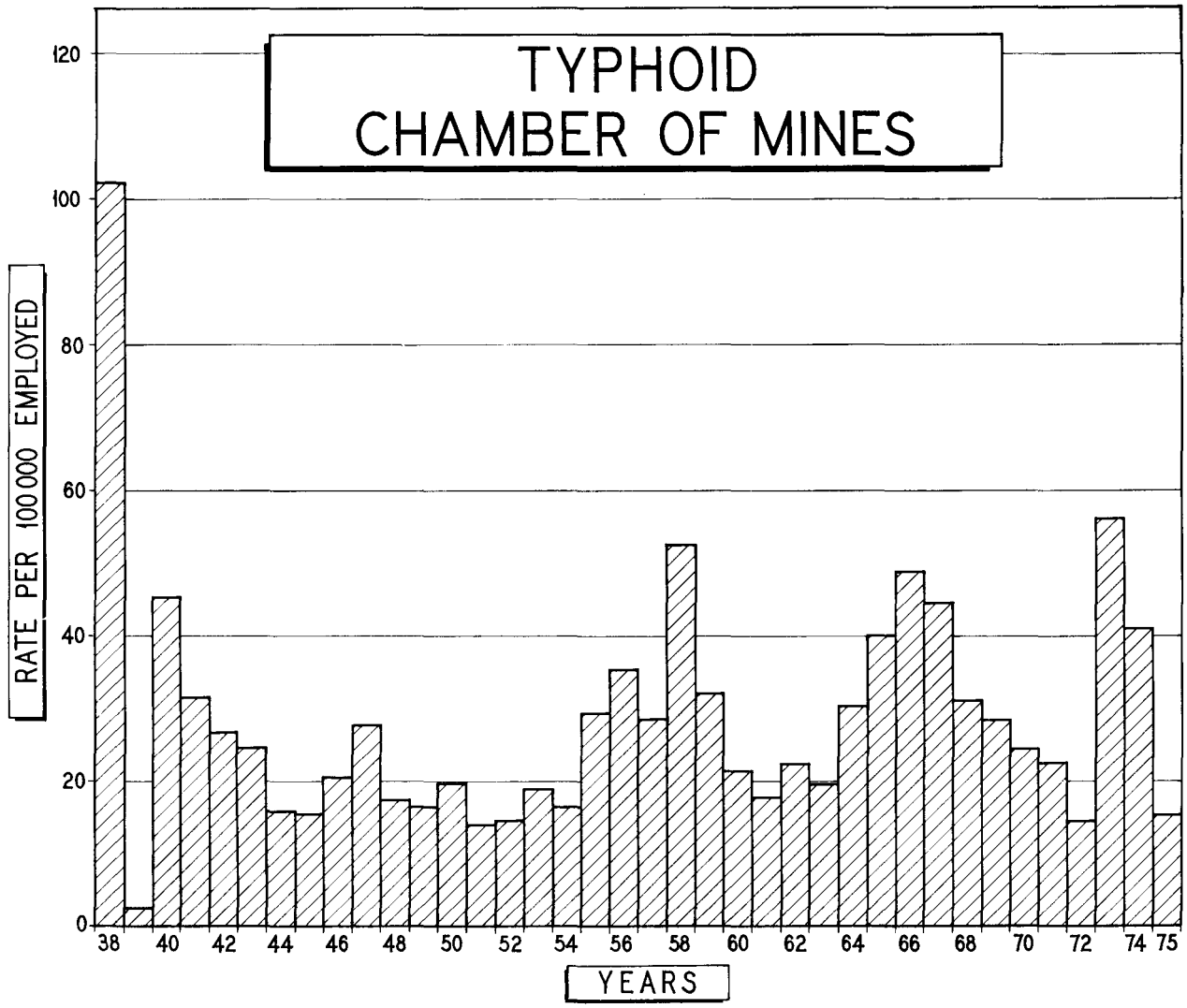


Fig. 1—The occurrence of typhoid in South African gold mines from 1938 to 1975

on surface, when the industrial water used on gardens is not always safe. Although the industrial water points for fire hydrants and gardens are clearly marked *Dangerous and not for human consumption*, it has often been noted that children and adults when hot and thirsty will drink this water.

The reduction works occasionally have problems with the industrial water used in their plants because of excessive amounts of oil and detergents polluting the water.

