An optimization procedure for the secondary cooling zone of a continuous billet caster

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Synopsis

A procedure for optimizing the secondary cooling zone of continuous casters is proposed and illustrated by a billet caster example. The procedure consists of quantifying deviations from the required conditions of the secondary cooling zone—as far as temperatures, metallurgical length and reheating are concerned—by means of a 'cost function'. The optimal spray settings are then found by minimizing the total 'cost'. The billet caster examples serve to emphasize the importance of specifying the required conditions in a consistent manner. Some envisaged practical limitations of this approach are discussed.

Introduction

Control of the temperature in the secondary cooling zone of continuous casters forms an important part of assuring the quality of the cast products. This discussion deals with billet casters; in these lack of control of the strand surface can cause cracking, by reheating of the strand surface when the strand passes from one spray zone to the next (or to the radiation zone), or by maintaining too-low surface temperatures in the straightener. These two mechanisms lead to midway cracks and surface cracks respectively. As a general guideline, midway cracks are avoided if the amount of reheating (measured as the maximum increase in temperature from the start of the spray zone) is kept to below 100°C[1], while surface cracks form if the surface temperature decreases into the zone of low ductility around 850°C[2,3].

If such quality problems are encountered in a casting operation, a rational basis is required for changing the settings in the secondary cooling zone, to yield a more satisfactory surface temperature profile. This paper presents one approach to balancing the different requirements of the secondary cooling zone; these requirements include maintaining the surface temperature within acceptable limits, limiting the amount of reheating upon passing from one spray zone to the next, and limiting the maximum allowable metallurgical length. The concept of a 'cost function', which gives a weighted average of the extent of deviation from the various criteria, is used in this procedure. While such approaches are probably used by designers of continuous casting machines, little is available on this topic in the open literature, and for this reason this work is considered to make a useful contribution.

To serve as background to this discussion, a schematic drawing of a billet caster is shown in Figure 1. The Figure shows the usual components of a continuous caster, with a curved water-cooled copper tube mould in this case, and three spray zones. No detailed discussion of the various components or the terminology is given here; the reader is referred to other sources for these[4,5]. The thickness of the solidified steel shell is around 10 mm at the exit from the mould, and solidification is complete beyond the last spray zone, where cooling occurs by radiation only. Figure 1 is based on a billet caster at a local steel company, who also supplied the data on zone lengths and water flow rates which were used in this investigation. The water flow rate to each of the three spray zones can be controlled separately. The aim of this paper is to present a procedure for choosing these water flow rates, given the constraints of the system.

Modelling approach

Calculation of surface temperatures

Ideally, controlling the surface temperature of the strand should be performed in feedback fashion, using measurements of the temperature within the spray zones.

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Difficulties such as the presence of steam within the spray chamber and scale formation on the strand surface render continuous direct temperature measurements largely impracticable. For this reason an indirect approach has to be used to estimate the effect of changes in spray conditions on the surface temperature. To this end, an explicit finite-difference model was employed, similar to that described by Brimacombe[6], from whose work the relevant physical properties (thermal conductivity and enthalpy) of steel were taken. The calculations were performed for one-quarter of the strand cross-section, assuming the temperature distribution to be symmetrical. The main boundary conditions for the calculation are the heat flux in the mould, and the heat transfer coefficient in the spray zone (which depends on the spray water flux).

The average mould heat flux was estimated from plant data for the mould water flow rate and temperature increase, which yielded an average yield flux of some 2 MW/m^2 for a 140 mm x 140 mm billet mould at a casting speed of 2 m/min. While high, this heat flux is within the range of values reported for billet casters[7,8]. To calculate the local heat flux in the mould, it was assumed that the heat flux decreases parabolically from the meniscus to the mould exit, with the heat flux at the exit being half of that at the meniscus; this appears realistic compared with measured local heat flux values in billet moulds[8].

The heat transfer coefficient in the spray zones was assumed to be a function of the spray water flux only, according to the following relationship[5,9]:

$$h = k_h V^n \qquad [1]$$

where V is the spray water flux in m^3/s per m^2 of strand surface, and k_h and n are model parameters which were taken to have values of 2.1 x 10^4 and 0.624 respectively, and where h is in W/m^{2}K. These give values for the heat transfer coefficient which fall in the middle of the band of literature data, as summarized by other workers[9]. While these parameters are realistic, in practical use of this approach they should be confirmed by in-plant measurements of the strand surface temperature.

