

The evaluation, design and construction of the uranium plant for Chemwes Limited

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SYNOPSIS

The Chemwes uranium plant was designed and constructed within fifteen months; commissioning started during June 1979, and the plant was producing at design capacity four months later.

This account highlights the procedures and methods adopted to bring the plant into production. The description of the various phases includes some details of the early evaluation, and the feasibility and optimization studies; of the financing, project management, design, construction, and commissioning of the plant; and of the training of personnel. Some of the mistakes made and the factors that contributed to the success are also listed.

SAMEVATTING

Die Chemwes uraanaanleg is binne vyftien maande ontwerp en opgerig. Die ingebruikneming het tydens Junie 1979 in aanvang geneem en vier maande later het die aanleg teen ontwerpde kapasiteit geproduseer.

In hierdie verslag val die klem op die prosedures en metodes gevolg om hierdie aanleg in produksie te bring. Die beskrywing van die verskillende fases sluit in besonderhede omtrent die vroeë besyfering en vooruitvoerbaarheidsstudies, die optimalisasie studies uitgevoer, die finansering, projek bestuur, ontwerp, oprigting en ingebruikneming van die aanleg en die opleiding van die personeel. Van die foute begaan, sowel as die hoofpunte wat bygedra het tot die sukses van die projek, word ook genoem.

Introduction

The South African uranium industry started in the early 1950s, and by 1957 a total of seventeen plants were in production. All these first-generation plants employed the same process, and most adopted the same design, thus simplifying the detailed design and construction.

A drop in the uranium price caused production to decline, and by 1966 only seven of the original plants remained on-stream. This decline was followed by a gradual recovery, and the years 1971 and 1972 were marked by the commissioning of three new plants. All the second-generation plants employed a slightly different process from that of the earlier plants.

The sharp increase in uranium price after the oil crisis of 1973 resulted in a spate of third-generation plants, together with extensions to existing installations. These latest plants use widely differing flowsheets, which have been developed as a result of recent advances in processes for the recovery of uranium.

For most of the first- and second-generation plants, the mining companies acted as their own project managers. At the time of construction they employed strong design and engineering teams, the plants being designed in-house using a common design or slight modifications to suit individual conditions. The plants were constructed by sub-contractors under the control of the mining companies.

Owing to the declining demand, some mining companies reduced their design and project-engineering teams during the early 1970s. As a result of this in-house shortage of qualified personnel, a number of the third-generation plants were designed and con-

structed by large engineering-services contractors, who acted as project managers for the mining companies. In most cases, the mining company and the engineering contractor formed a joint team. With the combined resources and expertise available, the joint team managed the evaluation, design, and construction.

This paper describes the evaluation, planning, design, control, and construction of one of these third-generation plants, which was constructed for Chemwes Ltd.

Historical Aspects

Stilfontein and Buffelsfontein are two gold mines operated by General Mining Union Corporation in the Klerksdorp district. The history of uranium production and stockpiling of uranium-bearing slimes at these mines is described briefly.

Stilfontein was one of the earlier South African mines to be awarded a uranium-production quota. The mine produced its first gold in July 1952, and uranium in October 1953. During 1953–1954, the plant was extended to double its former capacity, and by October 1954 the plant was treating its own slime, as well as gold-slime residue from four smaller mines operating in the Klerksdorp area.

The uranium content of the slime treated was generally low, and this, coupled with the operation of the joint pumping scheme catering for the four smaller mines supplying the supplementary tonnage, made the plant a high-cost uranium producer. Thus, late in 1960, when the original contract was renegotiated at new prices and delivery times were extended to 1970, it was decided to close the Stilfontein plant and sell its quota to a lower-cost producer. The mine's uranium-bearing slime was thus stockpiled from early in 1961.

Buffelsfontein started producing uranium from the middle of 1956. In the earlier years, the capacity of the uranium plant was less than that of the gold plant, and the excess gold residue was stockpiled.

After the increase in the uranium price in 1973–1974, it

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was decided to investigate the feasibility and economics of recovering uranium from stockpiled slime in the Klerksdorp area, with specific reference to the material stockpiled at Stilfontein and Buffelsfontein.

Early Investigations

Investigations into the recovery of uranium and other saleable products from untreated slimes dams started in 1974. These early investigations mainly involved the following.

- (1) Sampling of the slimes dams to accurately establish the grade and tonnage of the material on the dams, and to provide representative material for testwork.
- (2) Laboratory and pilot-plant testing of slimes-dam material to provide data on uranium leaching, liquid-solid separation with emphasis on thickening in a countercurrent-decantation (CCD) circuit, and pyrite flotation.
- (3) Preconcentration of the uranium prior to leaching.