A list of common enteric, bacterial, parasitic, and viral diseases that can be transmitted via water to man are listed in Tables I and II. Three bacterial diseases important in the mines are dealt with here: typhoid, dysentery, and cholera. All are preventable diseases and are almost non-existent in developed countries.

TABLE I

PRINCIPAL ENTERIC, BACTERIAL, AND PARASITIC DISEASES TRANSMITTED BY WATER

Disease	*Causative organism*
Cholera	Vibrio cholerae including bio-type el-tor
Typhoid fever	Salmonella typhi
Paratyphoid fever	Salmonella paratyphi A. B. and C.
Bacillary dysentery	Shigellae
Amoebic dysentery	Entamoeba histolytica
Round worms	

TABLE II

PRINCIPAL VIRAL DISEASES TRANSMITTED BY WATER

Infectious hepatitis
Adenoviruses
Coxsackie A and B
E.C.H.O.
Poliomyelitis
Reo viruses

Although the gold-mining industry in South Africa has been in existence for over 80 years, typhoid is still an endemic disease on the mines. As recently as 1973, there was an epidemic of typhoid at a gold mine, where 106 cases were diagnosed between April and May of that year. As shown in Fig. 1, epidemics of typhoid occurred during 1938, 1940, 1958, 1966, 1967, 1973, and 1974. Although it is still a killer disease, the availability of effective antibiotics has made it less serious than previously.

The dysentery occurring in the mining population includes amoebic and bacillary dysentery, and, as shown in Fig. 2, occurs excessively. The rate of occurrences of dysentery in the gold mines is far too high, and, as long as dysentery occurs in these numbers, typhoid cases can be expected.