Heat transfer by radiation was also taken into account by employing a radiation heat transfer coefficient, as follows[10]:

$$h_r = \sigma\varepsilon\left(T_w^2 + T_s^2\right)\left(T_w + T_s\right) \qquad [2]$$

where ε is the emissivity of the strand surface (taken to be 0.8), σ is the Stefan-Boltzmann constant (5.669 x 10^{-8} W/m^{2}K^4), T_w is the temperature of the surroundings, and T_s is the strand surface temperature (both temperatures in kelvin).

The model was tested for internal consistency and yielded results which compared well with data available in the literature (e.g.[6,11]).

As an example of the results of such a calculation, Figure 2 shows the calculated mid-face temperature for the current settings of the billet caster. These settings are summarized in Table I, which also shows the typical casting speed, and spray zone lengths. According to this calculation, substantial reheating is expected when the strand passes from the last spray zone into the radiation zone, indicating that the strand may currently be overcooled in the third zone. This is also indicated by the high value of the specific spray water rate (defined as the flow rate of spray water in *l*/s, divided by the rate at which steel is cast in kg/s), of 1.1 *l*/kg. This high water rate is characteristic of 'hard cooling'[5].

Figure 2 also shows that the surface temperature of the strand is predicted to be below 900°C when the strand leaves the mould. This low temperature is the result of the high heat

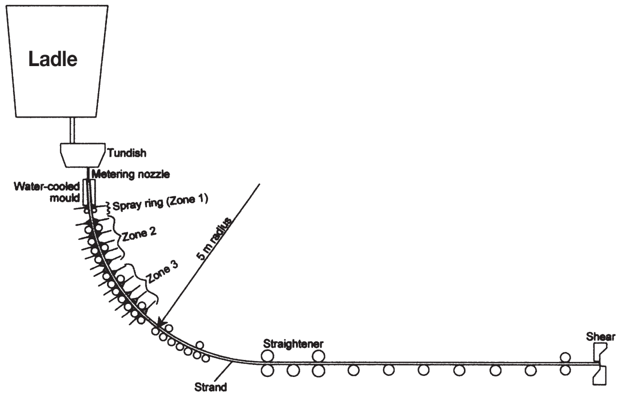

Figure 1—Schematic drawing of a billet caster

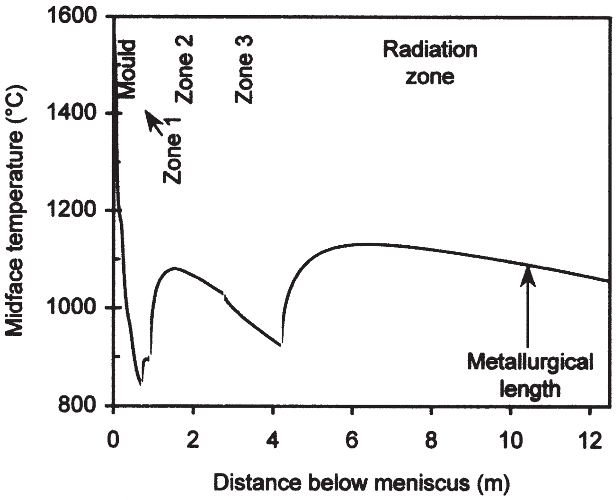

Figure 2—Calculated midface temperature for the current spray zone settings

Table I

Characteristics of billet caster

Working length of mould (m)	0.7	
Billet cross-section size	0.14 m x 0.14 m	
Casting speed (m/min)	2.0	
Superheat (°C)	35	
Spray zone lengths and water flow rates:		
Zone number	**Zone length (m)**	**Water flow rate (m^3/h)**
1	0.21	4.8
2	1.85	7.8
3	1.45	7.6
Specific spray water flow rate (l water sprayed per kg steel cast) **1.1**		
Calculated metallurgical length (m) **10.45**		

flux (of approximately 1 MW/m[2]) at the mould exit acting on the shell thickness of approximately 10 mm. Both of these figures appear to be realistic[8,12]. The low surface temperature at the mould exit implies that some reheating of the strand is inevitable, an effect which should be taken into account when trying to optimize the spray water settings.