At that time the National Institute for Metallurgy (NIM) was investigating the amenability of various gold-plant residues to concentration techniques. The preconcentration testwork, conducted in conjunction with NIM, was limited to the following:

- (a) gravity concentration of the uranium and the pyrite,
- (b) wet high-intensity magnetic separation (WHIMS) to prepare a uranium concentrate prior to leaching,
- (c) flotation of the slimes-dam material to produce a pyrite concentrate and a middlings product, the pyrite to be roasted in an acid plant and the combined calcine and middlings to be treated for the recovery of uranium and gold.

The main conclusions from the early investigations were (a) that the uranium should not be concentrated before the leach. The preconcentration techniques were all fairly new for uranium and untried on a commercial scale. This fact and the unfavourable economics led to the rejection of the preconcentration approach, and all further testwork and evaluations were related to direct leaching of the reclaimed slime. (b) Due to oxidation and bacterial action on the dams, the slimes-dam material gave better overall dissolutions and required less acid than current slime.

Prefeasibility Study

Based on the early testwork, a prefeasibility study was carried out in 1976 on a conventional process, which consisted of high-pressure water monitoring of the slimes dams, leaching in pachuca, CCD thickener, liquid-solid separation, continuous ion exchange (CIX), solvent extraction (SX), and conventional precipitation. The uranium residue was to be floated to produce a pyrite concentrate and middlings, which, after the former had been roasted in the existing acid plant, would both be cyanided for the recovery of gold.

The main objectives of the prefeasibility study were as follows:

- (i) to determine the economics of uranium recovery from certain accumulated slimes in the Klerksdorp area,
- (ii) to determine the optimum plant capacity, and

(iii) to determine the optimum sequence for the reclamation of the slime.

Plants of four capacities, namely 4 500, 9 000, 11 700, and 17 550 tpd were considered, and for each size, five different schemes of slime reclamation with varying grade and recovery characteristics were examined. Estimates of the capital and operating costs with production schedules were prepared for each of the twenty alternatives. Tax options, and infrastructure and personnel requirements, were also considered, as were the sensitivities of the various schemes to uranium price, gold price, capital cost, and working costs. A risk analysis with over five-hundred iterations was also carried out, and this, together with a sensitivity analysis, established that the project had an excellent chance of being a success.

The following were the main conclusions of the prefeasibility study.

- (1) A plant treating 9 000 tpd was economically the most attractive, and this throughput was used in all the subsequent studies.
- (2) The reclamation sequence should be material from the highest grade Stilfontein dam together with that from the Buffelsfontein dam on a 50 : 50 basis, followed by material from the remaining Stilfontein dams.

TABLE I
OPTIMIZATION STUDIES COMPLETED

Section	Alternatives considered for investigation	Conclusion
Reclamation	Monitoring, or bucket-wheel excavator or Marcanaflo, for Stilfontein dams	Bucket-wheel excavator
Leaching	Various sizes of air-agitated pachuca tanks, or various sizes and designs of mechanical mixers	Flat-bottom air-agitated pachuca tanks
Leaching	Optimization of pyrolytic milling	Closed-circuit milling to 95% minus 200 mesh
Leaching	Optimization of leaching conditions: acid and manganese dioxide addition, temperature, and time	H ₂ SO ₄ 25 kg/t MnO ₂ 4 kg/t 60°C and 24 hours
Liquid-solid separation	Number of CCD stages and solution-to-solids ratio	Five stages at 2 : 1
Liquid-solid separation	Conventional thickeners, Enviroclear thickeners, drum filters, or belt filters	Belt filters
CIX-SX	Purlex or Bufflex	Bufflex
CIX	Rössing of NIM design	NIM design
SX	Optimization of SX section	Conventional Bufflex design
Product recovery	Optimization of product-recovery section	Conventional precipitation, thickening, and filtration
Flotation	Pyrite concentrate only, or pyrite concentrate plus middlings	Pyrite concentrate only

