

The recovery of zinc from pickle liquors by ion exchange

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SYNOPSIS

Picklers and galvanizers in and around Johannesburg are encountering an ever-increasing problem in disposing of spent liquors from their hydrochloric acid pickling baths. Particularly troublesome is the zinc-contaminated liquor that is produced as a result of the clean-up of rejects from the galvanizing operation. Because of the volatility of zinc chloride, this liquor presents difficulties when processed in a conventional pyrohydrolysis acid-recovery unit.

The paper describes the Metsep Process, developed by the National Institute for Metallurgy and Woodall-Duckham S.A. (Pty) Ltd, which involves the use of continuous ion exchange for the separation of the zinc from the pickle liquor, and the use of liquid-liquid extraction for the conversion of zinc chloride eluate to salable zinc sulphate.

A description of laboratory and pilot-plant tests is given, and the approach used in the design of a full-scale continuous-ion-exchange plant is outlined.

SAMEVATTING

Bytwerkers en galvaniseerders in en om Johannesburg vind dit al hoe moeiliker om met die uitgeputte vloeistowwe van hul soutsuurbytbaddens weg te doen. Wat veral moeilikheid oplewer, is die met sink gekontameneerde vloeistof wat verkry word as gevolg van die skoonmaak van afgekeurde artikels na die galvaniseerproses. Vanweë die vlugtigheid van sinkchloried skep hierdie vloeistof probleme wanneer dit in 'n konvensionele pirohidrolise-suurherwinningseenheid verwerk word.

Die verhandeling beskryf die Metsep-proses wat deur die Nasionale Instituut vir Metallurgie en Woodall-Duckham S.A. (Edms) Bpk, ontwikkel is en die gebruik van deurlopende ionuitruiling vir die skeiding van die sink van die bytvloeistof en die gebruik van vloeistof-vloeistofekstraksie vir die omsetting van die sinkchlorieduitwasstof in verkoopbare sink-sulfaat.

Die laboratorium- en proefaanlegtoetse word beskryf en die benadering wat by die ontwerp van 'n volkskaalse deurlopende ionuitruilaanleg gebruik is, word in hooftrekke uiteengesit.

INTRODUCTION

The pickling and galvanizing industry in South Africa comprises a large number of relatively small companies. These are engaged either in surface-preparation work (for example, the pickling of steel to produce bright bar, and the pickling and galvanizing of wire) or in small jobbing activities. The latter companies generally offer the steel-fabrication industry a galvanizing service that includes the treatment of a variety of products from structural steelwork to castings.

A large number of picklers use hydrochloric acid for their operations. Although hydrochloric acid costs more, it has certain advantages over sulphuric acid:

- (a) it reacts more quickly,
- (b) it preferentially attacks the oxide layer (and not the parent metal), thus preventing pitting, and
- (c) the pickling baths can be operated at ambient temperatures.

It is usual to start pickling with an acid strength of between 16 and 18 per cent hydrochloric acid (m/m). It is used continually until the rate of reaction is so slow that further use is both unpractical and uneconomic. This occurs at a strength of about 2 per cent.

In galvanizing operations, some of this spent pickle liquor is used for stripping zinc that has accumulated on jigs from successive dipping in the galvanizing bath. In addition, the spent acid is used for stripping the zinc off any reject article.

The use of spent pickle liquor for stripping zinc has three advantages over the use of fresh acid:

- (1) it costs nothing,
- (2) it is very effective owing to the cementation effect of the ferrous chloride in solution, and
- (3) no additional baths or handling equipment are needed.

Up to the present, the picklers and galvanizers have neutralized their effluent and dumped it. However, over the past six or seven years, there has been increasing pressure from the authorities to

prevent this practice, and the industry has been looking at means of recovering and recycling the constituents.

The recovery of the hydrochloric acid and the iron from normal spent pickle liquor is technically possible. The usual technique employed is pyrohydrolysis, the Woodall-Duckham spray roaster being a typical example of the equipment used. However, when zinc is present, there are serious process difficulties as a result of the volatility of the zinc chloride.

Technical difficulties are not the only problems; the industry is also faced with financial problems. As previously mentioned, it comprises a large number of small jobbing companies, and no single company could economically justify an acid-recovery plant. This situation was soon realized by Woodall-Duckham S.A. (Pty) Ltd, and they considered the feasibility of setting up a central processing plant, based on their spray-roaster system, as a service to the pickling and galvanizing industry. However, al-

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though the company is experienced in the recovery of hydrochloric acid, at the time they had no knowledge of a process for zinc removal that could be used prior to pyrohydrolysis. For this reason the company approached the National Institute for Metallurgy (NIM) to assist in the development of such a process.

The criteria for an overall process involving the separation of zinc and the recovery of hydrochloric acid were as follows.

- (1) It had to produce no airborne, waterborne, or solid effluents.
- (2) It had to be economically viable; that is, all products from the process had to be salable.
- (3) Carry-over of zinc to the acid and iron products, and of iron and acid to the zinc product, had to be limited to very low concentrations compatible with market acceptability.
- (4) The cost of treatment had to have as little adverse effect as possible on the current cost of galvanizing and pickling.

Over the past three years, joint research and development work, which includes laboratory, pilot-plant, and design studies, has been carried out at the laboratories of NIM. This work culminated in the development of a complete process flowsheet¹ that uses ion-exchange and liquid-liquid-extraction techniques and is known as the NIM/W-D Metsep process. This process satisfies all the above criteria. A full-scale commercial plant has been constructed near Johannesburg and is at present being commissioned.