Cost function specification

The approach proposed here is to use a mathematical technique to find that spray water configuration which best fits the stated requirements of the spray zone. A cost function is used in this approach; this function is simply a summation of the total deviation from the desired conditions over the length of the spray zone. The mathematical form of the cost function as used here is an integral, as follows:

$$J = \int_{\substack{mould\\exit}}^{\substack{metallurgical\\length}} \Big(w_1\left[T(x) - T_{req}\right]^2 + w_2 \mathrm{x} \left\{\max\left[0, T(x) - T_{\max}\right]\right\}^2 + w_3 \mathrm{x} \left\{\min\left[0, T(x) - T_{\min}\right]\right\}^2$$
$$+ (w_4 + w_5 x) \mathrm{x} \left\{\max\left[0, T(x) - T_{zone-\min}(x)\right] \mathrm{x} \left[w_6 + \frac{w_7}{(x - x_{zone-\min})}\right]\right\}^2$$
$$+ w_8 \mathrm{x} \left\{\max\left[0, x - MaxLength\right]\right\}^2 \Big) dx. \qquad [3]$$

The cost function thus sums the importance of deviations from the required conditions, by assigning a weight (w_1 to w_8 in Equation [3]) to each deviation. The requirements considered here are, respectively, maintaining a constant temperature in the secondary cooling zone, maintaining the temperature below a maximum value, maintaining the temperature above a minimum value, avoiding reheating, and keeping the metallurgical length smaller than a given maximum value. The temperature considered here is that at the midface of the billet. As Equation [3] indicates, the cost function is summed over the whole length of the spray zone, from the mould exit, to the metallurgical length. In this equation, x is simply the distance from the mould.

The rationale behind the choice of the terms in the cost function is as follows. In Equation [3], the desired constant temperature is T_{req}, and deviations from this value (positive or negative) are given the weight w_1. Similarly, T_{max} is the desired maximum temperature, and excursions beyond this temperature are given the weight w_2; w_3 is the weight assigned to decreases in temperature below the minimum T_{min} (which would involve a danger of surface cracks, for example).

The next term (containing the weights w_4 to w_7) addresses reheating. In this term, $T_{zone-min}$ refers to the minimum temperature encountered up to a given point x in the current spray zone. If reheating occurs in a given spray zone, this minimum temperature will typically be encountered close to the start of the spray zone— and the difference $T(x)$-$T_{zone-min}(x)$ gives the local amount of reheating. The factor ($w_4 + w_5x$) is introduced because it appears that reheating somewhere along the strand is inevitable—given the predicted low mould exit temperature. Just below the mould the solidified shell is thin and not as rigid, and hence it is expected that the thermal stress imposed on the solidification front by reheating would be smaller than for thicker shells. Including the factor w_5x hence means that reheating which occurs further down the strand (where the shell is thicker) is considered to be more serious. The last factor in the reheating term reflects the idea that, in addition to the amount and position of reheating, the *rate* of reheating is also important—if the rate of reheating is low, deformation of the shell by creep should serve to keep the thermal stress low, with a resulting smaller danger of midway cracks. Dividing the temperature difference $T(x)$-$T_{zone-min}(x)$ by the distance x-$x_{zone-min}$ gives the average slope of the temperature (relative to distance down the strand), between the current position (x) and the position of minimum temperature in that spray zone ($x_{zone-min}$). (To avoid division by zero, this term was only quantified where $x \neq x_{zone-min}$).

The final term in the cost function assigns weight w_8 to the situation where the metallurgical length exceeds some set value (*MaxLength*). Reasons to include this term can be to avoid, as examples, unbending the strand on a liquid core, or shearing the strand where a liquid core is still present.

Optimization procedure

Finding new recommended settings for the spray zone involves choosing values for the parameters in the cost function (being the eight weights, the three temperatures, and the maximum metallurgical length as shown in Equation [3]), and then using a procedure to find the spray settings which gives the minimum value for the cost function (i.e. the least amounts of penalties incurred). In this work, the Nelder-Mead method[13] was used to find the settings which minimize the cost function. In this calculation, the quarter-section of the strand was divided into eight by eight nodes to find the surface temperature profile for each spray setting; the minimization procedure was repeated until the value of the cost function changed by less than 0.01 per try. Typically, the minimization procedure required 200-300 iterations to find the minimum, which took around 40 minutes on a Pentium personal computer.