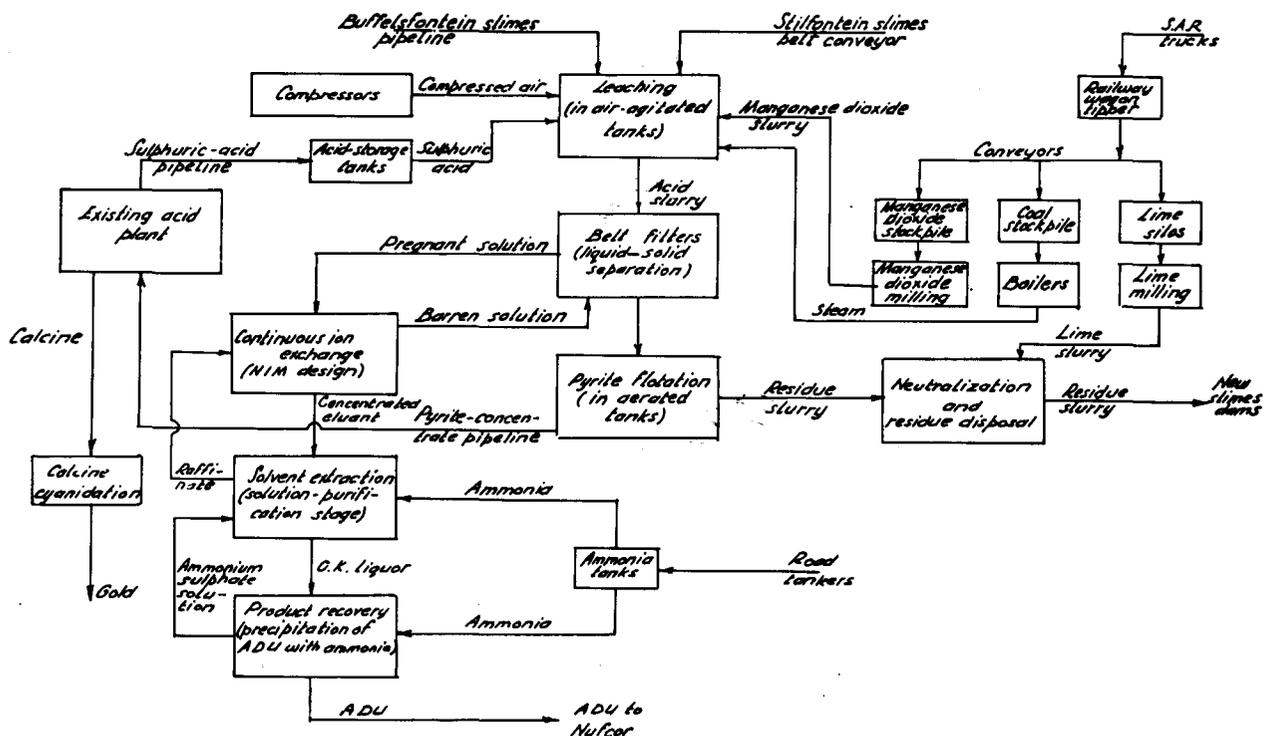


Fig. 1—Simplified flowsheet of the Chemwes plant

- (3) Financing of the project should be investigated.
- (4) Optimization studies should be carried out on all aspects of the recovery process. Such studies would involve additional testwork.

Feasibility Studies

Based on the acceptable economic evaluation made in the prefeasibility study, it was decided to proceed with more detailed market, financing, and technical evaluations. The financing team began to negotiate a contract for the expected production, and to investigate the various avenues for financing the project; and the metallurgical and engineering team began a series of detailed optimization studies, in conjunction with further laboratory and pilot-plant testwork, to optimize the flowsheet and to develop design and scale-up factors.

The slimes dams were sampled again to provide further data on the grade and tonnage of the material on the dams, and to provide representative material for the additional laboratory testwork.

The various process-optimization studies are summarized in Table I. In these optimization studies, it was necessary to consider the effect of each process or process variation on the total plant. For example, in the reclamation study, variations in the initial repulp density affected the recoveries and the operating and capital costs in most of the rest of the plant.

Before the flowsheet was finalized some of the investigators went abroad to view, under operating conditions, processes and equipment that were new to them. One team visited the U.S.A. and France to investigate belt filters, and CCD thickeners, and to examine uranium practice in the U.S.A. The other team visited various

installations in Europe to collect data and view equipment that would be suitable for the reclamation of Stilfontein and Buffelsfontein slimes dams.

The above studies were combined into the Final Feasibility Report, which included the final optimum flowsheet (shown in Fig. 1), design criteria, estimated capital and operating costs, production and revenue estimates, and the financial assessment.

Finance

Capital-intensive projects are normally financed in two ways.

- (a) The producer and the consumer negotiate an agreement by which the consumer provides the finance in return for an assured delivery of product.
- (b) The producer negotiates an agreement with a consumer for the purchase of a large portion of future production. The producer then approaches a banking institution and raises the necessary funds on the strength of the agreement.

Agreements were secured for the sale of a large portion of the Chemwes production, and loans were raised to provide funds for the complete project. By the use of such loans, the entire project was financed with limited funds from the shareholders.

The capital cost of Chemwes including plant, infrastructure, services, and fees was estimated as 68 million rands in terms of 1977 money. If an escalation figure of 1 per cent per month is used from the time that the contract was awarded in February 1978 to the time it was completed in June 1979, viz 17 months, the capital becomes 79,6 million rands, and there are indications

that the final cost will be some 5 million rands less than this.