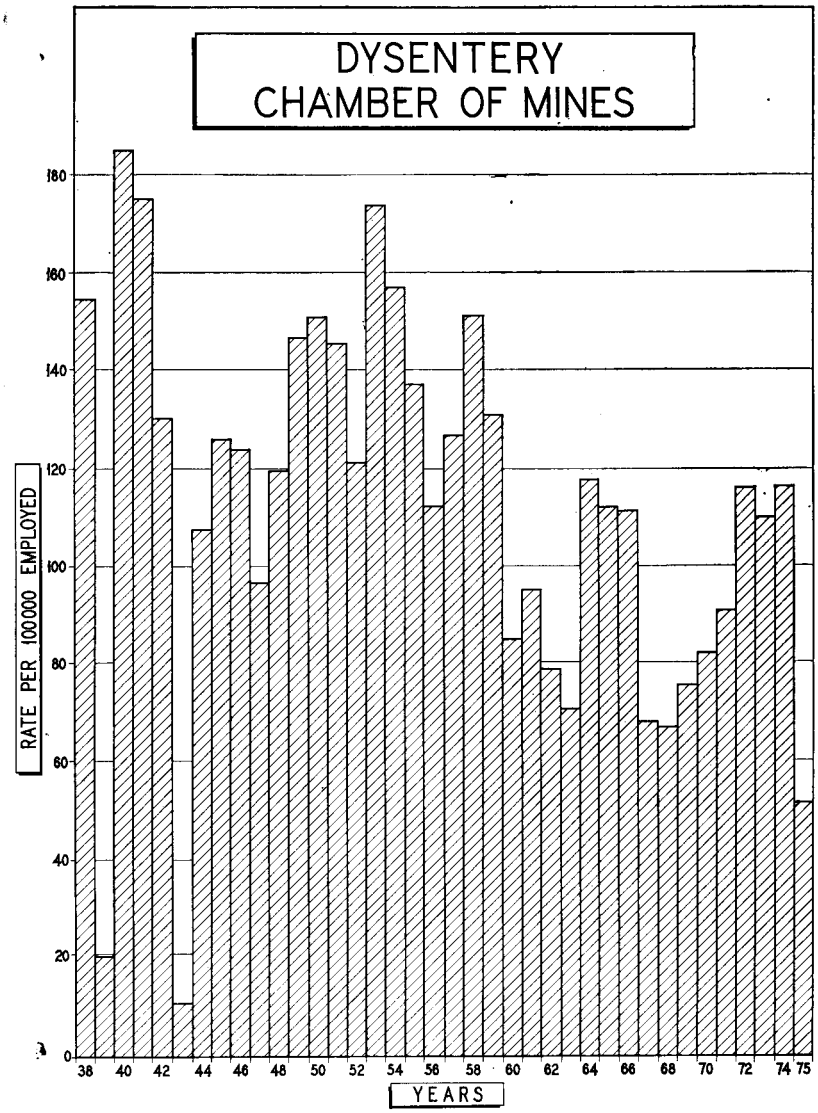


Fig. 2—The occurrence of dysentery in South African gold mines from 1938 to 1975

To prevent the occurrence of typhoid in an industrial population, one must realize that typhoid organisms leave the body via faeces and urine and infect man when he ingests them via food, including milk or water, that has been contaminated from these sources. Typhoid organisms are in the body and are excreted by acute cases of typhoid fever, by patients during convalescence after typhoid fever, and by carriers of typhoid. The faeces can be infectious from the beginning of the disease, when the patient may feel only out of sorts, so that the infection is easily spread via food, hands, and water during this period.

Occasionally, after a case has been treated, permanent carrier states can be established and relapses may occur with a further source of infection. Carriers are persons who excrete the typhoid organism but are asymptomatic and feel fit and well. There are three types of carriers: those who regularly excrete the organism, those who occasionally excrete the organism, and sub-clinical cases (people who feel well but have active typhoid).

In a study carried out by the author in 1960 to 1963, 1358 food handlers were investigated, and in 11 cases typhoid organisms were isolated from the urine and/or stool. The organisms were found persistently in 4 of these carriers, who can be regarded as chronic carriers. The other carriers, considered sub-clinical cases, were identified by the typhoid organism in their urine. This survey showed that, of the Blacks employed in South African gold mines, 2,94 per 1000 workers were chronic typhoid carriers. When all 11 excreters are included as possible disseminators of typhoid, the rate is increased to 8,1 per 1000 Black workers.

It is important to note that the urine of 8 foodhandlers was infected with typhoid organisms, which emphasizes the importance of the safe disposal of urine. Not one person in this survey developed clinical disease. However, cases of typhoid had occurred during this period, the typhoid rate per 1000 men employed being 0,215; 0,179; 0,221; and 0,197. At some stage before they reported ill or were diagnosed these men excreted typhoid organisms and so added to the potential pool of infection.

In March 1974, one of the mines experienced a cholera epidemic in which 31 symptomatic cases and 32 carriers

were identified, isolated, and treated. This has been the only cholera epidemic in South Africa and caused great anxiety at the mine, the neighbouring mines, and the adjoining town. Once again, water was the vehicle of transmission. The acclimatization centre on surface, where safe potable water was in fact available, was identified as the main focus of infection. Owing to unfortunate dispensing practices, the water became polluted. It was found that the water for regular half-hourly drinking purposes was provided in galvanized buckets, from which the water was scooped in cups. The water remaining in the buckets after issue was found to be heavily contaminated with faecal *coli*. Another unfortunate habit was that the buckets were filled from hoses connected to safe water taps, but the hoses lay on the floor of the chamber in water that was found to be heavily infected with cholera organisms and other faecal *coli*. The floors became infected from the sweat dripping off the workers' bodies after some of it had washed the faecally contaminated perineum areas of the body. The supervisory staff also became infected carriers during this period and so kept the cycle of infection going.

It should now be appreciated that there is sufficient infective material available in the working and living environment on South African gold mines to cause an infection of unprotected persons and so establish an endemic disease. Unprotected persons are those who do not have safe systems for the disposal of faeces and urine, and clean, safe food and water. Standards for safe water set by the South African Bureau of Standards are reproduced in Tables III to V, and these are the standards that should be aimed at.

TABLE III

STANDARDS FOR POTABLE WATER

Property	Recommended limit mg/l	Maximum allowable limit mg/l
Anionic surfactants (as Manoxol OT)	0,5	0,5
Chloride (as Cl)	250	600
Copper (as Cu)	1,0	1,5
Iron (as Fe)	0,3	0,7
Magnesium (as Mg)	100	150
Manganese (as Mn)	0,1	0,4
Phenolic compounds (as phenol)	0,001	0,002
Sulphate (as SO_4)	250	400
Dissolved solids	500	2 000
Zinc (as Zn)	5	15
Min. total hardness (as $CaCO_3$)	20	Not specified
Max. total hardness (as $CaCO_3$)	200	1 000
Min. pH value	6,0	5,5
Max. pH value	9,0	9,0