To test whether this approach is useful, two different sets of requirements were translated into the weights of the cost function. The two sets of requirements, and the results of the optimization procedure are discussed below. Certain features are common to both examples. These are: (i) The metallurgical length is limited to a maximum of 12 m, with a weight (w_8) of 10^{10} (this very high weight is designed to avoid any chance of the actual metallurgical length exceeding the stated maximum). (ii) The reheating term (with weights w_4 to w_7—see Equation [3]) had the same weights for the two examples. Since the surface temperature is calculated to be as low as 900°C at the mould exit, some reheating is inevitable; because (as explained above) reheating just below the mould is considered to be less deleterious than reheating further down the strand, w_4 was given a weight of 1, and w_5 a weight of 0.2—this means that reheating at the start at the radiation zone (where $x \approx 5$ m) has a total weight of ($w_4 + w_5 \times 0.2$) = 2, i.e. twice that just below the mould. As far as the rate of reheating is concerned, w_6 was given a value of 3, and w_7 a value of 1—the effect of this is to assign a higher weight to the absolute value of reheating (w_6), rather than the *rate* of reheating (w_7). While these values are here used only for the two examples, they are thought to reflect a realistic approach to weighting the relative importance of the different aspects of reheating.

Examples of the optimization procedure

Requirement: constant temperature in the secondary cooling zone

One way of avoiding reheating as the strand passes from one spray zone to the next, is to specify a constant surface temperature. The values of the weights and temperature values which were chosen to try to achieve this, are given in Table II. As the table shows, the set temperature (T_{req}) was given a value of 1000°C, and the maximum (T_{max}) and minimum temperatures (T_{min}) values of 1050°C and 950°C respectively; deviation from these were assigned equal weights of 1. The other values and weights (referring to the metallurgical length and reheating) were assigned the values as discussed above.

The resulting recommended spray settings (as produced by the optimization procedure) are given in Table II; the predicted temperature profile is shown in Figure 3. The Figure shows that the optimization procedure does yield spray settings which keep the surface temperature within the specified bounds–but with substantial reheating (of around 100°C) as the strand passes into the radiation zone. This reheating is in fact a direct consequence of the surface temperature specification: because the shell thickness at the transition from the third spray zone to the radiation zone is only some 32 mm, a substantial core of liquid steel (at its liquidus temperature of around 1500°C) is still present in the strand. The heat available in this liquid core is sufficient to reheat the strand surface to more than 1100°C in the radiation zone—whatever the surface temperature at the exit from the last spray zone. This effect is confirmed by comparing the maximum temperatures in the radiation zone in Figures 2 and 3, which are 1132°C and 1158°C respectively—these values are very similar, despite very different spray water settings, confirming the dominant effect of the remaining liquid core on the temperatures in the radiation zone.

The conclusion is that the requirements as used in this example (and given in Table II) are in fact not consistent: it is simply not possible to obtain a 1000°C surface temperature in the spray zones, while simultaneously avoiding reheating in the radiation zone. It must be emphasized that the resulting sub-optimal spray settings is the fault of the incorrect specification, and not of the numerical procedure. In the second example, a more appropriate specification was used, as discussed below.

Requirement: Surface temperature within a band (no constant-temperature requirement)

The specification used here differs from that of the first example in two main respects. Firstly, it is recognized that specifying a required temperature in addition to minimum and maximum values, in fact implies over-specification. The specific value of the surface temperature is not in itself that important; rather, the temperature should simply remain within the bounds defined by the avoidance of the low-ductility zone (below approximately 900°C) and too-low strength (above approximately 1200°C). Secondly, because of the dominant effect of the liquid core, this temperature band must lie at higher temperatures if reheating is to be avoided. These two changes were translated into the temperature values and weights given in Table III; the Table shows the minimum and maximum temperatures to be specified as 1000°C and 1150°C respectively, with a decrease below the minimum temperature being given a higher weight to avoid a low temperature at the exit from the third spray zone. The other weights and values remained as mentioned above.