Project Management

During and after the final feasibility study, an investigation was carried out on the most suitable strategic plan for the execution of the project. The total project could conveniently be split in two parts: the process plant (representing approximately 65 per cent of the total capital), and the peripheral installations, such as those for the reclamation of slimes, the new slimes dams, housing, and the air, power, and water supplies.

Since the total man-hours required for the design and construction of the Chemwes plant far exceeded Gencor's available resources, it was decided that Gencor personnel would handle only the process plant. This was designated the *In-house Section* and was the responsibility of the Gencor team, together with the co-ordination and supervision of all the activities associated with the complete project.

A number of alternatives were considered for the construction of the process plant including a turn-key project, a cost-plus project, a project managed by more than one contractor, and a project managed by a single contractor.

A project managed by a single contractor was considered the most attractive because of the following major aspects.

- (1) Adequate engineering and drawing office resources could be recruited and dispensed with relative ease.
- (2) The costs involved would be favourable.
- (3) The control and maintenance of the required standards in engineering and draughting would be easiest.
- (4) The interfacing difficulties and coordinating problems would be difficult if more than one contractor were used.

An enquiry document was prepared containing the following.

- (i) Fifty-one drawings, which showed the flowsheets, pipe and instrumentation diagrams, general arrangements, and plot plans with elevations and sections.
- (ii) General specifications for the mechanical, electrical, structural, and civil-engineering work.
- (iii) A list of equipment.
- (iv) Specifications for important criteria.

This enquiry was issued to a total of ten local and international companies, and tenderers were asked to submit the following information.

- (a) Full details of the personnel who would head the various divisions of their project team.
- (b) Details of the facilities, procedures, and office equipment that they would use in the metallurgical and engineering design.
- (c) The cost of project management for each section of the process plant.
- (d) The cost of equipment and machinery completely erected and commissioned for each section of the plant.

The tenders received were evaluated with due regard to the calibre of the senior personnel adjudged according to a personnel-rating method; the record of the company with particular reference to design and construction ex-

perience on uranium and similar metallurgical plants, adjudged according to a similar company-rating method; and the total estimated management cost and fee.

From the results obtained, a short list of four tenderers was prepared, and these tenderers were investigated with regards to the financial stability of the company, weaknesses in the contractor team and possible replacement of certain members, guarantees on the performances of the projects teams, and a possible bonus/penalty contract. After due consideration, the contract for the design, procurement, and project management of the erection of the process plant was awarded to Edward L. Bateman Limited.

The form of the project-management agreement was a cost-reimbursable contract plus management fee based on the final escalated target price. Incorporated in the terms of the contract was a bonus/penalty clause on both time and price. The bonus/penalty on time was limited to the management fee, the penalty or bonus being a percentage of the fee for each day the actual completion was behind or ahead of the contractual completion date, limited to 100 per cent of the fee on either side. The bonus/penalty on the contract price was based on 10 per cent of the savings or overrun of the final escalated target price.

Design

The first step was the creation of a strong project team. The top managements of Gencor and the contractor arranged the organizational structure for the combined teams, and, in effect, the teams were welded together to form a new team to manage the project. The normal activities associated with project work now commenced in parallel: those for the process plant at the contracting firm, and those for the in-house section at Gencor. The target time for the completion of the project was set at fifteen months, and the existing bar charts, activity networks, and S curves where applicable were amended accordingly. It was considered that the speed of execution would be set primarily by completion of the engineering design (the metallurgical design having already been completed by Gencor), timely purchase of equipment, and correct management of the site organization.

The main philosophy behind the design was conservatism: because of contractual commitments, there would be no time available for an extended commissioning. The plant had to produce, and the earlier it could do so the better.

Gencor approved the following documentation after preparation by the contractor: all the civil, structural, mechanical, electrical, instrumentation, and pipe-isometric drawings; the specifications and enquiries, the evaluation of quotations, and the orders.

Regular meetings were held between Gencor and the contractor to co-ordinate the activities of the contractor and Gencor, to assess actual progress against planned progress, and to evaluate quotations and the cost of selected equipment against the budgeted cost shown in the original estimates prepared by the contractor. Any variation from the plan was dealt with immediately. Where necessary, small teams were co-

opted to investigate deviations and to recommend corrective action. Quality-control reports were called for, and this activity was considered particularly important to ensure that the required standards were maintained. Where necessary, outside agencies were employed to implement quality-control procedures.

A regular monthly report was prepared for top management indicating the engineering progress; the capital expenditure, and the progress on site.

Some features of the design are of interest.