TABLE IV

TOXIC SUBSTANCES IN WATER

Constituent	Recommended limit mg/l	Maximum allowable limit mg/l
Arsenic (as As)	0,05	0,05
Cadmium (as Cd)	0,05	0,05
Cyanide (as Cn)	0,01	0,2
Fluoride (as F)	1,0	1,5
Hexavalent chromium (as Cr)	0,05	0,05
Lead (as Pb)	0,05	0,1
Nitrates (as N)	10	Not specified

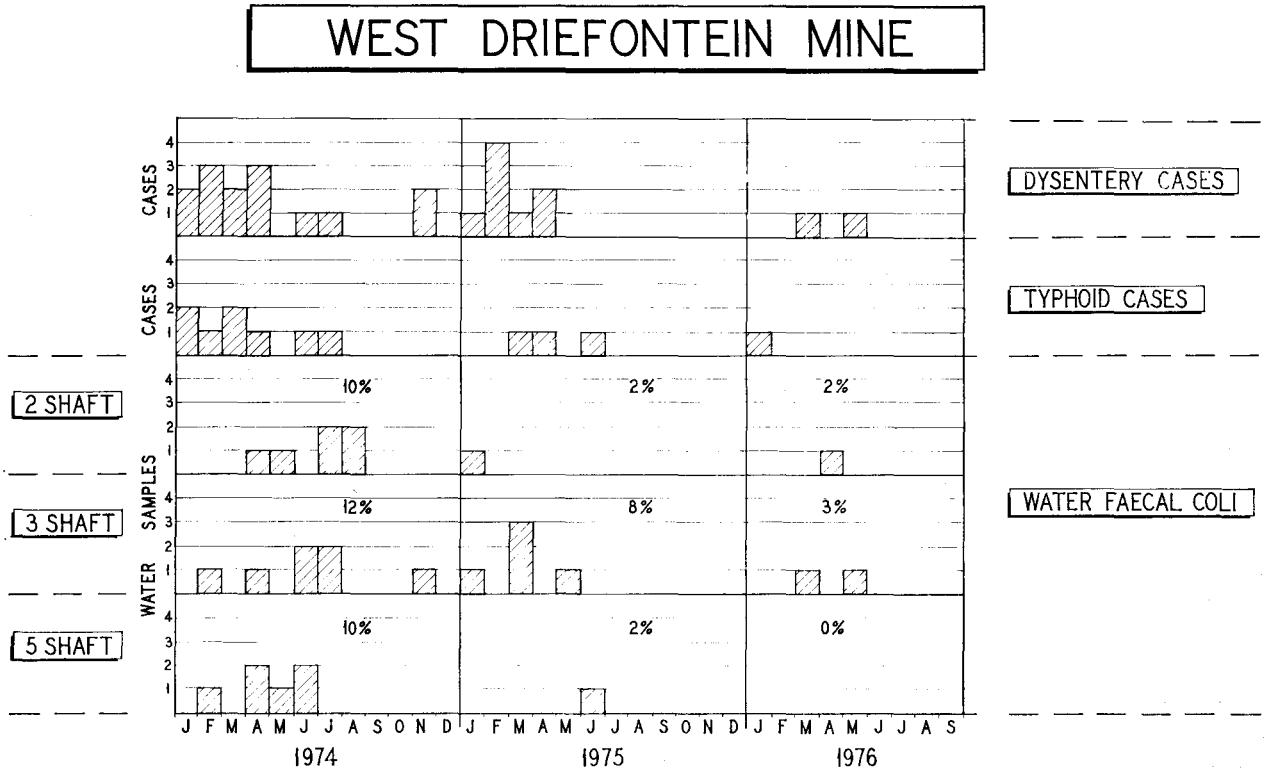


Fig. 3—Correlation of analyses of water samples with cases of dysentery and typhoid at West Driefontein Mine

TABLE V

BACTERIA IN WATER

Organism	Recommended limit	Maximum allowable limit
Coliform organisms, no. per 100 ml		10
E. Coli 1, no. per 100 ml	Nil	Nil
Total viable organisms, colonies per ml	100	Not specified

Causes of Water Pollution

On surface at the mines, there is water-borne sewage that provides for the safe disposal of human excreta, but underground there is still a mixture of sanitation systems, ranking from the pail to conservancy tanks, chemical latrine cars, and mobile gester latrines. The construction, supervision, and maintenance of underground latrines often fall far below safe health requirements; for example, the latrine is not always physically isolated and waste water and spillage enter mine water drains, supervision fails to prevent dumping of urine and faeces into drains (especially where buckets are used). Often the latrine area is not properly maintained, and there is a leakage of excreta and urine into drains. Frequently the latrines are too far from the working site or are unpleasant areas, with the result that the Blacks use old mine workings as latrines and this excreta is washed into the mine drain water. Regular checks of any mine drain water show human faecal contamination, but more so in the vicinity of the latrines. The water in the pump chambers is always polluted.