OUTLINE OF THE METSEP PROCESS

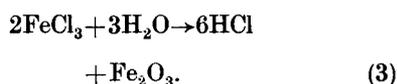
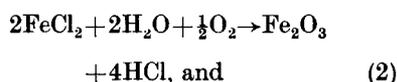
A block flowsheet for the Metsep process is given in Fig. 1. The feed to the plant, which will be brought in by road tanker and pipeline, comprises two streams:

- (a) uncontaminated pickle liquor containing about 220 g of FeCl₂ and 31 g of hydrochloric acid per litre, and
- (b) contaminated pickle liquor containing about 73 g of ZnCl₂, 230 g of FeCl₂, and 30 g of hydrochloric acid per litre.

The values are very approximate and the plant has been designed to

cope with very wide ranges of concentration.

The uncontaminated material is fed direct to the spray roaster in which the ferrous chloride and small quantities of ferric chloride are decomposed to oxides of iron and hydrochloric acid by the reactions



These reactions take place at temperatures above 500°C. The hydrogen chloride is absorbed in the raffinate from the liquid-liquid-extraction plant to produce acid having a strength of about 16 to 18 per cent by mass. The iron oxide, which is produced as a powder, is bagged for marketing.

The zinc-contaminated pickle liquor is fed to an ion-exchange plant in which the zinc is selectively removed. The barren solution from this plant is then combined with the zinc-free feed liquor.

The eluate produced in stripping the resin is slightly acid zinc chloride. At present, the zinc is not salable in this form. It is therefore fed to a liquid-liquid-extraction plant, where it is converted to zinc sulphate, which is salable. The raffinate is used as absorber water in the production of acid.

The ion-exchange and the liquid-liquid-extraction process, which are the two operations that were developed at the NIM laboratories, will be discussed in more detail. The pyrohydrolysis system is in commercial use, and for further information the reader is referred to publications on the Ruthner-Dravo hydrochloric acid pickling process^{2, 3, 4}.

ION-EXCHANGE SEPARATION OF ZINC

The main steps in the process are loading of the resin, washing of the occluded pickle liquor from the resin, and elution of the loaded resin.

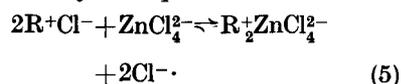
Selective Loading of the Resin

Under the conditions outlined earlier, the zinc chloride in the con-

taminated spent pickle liquor exists as an anionic complex, the predominant species being the divalent form ZnCl₄²⁻. The complexing is illustrated by the equation



Under similar conditions, ferrous iron will not form an anionic complex. Ferric iron will, but under the conditions given it is unlikely that the ferrous iron will oxidize to the ferric state. The zinc can therefore be selectively separated by anion exchangers. The separation is illustrated by the equation



Washing of the Loaded Resin

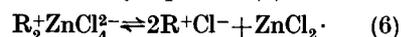
Before the resin can be eluted, the occluded pickle liquor has to be washed from the pores of the resin so that the final zinc product meets market specifications with respect to iron content. Water cannot be used because it would cause the equilibrium shown in equation (5) to be reversed and the zinc to be eluted. The following are two possible techniques:

- (a) the use of hydrochloric acid of sufficient strength to prevent the reversal of equilibrium, or
- (b) the feeding back of a fraction of the eluate as wash liquor.

If the elution step is run to give maximum concentration of zinc in the eluate, the eluate will contain sufficient free chloride to prevent reversal of equation (5). Some zinc can, of course, be expected to be removed during the washing step, but this is merely fed back to the feed solution to the loading step.

Elution of the Loaded Resin

The loaded resin, washed free of contaminating iron, is eluted with water. Reduction of the chloride concentration in solution means that the equilibrium depicted in equation (5) is simply reversed. An almost neutral solution of zinc chloride is formed, and the resin is left in the chloride form. This reaction is illustrated by equation (6):



The Use of Continuous Ion Exchange

Although the separation is theoretically possible and was demonstrated in the laboratory, two major

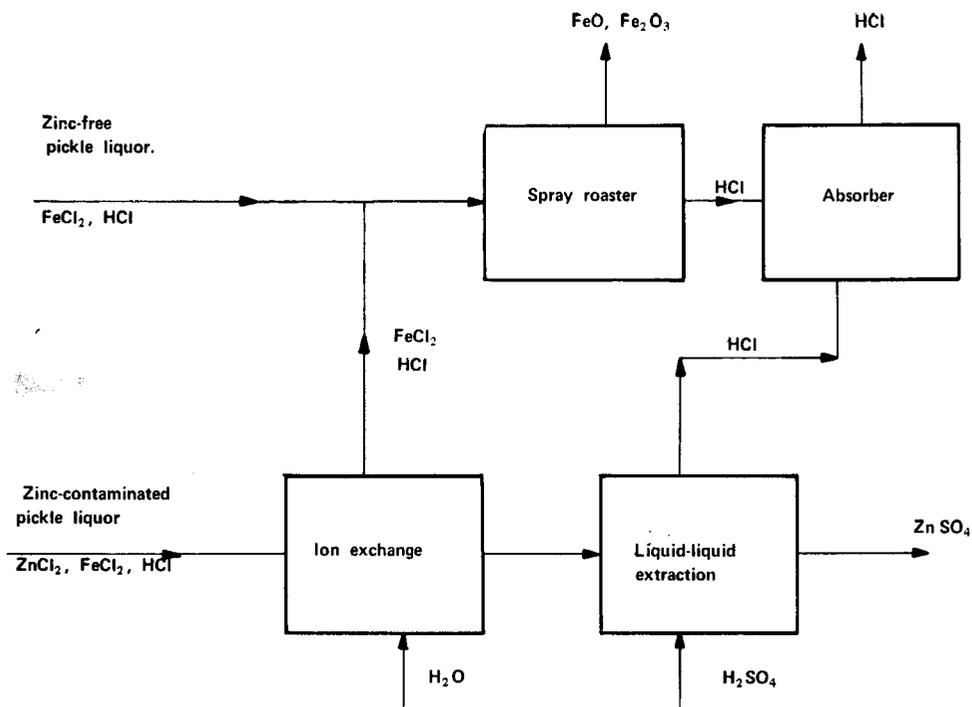


Fig. 1—Block flowsheet of the Metsep process

practical problems became apparent, the second being the more serious.

