Hunting Down the Neutrino

The first neutrinos in nature ever detected by man were "caught" in a unique laboratory some 3 km (over 2 miles) underground in one of the world's deepest mine shafts at East Rand Proprietary Mines (ERPM), Boksburg. Only 100 m from where gold is being mined from the rock face a small team of South African and American physicists work on one of the most fascinating and important fundamental research projects that is currently exciting the imagination of the scientific world.

Neutrinos are sub-atomic particles just as are protons, neutrons and electrons, but they are unique in that they have *neither electric charge nor mass.* Cosmic neutrinos travel at the speed of light and penetrate stars and planets. Even a million kilometres of solid lead would not provide a satisfactory shield against them. Stars are believed to "burn" by means of nuclear reactions which produce enormous fluxes of neutrinos. The sun, for example, illuminates the earth with visible light, but also bathes it with neutrinos.

After World War II, two American physicists, Profs Frederick Reines and Clyde Cowan, experimenting at a large nuclear reactor, succeeded in obtaining direct evidence of the existence of the laboratory-produced neutrino. It then became very important to establish whether neutrinos also existed in nature. This knowledge would lead to a greater understanding of the forces of nuclear physics, of the behaviour of nuclear particles and, indeed, is also relevant to astrophysics.

From the start it was clear that the search for "natural" neutrinos would be difficult. Questions which arose were —

★ how could they be traced if they were without mass or electric charge?

★ how could other nuclear particles be screened off?

★ could these not be wrongly detected, or even prevent accurate detection of neutrinos?

Neutrinos were known to be produced along with charged particles, by the reaction of primary cosmic rays with the constituents of the atmosphere. It was also known that when the neutrinos collided with matter, they themselves produced the same type of charged particle which could be detected if the unwanted charged particles from the atmosphere could be screened off.

What was needed, therefore, was a laboratory where the particles produced in the atmosphere could be screened out, yet which would receive and detect the particles produced by the neutrons' collision with the matter (solid rock) in the vicinity of the laboratory. This meant that scientists either had to build a laboratory with an enormously thick lead shield for their detection work . . . or they could go as near as possible to the centre of the earth where only charged nuclear particles of the very highest energies could penetrate. ERPM was clearly the most suitable place in the world where so effective a "neutrino trap" could be set.

Under more than 3 000 m of solid rock the apparatus for detecting neutrinos is well shielded against unwanted nuclear particles produced in the cosmic radiation which can reach the laboratory only in a steeply vertical trajectory. Other particles are easily stopped by the great thickness of rock.

The air-conditioned laboratory is at one end of a 150 m long tunnel, 2,5 m high and wide, blasted from the rock. The electronic recording equipment is housed here, while the rest of the tunnel is filled with the detection system. When a charged particle passes through a detector element, it produces a minute flash of light which is recorded and which triggers a flash-tube array. This then defines the trajectory of the charged particle, which is also recorded on film for analysis.

So far 82 neutrinos have been detected, 50 at the present level and 32 at a higher level, and the findings have borne out the physicists' theoretical expectations.

In this joint project Profs Reines, J. P. F. Sellschop, Director of the Witwatersrand University's Nuclear Research Unit and M. F. Crouch of the Case-Western Reserve University of Ohio are the Chief Investigators.

This unique endeavour has been made possible by financial support from the US Atomic Energy Commission, the University of the Witwatersrand and the Chamber of Mines of South Africa, as well as by the co-operation of the management and men of ERPM.