Another cause of faecal pollution of mine water is sweat. Sweat in the perineum area of the body washes off any faecal contamination of the surrounding skin, and, when one considers that at least $1\frac{1}{2}$ to 3 litres of sweat are produced per man at work, this is another real source of contamination of mine water.

Fortunately, not everyone drinking water polluted with typhoid or dysentery organisms will develop typhoid or dysentery, and the number of people infected is related to the available dose of the causative organisms. Therefore, explosive epidemics occur only when the dose of available organisms is high. Nevertheless, the mere fact that typhoid remains endemic in the gold-mining industry shows that the infecting agent remains in the population and environment, and ways of transmission are still available.

Mine drain water picks up organic material, dumped oil, and nitrous fumes that form nitrites, and ammonia. The nitrites and ammonia are strong reducing agents and come through the mine settlers unchanged. They are a nuisance when water is chlorinated because the chlorine is initially used to neutralize them before disinfecting the bacteria. In some mine water, up to 10 p.p.m. of chlorine are required before sufficient free chlorine is available for bacteriological action. This is why some mines find that chlorination is not effective. They are simply not providing sufficient chlorine for the water they are treating.

Since Gold Fields has been monitoring its water regularly with an ongoing and improving system of underground chlorination, the cases of typhoid and dysentery have dropped strikingly; but, because of the difficulties encountered with the varying qualities of mine water to be treated throughout the day and the week, cases continue to occur. This is illustrated in Fig. 3, in which analyses of water samples are correlated with typhoid and dysentery cases at West Driefontein Gold Mining Company.

Conclusion

It is the moral responsibility of modern industrialists, irrespective of the costs, to ensure that their personnel are protected from preventable diseases such as typhoid, dysentery, and cholera by providing safe water and safe facilities for the disposal of excreta. The medical profession can advise the engineers on what is required and, through health education of the population, attempt to ensure more responsible hygienic habits among the workers to prevent contamination of water. Pollution of water must be prevented and discouraged all the time, which will reduce the costs of purification for safe recycling purposes.

Water in underground works

On 18th to 22nd September, 1978, the National Association and the Superior Council of College of Mining Engineers of Spain will hold the International Symposium on Water in Mining and Underground Works (SIAMOS) in Granada. This Symposium has been made possible by the patronage of the University of Granada, the Hydrological Institute, the Superior Council of Scientific Research, the Spanish Geological and Mining Institute, and the National Water Well Association (U.S.A.). Steps are being taken to secure the sponsorship of other national and international associations and organizations.

Papers are to be grouped in the following sections:

— projects and works under the water table
— contribution of surface water to excavations and underground works
— role of water in the behaviour of excavations
— special techniques (freezing, injection, cementing, etc.)
— mathematical models applied to drainage systems
— other subjects.

The languages of the Symposium are Spanish, French, and English.

All enquiries should be directed to Prof. Dr. Eng. Rafael Fernández-Rubio, Director of the Work Group of Hydrogeology, Universidad de Granada, Apartado de Correos, 556, Granada, Spain.

NIM reports

The following reports are available free of charge from the National Institute for Metallurgy, Private Bag X3015, Randburg, 2125 South Africa.

Report no. 1776

The extraction of copper from copper–nickel catholyte by cation exchange. (26th Nov., 1975; re-issued Mar. 1977).

The work involved a laboratory study of the selectivity and capacity for copper of IMAC SYN 101 and Lewatit TP 207 resins. The sponsor had stated that the ion-exchange system could be incorporated into a closed process if the nickel content of the copper catholyte did not exceed 10 g/l and the additions of sulphuric acid and water did not exceed plant make-up rates.

The average results obtained to date are 43 g of copper and 3 g of nickel per litre of resin. These were obtained under the following conditions: a total number of bed volumes of 8 to 12, a temperature of at least 50°C, and a flow-rate of 8 to 12 bed volumes per hour.