(a) The high concentration of zinc in the feed allowed for the treatment of, at most, two volumes of solution for every volume of resin, depending on the capacity of the resin and the species of complex formed.

(b) Owing to the high concentration of iron in the feed solution, the resin required prolonged washing before it could be eluted.

The laboratory experiments (using fixed beds) that were initiated to study this problem showed that some five bed volumes of washing solution had to be used before the iron in the eluate was reduced to acceptable levels. This is equivalent to a minimum of $2\frac{1}{2}$ volumes of wash for every volume of feed. The use of hydrochloric acid as washing liquid was found to be completely uneconomical, and the use of eluate for washing was virtually impossible because the requirements for the concentration of zinc in the eluate meant that only three volumes of eluate could be produced for every volume of feed.

Early feasibility studies also showed that the high resin inventory required by a fixed-bed operation as a result of the high zinc concentration in the feed would

probably be uneconomic. Furthermore, although no similar plant had been built, the opinion of manufacturers of ion-exchange plant was that fixed-bed plants having 'break-throughs' of between 1 and 2 bed volumes would be very difficult to control.

Liquid-liquid extraction was considered but was rejected as being less attractive for the following reasons:

- (a) high loss of solvent,
- (b) the deleterious effect of the solvent on the rubber linings of the spray-roaster plant, and
- (c) the inadvisability of the use of two different solvents (cationic and anionic) on one plant.

It was therefore decided that the use of continuous ion exchange should be considered. This procedure was claimed to be capable of handling feed solutions of high ionic strength and it would utilize the advantages of countercurrent washing.

The technique decided on and tested was the semi-continuous multi-stage fluidized-bed column that is being developed at NIM for hydrometallurgical application, particularly to uranium extraction. Although the technique is relatively new and at the time no commercial plant had been operated, it was considered the only alternative.

The flowsheet of the ion-exchange plant on which the full-scale plant design was based is shown in Fig. 2.

All columns operate with the solution in upflow, the resin in each stage being expanded to some desired value. The resin movement is periodic and countercurrent to the solution flow. It is achieved by periodic shutting off of the feed to the column, which allows the resin to settle onto the solution distributors contained in each stage, and then reversal of the flow of solution⁵. This results in the transfer of a dense slug of resin from one stage to the one below it. Resin going out from the bottom stage of any one column is transferred to the next column for further processing by displacement. The dewatering step is included in the transfer line for eluted resin so that the evaporative load on the spray roaster is reduced.

A pilot plant based on the flowsheet given in Fig. 2 has been operated for an extended period. The system has been shown to be feasible, and the specifications (for barren solution and eluate) have been met. Details of the pilot-plant work and the approach to the design of the full-scale plant are discussed later.

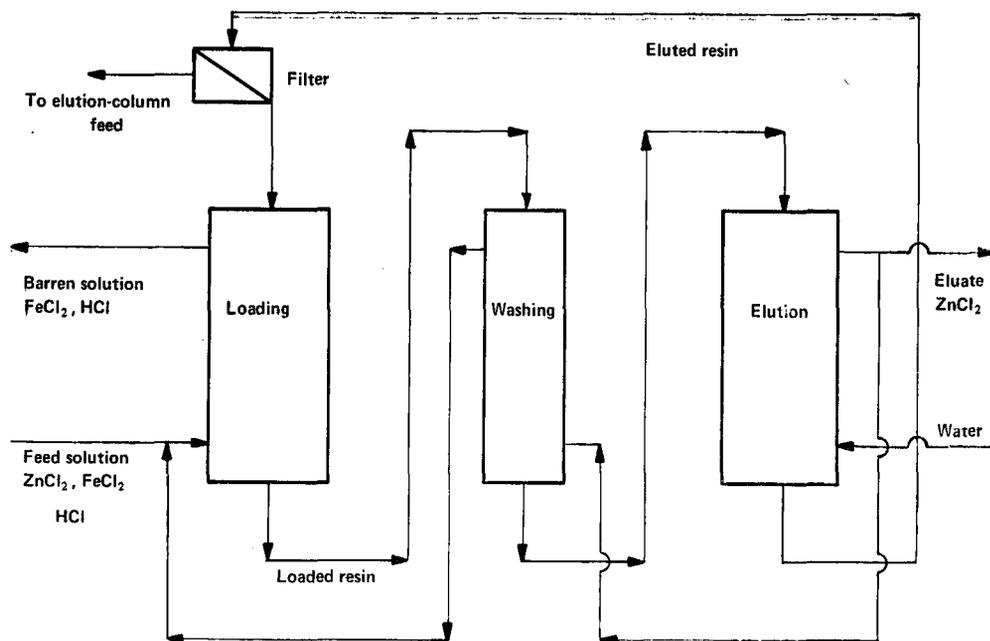


Fig. 2—Flowsheet of the ion-exchange plant

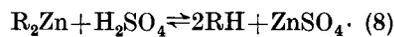
LIQUID-LIQUID EXTRACTION

The zinc chloride eluate is converted to salable zinc sulphate by simple cation-exchange technique using a liquid exchanger dissolved in paraffin. The process can be illustrated by the following equations:

