Some criteria for the selection of environmentally acceptable processes for the processing of lead- and zinc-containing flue dusts

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Synopsis

This paper gives an overview of some criteria for the selection of processes for the recovery of lead and zinc from various raw materials and/or intermediate products. A glossary of possible processes and process variants, is presented and discussed, as well as the way in which these are interlinked. Recent developments in metallurgical process synthesis are also discussed, and the results produced by an eco-techno-economic synthesis procedure for process routes in zinc metallurgy are given briefly. The way in which such a synthesis can complement a life-cycle assessment (LCA) of zinc-producing technologies is also described.

Introduction

The relevance of processes, processing concepts, and strategies for the processing of lead- and zinc-containing flue dusts must, as would be the case for any industrial process, continually be evaluated in order to ensure their long-term survival. Three quotes from the literature succinctly summarize this:

- 'a continuous evaluation of operation strategies by our industry in general and (zinc) smelters in particular is vital'[1]
- 'more and more pressure is put upon zinc companies to treat their historical residues and to produce environmental acceptable residues'[2]
- 'most of the processes applied to the primary treatment of zinc raw materials are also applicable to the treatment of intermediates'[3].

The criteria by which an industrial process, process concept, etc., can be evaluated is depicted in Figure 1. Initially, the technical feasibility of the process must be proved by, for example, mass and energy balances, and laboratory- and/or pilot-scale work. This process can mature into a full-scale operation only if it is economically viable and if it can compete on a global scale with other processes. This can be achieved if the operating costs for the process are less than the costs for the dumping of materials such as flue dusts. These aspects, however, do not guarantee the success of a process or a concept in its own right since environmental issues play a major role. It has been demonstrated that many processes can operate within environmentally acceptable standards, i.e. their emissions have acceptable values. However, during the development of new environmentally sound recycling concepts, care must be taken to investigate and highlight their long-term effects on the environment, by the use of an environmental impact assessment, to ensure that these processes do not eventually become a liability.

It must be noted that a process or concept, if it has any chance to survive, must at all times be acceptable to society, especially a society that is becoming more and more environmentally conscious.

Lead- and zinc-containing flue dusts

The recycling of all the residues from the production of iron and steel in order to create closed circuits is receiving much attention, especially the recycling of lead- and zinc-containing flue dusts. Figure 2 shows the locations at which these flue dusts are produced during iron and steel making. As an example, about 1 Mt of flue dusts were produced in the German iron and steel industry in 1992. In 1985, the European Community was confronted with approximately 4.5 to 5 Mt of blast and converter flue dusts per annum and approximately 0.6 Mt of electric-arc furnace (EAF) flue dusts per annum[4]. These dusts are either being processed or partially recycled internally, or are just dumped.

The chemical composition of these very fine flue dusts depends on their origin as

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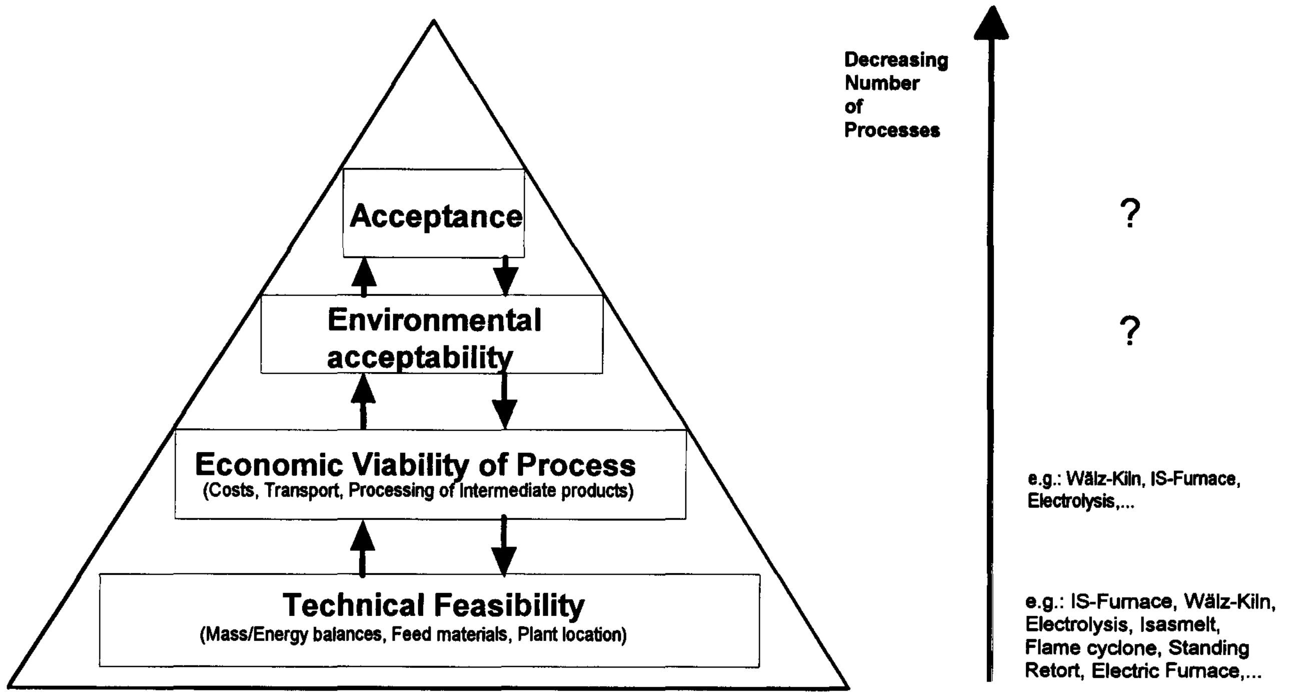

Figure 1—A structure for the evaluation of processes for the processing of lead- and zinc-containing flue dusts (IS = Imperial Smelting)

summarized in Figure 2, and the zinc and lead contents vary widely, as indicated in Table I.

More specifically, the zinc and lead contents in the various streams in Figure 2 are as follows[5]:

- sinter dust (<2% Zn, <1% Pb)
- offgas dust from the blast furnace (0–20% Zn, 1–12% Pb)
- converter dust (<6% Zn, <1.5% Pb)
- EAF dust (10–38% Zn, 2–10% Pb)

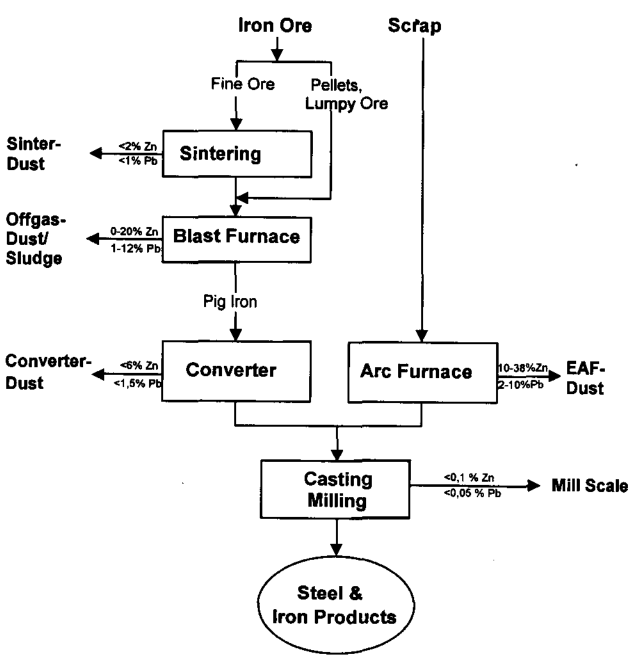

Figure 2—Locations for the creation of flue dusts, and their zinc and lead contents

Table I

Composition range of the flue dusts produced in the iron and steel industry[4]

Valuable elements	Range %	Other elements	Range %
Zn	0–38	Cl	0–7
Pb	0–12	F	0–3
Cr	0–15	S	0–1.4
Ni	0–9	Na_2O+K_2O	0–8.5
Cu	0–0.8		

- stainless-steel flue dust (2–4% Zn, 0.5–1% Pb).