A mass balance based on a three-stage process is included for the whole copper-production circuit. The fixed-column separation entails three stages, i.e., loading, scrubbing (removal of entrained feed solution and loaded nickel), and regeneration (replacement of the loaded copper and a minor quantity of nickel with the use of recycled electrolyte from the electrowinning tankhouse).

Calculations showed that the circuit is very sensitive to the nickel carry-over into the copper circuit. The results for the resin loading covered a wide range (especially for nickel), and it seems likely that more laboratory work will be required if the project continues.

IMAC GT 73, a cation-exchange resin, which was tested for the removal of impurities from nickel catholyte, was found to reduce the copper concentration from 0,25 p.p.m. to less than 0,05 p.p.m. (which is the detection limit).

It was decided that a small resin column on-line with one of the cells should be installed at Bindura. Its effect in purifying the solution should be immediately apparent from the quality of the cathode.

Report no. 1830

The determination of iron in zircon beach sands and its leachability. (14th Jan., 1977).

The determination of iron in the range 0,05 to 0,20 per cent by spectophotometric, atomic-absorption-spectrophotometric, and X-ray-fluorescence procedures was examined. The methods finally developed give consistent results and have a precision varying from 2 to 5 per cent.

A preliminary examination was made in this application of emission spectrography with an induction-coupled plasma torch as the source. X-ray and emission spectrography were found to give the most rapid routine control, although the atomic-absorption procedure is currently the best referee method.

It was concluded that sample variability is insufficient to account for the wide differences normally observed in the analyses for iron by different laboratories.

The laboratory leaching test developed indicates that all the surface iron is removed after a digestion period of 1 hour in hydrochloric acid.

Report no. 1856

A study of model systems in anion exchange. (14th Jan., 1977).

Preliminary experiments are reported on the preparation and characterization of anionic sulphate and chloride complexes of UO_2^{2+} and iron(III), benzyl-trimethylammonium cation being used as a model substance for the simulation of positive sites in an anion-exchange resin.

The structure of $(BTMA)_4$ $[UO_2Cl_3–O_2–Cl_3UO_2]$, a binuclear uranyl–peroxocomplex that has not been reported in the literature, was elucidated by single-crystal X-ray examination, and is described and discussed.

Report no. 1857

The determination of some trace elements in sulphide concentrates by spectrophotometry. (10th Feb., 1977).

The report describes the determination of trace amounts (as low as 1 to 10 p.p.m. depending on the element) of arsenic, germanium, molybdenum, nickel, phosphorus, selenium, tellurium, tin, and titanium in sulphide concentrates. The proposed methods, which are detailed in the appendices, are adaptations of established procedures that were modified to allow for the complex nature of the concentrates to be analysed.

Report no. 1865

A sensitive method for the measurement of osmium by atomic-absorption spectrophotometry. (15th Feb., 1977).

A sensitive method has been developed for the measurement of osmium by atomic-absorption spectrophotometry. With the use of simply constructed apparatus, volatile osmium generated in a small furnace is pulsed into a nitrous oxide–acetylene flame, permitting levels of osmium down to 0,2 μg to be measured. A large range of concentrations has been tested for many interferences. The best application for the method is as a sensitive means for the detection of osmium after osmium has been separated by distillation. For the determination of 5 μg of osmium, the method has a coefficient of variation of about 12 per cent.

Report no. 1869

The separation and determination of trace elements in iron ore. (26th Jan., 1977).

The separation, concentration, and determination of trace elements in iron ores are described. After the sample has been dissolved, the iron is separated by liquid-liquid extraction with a liquid cation-exchanger, di-(2-ethylhexyl) phosphoric acid. The trace elements aluminium, cadmium, calcium, chromium, cobalt, copper, lead, magnesium, manganese, mercury, potassium, sodium, vanadium, and zinc are determined in the aqueous phase by atomic-absorption spectrophotometry.

Report no. 1872

The determination of mercury by cold-vapour atomic-absorption spectrophotometry. (11th Feb., 1977).

This report describes an investigation into the determination of mercury, particularly in iron oxide and sulphide concentrates. The mercury is reduced by the addition of stannous chloride and is carried by a flow of air to the absorption tube, where its absorbance is measured and recorded on a chart recorder.