- (i) Because the soil consisted of weathered dolomites, it was eventually decided to pile for the heavily loaded foundations, and to cut and backfill for the more lightly loaded foundations.
- (ii) Pipe runs and electric cables between sections of the plant were installed on trestle steelwork above ground level.
- (iii) The general arrangement of the plant was such that the capacity could be doubled if necessary.
- (iv) Large flat-bottomed pachuca were to be used for the leaching of the uranium on a batch leach basis.
- (v) Stainless steel was used throughout the construction of the belt filters for the liquid-solid separation.
- (vi) The large continuous ion-exchange contactors were moulded in fibre-reinforced plastics.
- (vii) The flotation cells were of the large Outokumpu type.
- (viii) The plant is fairly well instrumented and a sophisticated control system (Honeywell TDC 2000) was installed. The control philosophy allows for each piece of machinery to be started locally, and the operation of each plant section can be monitored and controlled from local (seven in number) control rooms. There is a central control room that allows, through video display, every control loop or alarm on the plant to be monitored. It is envisaged, with operating experience and some further expansion of the plant instrumentation, that an experienced metallurgist on shift will be able to monitor and control, through a keyboard, many metallurgical aspects of the plant operation.
- (ix) The physical presence of operators on the various sections will always be necessary, although some reduction in number is possible in the future.

Construction

Because Chemwes is adjacent to a major gold mine and a town with established infrastructure, it was relatively easy to provide the services required during construction.

- (1) Water was supplied in a ringfeed round the periphery of the plant area.
- (2) Power was supplied via a high-tension ringfeed round the plant with mini sub-stations.
- (3) On arrival at site, each sub-contractor was given a demarcated area as a laydown and office area. This area was outside the plant but inside the security area.
- (4) As soon as it was possible after the backfill operation, all the bases for the permanent roads were formed and given a light tar spray and chip cover.

- (5) Because of other major capital extensions in the area, housing for all types of workers was at a premium. Therefore, most senior personnel were housed in rented houses, some as far as 40 km from site, and the more-junior personnel were established in single quarters in rented houses close to one another. Caravan parks with all modern facilities were established for the contractors and their senior workers, and a temporary construction camp was established for the labourers with full messing facilities. In addition, telex facilities and a PAX system with extensions to all contractors was provided.

Strict security was enforced from the first day. A security fence was erected round the whole work area, including the plant area and the laydown area for all contractors. Only two gates were allowed serving the internal road system. Both these gates were guarded twenty-four hours a day, and no person without a permit or identity document was allowed into the security area. A further personnel entrance was provided through the contractor's site office. The total security area was well illuminated with high-pressure lamps mounted on high-rise masts.

No work could be undertaken unless the checked and approved drawings were on site. For the civil work, about 94 per cent of the civil drawings and at least 75 per cent of all the drawings were on site before the construction started.

The sub-contractors were controlled by a 'point system'. For this system, each activity is broken down into jobs and each job is given a relative number of points. The total points earned by a sub-contractor was assessed on a weekly basis, and progress was correlated against the bar chart that the sub-contractor had accepted at the tendering stage. If the sub-contractor did not perform to requirements, action was taken immediately.

The following regular site meetings were held:

- (a) a monthly review meeting between Gencor and the contractor, which correlated all the aspects of the complete project,
- (b) site meetings whenever it was deemed necessary,
- (c) regular meetings with the sub-contractors, which were kept as short as possible and were held only to solve problems involving more than one party,
- (d) short daily meetings with the controlling team to discuss the day's priorities.

To assist in the subsequent cold commissioning and preparation of reagents, the construction was phased for certain sections of the plant to be completed ahead of other sections. This phasing permitted the unloading of reagents in March 1979 and the commencement of reagent preparation during April 1979, while the total plant was mechanically complete only in June 1979.

Safety was maintained at a high level. The labour force peaked at over 3000 people, and only one fatal and three reportable accidents occurred over the whole construction period.

General views of the final plant are presented in Figs. 2 and 3.