Essentially, the elements in the various flue dusts can be divided into those which can be recovered and resold (e.g. zinc, lead, nickel, chromium, copper, precious metals and, in some cases, iron) and those for which the recovery provides no economic incentive. In summary, the objectives for the processing of the flue dusts depicted in Figure 2 are as follows:

- recovery of the valuable elements (Zn, Pb, Fe, Cr, Ni, precious metals, and chlorides)
- capturing of the other economically uninteresting and, in some cases, environmentally critical elements, e.g. Cd[4] in a stable form, to ensure their environmental acceptability
- integration of the processing of the flue dusts into existing process routes for recovery of the metal
- development of the most economically viable operation of the processes.

The following sections discuss various concepts for the processing of flue dusts containing lead and zinc (Figure 1), which include the following:

- technically feasible and proven process technology

- possible emergent and pilot-scale process routes
- economic viability of these processes
- their environmental acceptability.

In addition, a brief overview is given of a published methodology in which the first three steps of Figure 1 are formalized mathematically by a procedure of eco-techno-economic synthesis, that permits a comparison of a vast number of processes on an ecological, technological, and economic basis[6,7]. Subsequently, the use of this synthesis procedure in complementing the life-cycle assessment is discussed.

Technical feasibility

Industrial processes for the processing of lead- and zinc-containing flue dusts

Most of the processes applied to the recovery of lead and zinc from primary raw materials can in principle be applied to the recovery of lead and zinc from flue dusts[8]. In most cases, however, the valuable elements in the flue dusts must be concentrated (e.g. to more than 30% Zn) before their processing can be justified economically.

Figure 3 summarizes the most important industrial processes that can be used to concentrate and process zinc and lead from flue dusts[5]. This figure depicts the operating ranges of the zinc contents of the intermediate or end products against the concentration of the input feed materials for the various depicted processes. From Figure 3 it can be seen that, in the region of preconcentration (2 to 18% Zn), there is no industrial-scale process for the processing of flue dusts.

Flue dusts with low zinc contents (<2%)

According to the representation in Figure 3, flue dusts with zinc contents of less than 2% must be preconcentrated in a process such as the rotary-furnace SPM/SDR process, which was used in Japan in the past[9]. This process produced a product with a zinc content of 10 to 30%. Other processes that operate in this region use the DKH blastfurnace[10] and the Inmetco furnace[11], which produce secondary flue dusts with zinc contents between 40 and 60%. Figure 4 depicts the DKH process, while Figure 5 depicts the Inmetco process.

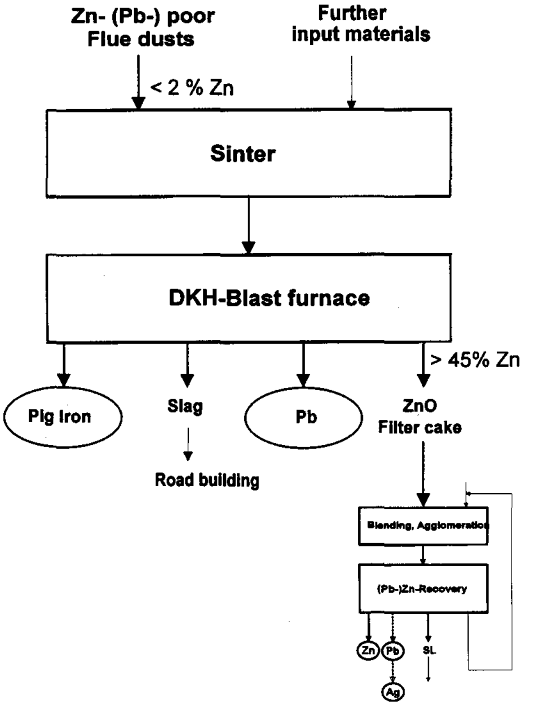

Figure 4—The DKH blastfurnace process[10]

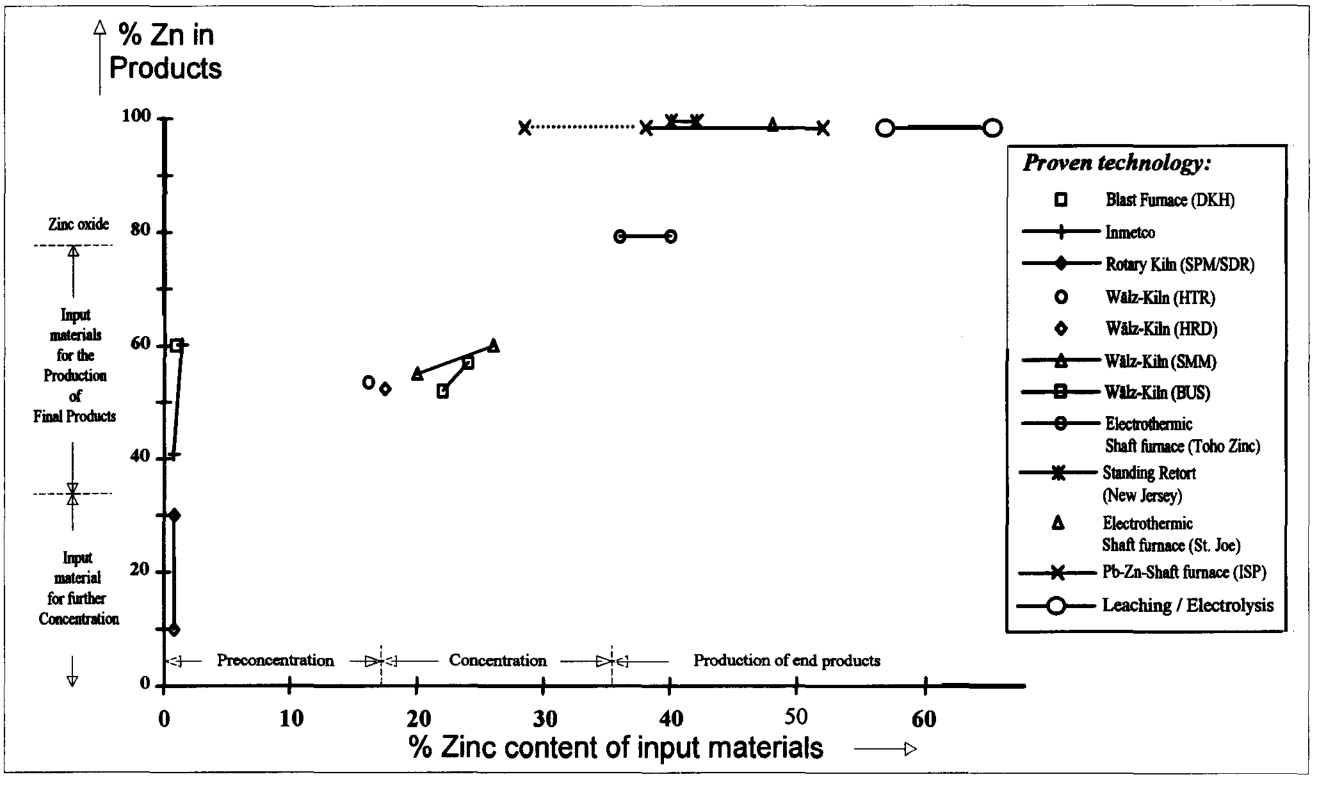

Figure 3—Various processes for the recovery of zinc and lead from flue dusts

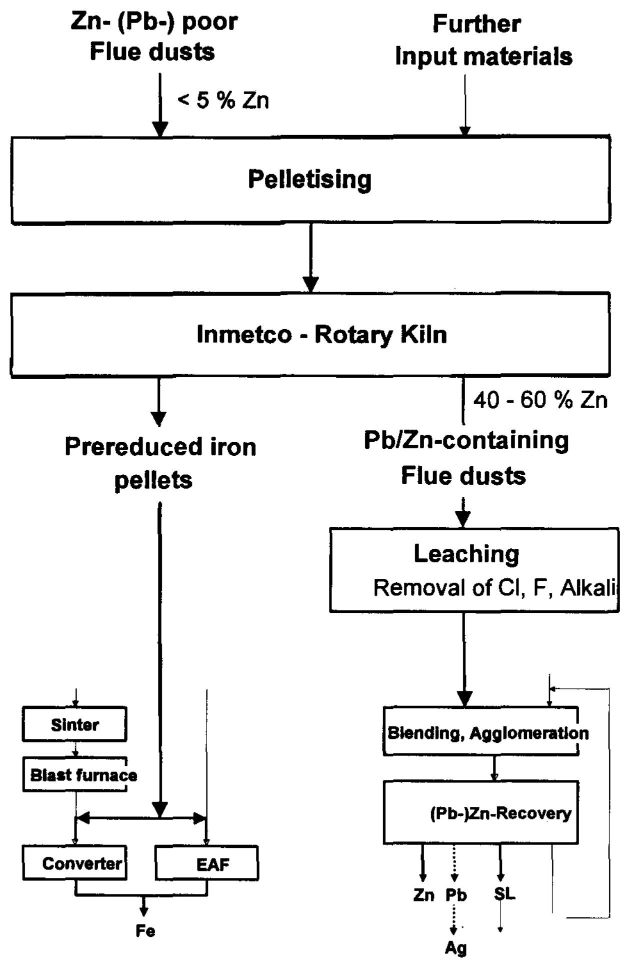

Figure 5—The Inmetco process[11]