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National Institute for Metallurgy

EXTRACTS FROM REPORTS

N.I.M. REPORT
No. 1093

THE CALCULATION OF THE EQUILIBRIUM DISTRIBUTION OF METAL-ION COMPLEXES IN MULTICOMPONENT AQUEOUS SYSTEMS

23rd November, 1970
Investigator: C. R. S. Needes

SYNOPSIS

A computer programme based on the generalized Newton-Raphson iterative method to solve n nonlinear implicit polynomial equations has been developed to calculate the equilibrium distribution of metal-ion complexes in a multicomponent system. The method is well suited to the solution of a group of equations where the separation of the variables is either impossible or leads to unwieldy polynomial expressions. The solutions of the three-component system $UO_2^{2+}-CO_3^{2-}-OH^-$, the four-component system $UO_2^{2+}-Fe^{3+}-SO_4^{2-}-OH^-$, and the six-component system $Cu^{2+}-Zn^{2+}-Fe^{3+}-Fe^{2+}-OH^--SO_4^{2-}$, are provided.

N.I.M. REPORT
No. 1144

THREE-DIMENSIONAL PREDOMINANT-AREA AND SOLUBILITY DIAGRAMS FOR THE URANYL CARBONATE AND URANYL SULPHATE SYSTEMS AT 25 °C

4th January, 1971
Investigator: C. R. S. Needes

SYNOPSIS

The equilibrium distribution of species in the systems $UO_2^{2+}-CO_3^{2-}-OH^-$ and $UO_2^{2+}-SO_4^{2-}-OH^-$ at 25 °C was calculated by use of a computer programme. The calculations were based on stability-constant data taken from the literature and applied to the following conditions: total-uranium concentrations of 10^{-6} to 10^{-1} M, total-ligand concentrations of 10^{-4} to 10 M, and pH values between -2 and 14. The data for each of the systems were condensed into three-dimensional diagrams representing the fields of predominance and solubility of the various ionic and solid species considered.

N.I.M. REPORT
No. 1267

THE DEVELOPMENT OF AN ELECTRODELESS CONDUCTIVITY METER

25th May, 1971
Investigators: G. T. W. Ormrod, P. Nerer

SYNOPSIS

An electrodeless conductivity meter having solid-state components is described. Although the meter effectively and reliably measures conductivity, there is a complex relation between conductivity and the free acid present. For a better understanding of this system a detailed description of the plant parameters and their influence on the measurement of conductivity is presented.

N.I.M. REPORT
No. 1308

HEAVY-MEDIUM TESTS FOR THE TREATMENT OF PEGMATITE ORES AND DUMP MATERIAL IN NAMAQUALAND

21st July, 1971
Investigators: P. W. Overbeek, J. M. L. Lewis

SYNOPSIS

Tests with a portable heavy-medium cyclone separator (capacity almost 2 tons per hour) were done in the Noumas and Durabees areas.

Heavy-medium separation (H.M.S.) was found to be an efficient method for the recovery of spodumene, provided that the contents of thin mica flakes in the feed material does not exceed 1.0 per cent. The presence of greater quantities of mica flakes results in high losses of medium, low grades of concentrate, and low recovery.

Mixed tantalite and columbite constituted between 0.29 and 0.66 per cent of the H.M.S. concentrates, and about 87 per cent of the tantalite—columbite was recovered by crushing and gravity concentration.

Spodumene concentrates having an LiO_2 content of approximately 5 per cent can be produced in a single stage of concentration, but retreatment is necessary for the production of a significantly higher grade.

Estimates indicate that only 16 per cent of the spodumene and 50 per cent of the beryl, tantalite—columbite, and mica in the ore are recovered by the method used at present (handsorting), and the waste dumps therefore contain considerable quantities of these minerals.

The operating costs of the pilot plant for medium, water, and power were 38 cents per ton of feed, but the costs of an industrial plant would be lower, mainly because of lower fuel costs.

H.M.S. can therefore be considered a practical method of treatment for the recovery of spodumene and tantalite—columbite from the pegmatite ores in these areas.

The report includes a summary that contains a tabulation of the results obtained by H.M.S.

N.I.M. REPORT
No. 1310

SOUTH AFRICAN COSTS OF INDUSTRIAL EQUIPMENT FOR THE METALLURGICAL INDUSTRY

27th July, 1971
Investigator: B. M. Wilson

SYNOPSIS

Average costs of the equipment used in crushing, grinding, classification, flotation, and thickening pro-

cesses are given. These costs are presented in the form of size exponents derived from data on the size and cost of equipment plotted on log-log graph paper, and are based on prices prevailing at the end of March 1971. An up-dated buyers' guide for the equipment is included.