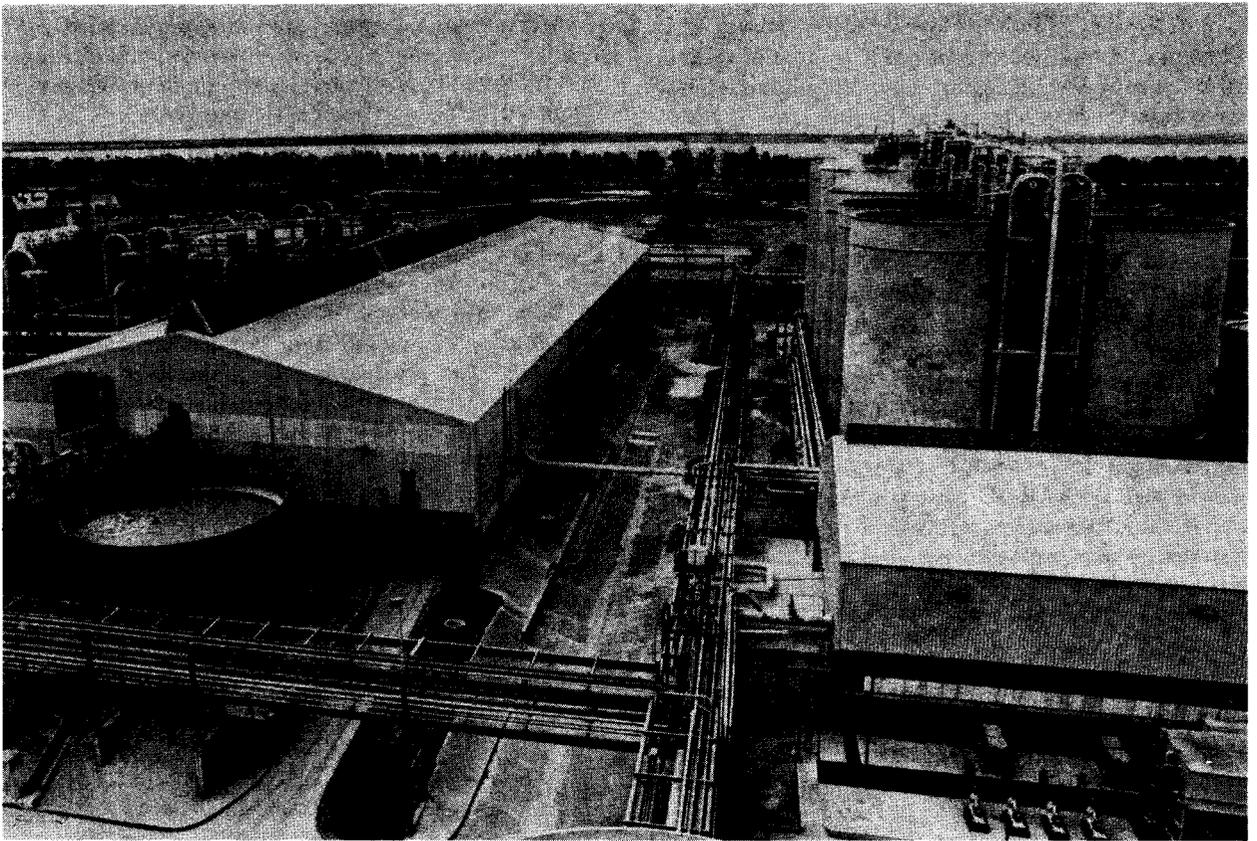


Fig. 2—A view of the plant showing the leaching pachucas and the filter building

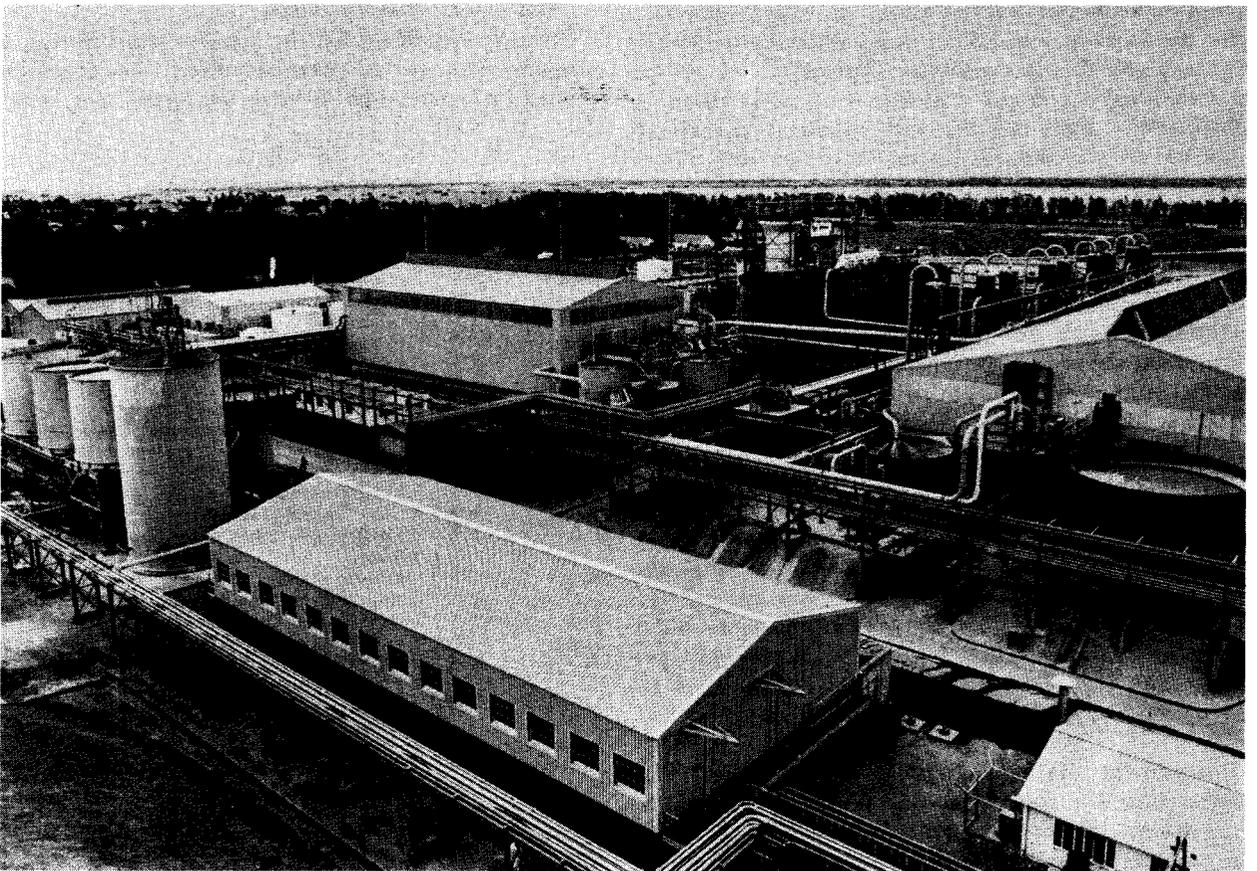


Fig. 3—A general view of the plant, with the flotation building and the CIX columns in the background (by courtesy of Public Relations Office of Gencor)

Company Organization

Chemwes, being an independent company, had to establish a complete operating, engineering, and administrative organization. The overall organization is headed by a General Manager, while the plant organization is headed by a Metallurgical Manager, to whom the Plant Engineer, the Plant Superintendent, and the Company Secretary report. The total number of employees is 400. The engineering complement numbers approximately 80, the operations section approximately 260, and the administrative section (including accounts and stores) approximately 60.

The basic philosophy behind senior staff appointments was that the people who designed the plant would have to make it work. Hence, the General Manager, Metallurgical Manager, Engineer, and Company Secretary were involved throughout in the design and construction. This gave rise to a commitment to succeed among the senior personnel, which was also adopted by those engaged later, and a well-motivated team spirit has been developed in the organization.

Training

The recruitment of personnel started about nine months before the start-up date. Appointments were made as early as possible in the project to allow the maximum period for training and growth, as it were, with the plant.

Gencor's policy is to train and develop all its human resources to their fullest potential. The training procedure employed by the Group is called Criterion Referenced Instruction (CRI), and a crash course based on this approach was employed. Basically, CRI allows the individual to progress at his own rate within a realistic time limit set by the instructor. Terminal objectives are set, and the aspects taught are only those which enable the student to reach the set objectives.

Operator training was the biggest challenge. Operating manuals, prepared and available approximately six months before the start-up, were used by the training team in preparing the training programmes. These operating manuals are a reference source of detailed information about each section of the plant. The manuals contain process descriptions, equipment lists, various operating and standard procedures, and a troubleshooting section.