Flue dusts with intermediate zinc contents (about 18 to 30%)

Dust with intermediate zinc contents (about 18 to 30%), e.g. SPM/SDR secondary flue dust, are generally concentrated to produce a secondary flue dust with a zinc content of more than 35%. These dusts can be cycled directly to producers of primary zinc metal. The process most often applied for concentrating flue dusts of intermediate zinc content is the Wälz kiln[4]. Various Wälz kilns of different operating strategies are in operation at a variety of locations and companies, among which are Sumitomo Metal Mining Co. (SMM), Ponte Nossa, Horsehead Resource Development (HRD), Espanola del Zinc, Himeji Tekko Refine (HTR), Berzelius Umwelt Service (BUS), Nisso Smelting Company, and Cerro de Pasco[4].

Normally, the flue dusts from the iron and steel industry with intermediate zinc contents (EAF dusts) contain reasonable quantities of fluorides, chlorides, and alkali (up to 7% Cl, 3% F, and 8.5% Na_2O+K_2O). These become concentrated together with the lead and zinc oxides in the secondary flue dust from the Wälz kiln, and create problems if processed in, for example the Imperial Smelting Process (ISP) or during the electrolytic recovery of zinc. Therefore, before these secondary dusts can be processed further, the problematic elements and compounds must be removed. The processes used can be divided roughly into hydrometallurgical approaches or rotary-kiln (clinker) processes[12–15].

A schematic flow diagram showing the processing of flue dusts according to the Wälz process, together with processes for the removal of the fluorides, chlorides, and alkali is given in Figure 6. It can be observed that, not only must the Wälz oxide be processed further, but also the iron-rich Wälz slag, in this case as depicted in an electric furnace. Furthermore, depending on the unit operation by which the Wälz oxide is subsequently treated, different pretreatment processing routes must be followed. For example, the ISP is capable of

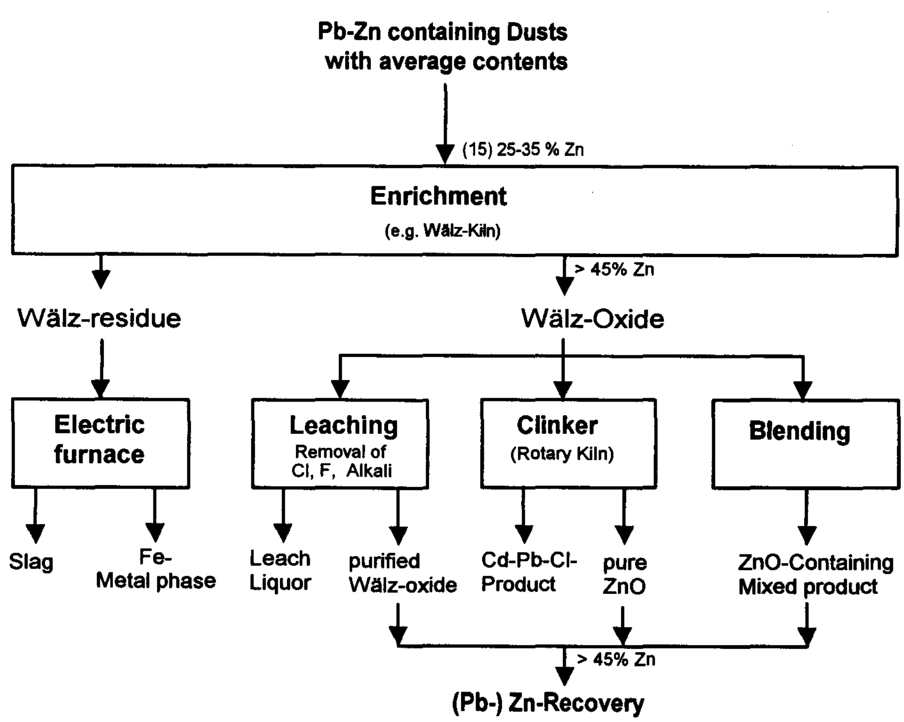

Figure 6—Enrichment of flue dusts of average zinc content in the Wälz kiln and subsequent removal of chlorides, fluorides, and alkali from the Wälz oxide

tolerating up to 1% chlorides in the feed, implying that blending could be used; in contrast, zinc electrolysis can tolerate a maximum of 300 p.p.m. of chlorides in the feed material, making leaching or a clinker process imperative.

Flue dusts with high zinc contents (>35%)

In the ISP[16], standing retort[17], or electrothermic shaft furnace[18], zinc metal is produced from materials of high zinc content (more than 35%). Only when the feed materials contain more than 55% zinc, are hydrometallurgical processing and electrolytical recovery applied[6,7]. From Figure 3 it is clear that the production of zinc metal from secondary materials can occur only through two to three steps. However, it should be noted that the feed materials to the Wälz kiln or to the ISP can be a blend of primary and secondary materials, thus permitting the limited usage in these furnaces of materials of lower zinc content than stated above.

Figure 7 compares the recovery of zinc metal by the ISP and electrolysis. It is clear that feed materials with different levels of pretreatment are required, and that the ISP is capable of recovering silver and lead in addition to zinc, which is not possible after the hydrometallurgical route. Depending on the silver price, the recovery of this element during the lead-refining step can add considerably to the profitability of the

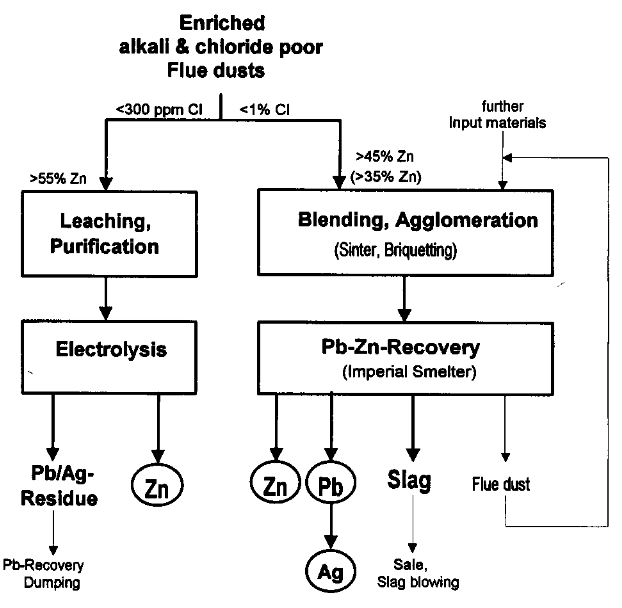

Figure 7—A comparison between the recovery of zinc metal in the ISP and via electrolysis

ISP, whereas the lead–silver residue from the hydrometallurgical process route must be dumped or processed further for the recovery of these elements.

Other processes for zinc- and lead-containing flue dusts

Table II lists additional processes (some unproven on an industrial scale) that can be integrated into a flowsheet for the processing of lead- and zinc-containing materials[3,4,6,7,19].

The operating ranges of some of the processes listed in Table II have been superimposed onto Figure 3 to yield Figure 8. It can be observed from Figure 8 that some of these processes operate in the preconcentration range (i.e. with between 2 and 18% zinc in the feed materials), which is of great importance to the processing of flue dusts from the steel industry. It should be noted that the Inmetco process has been used industrially for some years in the treatment of this type of dust.