The resulting recommended spray settings are given in Table III, with the predicted surface temperature in Figure 4. The surface temperature profile fulfills all the stated requirements—allowing reheating close to the mould to avoid reheating further down the strand. This is achieved by allowing the surface temperature to exceed the stated maximum of 1150°C slightly (by about 50°C) in the radiation zone (in line with excursions in temperature above the stated maximum being given a relatively small weight). In line with the specification, the metallurgical length was allowed to be increased to 12 m, but not beyond this value. The total spray

Table II

Constant temperature requirement in spray zone: Cost function specification and resulting recommended spray settings

Weights							
w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8
1.0	1.0	1.0	1.0	0.2	3.0	1.0	10^{10}

Constants in cost function			
T_{req} (°C)	T_{max} (°C)	T_{min} (°C)	*MaxLength* (m)
1000	1050	950	12.0

Recommended spray water settings	
Zone number	Water flow rate (m³/h)
1	3.8
2	11.2
3	2.2

Specific spray water flow rate (*l* water sprayed per kg steel cast): 0.93
Calculated metallurgical length (m): 10.78

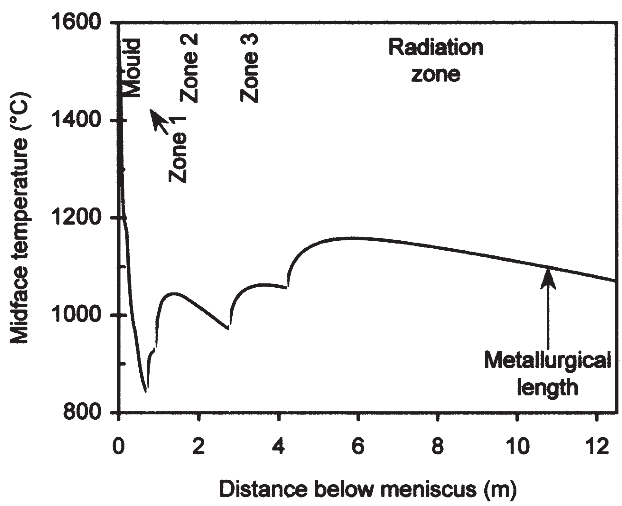

Figure 3—Calculated midface temperature profile, with the spray zone settings optimized to yield a constant surface temperature of 1000°C (settings of Table II)

water flow rate is reduced from the initial 1.1 *l*/kg to 0.4 *l*/kg, a change from 'hard cooling' to 'soft cooling'[5]. The water flow rate in the spray ring is reduced by the largest amount (to allow reheating just below the mould). This may imply unacceptably high temperatures at the foot rolls, but, if this is the case, another term can simply be added to the cost function to hold the temperature below a required maximum. (Other practical issues are considered in the next section.)

This example does serve to emphasize the point that the key to finding spray settings which yield the required temperature profile, is to be clear on what the real requirements of this temperature profile are, avoiding over-specification or conflicting requirements. Given that this optimization procedure can arrive at appropriate recommended spray water settings, several practical issues remain, which are briefly discussed in the next section.

Table III

Temperature band requirement in spray zone: Cost function specification and resulting recommended spray settings

Weights							
w_1	w_2	w_3	w_4	w_5	w_6	w_7	w_8
0	1.0	2.0	1.0	0.2	3.0	1.0	10^{10}

Constants in cost function			
T_{req} (°C)	T_{max} (°C)	T_{min} (°C)	*MaxLength* (m)
—	1150	1000	12.0

Recommended spray water settings	
Zone number	Water flow rate (m³/h)
1	0.47
2	6.0
3	1.1

Specific spray water flow rate (*l* water sprayed per kg steel cast): 0.41
Calculated metallurgical length (m): 12.0

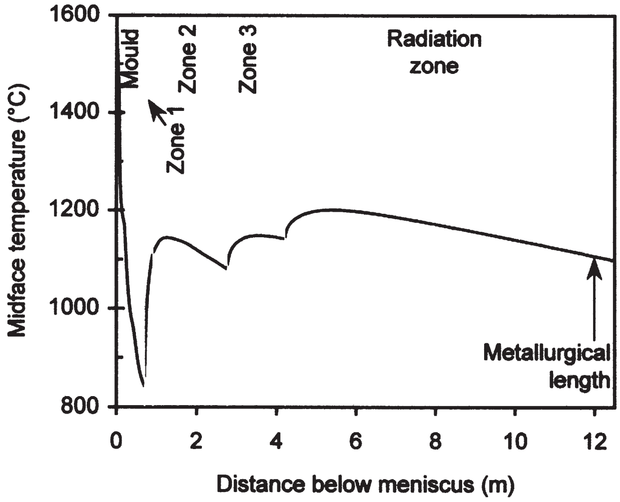

Figure 4—Calculated midface temperature profile, with the spray zone settings optimised to yield a temperature within the band 1000°C-1150°C (settings of Table III)

Practical implications

While these examples indicate the promise of this approach, several practical limitations need to be taken into account when applying this approach in practice. Two of these are listed below.