Loading:



Stripping:



Extraction of the zinc takes place in a multistage mixer-settler system in which some 85 per cent of the zinc is extracted. The remaining 15

per cent, which passes out in the raffinate used for absorption of the hydrogen chloride produced in the spray roaster, is at a concentration sufficiently low to meet the market specifications for hydrochloric acid. Prior to stripping, the solvent is washed free of entrained zinc chloride and hydrochloric acid with water—

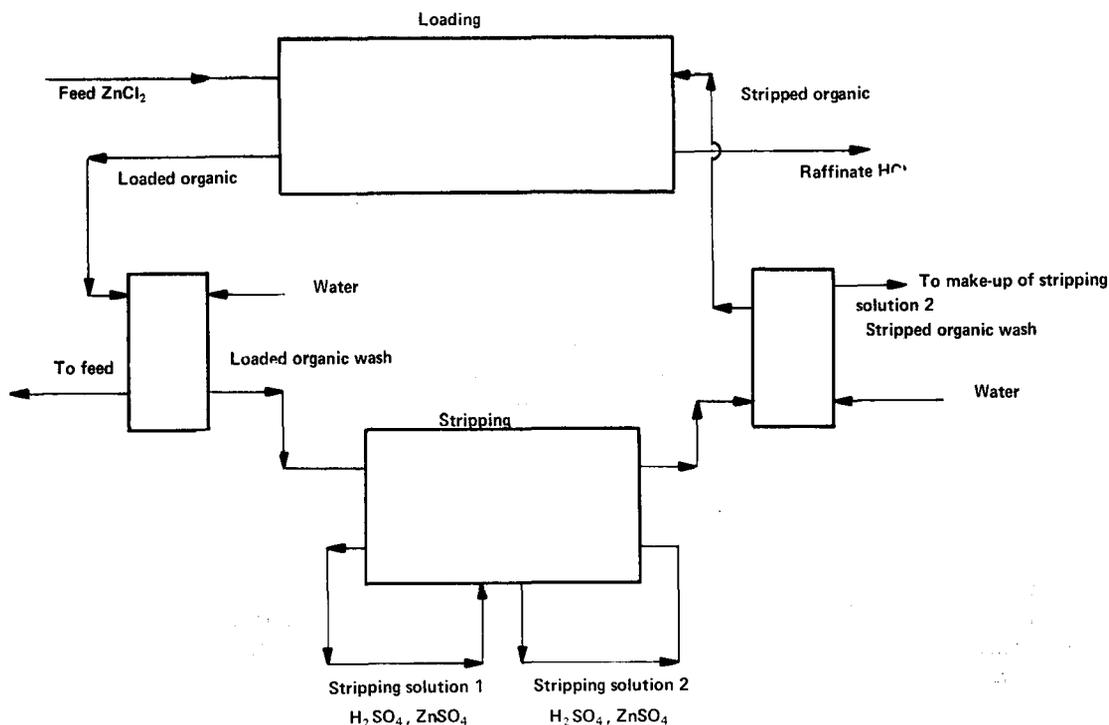


Fig. 3—Flowsheet of the liquid-liquid-extraction plant

again in mixer-settlers. The washing solution joins the feed.

The solvent is stripped by use of a batch countercurrent technique, which is illustrated in Fig. 3. The two stripping solutions are recycled until the concentration of zinc in stripping solution 1 reaches the marketable level. This is then replaced by stripping solution 2, which in turn is replaced by fresh sulphuric acid. The batch technique is used because of the high ratio of organic to aqueous flow required to give a high concentration of zinc in the stripping solution. It was found to be more convenient than the use of a continuous flow of stripping solution with a high recycle to give the conventional 1-to-1 flow ratio within the cells. The solvent is finally washed free of sulphuric acid and zinc sulphate.

THE RESEARCH AND DEVELOPMENT PROGRAMME

The programmes of work for ion exchange and liquid-liquid extraction are discussed separately.

ION EXCHANGE

The programme for research into the ion-exchange method for the separation of the zinc comprised preliminary small-scale fixed-bed experiments to prove the separation; laboratory determinations of resin fluidization characteristics, capacity, and kinetics for design purposes; and pilot-scale tests on continuous ion-exchange columns. In addition, life tests were conducted on a sample of the resin.

Laboratory Studies

The original laboratory tests were done on fixed beds of resin. The criteria for these tests were that

- (a) the zinc content of the barren solution from the ion-exchange column should be less than 0,1 per cent, and
- (b) the zinc-to-iron ratio in the eluate should be greater than 12 to 1.

It was found that requirement (a) could be met, but that, as discussed earlier, the use of a fixed-bed plant would present serious technical and economic problems. Requirement (b) could not be met within the limits imposed by material-balance calculations for a full-scale plant. The idea

TABLE I
TYPICAL RESULTS FROM THE SMALL-SCALE CONTINUOUS ION-EXCHANGE PLANT

	Fe ²⁺ g/l	Zn ²⁺ g/l	HCl g/l
Feed	117,0	20,3	26,3
Barren solution	90,0	0,3	30
Eluate	0,7	8,9	2,6

of fixed beds was therefore rejected, and the use of continuous ion exchange was pursued. Early work was carried out on a small-scale laboratory unit capable of handling up to 10 ml of feed per minute. The unit was set up according to the flow-sheet given in Fig. 2, except that fresh hydrochloric acid, instead of eluate, was used as washing solution. The resin used was of a strong-base variety. Typical results are given in Table I.

In addition to the laboratory and small-scale pilot-plant work to prove the separation process, the following tests were carried out for design purposes.