Economic viability

The processes that were highlighted earlier, (i.e. concentration in a Wälz kiln; removal of chlorides, fluorides, and alkali; and thermal or electrolytic zinc-recovery) can undoubtedly be classified as technically proven processes, which have also demonstrated that they can operate within the boundaries of set environmental standards, taking cognizance of the fact that these processes are being operated in countries with strict environmental legislation. Processes for the removal of chlorides, fluorides, and alkali are partially in operation on an industrial scale.

An economic comparison between electrolysis and the ISP furnace for the recovery of zinc from primary materials remains vague. A comparison by Maczek[20] in the early 1980s put the operating costs of the ISP 10% higher than those of the electrolytic recovery of zinc (17.98 and 16.14 cents per pound respectively). Verney[21], on the other hand, calculated the operating plus capital costs of operating an electrolytic process higher than those for the ISP (11.8 and 11.3 cents per pound respectively). However, it is not evident from either comparison whether the recovery of lead and precious metals from the ISP was included in the calculations. The electrolytic process is also very dependent on the costs of energy at a particular location. Furthermore, the low values of fluorides, chlorides, and alkali tolerated for the electrolytic recovery of zinc make a thorough pretreatment of the secondary flue dusts necessary.

A final economic comparison between the electrolytic process and the ISP is not made here. Under a given set of

Table II

Various other processes for the recovery of zinc-containing materials[3,4,6,7,19]

Shaft- and rotary-kiln processes	Bath-smelting processes	Hydrometallurgical processes	Electrical processes	Other/non-recoverable processes
Standing retort	QSL process	Flotation	Enviroplas	Vitrification
Lead blastfurnace	Kivcet Process	Leaching (e.g. HCl, NaOH, H_2SO_4)	ScanDust	Cebedeau
Half-shaft furnace	Flame cyclone	Zincex	Tetronics	
ZIA process	Slag fuming	Solvent extraction	Elkem	
Circulating fluidized bed	Isasmelt			
Kowa Seiko	TBRC			

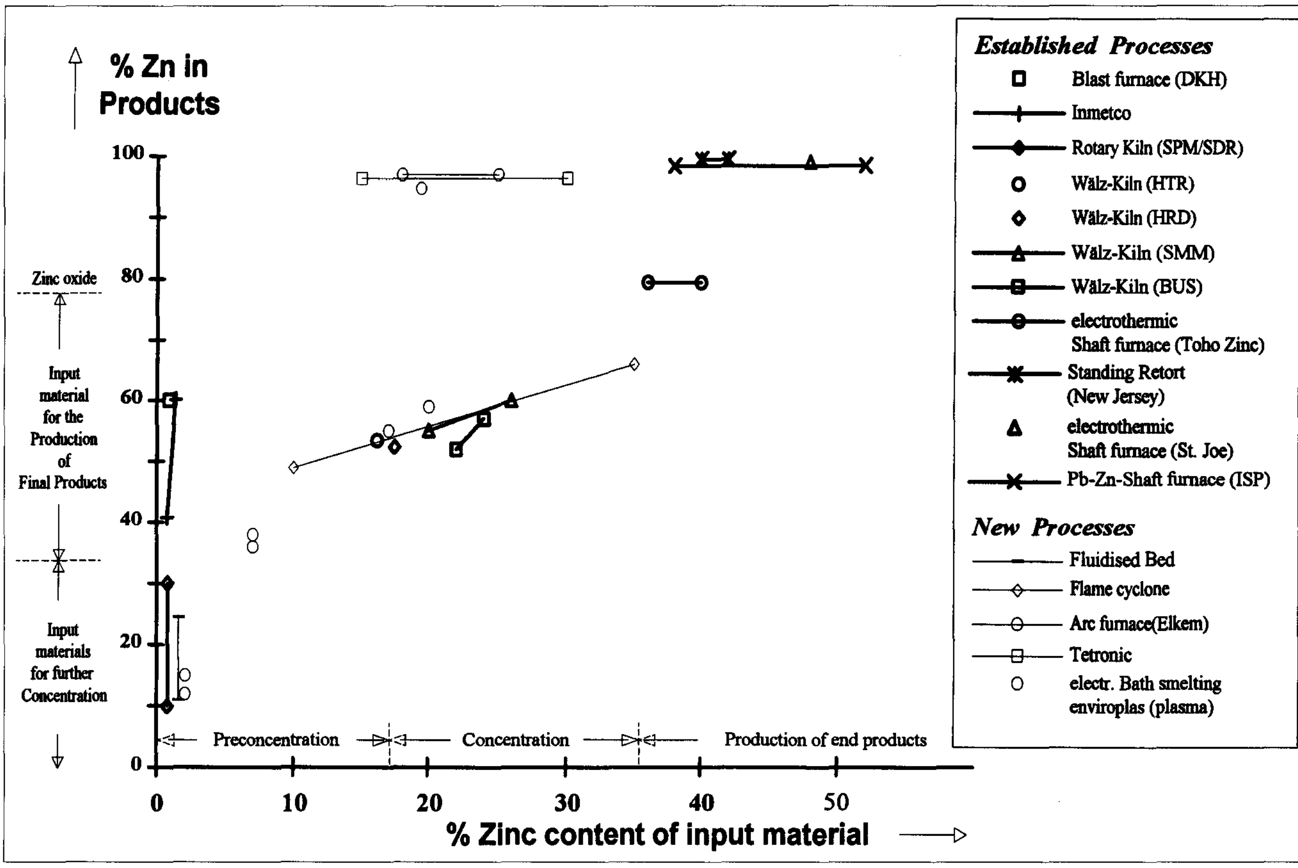

Figure 8—New processes for the recovery of zinc and lead from flue dusts in relationship to some existing technology[5]

favourable boundary conditions, both processes are economically viable. Whereas the electrolytic process can operate on flue dusts of high zinc content containing low levels of chlorides, fluorides, and alkali, the ISP can, in addition to zinc, recover elements such as lead, copper, and precious metals. Secondary materials with low contents of chlorides, fluorides, and alkali can be blended, without pretreatment, with primary feed materials and be treated directly.

So that a particular process can be evaluated objectively as to whether it is more economically viable than another, a synthesis procedure was formulated. This procedure[6,7], which also includes some environmental aspects, is discussed briefly in the following section.

Process synthesis of metallurgical process routes

From metallurgical experience it is evident that the two competing environmentally acceptable processes for the production of zinc metal from lead- and zinc-containing flue dusts are the combined leaching and electrolysis process and the ISP. However, depending on location, type of material, etc., other processes could be used to treat these flue dusts, for example in existing plants that are in close proximity to the origin of the flue dust or in newly developed processes such as the circulating fluidized-bed reactor and the Enviroplas process[19].

It has been suggested in recent papers that the neutral leach residues created during the hydrometallurgical treatment of roasted zinc ores should be treated pyrometallurgically. When this route is adopted, the available pyrometallurgical unit operations for the processing of the leach residues are available at the same time for the processing of lead- and zinc-containing flue dusts, as suggested by Figures 9 and 10. This represents a holistic approach to the recovery of zinc and lead, i.e. the primary and secondary recovery of lead and zinc are integrated in the most economical and environmentally favourable way subject to the availability of suitable unit operations.

It is clear from Figures 9 and 10 that there are a vast number of processes that can be used for the treatment of lead- and zinc-containing materials. This rather extensive overview of the possible processes and process routes would suggest that the selection of the right combination of economically and environmentally acceptable processes is a daunting task, especially if all possible combinations of the different process routes are to be analysed. This selection can be made only by very experienced metallurgists or can be based on suitable synthesis models, i.e. mathematical optimization models that can determine the optimal connection between various unit operations.