Accuracy of the heat transfer correlations

The accuracy of the correlation between the spray water flux and the heat transfer coefficient is essential to the optimization procedure. As mentioned earlier, literature correlations were used in these examples, but the wide band of literature data does indicate that the behaviour of actual spray zones may deviate substantially from the average. For this reason, the relationship should be verified by actual in-plant temperature measurements. Because the temperature at the exit from the last spray zone is quite sensitive to the heat transfer coefficient (see Figures 2 to 4) a surface temperature measurement at that point will help to improve accuracy.

Allowable range of water flow rates

In these calculations, it has been assumed that the spray water flow rate can be changed at will over a wide range. In practice, a given nozzle can only maintain a stable spray over a limited range of water flow rate (and feed pressure)[5,9], and if the water flow rate is to change outside the range, different nozzles must be used[14]. However, this limitation can again be incorporated into the optimization procedure, by including a term in the cost function which keeps the water flow rate between given minimum and maximum values.

Conclusion

A conceptually simple procedure—which specifies the performance criteria of the secondary cooling zone in terms of weights in a cost function—shows promise as a way to arrive at improved spray water settings in the secondary cooling zone. While this procedure has yet to be validated by in-plant measurements, example calculations show the underlying method to be mathematically feasible, and potentially practically useful.

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Mincom leads the way*

Mincom and IBM sign global alliance to target EAM market

Mincom, a leading Australian software developer, announce that they have become IBM's first Premier Alliance partner in Asia Pacific and will jointly develop world-class e-business solutions for the Enterprise Asset Management (EAM) market.

EAM software systems enable organizations, with vast sums invested in assets, to electronically manage plant and equipment to maximize the pay-back from their assets and minimize their cost throughout the asset's lifetime. This year alone the global EAM market will be worth US$ 913 million and by year 2002 it will grow to a staggering US$ 1.9 billion. Mincom is one of the world's leading developers of EAM software and provides solutions that are specifically designed for industries that face high costs in asset management and maintenance.

Under the alliance Mincom and IBM will utilize the skills and resources of both organizations to develop, market and sell hardware, software and service offerings worldwide. Mr. David Thodey, General Manager, Commercial Business, IBM, Australia said: 'Mincom provides business solutions that allow organizations to use networks to drive their businesses on-line, providing increased efficiencies and meeting customer needs. This provides perfect synergy with IBM's e-business strategy which is helping organizations transform their businesses by using networks to increase efficiencies and improve communication with employees, suppliers and customers'.

Mincom named Queensland exporter of the year

Mincom has been named Queensland's 1998 Exporter of the Year. It also received the award for export achievement in the 'Information Industries' category.

The awards recognized Mincom's success in forging a position as one of the world's leading developers of Enterprise Asset Management (EAM) software. The 'Information Industries' category, offered for the first time this year, rewards outstanding export achievement in the field of information technology, multimedia and communications products and services. This award gives Mincom automatic entry into the Australian Export Awards.

Mincom Executive Vice-president International Marketing, Jock O'Keeffe, said the company's international success was a result of its decision to specialize in producing whole-of-enterprise software solutions for its target industries. 'For example, we spent more than $50 million developing our flagship product MIMS Open Enterprise, launched late last year, and we have opened a number of new offices around the world in recent years. Mincom's products are now used in countries across the globe, including South Africa, UK, Indonesia, USA, Canada, Brazil and Australia', he said.

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Environmental risk exposures—A thorny issue for mine closures*

One of the most troublesome aspects of closing a mine in South Africa is obtaining a 'closure certificate' from government.

'There is great reluctance to issue closure certificates because government can rarely be convinced that the mine owners have eliminated the potential environmental risk exposures, even after all mining operations have ceased,' says John Easton, managing director of Envirocover, a specialist environmental risk management and risk finance division of the Price Forbes group.

Easton adds that, in terms of the Minerals Act of 1991, mining operations wishing to decommission cannot realize their assets until they have a closure certificate.

'Obstacles are also presented when the mining company wishes to sell the land to a third party. Responsibilities under other legislation, such as the Water Act, may also remain in force even after the mine has closed its operations. Envirocover provides a solution by managing the entire closure process.' Since 1987, only a few closure certificates have been awarded and Easton says no major mining operation has been allowed to close unconditionally.