1. INTRODUCTION

One of the functions of the Economics and Costing Division of the National Institute for Metallurgy (NIM) is the assessment of the technical and economic feasibility of proposed metallurgical processes. This report is concerned with the capital costs of equipment that are required for these assessments.

Although the costs of equipment manufactured and sold in the U.S.A. are readily available, there is not, as far as is known, a comparable source of information on the costs of equipment sold in South Africa. It was therefore decided that the local prices of equipment should be ascertained, and it was felt that, as NIM is a statutory organization, local manufacturers and suppliers might well be prepared to divulge their costs, even if these were confidential.

2. INITIAL CALCULATIONS

Following a preliminary study of published flowsheets of metallurgical processes, the conclusion was reached that a possibly favourable attitude towards requests for the prices of equipment might be altered to an unsympathetic outlook if the requests to suppliers were accompanied by lengthy lists of equipment types and sizes.

It was therefore decided that it would be acceptable for the purpose of costing if the prices of only two, or preferably three, different sizes of each type of machine were obtained. Graphs showing cost versus some performance or size parameter could then be prepared, and cost exponents could be calculated by the normal method shown in Fig. 1.

From the study of the flowsheets, three hypothetical milling processes of increasing magnitudes of output were considered and equipment lists compiled the intention being that only costs of this equipment would be sought.

3. BUYERS' GUIDE

During the course of the investigations, many suppliers of equipment were visited, and it was found that many of the published buyer's guides were out of date in the details given for the agencies held or the equipment supplied by various companies. It was therefore necessary for this information to be brought up to date.

4. RESULTS OF THE INVESTIGATION

Costs and performance data for equipment were readily supplied by most of the companies approached. Thus the costs of over 1 500 items of equipment, obtained from about 40 suppliers, were available for the preparation of the cost exponents. The costs of certain rather specialized items were not obtained. In many instances, these items, e.g. kilns, are manufactured to a customer's specification, and costs for a range of sizes are difficult to obtain; in other instances, the demand for this equipment, e.g. Herreshoff furnaces and Edwards roasters, is too small to warrant a supplier's having cost information for the entire size range. These costs will be obtained by NIM when required for its own budget-costing purposes.

Although most of the costs obtained were actual selling prices, the costs presented in this report must be regarded as average budget costs because rapid fluctuations in the cost of particular materials of construction or in discounts applicable to specific purchasers, or an alteration in specification or rating of a minor component of the machine, may well alter the selling price.

Graphs in which the selling price was used were initially plotted for each type of machine handled by a specific supplier.

Various unexpected discrepancies were observed during the plotting of these graphs, but details cannot be given because these would involve a betryal of confidential information. However, discussions with the supplier revealed inadvertent errors in the cost or performance data supplied or design changes necessitated by alterations to the size of the machine. In this manner, all the discrepancies were explained and corrected.

To avoid the use of actual costs, which must remain confidential to the supplier, the average cost for each particular type of machine was calculated, and the exponents were then determined from these average costs.

COSTS OF METALLURGICAL EQUIPMENT

The graphs contain the following confidential information:

(1) Cost versus output. Although the specification of outputs is difficult, this information was included for these machines where data are available for the processing of a standard material.

(2) Cost versus weight of equipment. These graphs enable the estimator to calculate the cost of (a) the transportation of the equipment from the factory to the intended process plant, and (b) the necessary foundations for the machine.

(3) Cost versus installed horsepower. These graphs assist in the estimation of operating costs and enable the cost of the required motor, drive, electrical switchgear, and wiring to be calculated.

(4) Cost versus size of machine. This information was included for various types of machine where the specification of the material to be processed is inconvenient.

The exponents listed are generally based on the size of the machine and it is left to the estimator to determine the output rates for particular materials considered.