The optimum parameters affecting reduction and measurement (among them the concentrations of acid and stannous chloride, the time allowed for the reduction of mercury, the air flow-rate, and the sample volume) were established. In addition, a number of dissolution procedures in which use is made of various mixtures of acids (sometimes under pressure in sealed apparatus) were tested in an attempt to obtain satisfactory decomposition of samples and recovery of mercury. The possible interference from these acids and from thirteen probable interfering elements was also investigated. No severe interference was observed, and the method of additions was used to compensate for the minor levels of interference observed.

Methods are proposed for the dissolution of samples and the measurement of mercury in amounts between 10 p.p.m. and 0,1 p.p.m. The coefficient of variation at 3,4 p.p.m. was 5,3 per cent.

Report no. 1875

The determination of tungsten and iron in ferrotungsten alloys by X-ray-fluorescence spectrometry. (11th Feb., 1977).

An accurate and precise method for the determination of tungsten and iron in ferrotungsten alloys is described. Samples are prepared for analysis by fusion with sodium peroxide and sodium hydroxide in a zirconium crucible. The melt is leached in water and acidified with hydrochloric acid. The tungstic acid thus produced is brought into solution by formation of a complex with tartaric acid. Matrix correction and calibration are achieved by means of the single-standard calibration method, use being made of a reference solution for tungsten prepared from sodium tungstate and a reference solution for iron prepared from iron wire.

American Mining Congress

The 1978 AMC International Mining Show will be held on 9th to 12th October in Las Vegas, Nevada. It will offer opportunities to discuss mining problems and to inspect the newest equipment and technologies for more than 20 000 participants. They will represent metal mining, coal mining, industrial minerals operations, manufacturers of mining equipment, and government officials.

As part of the AMC's continuing educational effort, more than 75 technical papers will be presented. They will deal with open, underground, and undersea mining . . . energy . . . the environment . . . management . . . health and safety . . . mineral processing . . . and other topics of importance.

If you are interested in exhibiting products or attending the 1978 AMC International Mining Show, contact the American Mining Congress, 1100 Ring Building, Washington DC 20036, U.S.A.

GUIDE TO THE PREPARATION OF PAPERS FOR PUBLICATION IN THE JOURNAL OF THE SOUTH AFRICAN INSTITUTE OF MINING AND METALLURGY

The following notes have been compiled to assist authors in the preparation of papers for presentation to the Institute and for publication in the *Journal*. All papers must meet the standards set by the Council of the Institute, and for this purpose all papers are referred to at least two referees appointed by the Council.

Although the worldwide readership of the *Journal* results in a preference for papers in English, the Council treats papers in Afrikaans on an equal basis, but, to meet the needs of the majority of readers, an English summary of some 500 to 750 words should be provided.

STANDARDS FOR ACCEPTANCE

To merit consideration, papers should conform to the high standards that have been established for publication over many years. Papers on research should contain matter that is new, interpretations that are novel or of new significance, and conclusions that cast a fresh light on old ideas. Descriptive papers should not be a repetition of well-known practices or ideas but should incorporate developments that would be of real interest to technical men and of benefit to the mining and metallurgical industry.

In some cases, a well-prepared review paper can be of value and will be considered for publication. All papers, particularly research papers, no matter how technical the subject, should be written with the average reader of the *Journal* in mind, to ensure wide interest.

The amount of textbook material included in a contribution should be the minimum essential to the argument. The length of a paper is not the criterion of its worth, and it sh ould be as brief and concise as possibleconsistent with the lucid presentation ofthe subject. Only in very exceptional circumstances should a paper exceed 15 pages of the *Journal* (15 000 words if there are no tables or diagrams). Six to ten pages is more normal.

NOTE: Papers in the *Journal* are printed in 10 point type, which is larger than the 8 point type used on this page. For special publications, Council may decide on page sizes smaller than A4 used for this *Journal*.

The text should be typewritten, double-spaced, on one side only on A4 size paper, leaving a left-hand margin of 4 cm, and should be submitted in triplicate to facilitate the work of the referees and editors.

LAYOUT AND STYLE

Orthodox sequence

Title and author's name, with author's degrees, titles, position.

Synopsis, including a brief statement of conclusions.

An Afrikaans translation of the synopsis.

Introduction.

Development of the main substance.

Conclusions, in more detail.

Acknowledgements.

References.

Title: This shou d be as *brief* as possible, yet give a good idea of the subject and character of the paper .

Style: Writing should conform to certain prescribed standards.

The Institute is guided in its requirements by:

Collins, F. H. *Authors & Printers' Dictionary*—Oxford University Press.