Before training could start, each job was identified and a full job description for each position was prepared. From the job descriptions, the minimum knowledge required to carry out the task satisfactorily was assessed, and a training programme for each job was designed to meet this minimum requirement. Courses were designed for all the operations staff, but the terminal objectives varied. The approach with the Black staff, owing to literacy variations, was almost exclusively at the verbal level.

Recruitment and training progressed steadily in parallel with the plant construction. By the time hot commissioning started, about 80 per cent of the operating and engineering staff were on site, and the majority of the operating personnel had completed their respective training programmes.

The ordering of spares and the preparation of the planned maintenance system progressed in parallel with recruitment. The stores and secretarial sections were also organized before the commissioning period.

Commissioning

The total commissioning period proceeded as follows.

- (1) Commissioning started with mechanical completion, which was defined in general as the stage at which the project works had been erected and installed in accordance with the specifications and drawings. Exceptions not affecting the operability, safety, or use of the project works for the purpose intended were recorded on an agreed exception list.
- (2) Cold commissioning was defined in general as the completion of the work necessary to prepare the project works for the introduction and processing of raw materials and feedstocks. The work mainly involved the water checking of vessels, pumps, and pipelines; the checking of electrical equipment and drives; and basic calibration checks on instrument systems.
- (3) The reagents were prepared; for example, the chloride-form resin was sulphated and the solvent required in the solvent-extraction section was prepared.
- (4) Hot commissioning started with the introduction and processing of the raw material and feedstocks, and was regarded as complete when the project works operated at design capacity and was put into full commercial operation.