Since the development of such a synthesis model has been the topic of two recent papers by the authors[6,7], the reader is referred to these for more detail. This development represents the first application of process synthesis in metallurgy. In contrast, there are a variety of applications in chemical engineering[22–24] and in minerals processing[25,26]. The methodology followed includes the following procedures:

- creation of a generalized flowsheet in which the products and residues of each unit operation are

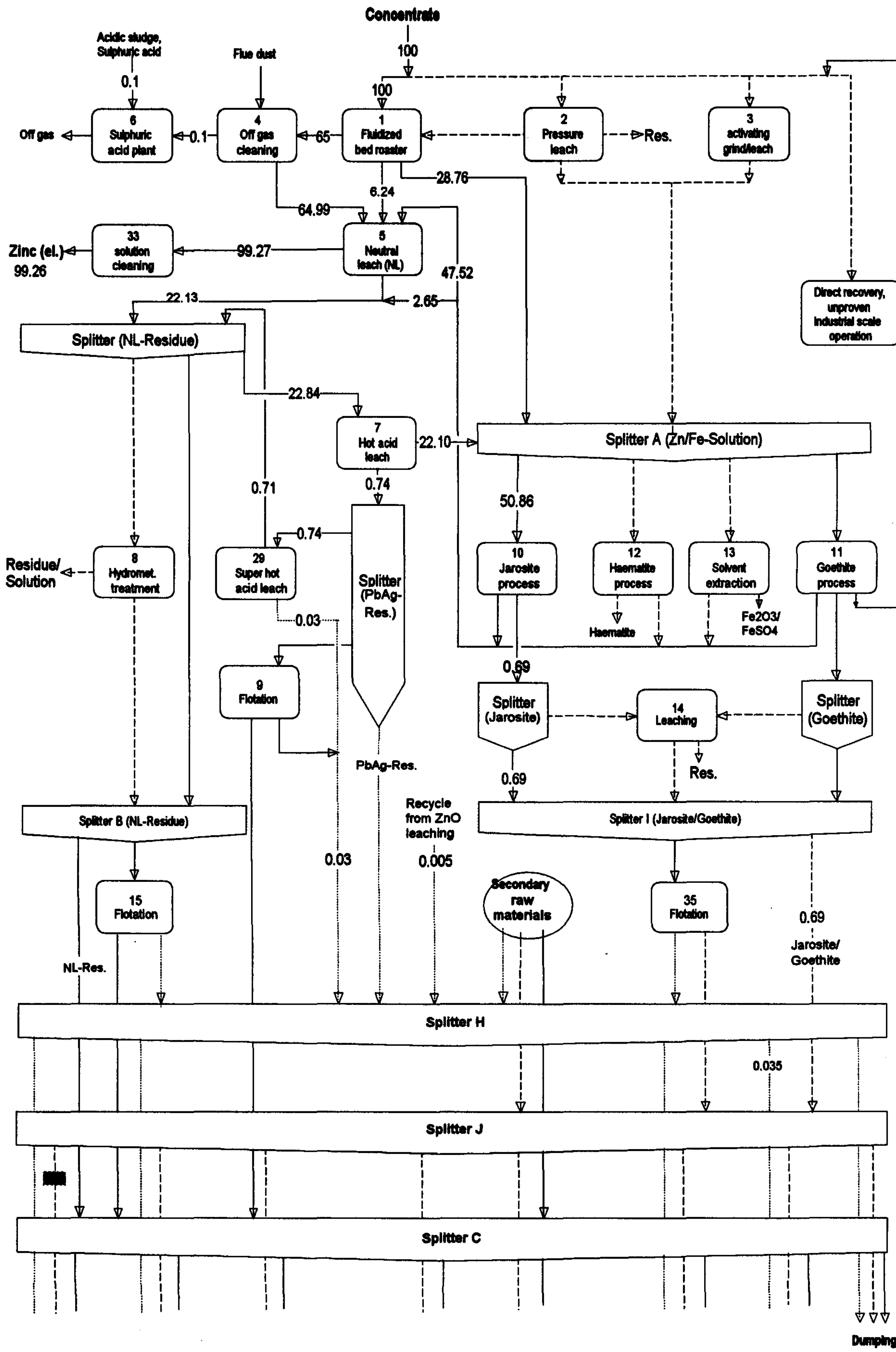

Figure 9—Hydrometallurgical processing of zinc-containing materials, and the feeding of secondary materials to pyrometallurgical unit operations[7]

recycled to appropriate other unit operations, as indicated in Figures 9 and 10

- production of a suitable 'split factor' for every unit operation and each element being considered, as well as for environmentally related data
- creation of a suitable set of generalized mass-balance equations that describe all the possible process routes, as well as the energy flow
- creation of a suitable optimization model (hence a suitable objective function)
- solving of the ensuing non-linear optimization model by a suitable optimization procedure.

This optimization model comprising the above constraints is linked to the criteria for the selection of suitable processes as depicted by Figure 1. In its simplest form, this equation is

$$J = \sum_{k=1}^{\text{Elements}} \left[m_k \cdot C_k - \sum_{i=1}^{\text{Unit operations}} \left(T_{i,k} + O_{i,k} + V_{i,k} + F_{i,k} \right) \cdot X_{i,k} \right], \quad [1]$$

where J = function that has to be optimized

$X_{i,k}$, m_k = mass flow of element k from unit i and total recovery of element k, respectively

C_k = revenue through the recovery of the valuable element k

$T_{i,k}$ = transport costs per mass of the considered element k for unit operation i

$O_{i,k}$ = operating costs per mass of the considered element k for unit operation I (including energy costs)

$V_{i,k}$ = costs for maintaining the environmental integrity of the process per unit mass of the considered element k for unit operation i (e.g. dumping costs, penalties for emissions, noise)

$F_{i,k}$ = fixed costs of the considered element k for unit operation i.

A closer look at this equation reveals that some of the criteria mentioned in Figure 1 are incorporated. For a specific location, environmentally related costs are considered, as are transport, fixed, energy, and operating costs. However, the incorporation of environmental aspects or criteria is a rather sensitive issue since there is no generally agreed methodology for the inclusion of these types of costs in calculations[27]. The optimization using this approach would produce a process configuration that would maximize J as a function of the various costs, boundary conditions, and environmental considerations.

The results produced by this model for a four-element system (lead, zinc, silver, and iron) indicate that neutral leach residues should be treated pyrometallurgically and, more specifically, by the ISP, which permits the recovery of lead, zinc, and silver, as well as the Wälz kiln. The following are some general results from the procedure.

- Optimization on the basis of only the zinc recovery (including the costs of the unit operation) produces a solution that suggests that the neutral leach residue should be processed in the ISP with subsequent slag blowing and leaching of the zinc-containing flue dust produced. As the costs of the unit operation increases fewer and fewer unit operations are incorporated into the flow diagram, with the final solution resulting in the dumping of the neutral leach residue, i.e. no processing of the residues.
- If no constraints other than split factors are incorporated, the jarosite route is the most favourable, with processing of the lead–silver residue by a lead producer and processing of the jarosite by, for example, the Isasmelt process. As soon as the costs of the unit operation are incorporated, the preferred route is processing of the neutral leach residue in pyrometallurgical unit operations such as the ISP, Wälz kiln, or flame cyclone. The results indicate that the ISP plays the most prominent role.
- Different solutions are produced depending on the type of feed and the prevailing metal prices. For example, when the silver price is high, the residues are treated in processes that can recover silver, such as the ISP, QSL, and lead blastfurnace.

Figure 10 reveals that the flue dusts can also be integrated in this flowsheet, providing a holistic approach to the creation of 'optimal' process routes for the recovery of zinc from various intermediate materials.

In summary, it can be stated that the synthesis procedure attempts to combine economic and some ecological weightings to establish 'optimal' process routes for zinc processing. The next logical step is to combine this procedure with life-cycle assessment (LCA), which is defined and discussed in the following section. This discussion also shows how the published eco-techno-economic synthesis procedure interacts with the LCA.

Life-cycle assessment

The environmental department (Umweltbundesamt) of Germany defines life-cycle assessment as follows[27]:

- Life-cycle assessment is a comparison of the environmental effects of two or more products, product groups, systems, or processes. Its aim is to expose weak aspects of processes, improve the environmental characteristics of the products, to provide guidance during buying, to advance environmentally friendly processes and products, to compare the behaviour of alternative products, and to justify the actions taken.

According to the same publication[27], LCA can also be defined as follows:

- Product life-cycle assessment is an objective process to evaluate the environmental burdens associated with a product, package, process, or activity by identifying and quantifying energy and material uses and resultant environmental releases during their entire life cycles... and evaluating opportunities and implementing changes to effect improvements.

According to the Umweltbundesamt, the standard model[27] for LCA is defined to comprise the following aspects.