The costs given are based on f.o.r. Johannesburg prices, including or excluding specified items such as motors and drives.

Certain types of equipment have not been included in this report for the following reasons:

(a) The information promised by certain companies has not yet been received.
(b) The information, although held on file, cannot be presented here because it is applicable to only two suppliers of a particular type of equipment that varies widely in cost for machines of the same size. This difference is due either to increased efficiency of operation or durability in the higher-priced item, or to the variation in price that can be expected between imported and locally manufactured equipment. This large cost difference would render a cost estimation derived from average costs meaningless.
(c) Costs were received for certain equipment from only one supplier, who requested that the information should be kept confidential.

5. CALCULATION OF EXPONENTS

All the data on average cost and performance or size for each type of machine were subjected to a regression analysis programmed for an IME 86S calculator in conjunction with a Digicorder programmer unit. The programme used enabled correlation coefficients, regression equations, and the exponents given in Appendix I to be calculated according to the method described in Section 2.

6. ACCURACY

The accuracy of calculations based on the exponents given in Appendix I was verified as being within 10 per cent of average selling prices. This figure was determined from a comparison between the actual costs of equipment at the extremities of the size ranges available and the costs calculated from the cost exponents.

It is quite possible that the use of parameters other than those chosen for the compilation of Appendix I in this report, for example, installed horsepower or weight instead of output or capacity, would result in increased accuracy of cost estimation. As more cost and performance data become available to NIM, investigations on parameters that would increase the accuracy of estimation are being pursued.

7. PERFORMANCE SPECIFICATIONS

Performance specifications were obtained from the suppliers together with the cost information and are available within the Economics and Costing Division. This information performs a two-fold function: it decreases the time required for the calculation, based on first principles, of the size of machine to be selected, and it increases the accuracy of the calculations.

Because this information is freely available from suppliers and because it is very bulky, it has not been included in this report.

8. CHEMICAL-PROCESSING EQUIPMENT

As this type of equipment, e.g. heat exchangers and evaporators, is being increasingly used for purely metallurgical processes, it was intended that costs would be obtained for these items, although at a lower priority than for the more frequently encountered metallurgical equipment. However, the South African Institute of Chemical Engineers intends publishing data that have been made available by SASOL on the costs of chemical-engineering equipment. Because of this intended publication, NIM will not proceed further with this aspect of equipment costs.

9. LABORATORY AND PILOT-PLANT EQUIPMENT

No information on the costs of this equipment was obtained because the operations involved at these levels of output are of little or no interest for the purposes of the present economic assessments.

10. UPDATING OF COST INFORMATION

It is intended that the costs will be reviewed at approximateky one-year intervals, but the interval will be reduced if any general cost increases in labour or material occur within that period.

At the start of this project it was intended that the costs of equipment current at the end of 1970 would be published, but recent increases in the costs of materials and labour have necessitated the updating of the costs to those prevailing at the end of March 1971. Although the costs at the end of the third quarter of 1970 are on file, it was decided that, as this information is now of historical interest, it would not be incorporated in this report but would be retained for possible use as an economic indicator of changes in the cost of metallurgical equipment.

11. METRICATION

The units specified in this report are those at present used by the manufacturers and suppliers of metallurgical equipment. However, all these concerns are in the process of converting their specifications to metric units, and an updated report using metric units will be issued when this operation is complete.

12. MATERIALS OF CONSTRUCTION

Some information on the costs of materials of construction has been included in Appendix II to assist in the cost estimation of fabricated items such as tanks and piping layouts.

13. CONCLUSIONS

The response from the suppliers of equipment was most encouraging, and the costs of about 1 500 items of equipment were obtained from some 40 suppliers.

All anomalies in the costs supplied were investigated, explained, and corrected before the cost data were processed into the form given in Appendix I.

Not all types of metallurgical processing equipment are included in this report, nor has all the information obtained been presented — the data for some items were insufficient for the calculation of average costs. However, information is continually being collected so that additional costs can be calculated.