Tests of Resin Capacity and Kinetics. Results of this work are given in Figs. 4 and 5, which compare a strong-base resin with a weak-base resin. It can be noted that, at the saturation capacity, the distribution ratio for both resins is close to 1. This led to the required solution-to-resin flow ratio of almost 1 to 1 in a continuous plant, and caused some problems with the design of the full-scale plant.

Tests of Resin Hydraulics. Experiments were carried out in which the expansion of fluidized beds of strong-base and weak-base resins was compared under various conditions. It was found that the unloaded strong-base resin floated in the spent pickle liquor at concentrations that could be expected in a production plant. Further work on this resin was therefore abandoned, and it was decided to continue work on one weak-base resin only. This resin is the only one on the market that has sufficient density for successful operation in spent pickle liquor. The results are given in Fig. 6.

Life Tests. A sample of strong-base resin was subjected to 500 cycles of loading and elution, which are equivalent to approximately 18 months of operation in a production plant. It was found that the capacity

decreased by only 3 per cent. Similar tests have not been carried out on the weak-base resin, but problems are not expected since it is claimed that the resin is as stable as the strong-base resin under similar conditions.

Pilot-plant Tests

A continuous pilot-plant programme succeeded the laboratory work so that optimum conditions for the design could be established and the operability of the process could be tested over a continuous period of time. The required information included the following:

- (1) the minimum achievable concentration of zinc in the barren solution,
- (2) the maximum ratio of zinc to iron in the eluate, and
- (3) the minimum dilution of the barren solution with washing liquor.

The last requirement was considered very important in that the concentration of the feed to the spray roaster strongly influences the operating cost of the plant (since water has to be evaporated) and the concentration of the hydrochloric acid product.

The flowsheet was similar to that previously used, but this time eluate, instead of fresh hydrochloric acid, was used for washing. The three continuous ion-exchange columns were constructed from 150 mm sections of 100 mm diameter Quickfit glass column. Each section was equivalent to one stage, and the stages were separated by perforated PVC plates. The plant contained 11 stages for loading, 5 stages for washing, and 10 stages for elution, and was capable of handling up to 5 litres of feed solution per hour.

Typical results taken over a period of approximately 12 hours during a two-day operating campaign are given in Table II.

From the results of this run and others, it was possible to conclude

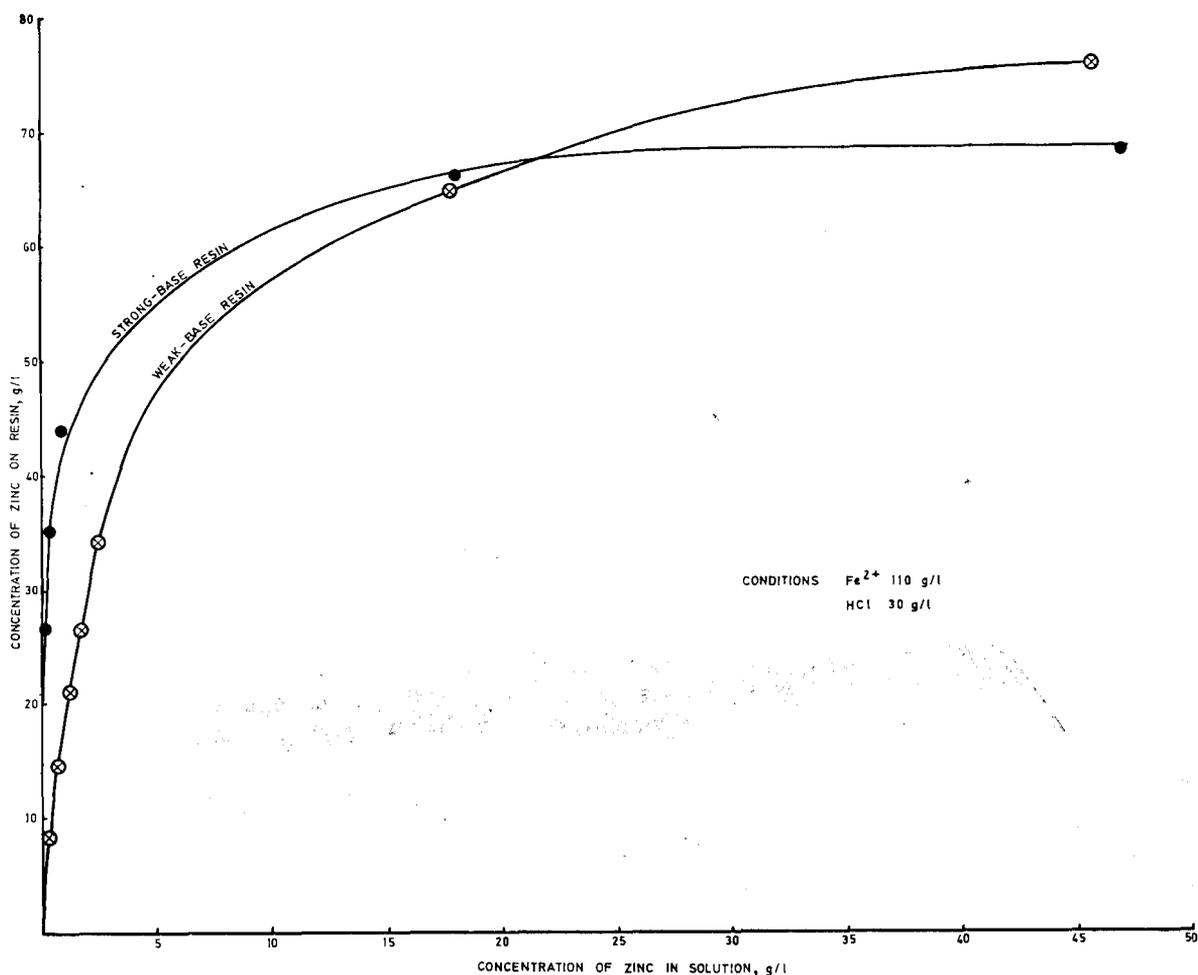


Fig. 4—Equilibrium distributions for zinc in spent pickle liquor

that the process could be controlled to produce suitable feed concentrations for the spray roaster and the liquid-liquid-extraction plant. It was also found that the dilution of the barren solution with the wash could be kept down to a value of about 30 per cent, which was considered acceptable, provided the resin entering the loading column was de-watered. Furthermore, the weak-base resin performed satisfactorily.