- **Goal definition.** This involves the setting of the system and the system boundaries for the assessment (e.g. geographical boundaries, types of process) and the functional units (units used as a basis for the comparison of the environmental impact).
- **Life-cycle inventory (LCI).** An LCI results in a list of environmental impacts or an impact table, including

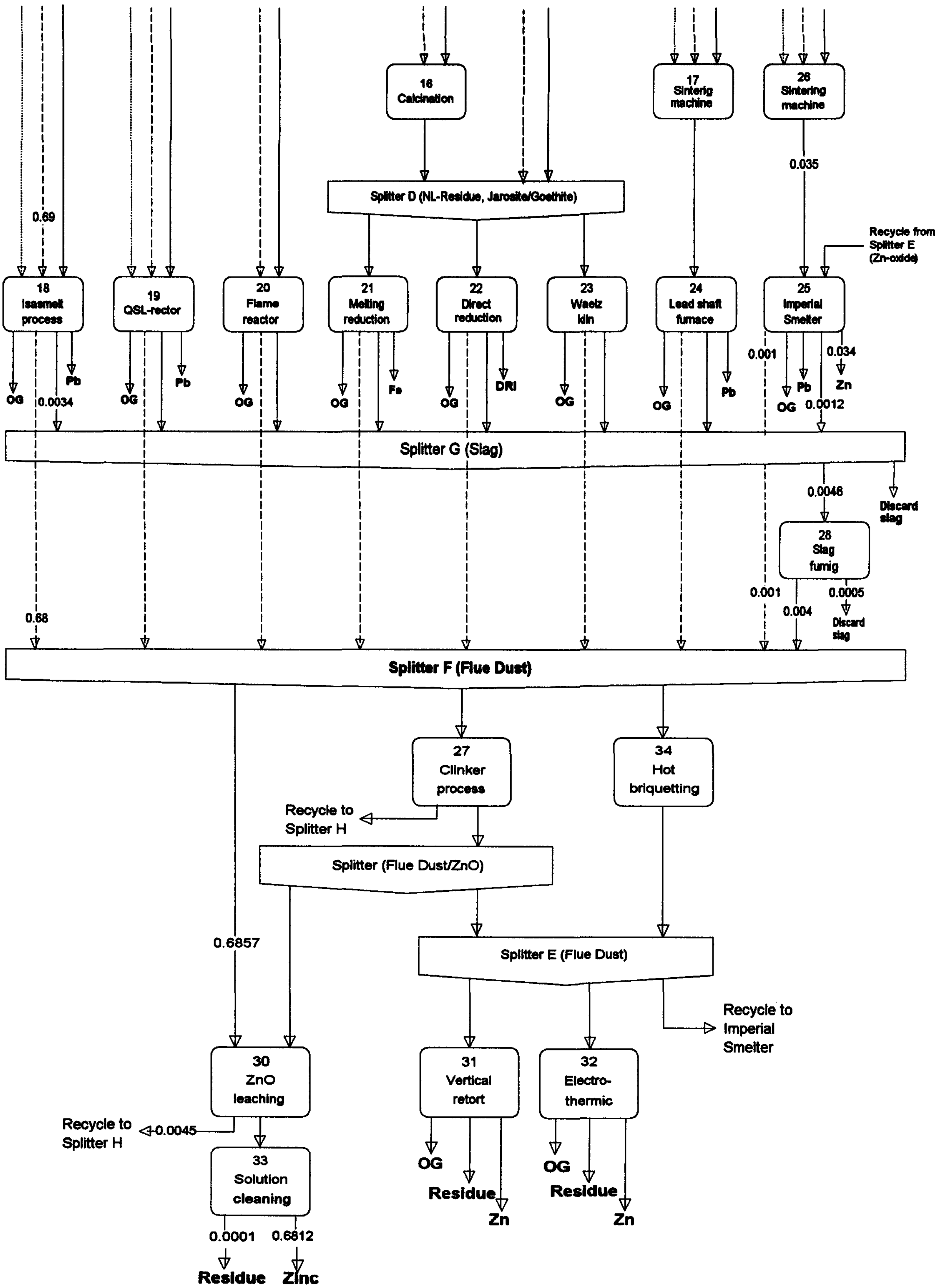

Figure 10—Pyrometallurgical and hydrometallurgical treatment of intermediate products and residues[7]

information such as the mass flow of various products, energy consumption, quantity of created residues or wastes, emissions to air and water, transport used, and a qualitative discussion of the resulting environmental effects. An example in metallurgy is the recent LCI produced for the German copper industry[28].

- **Environmental impact assessment (EIA).** The effects of the LCI on the environment, e.g. changes to climate, toxicity effects on humans and surrounding nature, demands placed on raw-material resources, generation of heat and noise, and odours created are pinpointed by this assessment.
- **Evaluation.** The results obtained for the LCI and the EIA are evaluated.
- **Improvement analysis.** Processes are improved as a function of the weak points identified during the LCA.

Recently, Stewart and Petrie[29] discussed how LCA can couple environmental and economic factors in a multi-variable optimization of process performance. They conclude that it would be possible to evaluate a set of 'non-inferior' operating conditions in metallurgical processes in which the trade-offs between economic efficiency and environmental performance can be made explicit by the application of process synthesis. It is evident that there is much similarity between the detailed zinc application discussed in this paper and the more general approach covering a wider spectrum of processes as discussed by Stewart and Petrie. However, since these authors are in the process of developing an optimization procedure for their model, no results have yet been presented.

If the synthesis procedure given in this paper and the definition of LCA are compared, there are a number of common aspects, indicating that metallurgical process synthesis can assist during LCA very much as Stewart and Petrie[29] postulate. The following are common points.

- The mass balance that is generated by the optimization procedure gives a complete flow of the elements through the generated process flowsheet. At the same time, the energy consumption is produced. As demonstrated in one of the authors' papers[7], it is possible to change scenarios and establish the effects of the change on the synthesized process routes; the effect of process efficiencies and economic indicators can also be elucidated. It is clear that these are all typical aspects of an inventory analysis.
- As discussed by Stewart and Petrie[29], LCA requires a quantitative link between the generation of waste and its environmental impact. As discussed earlier, each process is provided with an environmental weighting relative to an element k as given by equation [1]. This is not quite in accordance with LCA and its impact analysis, which requires, for example the aggregation of waste inventories around recognized global environmental problems, or the degradation of primary resources as a function of waste generation. Nevertheless, the suggested synthesis procedure does select processes that would minimize this aspect of the given objective function, and therefore minimize the total environmental burden. In so doing, the proposed methodology covers some aspects of impact analysis.
- Each 'optimal solution' produced by the proposed procedure is a function of all the boundary conditions. A change in the boundary conditions would obviously change the solution, and solutions can therefore be improved iteratively as a function of these. In effect, this covers the evaluation and improvement analysis steps of LCA.

From the above it is evident that some aspects of LCA are included in the synthesis procedure proposed here. However, as formulated to date, this synthesis procedure does not form part of an LCA.

Discussion

Depending on the zinc content of the feed materials, three steps are currently used on an industrial scale for zinc-poor materials, or one step for zinc-rich materials. A large group of steel flue dusts containing intermediate levels of zinc (about 20 to 30%), are primarily enriched by the Wälz process. The secondary flue dusts produced (about 45 to 60% zinc) are processed subsequently by the usual zinc-metal processes.

The principal processes for the production of zinc and zinc–lead metal are leaching–electrolysis and the ISP respectively. In both processes, however, the feed materials may contain only limited quantities of fluorides, chlorides, and alkali. Therefore, before flue dusts from, for example, the Wälz process can be used in these processes, they have to be pretreated, e.g. by leaching. If the leaching route is followed, the feed material may contain only 300 p.p.m. of chlorides, whereas the level may reach 1% for the ISP. In addition, the ISP permits the recovery of lead and silver, making it more attractive than electrolytic recovery (which produces a lead–silver residue that has to be processed further).

By use of the synthesis model proposed for the automatic evaluation of the available process routes for the recovery of zinc and lead, process routes that are optimal with respect to their technologies, and to their economic and ecological performance can be selected. In addition to LCA formalism, this synthesis model is a useful tool in the bag of the environmental engineer.