The responsibilities for the process plant during the commissioning period were twofold: the contractor, assisted by Gencor and Chemwes personnel, was respon-

TABLE II
MILESTONES IN THE PROJECT

Date	Activity
April 1976	Completion of pre-feasibility study
January 1977	Completion of four process-optimization studies
February 1977	Completion of preliminary feasibility report
July 1977	Completion of a further seven optimization studies
August 1977	Overseas visit by two teams
November 1977	Enquiry for project-management tenders
December 1977	Evaluation of tenders received
January 1978	Completion of final feasibility report
February 1978	E. L. Bateman appointed as project managers
March 1978	Start of detailed design
April 1978	Award of contracts for piling and main civil works
May 1978	Concrete pouring started
June 1978	Tank steel erection started
July 1978	Large-diameter piling completed
August 1978	Building steel erection started
September 1978	Engineering and design complete
October 1978	First filter delivered
November 1978	Electrical and instrumentation contract started
December 1978	First three filter frames erected
January 1979	Completion of main reinforced earthworks
February 1979	Cold commissioning started
March 1979	First reagents unloaded
April 1979	Preparation of reagents started
June 1979	First slime reclaimed and treated
July 1979	First uranium produced
October 1979	Design capacity achieved

sible for mechanical completion and cold commissioning, and Gencor and Chemwes, assisted by the contractor's personnel were responsible during the reagent-preparation and hot commissioning.

The total activities during the hot commissioning were under the control of a senior metallurgist, who directed and co-ordinated the activities in the various sections through appointed metallurgists responsible for each section.

The hot commissioning started in mid-June 1979, when the first slime was reclaimed from the slimes dams. The tonnage treated and the efficiencies improved steadily, and four months later, in October 1979, the plant achieved its design capacity.

Performance

The construction of the Chemwes plant was achieved in a short period. The design and construction took fifteen months from the time that the pipe and instrumentation drawings were 'frozen' (13th March, 1978) to the time that the cold commissioning was completed (13th June, 1979). The hot commissioning took four months, and the plant was producing at design capacity by mid-October 1979. Some of the milestones in the project are listed in Table II.

This outstanding performance was due mainly to the very thorough investigation and optimization studies carried out by the Gencor project team over a period of some three years, and the skilful management by the contractor.

Full capacity was achieved much earlier than anticipated, as indicated in Table III. Teething troubles were experienced and certain modifications were necessary, but generally speaking the plant operated exceptionally well. Full production was achieved after four months, and efficiencies, with the exception of the loss of dissolved uranium in the filter section, were better than anticipated. Working costs, though it is too early to evaluate them thoroughly, were slightly better than planned.

Conclusion

It can be seen that this project was most successful from Gencor's point of view. Some factors that contributed to the success are listed below:

- (1) The considerable effort and conceptual thought that went into the feasibility studies, resulting in a comprehensive enquiry document;
- (2) the type of contract with a bonus or penalty on time and money;
- (3) the early 'freezing' of the piping and instrumentation drawings as a result of (1);
- (4) the residence of Gencor personnel in the contractor's offices, which expedited the approval of designs on an ongoing basis and facilitated rapid decision-making;
- (5) the excellent rapport and commitment that existed between the team members from Gencor and the contractor;
- (6) the implementation and observances of strict formal procedures in all facets of the design, procurement,

TABLE III
TREATMENT RATE DURING COMMISSIONING

Month 1979	Slime treated, t	
	Planned	Actual
July	54 000	93 000
August	81 000	220 700
September	135 000	231 000
October	162 000	280 000

- communication, administration, monitoring of scope changes, accounting, etc.;
- (7) the clearly defined lines of responsibility and strict discipline;
 - (8) specifications of a high order;
 - (9) the early placing of orders and the depressed state of the market, permitting favourable deliveries at the best prices;
 - (10) the attention paid to expediting and quality control;
 - (11) the expeditious design, which enabled construction to proceed unimpeded;
 - (12) the use, from the inception of the project to its completion, of senior staff and key personnel for plant management and operation;
 - (13) the early recruitment of personnel, which allowed the maximum period for training;
 - (14) the training of the personnel, which resulted in trained operators being available on all sections of the plant when the hot commissioning started.

Performance can always be improved, and certain mistakes would be avoided if a similar project were to be undertaken now. It is realized that the Gencor team should have been larger to cope with 'interface' aspects between the in-house work and the contractor's scope. The use of scale models would have assisted generally, and would perhaps have improved the routing of pipework and cabling. A point to be borne in mind is that the type of contract with bonus/penalty on cost can present problems: unless strictly controlled, the contractor could compromise on quality in order to save capital.

However, there is no general procedure for the evaluation, financing, and construction of a large metallurgical plant. The procedures discussed in this paper worked well for the Chemwes project and resulted in a most successful venture, but may not be the most suitable approach in other projects.

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