LIQUID-LIQUID EXTRACTION

Again, the experimental work consisted of laboratory and pilot-plant tests.

Laboratory Studies

The laboratory work comprised a series of shake-out tests using a 25 per cent (v/v) solution of liquid cation exchanger in illuminating paraffin. Two experimental methods were used, the first being a rapid test to determine the approximate conditions for a more accurate series.

The first consisted in the contacting of various ratios of aqueous to organic phases and the determination of equilibrium concentrations. The results are given in Table III.

In the second series of tests, a multiple-stage batch countercurrent shake-out test was conducted. Strip-

ping of the organic phase was accomplished when the organic phase was contacted twice with 20 per cent (v/v) sulphuric acid at an organic-to-aqueous ratio of 0,25. Results of these tests are given in Table IV.

Although some difficulty was experienced in the achievement of good mass balances for these runs, they demonstrated the feasibility of the conversion from chloride to sulphate.

Pilot-plant Tests

Following the laboratory work, a continuous pilot-plant operating campaign was initiated. The experiments were carried out in a series of small-scale mixer-settlers capable of handling 10 ml of feed solution per minute and set up according to the flowsheet given in Fig. 3. The purposes of the campaign were as follows:

(a) to prove the extraction results

TABLE II
RESULTS OF PILOT-PLANT TRIALS

	Zn ²⁺ g/l	Fe ²⁺ g/l	HCl g/l
Feed	59,0	120,0	20,0
Barren solution	0,05	55,2	6,3
Eluate	15,0	1,09	0,8