Hart, H. *Rules for Compositors and Readers*—Humphrey Milford (familiarly known as the *Oxford Rules*).

Fowler, H. W. & F. G. *The King's English*—Oxford University Press.

General: A few well-selected diagrams and illustrations are often more pertinent than an amorphous mass of text. Overstatement and dogmatism are jarring and have no place in technical writing. Avoid the use of the first person, be objective, and do not include irrelevant or extraneous matter. Avoid unnecessary use of capitals and hyphens; punctuation should be used sparingly and be governed by the needs of sense and diction. Sentences should be short, uninvolved, and unambiguous. Paragraphs should also be short and serve to separate basic ideas into compact groups. Quotation marks should be of the 'single' type for quotations and "double" for quoted matter within quotations.

Interpretations in the text should be marked off by parentheses ( ), whereas brackets [ ] are employed to enclose explanatory matter in the text.

Words to be printed in italics should be underlined *singly*. For small capitals they are to be underlined DOUBLY and for large capitals TREBLY.

If there is any problem in producing formulae accurately by typewriter, they should be handwritten in ink.

Abbreviations and symbols are laid down in *British Standard* 1991. Abbreviations are the same for the singular and plural, e.g., cm for centimetre and centimetres, kg for kilogram and kilograms. Percentages are written in the text as per cent; the symbol % is restricted to tables. A full stop after an abbreviation is used only if there is likely to be confusion of meaning.

Metric System: The Système International d'Unités (SI) is to be used for expressing quantities. This is a coherent system of metric units derived from six basic units (metre, kilogram, second, ampere, kelvin, and candela), from which are derived all other units, e.g., the unit of force is the newton (N) for kilogram metre per square second (kg m/s^2). Always use the standard metric abbreviations.

The comma must be used as a decimal indicator and must not be used for separating groups of digits. For ease of reading, digits should be grouped in threes counting from the decimal indicator towards the left and right. However, where there are only four digits to the left or right of the decimal indicator, there should be no grouping.

Illustrations: Drawings and diagrams are to be in black India ink and should be about 18 cm wide. When submitting graphical representations, avoid a fine grid if possible. Curves should be in heavy line to stand out. Lettering too should be bold, as a reduction in size is often involved in the printing process.

Numbering of tables should be in Roman numerals: I, II, etc., and figures in Arabic numerals: Fig. 1, Fig. 2, etc. (Always use the abbreviation for figure.) Photographs should be black and white glossy prints.

As a guide to the printer, the author should indicate by means of notes in the typescript where tables and figures, etc. are to appear in the text.

Paragraphs: A decimal system of numbering paragraphs may be used when the paper is long and complicated and there is a need for frequent reference to other parts of the paper.

Proof correction: Galley proofs are sent to authors for the correction of printers' errors and not for the purpose of making alterations and additions, which may be expensive. Should an author make alterations that are considered excessive, he may be required to pay for them. Standard symbols as laid down in *British Standard* 1219*C* should be used.

SYNOPSIS

It is most important that the synopsis should provide a clear outline of the contents of the paper, the results obtained, and the author's conclusions. It should be written concisely and in normal, rather than abbreviated,English, and should not exceed 250 words, except when an English summary of an Afrikaans paper is involved. While the emphasis is on brevity, this should not be laboured to the extent of leaving out important matter or impairing intelligibility. Summaries simplify the task of abstractors and therefore should present a balanced and complete picture. It is preferable to use standard rather than proprietary terms.

FOOTNOTES AND REFERENCES

Footnotes should be used only when they are indispensible. In the typescript they should appear immediately below the line to which they refer and not at the foot of the page.

References should be indicated by super-script, thus . . .[1] . . .[2]. Do not use the word *Bibliography*. When authors cite publications of other societies or technical and trade journals, titles should be abbreviated in accordance with the standards adopted by this *Journal*.

GENERAL

The Council will consider the publication of technical notes taking up to three pages (maximum 3000 words).

Written contributions are invited to the discussion of all papers published in the *Journal*. The editors, however, are empowered by the Council to edit all contributions. Once a paper or a note has been submitted to the Institute, that document becomes the property of the Institute, which then holds the copyright when it is published. The Institute as a body is, however, not responsible for the statements made or opinions expressed in any of its publications. Reproduction from the *Journal* is permitted provided there is full acknowledgement of the source. These points should be borne in mind by authors who submit their work to other organizations as well as to the Institute.