'The concern on the part of the authorities is compounded by the fact that the State does not have the resources itself to deal with post-closure environmental pollution at mines in South Africa.'

A mining company that has mines already decommissioned, or that plan closures over the next few years, needs a clear-cut programme to deal with this situation. Easton says the authorities feel more comfortable about awarding closure certificates where a recognized, independent third party organization provides interface between the mine owners and government.

'If the third party can prove that the residual environmental risks are quantifiable, are funded by insurance and that they will be satisfactorily managed, then the authorities have shown willingness to issue closure certificates. However, the third party must have the necessary expertise and the financial facilities to respond to the environmental risks involved.'

Envirocover was the first company to be accepted as a 'specialist third party' in terms of the Department of Mineral and Energy Affairs Mine Closure Policy. The Envirocover solution allows decommissioning and closure without the retention of environmental liabilities by companies or their directors and staff.

'We incorporate three key aspects: professional environmental risk assessments; an insurance facility for environmental liabilities; and post-closure environmental management, which amounts to 'in-the-field' treatment of any residual risks,' says Easton.

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'Investment opportunities in Indian mining 99' Conference

9–10 February 1999 London, England

With the backing of the Federation of Indian Mineral Industries, the Institution of Mining and Metallurgy, the DTI and the Indo British Partnership, the conference will examine in detail the investment opportunities in the Indian mineral marketplace. As a result of recent revisions to the National Mineral Policy, the introduction of the Mines and Minerals Regulation and Development Act, and further liberalization of regulatory restrictions, the sector is experiencing a high level of foreign investment. Consequently, an increasing number of Indian operators are seeking joint operations with foreign investors. This is impacting greatly on the levels of technology in the industry, the implementation of new extractive techniques and substantial restructuring across all sectors from fuel minerals, metallic ores, non-ferrous deposits through to gold and diamond prospecting. The conference addresses the needs of those interested in entering the market-place by covering all aspects of the process from taxation, regulatory procedures, joint venture projects, technology transfer and project finance, backed up with numerous case studies from the market leaders.

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Wits engineering researcher achieves highest honour*

Following evaluation by the Foundation for Research Development (FRD), Professor David Glasser, AECI Professor of Chemical Engineering of the School of Process and Materials Engineering in the Faculty of Engineering, University of the Witwatersrand, has been accorded an 'A1' rating—the FRD's highest rating. This appointment means that out of 14 such researchers in the country, Wits now has three.

This accolade recognizes Prof. Glasser's considerable international reputation as an independent researcher in the field of process development and synthesis. It is also an acknowledgement of his acceptance by the international science, engineering and technology community as being among its top leaders, because of the high quality of his research output.

Professor Glasser's recognition follows on Professor Robert McCutcheon's upgrading to a 'B' category researcher earlier this year. Prof. McCutcheon heads the Department of Civil Engineering at Wits and has conducted research into employment creation in construction. His upgrade is 'in recognition of his considerable international reputation as an independent researcher' and is also an acknowledgement of the high quality and impact of Prof. McCutcheon's research output.

The Faculty of Engineering at Wits now has three 'A'-rated researchers—Professors Geoff Blight, David Glasser and Beric Skews and five 'B'-rated researchers—Professors Alan Kemp, Sylvana Luyckx, Robert McCutcheon, Mike Moys and Ian Macleod. ◆

* *Issued by: Lynne Hancock Communications, P.O. Box 180, Witkoppen 2068*

Appointment notice*

Professor Geoffrey Blight, of the University of the Witwatersrand, has been elected a Fellow of the Institute of Waste Management. ◆

* *Issued by: Lynne Hancock Communications, P.O. Box 180, Witkoppen 2068 Tel: (011) 460-1000*

Knelson announcements

A Salute to Innovation and Leadership

The Canadian Institute of Mining, Metallurgy and Petroleum Centennial Corporation has presented Byron Knelson, the inventor of the Knelson Concentrator, with a 'Certificate of Achievement'. A salute to innovation and leadership for his outstanding contribution to the successes of the Canadian minerals industries and for his exceptional dedication.

New President

Byron Knelson, Chairman of the Board of The Knelson Group, is pleased to announce the appointment of Bob Adams to the position of President and General Manager. Bob Adams brings with him over 25 years experience in the manufacturing sector. He has held senior management positions in automotive parts, pre-engineered buildings and custom steel fabricating industries. Bob will lead The Knelson Group's continued growth into the 21st century. ◆