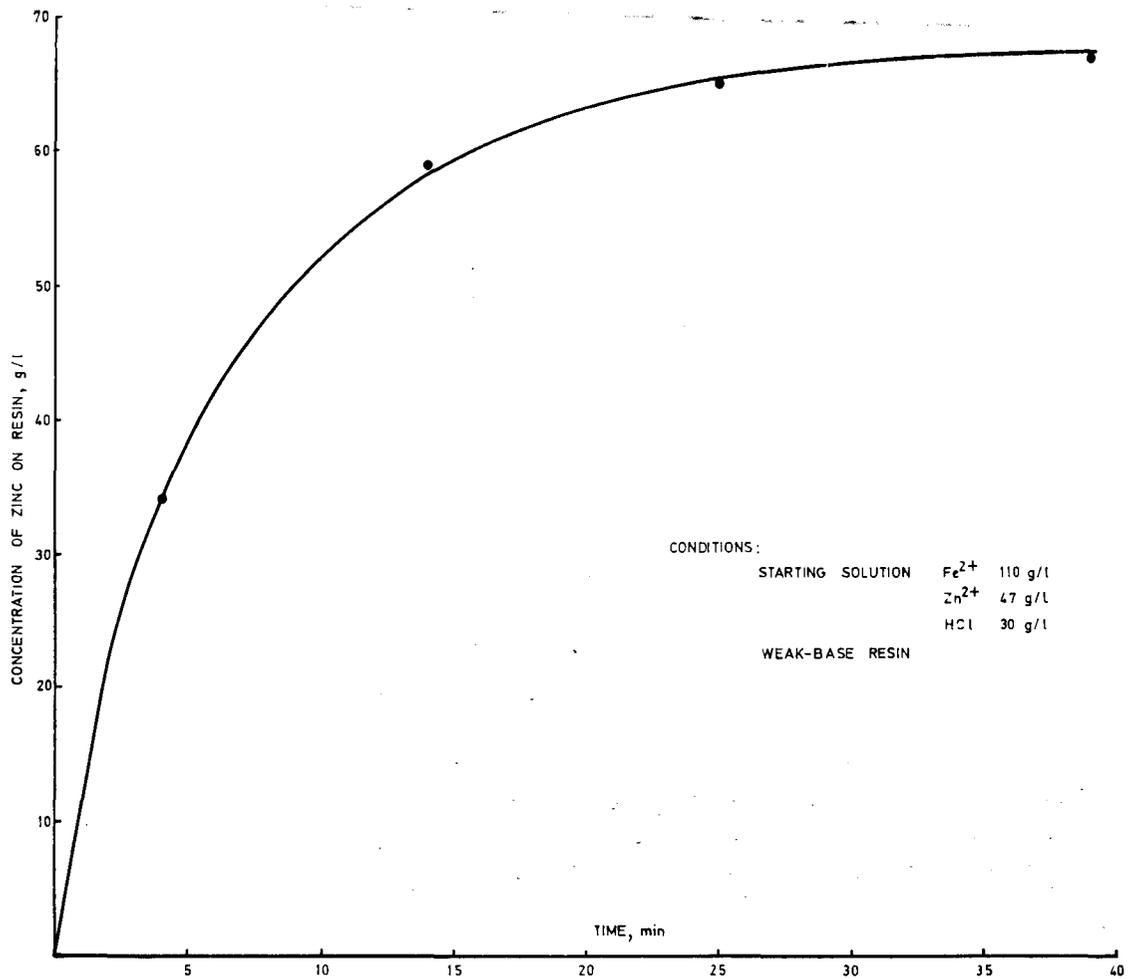


Fig. 5—Rate of loading of zinc from spent pickle liquor

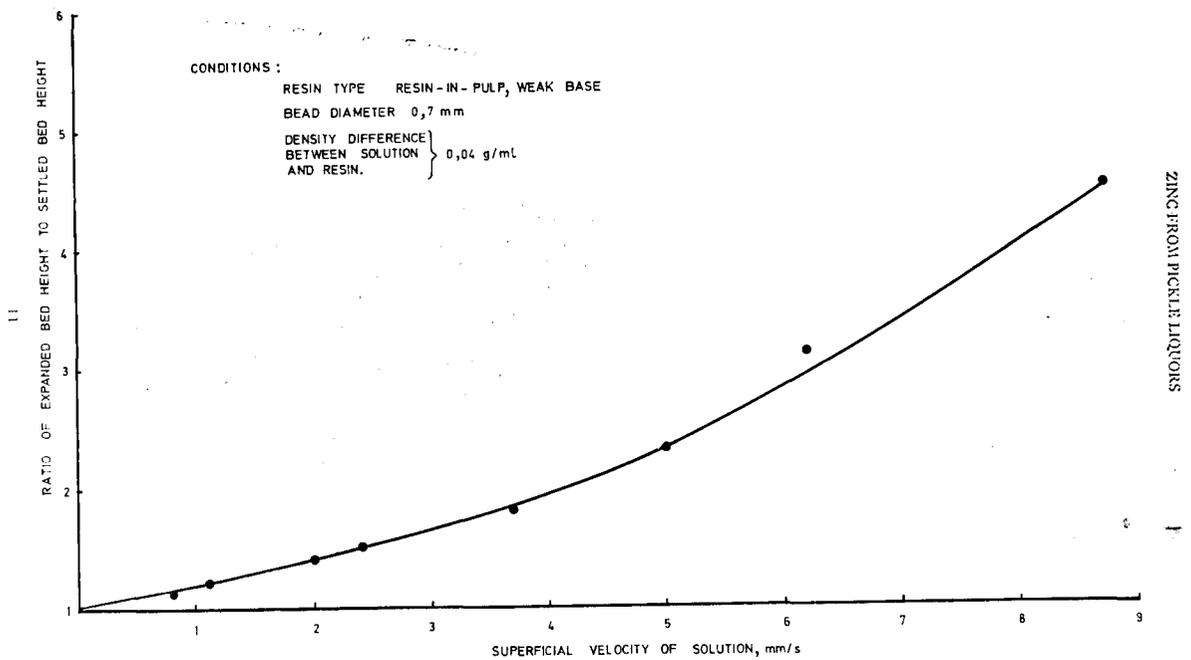


Fig. 6—Expansion characteristics of a fluidized bed of resin

TABLE III
RESULTS OF EQUILIBRIUM SHAKE-OUT TESTS

Test solution:
Zn²⁺ 20 g/l
Fe²⁺ 1,25 g/l
HCl, Test 1 1,0 g/l
Test 2 2,0 g/l

Organic-to-aqueous ratio	Zn determined in test 1		Zn determined in test 2	
	Organic g/l	Aqueous g/l	Organic g/l	Aqueous g/l
0,25	9,69	17,50	8,15	18,19
0,5	7,14	16,65	6,08	16,82
2	3,19	14,31	2,92	14,01
4	2,02	11,69	1,92	12,33
6	1,60	10,40	1,48	10,90

TABLE IV
RESULTS OF BATCH COUNTERCURRENT SHAKE-OUT TESTS

Test solution:
Zn²⁺ As shown in table
Fe²⁺ 1,25 g/l
HCl 2,0 g/l

	Ratio of organic to aqueous flow		
	20	30	15
	Zinc concentration, g/l		
Feed	20,0	20,0	15,0
Raffinate	3,52	3,15	1,14
Loaded solvent	1,17	0,78	1,06

obtained from the simulated batch countercurrent system could be established on a continuous system,

- (b) to establish satisfactory operating conditions, and
- (c) to estimate various design parameters.

The feed solution, which was synthetic, was made up as follows:

ZnCl₂ 31,4 g/l
FeCl₂ 4,5 g/l
HCl 1,1 g/l.

Results taken at the start and finish of a 12-hour run are given in Table V.

These results indicate that the results obtained from batch tests can be achieved in continuous operation.

The plant was also run in order to estimate mixer residence time, settling areas, internal phase ratios, and maximum free-acid concentration of the feed. In addition, it provided a sound practical basis for the design of the full-scale plant.

PROCESS DESIGN OF THE FULL-SCALE CONTINUOUS-ION-EXCHANGE PLANT

In the design of the ion-exchange columns for the production plant, difficulty was experienced in the scaling up of the pilot-plant data for the following reasons.

- (a) The pilot plant comprised a large number of small stages (for example eleven 150 mm stages in

the extraction column), which would be unpractical on a commercial plant.

- (b) The expected concentrations of metal ions in the feed for the production plant were not identical to those of the material fed to the pilot plant.

It was therefore decided that a mathematical model of the loading column should be developed and that the model should be used in an estimate of the size of the production unit.

The development of the design model for the continuous ion-exchange column was complicated by the non-linearity of the mass-transfer process and the periodic nature of the resin movement. This work is continuing and is not ready for publication. Only an outline of the approach will therefore be given here.