Although this paper focuses on zinc- and lead-containing materials, its principles are applicable to the environmentally conscious processing of all materials containing any number of elements or compounds.

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Mobile air rescue station (MARS)*

The CSIR: Mining Technology, together with Boart SA (BMSA), has developed a self-contained, easy-to-operate mobile air rescue station, MARS, which acts as a mobile life-support system for underground workers in the event of the development of an acute irrespirable atmosphere.

Designed to accommodate and provide emergency life support for 18 persons for a maximum period of 13 hours, MARS provides respirable air through two independent systems: a primary and a secondary system of air supply. The primary air-supply system consists of eighteen 50-litre cylinders that can sustain life for up to 8 hours, while the secondary air-supply system, 18 GME-approved long-duration chemical oxygen self-rescuers, can sustain life for an additional 5 to 6 hours. The primary air-supply system is connected to escape hoods and delivers a set flow of breathing air to the user. A positive pressure is created inside the hoods, which allow breathing and prevent the ingress of contaminants into the hoods.

The system can be located close to working areas, thereby enabling workers to reach the system with body-worn SCSRs, even under conditions of low or zero visibility. However, the system is not an alternative to formal refuge bays, but should be seen as complementary to existing refuge bays or other places of safety.

A circulating light that is connected to the mine power supply is mounted on top of the trailer to act as a beacon for easy location. In case of power-supply failure, a solenoid valve automatically activates a low-frequency air-driven alarm siren, which can also be activated and de-activated mechanically.

MARS advances with the working face, and can be pulled out in case of an emergency. It can also be adapted to suit the needs of individual mines.

The system has a number of accessories including a first-aid kit, resuscitators, fire extinguishers, gas monitors for Ex, Ox, and Tox, and stretchers. ◆

* *Further information is available from: Trompie van Rensburg, tel: (011) 358-0207, e-mail: TVRENSBU@CSIR.CO.ZA.*

Wits engineering students seek new metallurgical solutions*

Students in the School of Process and Materials Engineering at the University of the Witwatersrand have ended the year with an impressive display of posters illustrating their 1996 research projects, many of which have been sponsored by industry.

Awards were presented for the best undergraduate (fourth year) and postgraduate posters in physical metallurgy, corrosion, extractive metallurgy/minerals processing and chemical engineering.

A poster by Ph.D. student Zaid Bulbulia was selected as the best postgraduate display in physical metallurgy. Sponsored by Mintek, Zaid's project concerned the room temperature catalytic oxidation of CO to CO_2 and reduction of NO_xs. 'One of the biggest challenges of modern day engineering has been the cost-effective removal of environmental pollution which causes global warming and acid rain', he said. However, the solutions are generally prohibitively expensive.

'This project was designed to challenge the existing paradigms in current solutions to these gaseous pollutants and to find alternative cost-effective methods of doing so. The results to date have been extremely encouraging in that the catalytic oxidation of CO and the reduction of NO_xs have been achieved at room temperature.

'The implication of these results, with the appropriate engineering, could therefore be phenomenal', said Zaid. He was supervised in this project by lecturer Dr Andre van Bennekom.

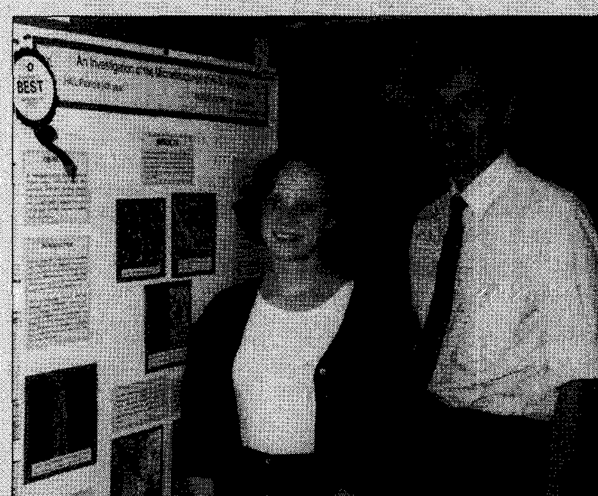
The winning undergraduate poster in physical metallurgy was the work of fourth-year student Patricia Hill. Her poster depicted her investigation of the microstructures of Al-Ru-Ni alloys, supervised by Dr Mike Witcomb and Dr Lesley Cornish.

Patricia studied the microstructures of Al-Ru-Ni alloys between the intermetallic compounds AlRu and NiAl using the scanning electron microscope and the transmission electron microscope to determine the reason for a peak hardness observed in alloys with nominal atomic composition 48%Al, 26%Ni and 26%Ru.

It was found that a binary sample containing 47%Al and 53%Ru had a very high dislocation density while a sample of a ternary alloy within the composition range in which high hardnesses were observed did not contain any dislocations.

'This indicates that dislocation mobility in the harder material is very limited and could explain the peak hardness values obtained for this alloy.' ◆

With the winning postgraduate poster in physical metallurgy at Wits University's School of Process and Materials Engineering are supervisor Dr Andre van Bennekom (left) and the author of the poster, Ph.D. student Zaid Bulbulia



Fourth-year student Patricia Hill and supervisor Dr Mike Witcomb with Patricia's winning poster in the School of Process and Materials Engineering at Wits University

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

Gold Fields funding of Wits engineering*

The Faculty of Engineering at the University of the Witwatersrand has officially thanked Gold Fields of South Africa for their valuable support of its electrical- and mechanical-engineering teaching facilities in recent years. Top Gold Fields officials were recently invited to view the equipment used for teaching and research purposes that was funded by grants from the Gold Fields Foundation.

In the Department of Electrical Engineering, the Gold Fields Computer Laboratory was started in 1990 with an initial grant of R350 000 from the Gold Fields Foundation. The 286 computers, which were then top-of-the-range machines, served the need at the time but have now been replaced. Today, the laboratory has fully networked state-of-the-art Pentium computers, together with a vast library of software, all again sponsored by Gold Fields. Professor Charles Landy, head of the department, says that this laboratory has become the backbone of teaching for the third- and final-year students. 'Through this facility, the lecturers are able to introduce students to the modern tools used in solving engineering problems'.

The School of Mechanical Engineering has also received Gold Fields' support for the past six years. In 1990, the funds were used to acquire gas-analysis equipment for the measurement of gas emissions. This has been an invaluable aid in many post-graduate research projects on topics as diverse as rural cooking stoves, mine ventilation, and diesel engines.

In 1993, Gold Fields Foundation made further funds available for the construction of a modern engine test-bed with dynamometer. This facility enables students and staff to test the performance of all types of engines at constant torque or speed, providing reproducible results and eliminating the need for manual controls. This year the School of Mechanical Engineering received additional sponsorship to equip the Gold Fields Engine Test Facility with advanced equipment for the analysis of exhaust gases. ◆

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Viewing the engine test-bed in the School of Mechanical Engineering at Wits are (from left): Prof. John Sheer, head of the School; vice chancellor of Wits, Prof. Robert Charlton; Peter Nienaber, assistant consulting mechanical and electrical engineer at Gold Fields; Prof. Jan Reynders, dean of the Wits Engineering Faculty; and Peter Janisch executive director of Gold Fields.

Pictured in the Gold Fields Computer Laboratory in the Department of Electrical Engineering at Wits are (seated) post-graduate student Vinesh Reddy demonstrating a sign-language teaching system; and (standing from left) Brian Nattrass, a manager at Gold Fields and Foundation committee member; Peter Janisch, Gold Fields executive director; vice-chancellor of Wits, Prof. Robert Charlton; Prof. Charles Landy, head of the Department of Electrical Engineering; and Willie Jacobsz, administrator of the Gold Fields Foundation.

Pen Profile: Bryan Berry

50 years membership SAIMM

Bryan was born on 28 April 1921. He attended school in Johannesburg starting at King Edward School, then a period at St John's before matriculating at Michaelhouse in KwaZulu Natal in 1937. In 1938 he did a post-matric course with the Chamber of Mines.

In 1939 he enrolled at the University of the Witwatersrand as a Metallurgical student, completing his degree in 1942. Bryan joined the Institute as a student while at Wits and has kept up his association ever since.

After university, Bryan joined the Special Signal Services to be trained as a Radar Technician. Radar was very new and state-of-the-art in those years. After four years of service Bryan joined the gold mining industry as an official learner at Grootvlei Gold Mine on the far East Rand.