The non-linear models were first developed to describe the equilibrium and rate curves illustrated in Figs. 4 and 5. Values of the coefficients were then used in a stage-wise calculation for various values of resin inventory in each stage. The inventory of resin in each stage was determined from a knowledge of an assumed value for the total height of the stage, the expansion of the fluidized bed of resin, and the linear flowrate.

The model was tested on the results from the pilot-plant trials. Initially it tended to overpredict. For example, in one test it was found that the model predicted that fourteen stages would be required in the loading column to give the measured performance, whereas eleven were used in practice. This discrepancy was not considered serious because, as a result of the high resin loading achieved and,

TABLE V
RESULTS OF A CONTINUOUS PILOT-PLANT LIQUID-LIQUID-EXTRACTION RUN

	Start				Finish			
	Zn ²⁺	Fe ²⁺	Cl ⁻	SO ₄ ²⁻	Zn ²⁺	Fe ²⁺	Cl ⁻	SO ₄ ²⁻
Feed	15,8	2,1	21,6	—	—	—	—	—
Raffinate	—	—	—	—	2,8	2,0	20,7	0,2
1st strip	10,7	0,07	0,35	436,0	67,4	0,1	0,7	402,0
2nd strip	0,96	0,005	0,02	183,0	23,0	0,005	0,7	199,0
Loaded solvent wash	—	—	—	—	0,3	0,03	2,3	0,5
Stripped solvent	—	—	—	—	0,09	0,006	0,2	4,8

hence, the close proximity to the equilibrium loading values, the model was working in a very sensitive region. The measured loading was some 63 g of zinc per litre of wet-settled resin. The model was found to predict the eleven stages if the loading was assumed to be just 4 g/l less. The accuracy of the technique for the analysis of the resin was not considered to be much better than this.

However, with improvements in the analysis of the resin for zinc loading, the model proved sufficiently precise for the determination of the final design criteria and was therefore used. Details of the design cannot be disclosed at this stage.

Because of the difficulty in obtaining reliable kinetic and equilibrium data on the elution, the designs of both the washing and the elution columns were based on residence time.

ACKNOWLEDGEMENTS

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General of the National Institute for Metallurgy.

REFERENCES

1. TUNLEY, T. H., and SAMPSON, T. D. Treatment of chloride solutions. *S. Afr. Pat.* 70/8558. Dec. 1970.
2. PERKINS, E., and MABLEY, L. S. Hydrochloric acid pickling and acid regeneration. *Iron Steel Engng*, vol. 42, no. 4. 1965. pp. 156-159.
3. POOLE, D. E. Republic's continuous-reclamation hydrochloric acid pickling at Gadsden, Alabama. *Ibid.*, pp. 160-163.
4. BROWN, C. M. High-purity iron oxide from spent hydrochloric acid pickle liquor. *Proceedings, Symposium on continuous processing and process control. Ingraham, T. R. (ed.)*. New York, Gordon and Breach, *AIME Conf. Series*, pp. 93-104.
5. CLOETE, F. L. D., and STREAT, M. Improvements to fluid solid contacting. *Brit. Pat.* 1 070 251. 1967.

Symposium on Uranium Prospecting

The Geology Division of the Atomic Energy Board is organizing the above symposium, which is to be held at the National Nuclear Research Centre, Pelindaba, on 21st and 22nd March, 1974.

The main purpose of the symposium is to give some guidance to geologists involved in uranium prospecting and to those responsible for the planning of these operations. The lectures presented, which will be based on experience gained by the Atomic Energy Board, the National Institute for Metallurgy, the Geological Survey, and the mining industry, will deal with the following

- topics:
- World uranium reserves
 - Basic physics pertaining to prospecting for source materials
 - Instrumentation
 - Neutron activation analysis as an aid to prospecting for uranium
 - Airborne radiometric survey techniques and interpretation of data
 - Practical aspects of flying and planning an airborne radiometric survey
 - Ground radiometric survey techniques
 - The geochemistry of uranium
 - The mode of occurrence of

- uranium
 - Case histories.
- Delegates will be given the opportunity of visiting the SAFARI-I reactor, the neutron activation facility, and other places of interest at Pelindaba, and the calibration facility will be available to delegates who wish to calibrate their scintillometers. It is hoped that an exhibition of instruments can also be arranged.
- Enquiries should be directed to Dr P. D. Toens, Convenor: Symposium on Uranium Prospecting, Atomic Energy Board, Private Bag X256, Pretoria.

Solvent extraction and ion exchange in hydrometallurgy

The Solvent Extraction and Ion Exchange Group of the Society of Chemical Industry is to hold a symposium on the above subject in Leeds, England, on 4th and 5th April, 1974. The speakers and subjects will be as follows.

- Mr K. C. Knudsen (Superfos a/s, Copenhagen)
 'Fertilizer Production by Ion Exchange'
 Dr G. J. Lawson (University of

- Birmingham)
 'Solvent Extraction of Metals from Chloride Solutions'
 Mr D. Naden (Davy-Power Gas Ltd)
 'Application of Continuous Ion Exchange to Copper Recovery Problems'
 Dr N. M. Rice (University of Leeds)
 'Recovery of Zinc, Cadmium, and Mercury by Solvent Extraction'
 Dr M. J. Slater (University of Brad-

- ford)
 'Ion Exchange in Fluidized Beds'
 Dr M. Streat (Imperial College of Science and Technology, London)
 'Anion Exchange of Uranium from Aqueous Sulphuric Acid Solutions: Diffusion Kinetics'.
 Enquiries should be directed to the Director of Special Courses, Department of Adult Education and Extramural Studies, The University of Leeds, Leeds LS2 9JT, England.