After four years in the mining industry the call of the steel manufacturing industry was too great and Bryan joined Haggie & Son. He moved through the ranks as a Rope Application Technician to Operation Manager and then Technical Director of Haggie Steel Ropes.

Bryan married Maureen May, who was a nursing sister at the Johannesburg General Hospital, in 1952. They had two sons, Richard and Stephen. Richard passed away a few years ago, Stephen is now farming with Dad in the Buffelsvlei area between Lydenburg and Burgersfort. They farm citrus, avocados and cash crops.

Bryan and Maureen are both in excellent health, suntanned and enjoying the outdoor life of a farmer and his wife.

To commemorate Bryan's 50-year membership of the SAIMM he and Maureen were treated to a luncheon at Dullstroom by the Mpumalanga Branch Committee and Richard Jennings, Branch Chairman, presented Bryan with his 50-year award. ◆

Full-scale training for Gold Fields*

International Risk Control Africa (IRCA) has signed a contract with Gold Fields for the presentation of a full-scale training programme on risk identification and assessment. Gold Fields decided to invest the money some two years ago before the promulgation of the new Mine Health Safety Act, which requires risk management. Thus, the manager of every mine will in future have to assure that all risks on his mine are identified, and that all the hazards associated with those risks are eliminated, reduced, or properly controlled.

Mr Les Faulds, Group safety officer for Gold Fields, pointed out that the new legislation is long overdue: although mines in South Africa have reasonably good safety records, recent reports have shown that the standards in the workplace need to be improved. This can be achieved only on a tripartite basis in which management, employees, and the state work together towards greater mine safety.

IRCA was contracted to develop a seven-week course in conjunction with Gold Fields safety personnel and the Technikon SA. The first of three groups of 25 students have now completed the seven-week course, which was presented at Dikhololo, near Brits. Top student, Philip Stander from Deelkraal Mine near Carletonville, said that he appreciates the professional way in which the course was presented. 'The knowledge we gained is directly applicable to our work situation and according to what the new act requires', he added. He also commented on the high standard of the lectures, especially those presented by Messrs Kurt Hubert and Andrew Jameson.

The course covered the legal duties of employers and employees regarding safety on mines; and the content of the Mine Health and Safety Act and Regulations, as well as of the Occupational Health and Safety Act No. 85 of 1993. Participants were exposed to the responsibility for contractor activities on mine premises, and future developments within the mining legislation. An in-depth study was made of the Compensation for Occupational Injuries and Diseases Act of 1993. The last three weeks of the course were devoted to case studies.

IRCA has also trained a group of sixty instructors, who are now training people below shift supervisor level. In this way, Gold Fields will complete the mammoth task of training 80 000 people on its mines throughout the country.

At the diploma presentation ceremony, Mr Peter Janisch, technical director of Gold Fields, pointed out that risk profiles differ from mine to mine. It is therefore a great challenge for the course participants to go and apply their knowledge in such a way that their colleagues and subordinates alike are inspired to increase their knowledge on this very important subject. 'Risks can be afforded when it comes to new technology but, where safety is concerned, Gold Fields takes no risks', he added. ◆

* *Issued by adformo, P.O. Box 786421, Sandton 2146.*

A billion rands of extra profit to be had in the mining industry

The South African Institute of Mining and Metallurgy recently held a special seminar to bring to the attention of decision-makers in the mining industry developments with proven major financial and other benefits to the industry. Nic Barcza, President of the SAIMM, who opened the seminar, said, 'It is somewhat surprising that these developments have not been more widely adopted'.

Proven technologies with the following benefits were identified:

- using electronic detonators, face advance is increased and stope width reduced, and other operational and safety benefits accrue;
- the use of yielding support in tunnels can be cheaper and still provide more than ten times the energy-absorbing capacity of support commonly used at present;
- backfill correctly placed in more than 60% of the mined-out area provides major safety benefits. Financial benefits such as in the ventilation field are known to be significant, but have not been fully quantified yet;
- recirculation of ventilation, a common practice in office buildings, could save the industry hundreds of millions per year in operating costs, and more in capital costs;
- close to face blast on prop support implemented on one mine has given a 50% increase in profit and a 57% improvement in safety.

All of these benefits are cumulative, and there is a major safety benefit inherent in them all. Roger Dixon, Vice-President of the SAIMM, summed up, '*More than a billion rands of extra profit per annum* would result from an industry increase in face advance per blast of 10 cms, and a decrease in stoping width of 5 cms, both proven to be easily achievable'.

The seminar is to be repeated in 1997 at a function to be organized by the Johannesburg Branch of the SAIMM. ◆

Wits engineering students tackle corrosion*

The best corrosion posters in Wits University's School of Process and Materials Engineering—supervisor Dr Andre van Bennekom is flanked by winners Indrin Naidoo (left) and Ryan Steele (right)

Students in the School of Process and Materials Engineering at the University of the Witwatersrand have ended the year with an impressive display of posters illustrating their 1996 research projects, many of which have been sponsored by industry.

Awards were presented for the best undergraduate (fourth year) and postgraduate posters in corrosion, physical metallurgy, extractive metallurgy/minerals processing and chemical engineering.

The best undergraduate poster in corrosion, the work of Ryan Steele, was based on an investigation of aluminium cathodes used in the process of zinc electrowinning to determine the effects of the composition and surface conditions of the aluminium cathodes and the electrolyte on the adhesion of zinc to the cathodes. The project was sponsored by Hulett Aluminium.

It was determined that the 'sticking' of the zinc to the cathodes was related to the thinning of the aluminium oxide film present on the surface of the cathodes. The thinning of the oxide layer could be attributed to a soaking time within the acidic electrolyte.

The adhesion of the zinc to the cathodes was also affected by the surface finish, with an increase in roughness increasing the mechanical adhesion of the zinc to the cathodes.

The effect of fluoride ions on the corrosion properties of various aluminium alloys was also investigated. An increasing concentration of fluoride ions caused an increasing trend in the corrosion rates and susceptibility of all the aluminium alloys.

M.Sc. (Eng) student Indrin Naidoo's poster, depicting his study of atmospheric corrosion monitoring techniques, was judged the best in the postgraduate corrosion category.

Indrin investigated several atmospheric corrosion monitoring techniques, selecting copper and silver corrosivity monitors as the ideal method. 'This technique had the advantages of simplicity and low cost, required short exposure duration (14 to 30 days) and was sufficiently sensitive to detect microclimates', he reported.

Several exposure programmes were performed to validate the use of copper and silver corrosivity monitors. Environments tested included coastal (Durban), urban (Johannesburg), industrial (Secunda) and, most important, a mine environment (Welkom), where no corrosivity investigations using this technique had ever been recorded. ◆

A boost from Motorola for Wits Electrical Engineering students*

Motorola Southern Africa chairman Sello Matsabu (centre), flanked by Professor Hu Hanrahan (left, and Dr Francis Swarts of the University of the Witwatersrand, Department of Electrical Engineering

A donation of microcontroller equipment by Motorola Southern Africa will be of particular value to undergraduate students in the Department of Electrical Engineering at the University of the Witwatersrand.

The donation includes microcontroller development boards plus a suite of software for use in the Department's undergraduate computer laboratories. According to Hu Hanrahan, Professor of Communications Engineering, it will be used to train second year students on the programming of microprocessors and their connection with the outside world.

Handing over the equipment to the Department of Electrical Engineering, Motorola Southern Africa chairman Sello Matsabu said the University of the Witwatersrand was a shining example of an institution committed to providing the highest standards of technical skills.

'Co-operation with universities around the world is important for companies like Motorola, which is one of the world's leading providers of wireless communications, semiconductors and advanced electronic system', he added. 'Universities are a resource for technical talent and a reservoir of fresh ideas, which are critical to our continued success.

'It is also important for international companies to contribute to the technological upliftment of developing countries like ours. Use of real life technology by students reinforces the theory acquired in the classroom and brings the student closer to the real world.'

Thanking Motorola for its assistance, Professor Hanrahan agreed that the new equipment would help to make undergraduate teaching more practical. 'This sort of purchase could not be made on normal university budgets and industry support is therefore crucial to the success of our students.' ◆

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